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User's Manual for the BROOM Decision Support System

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Abstract

The Building Restoration Operations Optimization Model (BROOM) software system, developed by Sandia National Laboratories, is a comprehensive system designed to improve the efficiency and quality of sample collection, data management, and interpretation. Currently, BROOM is capable of supporting sampling efforts at facilities contaminated with chemical and/or biological agents. BROOM provides advanced visualization, analysis, and sampling optimization functions, which speed up the sampling process and lower the associated sampling costs. BROOM enables the user to develop a defensible sampling plan based on statistical analysis of sample results. BROOM consists of two applications: one that runs on a hand-held PDA and one that runs on a Windows desktop/laptop. This document covers the installation and basic operation of both components and provides examples of the application of these tools during and following an actual field exercise.

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NOMENCLATURE

BROOM	Building Restoration Operations Optimization Model
CAD	Computer-Aided Design
CD	Compact Disc
CFU	Colony-Forming Units
DHS	Department of Homeland Security
EPA	Environmental Protection Agency
GB	Gigabytes
GPS	Global Positioning System
IDW	inverse distance mapping tool
IP	Internet Protocol
LAN	Local-Area Network
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MB	Megabytes
MSDE	Microsoft SQL Server Desktop Engine
PAST	Probabilistic Adaptive Sampling Technique
PC	Personal Computer
PDA	Personal Digital Assistant
QPCR	Quantitative Polymerase Chain Reaction
RAM	Random-Access Memory
SNL	Sandia National Laboratories
SSID	Service Set Identifier
TCP	Transmission Control Protocol
TKIP	Temporal Key Integrity Protocol
UDP	User Datagram Protocol
VSP	Visual Sample Plan
WEP	Wired Equivalent Privacy
WPA	Wi-Fi Protected Access
XML	Extensible Markup Language

1. BROOM OVERVIEW

The task of sampling a biologically or chemically contaminated facility is an immense one; thousands, if not tens of thousands, of samples must be collected, managed, and interpreted. To date, there has been no comprehensive system for handling and assisting with this process. The Building Restoration Operations Optimization Model (BROOM) software system was developed by Sandia National Laboratories (SNL) to meet this need. BROOM improves the efficiency and quality of sample collection and data management, and additionally provides advanced visualization, analysis, and sampling optimization functions. This cohesive set of features speeds up and lowers the costs of the sampling process.

BROOM consists of two applications: one that runs on a hand-held PDA and one that runs on a Windows desktop/laptop. Each provides the following functionality:

PDA

- Sample Collection

Desktop

- Data Management
- Visualization
- Analysis
- Sampling Optimization

1.1. Sample Collection

BROOM's PDA-based application improves the process of sample collection. It will run on any Windows Mobile 4+ (6+ preferred) PDA, such as the Hewlett Packard iPAQ or Trimble Nomad. This application guides the sampling team to desired sampling locations and establishes accurate sample positions through the use of an innovative, patented, map-based laser range-finding system. Simple, intuitive forms on the PDA guide the team through data entry of attributes, such as the collection method and characteristics of the sampled surface. These forms and integrated barcode scanners eliminate the clerical errors inherent in paper-based systems and ensure the quality of the sample data. Collected data are wirelessly transferred out of the contaminated area to a secure database and displayed on the desktop application, yielding instant updates for the field commanders. The PDA also maintains close contact with the desktop application when possible, allowing the current locations of sampling teams to be tracked on the building maps.

1.2. Data Management

The desktop application provides a building model (floors, rooms, zones, etc.) in which sample data is stored and managed. BROOM takes data management to the next level by intertwining the sample data with laboratory results, floor plans, ventilation schematics, aerial photographs, analysis, etc., to provide a comprehensive and descriptive data set.

Management of this complex data is simplified through the use of convenient interfaces, such as a hierarchical project tree, spreadsheet-like data grids, and the building map itself. This information is stored in a secure, industrial-strength Microsoft SQL Server relational database. While the full commercial version of SQL Server is recommended for full-scale deployments, BROOM is also compatible and distributed with the free scaled-down Microsoft SQL Server

Express (2005 or 2008). The use of this database system allows secure, concurrent access by multiple users anywhere in the world.

Furthermore, BROOM's sample data are digital from the moment of creation, thus eliminating the multiple opportunities for data transcription and interpretation errors inherent in existing systems. Likewise, laboratory results are received and imported electronically, again improving speed and data integrity. The PDA and desktop applications also track the chain of custody of the sensitive and hazardous physical samples.

1.3. Data Visualization

A spreadsheet containing sample coordinates and laboratory results is not a practical representation of the overall picture. Manually mapping these data is not desirable either, as this is a slow, inaccurate, and error-prone process.

The centerpiece of BROOM's data visualization system is the building map. Samples are displayed on this map from the moment they are received from the PDA application. These samples become color-coded once the laboratory results are received. This color-coding can represent the raw quantity measured or the more intelligent surface contamination value, which normalizes sample values based on the sampled surface area and losses in the processes of collecting, extracting, and detecting the biological or chemical agent. The building map also serves as the backdrop for insightful contamination and uncertainty maps generated by BROOM's advanced analysis capabilities.

Sample and analysis data can also be examined in BROOM's 3D viewer. This viewer allows samples and contamination maps to be experienced from the viewpoint of a person walking through the building, from a bird's eye view, or anywhere in between with full 3D movement and viewpoint control.

1.4. Analysis and Optimization

Sample collection and laboratory analysis is an expensive and time-intensive process; reducing the number of samples is a primary goal of the BROOM system. BROOM features many analysis capabilities designed to provide a comprehensive overall picture and optimize the number of required samples.

The discrete data points of known samples can be analyzed to provide a continuous map of the contamination present in the facility. Sample locations are proposed by BROOM through the combination of the contamination map with other analysis methods. These proposed samples can be generated to achieve various goals, such as identifying hot spots, establishing the boundary of contamination, or minimizing overall uncertainty. Proposed samples are then transferred to the PDA applications, which in turn guide the sampling teams in taking the next round of samples. This iterative process of sampling and analysis both minimizes the number of samples and increases the confidence in the overall picture.

2. USER'S MANUAL OVERVIEW

In this manual, the two software applications are commonly referred to as the “desktop application” and the “PDA application.” The desktop application does not necessarily require a desktop computer—the term “desktop” can also refer to a laptop computer. The term is used merely to distinguish it from the PDA application.

The desktop application stores facility and sample information in a secure relational database. That database can be located on the same computer as BROOM or a server accessible via a network.

This manual covers the process of installing both the desktop and PDA BROOM applications. Next, the manual shows how to create a project and import facility information. Step-by-step instructions covering sample visualization, analysis, and data importing/exporting features follow. A comprehensive tour of the PDA sample collection tool completes this hands-on guide.

3. INSTALLING BROOM

This section of the manual will guide you through installation of the BROOM software. You install the BROOM system from a CD. First, you install BROOM on a desktop or laptop computer. Then, if you choose, you may install BROOM onto a handheld PDA.

3.1. System Requirements

BROOM runs on most off-the-shelf computers. Fully featured PDAs are used for sample data collection. Administrator-level access is required for installation, but not necessarily for operation.

