Geospatial Mapping of Environmental Hazards

By

Henry Mayer, Roger Keren, Christine Danis, Michael Greenberg, Vikram Vyas,
Charles Powers, Michael Gochfeld, Joanna Burger, David Kosson and Paul Lioy

Consortium for Risk Evaluation with Stakeholder Participation – CRESP

Social and Economic Center of Expertise
CRESP

Report 83

June 12, 2003

INTRODUCTION

CRESP was asked to design a core set of geospatial maps that can be developed and used by all of the Department of Energy's former nuclear weapons sites. Their purpose would be to effectively depict the site's current environmental and physical conditions, with a focus on the existing on and off-site risks to human and ecological receptors, as well as the end-state vision for the site that would be developed through the DOE's Risk-Based End State (RBES) project. These maps would also permit a comparison between that end-state vision and the end-state currently defined by existing regulatory agreements and federal facility plans. Integrating and presenting technical information so that complex current and future site conditions are readily understandable to laypeople, government officials and scientists alike, will be a critical factor in gaining public and regulatory support for this new end-state approach to environmental cleanup decisions. Comparability and consistency across all DOE sites will also improve communication with regulators and others who are responsible for overseeing multiple sites.

The core set maps described in this paper are intended to identify the location of sources of potential risk, and the interfaces and possible pathways that might bring them into contact with at risk human and ecological populations. The ability to reduce or eliminate the contaminant, and/or to control its ability to reach human and ecological receptors would be shown on the maps depicting the site's end-state vision. These maps are a foundation for quantifying, but not a depiction of the actual or relative level of risk represented by each contaminate source.

The composition and content of each map, the colors used to depict land uses, land cover and contaminant categories, and the legends used to identify buildings and other important physical features, have been developed over the past several months in partnership with DOE Headquarters and Field staff, and MSE, Inc. an environmental consultant to DOE. CRESP's Report 82 of April 21, 2003 "Risk-Based End State Guidance: Geospatial Mapping Tool, A Report Prepared for DOE – HQ" provided the critical foundation for these discussions, and most of the agreed upon changes are refinements of that initial work are intended to provide a more concise mapping guidance to the sites. To provide additional clarity to the process, we prepared a full set of example or sample maps, based loosely around the Brookhaven National Laboratory site, which are included with this paper.

We have divided this paper into four sections:

1. An overview of the geospatial map types and the physical, human, ecological, and hazard attributes that are to be depicted on each;
2. A discussion on the need to use standardized definitions, scales and formats in the collection and display of georeferenced data on these core maps, and a review of the mapping formats, colors, scales and legends that the sites should use;
3. Review of the DOE's GEMS system and the availability of internal GIS and Internet resources at the Grand Junction Office; and,
4. A discussion of the next steps needed to ensure that the DOE sites utilize this mapping guidance in their risk-based end state visioning process, and that DOE

begin to integrate this geospatial data and mapping framework into its broader information and technology systems across all sites.

1.0 MAP TYPES AND ATTRIBUTES

The DOE complex of sites requiring remediation is remarkably heterogeneous. Some sites are small, others are large. Some sites are in arid environments, others in wet ones. Some sites have massive contamination, others do not. Developing a way of depicting what will have been achieved when remediation, mitigation and/or encapsulation have made them risk protective is daunting because of the variety of environmental and institutional conditions. The development of geospatial maps provides a means for integrating diverse databases and creating accurate and broadly understandable visual presentations and descriptions of complex environmental, physical site and human health conditions. However, producing maps that are inconsistent in their terminology and definitions, and in their the portrayal of contaminants and associated risks, can lead to confusion and a possible misunderstanding of what is being presented to the public or regulatory officials. The challenge is to provide consistency in the maps without sacrificing unique site attributes.

Three types of geospatial maps are needed to help stakeholders visualize current site conditions and those anticipated in the risk-based end-state vision for the site. They are:

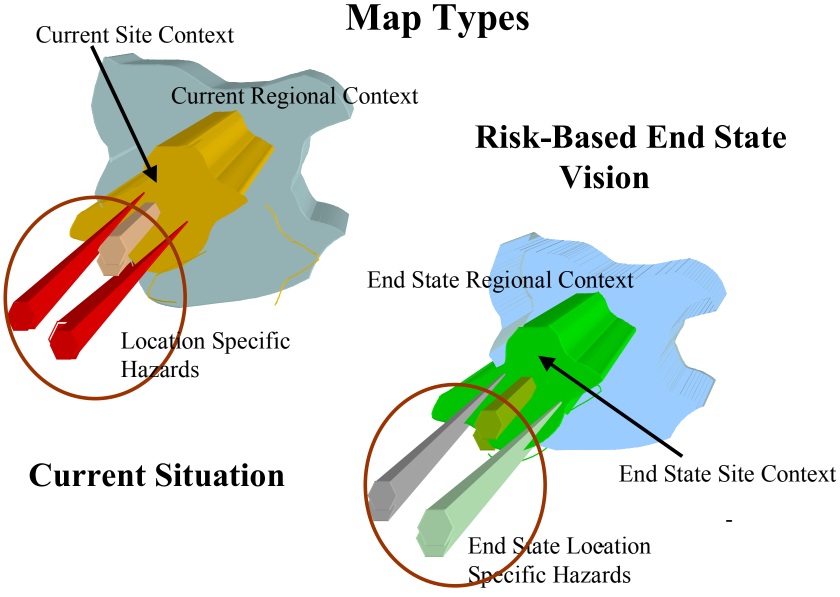
- *Regional Context*: A map that places the site within its larger geographic regional area and in relationship to important ecological or human receptors of concern.

- *Site-Wide Context*: Maps that focus on the site and contiguous off-site areas of concern. They show greater amounts of data and detail, including the location of hazardous conditions in relationship to environmentally sensitive areas, or to possible exposure and potential risk pathways and receptors.

- *Location Specific Hazards:* Maps that zoom in and more closely examine each of the hazardous areas of concern identified on the *Site-Wide Context* maps. Greater detail, such as concentration isopleths for soil, sediment and groundwater contamination would be required where appropriate.

The *Location Specific Hazards* maps are a subset of the *Site-Wide Context* maps, which are in turn a subset of the *Regional Context* map. Each provides a greater level of detail on a smaller geographic or subject area of interest. One set of these maps would be prepared to depict current conditions, and a second set would be used to provide a visualization of the site consistent with its risk-based end-state vision. Where appropriate, a third set would be prepared that shows the end-state condition currently envisioned under existing regulatory agreements and federal facility plans.

Map Types



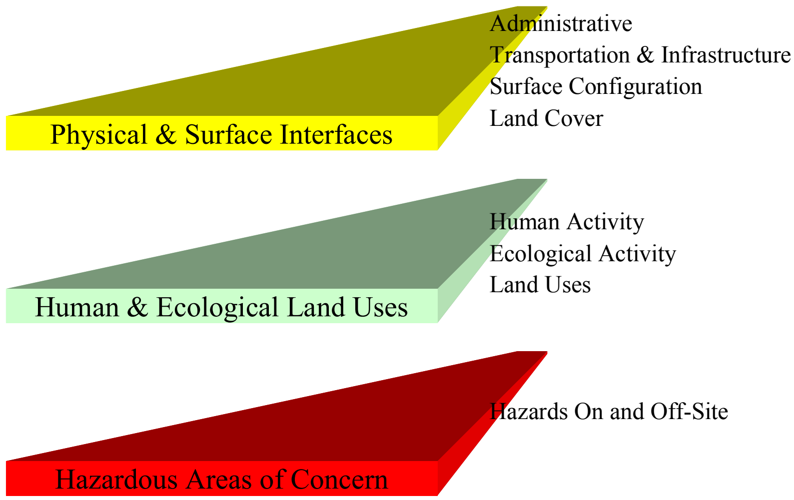
Three types of data would be geospatially displayed on these maps. They correspond to the potential sources of risk, possible interfaces or pathways, and the human and ecological populations that would be considered in any risk assessment process.

- ***Physical and Surface Interfaces***: The attributes of the site and surrounding geographic area that identify **Administrative** characteristics, such as boundaries, building footprints, and ownership; the location of **Transportation and Infrastructure**, such as roads and utilities; **Land Cover**, such as water, wetlands and vegetated non-agricultural; and **Surface Configuration** characteristics, such as mountains, rivers, and streams.

- ***Human and Ecological Land Uses***: The attributes of the site and surrounding area that identify **Human Activity**, such as the location of at risk populations and schools; **Ecological Activity**, such as the location of habitats of concern and critical watersheds; and physical **Land Uses**, such as residential, industrial and open space areas.

- ***Hazard Areas of Concern***: Identification of hazardous areas on-site such as contaminated buildings, underground contaminant plumes, discharge points of air emissions, and those off-site such as hazardous landfills, waste processing facilities, and underground contaminant plumes.

Data Groupings & Feature Categories



The following is a description of each type of core map, and the associated features and attributes that would be geospatially identified and displayed.

1.1 Regional Context Map

The Regional Context maps are intended to geospatially place the site within its larger contiguous regional area, and specifically its location in relationship to important physical features, other hazardous materials, and human and ecological land uses of the area. The size and boundaries of the Regional Context maps will differ from site to site because of their differences in land size and complexity, and because of differences among nearby population centers, habitat and ecology areas, watersheds, and other areas that could be impacted by contamination and other hazards that are both on and off the site. As a guidance, the regional boundaries should not be a fixed number of miles from the site's boundary, but rather they should follow the boundaries of all contiguous local and county governments, and tribal nations that surround the site. They should also encompass all watersheds, habitat and ecology areas, and other off-site areas that could be affected by site contamination. At some of the larger sites, the regional context may be hundreds of square miles and many counties, while at some small sites the regional context may be only a few square miles, made up of the surrounding local or county government and perhaps a critical watershed.

Examples: At the Savannah River Site, the regional context maps should extend to the outer legal boundaries of adjacent Aiken and Barnwell counties in South Carolina, and Richmond and Burke counties in Georgia. In addition, Allendale (SC) should probably be included, because of its high minority composition and location on the Savannah River downstream of the site.

At the much smaller Brookhaven National Laboratory site, the regional context maps need only extend to the legal boundaries of Suffolk County, on Long Island.

Two regional context maps should be prepared, and should include the following important attributes where relevant and appropriate:

***Map 1 - Physical and Surface Interfaces*:**

Administrative

Legal boundaries of local & county governments, tribal nations, national wildlife and wilderness areas, etc.
DOE Site boundaries
Legal ownership (identify private and government)

Transportation & Infrastructure

Major highways, roads and railroads
Major infrastructure (dams, power plants, etc.)

Surface Configuration

Major topography (mountains, lakes, rivers, etc.)
Other important physical features

Hazardous Areas of Concern

Major potential or actual hazards on and off-site such as NPL sites, landfills, groundwater plumes, coal & nuclear power plants, and potentially hazardous facilities

Map 2 - Human and Ecological Land Uses:

Human Activities

Population centers (location of towns and cities)

Ecological Activity

Conservation and ecological areas
Habitats of concern
Watershed, floodplains, wetlands, marshes

Land Cover

Follow DOE definitions and color codes

Hazardous Areas of Concern

Major potential or actual hazards on and off-site such as NPL sites, landfills, groundwater plumes, coal & nuclear power plants, and potentially hazardous facilities

Not all of these attributes will be germane to every site, but every effort should be made to include those attributes that are relevant and appropriate to locating the site and hazardous areas of concern in the context of potential pathways and at-risk receptors within the region.

1.11 Example Regional Context Maps

With assistance from the GIS staff at Brookhaven National Laboratory on Long Island, New York, we have prepared examples of what these two *Regional Context* maps might look like. These maps do not depict actual or proposed conditions, and are solely intended to be examples of how the various attributes should be used and depicted. Both maps utilize the DOE standardized definitions, colors, legends and symbols that are discussed later in this paper. These maps are included in the attached Appendix A.

1.2 Site-Wide Context Maps

The *Site-Wide Context* maps are subsets of the larger *Regional Context* maps. They are intended to show greater amounts of data and detail, including the location of hazardous conditions on and off-site in relationship to environmentally sensitive areas, or to possible exposure and potential risk pathways and receptors. The boundaries for these maps should extend beyond the site to include all contiguous population and environmentally sensitive areas, that might be affected by site contaminates and/or any off-site hazardous materials (e.g. superfund and brownfield sites, nuclear power plants, and land fills) located in close proximity to the site. Even in instances where the only hazardous areas are totally contained within the site boundaries, the site-wide maps should show human and ecological areas that are in close proximity to the site. Rather than strictly following legal boundaries of adjacent counties or cities, each site must determine what off-site features or areas should be included.

As a rule of thumb, the site itself should be no greater than one-half the total area shown on the site-wide maps, and in some instances it should be no more than one-fourth the total map area. The larger the geographic size of the site, the larger percentage of the total map it will occupy.

Examples: The Savannah River Site is about 325 square miles in size. If SRS made up one-half of its the site-wide map area, the maps would cover a total area of about 650 square miles. If SRS were perfectly square, the boundaries of these site-wide maps would extend an average of 3.5 miles from the site boundaries in each direction.

