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The Geophysical Data Fusion System (GDFS)

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13. ABSTRACT *(Maximum 200 words)*

This report describes the functionality of the Geophysical Data Fusion System (GDFS), which is a software system designed for use in support of environmental remediation studies at United States Air Force bases. Specifically, this report provides a detailed description of the version of GDFS which has been implemented at Maxwell Federal Division's Reston, Virginia Geophysics Office and installed on a UNIX workstation at the Phillips Laboratory facility at Hanscom Air Force Base in Massachusetts. This prototype system is directed toward a specific application to the Massachusetts Military Reservation (MMR) located on Cape Cod, and incorporates a wide variety of site specific environmental and geotechnical data, as well as selected geophysical analysis modules. Access to these data and analysis capabilities is provided via a graphical user interface operating off of a SPOT® satellite image of western Cape Cod. An overview of the functionality of the software is presented in the main body of the text; installation and startup instructions, a sample session and a comprehensive system reference are presented in Appendices.

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SECTION 1

INTRODUCTION

The Air Force has recently adopted a goal to insure that all of their facilities shall be environmentally clean by the year 2005. A significant element of the program which is being designed to achieve this goal is the development of new geophysical technology for characterizing hazardous waste sites, with particular emphasis on the assessment and remediation of any polluted groundwater aquifers which may exist at the wide variety of different Air Force facilities which are distributed throughout the U.S. This is a significant challenge in that these sites represent a great diversity of geological and hydrological environments and, consequently, their effective characterization is likely to involve many different types of information and geophysical survey data. Thus, an ability to efficiently integrate or fuse all of these disparate data and analysis results will be an important component of any successful environmental assessment program.

The research described in this report has the objective of improving the Air Force's capability to evaluate site specific environmental hazards through the development of an innovative, workstation-based data management, analysis and visualization system which will permit an analyst to easily apply a wide variety of different site information and geophysical analysis tools to the assessment of specific sites. The ultimate goal is to develop a system which will integrate a comprehensive, on-line environmental database for a selected site together with a map-based graphical user interface which facilitates analyst access to the databases and analysis tools, an analysis module containing state-of-the-art geophysical simulation models and a visualization system for the display and evaluation of data and model simulation results within a single, homogeneous analysis environment.

The prototype Geophysical Data Fusion System (GDFS) described in this report is directed toward a specific application to the Massachusetts Military Reservation (formerly Otis Air Force Base) located on Cape Cod, Massachusetts. A wide variety of site specific environmental and geotechnical data have been collected at this site over the past decade, and representative samples of these data have been acquired and merged into an online database for demonstration purposes. Access to these data, as well as to selected geophysical modeling and analysis capabilities, is provided in GDFS via a graphical user interface operating off of a SPOT® satellite image of the western portion of Cape Cod encompassing the MMR.

The user interface to the system has been designed to be completely menu-driven and mouse-activated and requires no keyboard entry by the user once the system has been started. This graphical user interface has been built using the X Window system; X was designed specifically to allow hardware independence, to foster ease in porting applications to machines other than those on which they were developed, and to permit running of applications on one computer while displaying their output on another, even if the computers are of different manufacture. GDFS was designed and implemented on Sun

SPARC computers, but transfer to any other system that supports X Windows and UNIX could easily be accomplished.

GDFS comprises a suite of applications. The front end is a program that performs most of the work of showing data in context and providing menu- and mouse-click access to well-log and other data. Auxiliary applications display recorded data, modeling results, and summaries of data. All the software has been written in C or FORTRAN. C was chosen because the application programmers' interface to X Window procedures is in C and because C is well suited to the design of complex systems with a variety of data structures. FORTRAN was used for certain legacy applications, particularly the modeling programs, with C and X front ends grafted on for purposes of displaying the results of the calculations to the user. Database functions are performed by procedures written as part of the GDFS effort. The database structure is compatible with commercial relational database management systems such as Oracle.

This document provides a summary report of the development of GDFS. In the next section, the capabilities and functionality of the system are illustrated using captured screen images that would be encountered by a user in a typical session. A detailed script leading to the displays shown in Section 2 is provided in Appendix B. A comprehensive description of all GDFS controls and options is presented in Appendix C.

SECTION 2

OVERVIEW OF GDFS CAPABILITIES

In this section, some of the capabilities and functionality of GDFS will be illustrated through images of the screens encountered in a typical session. For this example, data from Otis Air Force Base within the Massachusetts Military Reservation (MMR) on Cape Cod will be examined to illustrate features of the system. A detailed script of the operator actions required to reproduce this sample session is provided in Appendix B.

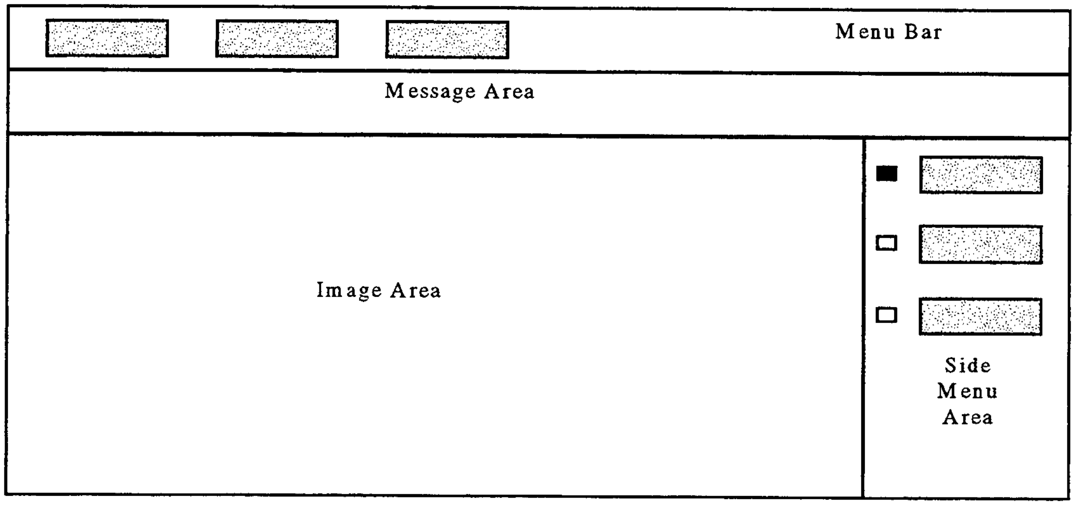

Figure 1. General appearance of GDFS applications.

The layouts of the GDFS application modules follow the pattern shown in Figure 1. The parts of the display are as follows:

- menu bar - an area at the top of the display that contains buttons that cause menus to be displayed
- message area - a strip just under the menu bar that displays short messages from the application
- image area - the main display area of an application
- side menu area - an area to the right of the image area that contains switches to control the functionality of the mouse. When a particular mouse function is selected, an indicator is illuminated next to the name of the function.

All applications in GDFS use the same layout, though not all applications use all parts shown.

We will present this overview of GDFS functionality by showing a series of screen images taken from a sample session. Each image has accompanying text describing the content of the screen.

The initial GDFS display is reproduced in Figure 2; a compressed (50 meters per pixel) SPOT® image of Cape Cod is shown in the context of the application's information interface. The main menu contains the menu-access buttons *Images, Overlays, Locations, Refresh, Function, Models*, and *Help*; and action buttons *Copy* and *Quit*. Besides the satellite image, the image contains labels for the main geographic areas in the image, and shows the boundary of the Massachusetts Military Reservation.

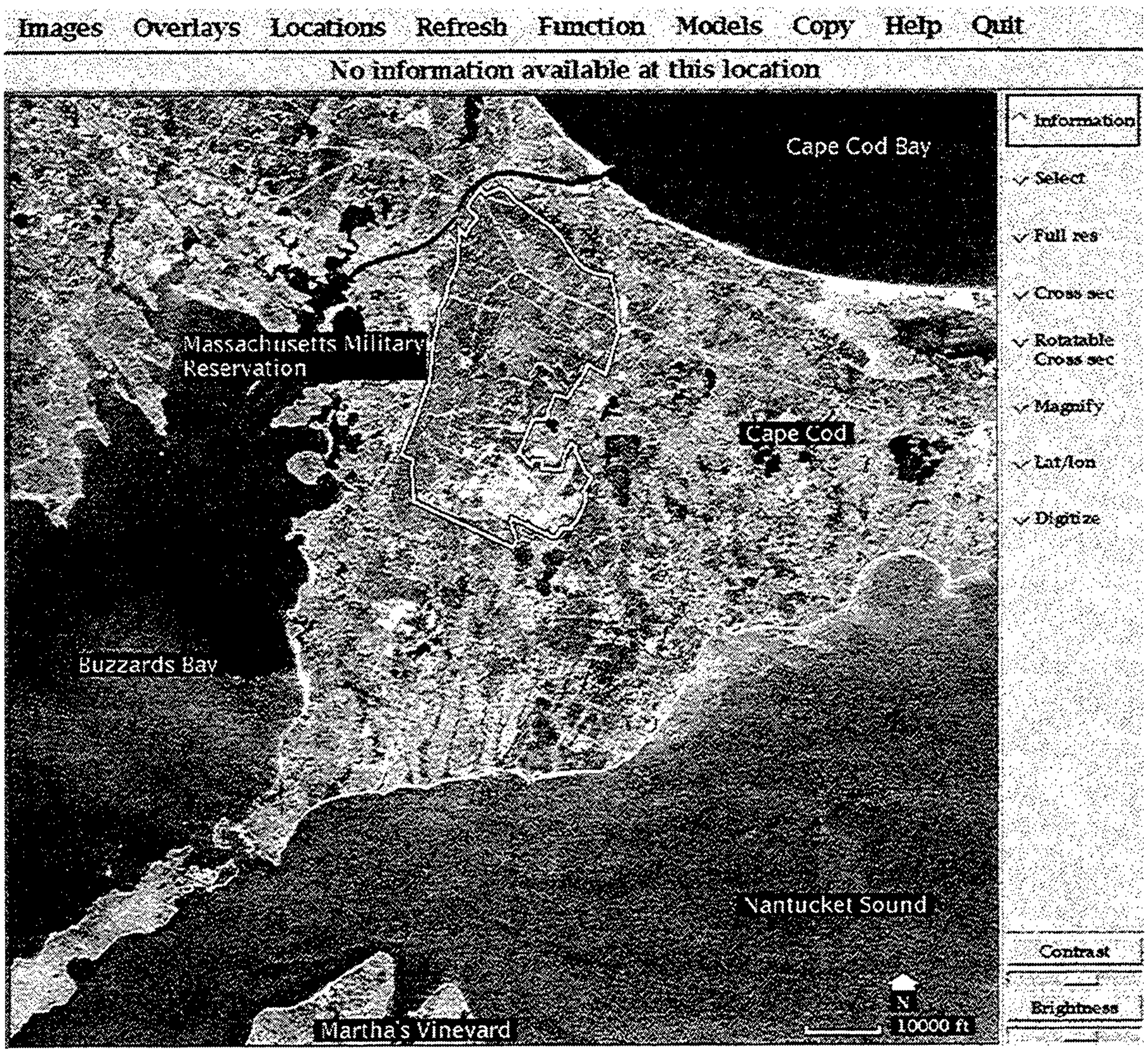

Figure 2. GDFS initial display, showing the boundary of MMR.

Before presenting the overview of GDFS, a description of the effects of the various menus on the main image display will be presented. Figure 3 shows the main GDFS menu and its submenus.

The **Images menu** gives the user the ability to select from among a series of images to serve as the background to other operations. Available selections include the SPOT® image mentioned above, a color-coded contour display of Cape Cod topography derived from Defense Mapping Agency data for the area, and a color-coded contour display of the water table in the area as modeled by the United States Geological Survey. All of these images have been registered to geographic coordinates so that latitude and longitude measurements can be made. Other items on the menu are for special purposes and will be discussed below.

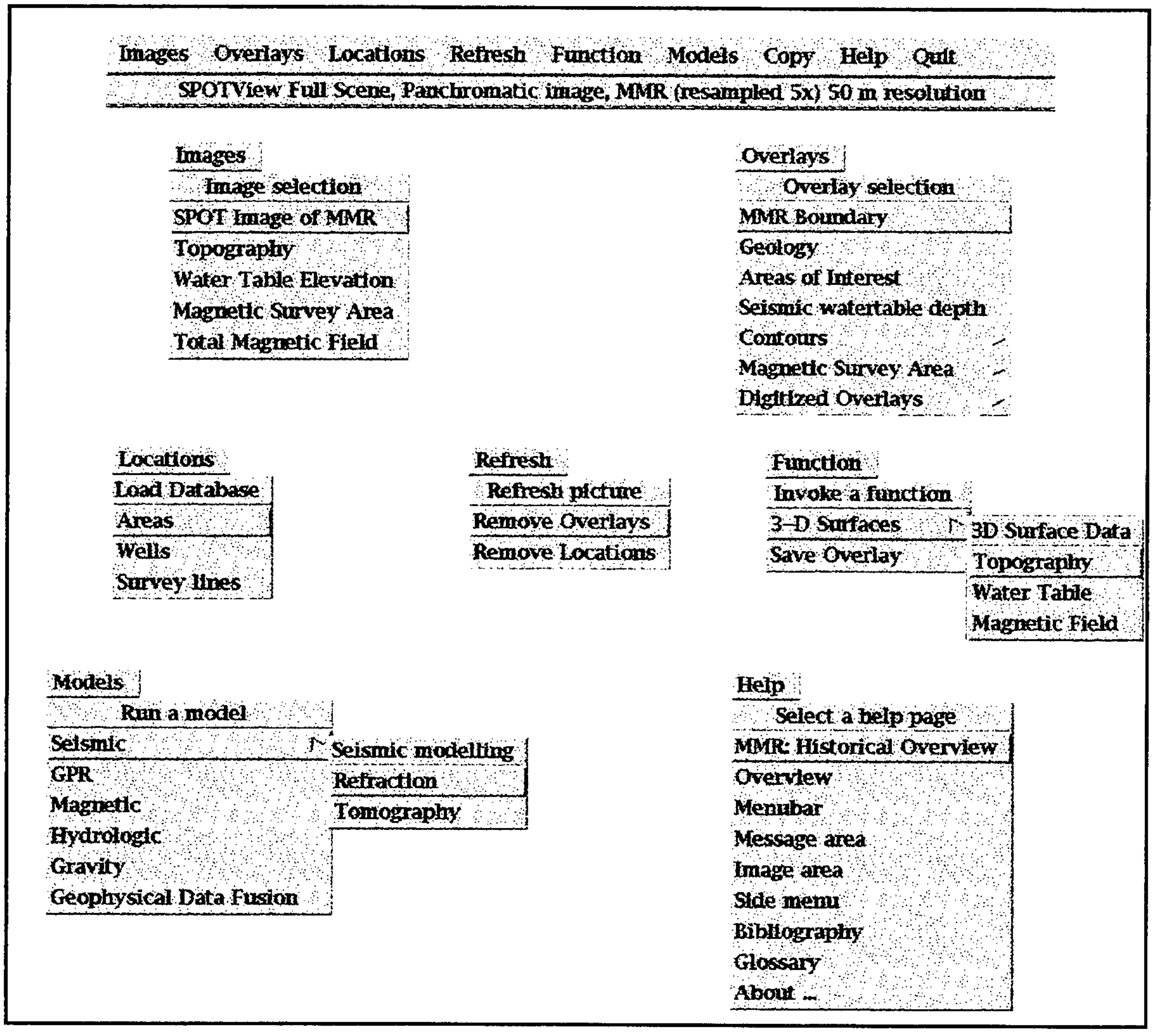

Figure 3. GDFS main menu with submenus and selected pulldown menus.

The **Overlays menu** allows the user to place geographically-referenced vector overlays onto the main image. These overlays are registered to latitude and longitude, and so can be placed on any of the geographically-registered base images available throughout GDFS. Overlays available at the time of this report include the boundary of the MMR, outlines of the surface geology of western Cape Cod that are relevant to MMR, outlines of the areas of interest for environmental remediation, contours of the USGS model of watertable elevation, and other items.

The **Locations menu** gives the user access to items in the database of information about the MMR. Selection of an item from this menu causes symbols to be placed onto the base image that, when clicked with the mouse, extract information about the selected object from the database and display it to the user. It includes *Areas*, that shows the various areas of interest for environmental remediation as colored squares; *Wells*, that shows circles for water wells and diamonds for geologic wells; and *Survey lines*, that gives access to data for demonstrating certain geophysical analysis techniques discussed in more detail below.

Sometimes a user will wish to remove locations and/or overlays from the display in order to clear the way for display of another kind of data. The **Refresh menu** permits the user to *Remove Overlays* or to *Remove Locations*.