3.1.1. Hardware

BROOM operates on a desktop or laptop PC running the 32-bit Microsoft Windows XP, Vista, or Windows 7 operating system. At this time, BROOM will not operate on 64-bit operating systems. BROOM has been tested on systems having as little as 256 MB RAM memory. The recommended minimum system configuration is:

- Windows XP or Windows 7, running 32-bit system (will not run on 64-bit)
- 2 GHz processor
- 1 GB RAM
- Monitor/video card supporting at least 1024x768 resolution and 16-bit color
- At least 5 GB free space on the hard drive (particularly if hosting the SQL Server locally on the same machine)

BROOM PDA software requires a PDA running the Windows Mobile 4.0 (or greater – version 6 is preferred) operating system, 802.11 (b or g) wireless networking capability, Bluetooth wireless capability and either an integrated barcode scanner or an expansion slot that will accept a third-party barcode scanner. The PDA must have 64 MB of memory installed (128 MB is preferred). Installation instructions are tailored to the Trimble Nomad 800LE PDA as it is the preferred system.

3.1.2. Windows User Privileges

You must have Administrator user privileges to install BROOM on a computer. Administrator privileges allow the BROOM installation routines to properly configure your computer to work with BROOM.

3.1.2.1. Checking User Privileges

If you do not know whether you have administrative privileges on your computer, you can check in five simple steps (Figure 3-1). These steps pertain to Windows XP – if you are running Vista or Windows 7, you may need assistance from your tech support. First, find the *My Computer* icon on your computer desktop and right-click on it. This brings up a context menu at your mouse cursor. Select **Manage** from the context menu and click with your left mouse button. On left panel of the *Computer Management* dialog, open the **Local Users and Groups** folder, and then the **Groups** folder under that. A list of groups appears in the right hand panel of the

Computer Management dialog. Double click on the **Administrators** item in the list. The *Administrators Properties* dialog lists all users who have administrator privileges on your computer. Check the list for the user name that you used to log into your computer. If your user name shows up on that list, you have sufficient privileges to install BROOM. Click the X buttons at the upper-right corner on the two dialogs to clear them from your screen.

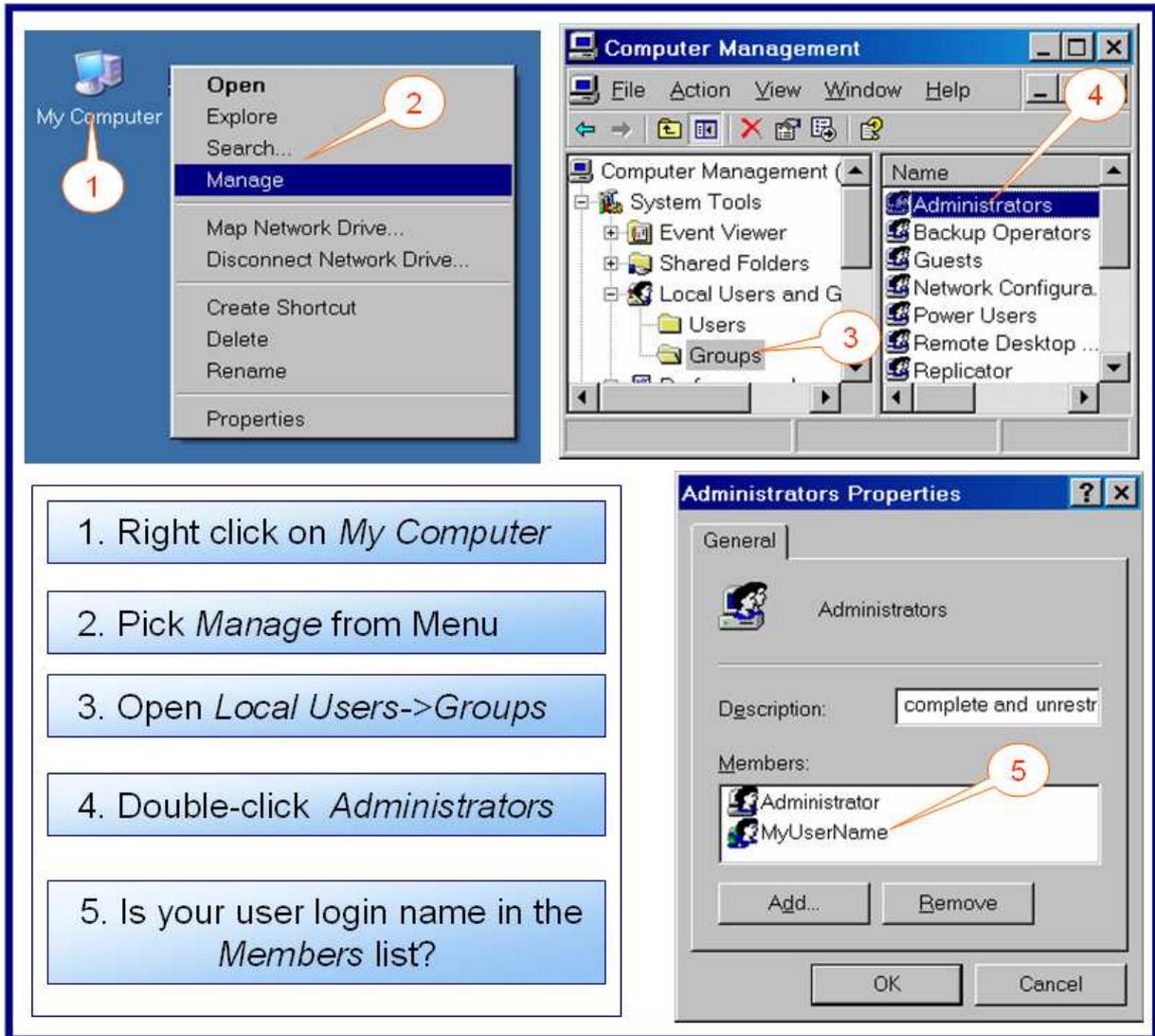


Figure 3-1. Steps to Check for Administrator Privileges (Windows XP).

If you do not have Administrator privileges on your computer, do **not** proceed with BROOM installation. Consult your system administrator about configuring your machine properly. Alternatively, you may consult your computer owner's manuals or your Windows system documentation about how to configure your computer.

3.2. Installing Desktop BROOM

To install BROOM on a desktop or laptop computer you will simply run the installation program on the CD and follow the on-screen instructions.

3.2.1. *Installed Components*

The BROOM installation program installs the BROOM software as well as other software components that BROOM need in order to run. Below is the list of components installed by the installation program, in the order of installation:

- Microsoft .NET Framework 3.5 SP1
- MapObjects 2.3
- SQL Server 2008 R2 Express
- Example SQL database
- BROOM Desktop

Microsoft .NET Framework 3.5 is included with Windows 7, but is included in the installer for installing on Windows XP.

3.2.2. *Starting the Installation Program Manually*

Start the installation program by following these steps:

1. Right-click on the Windows *Start* button and select *Explore*.
2. Navigate to your CD drive in the left panel and click on the drive.
3. Now, in the right panel you should see all of the files in the root folder of the CD.
4. Double click on the **BROOM N.NN** executable file (**Error! Reference source not found.**).

Alternatively, you may use the Windows *Command Prompt* to run the installation program.

