Using GIS to Identify Remediation Areas in Landfills

Authors: Linda Tedrow, Bruce Becker

Abstract

This paper reports the use of GIS mapping software — ArcMap and ArcInfo Workstation — by the Idaho National Engineering and Environmental Laboratory (INEEL) as a non-intrusive method to locate and characterize radioactive waste in a 97-acre landfill to aid in planning cleanup efforts. The fine-scale techniques and methods used offer potential application for other burial sites for which hazards indicate a non-intrusive approach.

By converting many boxes of paper shipping records in multiple formats into a relational database linked to spatial data, the INEEL has related the paper history to our current GIS technologies and spatial data layers. The wide breadth of GIS techniques and tools quickly display areas in need of remediation as well as evaluate methods of remediation for specific areas as the site characterization is better understood and early assumptions are refined.

Introduction

The Subsurface Disposal Area (SDA) is a radioactive waste landfill located at the INEEL in southeastern Idaho. Contaminants in the SDA include elements resulting from weapons component manufacturing at the Rocky Flats Plant in Colorado, fission and activation products resulting from on-site INEEL reactor operations and radioactive waste from private sources such as universities, hospital and research institutes as well as hazardous chemicals associated with all waste sources.

The shipping records for the wastes going to the SDA are the basis for the GIS work discussed in this paper. The earliest shipping records are from 1953, range until the present, and account for more than 28,000 records. This large quantity of data could not be assimilated without a database.

The GIS System was used to determine where waste containing high concentrations of highly mobile volatile organic compounds (VOCs) and various isotopes of uranium and transuranic elements are located and could be removed. Two Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) non-time critical removal actions are currently being proposed in the SDA: (1) to grout beryllium block disposals in 15 distinct locations identified by the GIS system and (2) to retrieve Rocky Flats Plant waste from a 1/2-acre pit area. The GIS system has been used to determine the locations of waste for both actions.

Cleanup Efforts

The responsibility to perform response actions under CERCLA Section 104 (42 USC § 9601 et seq., 1980) on DOE facilities was delegated by Presidential Executive Order 12580 (DOE 1987) to DOE. CERCLA response actions include both remedial actions and removal actions. Remedial actions involve extensive analysis, documentation, planning, and execution with the goal of complete and final response to all releases of hazardous substances into the environment at the Site. Removal actions are discrete, positive steps, not necessarily physical removal, addressing hazardous substance releases, which can be undertaken without the extensive analysis involved in remedial actions and therefore can be initiated more expeditiously.

Remedial actions at federal facilities such as the INEEL must be conducted consistent with CERCLA Section 120 (42 USC § 9601 et seq., 1980), which requires that, at federal facilities placed by the EPA onto the CERCLA National Priorities List, those remedial actions must have concurrence from the EPA. By agreement between the EPA and DOE, a federal facility agreement is established for each DOE facility on the National Priorities List, which establishes a process for implementing the respective authorities and duties of each federal agency.

The federal facility agreement for the INEEL also fulfills the requirement in the "Resource Conservation and Recovery Act of 1976 (Solid Waste Disposal Act)" (42 USC § 6901 et seq., 1976), as amended by the Hazardous and Solid Waste Amendments of 1984, for a corrective action plan to address all solid waste management units within a facility containing hazardous waste treatment, storage, or disposal units that are permitted under the Resource Conservation and Recovery Act (RCRA) in cooperation with the IDEQ (Idaho Department of Environmental Quality), which has been authorized by EPA to administer RCRA in Idaho. The federal facility agreement, therefore, has been designated a consent order for purposes of the "Hazardous Waste Management Act of 1983" (Idaho Code § 39-4401 et seq., 1983) and is referred to as the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (DOE-ID 1991).

The overall remediation of the SDA is being evaluated through a CERCLA Remedial Investigation/Feasibility Study (RI/FS). Ultimately the RI/FS will lead to risk management decisions and selection of a final comprehensive remedial approach through development of a CERCLA Record Of Decision and follow-on remedial design and activities.