It's possible under GDFS to display areal data in a number of ways. Vector contours are available via the *Overlays* menu and color-coded contour maps of data are available via the *Images* menu, discussed above. GDFS also permits the user to view various data as three-dimensional wireframes that can be rotated by viewing azimuth. The **Function menu** item *3D Surfaces ⇒ Topography* gives the user access to a set of wireframe images of topography, while *3D Surfaces ⇒ Water Table* provides access to an alternative display of the watertable data measured by the USGS, and *3D Surfaces ⇒ Magnetic Field* shows the results of a magnetic survey of a small area of the MMR. All of these will be shown in more detail below.

The **Models menu** provides access to various geophysical analytical techniques. Currently, only certain options are enabled. These will be described later in this section.

The **Copy button** on the Menu Bar captures an image to a file. When the user presses this button, a dialog box asks for the name of a file to which the screen image is to be saved. Screen images are saved to whatever directory the user was in when GDFS was launched, in a form suitable for output to a printer or for editing by a graphics program.

The **Side menu** of this application contains switches that determine the action taken when the left mouse button is pressed while the cursor is in the main image display area. This menu appears on the right side of the main image display shown in Figure 2. The active selection is delineated by a highlight in the diamond next to the selected button's name. Functions of each switch will be mentioned as they are used in the sections appearing below.

Figure 4 shows the result of exercising certain of these menus. The SPOT® satellite image has been replaced with the color-coded topography map by selecting *Images ⇒ Topography*; the limits of geologic areas relevant to MMR are shown as a consequence of specifying *Overlays ⇒ Geology*; and selection of *Overlays ⇒ MMR boundary* causes the perimeter of MMR to be drawn on the base image. Notice that the base image in Figure 4 has a slightly larger scale than the SPOT® image on which the MMR boundary was shown previously, in Figure 2; this illustrates that georeferenced vectors can be displayed on any base image regardless of scale.

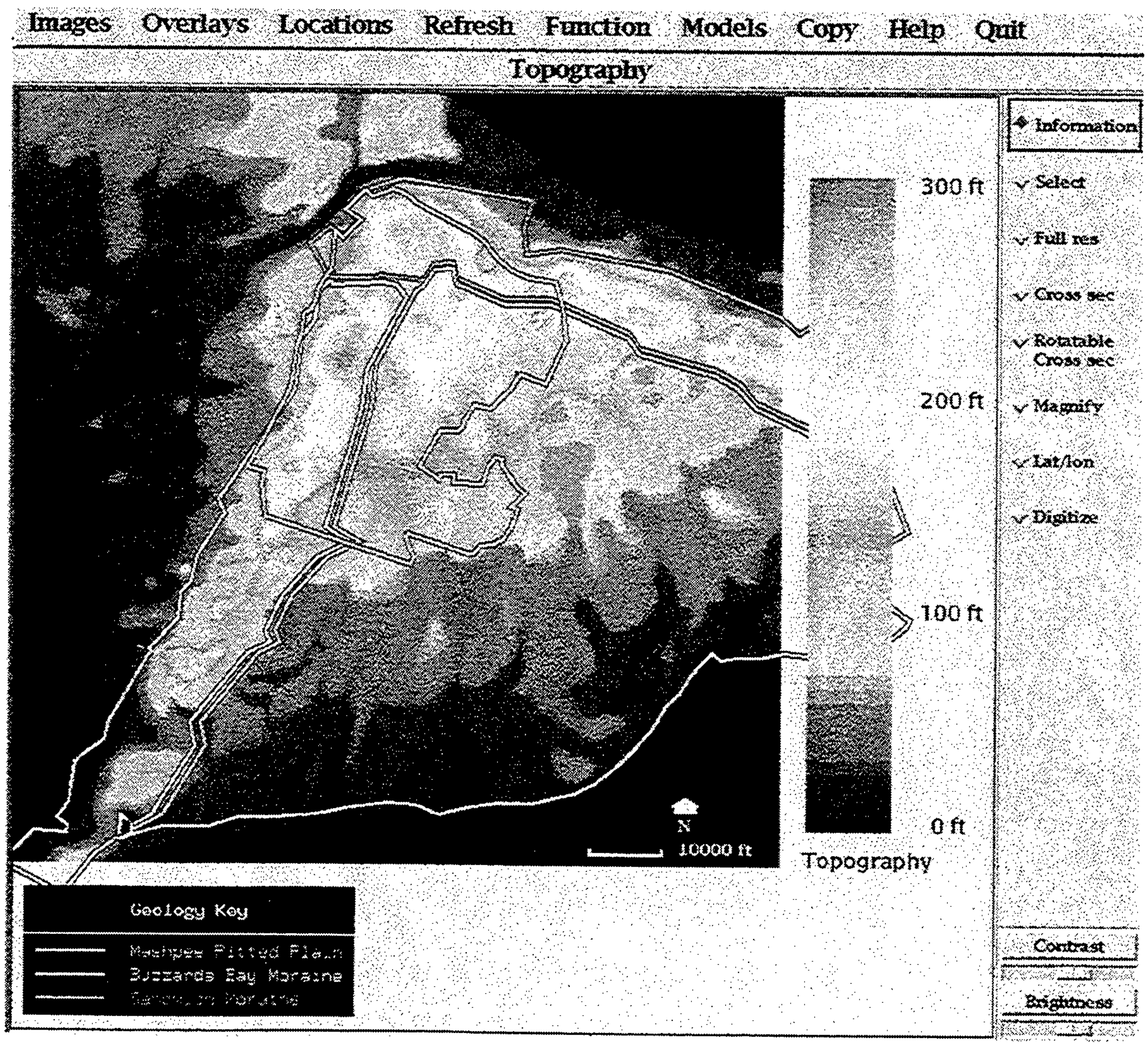

Figure 4. Color topographic map with geological boundaries and MMR perimeter overlaid.

The previous image showed topography as a color-coded map display. Another way to display topographic data is as a wireframe 3D image, as in Figure 5. One accesses this image by selecting *Function* ⇒ *3D Surfaces* ⇒ *Topography*. Viewing azimuth is selectable by manipulating a slider in a dialog box, and a *Cycle* option in that dialog box starts an automatic sequential display at viewing azimuths of 20°, 40°, and so on. Figure 5 has a viewing aziumuth of 20°.

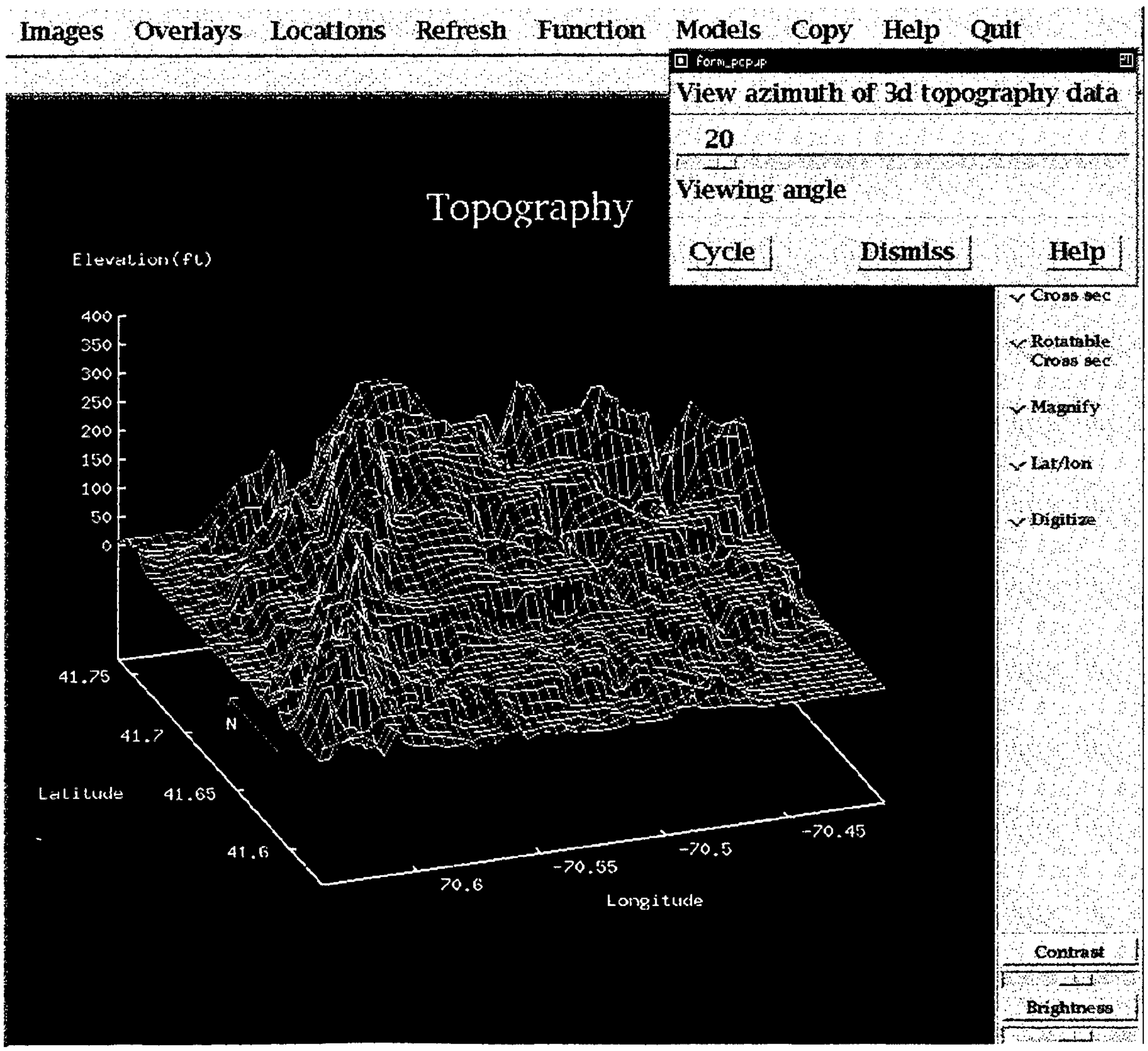

Figure 5. Wireframe image of Cape Cod topography.

Just as elevation is displayable in several ways, so is the location and elevation of the watertable at the site viewable as contour lines, as a color-coded map, and as a 3D wireframe image. Figure 6 shows three ways of looking at watertable elevation. In the upper left image, color contour lines are overlaid on the SPOT® satellite image of Cape Cod. On a computer screen, the elevation contours are in different colors as shown in a key on the bottom left side of the image. The upper right image is a representation of the color-coded map of watertable elevation. Finally, the lower image shows a view of the 3D wireframe representation of the watertable.

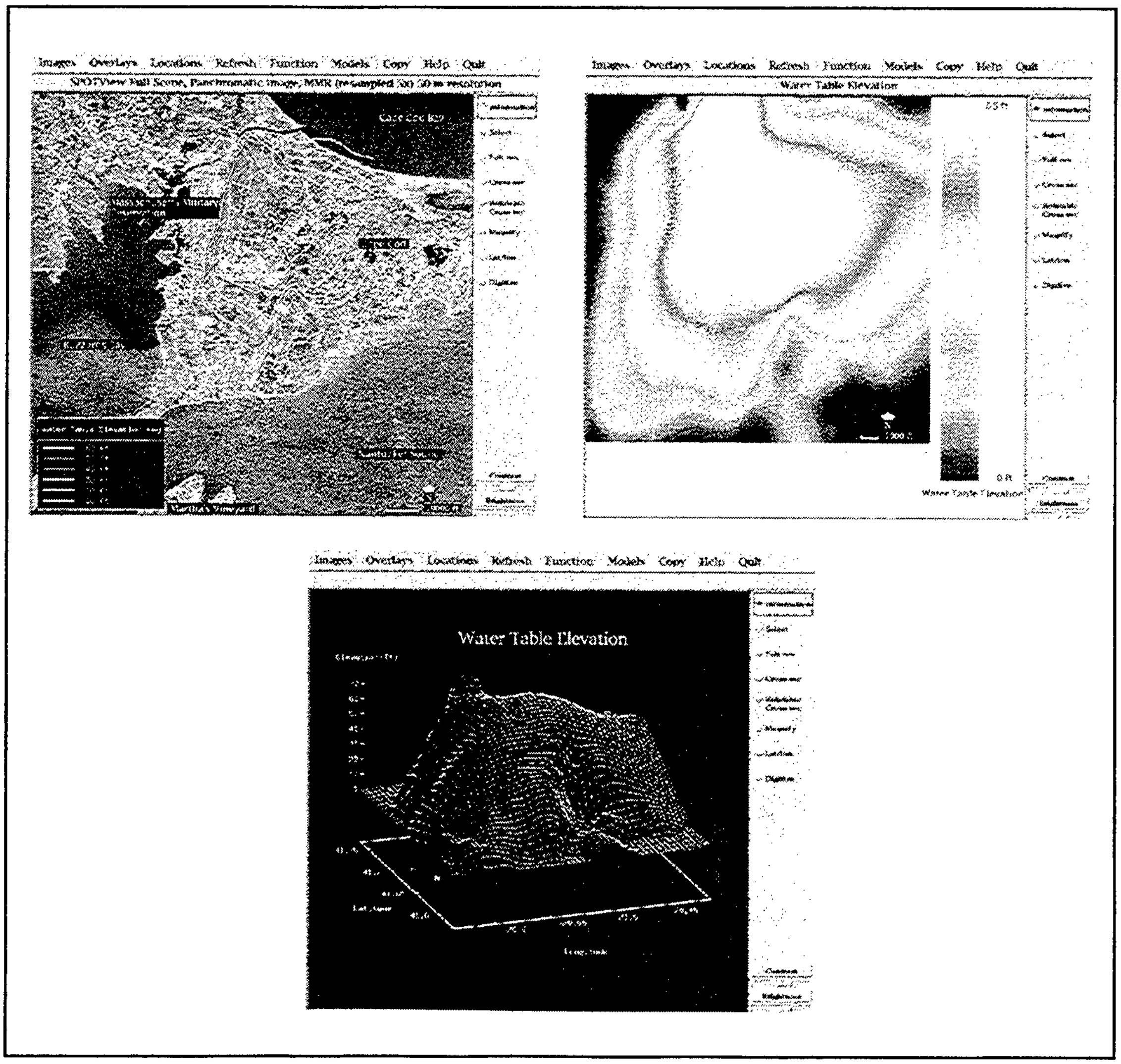

Figure 6. Three representations of the elevation of the watertable under MMR.

The data comprising the topography and watertable elevation datasets are also available to the user as a vertical section along an interactively specified line. If one of the side menu items *Cross-sec* or *Rotatable Cross-sec* is selected, it's possible to take a cross-section along any arbitrary line placed on the base image. If Cross-sec is active, clicking the mouse button on any two points on the image causes a cross-section along a line with the selected endpoints to be drawn. Such an section is shown in Figure 7, where the endpoints were on the mainland just northwest of the Cape Cod Canal and offshore to the southeast of MMR, approximately south of the "Cape Cod" label visible on Figure 2. The upper, lighter-colored part of the cross-section represents topography, while the lower, darker-colored area represents the watertable.

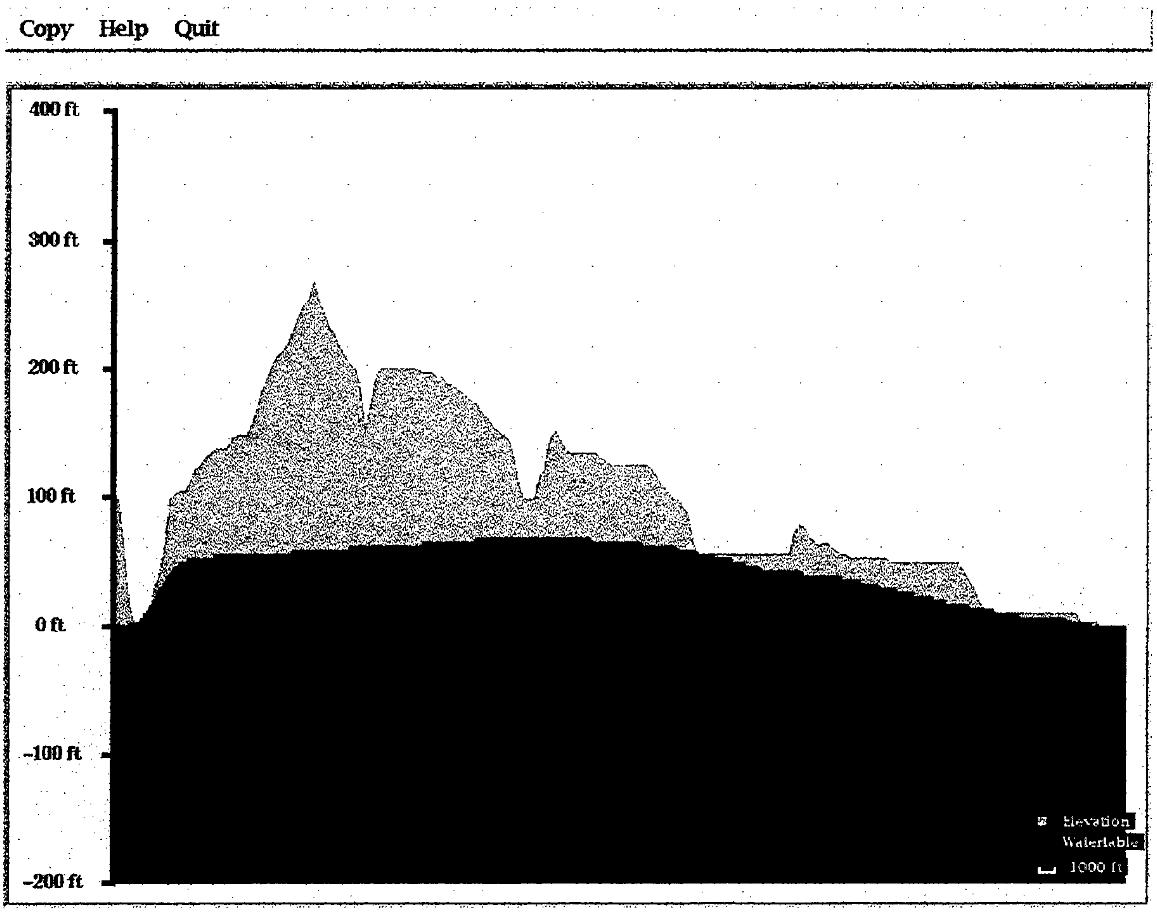

Figure 7. Cross-section through Cape Cod showing elevation and water table.