After you launch the BROOM installer, you may not see anything on the screen right away. Be patient. It takes a few seconds for the installer to load into memory. Disk activity will indicate that the installer is running

* On Windows Vista or Windows 7, you will be prompted by User Account Control to allow the program to make changes to your computer. Click **Yes** to proceed.

The installation proceeds mostly without input from you. You will see various progress bars and dialogs appearing. Do nothing with them. Your first input will be on the SQL Server installation screen.

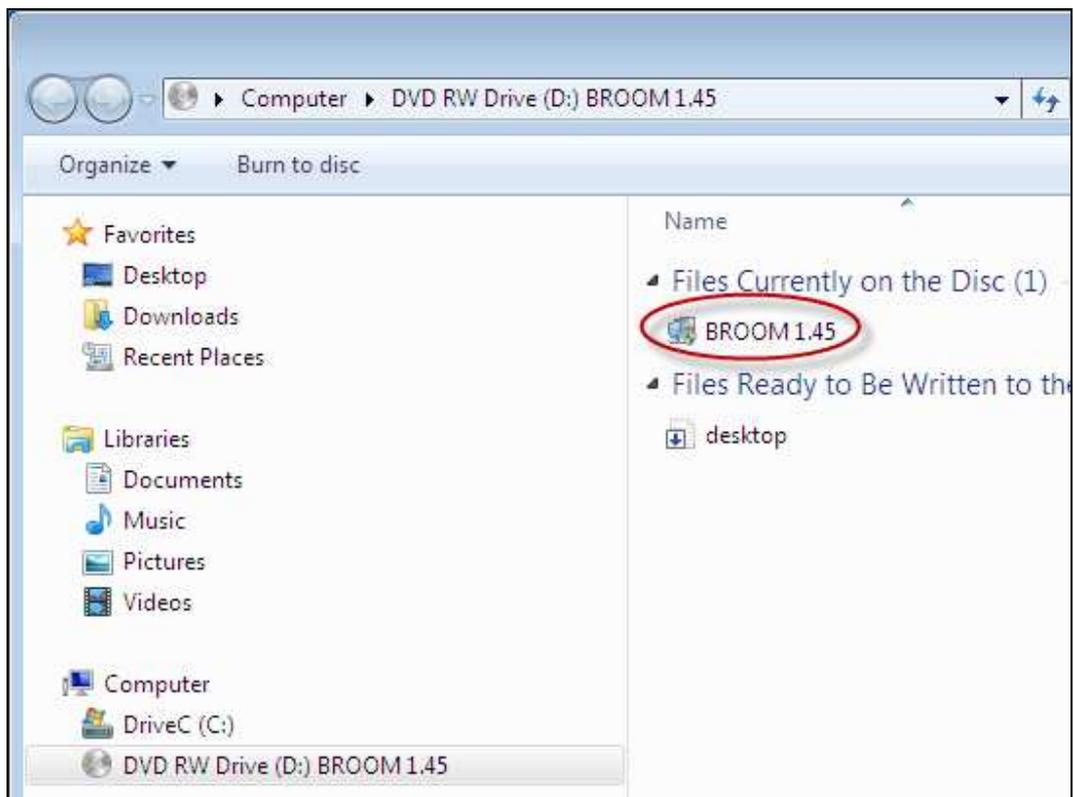


Figure 3-2. Starting the BROOM Installation.

3.2.3. Continuing with Installation

To continue with the installation of BROOM, enter a six-character password on the Microsoft SQL Server screen and then click the **Next** button. The required SQL components will then be configured and installed on your system.

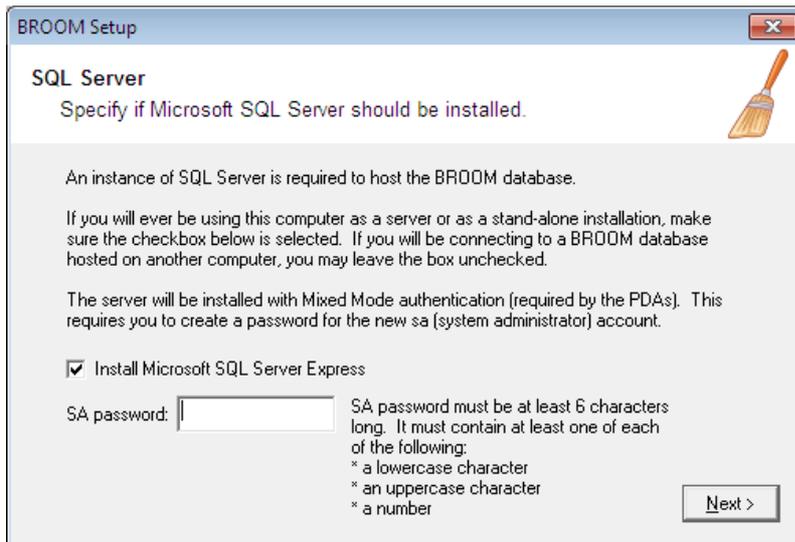


Figure 3-3. SQL Server Installation Screen.

After you have successfully installed SQL Server, you are prompted to install BROOM itself. Click the **Next** button on the Welcome screen.



Figure 3-4. BROOM Installation Wizard Welcome screen.

On the subsequent screens, enter the requested information and click the Next button to proceed.

Finally, click the **Finish** button when you see the screen “BROOM has been successfully installed”.

**** Then **REBOOT** after the installation exits. ****

Rebooting restarts the SQL Server so BROOM can connect to a database.

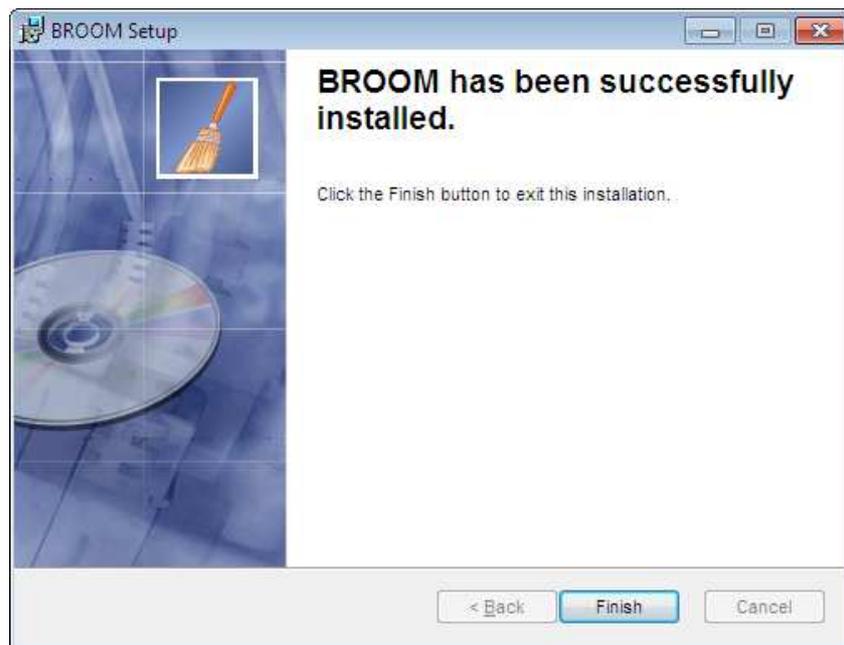


Figure 3-5. BROOM successfully installed.