The SDA is one of 10 Operable Units at the INEEL being investigated under CERCLA. This CERCLA investigation included a risk assessment that showed C-14 posed a risk to groundwater at the site. By linking the disposal records to the location information by means of a GIS database, it was determined that the C-14 waste stream posing the greatest threat is in an isolated location and is amenable to an early action under CERCLA to mitigate further release while the remainder of the evaluation continues.

The C-14 waste stream is being released by the corrosion of activated beryllium blocks used in an experimental nuclear reactor.

Transuranic waste (TRU) is another concern for the SDA. The bulk of the TRU was shipped from weapons production work at the Rocky Flats Plant near Boulder Colorado. There is a court order to remove the TRU from Idaho before 2035. A 1/2-acre area in Pit 4 was selected to demonstrate the ability to safely retrieve the TRU and ship it to the Waste Isolation Pilot Plant (WIPP). The 1/2-acre area was chosen using the GIS system because it contained the highest concentration of TRU, significant amounts of volatile organic compounds (VOCs) and uranium.

In addition, the GIS system developed is being used to focus remedial options for the feasibility study (FS) required under CERCLA that will eventually be used in the design of any remedial action taken at the SDA.

GIS Data Development

The shipping records are in a wide range of formats. In the early 1950s, the records were in logbooks some of which were lost. Other early formats included trailer load lists. Beginning in 1957, on-site disposal records were added to the off-site shipping manifests and logbooks. As regulations for contents being buried in radioactive waste landfills has changed, the data required in the completion of shipping records has also changed. The on-site disposal records are summary information thus do not necessarily include characterization of the compounds and/or the radioisotopes contained.

In order to quantify the contents a normalized database was essential. However, because of the diverse nature of the records, this could not be done without several iterations. The first attempt was made by painstakingly transferring data from hand written forms to spreadsheets. After developing spreadsheets for each of the burial units, the spreadsheets were converted to a Microsoft Access database and then to Oracle.

These hand written forms were often difficult to read and, even more frequently, were missing essential information, i.e. burial location, or weight or volume.

The physical burial location descriptions are in a variety of configurations. There were three types of burial units: pits, trenches, and soil vault rows. The configuration of the physical burial location descriptions have a general format for each of type of burial unit. Using algorithms for each type of burial unit, Excel spreadsheets, and the principles of trigonometry, real world coordinates were developed for most of the individual waste disposals.

Many of the handwritten forms have missing fields or contradictory data. Analysts pieced together the location information from logbooks, hand-drawn maps from the 1950s, and time histories of the shipping records. Geophysical data was used to confirm the interpretation of the location data. Interpretation of the manifest data was made using information provided by long time waste management personnel and by contacting retired employees from the facilities sending the waste.

The initial inventory developed for the material disposed in the SDA was performed without consulting the shipping records. The waste generators were asked to identify the process that generated and sent waste to the SDA and identify the amount of radionuclides and hazardous waste shipped. Most generators used process knowledge to develop the inventory and did not tie the information to specific disposals. Errors identified in some of the individual generators inventory forced re-evaluation of the inventory from some of the on-site generators. These new inventories were tied to specific shipments. For the off-site and other on-site generators, a methodology had to be developed to relate the inventory to the generator and waste type information on the shipping manifests. Considerable effort was put into making this as specific as possible. Once the inventory was related to specific shipments, an inventory density or radiological and hazardous constituents could be developed. This was used to develop priority remediation areas.

GIS System

ESRI's mapping softwares (ArcMap, ArcInfoWorkstation, and ArcView) have been useful tools in helping to determine the appropriate remedial actions at the INEEL. Using ArcInfoWorkstation, ArcMacroLanguage (AML) and text files with coordinates and shipment identifiers as attributes, coverages were developed using regions to identify specific locations of shipments. Displaying the character of the waste and statistical data of the waste in the burial areas has been achieved with ArcMap. Areas containing specific contaminants and areas with the greatest quantities of transuranic waste were then identified.