A variant on *Cross-sec* is *Rotatable Cross-sec.* In the latter, one specifies a center point and an endpoint; the length of the line is then doubled, and a cross-section along that line is displayed. A dialog box that appears upon selection of *Rotatable Cross-sec* permits the user to take a cross-section centered on the same centerpoint and of the same length, but along a different azimuth, so that a feeling for the three-dimensional surface and subsurface geometry of a region can be achieved.

The pixel size of the SPOT® images shown so far has been 50 meters; that is, each dot on the picture represents an area 50 meters on a side. These images were compressed from the original SPOT® data so that the entire Cape Cod region could be shown on the computer screen at one time. The original data, however, has a pixel size of 10 meters. One can view the satellite image at its full resolution by selecting the side menu item *Full res*, then clicking at any location of interest on the compressed image. The full resolution data has been divided into sections, and the section whose center is closest to the location of the mouse click will be displayed. Figure 8 shows a full-resolution SPOT® image at the southeast corner of MMR, with overlays identifying various features obtained using the *Overlays* ⇒ *Digitized Overlays* menu option.

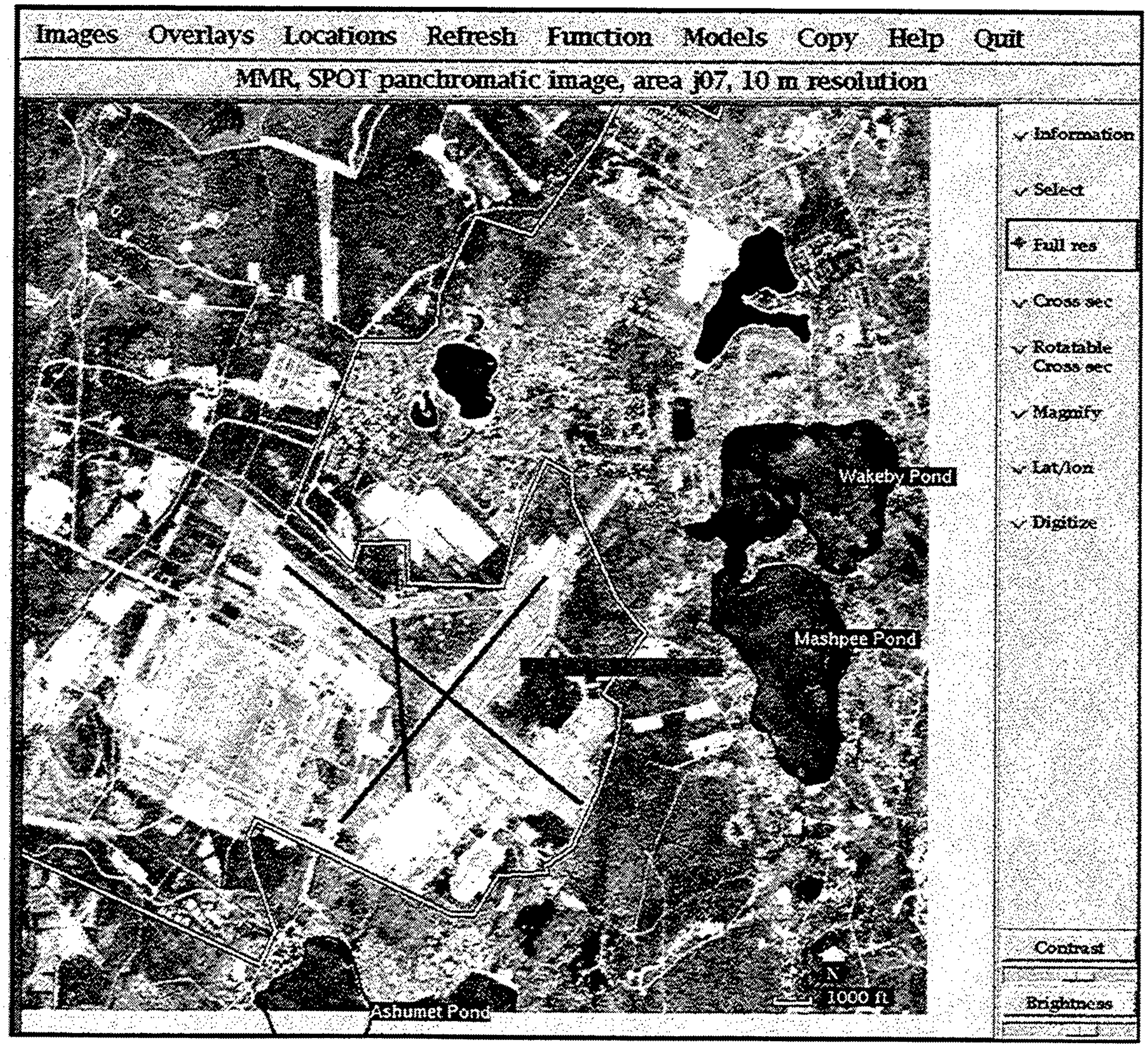

Figure 8. Full-resolution SPOT® image of southeast corner of MMR, showing MMR boundary, outlines of nearby ponds, and locations of Otis AFB runways.

As long as the side menu item *Full res* is active, one can move around the full resolution SPOT® image by clicking the mouse near any boundary of the current image; e.g, clicking near the distance scale would cause the next image to the southeast to appear.

Rudimentary image processing capabilities are included in GDFS. Two of these are the ability to control contrast and brightness of the image by means of a pair of sliders located at the bottom right corner of the display. Figure 9 shows the same area displayed in Figure 8, but with contrast and brightness adjusted so that the image is shown as a negative to enhance the visibility of certain features.

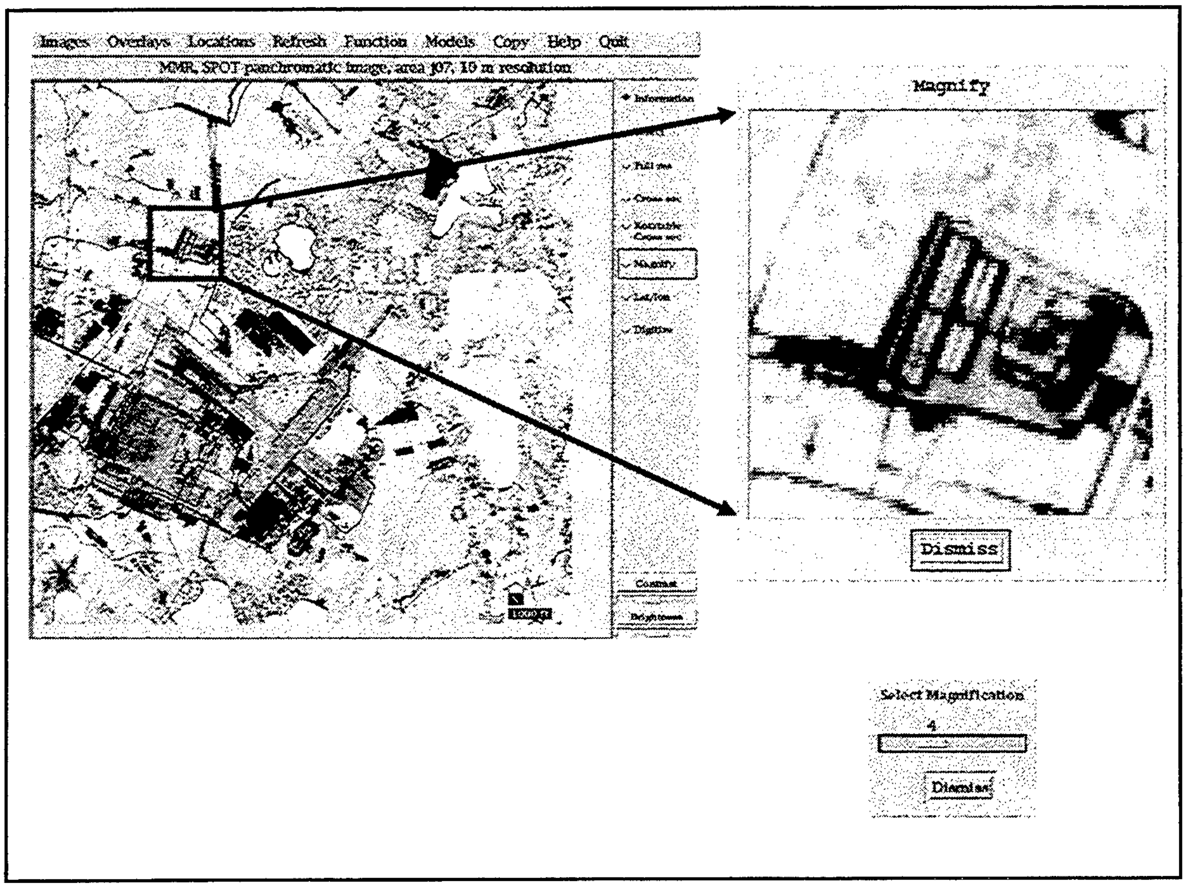

Figure 9. Magnification of part of a full-resolution satellite photo.

Figure 9 also illustrates the ability of GDFS to magnify selected parts of the image. When the side menu item *Magnify* is selected, a dialog box appears to let the user specify the desired magnification by means of a slider; once the magnification is selected, clicking the mouse in the main image causes a magnified version of a small region of the picture to be displayed in a dialog box.

A core functionality of GDFS is to provide the user with access to a database of information about areas of environmental concern at MMR. To access these data, the user loads desired information using the *Locations* ⇒ *Areas* item from the main menu bar, selects *Information* from the side menu, and clicks in one of the boxes on the display. Using the same region of MMR that's been shown before, the data access display looks like Figure 10. Clicking the mouse button in one of the boxes brings up a dialog box like the one shown to the right of the satellite photo in the Figure.

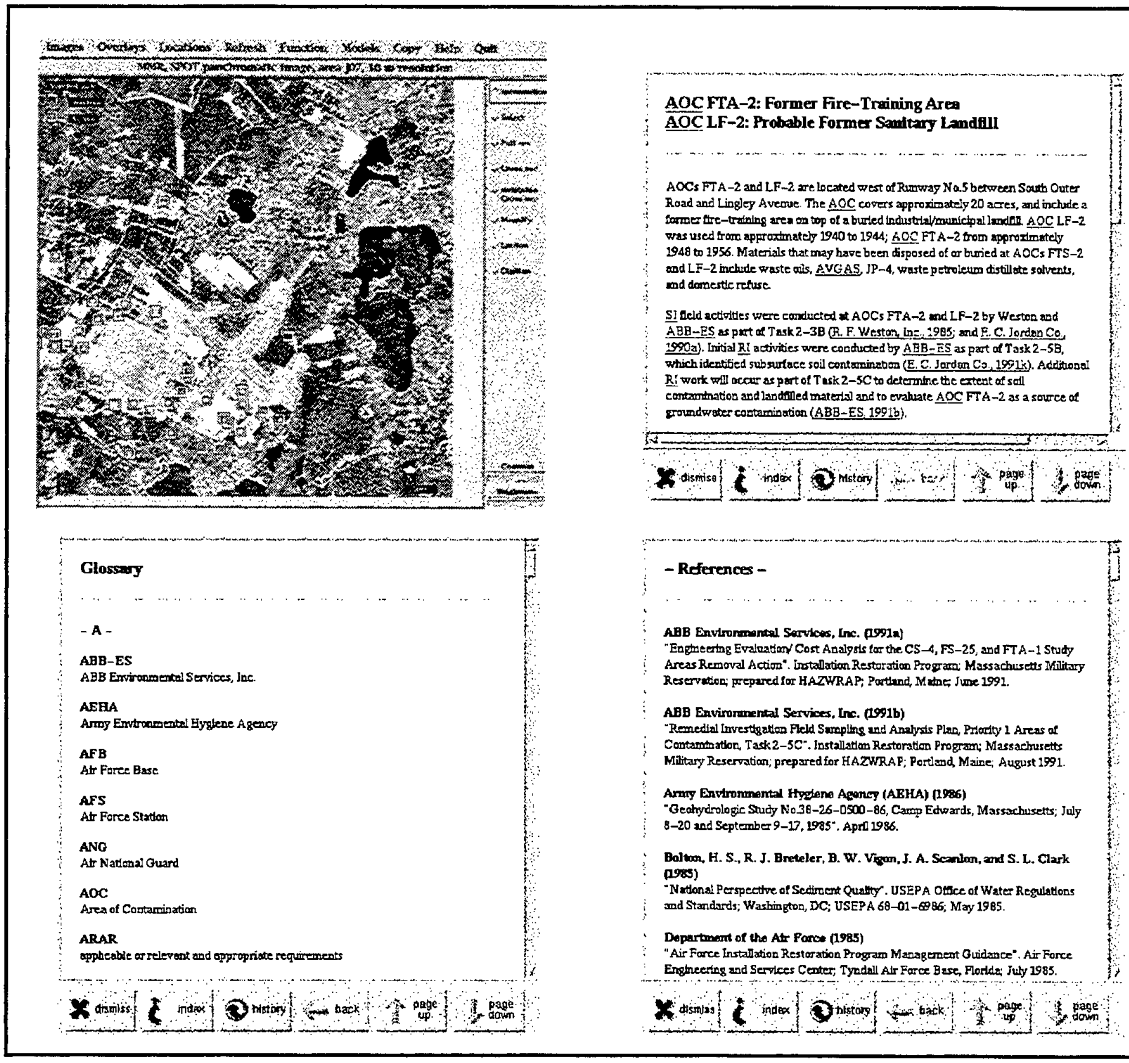

Figure 10. Areas of interest and associated information page

The information dialog box is a hyptertext window; that is, one can click on highlighted items to get more information about the highlighted item. The information pages for areas of concern are connected to both a glossary and to a bibliography; sample displays of these are shown in the lower half of Figure 10.

Another central function of GDFS is to access data about individual monitoring and geologic wells that were drilled at the remediation site. Figure 11 illustrates the process of interrogating the database for a particular well. There are two paths to access: via the satellite image and via a cross-section. On the satellite image, selecting *Locations ⇒ Wells* puts symbols representing water monitoring and geologic wells onto the base image, which then can be queried with the mouse. The alternative method is to take a cross section along a line that intersects several wells; such a cross-section appears in Figure 11, where the interrogation points are the small boxes that appear below each well in the cross-section.