3.2.4. Installing the PDA software

The BROOM PDA software is distributed as a .CAB file. The BROOM PDA software depends on the Microsoft .NET Compact Framework and SQL Server Compact (SQL CE) software. These packages must be installed on the PDA before the BROOM software is installed. These packages are also distributed as .CAB files. All these files are included in the BROOM distribution CD. The steps for installation are:

1. Connect the PDA to the computer via a USB cable.
2. If ActiveSync attempts to create a partnership, choose to create a **Guest** partnership.
3. From your computer's **Start** menu, select **Run->Browse**.
4. In the *Browse* dialog, navigate to the CD drive.
5. Open the **BROOM PDA** folder of the BROOM distribution CD in the *Browse* dialog.
6. Copy all the .CAB files from the CD to the PDA. On the Trimble Nomad, the Storage Card is a good location.
7. ON THE PDA, tap each of the following files, in this order, to install them:
 - a. NETCFv35.wm.armv4i.CAB
 - b. sqlce.dev.ENU.wce5.armv4i.CAB
 - c. sqlce.repl.wce5.armv4i.CAB
 - d. sqlce.wce5.armv4i.CAB
 - e. CAB Installer.CAB
8. Tap OK if a dialog pops up saying "The previous version of XXX will be removed before the new one is installed..."
9. Select "Device" if offered a choice of the location to install each package.

4. USING THE DESKTOP APPLICATION

This section of the manual leads you through starting the BROOM desktop application and shows how to use the major features of the system.

4.1. Starting BROOM

BROOM may be started by double-clicking on the desktop icon, if present (see Figure 4-1). Alternatively, you can start BROOM from the Windows *Start* menu: click **Start > All Programs > Sandia National Laboratories > BROOM**.



Figure 4-1. BROOM Application Icon.

4.2. The BROOM User Interface

The BROOM interface is divided into multiple areas and control groups. Figure 4-2 identifies each of these components described below:

- The *menu* and *main toolbar* provide access to most BROOM functions.

- The *project tree* provides hierarchical access to all levels of project data (project, buildings, floors, drawings, samples, analysis, etc.). Most items in the project tree will display their properties in the *property grid* when selected. Also, most items can be expanded to reveal their subitems by clicking the “+” to their left (or by double-clicking the item itself). A building node in the project tree can be expanded to reveal its floors, for example.

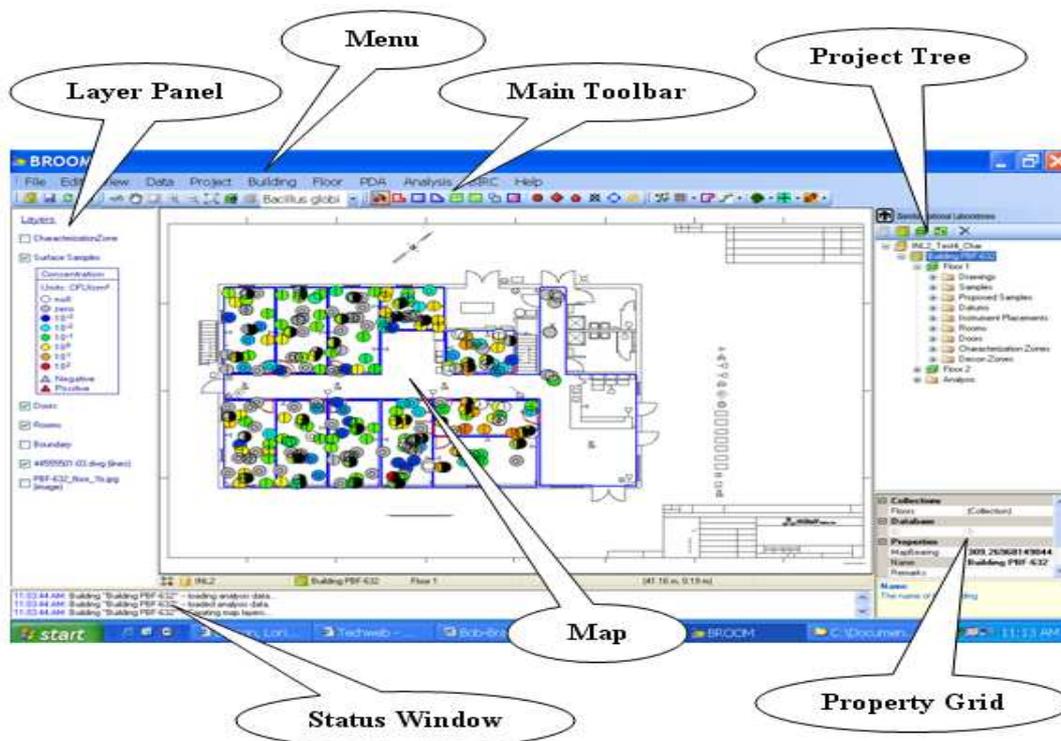


Figure 4-2. BROOM Interface Layout.

- The *property grid* displays the properties of the item currently selected in the *project tree*. The properties are unique and relevant to the type of item selected. Some properties are editable, while others are read-only.
- The *status window* displays messages pertaining to current activities—status reports on the various stages of loading a project, for example.
- The *map* is the primary component of the BROOM interface. This area provides the graphical representation of buildings (floor plans), samples, analysis maps, etc. The map is composed of various layers whose visibility can be controlled by the checkboxes in the *layer panel*. Some functions can be performed by right-clicking in the map area to open a context menu. The items on this menu depend on the current map mode (as determined by the mode selected on the *main toolbar*).
- The *layer panel* contains a list of checkboxes used to control the visibility of various map layers. Checking a box makes the layer visible; unchecking a box hides the layer. Some layers contain transparency while others are opaque. Because of this, there may be times when you would like to rearrange the order of the layers. This can be done by holding down the left mouse button and dragging the layer name to another position within the list.

4.3. Opening a Project

A “project” is the fundamental grouping of data in BROOM. A project contains one or more buildings and their associated data (maps, samples, etc.). The *Select Project* form is the first thing to appear when BROOM is started (Figure 4-3). This form allows you to create or open a project.

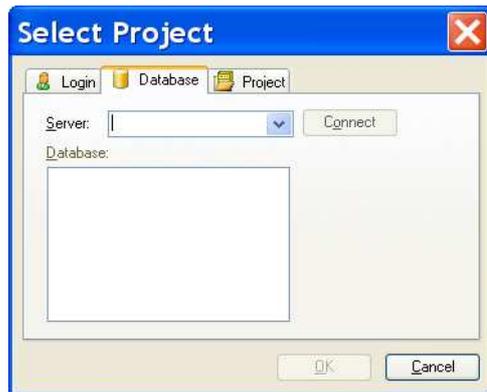


Figure 4-3. Select Project Form.

Projects are stored in a database. SQL Server is the Microsoft application that manages the database. SQL Server may be running on your local computer or another computer on the network. From here on, “SQL Server” may refer to a full-scale SQL Server installation or to the free Microsoft SQL Server Express that is distributed with BROOM.

There are four steps involved in opening a project from a SQL Server database:

1. Select the database login method (*Login* tab).
2. Specify the name of the server (*Database* tab).
3. Select the database on the server (*Database* tab).
4. Select the project from the database (*Project* tab).

The following sections describe these steps in greater detail.