The Brookhaven National Laboratory site is approximately 5 square miles in size. If BNL made up one-fourth of its the site-wide map area, the maps would cover a total area of about 20 square miles. If BNL were perfectly square, the boundaries of these site-wide maps would extend an average of 1.1 miles from the site boundaries.

Two *Site-Wide Context* maps should be prepared, and should include the following important attributes where relevant and appropriate:

Map 1 - Physical & Surface Interfaces:

Administrative

- Legal boundaries of contiguous local governments, tribal nations, national wildlife and wilderness areas, etc.
- DOE Site boundaries
- DOE Fence lines
- Historical and cultural resources
- Ownership of land

Transportation & Infrastructure

- Highways, roads and railroads, detailed as relevant
- Surface and subsurface utility lines
- Building footprints and infrastructure – DOE buildings, reactors, facilities and waste sites; dams, water treatment plants, and power plants

Surface Configuration
Mountains, lakes, rivers, watersheds
Other important physical features
Hazardous Areas of Concern
Location of contaminated surface water, ground water plumes (show flow direction and discharge locations), sediments and soils; DOE contaminated buildings, reactors, tanks, facilities, waste cells; wind rose information where relevant. Also show locations of monitoring wells and drinking water wells/potential interceptors, control points/institutional controls/no access points/buffer zones and any off-site hazards in the vicinity of DOE boundaries.

Map 2 - Human & Ecological Land Uses
Human Activity
Population density and identification of vulnerable subpopulations (seniors and children), socio-economic status of different groups, and distribution of minorities in close proximity to site, where appropriate.
Drinking water supply sources
Ecological Activity
Conservation and ecological areas
Habitats of concern (especially unique habitats)
Watershed delineation
Land Use
Follow DOE definitions and color codes
Hazardous Areas of Concern
Location of contaminated surface water, ground water plumes (show flow direction and discharge locations), sediments and soils; DOE contaminated buildings, reactors, tanks, facilities, waste cells; wind rose information where relevant. Also show locations of monitoring wells and drinking water wells/potential interceptors, control points/institutional controls/no access points/buffer zones and any off-site hazards in the vicinity of DOE boundaries.

Again, not all of the attributes recommended for these two maps will be germane to every site, but an effort should be made to include those attributes that are relevant to the site and local area, or which may be perceived by the public to be of concern. One area that is likely to be germane to all sites is the identification and delineation of watershed areas, as they are critical for determining the transport of contamination to both potable water supplies and ecological systems.

1.21 Optional Site Defined Custom Configuration Maps
Many sites may have a need or desire to prepare *Site-Wide Context* maps that show many of these same attributes, but in different combinations than are required as part of this core map set. Others may have maps that show additional types of information specific to the site, such as the location of different ecological habitat types or populations of biota. The sites are to have the flexibility to prepare and use these additional maps, but

they must use the same DOE standardized definitions, color codes and legends used to prepare the core set of maps. In addition, sites should have the flexibility of using aerial photos to provide additional information regarding the location of important physical and land use features.

1.22 Example Site-Wide Context Maps

With assistance from the GIS staff at Brookhaven National Laboratory, we prepared examples of what the two core *Site-Wide Context* maps might look like, as well as an example of a *Site Defined Custom* map, titled "Site Hazards & Ground Water Sampling," might look like. These maps do not depict actual or proposed conditions, and are solely intended to be examples of how the various attributes should be used and depicted. All three maps utilize the DOE standardized definitions, colors, legends and symbols that are discussed later in this paper, and are included in the attached Appendix A.

1.3 Location Specific Hazard Maps

The third group of maps should zoom in and more closely examine each of the hazardous areas of concern that were identified on the *Site-Wide Context* maps. Greater detail and information that helps to qualify or quantify the nature of the hazard present, the potential of the hazard to have an impact on human health or the environment, and any mitigation of the hazard should be shown on these maps. At a minimum, the sites should prepare maps showing small individual sections of the site where highly contaminated buildings, reactors, tanks, facilities, waste cells hazardous, ground water plumes, sediments and soils are located. These maps should show the location of these hazards in relationship to ***Physical and Surface Interface***, and ***Human and Ecological Land Use*** attributes that may be relevant or needed to evaluate their potential risk to human health or the environment. These map depictions can be augmented, where appropriate with:

- Surface and subsurface contaminant concentration profiles for soil and ground water
- Subsurface diagrams/cross-sections of contaminant plumes
- Current/Future RBES plume size and location
- Location and use of control mechanisms, barriers, and buffer zones (i.e., active and passive institutional controls
- Environmental monitoring and surveillance points such as monitoring wells
- Facility disposition

1.31 Example Location Specific Hazard Maps

Here also, we have prepared examples, with assistance from the GIS staff at Brookhaven National Laboratory, of what *Location Specific Hazard* maps might look like. Again, these maps do not depict actual or proposed conditions, and are solely intended to be examples of how the various attributes should be used and depicted. The first map zooms in on a section of the example site that shows a combination of contaminated soils, several different groundwater plumes, and several contaminated buildings. The second map shows contamination along a river or stream located in an ecological conservation area. Both maps utilize the DOE standardized definitions, colors, legends and symbols that are discussed later in this paper. In addition, BNL has provided us with an example of a modeled cross-section of a groundwater plume, and its location relative to various surface streets and groundwater monitoring wells. The two maps and cross-sectional diagram are included in the attached Appendix A.

1.4 End-State Vision Maps

The three sets of maps described above should first be developed for the purpose of showing current environmental and physical conditions at the site, with a focus on effectively communicating the types of potential risk that currently exist to on and off-site human and ecological receptors. A second set of these maps, depicting the risk-based end-state vision for each hazardous area of concern, as well as the vision for the site as a whole, should then be prepared.

The first set of *End-State Vision* maps should mirror each of those developed under the *Location Specific Hazard* map section above, except that they should show each area of concern after remediation, mitigation and/or implementation of other forms of protection (institutional controls, land use, etc.). The risk-based end state vision for each area would need to be accompanied by a verbal or written explanation of the cleanup approach that is intended to be used, and the planned monitoring and other long-term stewardship requirements, if any. Where the end-state vision for a hazardous area is not expected to be reached in the next 10 years, it would be advisable to develop a series of temporal maps that show the condition of these areas at the end of different points in time into the future.

The second set of *End-State Vision* maps in this group should follow the structure of the *Site-Wide Context* maps that were prepared earlier to show the current environmental and physical condition of the site. The first map should show the risk-based end-state vision for the site, in relationship to the area's ***Physical and Surface Interfaces***. As such, it should show all of the features and attributes displayed on the earlier *Site-Wide Context* map, after adjusting for all proposed changes in roads, buildings, infrastructure, utilities, boundaries and fence lines, land cover, land contours and other physical features contemplated under the end-state vision. The ***Hazardous Sources*** component of the map should also show the same features as the earlier map, after adjusting for the effects of removing or mitigating the various hazardous areas of concern previously identified. It should also show the location of all monitoring wells, pump and treat facilities, permanent storage units, and permanently restricted areas that are part of the end-state vision for the site.

The second map in this group should show the mitigated risk-based end-state vision for the site, in relationship to the area's ***Human & Ecological Land Uses***. This map should show all of the features and attributes described on page 7 of this paper and used earlier to develop the "current condition" *Site-Wide Context* map, after adjusting for any anticipated on and off-site changes in human and ecological activities and land uses. The ***Hazardous Sources*** component of the map should also show the same features of that earlier map, adjusted for the effects of removing or mitigating the various hazardous areas of concern previously identified. It should also show the location of all monitoring wells, pump and treat facilities, permanent storage units, and permanently restricted areas that are part of the end-state vision for the site. This map will be especially important where long-lived radioactive contamination will remain on the site under the proposed end-state vision, such as with Hanford, Rocky Flats and Mound.

The third *End-State Vision* map set should mirror the structure of the two *Regional Context* maps that were prepared earlier to geospatially place the current site within its larger contiguous regional area, and in relationship to the possible off-site pathways and ecological or human receptors that are of concern. These maps should show the same attributes displayed on the "current condition" *Regional Context* maps, after adjusting for any changes in ***Physical & Surface Interfaces, Human & Ecological Land Uses,*** and ***Hazardous Sources*** included in the site-wide *End-State Vision* maps discussed above.

2.0 NEED FOR MAPPING STANDARDIZATION

We believe that these core maps can be developed at every DOE site with a minimal cost and a maximal reliance on readily available data. Most of the sites have previously developed maps showing infrastructure, building footprints, contaminant areas, and other on-site attributes described above. In addition, most, if not all, of the sites already have, or have ready access to, georeferenced data on many of these same attributes. As a first step, we recommend that all of the sites take an inventory of existing in-house data and other relevant information (including that held by outside consultants and contractors), and from that determine what data gaps may exist versus the attributes listed below. In some instances, such as with smaller sites, it may be necessary to use a portable or mobile Global Positioning System (GPS) unit to georeference the exact location of monitoring wells, or to use georeferenced orthophotos of the full site to develop a more accurate data set. We believe, however, that the question that is most likely to be raised, is where can they obtain the off-site data needed for the *Regional* and *Site-Wide Context* maps.

2.1 Major Sources of Information

State and federal governments and their agencies have developed a huge amount of geospatial data that can be readily accessed by the sites via the Internet to meet these needs. Major contributors include USGS, the Bureau of Land Management, Department of Agriculture, Department of Housing and Urban Development, U.S. Census Bureau, the Environmental Protection Agency, and U.S. Park Service. Many states, such as South Carolina, provide web access to more localized data, and others will make information available on CDs for a fee. Much of the data has also been converted into georeferenced maps, which are available for viewing and download over the Internet using GIS software packages already owned by many DOE sites or through the use of free shareware, such as ESRI's free ArcExplorer software package for viewing.

There are many web sites from which the GIS practitioner can obtain on and off-site regional data, including the *National Geospatial Data Clearinghouse* which is operated by the Federal Geographic Data Committee. We believe that the *Center for Advanced Spatial Technologies (CAST)* facility at the University of Arkansas maintains one of the most comprehensive and easy to use web sites. It is titled *Starting the Hunt: Guide to Mostly On-Line and Mostly Free U.S. Geospatial and Attribute Data.* CAST has organized several hundred web-based data sources into two broad classifications:

National Aggregations and State and Local Aggregations. The vast majority of these web sites require ArcView or other GIS software systems to view and download the data, but many provide data in Adobe Acrobat (pdf) or picture (jpeg) formats. A detailed review of available geospatial data and map sources is attached as Appendix B.

2.2 Need for Data and Mapping Standardization

During remedial investigations, a significant amount of data of varying quality and formats are collected and compiled in a multitude of database structures. Other data, such as the site's topography, location of roads, streams and buildings, and land uses are similarly collected and stored in various databases and formats, including paper documents. Additional data such as satellite images, and information on land uses and populations outside the site boundaries may be downloaded from local, state and federal governments sites. Much of this data is georeferenced, or linked to specific geographic coordinates on the site, but some is not. The degree and consistency of the maps that would be developed from this data would therefore vary in accuracy, resolution, projection and scale.

The content standard for digital geospatial metadata in the federal government was promulgated in 1994 through Executive Order 12906. The purpose was to standardize procedures so the prospective user could determine the availability of a set of geospatial data, determine the fitness of the set of geospatial data for an intended use, determine the means of accessing the set of geospatial data, and successfully to transfer the set of geospatial data. In 1990 the federal government formed the interagency Federal Geographic Data Committee (FGDC) which not only developed the standards in the Executive Order, but under OMB Circular A-16, FGDC continues to promote the coordinated use, sharing, and dissemination of geospatial data on a national basis. One of its most important contributions to this effort is the development of the National Spatial Data Infrastructure (NSDI), in cooperation with organizations from State, local and tribal governments, the academic community, and the private sector. The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data. DOE Headquarters has been an active member of FGDC since its inception, with Guy Caruso and Karen Evans currently serving as Steering Committee members and John Stewart and three other DOE staff participating on the Coordination Group.

While these efforts are critical to the development and maintenance of geospatial data on a consistent basis across the DOE, they do not address the need to develop and implement standardized definitions and classifications of the descriptive elements in the spatial data set. As we noted earlier, the development of geospatial maps provide a means for integrating diverse databases and creating accurate visual presentations and descriptions of complex environmental, physical site and human health conditions. However, producing maps that are inconsistent in their terminology and definitions, and in their the portrayal of contaminants and associated risks, can lead to confusion and a possible misunderstanding of what is being presented to the public and/or regulatory officials. For example, a land classified and geocoded as agricultural at SRS should have the same, or as close to as possible, criteria as agricultural land at Hanford, Oak Ridge or Mound.

Similarly, care must be taken to ensure that maps and diagrams of surface or underground contaminant plumes, which have been developed using a variety of statistical and graphical software packages, are based on accurate and minimal number of data readings, and depicted on maps using a consistent set of colors, legends and symbols.