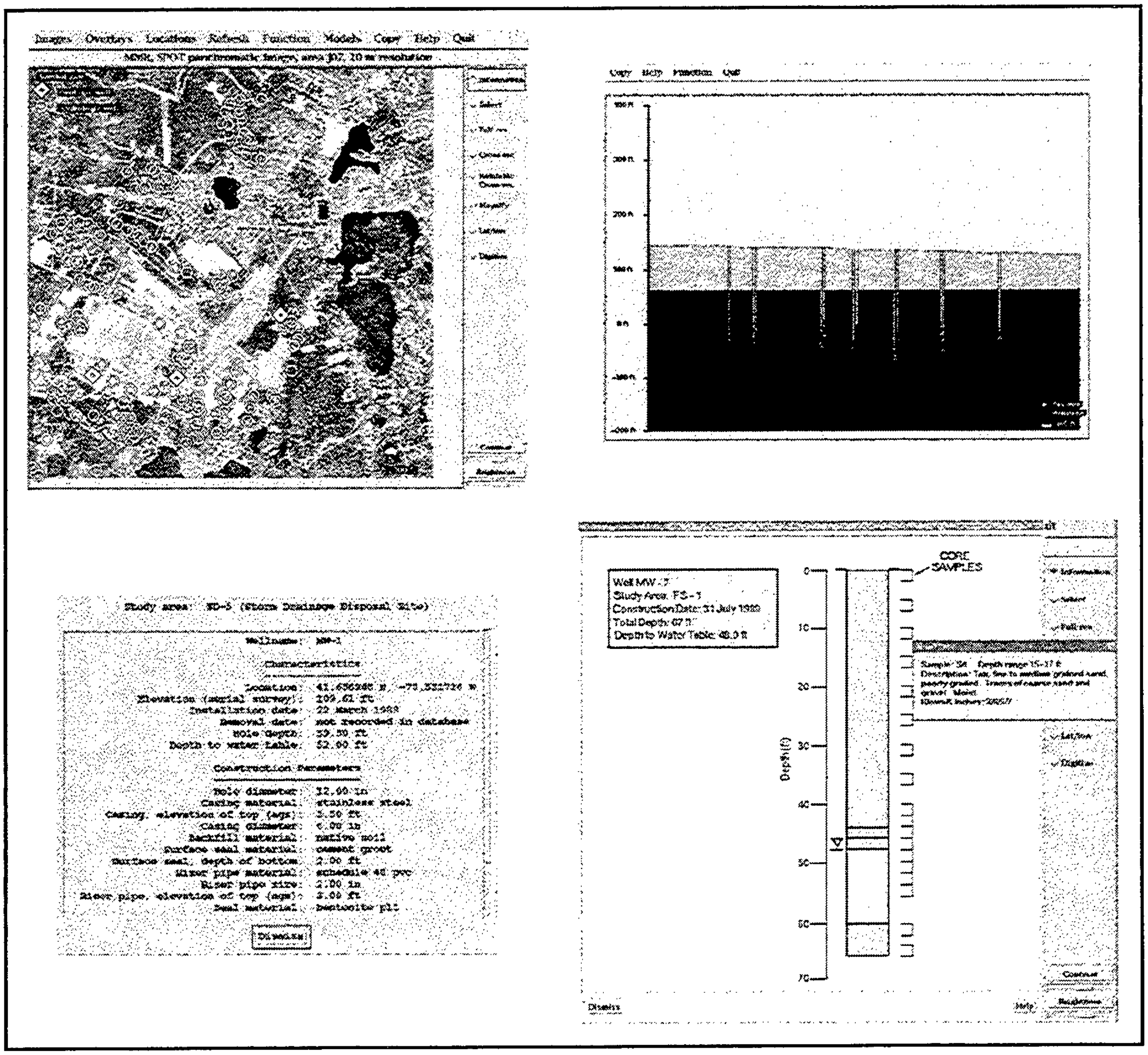

Figure 11. Access to information about individual wells.

The database contents about monitoring wells currently comprise mostly construction information, as shown at the bottom left of Figure 11. For certain geologic wells, color representations of the various layers encountered while drilling are shown, and observers' notes are available by clicking and holding the mouse in the box to the right of the cartoon representing the well. The bottom right of Figure 11 illustrates such a display.
Another task of the GDFS project was to illustrate how various geophysical methods could be brought to bear on the environmental remediation problems at military bases.

Methods included in the work performed under this contract include seismic refraction surveys and seismic cross-hole tomography surveys and ground penetrating radar (GPR).

To begin accessing seismic data, the user would select *Locations ⇒ Survey Lines* from the menu bar. The symbols representing access points to seismic refraction data and cross-hole tomography and GPR data are shown in Figure 12.

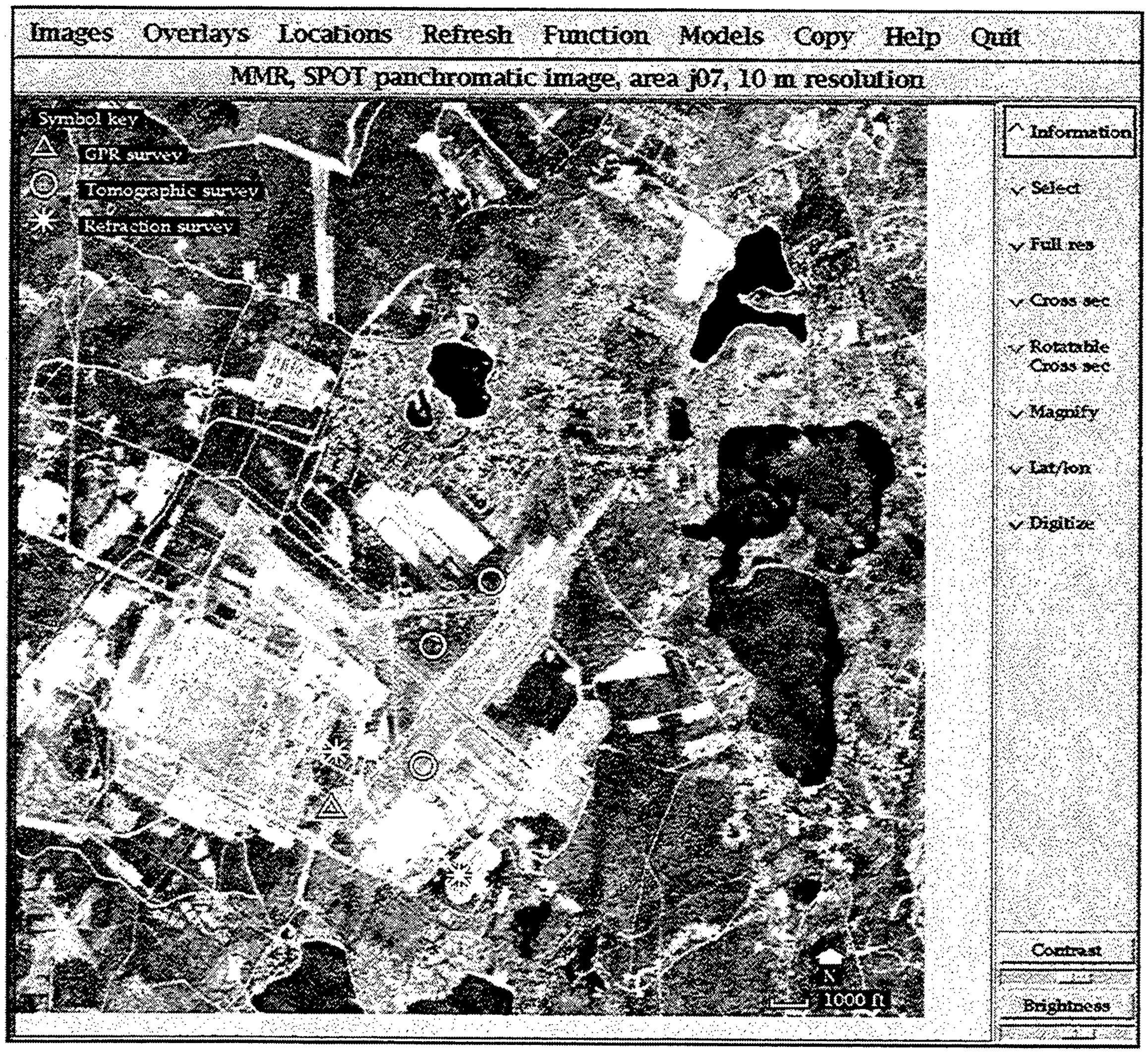

Figure 12. Access to simulated seismic data.

Selecting one of the seismic refraction surveys from Figure 11 results in displays like those shown in Figure 13. The processing stream and controls are discussed more fully in Appendix C, but the general flow is:

- select first arrival times from the seismic refraction data, as shown at the upper left.
- examine the arrival time versus distance plot to select the critical distance. This is shown in the upper right.
- display the seismic velocity versus depth model resulting from the automatic inversion analysis, as shown in the lower left section of the Figure.
- optionally show the depth associated with the seismic velocity change on the depth to watertable image, as shown at the lower right of the Figure.

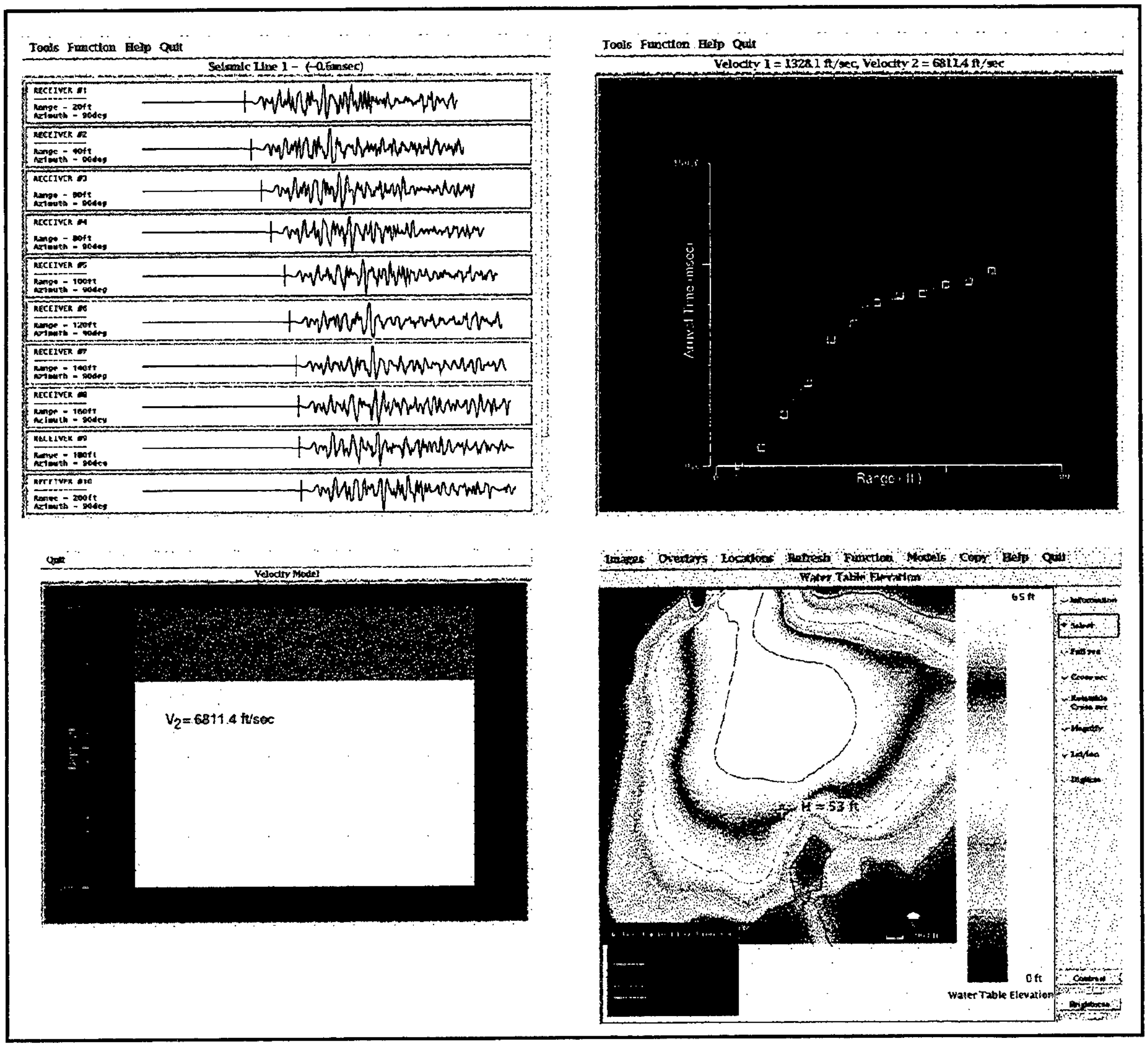

Figure 13. Using seismic refraction data to infer water table location.

Cross-hole seismic tomography is also modeled in GDFS. For this process, one starts with a set of travel time measurements from many sources in one well as received by many receivers in a second well. The intervening volume is divided into elements, and by iteratively inverting a series of linear equations a seismic velocity is assigned to each element. Since no cross-hole surveys have yet been conducted at MMR, Figure 14 shows three figures from a sample seismic tomographic inversion, using synthetic data to illustrate the analysis procedure.

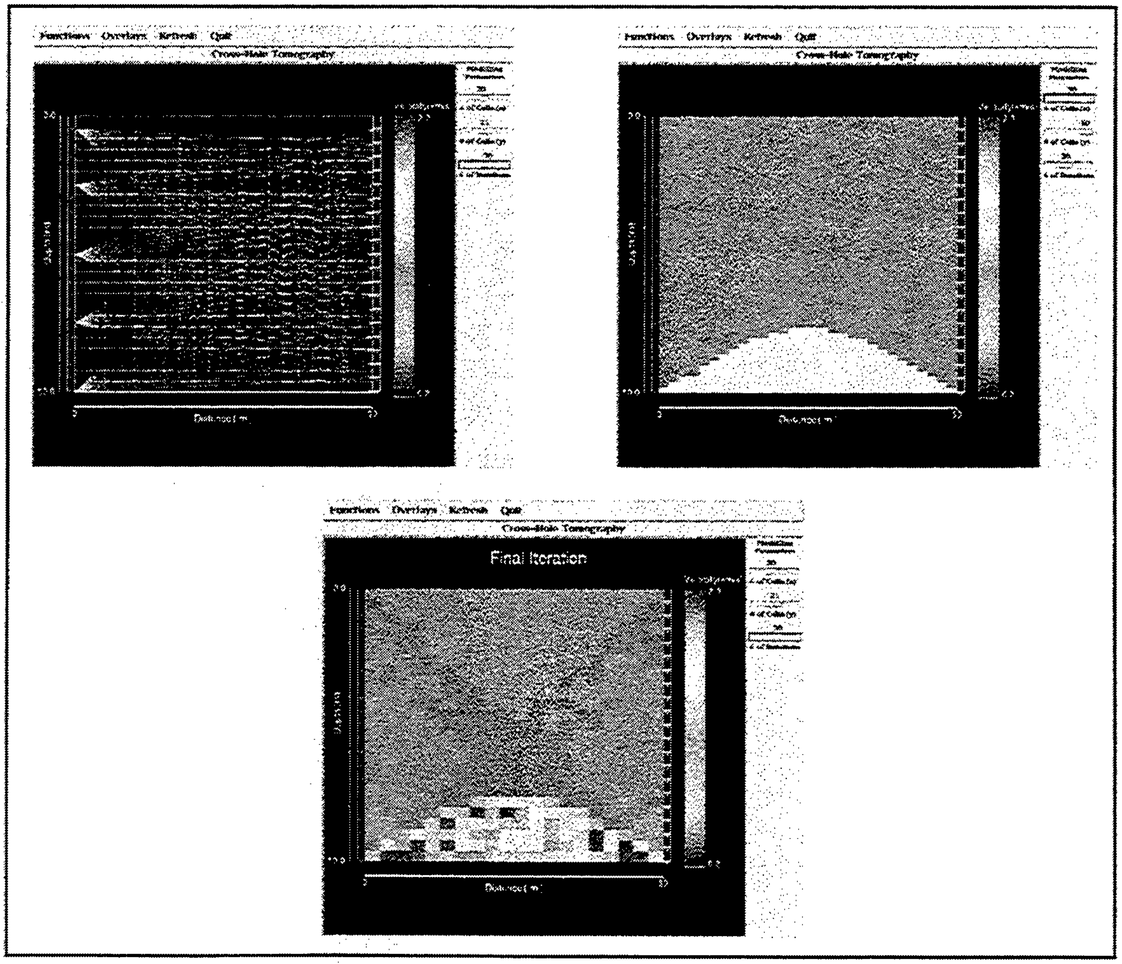

Figure 14. Cross-hole tomography example.

The upper left image in Figure 14 shows two wells, a grid between them, and seismic source and receiver locations in the two wells. Also shown are raypaths from selected sources to all receivers, to illustrate the relative coverage enjoyed by various elements in the grid. The upper right image in the Figure shows a model that was used to generate synthetic travel times; it contains a perched water table of higher seismic velocity embedded in a background of lower seismic velocity. The bottom part of the Figure shows the result of 30 iterations of the seismic tomography code; while the image is clearer in color, even in this grayscale representation the potential resolving power of the tomographic inversion process is well illustrated.