4.3.1. Select Project – Login Tab

SQL Server requires the user to login to be able to access a database. The *Login* tab is used to specify the database login method (Figure 4-4). See Section **Error! Reference source not found.** for an explanation of the two login methods. You must have an account on SQL Server you are attempting to login to, and that account must have permission to access the relevant BROOM database. See Section 0 if you installed SQL Server on your local computer and are using it for the first time. Otherwise, consult your system administrator if you are attempting to login to a SQL Server elsewhere on your network.

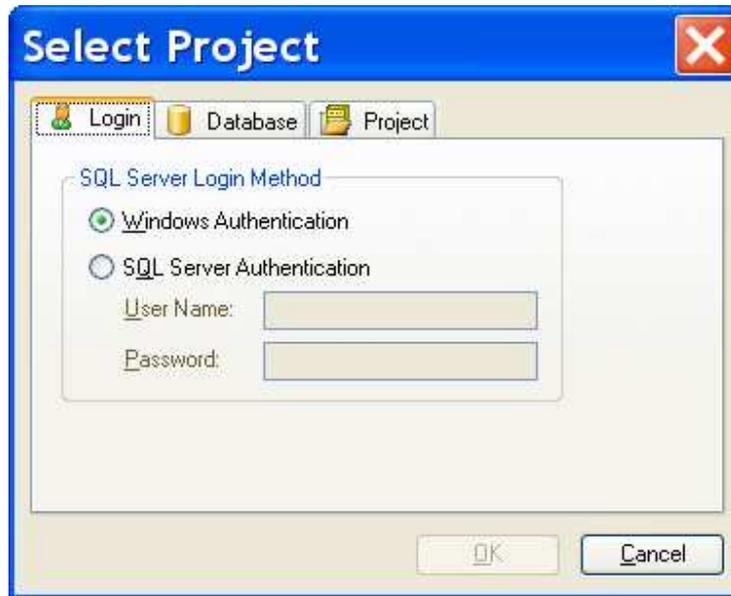


Figure 4-4. Login Tab on the *Select Project* Form.

Every time you return to this form, it will remember the previously used login method. If you are using the SQL Server Authentication method, it will remember the User Name but not the Password (for security reasons).

4.3.2. *Select Project – Database Tab*

The *Database* tab (Figure 4-5) allows you to specify the server and database to which you wish to connect. The server is the computer on which SQL Server is running. This may be your local computer or another computer on the network. To connect to SQL Server running on your own computer, type “(local)” (without the quotes) in the **Server** box and click **Connect**. To connect to SQL Server running on another computer, ask your system administrator for the server name and verify you have an account on it. If you have previously opened a project, the **Server** box will remember the last-used server. You can also click on the box’s drop-down arrow to select from a list of recently used servers.

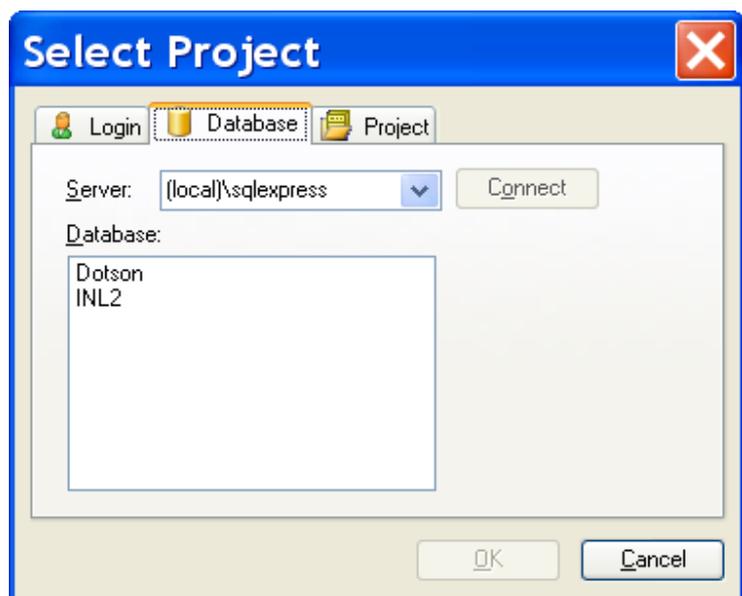


Figure 4-5. Database Tab on the *Select Project* Form.

There can be a 10 to 30-second delay if you attempt to connect to

an off-line or nonexistent server.

Once you have connected to the server, the *Database* list on the form will display the databases on the server. You will only see databases that you have access to (based on your login account). The list may be empty if no one has created a BROOM database yet. If you need to create a database, click **Cancel** on this form, follow the steps in Section 4.4, and then return to this form by selecting **File > Open Project** on the main menu.

If there are one or more databases listed, select a database (click on the name) then click on the **Project** tab.

There can be non-BROOM databases on the server. The form will alert you if you attempt to select a non-BROOM database.

4.3.3. Select Project – Project Tab

The *Project* tab allows you to select an existing project or create a new project. Select an existing project from the list or select **Create new project** and enter a project **Name**. At this point, the **OK** button will become enabled. Click **OK** to open or create the project.

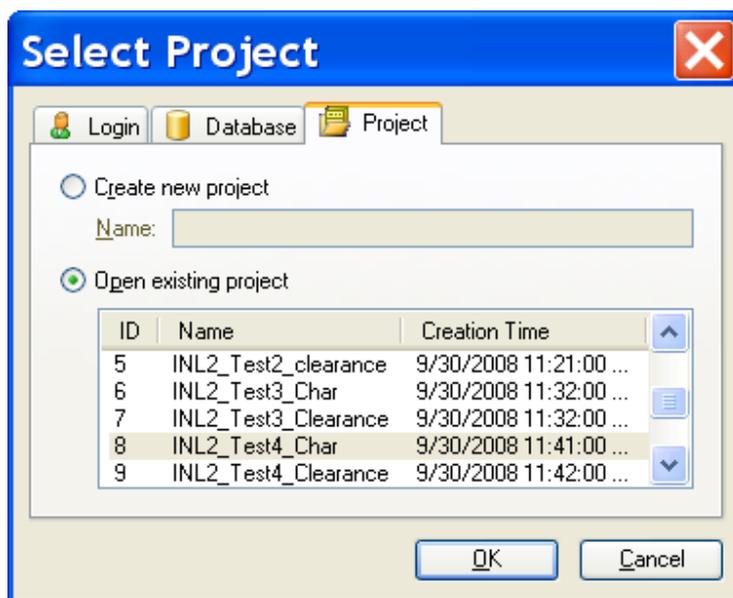


Figure 4-6. *Project* Tab on the *Select Project* Form.

4.4. Creating a Database

Before you can create a project, you must have a database in which to save it. Follow these steps to create a new database:

1. From the main menu, select **Data > Database > Create New Database**. This will open the *Create New Database* form shown in Figure 4-7.



Figure 4-7. Form for Creating a Database.

2. Enter a name for the new database in the **Database Name** textbox.
3. Unless otherwise instructed by your system administrator, leave **Use Default Characteristics** checked.
4. Enter the name of the **Server** where you would like to create the database. See Section 4.3.2 for help determining the server name.
5. Select the login method (**Windows Authentication** or **SQL Server Authentication**) for the SQL Server account that will be used to create the database. This account must have permission to create databases (must be a system administrator within the SQL Server or a member of the “dbcreate” group). See Section **Error! Reference source not found.** or consult your system administrator for help with this.
6. Click **OK** to create the database.