There are many different protocols or formats at the DOE sites for collecting and managing data, and for developing and displaying maps of the nature described in this paper. Although one or more of these in-house protocols might be a good model for certain aspects of the Department's overall mapping needs, a broader study was undertaken to determine whether more dynamic and universally applicable systems were available from government and private sector organizations. The objective was to identify data and mapping protocols for land cover, infrastructure, land use and contaminants that were broad, deep and easily transferable to the DOE sites. They also needed to be integrated structures that included clear definitions and codes for each of these attributes and data elements, and associated map scales, legends, colors and symbols that could be used to produce consistent maps across all sites.

No one organization was found to have the breadth and depth of information and tools needed to develop and maintain the core set of geospatial maps proposed. As a result, we chose three organizations that excel in areas that do not greatly overlap, and that when combined create the strongest data and mapping tools available for the land cover, soil type, infrastructure, land use and contaminant attributes being sought. They were chosen because they provide widely used definitions of each attribute cataloged, and associated legends, colors and symbols for use in preparing consistent maps across all DOE sites. We then condensed and reduced the number of different land cover, land use and contaminant categories used by the three organizations, in an effort to make these core maps easier to prepare and more consistent across the DOE complex of sites. We also refined the color codes associated with some of the land cover and land use categories to use the same color for depicting similar conditions (i.e., yellow for residential developed cover and residential land use, and green for agricultural cover and agricultural use).

2.3 Land Cover Attributes

The following format is to be used for data characterization and mapping of Land Cover attributes. It is a condensed version of the 21 land cover codes developed and used by the U.S. Geological Survey (USGS). The USGS National Land Cover Characterization project was created in 1995 to support the original Multi-Resolution Land Characterization (MRLC) initiative and fulfill the requirement to develop a nationally consistent land cover data set from MRLC data called National Land Cover Data 1992 (NLCD 1992). The resulting land cover dataset is being used for a wide variety of national and regional applications, including watershed management, environmental inventories, transportation modeling, fire risk assessment, and land management. The land cover classes, codes and associated definitions for the DOE's more streamlined version are:

10 Water - All areas of open water, generally with less than 25% cover of vegetation/land cover, and all areas characterized by year-long surface cover of ice and/or snow.

20 Residential Developed - Areas with a mixture of constructed materials and vegetation that are principally used for residential housing. Examples include single-family housing units, apartment complexes and row houses. Population densities will vary with the type of development.

30 Commercial/Industrial/Transportation - Includes infrastructure (e.g. roads, railroads, etc.) and all highly developed areas not classified as High Intensity Residential.

40 Barren - Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Includes areas of extractive mining activities with significant surface expression. Vegetation, if present, is more widely spaced and scrubby than that in the "green" vegetated categories; lichen cover may be extensive. Also includes areas of sparse vegetative cover (less than 25 percent of cover) that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.).

50 Non-Agricultural Vegetated - Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover. Also includes shrubland, which is characterized by natural or semi-natural woody vegetation with aerial stems, generally less than 6 meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included. In addition, it includes urban/recreational grasses that are planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

60 Agricultural - Areas planted or intensively managed for the production of food, feed, or fiber; or is maintained in developed settings for specific purposes. Includes areas of pasture; hay; row crops; small grains; orchards, vineyards, and other areas planted or maintained for the production of fruits, nuts, berries, or ornamentals; grasslands/herbaceous areas dominated by upland grasses and forbs often used for grazing; and areas used for the production of crops that do not exhibit visible vegetation as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage.

70 Wetlands - Areas where the soil or substrate is periodically saturated with or covered with water as defined by Cowardin et al. This includes both woody wetlands and emergent herbaceous wetland areas.

The color legends for each of these land covers are shown below. A description of which USGS Land Cover categories should be mapped to each of these condensed DOE categories is included in Appendix C.

DOE Land Cover Classification System

Color Key	Description	RGB Value
	10 Water	102, 140, 190
	20 Residential Developed	255, 255, 0
	30 Commercial, Industrial; Transportation	255, 0, 0
	40 Barren	137, 112, 68
	50 Non-Agricultural Vegetated	144, 238, 144
	60 Agricultural	34, 139, 34
	70 Wetlands	201, 230, 249

2.4 Land Use Attributes

We used the Land Based Classification Standards (LBCS) developed by the American Planning Association (APA) as the basis for developing and defining a DOE Land Use coding system. The LBCS is an update of the 1965 Standard Land Use Coding Model, and provides a consistent model for classifying land uses based on their characteristics. The LBCS model extends the notion of classifying land uses by refining traditional categories into five multiple dimensions - activities, functions, building types, site development character, and ownership constraints. Each dimension has its own set of categories and subcategories.

Activity refers to the actual use of land based on its observable characteristics. It describes what actually takes place in physical or observable terms (e.g., farming, shopping, manufacturing, vehicular movement, etc.). An office activity, for example, refers only to the physical activity on the premises, which could apply equally to a law firm, a nonprofit institution, a courthouse, a corporate office, or any other office use. Similarly, residential uses in single-family dwellings, multi-family structures, manufactured houses, or any other type of building, would all be classified as residential activity.

Function refers to the economic function or type of establishment using the land. Every land use can be characterized by the type of establishment it serves. Land-use terms, such as agricultural, commercial, industrial, relate to enterprises. The type of economic function served by the land use gets classified in this dimension; it is independent of actual activity on the land. Establishments can have a variety of activities on their premises, yet serve a single function. For example, two parcels are said to be in the same functional category if they belong to the same establishment, even if one is an office building and the other is a factory.

Structure refers to the type of structure or building on the land. Land-use terms embody a structural or building characteristic, which suggests the utility of the space (in a building) or land (when there is no building). Land-use terms, such as single-family house, office building, warehouse, hospital building, or highway, also describe structural characteristic. Although many activities and functions are closely associated with certain structures, it is not always so. Many buildings are often adapted for uses other than its original use. For instance, a single-family residential structure may be used as an office.

Site development character refers to the overall physical development character of the land. It describes "what is on the land" in general physical terms. For most land uses, it is simply expressed in terms of whether the site is developed or not. But not all sites without observable development can be treated as undeveloped. Land uses, such as parks and open spaces, which often have a complex mix of activities, functions, and structures on them, need categories independent of other dimensions. This dimension uses categories that describe the overall site development characteristics.

Ownership refers to the relationship between the use and its land rights. Since the function of most land uses is either public or private and not both, distinguishing ownership characteristics seems obvious. However, relying solely on the functional character may obscure such uses as private parks, public theaters, private stadiums, private prisons, and mixed public and private ownership. Moreover, easements and similar legal devices also limit or constrain land-use activities and functions. This dimension allows classifying such ownership characteristics more accurately.

Of the five dimensions to choose from, the most appropriate for the DOE is the classification of land uses by their ***Function***. However, in reviewing the nine functional land use categories of this system we found that several lacked sufficient clarity and certain existing or proposed land uses appeared to be missing. Working with the DOE, we condensed and restructured these nine APA categories into six. We then added a seventh for land highly restricted because of national security or serious health risks.

1000 Residential

This category comprises all types of residential uses, such as homes, apartments, condominiums, barracks, temporary housing, and housing for the elderly. It does not include hotels, which are included under commercial uses.

2000 Commercial

The category comprises all types of commercial, retail and service oriented land uses, such as finance and insurance; business, professional, scientific, and technical services; retail sales and service; automobile sales or service; food services; consumer goods; hotels, resorts, amusement parks and sports facilities; and health and personal care. It also includes land used by hospitals, medical centers, educational facilities, libraries, police, fire, government offices, and other public buildings.

3000 Manufacturing, Industrial and Mining

This is a large catch-all category for all land uses that are not residential, commercial, agricultural or open-space. It includes lands used for all forms of manufacturing, industrial, transportation, communication, utilities, and mining and extraction purposes.

4000 Agricultural

This category includes all land uses associated with growing crops, raising animals, harvesting timber, and harvesting fish and other animals from a farm, ranch, or their natural habitats, as well as areas used for the production of crops that do not exhibit visible vegetation as a result of being tilled in a management practice that incorporates prescribed alternation between cropping and tillage. They may be described as farms, ranches, dairies, greenhouses, nurseries, orchards, or hatcheries. For agricultural research establishments administering programs for regulating and conserving land, mineral, wildlife, and forest use, apply the Open Space - Ecological Conservation land use category.

5000 Open space – Recreational (implies unrestricted public access)

This category includes all land uses associated with open space, such as parks, forests, historic sites, and beaches, which have unrestricted public use.

6000 Open space – Ecological Conservation & Preservation

This category includes all restricted open space land uses, such as designated wildlife preserves, ecological preserves, conservation areas, and other areas where public use is restricted.

7000 Restricted Access

This land use category includes military bases, waste sites, high hazard areas and other areas where public access is highly restricted because of national security or serious health risks.

The colors for the DOE Land Use Classification System, that relate to the definitions described above, are shown below.

DOE Land Use Classification System

Color Key	Description	RGB Value
	Residential	255, 255, 0
	Commercial	255, 0, 0
	Manufacturing, Industrial & Mining	160, 32, 240
	Agriculture	34, 139, 34
	Open Space - Recreational (implies unrestricted public use)	144, 238, 144
	Open Space - Ecological Conservation & Preservation	0, 0, 139
	Restricted Access	156, 156, 156

2.5 Infrastructure and Hazardous Attributes

In our Report 82 we recommended that the DOE follow the format developed by the U.S. Department of Defense's CADD/GIS Technology Center for Facilities, Infrastructure, and Environment for data characterization and mapping of Infrastructure and Hazardous attributes. The "Center" is located at the U.S. Army Engineer Research and Development Center, Information Technology Laboratory in Vicksburg, Mississippi. One of the major initiatives assigned to the Center has been the development of the Spatial Data Standard for Facilities, Infrastructure, and Environment (SDSFIE), which is focused on the development of graphic and nongraphic standards for GIS implementations at Air Force, Army, Navy, and Marine Corps installations, U.S. Army Corps of Engineers Civil Works activities, and other Government organizations.

The SDSFIE data model consists of five basic levels of hierarchy: *Entity Sets, Entity Classes, Entity Types, Attribute Tables,* and *Domain Tables.* The SDSFIE Release 2.10 structure contains twenty-six Entity Sets, of which seven appear to best meet the standardization needs of this core mapping project in the areas of infrastructure and hazardous attributes. They are:

Buildings	Communications
Cultural	Evironmental Hazards

Improvement
Utilities

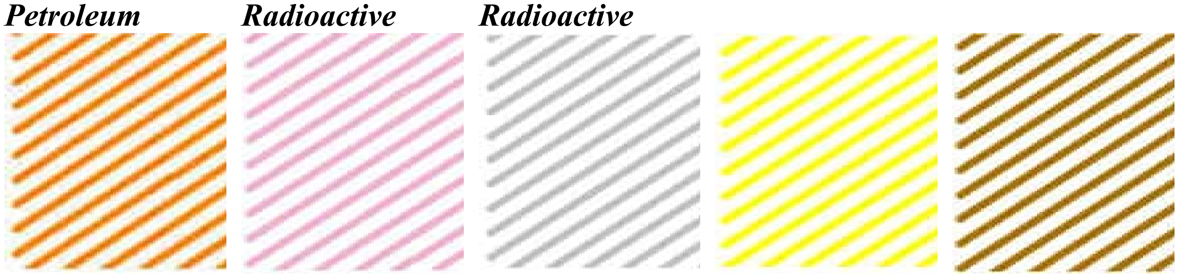
Transportation

Each *Entity Class* contains one or more *Entity Types.* An *Entity Type* roughly corresponds to a set of features, which attach to the same table and can be differentiated through the use of an attribute. The *Attributes* correspond to the data or information, which is retained regarding each *Entity Type*. In the SDSFIE structure, these are organized into relational groupings called *Attribute Tables.* In total, there are over 1,000 Attribute Tables, with 27,000 Attribute Fields, many of which could be potentially used to identify and code environmental project types, RCRA waste categories, and site remediation types. These Tables and Fields have unique definitions and codes, but do not have specific colors, symbols or other mapping legends associated with them. They are also far more detailed than needed to meet the more basic standardized mapping needs envisioned in this project. We therefore chose to develop a unique DOE color and line coding system for the depiction of major types of contaminants found on DOE sites and the current status of their control or containment.