Selecting the GPR survey from Figure 11 results in displays like those shown in Figure 15. Ground - penetrating radar is incorporated into GDFS as a tool for designing surveys to locate buried structures. This forward modeling technique allows the user to simulate GPR profile data for different types of objects buried in varying background media. The basic solution for the radar reflectivity response that is used to simulate the data relies on the assumption that the earth model is 1-dimensional, i.e. the shallow subsurface can be approximated by a stack of homogeneous layers. By performing a series of 1-dimensional calculations along a line on the earth's surface, using a forward modeling code developed by Steve Cardimona of Phillips Laboratory, the outline of buried bodies in a 2-dimensional sub-surface background can be obtained.

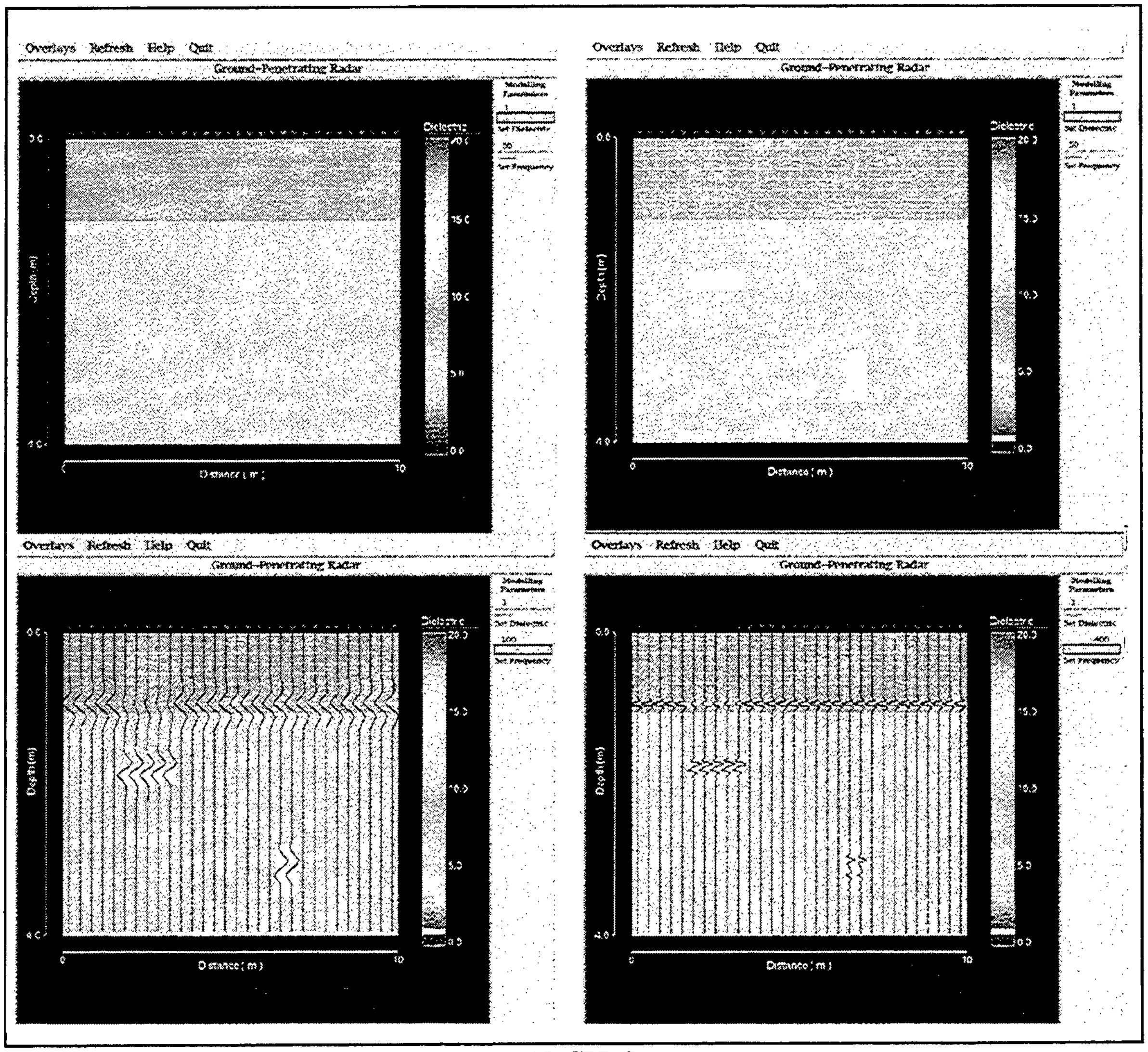

Figure 15. GPR Survey

The sequence of four images in Figure 15 are from a sample GPR survey calculation. The first image, in the upper left, shows an initial sub-surface background model consisting of a shallow layer of dry, unconsolidated material on top of a thicker layer of partially saturated material. The different sub-surface materials in this picture are color-coded according to their dielectric constant, which is one of the important electrical material properties affecting the transmission and reflection of the radar waves used in this technique. In the second image, in the upper right, the sub-surface area has been gridded and two shallow bodies have been interactively placed into the background material by the user. The bottom two images show the calculated radar signals for a low-frequency source (left) and a high-frequency source (right). The frequency to be used is interactively set by the user and the resulting radar traces are plotted as overlays to the sub-surface model. To initiate the calculation for a particular vertical profile, the user clicks on the instrument location at the surface above the profile.

A small amount of magnetic data were collected southwest of the runways at Otis AFB, as outlined in the upper left image in Figure 16. Information about those data are available by selecting *Images ⇒ Survey Area*, then selecting various items from *Overlays ⇒ Survey Areas*.

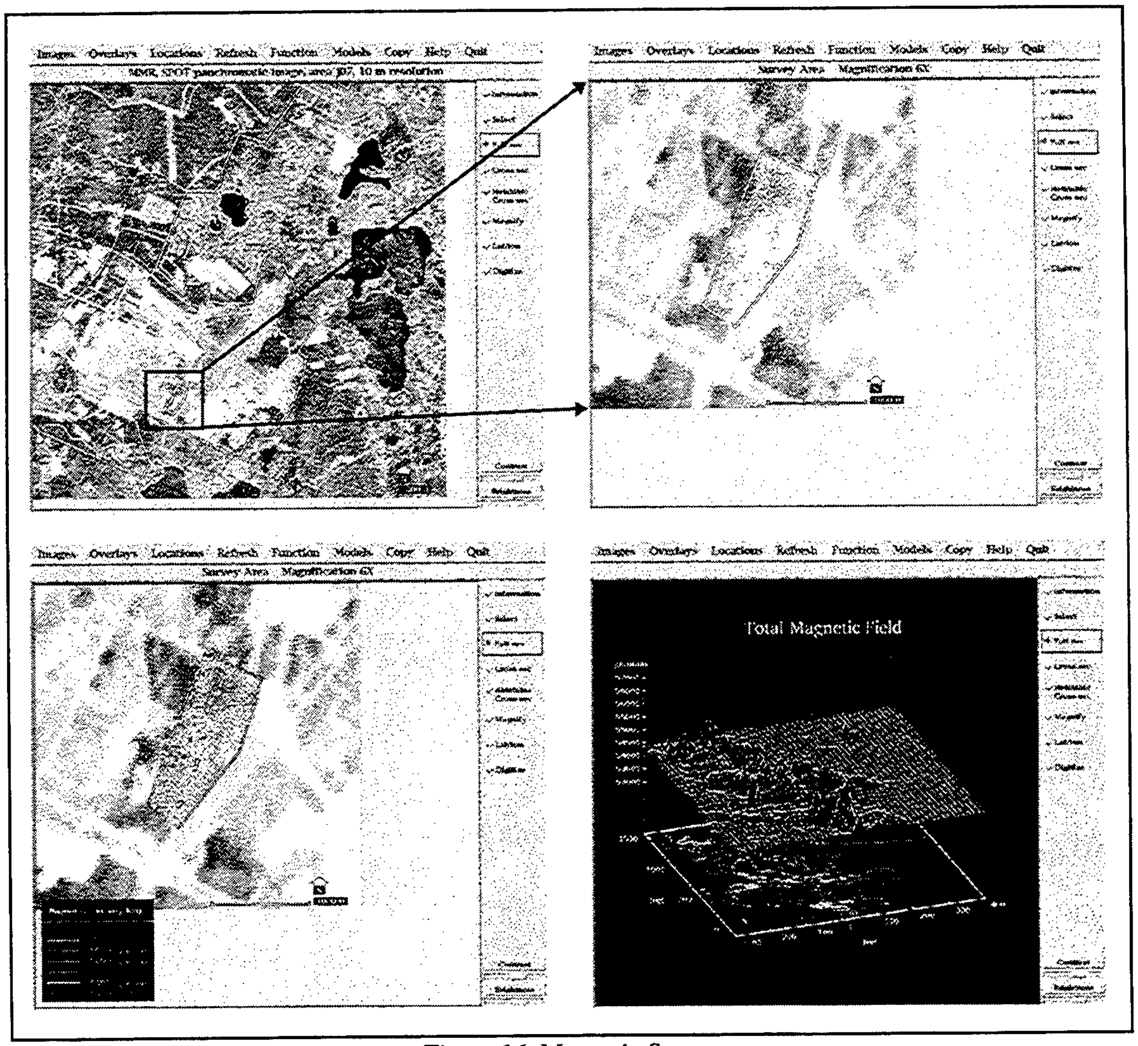

Figure 16. Magnetic Survey

Available items include Survey Boundary, Magnetic Survey Lines, and Magnetic Survey Contours. The upper right part of Figure 16 shows the boundary and the survey lines, while the lower left part of the Figure shows the boundary and the contours.

There are alternatives available for the display of the magnetic survey contours. In the lower left portion of Figure 16, contour lines are shown overlaid on a magnified satellite photo, while the lower right part of the Figure shows a 3D wireframe representation of the same data, presented in the same manner as wireframe displays discussed above in this section. A color contour map of the magnetic field in the survey area is available from the *Images* menu.

SECTION 3

CONCLUSION

In this report we have presented an in-depth description of the research investigations directed toward the development of the Geophysical Data Fusion System. In its current configuration, GDFS is applicable to data collected at the Massachusetts Military Reservation on Cape Cod, Massachusetts and encompasses an online database of approximately 1000 well construction logs and assays, as well as some preliminary seismic refraction, seismic tomography, GPR, and other models. Total data volume at the time of this report is about 270 MB. An overview of the functionality of the software was presented in the main body of the text; installation and startup instructions, a sample session, and a comprehensive reference are presented in appendices.

The capabilities and functionality of GDFS were illustrated in Section 2 using displays of the screens encountered by a user in a typical processing session. The selected capabilities displayed in this sample session were related to a more complete definition of the system functionality through reference to a series of appendices containing a detailed script of the user actions required to reproduce a complete sample session (Appendix B); a complete description of all currently-available system options (Appendix C); and information regarding software and hardware implementation requirements (Appendix A). Taken together, Section 2 and its associated appendices provide a concise description of the results of the GDFS development effort.

APPENDIX A

REQUIREMENTS AND STARTUP INSTRUCTIONS

A.1. HARDWARE REQUIREMENTS.

GDFS was developed initially on Sun SPARCStations running SunOS 4.1.x, then was moved to SunOS 5.x, also known as Solaris 2. The current version runs on a SPARCStation 20 under Solaris 2.5. The machines used to develop the system all had a minimum of 32MB of resident memory. GDFS uses the standard Sun 8-bit color monitor with a resolution of 1152x900 pixels and also uses the standard Sun three-button mouse. As currently configured, GDFS occupies about 470 MB of hard disk space.
When run over a network, it has displayed successfully on several vintages of Sun computers as well as a standard Windows 95 computer with a screen large enough to display the application and a commercial X server.

A.2. SOFTWARE REQUIREMENTS.

GDFS is written in C and FORTRAN and uses the X Window System version 11 release 5 and the Motif release 1.2 widget set. It has been compiled successfully using the GNU C/C++ compiler, versions 2.5 and later, and the Sun FORTRAN compiler.

A.3. STARTUP INSTRUCTIONS.

The procedure used to launch GDFS varies somewhat according to the platform being used. The platform available at the time of this report is a UNIX workstation running the X Windows system, both on a local machine and over a network. Whichever launching path is applicable to a particular installation, the first GDFS display you will see will be a title page.

GDFS can be launched with an optional demonstration script on the screen, as shown in Appendix B, Figure B-1. To launch that version, substitute the command *GDFS_script* for the command *GDFS* as shown below.

To launch GDFS on a UNIX workstation running X Windows, displaying on the same machine:

1. change directory to the GDFS home directory.
2. execute the initialization script "Init" under the C-Shell.
3. launch the application.

Example:
Assume GDFS resides in a directory called "/data/d/GDFS".

```
prompt> cd /data/d/GDFS
prompt> source Init
prompt> GDFS & (or GDFS_script & for scripted version)
```

To launch GDFS on a remote UNIX workstation running X Windows, but displayed on a local machine:

1. open a terminal window on the local machine.
2. command the local machine to permit remote machines to display X Windows output.
3. login to the remote machine on which GDFS will be executed.
4. on the remote machine, change directory to the GDFS home directory.
5. on the remote machine, execute the initialization script "Init" under the C-Shell.
6. inform the remote machine that X Windows output is to be displayed on the local computer.
7. launch the application.

Example:
Assume LosAngeles is the name of the remote computer on which GDFS will run and that NewYork is the local machine on which X Windows will display application output. As before, GDFS resides in "/data/d/GDFS". Prompts on the two machines are indicated by the machine name followed by a ">".

```
on NewYork:  launch an xterm
NewYork> xhost +
NewYork> telnet LosAngeles
   Trying 123.456.78.90...
   Connected to LosAngeles.
   Escape character is '^]'.

   SunOS UNIX (LosAngeles)

   login:  myname
   Password:  ********
   Last login:  ... [more output from remote computer
                LosAngeles] ...
LosAngeles> cd /data/d/GDFS
LosAngeles> source Init
LosAngeles> setenv DISPLAY NewYork:0.0
LosAngeles> GDFS & (or GDFS_script &  for scripted version)
```

A.4. SHUTDOWN INSTRUCTIONS.

To shut down GDFS:

- Choose Quit from the main menu of all open GDFS applications.
- If running under X over a network, the user can shut down X. The details vary according to local convention, so the local system administrator should be consulted for details.

APPENDIX B

A SAMPLE SESSION WITH GDFS

In this appendix, we present a script listing the actions necessary to duplicate a sample session with GDFS.

One feature of GDFS is its ability to display an on-screen demonstration script to allow the neophyte user to become familiar with the application. Figure B-1 shows the GDFS main image display (MID) with the on-screen script showing. The user scrolls down the script while working through the application. The text appearing below is the text of the online demonstration script.

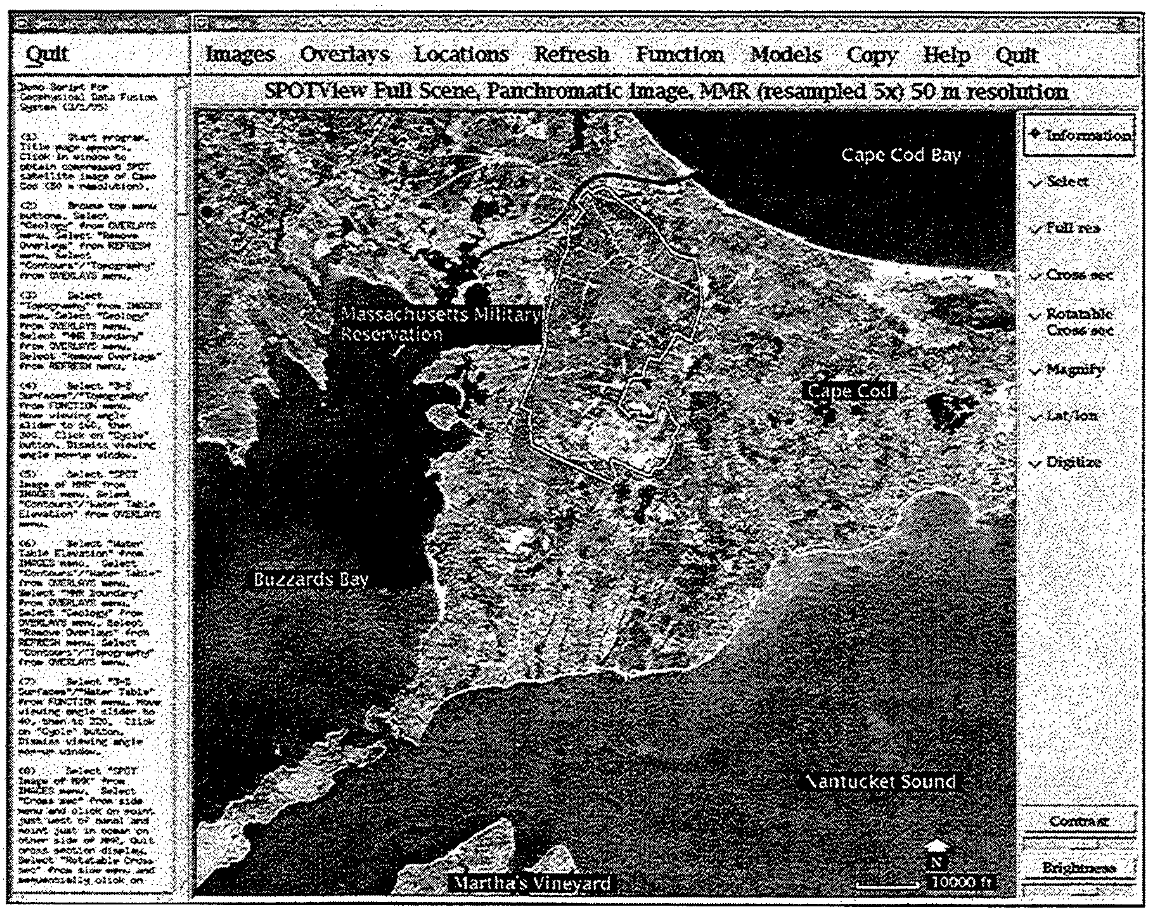

Figure B-1. GDFS startupscreen and on-screen script.