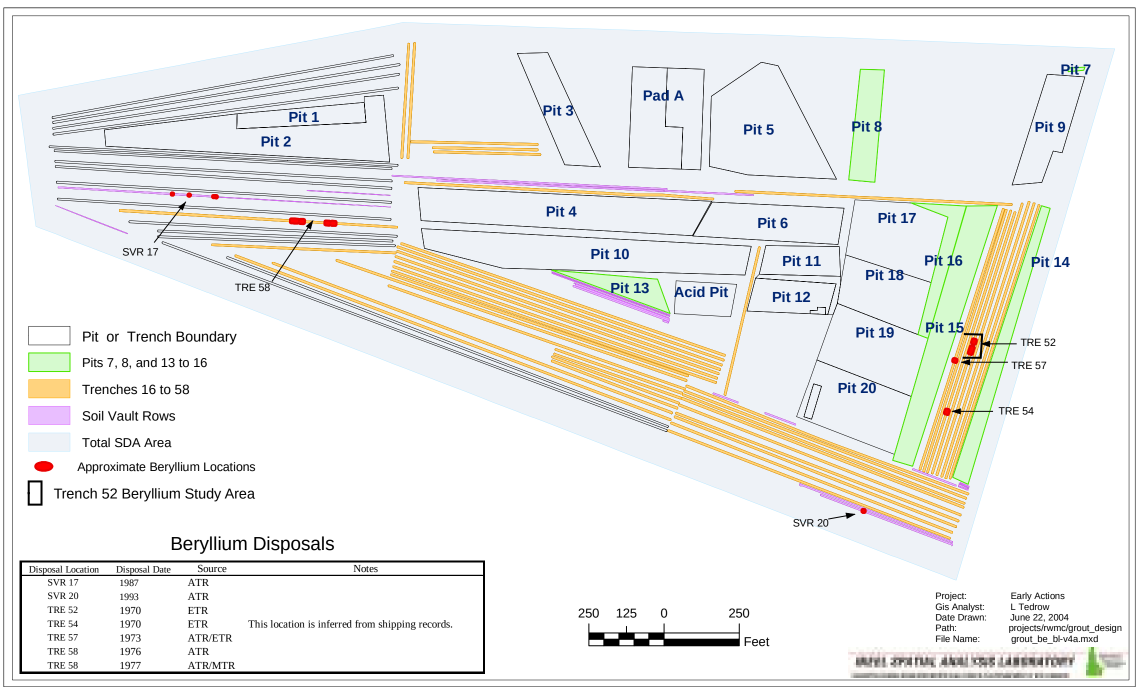
The capability for non-GIS analysts to query, explore, analyze, and visualize the waste characterization and inventory data was needed. The WasteOScope application is a customization of ArcView 3.2. In this application, developed by INEEL's Spatial Analysis Lab, the GIS layers are physically linked to data tables and could be provided to users on a disk or a stand-alone program. Other geophysical data was added to supplement this knowledge: geophysics, well locations, monitoring sites, etc.

The need to quantify contaminants within burial units resulted in the decision to normalize the database tables. ArcMap and SDE were found to be the environments needed for future GIS work. In addition, the region feature type within a coverage has limitations. It was a labor intensive and time consuming task to build. The topological integrity of the region features was lost when adding new data to the coverage.

The next step was to develop a geodatabase that provided the flexibility needed for this map layer. The current methodology in use converts coordinate textfiles to polygons within a geodatabase. As data is added and location coordinates are found the map layer (geodatabase) is modified to reflect the current status and interpretation.

Beryllium Block Disposal Grouting

Preliminary risk assessments (Holdren, *et al.*, 2002) have identified several contaminants that are of potential concern, including C-14 that is being released by corrosion of activated beryllium blocks used in an experimental nuclear reactor. The risk assessment shows that C-14 is mobile and could pose a risk to the groundwater under the INEEL. Rather than wait until 2006 for the final record of decision (ROD) to take action, the INEEL has decided to prevent further release of the C-14 by in situ grouting of the beryllium blocks, the waste stream shown to be releasing C-14. The GIS system identified 15 distinct locations of beryllium block disposals which could be grouted. The blocks are a large source of H-3. An H-3 survey was conducted as well as a geophysical survey. These data were overlain in the GIS system to positively identify the locations to grout.