It may take a moment for the database to be created. If successful, you will see a *Database Created* message appear.

You can now create a new project in this database by selecting **File > New Project** from the main menu. See Section 4.2 for further help with creating or opening a project.

4.5. Project Properties

As mentioned in Section 4.2, selecting an item in the project tree loads the item's properties into the property grid. By selecting the project in the tree (topmost node), you can edit the project's name and temporary file directories (Figure 4-8). You can change the project name at any time. The *DrawingFileFolder* and *ShapeFileFolder* determine where BROOM will store temporary graphics files on your computer.

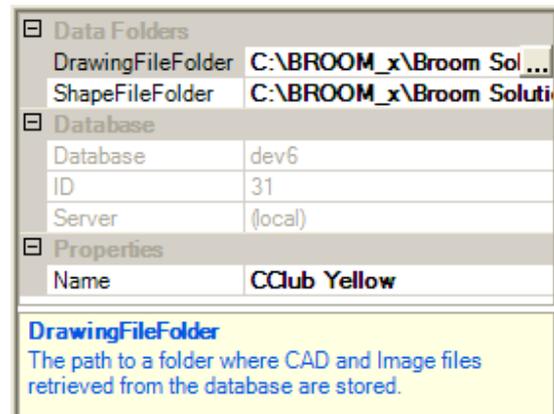


Figure 4-8. Project Property Grid.

4.6. Creating a Building

A new project is initially empty. The first thing to do is create a building. To add a new building to the project, click the **Add Building** button above the project tree (Figure 4-9). The new building name will default to "Building 1," however, you can rename this building by clicking on it in the tree and then editing the *Name* in the property grid near the bottom-right of the window. New buildings are empty; you must now define some floors for this building.



Figure 4-9. Add Building Button.



Figure 4-10. New Building in Project.

4.6.1. Adding Floors to a Building

A new building is initially empty. You must add one or more floors by clicking the **Add Floor** button (Figure 4-11). A new floor will appear under the building in the project tree (Figure 4-12). The first new floor will have a default name of "Floor 1." You can rename the floor by editing its *Name* in the property grid. Expand the floor node in the tree (click the "+" to its left) and notice all of the items that belong to a floor (drawings, samples, room, etc.).

To make a floor useful, the next step is to add a drawing for the floor.

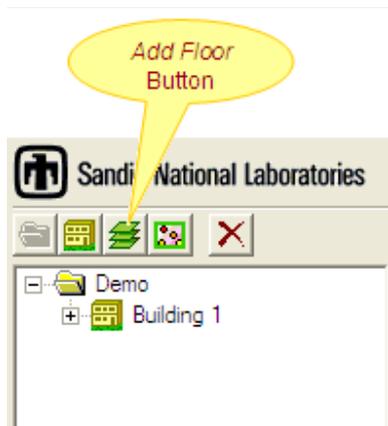


Figure 4-11. Add Floor Button.

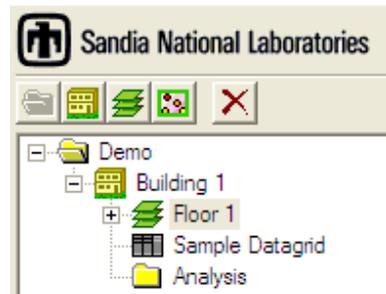


Figure 4-12. New Floor in a Building.

4.6.2. Adding a Drawing to a Floor

A new floor initially has no graphical representation of its layout. For a floor to be meaningful and useful, a drawing (i.e., a floor plan) must be assigned to the floor. This drawing will appear in the map area and provide the basis for locations of items such as samples. A drawing can be anything from a highly detailed architectural CAD file to a scanned-in pencil-and-paper sketch of the floor plan. A floor can have any number of drawings, which can be selectively shown or hidden via the checkboxes in the layer panel to the left of the map.

BROOM supports the following file formats:

- AutoCAD® drawings (.dwg, .dxf)
- MicroStation® CAD drawings (.dwg, .dgn)
- JPEG images (.jpg)
- GIF images (.gif)
- Bitmap images (.bmp)
- Shapefiles (.shp)

There are several ways to add a drawing to a floor:

- Right-click on the floor node in the project tree and select **Add Drawing**.
- Or, right-click on a floor's drawing folder in the project tree and select **Add**.
- Or, on the main menu, select **Floor > Add Drawing**.

Any of these methods will open a window that allows you to browse for and select a drawing file. For the case of a CAD drawing, the preference is a .dxf file. Once the file is selected the user is prompted to identify the base scale for the CAD drawing, whether it is in inches, feet, or meters, as shown in Figure 4-13. The dialog also allows the user to set an offset to the coordinate system and to rotate the image, if desired.

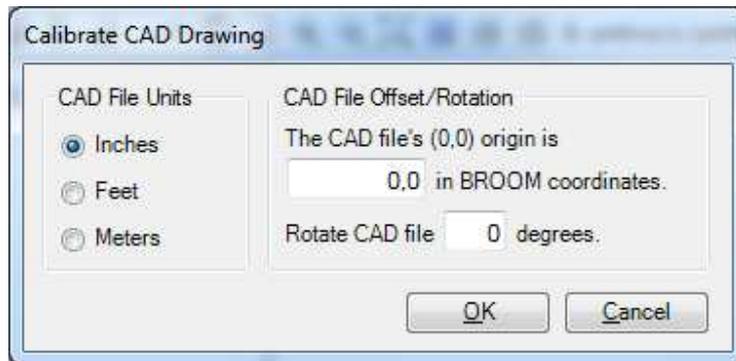


Figure 4-13. The CAD import dialog.

Once imported, the CAD drawing will look something like Figure 4-14.