Screen displays resulting from the actions described here appear in Section 2.

(1) Start program. Title page appears. Click in window to obtain compressed SPOT satellite image of Cape Cod (50 m resolution).

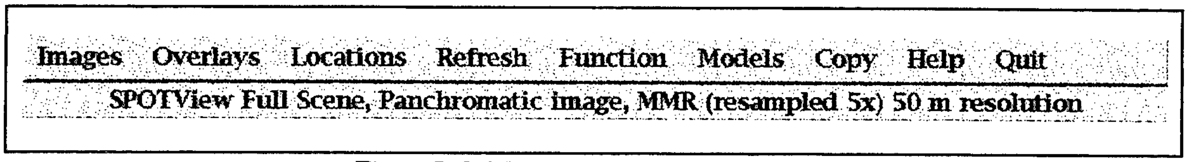

Figure B-2. Main menu and information line

(2) Browse top menu buttons. Select "Geology" from OVERLAYS menu. Select "Remove Overlays" from REFRESH menu. Select "Contours"/ "Topography" from OVERLAYS menu.

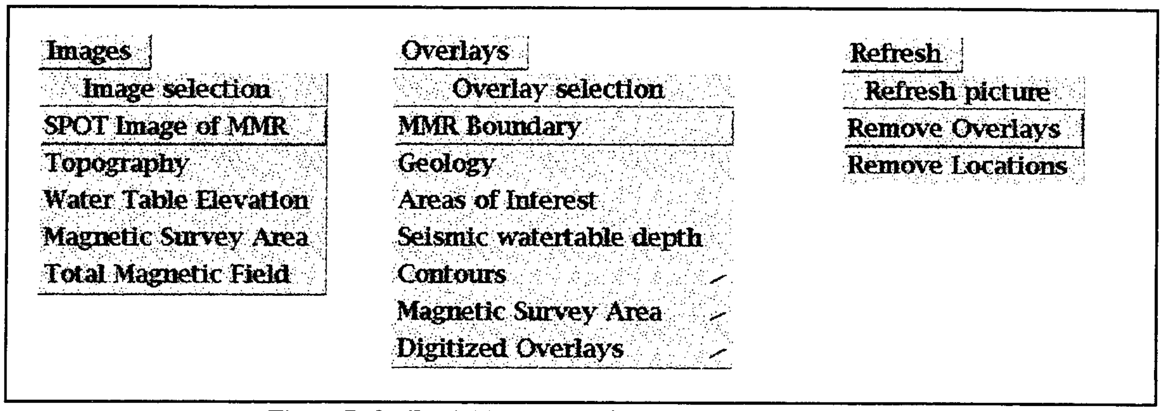

Figure B-3. The MID Images, Overlays, and Refresh menus

(3) Select "Topography" from IMAGES menu. Select "Geology" from OVERLAYS menu. Select "MMR Boundary" from OVERLAYS menu. Select "Remove Overlays" from REFRESH menu.

(4) Select "3-D Surfaces"/ "Topography" from FUNCTION menu. Move viewing angle slider to 160, then 300. Click on "Cycle" button. Dismiss viewing angle pop-up window.

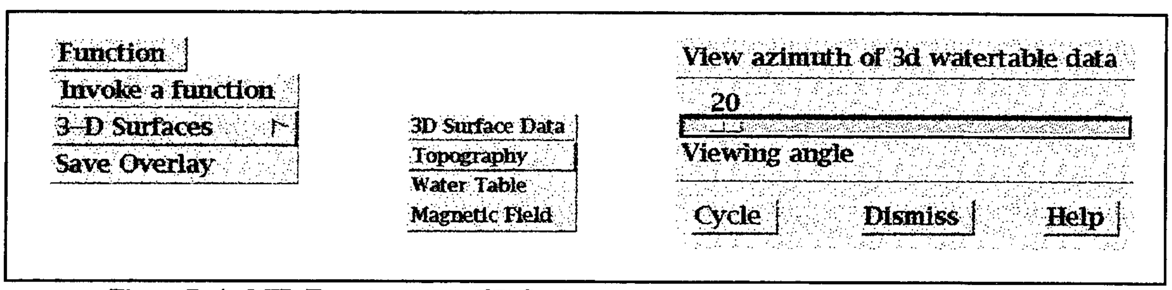

Figure B-4. MID Function menu, 3D Surface submenu, and viewing angle selection box.

(5) Select "SPOT Image of MMR" from IMAGES menu. Select "Contours"/ "Water Table Elevation" from OVERLAYS menu.

(6) Select "Water Table Elevation" from IMAGES menu. Select "Contours"/ "Water Table" from OVERLAYS menu. Select "MMR Boundary" from OVERLAYS menu. Select "Geology" from OVERLAYS menu. Select "Remove Overlays" from REFRESH menu. Select "Contours"/ "Topography" from OVERLAYS menu.

(7) Select "3-D Surfaces"/ "Water Table" from FUNCTION menu. Move viewing angle slider to 40, then to 320. Click on "Cycle" button. Dismiss viewing angle pop-up window.

(8) Select "SPOT Image of MMR" from IMAGES menu. Select "Cross sec" from side menu and click on point just west of canal and point just in ocean on other side of MMR. Quit cross section display. Select "Rotatable Cross sec" from side menu and sequentially click on two points along N/S line in MMR. Quit the cross section display and move Rotatable Crosssec slider to 90. Quit cross sec display. Dismiss azimuth pop-up window. Select "Remove Overlays" from REFRESH menu.

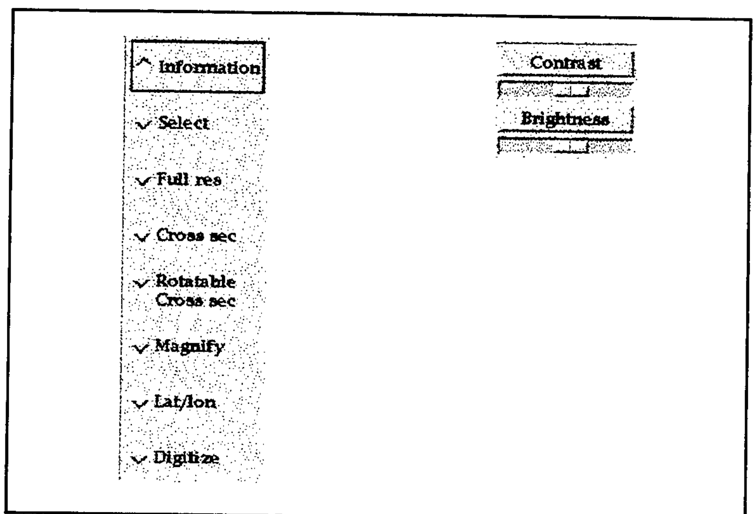

Figure B-5. Side menu and Contrast/Brightness controls.

(9) Select "Lat/lon" from side menu. Point to points on image and note latitude, longitude values displayed on information line. Adjust "Contrast" and "Brightness" sliders on side menu over a range and note effects on water areas. Click on "Contrast" and "Brightness" labels to return to original values.

(10) Select "Full Res" from side menu. Click near east end of canal. Walk to west end of canal by continuously clicking on left edges of displayed images. Select "SPOT Image of MMR" from IMAGES menu.

(11) Click near SE corner of MMR base area where buildings occur. Select "MMR Boundary" from OVERLAYS menu. Sequentially select "Digitized Overlays"/

"Mashpee Pond", / "Wakeby Pond", / "MMR/Otis AFB runways" from OVERLAYS menu.

(12) Select "Digitize" from side menu. Click on a number of points representing a closed outline boundary of another pond. Select "Digitized Overlays"/ "Current" from OVERLAYS menu. Select "Save Overlay" from FUNCTION menu, type in name, dismiss without saving.

(13) Select "Remove Overlays" from REFRESH menu. Adjust "Contrast" and "Brightness" sliders on side menu to reverse contrast. Select "Magnify" from side menu. Adjust magnification slider to 4 and click on building. Vary "Contrast" and "Brightness." Dismiss magnified image. Click on houses east of base. Dismiss magnified image. Dismiss magnification pop-up window.

(14) Select "Remove Overlays" from REFRESH menu. Select "Areas of Interest" from OVERLAYS menu. Select "Areas" from LOCATIONS menu. Select "Information" from side menu and click on an area location button. Scroll through descriptive text window. Click on a report reference to bring up the system bibliography. Click on an acronym to bring up system glossary. Click on several other location buttons and dismiss the text windows.

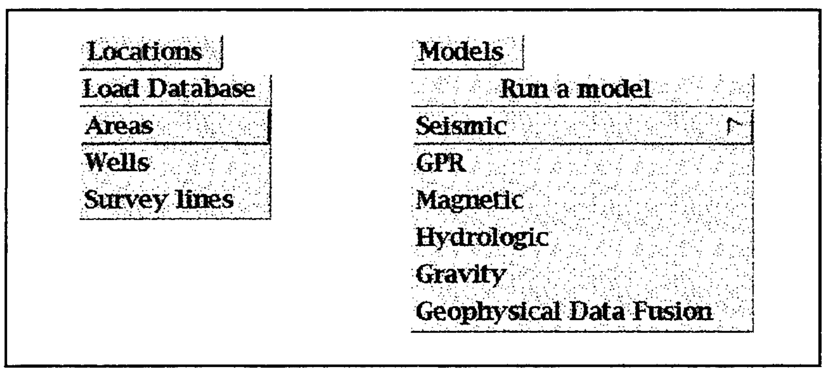

Figure B-6. MID Locations and Models menus.

(15) Select "Remove Locations" from REFRESH menu. Select "Wells" from LOCATIONS menu. Click on several hydrologic wells and view information text. Click on several geologic wells in sequence. Move mouse into brackets to right of well and HOLD MOUSE BUTTON DOWN to view well logging information corresponding to that depth interval. Quit the well display.

(16) Select "Cross sec" from side menu and click on two points on a line through hydrologic and geologic wells. Click on boxes beneath several wells. Dismiss cross section.

(17) Select "Remove Locations" from REFRESH menu. Select "Select" button from side menu. Select "Survey Lines" from LOCATIONS menu. Click on asterisk

(i.e. shot location) to display information about seismic survey on information line. Double click on asterisk for Line 1 to select seismic line for analysis.

(18) Select "Seismic"/ "Refraction" from MODELS menu. This will bring up an analyst station display of the refraction profile seismic waveforms shown in increasing order of distance from the shot. The dashed vertical yellow line denotes zero or shot time. Use scroll bar on right to scroll to the bottom of the page. Scroll back to top.

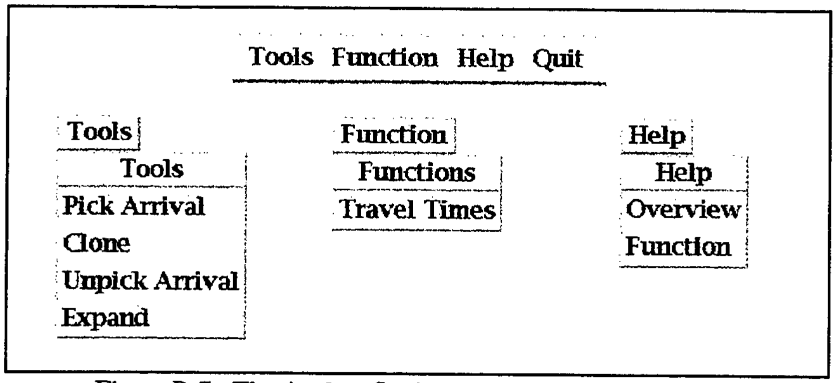

Figure B-7. The Analyst Station main menu and submenus.

(19) Select "Pick Arrivals" from "Tools" menu. Move cursor to onset of positive motion on first trace and click. Note selected arrival time displayed on information line. Select "Expand" from "Tools" menu and click on second trace. Note that this feature is useful for defining onset of first motion. Select "Quit" to dismiss expanded display. Select "Clone" from "Tools" menu. Click on first trace and drag it to overlay on second trace. Note that this feature is useful in correlating waveforms to pick consistent arrival times. Select "Pick Arrivals" from "Tools" menu and mark onsets on all traces (note: scroll to bottom to access last two traces). Purposely pick last arrival several cycles late.

(20) Select "Travel Times" from "Function" menu to view selected arrival times as a function of distance. Click on boxes to have corresponding times and distances displayed in a pop-up window. Note that the last point is an outlier. Quit the travel time display and return to the analyst station display. Select "Pick Arrivals" from "Tools" menu, scroll to bottom of page and repick the onset time on the last trace. Again select "Travel Times" from "Function" menu to view the corrected travel time display.

(21) Select "Critical Distance" from the "Tools" menu, move cursor to critical distance (anywhere between 5th and 6th point on Line 1, between 6th and 7th point on Line 2) and click. Note least squares lines with associated velocities V1,V2 displayed on information line. Select "Velocity vs. Depth" from the "Function" menu to view the inferred subsurface section beneath the seismic line. Quit the cross section display, select "Critical Distance" from the "Tools" menu and select a different critical distance (e.g. between 7th and 8th points). Note how velocity estimates

change. Select "Velocity vs. Depth" from the "Function" menu and note how depth changed (i.e. from 45 to 57 ft). Quit the cross section display, select "Critical Distance" from the "Tools" menu and reselect the proper (i.e. first) critical distance. Quit travel time and analyst station displays.

(22) Select "Water Table Elevation" from IMAGES menu. Select "Contours"/ "Water Table" from OVERLAYS menu. Select "Seismic Wtable Depth" from OVERLAYS menu. Note agreement between hydrologic and seismic estimates of water table depth (i.e. "data fusion"). Repeat steps 17-22 for seismic Line 2 if time/interest dictates. Note different water table depth estimate correlates with hydrologic estimate for Line 2 location.

(23) Select "SPOT Image of MMR" from IMAGES menu. Select "Full Res" from side menu. Click near SE corner of MMR base area. Select "MMR Boundary" from OVERLAYS menu. Select "Select" button from side menu. Select "Survey Lines" from LOCATIONS menu. Click on the southern most displayed circle (i.e., crosshole seismic survey location, perched water table example) to display information about survey. Double click to select that survey.

(24) Select "Seismic"/ "Tomography" from MODELS menu. Select "Actual Model" from OVERLAYS menu. Move "Number of Cells (x)" slider to 20, "Number of Cells (y)" slider to 25 and "Number of Iterations" slider to 30. Click on asterisks in left drill hole to see initial ray path estimates (i.e., for homogeneous model). Select "Tomography" from FUNCTIONS menu and watch iterations to final solution. Select "Model Comparison" from OVERLAYS menu. (If slightly better model result is of interest, move "Number of Iterations" slider to 50, select "Tomography" from FUNCTIONS menu and watch iterations to final solution. Select "Model Comparison" from OVERLAYS menu.) Quit the tomographic display to return to SPOT. Select a different tomographic survey and repeat the above steps if sufficient audience interest. (The other two surveys are for tabular inclusions of different velocity materials.)

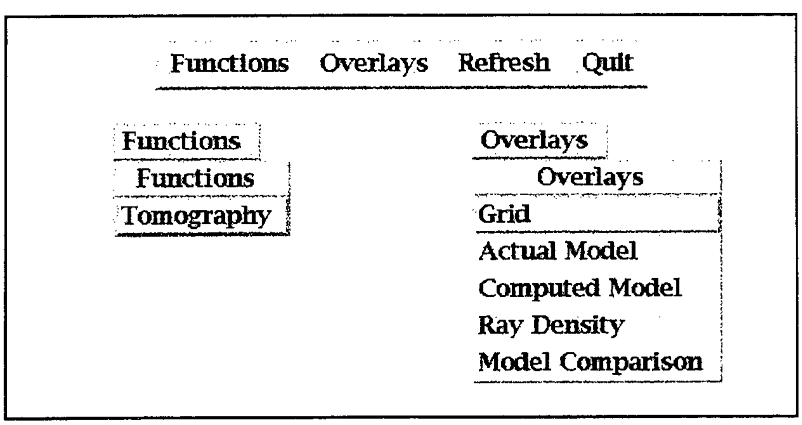

Figure B-8. Tomography program menus.