2.51 Type of Contaminant – Hatched Colors

All contaminants types have been collapsed into one of five major categories for mapping purposes, and each is depicted by a specific color displayed as hatched or diagonal striped lines. We have chosen neutral colors in an effort not to attach any relative risk connotation to their use. They are:

Chemical & Petroleum ***High Level Radioactive*** ***Low Level Radioactive*** ***TRU Waste*** ***Mixed Waste***



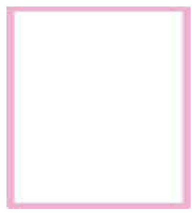
2.52 Status of Contaminant Containment or Control – Borders

The status of each contaminant's containment or control was collapsed into one of three descriptions, and is depicted by an associated border attached to the hatched color. The borders are the same color as the contaminant. They are:

1. **Not Under Control, Remediation or Treatment - No Border**

2. **Under Limited Control and/or Being Remediated or Treated – Dotted Border**

3. Fully Contained – Solid Border

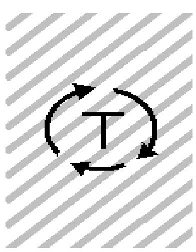


2.53 Physical State or Location of Contamination – DOD Symbols

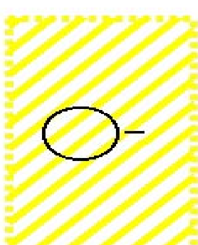
SDSFIE also has a extensive library of standardized symbols, many of which can be used for identifying the physical structures and environmental hazards considered to be most relevant to the DOE sites. We have extracted those most pertinent to the DOE sites, and attached the Table to this paper as Appendix C.

We recommend that the physical state or location of the contaminant; i.e., building, tank, underground storage, etc., be depicted by adding the SFSDIE symbol to the above described diagonal color and border scheme for identifying the type and remediation status of the contaminant.

The following represent several examples of how theses three elements would be used together:



Area with low level contamination, low to no control, and a solid waste transfer station



Area with TRU contamination, moderately controlled, and a regulated above ground storage tank

Area with high level contamination, high control, and a contained hazmat storage building

2.6 MAP SCALES

It is equally important that all DOE sites use a standard or common set of map scales, and that maps in the same grouping use the same scale. This will permit an easy comparison at DOE-HQ of regional and site-wide map sets prepared by different DOE sites. A map scale defines the relationship between distance on a map and the corresponding distance on the ground, which is often expressed as a representative fraction of distance, such as 1:24,000 (one unit of distance on the map represents 24,000 of the same units of distance on the Earth). Map scale can also be expressed as a statement of equivalence using different units; for example, 1 inch = 1 mile or 1 inch = 2,000 feet. In this case the ratio 1:24,000 is the same as 1 inch = 2,000 feet.

These conventions of map scale have been standardized by USGS and others:

Map Scale	One Inch on Map Equals
1:12,000	1,000 feet
1:24,000	2,000 feet
1:62,500	1 mile
1:100,000	1.58 miles
1:250,000	3.95 miles
1:500,000	7.89 miles
1:2,000,000	78.9 miles

2.7 DATA MANAGEMENT AND QUALITY

In a very broad sense, working with geospatial data involves three tasks: data generation, data management, and data dissemination. Data generation involves data collection and QA/QC practices; Data management involves archival of data into databases and generation of metadata; and Data dissemination involves production of maps and/or reports for conveying the substance of the data to the intended target audience.

If the focus is on obtaining new geospatial data that is currently unavailable, then data generation becomes a consideration. However, for this project the greater focus is on collecting, organizing, and disseminating available data through these core maps. Good geospatial data management practices are no different from good general information management practices, except for the additional stress on the spatial (and possibly spatial-temporal) dimensions of data being managed. There are several dimensions to data management, such as choice of relational database management software, the architecture of the database, formatting standards, security and access control criteria, documentation and cataloguing of data, and so on. Each of these subjects are critical to the accurate depiction of hazardous areas of concern, possible pathways, and potential receptors at each of the DOE sites, but it is an area that is far more technical than can be addressed in this paper. A brief discussion of metadata and metadata standards is attached as Appendix D.

3.0 GEMS AND INTERNAL DOE RESOURCES

The Geospatial Environmental Mapping System (GEMS) was designed to provide dynamic mapping and environmental monitoring data display for sites under stewardship by the DOE Grand Junction Office (DOE-GJO) Long-Term Surveillance and Maintenance (LTSM) Program. GEMS is the result of a pilot project in 2002 to develop a web-based GIS for the LTSM program that could be used by all stakeholders, including DOE, regulatory agencies, LTSM program staff and local community members. The first phase consisted of assessing the information needs and developing web application specifications. Based on these requirements, a prototype was developed and demonstrated. This was followed by final development and deployment of basic mapping data layers and environmental monitoring information at 28 LTSM sites .

The Grand Junction Office retains responsibility for maintaining and updating the environmental monitoring data and mapping data layers for these existing sites, and a similar function will be performed as more sites are transitioned into the LTSM Program. With GEMS, the user can start with a map of the US and then click on a state with sites listed or use the drop-down site menu and select a specific LTSM site. GEMS employs simple user-friendly navigational tools which includes the ability to zoom in and out, to pan, to print etc. The data layers presented include monitoring wells, fences, roads, streams, water bodies, disposal cell boundaries, and site boundaries. USGS 1:24000 guadrangle maps and georeferenced orthophotography (if available) can also be displayed to provide a more regional context view of the site.

The GEMS format differs from our core maps in two ways. The first is that, at least in its current configuration, GEMS does not intend to show many of the human and ecological activity attributes that we are recommending. In fact, they were not listed in the Pilot Project survey document that was used to determine needs and priorities. The second difference is that much more extensive contaminant data has been collected and made available for easy access through the GEMS web-based interactive maps, than is being considered for these core maps. The GEMS user is able to click on any monitoring well displayed, and obtain a wealth of current and historical information about multiple contaminants, some even in graphic form. Photos from the annual site inspection are also available on most of the sites.

These mapping differences result from differences in the status of these DOE sites versus those that we are addressing in this report, and not from any inconsistency or differences in geospatial data collection or mapping philosophy. The LTSM sites are not undergoing active remediation and restoration and thus are not in need of developing a risk-based end-state vision. They are largely inactive sites, except for ongoing monitoring, surveillance and other long-term stewardship requirements. As such, their priority is to provide regulators and the public with data and other information that shows that any remaining contaminants are being effectively monitored and controlled.

GEMS, and more specifically the Grand Junction Office, represent a valuable resource that should be used to help implement this core map program at DOE sites across the country. Grand Junction has, through the lessons learned in converting 30 sites, developed a deep understanding of the problems, issues and challenges of building a geospatial database and mapping system for sites with little or no understanding of the subject. It learned early on that the effort required is in proportion with the quality and availability of the data. In response, Grand Junction has developed a process or protocol for working with new sites, even before cleanup is completed and they are transferred to the LTSM Program. This seasoned approach and the availability of DOE staff experienced in developing web-based GIS systems for a variety of sites should be factored into any proposed core map implementation program.

We have recently begun working with the GEMS staff to test the feasibility of applying these new mapping standards to their existing map structure, and the results to date generally support or thesis that our two systems of approach are compatible and efficient.

A more descriptive discussion of the GEMS system and its possible application to the RBES Project has been prepared by John Stewart (DOE-HQ) and Dan Collette DOE-GJO), and is included as Appendix D.

5.0 DISCUSSION AND NEXT STEPS

As noted at the beginning of the paper, this core set of geospatial maps are intended to identify the location of sources of potential risk, and the interfaces and possible pathways that might bring them into contact with at risk human and ecological populations. The ability to reduce or eliminate the contaminant, and/or to control its ability to reach human and ecological receptors would be shown on the maps depicting the site's end-state vision. These maps are a foundation for quantifying, but not a depiction of the actual or relative level of risk represented by each contaminate source.

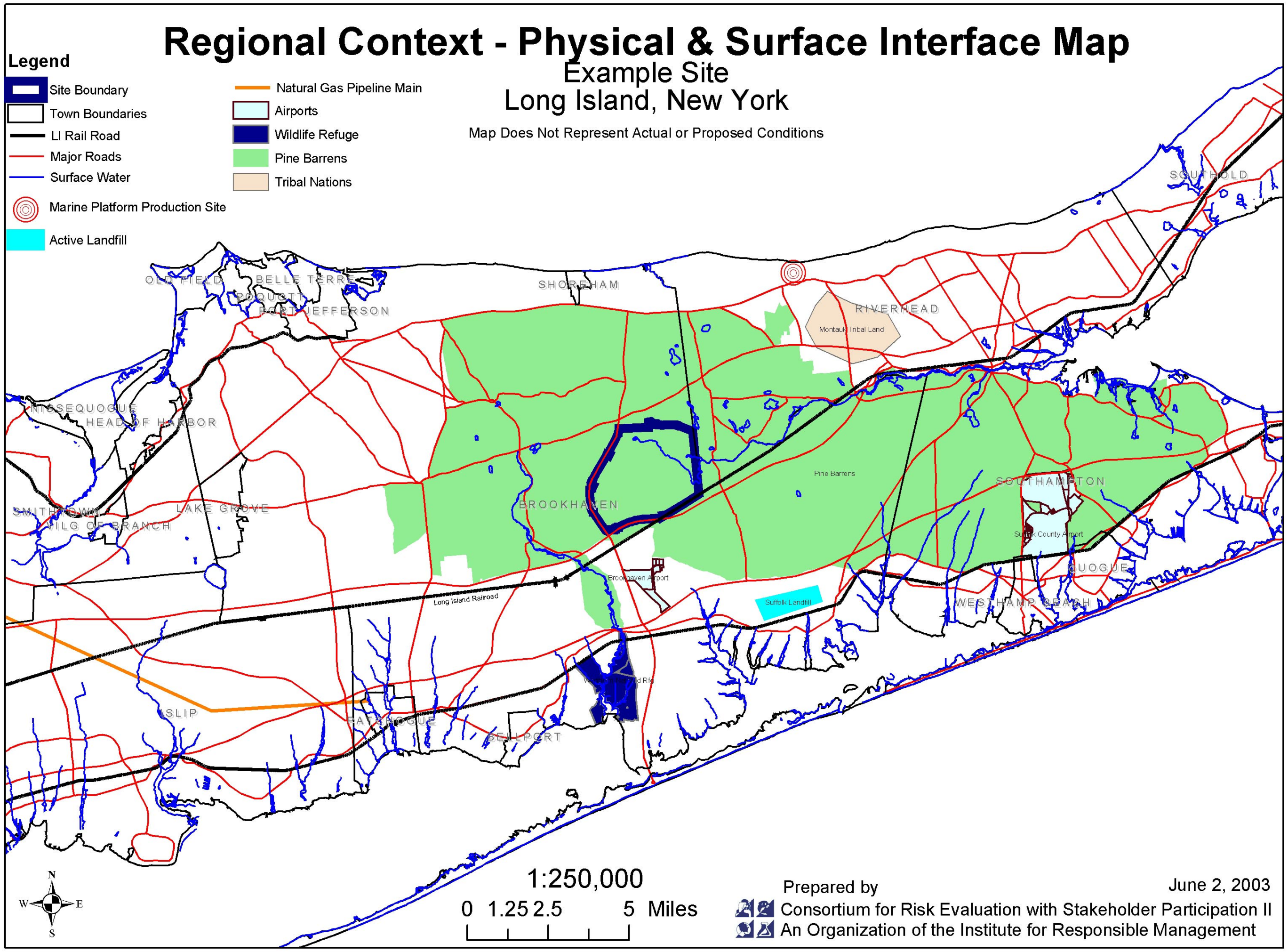
As noted above, we have begun working with the GEMS staff at Grand Junction to test the feasibility of integrating these new mapping standards into their existing GIS and web-based framework, and results to date have been positive. We have worked with the GIS staff at Brookhaven to develop the example maps that are attached in this paper. That exercise has enabled us to use a large amount of already collected and formatted geospatial data to test the feasibility and time involved in converting the data and displaying it through these new core maps. We are currently working with the Ashtabula site to better understand how these maps can be developed at a small site with little geospatial data available on or off-site. And lastly, we hope to engage the Savannah River site in testing out the feasibility, time and cost of developing these core maps using their extensive GIS databases. This process of testing and possibly refining the mapping standards outline in this paper should continue over the next several months as a large number of DOE sites begin developing their risk-based end state visions, and the associated core set of maps that will be become a critical part of that document.

Acknowledgments
This project was supported by a cooperative grant to the Consortium for Risk Evaluation with Stakeholder Participation (CRESP) from the U.S. Department of Energy, *Instrument DE-FG-00NT40938.* The authors accept full responsibility for the ideas and recommendations in this report.