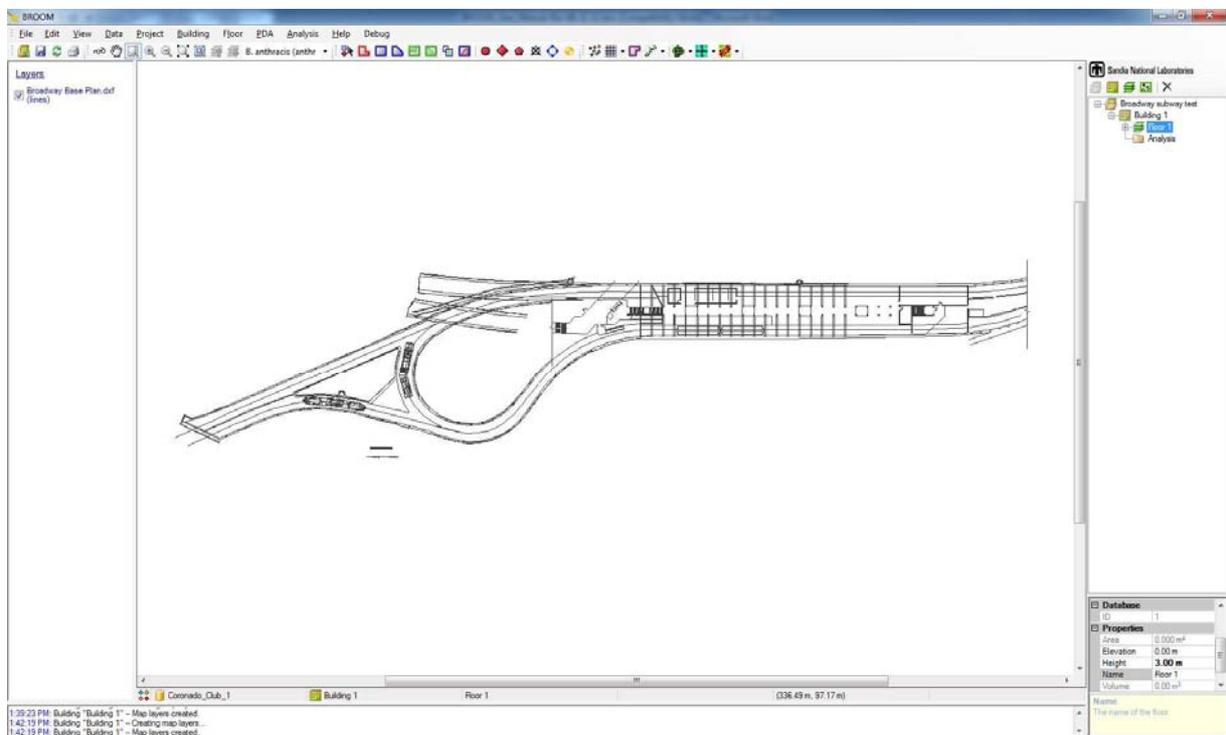


Figure 4-14. A CAD drawing in the BROOM system.

To bring in the bitmap imagery (e.g., jpg, bmp, etc.), the user needs to establish a point of reference to register the drawing to in order to establish the appropriate scale of the drawing. In the case of bringing a bitmap image of a CAD drawing it is relatively easy to make match points between the two drawings. If no CAD drawing exists, then a polygon of known dimensions should be input as a room and the bitmap image register to it. This polygon could be a rectangular room, for instance. Once the registration has taken place, the polygon could be erased.

The process of bringing in the bitmap image to register it begins with selecting the Add option under the Building > Floor > Drawings option in the right hand pane and selecting the appropriate drawing. A pop-up window will appear with the image of the main screen and the bitmap image that is to be imported. Figure 4-15 shows an example of this fitting registration where the user controls the pan and zoom features to accurately position two match points, a green and a red on both screens.

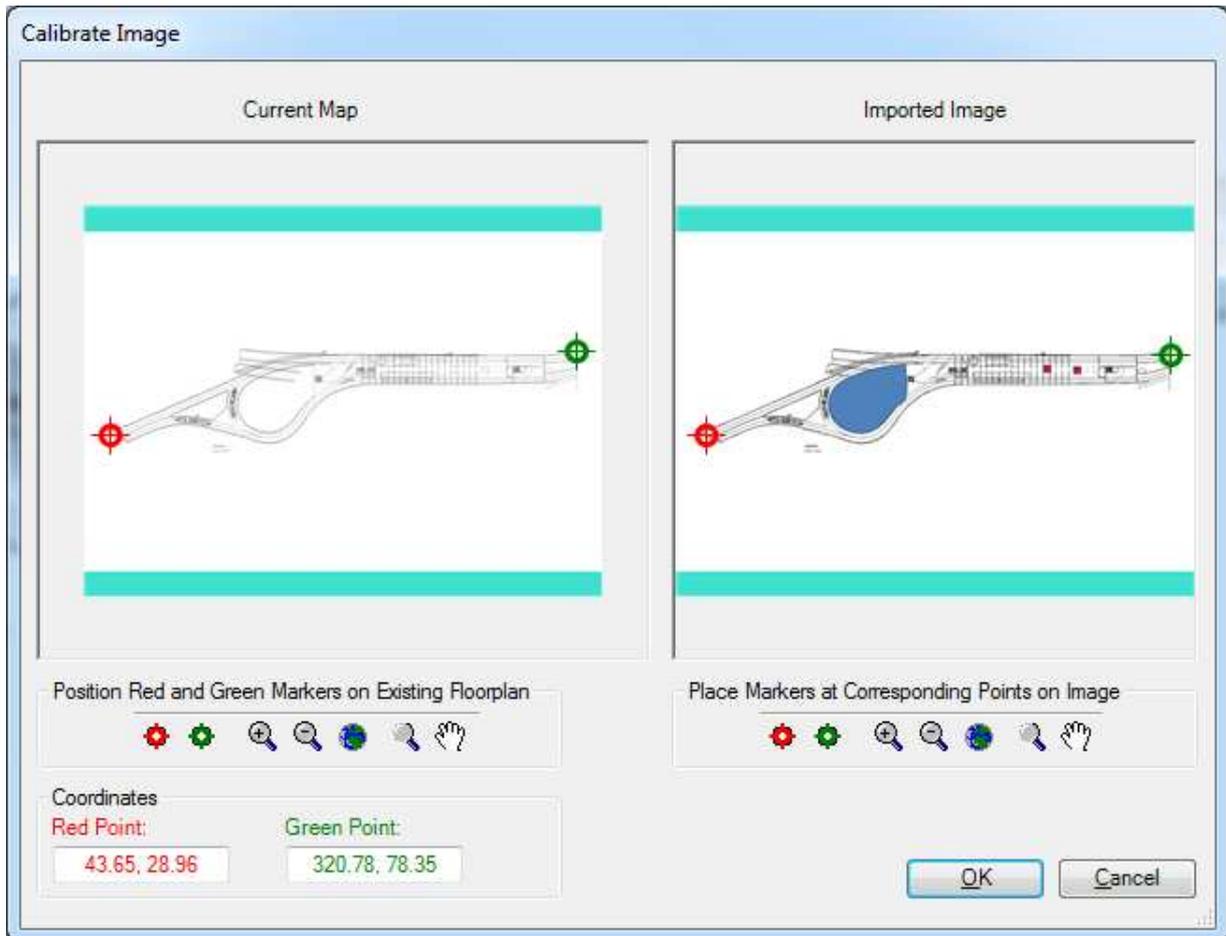


Figure 4-15. Registering a bitmap drawing to another map or image.

Once the registration process is completed, the user clicks OK and the image will be stored at the appropriate scale.

4.7. Adding Rooms to a Floor

Rooms are polygons on the map that represent the outlines of rooms. Rooms occupy their own map layer and are overlaid onto the floor's drawings (see Section 4.6.2). You can draw rooms using the CAD file or bitmap image as background for guidance. If you do not have CAD or bitmap files for a building, you can use the room drawing tools to generate rooms in the building.

4.7.1. Rectangular Rooms

To begin drawing rectangular rooms on the map, click the **add rectangular rooms** button on the main toolbar (Figure 4-16). This sets the current map interaction mode for drawing rooms. Now, whenever you click your mouse within the map area, BROOM will interpret your action as an intention to draw rooms on the map.



Figure 4-16.

Add Rectangular Rooms Button.

To draw a rectangular room, determine the location on the map where you want one corner of the room. Then, while holding the left mouse button down, drag the cursor to the location on the map where you want the opposite corner of the room to be. When you release the mouse button, BROOM will draw a blue rectangle room at the location you specified.