Overlays Refresh Help Quit

Overlays
Overlays
Grid

Figure B-9. GPR program menus.

(25) Click on the triangle (i.e., GPR survey location) to display information about survey. Double click to select that survey. Select "GPR" from MODELS menu. Select "Grid" from OVERLAYS menu to overlay grid on the background medium. Move "Set Dielectric" slider to 1. Insert a body with a dielectric constant value of 1 ($coulomb^2/N \cdot m^2$) by clicking on a rectangle of squares in the background. Move "Set Frequency" slider to 100. Click on asterisks on the surface above and near the body one at a time, waiting after each for the GPR trace to appear as an overlay. Click on REFRESH menu. Move "Set Frequency" slider to 400 and repeat for a higher frequency source. Quit the GPR display to return to SPOT.

(26) Select "Remove Locations" from the REFRESH menu. Select "MMR Boundary" from OVERLAYS menu. Select "Magnetic Survey Area"/ "Survey Boundary" from OVERLAYS menu. Select "Survey Area" from IMAGES menu. Select "Magnetic Survey Area"/ "Survey Boundary" from OVERLAYS menu. Select "Areas of Interest" from OVERLAYS menu. Select "Areas" from LOCATIONS menu. Select "Information" from side menu. Click on area button in survey area, select "LF-2" from pop-up, view info file, dismiss.

(27) Select "Remove Locations" from REFRESH menu. Select "Magnetic Survey Area"/ "Survey Boundary", / "Magnetic Survey Lines" from OVERLAYS menu. Select "Remove Overlays" from REFRESH menu. Select "Magnetic Survey Area"/ "Magnetic Survey Contours", / "Survey Boundary" from OVERLAYS menu.

(28) Select "Total Magnetic Field" from IMAGES menu. Select "Magnetic Survey Area"/ "Magnetic Survey Contours", .../ "Survey Boundary" from OVERLAYS menu.

(29) Select "3-D Surfaces"/ "Magnetic field" from FUNCTION menu. Move viewing angle slider to 140, then 200. Click on "Cycle" button.

APPENDIX C

A COMPREHENSIVE REFERENCE TO GDFS FUNCTIONALITY

In this section, all of the capabilities and functionality of the Geophysical Data Fusion System (GDFS) will be described in detail.

C.1. GENERAL LAYOUT OF GDFS APPLICATIONS.

All applications that are part of GDFS have similar appearance. The parts of the displays used are as follows:

- menu bar - an area at the top of the display that contains buttons that cause menus to be displayed
- message area - a strip just under the menu bar that displays short messages from the application
- image area - the main display area of an application
- side menu area - an area to the right of the image area that contains switches to control the functionality of the mouse. When a particular mouse function is selected, an indicator is illuminated next to the name of the function.

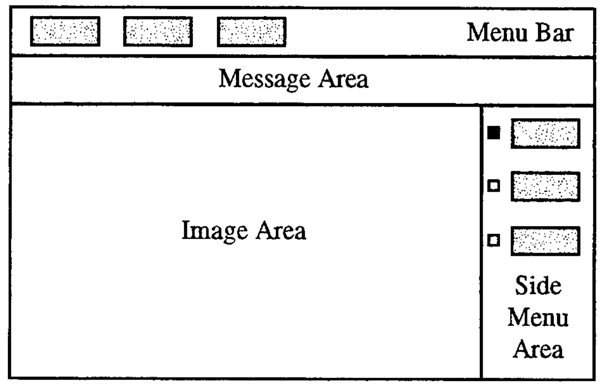

Figure C-1. General layout of GDFS applications.

These areas are illustrated in Figure C-1. Some GDFS applications do not contain all areas.

In addition to the areas described above, some actions cause dialog boxes to appear on the screen. A dialog box is a temporary window opened by the application to communicate information or to request input. Typically, the user responds to a dialog box by moving a slider or typing text into an input area, then tells the application to proceed by pressing an acceptance button, or to cancel the operation by pressing a cancel button. Some dialog boxes also have associated help text that describes the function of the dialog box and the nature of the requested input. Dialog boxes disappear when dismissed.

C.2. THE MAIN IMAGE DISPLAY APPLICATION.

The main user interface of the GDFS application is through an image-display application. The layout of this application follows the pattern shown in figure C-1. This module provides the mechanism by which much of the general information provided by GDFS is presented to the user.

C.2.1. The Menu Bar.

The menu bar of the GDFS main image display (MID) contains several buttons, most of which cause menus to be displayed. The menu buttons are labeled *Images, Overlays, Locations, Refresh, Function, Models, Copy, Help*, and *Quit*, and are described in detail below. Figure C-2 illustrates the MID main menu.

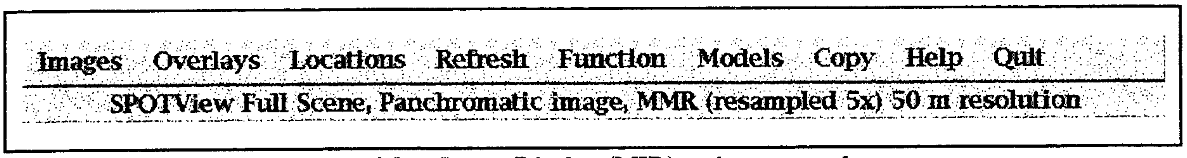

Figure C-2. The Main Image Display (MID) main menu and message area.

The **Images menu,** shown in Figure C-3, allows the user to specify which of the several available images is to be displayed as the background image in the Main Image Display. Images that cover all of the MMR region of Cape Cod include a compressed (50 m/pixel) SPOT® image, a color-coded topographic map, and a color-coded water table elevation map. Other images are a magnified portion of the SPOT image around an area where a magnetic survey was taken and a color-coded map of the total magnetic field as measured during the survey. All of the images cited above are registered to geographic coordinates, so vector overlays can be displayed on top of these images, as discussed below.

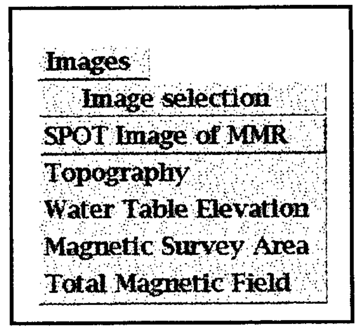

Figure C-3.
MID Images menu and submenu.

The **Overlays menu,** shown in Figure C-4, affords the user access to a variety of digitized, georeferenced vector overlays that can be displayed on top of the images that were selected from the *Images* menu. Since each overlay is associated with geographic references, it can be placed on any base image regardless of the scale of the base image; this capability will be explored in greater depth below.

The Overlays menu contains several buttons that directly place overlays onto the base image as well as three submenus containing specialized overlays. The overlays that are available directly from this menu are:

- MMR Boundary - displays a colored line indicating the perimeter of the Massachusetts Military Reservation.
- Geology - shows the boundaries of several geologic regimes on Cape Cod
- Areas of Interest - shows outlines of the several areas that are of particular interest for environmental remediation efforts
- Seismic Watertable Depth - interacts with seismic refraction modeling, discussed below, to place an indicator of seismically-determined depth to watertable onto the base image. The most recently analyzed refraction survey line results are shown.

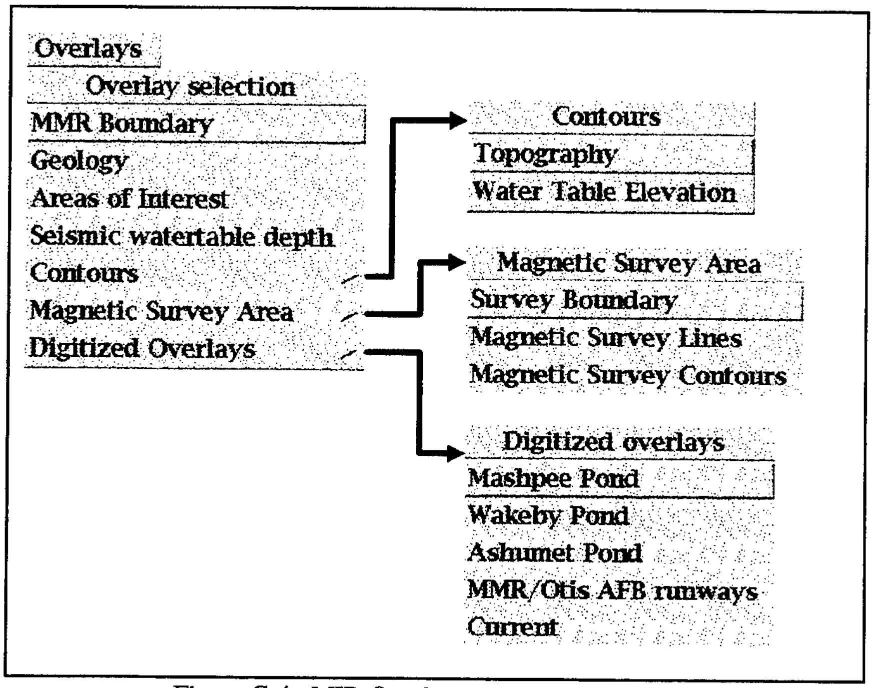

Figure C-4. MID Overlays menu and submenus.

In addition, the Overlays menu contains three submenus containing specialized overlays. These sets of overlays are:

- Contours
  - ◊ Topography - the topography of the MMR area, expressed as color-coded lines.
  - ◊ Water Table Elevations - line contours describing the elevation of the watertable.
- Magnetic Survey Area
  - ◊ Survey Boundary - the perimeter of the area surveyed with magnetometers.
  - ◊ Magnetic Survey Lines - the lines along which the magnetic survey was taken.
  - ◊ Magnetic Survey Contours - the results of the magnetic survey.
- Digitized Overlays
  - ◊ Mashpee Pond - the outline of Mashpee Pond, to the east of MMR.
  - ◊ Wakeby Pond - the outline of Wakeby Pond, to the east of MMR.
  - ◊ Ashumet Pond - the outline of Ashumet Pond, south/southeast of MMR.
  - ◊ MMR/Otis AFB Runways - the locations of the runways on Otis Air Force Base.
  - ◊ Current - used in collaboration with GDFS digitization facilities, discussed below, to show features digitized during the current session.

The **Locations menu** provides access to various types of data from the database associated with GDFS. Current selections are *Areas*, *Wells*, and *Survey lines*, as shown in Figure C-5. When the user selects Areas, icons representing the various areas of environmental concern are placed onto the base image, while the Wells selection puts symbols for hydrologic and geologic wells from MMR onto the base image. In each case, the icon representing a particular object can be interrogated by the user for information about that object, provided that the *Side menu* item *Information* is selected.

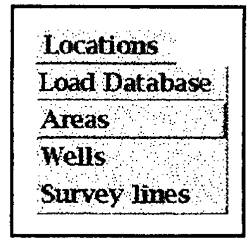

Figure C-5.
The MID
Locations menu.

For *Locations* menu item *Survey lines*, symbols representing geophysical survey lines are displayed. Demonstration cases are selected in conjunction with the *Side menu* item *Select* and the *Models* menu selections *Seismic ⇒ Refraction*, *Seismic ⇒ Tomography*, and *GPR*; these procedures are explained in more detail below.

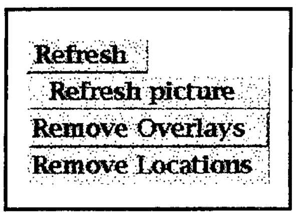

Figure C-6.
The MID Refresh menu.

The **Refresh menu** gives the user the ability to remove previously-selected overlays and locations from the display. Selecting the *Remove Overlays* item merely removes overlays from the display. The *Remove Locations* selection, by contrast, removes the visual aspects of a set of locations and in addition unloads the data recovered from the database from active memory. Figure C-6 shows the *Refresh* menu.

The **Function menu**, illustrated in Figure C-7, provides access to certain display functions of GDFS. As currently implemented, there are two types of functions available. The first, collected under the *3-D Surfaces* submenu, gives the user access to 3-D wireframe representations of *Topography*, *Water Table*, and *Magnetic Field.* The second selection in the *Function* menu, *Save Overlay*, allows the user to save digitized overlays created during the current session to a named file and to add the name of that file to the *Overlays ⇒ Digitized Overlays* menu; saving the digitized lines is done via a dialog box that appears when *Save Overlay* is selected.

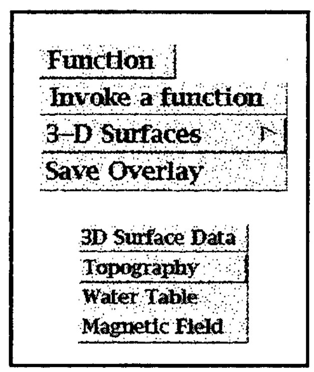

Figure C-7.
The MID Function menu.

Selection of any of the *3-D Surfaces* items causes a dialog box like that shown in Figure C-8 to appear. That dialog box gives the user the ability to control the viewing azimuth of the wireframe by manipulating a slider; to initiate a sequence of displays showing the wireframe at viewing azimuths separated by 20° by pressing the *Cycle* button; or to show a help page about the image via a *Help* button.

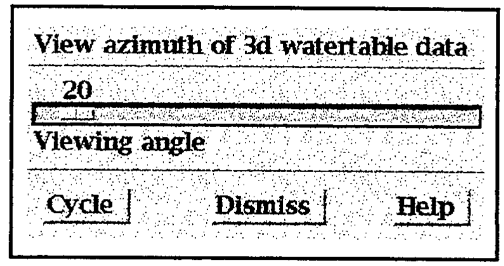

Figure C-8.
A typical dialog box for controlling viewing azimuth for 3-D wireframes.

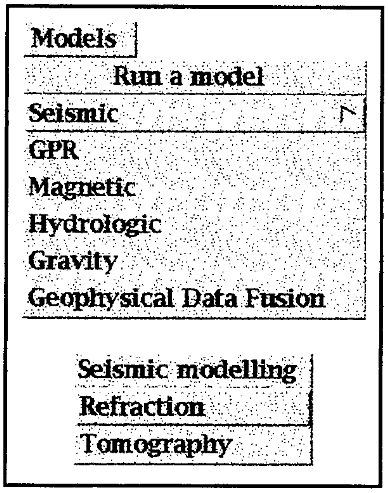

Figure C-9.
The MID Models menu and Seismic modeling submenu.

Part of the purpose of GDFS was to demonstrate the utility of various geophysical techniques in support of environmental remediation efforts. The **Models menu** provides access to the modeling codes that have been incorporated into GDFS. At the present time, the only models implemented are *Seismic* ⇒ *Refraction*, *Seismic* ⇒ *Tomography*, and *GPR*. To run these applications, one loads the data into GDFS by selecting *Locations* ⇒ *Survey lines*; then chooses *Select* from the *Side menu*; next, selects an icon representing a refraction survey, a tomographic survey, or a GPR survey from the Main Image Display; and finally choosing *Seismic* ⇒ *Refraction*, *Seismic* ⇒ *Tomography*, or *GPR*, as appropriate, from the *Models* menu. Figure C-9 shows the *Models* menu and its *Seismic modeling* submenu. The capabilities of the seismic refraction display application, tomographic inversion, and GPR model are described in more detail below.

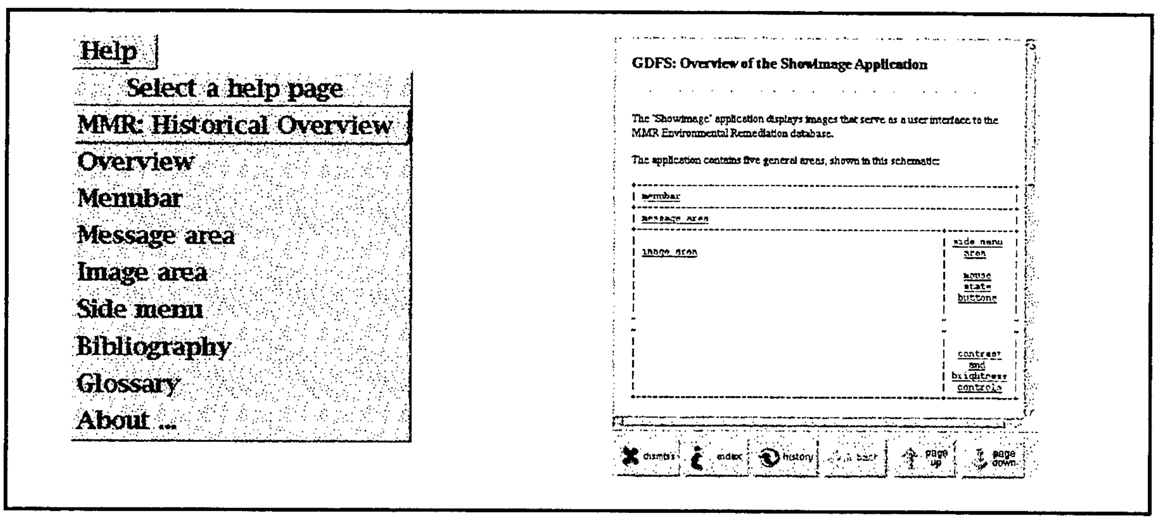

Figure C-10. MID Help menu and a Help dialog box.