Appendix A

Mapping Examples

These example maps were developed with the assistance of the GIS staff at Brookhaven National Laboratories on Long Island, New York. They utilize a combination of geospatial data provided by BNL, data downloaded from Sulfolk County, U.S. Census Bureau and U.S. Geologic Survey web sites, and data which we created in order to make the maps more illustrative of the different attributes that should be depicted on site maps. ***As such, these example maps should not in any way be construed as accurately depicting the contaminant types, remediation or mitigation status, and end-state vision of the Brookhaven site. They are solely intended to be examples of how the various attributes should be used and depicted on these core maps.***



Regional Context - Physical & Surface Interface Map
Example Site
Long Island, New York
Map Does Not Represent Actual or Proposed Conditions
Legend
Site Boundary
Town Boundaries
LI Rail Road
Major Roads
Surface Water
Marine Platform Production Site
Active Landfill
Natural Gas Pipeline Main
Airports
Wildlife Refuge
Pine Barrens
Tribal Nations
OLD FIELD
BELLE TERRE
POQUOTT
PORT JEFFERSON
SHOREHAM
RIVERHEAD
Montauk Tribal Land
SOUTHOLD
NISSEQUOGUE
HEAD OF HARBOR
SMITHTOWN
VILG OF BRANCH
LAKE GROVE
BROOKHAVEN
Pine Barrens
SOUTHAMPTON
Suffolk County Airport
QUOGUE
WESTHAMPTON BEACH
Brookhaven Airport
Suffolk Landfill
Long Island Railroad
SLIP
PATCHOGUE
BELLPORT
N
W
E
S
1:250,000
0 1.25 2.5 5 Miles
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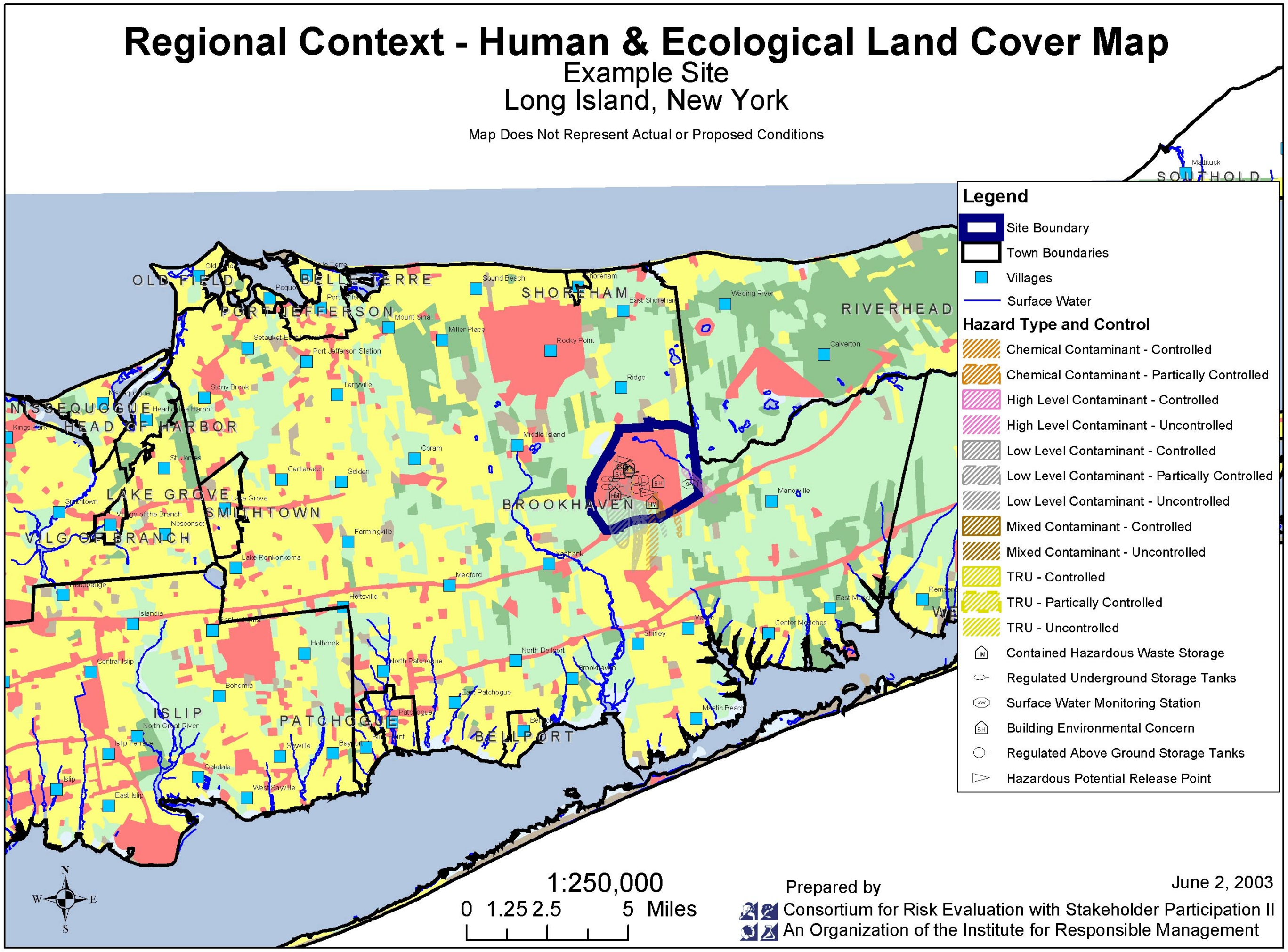
June 2, 2003


Regional Context - Human & Ecological Land Cover Map
Example Site
Long Island, New York
Map Does Not Represent Actual or Proposed Conditions
Legend
Site Boundary
Town Boundaries
Villages
Surface Water
Hazard Type and Control
Chemical Contaminant - Controlled
Chemical Contaminant - Partically Controlled
High Level Contaminant - Controlled
High Level Contaminant - Uncontrolled
Low Level Contaminant - Controlled
Low Level Contaminant - Partically Controlled
Low Level Contaminant - Uncontrolled
Mixed Contaminant - Controlled
Mixed Contaminant - Uncontrolled
TRU - Controlled
TRU - Partically Controlled
TRU - Uncontrolled
Contained Hazardous Waste Storage
Regulated Underground Storage Tanks
Surface Water Monitoring Station
Building Environmental Concern
Regulated Above Ground Storage Tanks
Hazardous Potential Release Point
OLD FIELD
BELLE TERRE
PORT JEFFERSON
SHOREHAM
RIVERHEAD
SOUTHOLD
NISSEQUOGUE
HEAD OF HARBOR
LAKE GROVE
SMITHTOWN
VLG OF BRANCH
BROOKHAVEN
ISLIP
PATCHOGUE
BELLPORT
1:250,000
0 1.25 2.5 5 Miles
Prepared by
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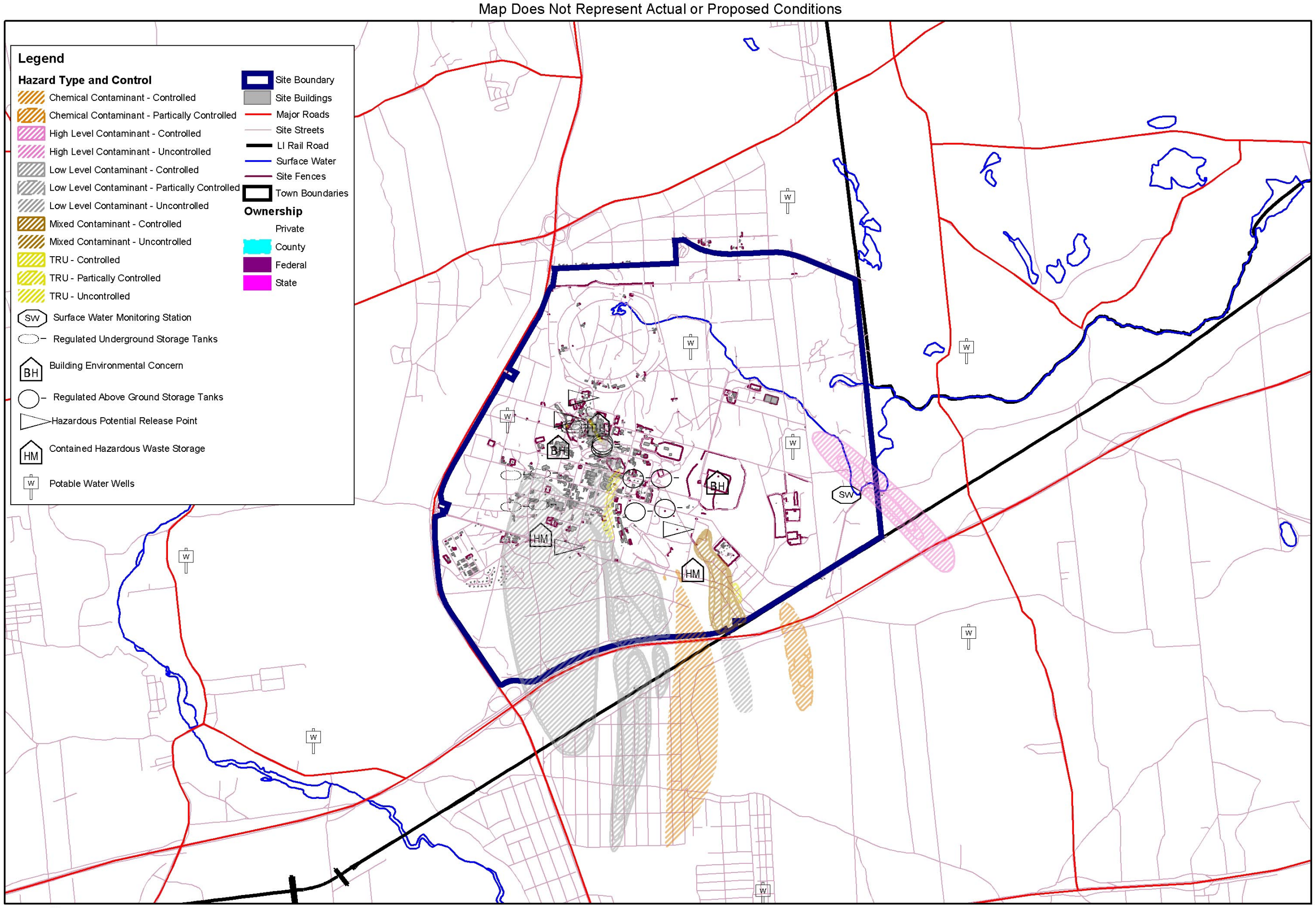
June 2, 2003

Site Context - Physical & Surface Interface Map

Example Site

Long Island, New York

Map Does Not Represent Actual or Proposed Conditions



N W E S 0 0.5 1 2 Miles

1:62,500

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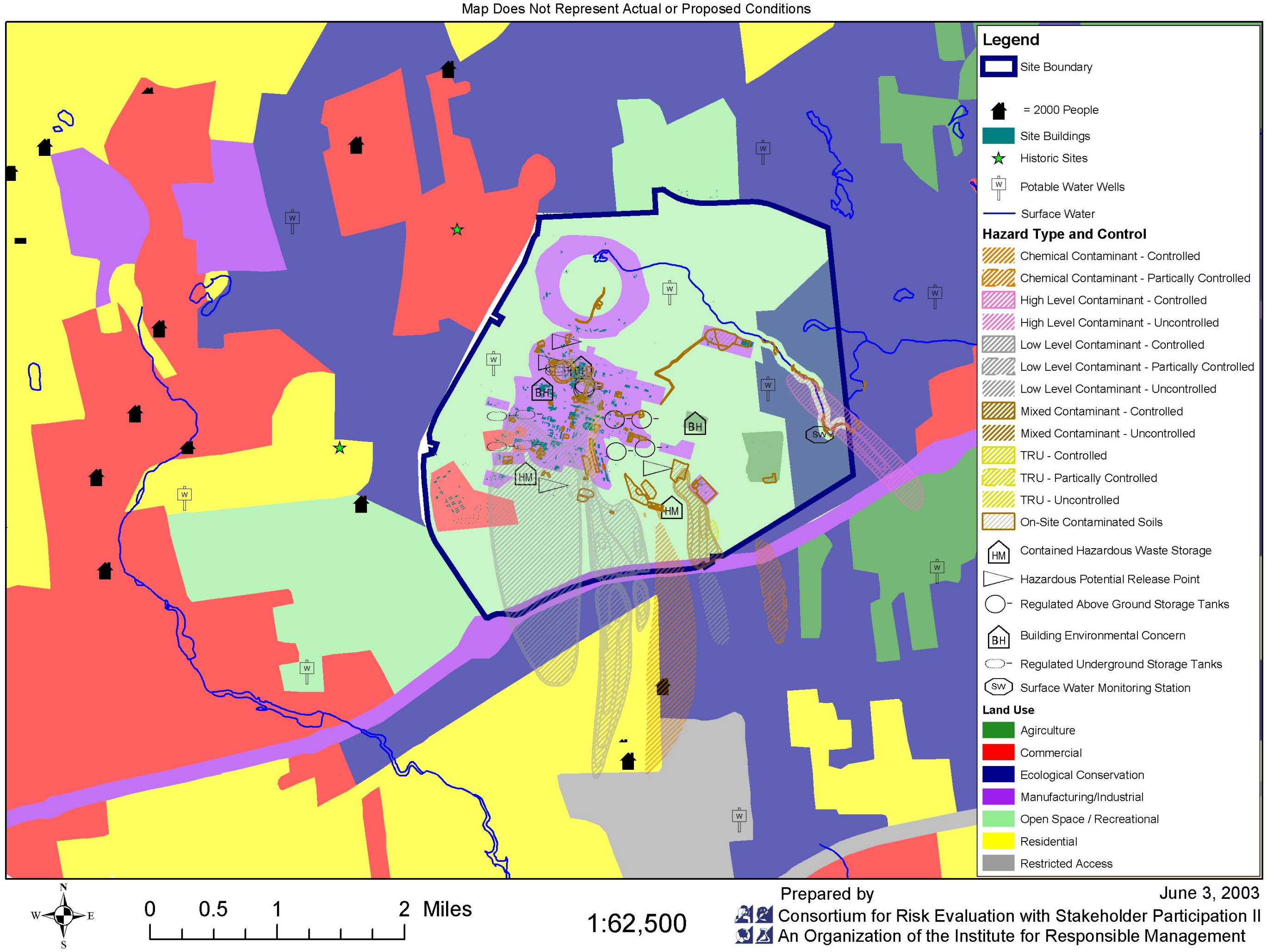
June 3, 2003