Disposal Location	Disposal Date	Source	Notes
SVR 17	1987	ATR	
SVR 20	1993	ATR	
TRE 52	1970	ETR	
TRE 54	1970	ETR	This location is inferred from shipping records.
TRE 57	1973	ATR/ETR	
TRE 58	1976	ATR	
TRE 58	1977	ATR/MTR	

Figure 1. Locations of beryllium blocks disposed in the SDA.

Figure 1 provides a map of the SDA showing locations of pits, trenches and soil vault rows as well as the approximate locations of beryllium block disposals. The rectangle on the right side of the map surrounds 3 of the distinct locations of beryllium block disposals. This rectangle shows the approximate location of Figure 2.

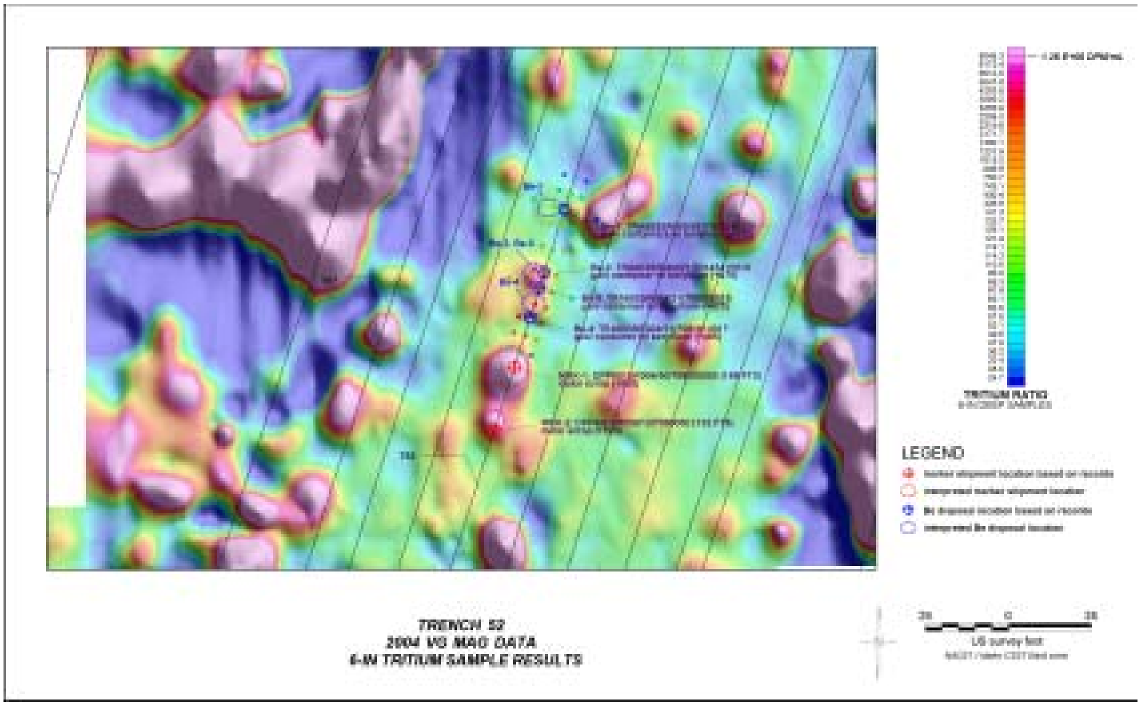


Figure 2. Magnetic Survey and H-3 survey data near beryllium disposals in Trench 52.

Figure 2 (Josten, 2004) overlays disposal information for Trench 52 with the magnetic geophysical survey and the H-3 survey data. The beryllium shipments are identified by the red circle with a cross; near-by shipments are identified by the red circle with a cross. Most of the shipments contain large amounts of iron so show as magenta in the magnetic data. The map illustrates the correlation of the shipping data with the magnetic data. There are small magnetic signatures at the beryllium shipment locations associated with the steel hardware used to ship the beryllium blocks. There are larger steel shipments south of the beryllium blocks that show a larger magnetic response; the vertical gradient magnetic layer illustrates this with pink shading that appears higher than surrounding area. The H-3 survey data is presented on the map in Figure 2 as the small colored circles. The circles are in a grid pattern overlaying the beryllium locations. The highest concentrations are used to pinpoint the location of the blocks.