The **Copy button** on the Menu Bar captures the image to a file. When the user presses this button, a dialog box asks for the name of a file to which the screen image is to be saved. Images are saved to whatever directory the user was in when GDFS was launched in a form suitable for output to a printer.

The **Help menu** provides access to a series of pages of text describing how to use every GDFS application. This text is presented in the form of a dialog box with a scrolling text window, as shown in Figure C-10.

Pressing the **Quit button** causes the application to terminate execution.

C.2.2. The Message Area.

The Main Image Display provides textual output in response to certain actions. If the amount of text is small, it is displayed in this area of the display. The message area appears just below the main menu, as shown in Figure C-2.

C.2.3. The Side Menu.

The behavior of the left mouse button in the Main Image Display varies according to the settings of the radio buttons in the side menu. (The name radio buttons derives from car radios, meaning that only one of them may be selected at any time.) The radio buttons are shown in Figure C-11. A small diamond is associated with the text of each button; when the button is selected, the diamond fills with a bright color to indicate the current state of the radio buttons. Brief descriptions of the actions performed when the left mouse button is pressed when the function is enabled are:

- Information - pressing the left mouse button on an object in the Image Area causes information about that object to be displayed. Depending on the amount of information available, it may be displayed in the Message Area or in a dialog box.
- Select - allows the user to select a well or seismic line to be selected for further processing.

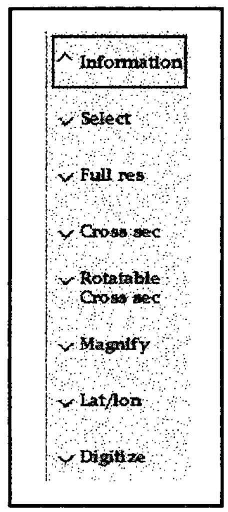

Figure C-11.
MID Side Menu.

- Full res - when this is active, pressing the left mouse button in the Image Area causes the full-resolution (10 m/pixel) SPOT® image whose center is nearest the selected point to be displayed.
- Cross sec - when this button is on, a vertical subsurface geologic section along a line between any two points on the image can be created and displayed by sequentially selecting the points with the mouse. The *Quit* button on the cross section display is used to refresh the underlying image display, from which another cross section can be initiated, or, upon completion, the process can be terminated by turning off the *Cross sec* button.
- Rotatable Cross sec - similar to Cross sec, but the user selects a center point and an endpoint; the length of the line is doubled about the center point and a cross-section is

displayed. A companion dialog box permits the user to view cross-sections at various azimuths about the defined center point.

- Magnify - presents a magnified view of the area surrounding a mouse-selected point. Magnification is controllable to values between 2 and 8 via a companion dialog box.
- Lat/lon - shows the latitude and longitude of any point in a geo-registered image (i.e., a SPOT® image, a color-coded topographic map, or the geologic map).
- Digitize - permits the user to digitize arbitrary points on any image. If the image is geo-registered, latitude and longitude are used for coordinates; otherwise, pixel locations are used. Following digitization, the digitized points can be accessed from the *Overlays ⇒ Current Overlay* menu item which causes the points to be displayed on the currently displayed image, connected by straight lines.

The Main Image Display includes some display-altering controls on the side menu labeled **Contrast** and **Brightness**. These controls alter the contrast and brightness of grayscale images by means of sliders. Pressing the *Contrast* or *Brightness* buttons restores those parameters to their original values. The contrast and brightness controls are shown in Figure C-12.

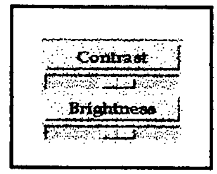

Figure C-12.
MID Contrast and Brightness controls.

C.2.4. The Image Area.

Almost all of the information communicated by GDFS is displayed in the Image Area. The user can interact with the image, if appropriate, via the mouse and according to the selection in the Side Menu, as discussed above. Many examples of images displayed in this region of the Main Image Display are shown in Chapter 2.

C.2.5. Image Area Information Dialog Boxes.

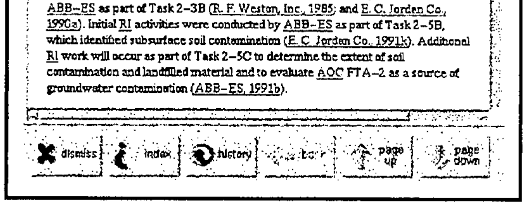

Figure C-13.
A hypertext information dialog box.

Given that the user has loaded the icons representing areas being studied for environmental remediation by choosing *Locations ⇒ Areas*, and has chosen *Information* from the side menu, the user can cause a dialog box to appear by clicking on an icon. The dialog box that appears is a hypertext display application called xmhelp 1.11, written by Thomas Harrer of the Institute of Parallel and Distributed High-Performance Systems, University of Stuttgart, and obtained from the Internet; but any hypertext browser could be substituted. In Figure C-13, a sample hypertext dialog box is shown. If the user clicks on any underlined word, a so-called hyperlink is followed and the associated text appears. For example, if the user clicks the mouse on the text "AOC" in Figure C-13, a glossary will appear so the meaning of the phrase can be viewed; alternatively, if the user clicks the mouse on a citation, a bibliography will appear so that the user can see the details of the reference.

C.3. CROSS-SEC.

The cross-section display is launched from the main image display application when either the Cross sec or Rotatable Cross sec side menu buttons are selected. See the discussion under the previous section for more details about creating a cross-section. Both methods of creating cross-sections use the same cross-section display application.

Figure C-14.
Cross-section main menu.

The cross-section display contains a menu bar, a message area, and an image area. The functionality of the mouse is limited to querying on-screen objects for information.

C.3.1. The Menu Bar

The menu bar contains menu buttons labeled *Copy*, *Help* and *Quit*. The **Copy button** on the menu bar captures the image to a file. When the user presses this button, a dialog box asks for the name of a file to which the screen image is to be saved. Images are saved to whatever directory the user was in when GDFS was launched. The **Help Button** behaves as described earlier. Pressing the **Quit button** causes the application to terminate.

C.3.2. The Image Area.

The image area of Cross-sec contains a cross-section along the line selected from the Main Image Display. Horizontal and vertical scales are shown in the image. The vertical exaggeration of the cross-section is determined by the vertical size of the display area: cross-sections are scaled to fill the display with a small border at the top and bottom. If the user creates a cross-section through an area containing well icons, representations of the wells will appear on the cross-sections; clicking on the box at the bottom of a well will cause an information dialog box about the well to appear.

C.4. THE SEISMIC/REFRACTION DISPLAY MODULE.

When *Seismic ⇒ Refraction* is selected from the **Models menu** of the main image display, this module is initiated using data from the selected survey line. It displays ground motion versus elapsed time from the beginning of the digitized record. The display contains a main menu bar, a message area, and an image area containing one or more plots of time series. If there are more time series than will fit on a single screen, a scrollbar will appear along the right edge of the image area; the user can drag the scrollbar down to see time series that didn't fit on the initial display. Each time series is plotted in its own window, along with text indicating the distance of the receiver from the source and the azimuth from the receiver to the source. This application is included in GDFS as part of a demonstration of the applicability of refraction seismology to monitoring environmental remediation efforts.

C.4.1. The Menu Bar.

Figure C-15.
Analyst Station Main Menu.

The menu bar of the Analyst Station contains menu buttons labeled *Tools*, *Function*, and *Help*; and an action button labeled *Quit*. Figure C-15 shows the main menu bar of the Analyst Station.

The **Tools menu** allows the user to interact with the data in various ways. This menu is shown in Figure C-16. The choices available are:

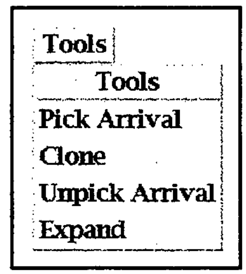

Figure C-16.
Analyst Station
Tools menu.

- Pick Arrival - when this choice is selected the user can click on a location along the time axis of a time series to select where the signal is interpreted to start. This action is central to the interpretation of refraction seismic data.
- Clone - if this choice is selected and the user clicks on any time series, a moveable colored copy of it is produced. The user may then drag the copy around the display to overlay it on another time series to examine similarities. The first mouse-click selects the trace to be copied; a second mouse click dismisses the copy. If the user holds the left mouse button down after the first click, the copy will move smoothly over the display; alternatively, if the user releases the left mouse button after the first click, the copy will jump from location to location after a computer-system-set threshold time has passed.
- Unpick Arrival - reverses the effect of the Pick Arrival tool.
- Expand - produces a full-page display of any selected time series. A second instance of the Analyst Station is started to display this single time-series, so all other functionality of the Analyst Station may be brought to bear on the time series.

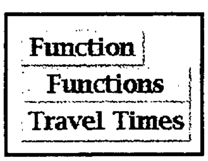

Figure C-17.
Analyst Station
Functions menu.

The **Function menu** allows the user to invoke the next step in the interpretation of refraction seismic data. The menu contains a single selection, namely *Travel Times*. Once arrival times have been chosen for each time series in the Analyst Station, invoking this function will display a travel time versus source-receiver distance plot. Figure C-17 shows this menu. The resulting plot and its menus are described in the next section.

The **Help menu** provides access to a series of pages of text describing how to use the application, as described in previous sections.

Pressing **Quit** causes the application to terminate execution.

C.4.2. The Image Area.

Plots of time series are displayed here. Each time series is displayed in its own subwindow. If there are too many time series to be displayed at reasonable size on the screen, a vertical slider at the right side of the image area enables the user to scroll the display to view more time series plots.

C.5. CRITICAL DISTANCE DETERMINATION.

After choosing first arrival times in the Analyst Station and selecting *Function ⇒ Travel Times* from the Analyst Station main menu, the user is presented with a travel time versus distance plot corresponding to the chosen arrival times. The *Critical Distance* determination application permits the user to locate the distance at which seismic arrival times began to be affected by the presence of a higher-velocity layer beneath the surface layer.

In the case of GDFS, a simple layer-over-halfspace model is supported, e.g., dry sand over wet sand.

C.5.1. The Menu Bar.

The menu bar of the critical distance determination application contains menu buttons labeled *Tools*, *Function*, and *Help*; and an action button labeled *Quit*. Figure C-18 shows the main menu bar of the critical distance module.

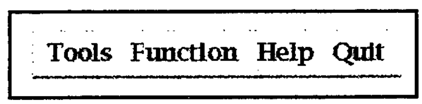

Figure C-18.
Critical Distance main menu.

The **Tools menu** allows the user to interact with the data in various ways. This menu is shown in Figure C-19. The choices available are:

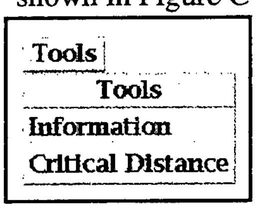

Figure C-19.
Critical Distance
Tools menu.

- Information - shows range, azimuth, and arrival time information about a particular time-versus-distance point.
- Critical Distance - in interpreting simple seismic refraction data, one approximates a line through each set of traveltime-versus-distance points that seem to lie in a line. When *Critical Distance* is selected, click the mouse into a space between endpoints of two sets of traveltimes to select the so-called critical distance, the distance at which seismic waves began to spend part of their travel time in the higher velocity lower level. Two lines will be drawn through the two sets of traveltime-versus-distance points to permit the user to gauge how well the critical distance selection matches the data. This selection determines the velocity model interpreted from the data.

The **Function menu** gives the user access to a visual display of the velocity model derived from the interpretation of the travel times. After selecting the critical distance as described above, the user selects *Function* ⇒ *Velocity vs Depth* to display the model.

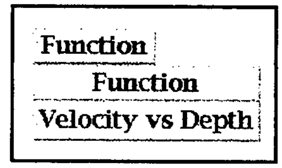

Figure C-20.
Critical Distance
Function menu.

The **Help menu** provides access to a series of pages of text describing how to use the application, as described in previous sections.

Pressing **Quit** causes the application to terminate execution.

C.5.2. The Image Area.

Traveltime versus distance points are shown in this area. The user can query individual data points to see information about those points or can select critical distance for the refraction survey, depending on the setting chosen from the *Tools* menu.

C.6. VELOCITY MODEL DISPLAY.

This application shows the velocity model derived from the arrival time picks made in the Analyst Station combined with the determination of critical distance made using the Critical Distance Determination application.

C.6.1. The Menu Bar.

This menu displays only one selection, *Quit*. After viewing the display, pressing this button terminates the application.

C.6.2. The Image Area.

This application displays a cross-sectional view of the model, with axes and labels indicating depths of layers and seismic velocities.

C.7. TOMOGRAPHY.

The tomography display is launched by the selection *Seismic* ⇒ *Tomography* from the **Models Menu** of the main image display. The individual model to be run is selected first by invoking the *Select* side menu item. Figure C-21 shows the menus available from the tomography display.

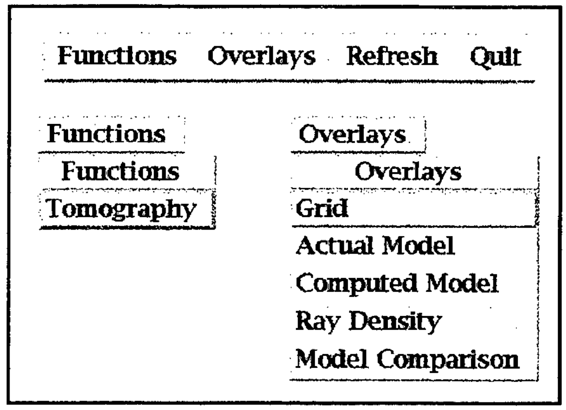

Figure C-21. Tomography menus.

The **Functions menu** allows the user to invoke tomographic inversion for the selected model. The menu contains a single selection, namely *Tomography*. This item is selected when all control adjustments, discussed below, have been made.

To prepare for the tomographic inversion process, the user first selects the number of cells in the horizontal and vertical directions and the number of iterations to perform by manipulating sliders in the side menu.

The **Overlays menu** offers pre- and post-inversion assistance to the user. The available choices and their applications are:

- Grid - overlays the grid defined by the side menu sliders onto the image area.
- Actual Model - displays the actual model used in computing the seismic data to be used in the inversion.
- Computed Model - when inversion has been completed, shows the result.
- Ray Density - shows a color-coded image of seismic ray densities in the cells of the image.
- Model Comparison - shows the initial model and the result as determined by tomographic inversion together on the screen.

C.8. GROUND-PENETRATING RADAR (GPR).

The GPR display is launched by the selection *GPR* from the **Models Menu** of the main image display. The individual model to be run is selected first by invoking *Select* from the side menu of the MID and then selecting a GPR survey from the image area of the MID. This causes a subsurface vertical section to be displayed showing the variations in the background values of the dielectric constant beneath the selected survey line. Figure C-22 shows the menus available from the GPR display.

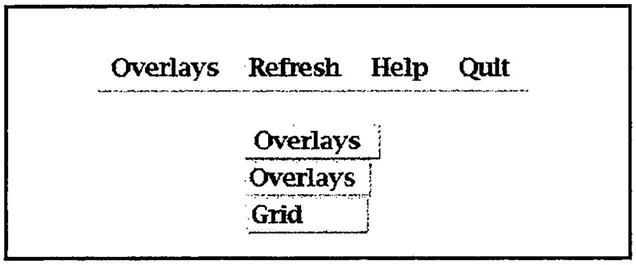

Figure C-22. GPR program menus.

The **Overlays menu** contains a single selection, namely *GRID*. This item overlays a grid onto the background model. After the grid is applied the dielectric constant in any individual grid element can be changed by setting a dielectric constant value using the slider in the side menu, and clicking on the grid element you wish to change. In this way a body of any shape and dielectric constant can be inserted into the subsurface material.

At the surface of each vertical profile in the gridded material there is an asterisk representing a radar source and receiver. When the user clicks on this symbol a GPR calculation is performed and the simulated profile data is overlayed onto that vertical profile. The calculation is performed at a frequency (MHz) that is set by the user using a slider in the side menu area.

Selecting **Refresh** will clear the screen of the simulated radar traces so that a new frequency can be set.

Help and **Quit** behave as in the other applications.

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