Site Context Map - Human & Ecological Land Use

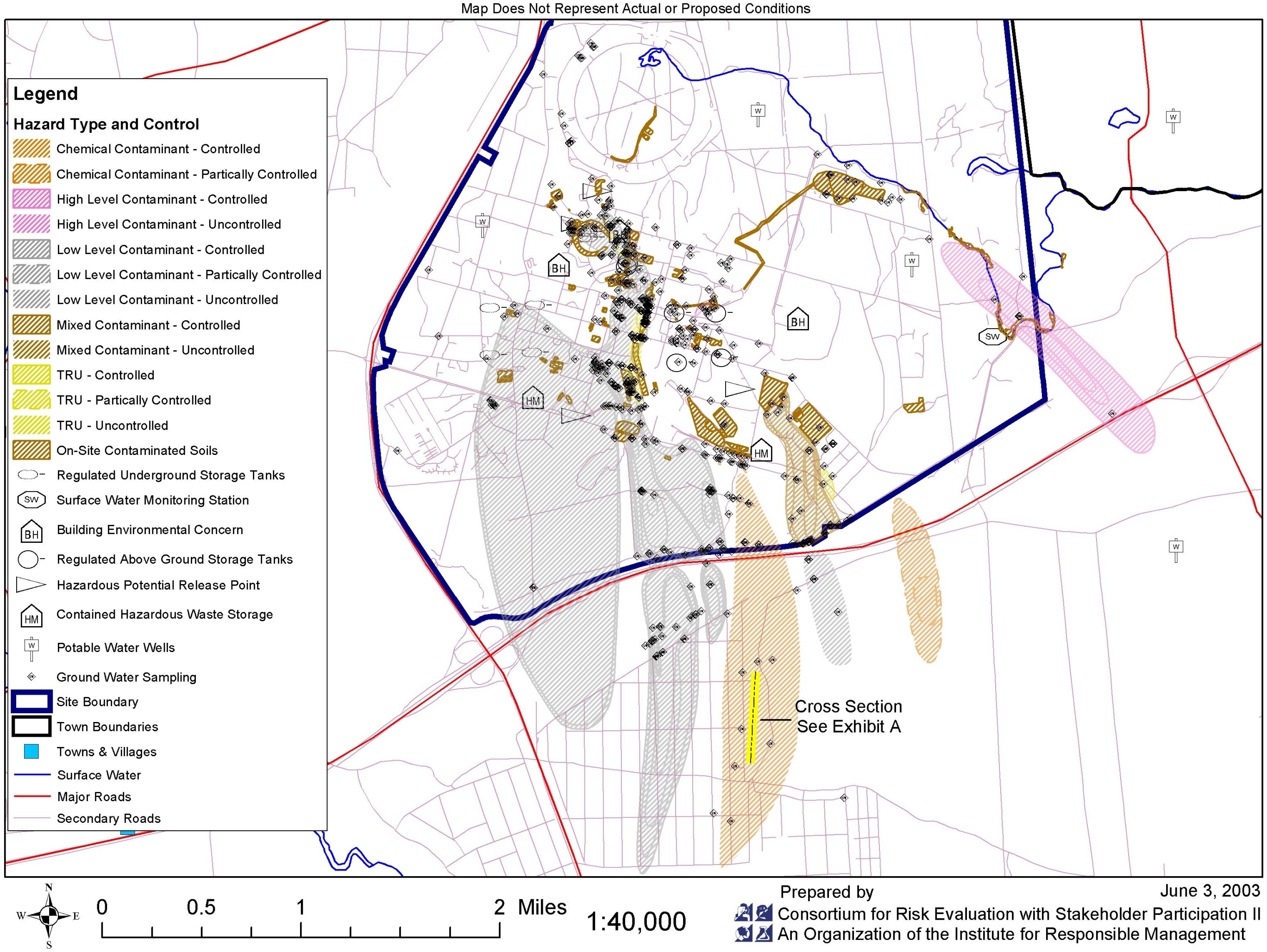
Example Site
Long Island, New York
Map Does Not Represent Actual or Proposed Conditions



Site Hazards & Ground Water Sampling - (Site-Defined Custom)

Example Site
Long Island, New York

Map Does Not Represent Actual or Proposed Conditions



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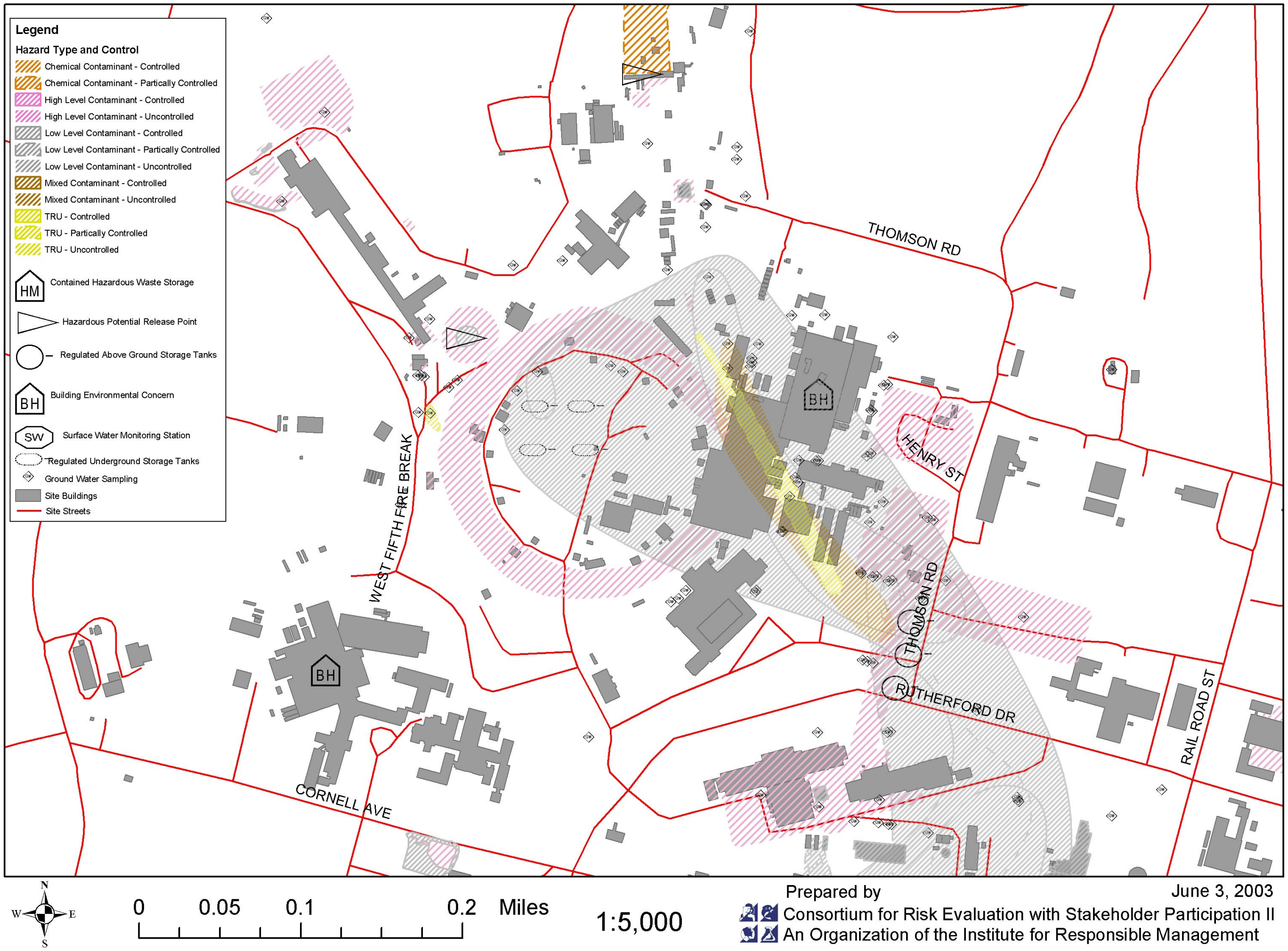
Local-Specific Hazards

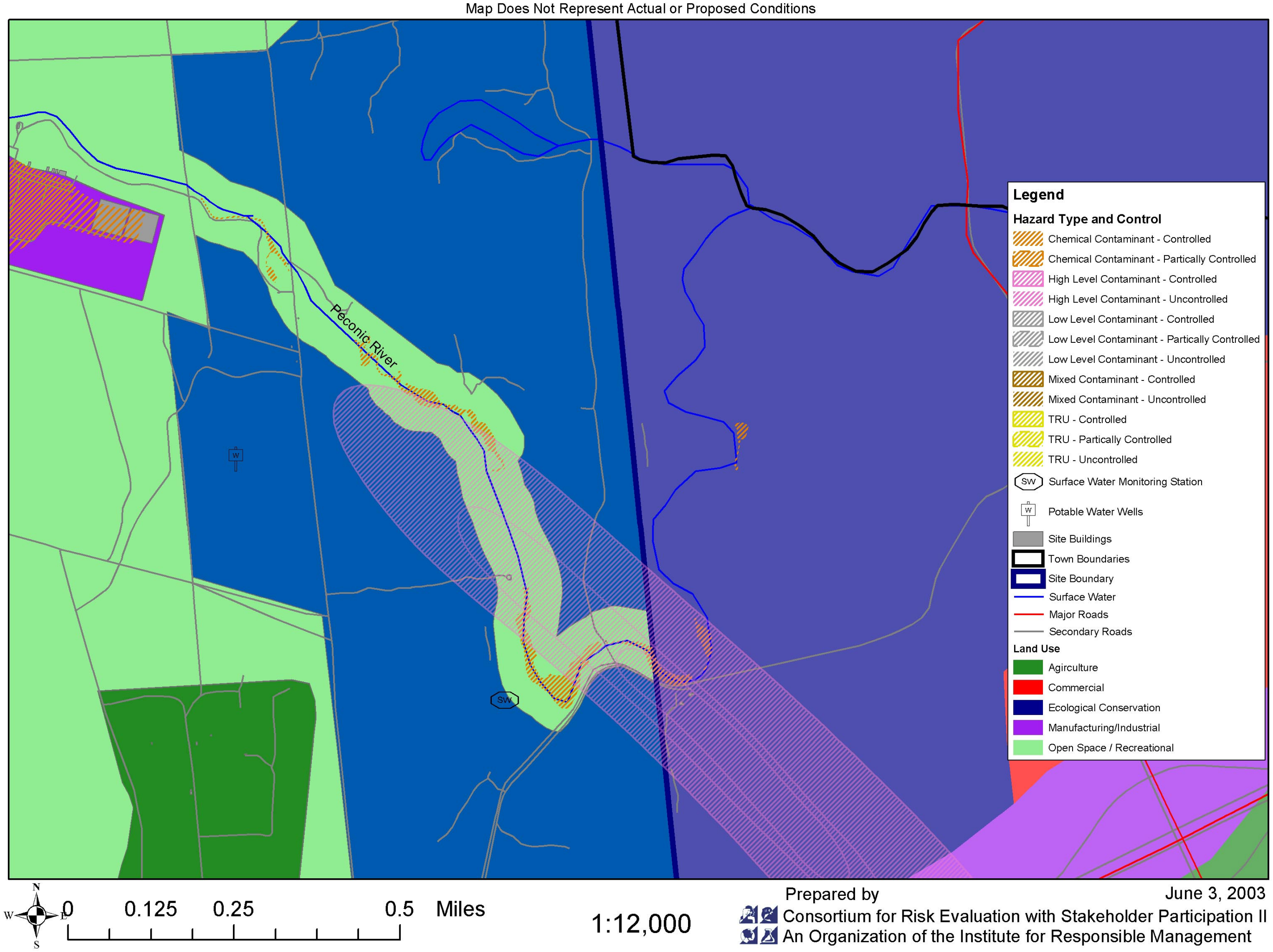
Example Site
Long Island, New York

Map Does Not Represent Actual or Proposed Conditions



Local-Specific Hazards / Hazard Mitigation Map - Current State

Example Site
Long Island, New York
Map Does Not Represent Actual or Proposed Conditions