The ability to pinpoint the location of the beryllium blocks allows localized grouting of just the block disposals. This not only saves time and money but also increases the safety of the workers by avoiding intrusion into other waste types and possibly bringing hazardous material to the surface.

Retrieve Rocky Flats Plant Waste From ½-Acre Pit Area

Because the waste from Rocky Flats Plant contains TRU waste and several other contaminants of concern, it has been targeted for retrieval as another non-time critical removal action. While the risk reduction will not be as dramatic as grouting the beryllium blocks, roughly 12% of the TRU inventory can be removed by retrieving a ½-acre section of Pit 4 (See Figure 3). This estimate of the amount of TRU waste was developed by relating the inventory data to specific waste types listed in the disposal records. The TRU curies for each waste type was then divided among the waste packages based on the weight of the package. This averages the curie loading of the waste packages but with more than 100,000 drums and boxes disposed, an average amount is statistically reasonable. Several ½-acre areas were evaluated and the one shown in Figure 3 was selected because it contained the highest amount of TRU and also contained VOC and uranium contamination.

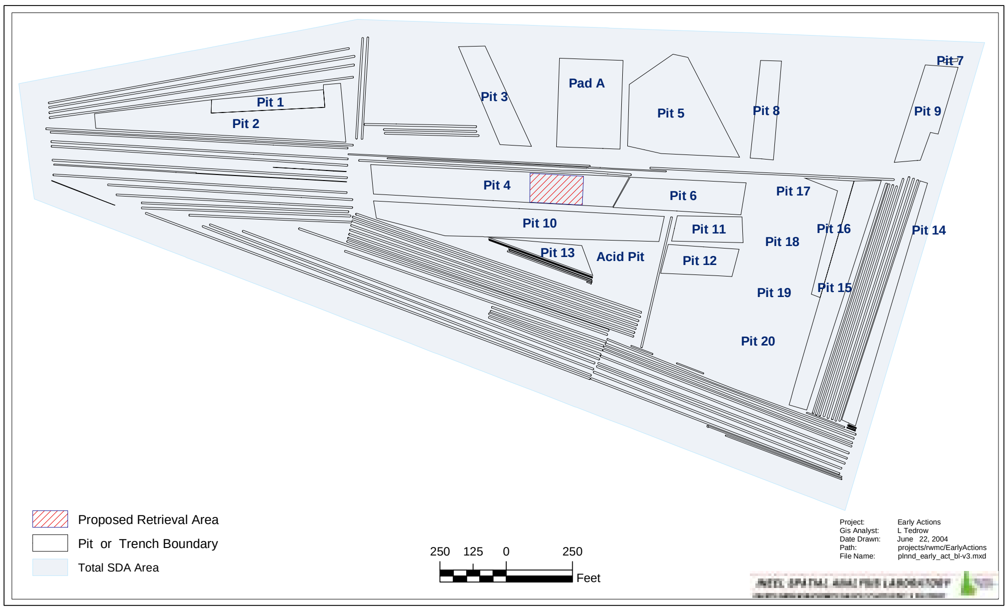
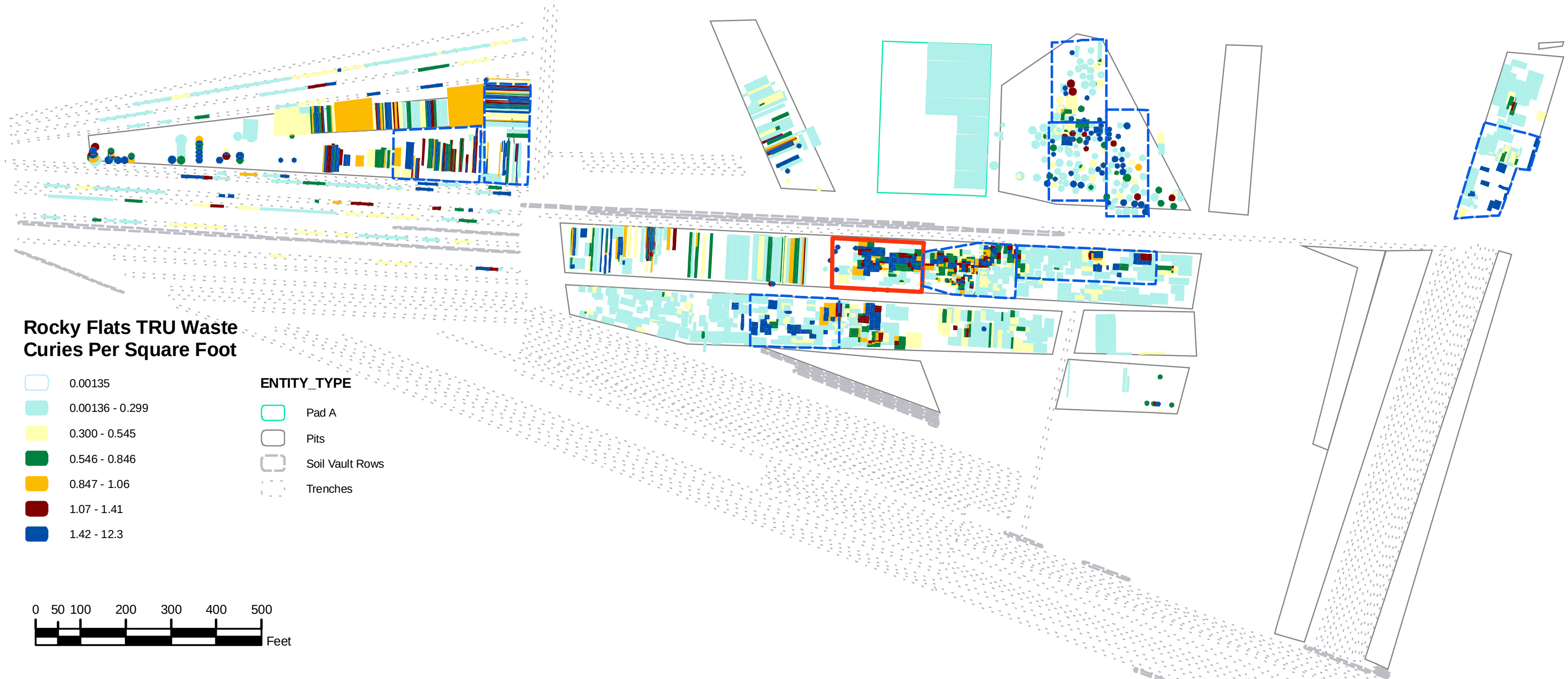


Figure 3 – Proposed Retrieval Area

Figure 4 is a map that illustrates the TRU density on an aerial basis. The ½-acre areas evaluated are shown as dashed lines and the selected ½-acre area in Pit 4 is shown with a solid line. Having the complete disposal records has been critical not only to selecting the area to be excavated but also for the safety analysis and for designing the excavation equipment. For the safety analysis, the records were searched for pyrophoric materials, remote handled high radiation waste, and other hazardous waste that would impact the safety of the work environment. The design team used the location information and shipping records to evaluate the volume of the targeted waste streams to estimate the cost to ship the waste to WIPP. They also used the shipping information to identify problem disposals, such as large objects, to size excavation equipment and to develop operational procedures for dealing with problem waste that will stay in the pit.