1:12,000

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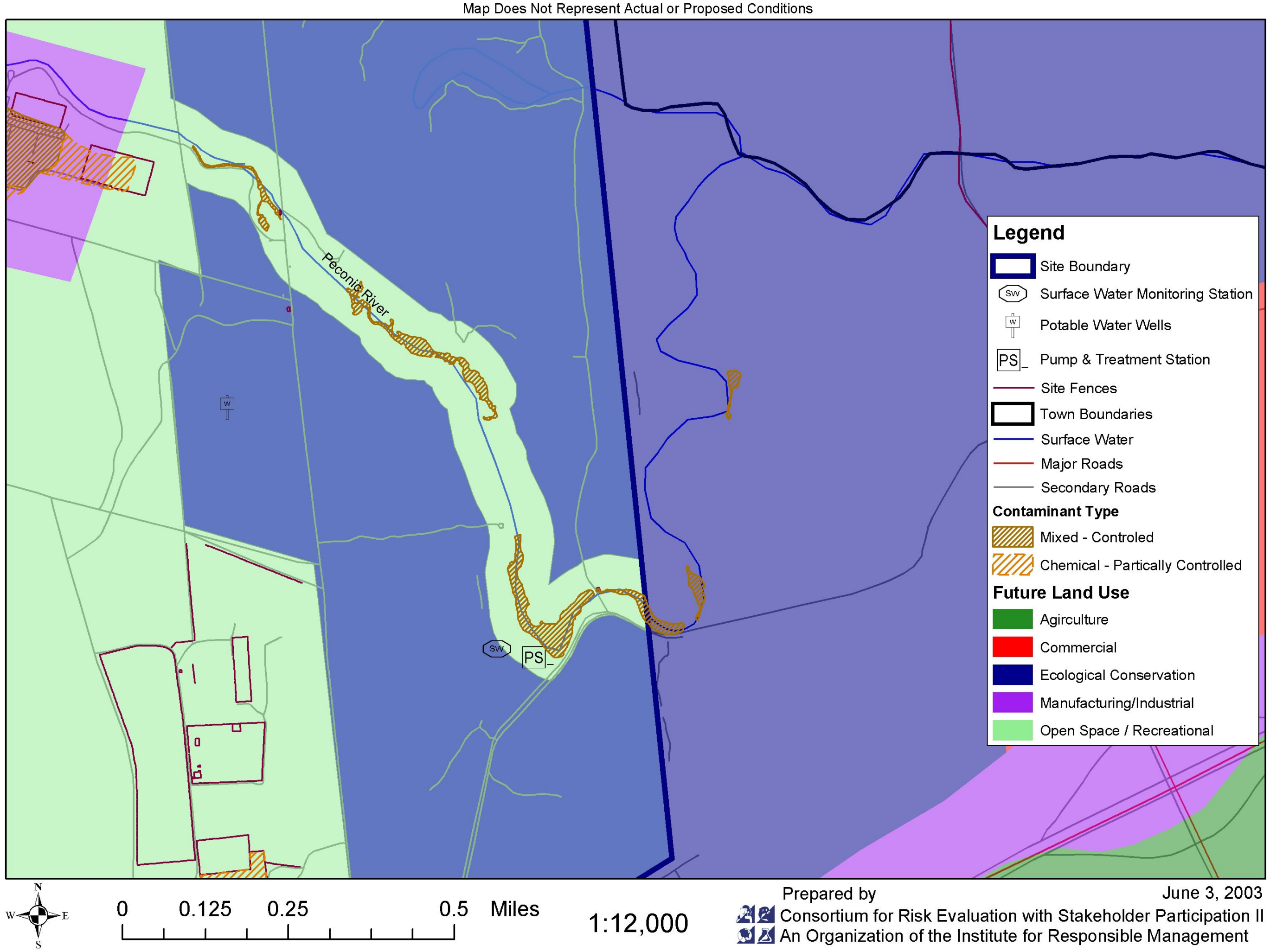
Local-Specific Hazards / Hazard Mitigation Map - End State (2023)

Example Site
Long Island, New York
Map Does Not Represent Actual or Proposed Conditions



Prepared by
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An Organization of the Institute for Responsible Management

June 3, 2003

Appendix B

Geospatial Data and Mapping Sources

We have recommended a set of geospatial core maps, which in our best judgment can be developed at every DOE site with a minimal cost and a maximal reliance on readily available data. We believe that most, if not all, of the sites already have or have ready access to, geospatial or paper data on most of the on-site attributes needed to prepare the *Site-Wide Context* and *Hazardous Area of Concern* maps. Most of the sites have previously developed maps showing infrastructure, building footprints, contaminant areas, and other on-site attributes, and as a first step we recommend that they do an inventory of existing in-house (DOE and contractor) spatial data. The question that is most likely to be raised is where can they obtain the off-site data needed for the *Regional Context* maps.

This Appendix has been prepared to provide the reader with a small glimpse of the huge amount of geospatial data that has been developed by state and federal governments and their agencies. Most of the maps are available for viewing and download over the Internet using GIS software packages already owned by many DOE sites. Smaller sites that do not have GIS capability can download and use ESRI's free ArcExplorer software package – see http://www.esri.com/software/arcexplorer/index.html

There are many web sites from which the researcher or GIS practitioner can begin to search for on and off-site regional data, including the ***National Geospatial Data Clearinghouse*** which is operated by the Federal Geographic Data Committee. We believe that the ***Center for Advanced Spatial Technologies (CAST)*** facility at the University of Arkansas maintains one of the most comprehensive and easy to use web sites. It is titled ***Starting the Hunt: Guide to Mostly On-Line and Mostly Free U.S. Geospatial and Attribute Data.*** Please go to http://www.cast.uark.edu/local/hunt/index.html and click on **Second Edition.**

As you will see, the Center has organized several hundred web-based data sources into two broad classifications: **National Aggregations** and **State and Local Aggregations**. The vast majority of these web sites require ArcView or other GIS software systems to view the data, which severally limits our ability to show the reader of this Addendum the depth and quality of the maps and data available, but a sufficient number of these sites are accessible without using ArcView to demonstrate the value and flexibility of this large web-based geospatial data source.

One example that permits us to show the depth of some of the information available is under the State of South Carolina. Please scroll down to *South Carolina*, click on the *South Carolina Department of Natural Resources GIS Data Clearinghouse* site. When you reach that site, click on *Download Data* from the menu on the left. You can either register and obtain your own ID number, or if you like you can type in Henry in the box for *First Name* and the number 17515 for *Reference ID*. When you reach the Main Menu, click on the *County Map Query* on the left, and when the map of the state appears,

click on *Aiken County* (home of the Savannah River Site). On the next map click on either the *Aiken, New Ellenton,* or *Hollow Creek* boxes. Assuming everything worked correctly you should be at a table showing the various types of data available for that Quad and when it was last updated, along with web links to the related geospatial maps and metadata. For Aiken this page is located at:
http://www.dnr.state.sc.us/pls/gisdata/quad.qselect?ptilename=AIKEN&pcounty=aiken

Among the databases available for viewing and download are digital orthophotos (aerial photos taken in 1999); data from USGS on hydrography, topography, elevation, pipe/transmission lines, roads and railroads; wetlands data from the U.S. Fish & Wildlife Service; and, soils data from the National Cooperative Survey. All are in standard 7.5 Quad map format, with the exception of the orthophotos, which are available in quarter quads.

Another example of the depth and type of geospatial data available through the ***CAST*** site is under the State of Ohio. Returning to the ***CAST*** main menu page http://libinfo.uark.edu/GIS/us.asp scroll down to *Ohio*, and then click on the *OhioLINK Media Center* and its Landsat 7 Satellite Images site. Then click on the *Path 20 Row 32* area of the state map that appears, and choose the High Resolution Monochrome option. This produces a satellite image of the entire central western area of the state. A variety of dates can be chosen if the image that appears is not sharp enough because of clouds, smoke or other interference. Using the Navigation Tool on the right, the user can zoom in on a smaller geographic area of interest. In addition, the user can click on the *Topographic Map Area of this Region* tool and *1:100,000 scale* to generate a topographical map of an even smaller area. And with a few further adjustments we can generate a map of Miamisburg that shows the location of the DOE's Mound facility, produced by TopoZone.com. Please go to:
http://www.topozone.com/map.asp?lat=39.6223318006107&lon=-84.2788917130149&s=100&sizes=s

Zooming to *1:25,000* scale on the Mound site produces an even finer topographical map, which when blown up to the map's *Medium* and *Large* versions shows the site's location relative to a golf course, local sewage disposal facility, and various residential areas. See – http://www.topozone.com/map.asp?z=16&n=4389427&e=732881&s=25&size=m

What we also learn in the process of this exercise is that TopoZone.com has worked with USGS to produce interactive topographical maps for the entire United States. Thus, we can quickly access similar information on virtually any area of the country. As an example, the following is a large map at 1:50,000 scale of the DOE's Rocky Flats (Rocky Mountain Arsenal) site. See -
http://www.topozone.com/map.asp?z=13&n=4407530&e=513913&s=50&size=l

Summary

These several examples provide a small glimpse into the huge number of geospatial and other databases that are readily available through the ***Center for Advanced Spatial***

Technologies (CAST) web site. There are a large number of federal government and agency web sites with valuable geospatial data that can be accessed via ***CAST*** or reached directly, such as USGS, the Bureau of Land Management, Department of Agriculture, Department of Housing and Urban Development, the Environmental Protection Agency, and U.S. Park Service. Many states, such as South Carolina, provide web access to more localized data, and others will make information available on CDs for a fee.

Appendix C

I. Similarities and Differences Between DOE and National Land Cover Systems:

Water: This class combined open water with perennial ice/snow.

Residential Developed: Low intensity and high intensity residential were combined as one DOE land cover class to show where people reside. The RGB value (255, 255, 0) is identical to the APA LBCS residential function.

Commercial, Industrial, Transportation: No change from the NLCD. However, the RGB value (255, 0, 0) is identical to the APA LBCS commercial function.

Barren: This classification combined bare rock/sand/clay; quarries/strip mines, gravel pits, and transitional areas. Independent of the use of the land these lands typically is barren of vegetation.

Non-Agricultural Vegetated: Deciduous, Evergreen and Mixed forests were combined with Shrubland and Urban/Recreational Grasses. These are areas with vegetation typically not for consumption and sporadic human activity. The RGB value (144, 238, 144) is identical to the APA LBCS arts, entertainment, and recreation function.

Agricultural: The most significant change to incorporate non-natural woody such as orchards and vineyards and herbaceous such as grasslands. The common denominators being that these lands are agricultural with a high probability for direct consumption or to support human consumption. The RGB value (34, 139, 34) is identical to the APA LBCS agriculture function.

Wetlands: Woody and emergent wetlands were combined.

II. Similarities and Differences Between the DOE and APA Land-Based Classification Standards (LBCS):

Residential: Hotels, motels and other accommodation services (Function 1300) was removed from this category and moved to commercial.

Commercial: Education, public administration, health care, and other institutions were grouped into this classification (Function 6000). Hotels, motels and other accommodation services (Function 1300) were moved from Residential.

Manufacturing and Industrial: This classification incorporates mining and extraction establishments (Function 8000) and construction related business (Function 7000).

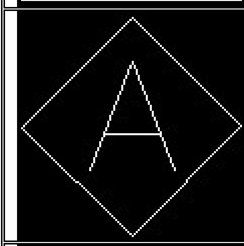
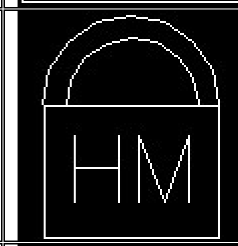
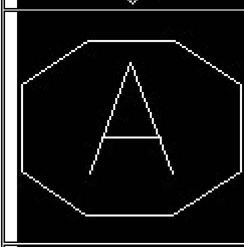
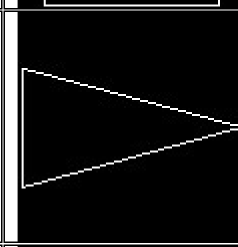
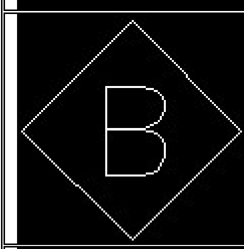
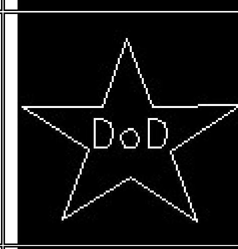
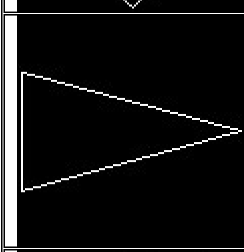
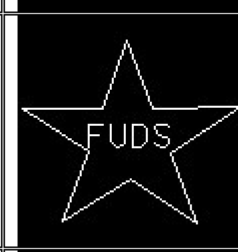
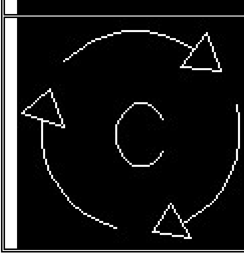
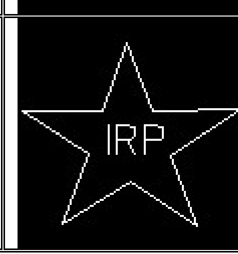
Agriculture: This category is similar to Agriculture, forestry, fishing, and hunting (Function 9000).

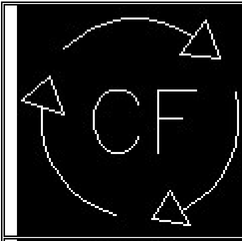
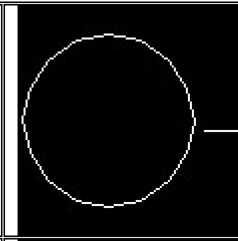
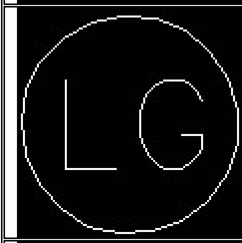
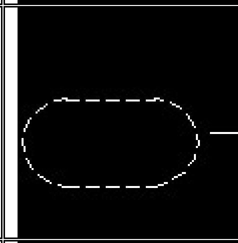
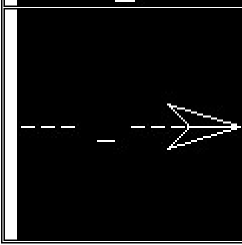
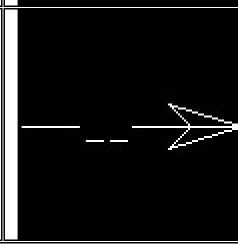
Open Space / Recreational (implies unrestricted public use): This category is similar to the LBCS arts, entertainment, and recreation category (Function 5000).

Open Space / Ecological Conservation / Preservation: The LBCS function classification system considers these lands as part of recreation (Function 5500). Access playing a critical role, a better classification is the LBCD Ownership system is Some Constraints – easements or restricted use (Ownership 2000).

Restricted Access: This category is not covered by the LBCS and is exclusive to the DOE classification system. The color-coding was chosen based so as to not conflict with other Land Use or Land Cover categories.

III. Environmental Hazard Mapping Symbols

Symbol Image	Entity Type	Symbol Image	Entity Type
	Building environmental concern site		Contained hazmat storage building point
	Field sample air collection location point		Hazardous materiels storage vault point
	Air quality monitoring station point		Pollution source point
	Field sample biological collection location point		DOD formerly used defense site
	Hazards potential release point		Environmental restoration site
	Solid waste compactor point		Environmental restoration site

	Solid waste composting facility point		Regulated aboveground storage tank site
	Landfill gas collection well point		Regulated underground storage tank point
	Subsurface water flow direction arrow		Surface water flow direction arrow

APPENDIX D

Metadata and Metatdata Standards

Metadata have been widely defined as "data about data", or in other words, detailed descriptions about the content of a particular data set. Metadata are intended to provide the user a detailed characterization of the content, quality, conditions and other attributes of the data, without having to access the actual data (FGDC, 2000). A completed 1040 Tax form is, in a sense, metadata regarding an individual's financial information.

As noted earlier, the content standard for digital geospatial metadata within the federal government was promulgated in 1994 through Executive Order 12906. The purpose was to standardize procedures so the prospective user could determine the availability of a set of geospatial data, determine the fitness of the set of geospatial data for an intended use, determine the means of accessing the set of geospatial data, and successfully to transfer the set of geospatial data.

How are metadata generated and maintained?
Metadata are generated and maintained by individuals in charge of developing and maintaining GIS coverages. Metadata generation should ideally begin with collection of data; however, metadata can also later be generated for legacy datasets. Essentially, metadata generation entails production of standardized data description forms. For someone knowledgeable about the data coverage being described, generating metadata is no different from filling out a tax form. No specialized technical skills beyond an intimate knowledge of the data being described are required. And, as in filling tax forms, software packages are readily available to ease the process of metadata generation and maintenance.

While generating and maintaining metadata is not a time consuming, complicated, or expensive exercise in itself, there can be significant administrative blocks in the process of developing metadata. Metadata are often developed as an afterthought, and the task of generating and maintaining them is regarded as trivial or a time-consuming chore. Generating data descriptions is also incorrectly regarded as being a non-essential or bureaucratic requirement that can compromise confidentiality of data.

U.S. standards for metadata generation are currently set by the Federal Geographic Data Committee (FDGC) in FDGC-STD-001-1998 (FDGC, 1998). That document gives the structure, content and semantic convention criteria to be used for metadata documents. Detailed guidelines for metadata generation and maintenance are given in the accompanying workbook (FDGC, 2000).

It is not enough to merely generate metadata once. Since databases are living, evolving entities, metadata maintenance is a continuous process that is an integral part of a sound data management policy. Every time a database is modified or expanded, the changes should be noted in the metadata document. Equally importantly, contact information should always remain current to enable users to contact the right person for accessing the data or for seeking further details about the data.

The administrative blocks preventing metadata management can be overcome through DOE-HQ policy decisions. The actual task of generating and maintaining metadata falls to relatively junior staff, so there is a danger that metadata quality may be variable, maintenance and updating of metadata may be neglected, and metadata formats may be inconsistent across different departments in the same organization. These pitfalls can be avoided through level policy directives about metadata generation and maintenance practices. Standardized metadata forms conforming to FDGC or ISO standards are readily available and are already being implemented by several federal, state and local agencies. Procuring standardized forms is trivial and free, and a clearly enunciated policy goes a long way in overcoming institutional inertia in managing metadata.

Appendix E

ANAYLSIS OF THE POSSIBLE APPLICATION OF GEMS IN MEETING THE MAPPING GUDIANCE NEEDS FOR PROJECT 7

By
John Stewart (DOE-EM) and Dan Collette (DOE-GJO)

The Geospatial Environmental Mapping System (GEMS) was designed to provide dynamic mapping and environmental monitoring data display for sites under stewardship by the DOE Grand Junction Office Long-Term Surveillance and Maintenance (LTSM) Program. The information made available and the environmental data display tools developed for GEMS were done based on input from various stakeholders including regulatory agencies, the public and DOE. Although GEMS was specifically developed for the LTSM program at the Grand Junction Office (GJO), the mapping aspect of the system could have direct applications to the Risk Based End State (Project 7) study currently in progress.

MORE ABOUT GEMS: GEMS was initially developed as a pilot project to provide stakeholders access to basic monitoring well information, groundwater quality information, water level information, and annual site inspection photographs for approximately 30 sites currently under stewardship at the GJO. One of the biggest challenges facing DOE today is being able to properly georeference the location and extent of disposal cells and monitoring wells for future tracking and regulatory compliance needs. Too often this critical information has been lost for future generations (often within only a few years) despite the tremendous cost for cleanup and monitoring and the commitments made to regulators and the public. The GJO has successfully geo-referenced data from a number of smaller sites and continue to perform the ongoing environmental data management functions required for stewardship. GEMS provides a method for displaying this information in a uniform manner for all LTSM sites.

Currently with GEMS, the user can start with a map of the US and then click on a state with sites listed or use the drop-down site menu and select a specific LTS site. GEMS employs simple user-friendly click on navigational tools including the ability to zoom in and out, to pan, to print etc. The data layers include groundwater monitoring wells, fences, roads, site boundaries, aerial photography, USGS quad sheets, etc. GEMS can be accessed from the LTSM Program home page http://www.gjo.doe.gov/programs/ltsm or directly at http://gems.gjo.doe.gov. More information including the LTS GIS Pilot Project Needs Assessment Report, the LTS GIS Pilot Project Final Report, and the GEMS Users Guide is available on the GEMS web site.

LESSONS LEARN AND HOW GEMS WAS DEVELOPED

One of the lessons learned by the GJO pertained to mapping data layer management. This, in conjunction with the lessons learned in the development of the GEMS system, could be especially helpful for developing the data management and mapping needs of smaller sites that currently have no geographic information systems (GIS) or adequate collection of georeferenced source maps. Many of the LTSM sites had very limited map sources which often included only paper maps that were not georeferenced to any standard grid such as the State coordinates, Lat-Long, or UTM. To geospatially locate a site for GEMS, it was sometimes necessary to convert site drawings to a geographic or a projected coordinate system.

In order to properly geo-rectify the location of needed data such as the disposal cells and monitoring wells, it was often necessary to field verify or even re-survey the site using conventional ground survey or aerial survey techniques. The time that is required and the additional costs that were incurred for conducting such field ground truthing or re-surveying varied greatly based upon the availability of the "trusted" geo-referenced data. This points to the urgent need for data standards, namely data layers requirements, data layer naming and attributing standards, and electronic format standards to meet the needs for DOE. (Reference the GJO Lessons Learned document for more information as the how these non-georeferenced maps were translated into a global coordinate system.[1])

POSSIBLE APPLICATION OF GEMS TO PROJECT 7

GEMS has proven itself to be an excellent tool for displaying LTS environmental monitoring data in a mapped format with very easy public access via the Internet. Although it was developed primarily as a LTS tool, it may have a direct application to addressing the mapping needs for displaying risk-based end state information as needed in Project 7. All the displayed GEMS data, such as the location of wells, fences, roads, site boundaries, surface water, disposal cells, etc. should also be included in any risk-based analysis. In addition, while not currently displayed with GEMS, the system could display other data layers such as the location and extent of contamination plumes for both on site and off site locations in either 2D or 3D. Institutional control (IC) boundaries and the data associated with them could also be a data layer available on GEMS. Additional risk-based information can be added to the system as needed from various sources, depending on availability.

Another good quality of GEMS is that it is was not just site specific but can include site-specific data layers on as needed bases. For example, GEMS displays information on the location and data for the numerous wells offsite in the Monticello community. Other risk-based, IC and environmental data can easily be displayed since the site inventories includes aerial photos and UGSG 1:24,000 (large scale) coverage for both onsite and offsite.

MAPPING STANDARDS AND THE NEED FOR UNIFORM SYMBOLOGY

To maintain uniformity and to be able to compare information between the various sites, it is important to maintain both mapping and symbology standards. If property georeferenced, this allows for the aggregation of spatial information (such as the size and

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[1] GJO Lessons Learned Working with Long Term Stewardship Sites from a Data Management/ GIS perspective

extent of risk based information) for the DOE complex. Aggregate risk based information allows for good summarization of the risk-based process, and to display the progress of risk-based cleanup efforts to Congress and the public

There is universal 1:24,000 USGS map coverage for the nation. Also, this mapping information is available from the USGS at reasonable cost in a raster digital format (DRG) and digital line graph format (DLG). Orders for DRGs can be made to Sioux Falls, S.D. at 605-594-6151 or through a USGS business partner. These maps have basically eight layers on information: transportation, hydrology, hypsography (topographic contours), man-made structures, survey contour layers (bench marks, etc.), vegetative cover, non-vegetative cover (open fields, etc.) and boundaries (state, county, etc.)

The DRGs are excellent backdrop maps for providing background information for the sites and surrounding areas since they are universally available with consistent scale and consistent symbology. However, since it is a raster product, individual layers cannot be turned on and off. This can make the map "very busy" and as additional layers are added, such as monitoring wells, legibility becomes a problem. Another option is to take the DRG maps and remove layer by layer the data that is not needed for the base maps. Assistance for this mapping process can also be provided by the USGS.

DLGs, on the other hand, is vector data for each of the eight data sets that can be turned on and off as desired. The USGS has addressed the need for producing vector maps for displaying various layers for the USGS quads.[2] They have worked with the states in the past to produce digitized vector quad maps. A list of quads already in a vector format can be obtained from the USGS or one of their business partners. Also, the UGSG can produce additional vector quad maps at cost depending on the complexity of the quad maps and coverage, etc. Other layers, , such as end state land use for Project 7, can then be added to the base map as an additional overlay.

It is important that uniform symbology and colors be used for maps developed in support of Project 7. Perhaps the most universally accepted symbology for map legends are those used by the USGS on their quad maps (see http://mac.usgs.gov/mac/isb/pubs/booklets/symbols/ for more information). It is suggested that we seriously consider using these symbols for maps in support of Project 7. ArcView (ESRI product) uses the UGSG symbols to display this symbology in their mapping software programs. This is important because most DOE sites already use ESRI projects.

RECOMMENDATIONS: It is suggested that consideration be given to use the GEMS program as a model for web-based maps that display risk-based information in support of Project 7. This is a working DOE system that is readily accessible for review by the public via the Internet and is user friendly. Consideration should be given to using the 1:24,000 USGS quads in DRG and/or DLG form as base maps if the site currently does

[2] Based upon conversations with Bruce Wallace, UGSG, 703-648-5526, April 3, 2003

not have georeferenced base maps. It should be recognized that the quad map is only as current as it's last update. .

While the GEMS model may be a good model to use, consideration should be given to incorporating LandTrek elements and suitable elements from other GIS programs that have applications in meet this mapping need. As mentioned by CRESP, we need to also check into various GIS inventory systems throughout the nation (especially at universities and at the Federal Geographic Data Committee One-Stop program) to see what georeference environmental data may already be readily available. In addition, the new LandView 5 develop jointly by USGS, Census, and EPA has universal coverage for social-economic data (including race, income, etc.) and risk-based information (including location of NPL sites and other sources of contamination). LandView 5 has been updated to include nation-wide 2000 census data.