Map Development

This map of contaminant density uses information from two sources: (1) shippers' documentation providing the total number of containers in the SDA and total number of shipments, and (2) INEEL's documentation providing the total activity (Ci) in the SDA and the locations of buried shipments. Creating the map followed this process:

1. The total number of waste containers was determined from the shipping documentation.
2. The total activity (Ci) for a specific waste type was divided equally among all the containers having that waste, regardless of the size of the container.
3. The activity for each waste type was calculated as the number of containers per type, times the activity per container having that type.
4. The activity for a shipment was calculated by summing the activity for each waste type.
5. The total activity of each shipment was assumed to be distributed uniformly over the disposal area designated for that shipment.
6. A polygon was created for each shipment, showing a uniform contaminant density (Ci/ft^2) over its disposal area.
7. Activities in overlapping areas of polygons were summed to show the cumulative contaminant density of collocated shipments.

Assumptions and Limitations

- Only Rocky Flats Plant (RFP) densities are illustrated.
- Curies are not assigned to large groups of shipments that had inadequate information either to determine the content or to locate the disposal. These shipments include some of the RFP disposals in Trenches 1 through 10, all of the RFP disposals in Trenches 11 through 15, and some of the RFP disposals in Pits 1, 2, and 4. The areas that probably received RFP in these regions are shaded hot pink on the map.
- Point locations are assigned a 100-ft^2 disposal area.
- Line locations are assigned a 7-ft width.
- Waste type designators (from RFP shipping records) are:
  - **Type I** – Combustibles
  - **Type II** – Glass and ceramics
  - **Type III** – HEPA filters
  - **Type IV** – Sludges from co-precipitation treatment
  - **Type V** – Noncombustibles

Project: Operable Unit 7 - 13/14
Map Requestor: B Becker
G I S Analyst: L Tedrow
Date Drawn: June 23, 2004
Path: /rwmc/sda/
File Name: rfo_tru_al_v1.mxd

Figure 4 TRU Densities in the SDA

This retrieval is scheduled for Fall of 2004. The knowledge obtained from this retrieval will aid in estimating specific contaminant concentration levels in other areas of the SDA. Analysis of the retrieval data and comparison of these results with the on-site disposal records and waste inventories will aid in refining the assumptions made in the GIS system where the original documents are missing fields or include contradictory data. This improved database will permit targeting refined areas with concentrated hazardous contaminants.

Ongoing work

Density maps are being developed for each of the contaminants of potential concern identified in preliminary risk assessments (Holdren, *et al.*, 2002). These will be done on a waste stream specific basis because, like in the C-14 example, some contribute more to the risk than other waste streams. These maps will be used to prioritize the areas needing remediation and be used to help select technologies appropriate for the areas identified.

Having the inventory linked to the geodatabase increases the ability to look for other contaminants that could pose problems for remedial technologies applied in specific areas. For example, cement based grout has been proposed to chemically bind the uranium and prevent migration to the aquifer. However, large amounts of nitrate salts were co-disposed in some areas and high nitrate concentrations are not compatible with cement-based grouts. Alternative technologies or alternative grout formulations might need to be developed.

The maps and anaylsis shown and discussed in this report were developed using manual processes that are time consuming, labor intensive and prone to error. Under development is a system that uses ArcObjects, ArcMap and ArcSDE to automate the generation of the density maps. The user defines how to distribute the inventory and the system steps through the entire map building process. Built into this system is a series of checks to insure that the final map is representative of the inventory and not missing mass.

The automation of this process will allow for quickly presenting and analyzing remediation alternatives as well as increasing the ability to estimate the volume and spatial distribution of contaminants.

Product Disclaimer

References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with the Idaho National Engineering and Environmental Laboratory.

References:

Holdren, K. Jean, Bruce H. Becker, Nancy L. Hampton, L. Don Koeppen, Swen O. Magnuson, T. J. Meyer, Gail L. Olson, and A. Jeffrey Sondrup, 2002, *Ancillary Basis for Risk Analysis of the Subsurface Disposal Area*, INEEL/EXT-02-01125, Rev. 0, Idaho National Engineering and Environmental Laboratory, September 2002.

Josten, N.W., *Determination of Beryllium Block Disposal Locations for Early Action In Situ Grouting*, EDF-4899, Idaho National Engineering and Environmental Laboratory, Working Paper, 2004

Acknowledgements

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