Sometimes it may be difficult to click exactly on the corner of the room (on the underlying map image) where you want the room to begin. If you have a CAD drawing visible, you can tell broom to use *corner snapping* to make room drawing more accurate. Corner snapping means that you can click your mouse close to a corner on the CAD drawing and BROOM will adjust the point you selected to be exactly the point in the corner of the CAD drawing. This makes the rooms as accurate as the CAD drawings and improves the speed and ease of creating rooms.

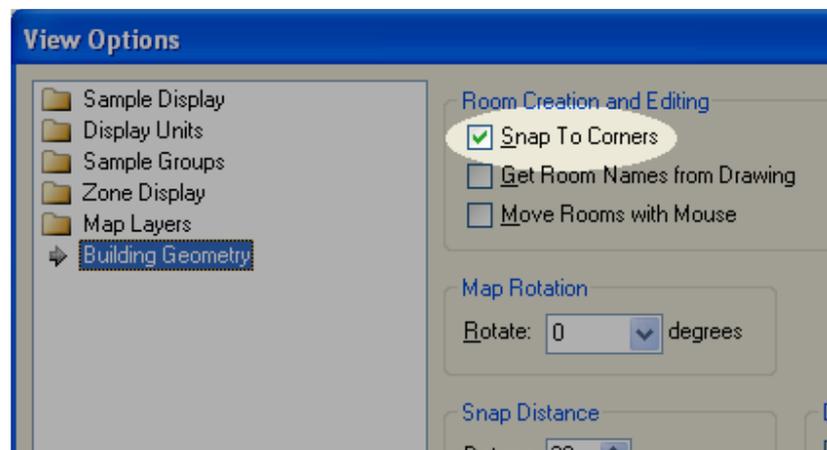


Figure 4-17.

Corner Snapping Option.

To enable corner snapping, select **View > View Options** on the main menu.

This brings up the window shown in Figure 4-17. Select the **Building Geometry** folder at the left. A check mark next to **Snap to Corners** indicates corner snapping is active. Clicking this checkbox with the left mouse button will toggle corner snapping on and off.

As you add rooms to the building map, notice that the individual rooms are also added to the project tree under the *Rooms* folder of the current floor.

4.7.2. Polygonal Rooms

Most rooms in can be drawn as simple rectangle. However, some rooms have walls at odd angles or are more complex than a simple rectangle.

The *polygonal room mode* is used to draw irregularly shaped rooms. To draw polygonal rooms, left-click the **add polygonal rooms** button on the main toolbar (Figure 4-18).



Figure 4-18. Add Polygonal Rooms Button.

Now you are in polygonal room drawing mode. You can create rooms by simply clicking the corners of a room in sequence (Figure 4-19). To complete a room, double-click the mouse and BROOM will connect all the corners you have marked and construct a room polygon. All room outlines are colored blue by BROOM and posted onto the project tree regardless of whether they were drawn as rectangular rooms or polygonal rooms (Figure 4-20).

Note that corner snapping works for polygonal rooms just as it does for rectangular rooms.

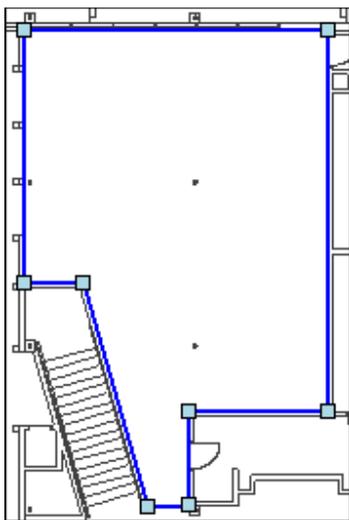


Figure 4-19. Adding Room Corners in Polygon Mode.

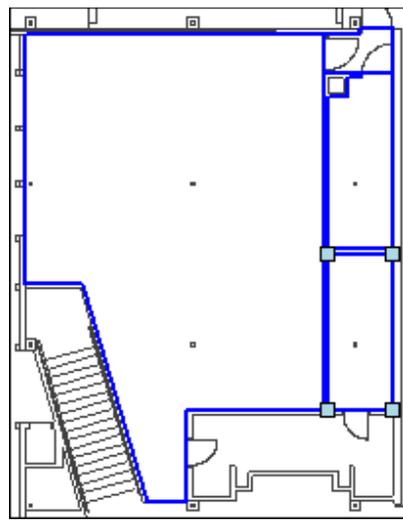


Figure 4-20. Completed Rooms in Blue.

4.7.3. Editing Rooms

You may wish to edit the dimensions of a room after it has been created. There are several different ways to do this.

Sometimes corner snapping can be a disadvantage. Occasionally the room corner will snap to the wrong corner on the CAD floor plan (Figure 4-22). Often these corner-snapping problems can be minimized by being zoomed-in more closely when drawing rooms. However, if a room is drawn incorrectly, you must either delete it and redraw the room or edit the room that you have drawn. To delete a room, select it in the project tree and click the **Delete** button on the toolbar above the tree (Figure 4-21). The next section of the manual explains how to edit rooms by moving and adding room corners.



Figure 4-21. Delete Button.

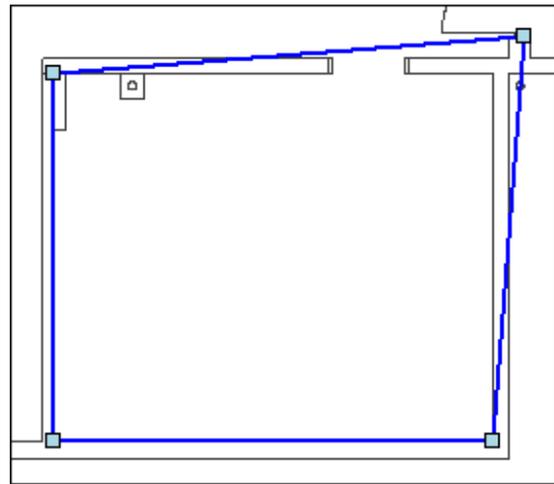


Figure 4-22. Room Snapped to the Wrong Corner

4.7.3.1. Moving Room Corners

If the corner of a room is in the wrong place, it can easily be moved to the correct location. First, pick the **Select Object** button on the main toolbar (Figure 4-23). By selecting *Select Object* mode, you are deselecting *Add Room* mode. This allows you to click on the misplaced corner and move it to the correct location.

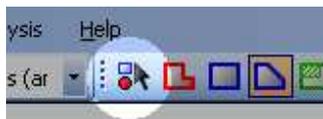


Figure 4-23. Select Object Button.

Figure 4-24 shows a room with an incorrectly placed corner. To fix this, simply place the mouse cursor directly over the point. Click on the point and move the mouse cursor to the correct location. Then release the mouse button, and the room corner will move to the new position you indicated with the mouse (Figure 4-25).

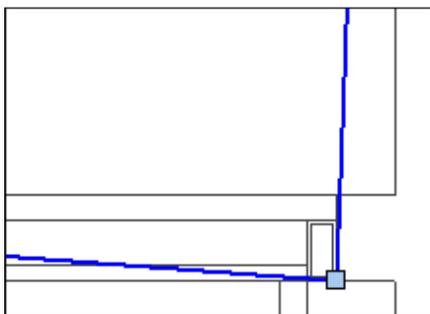


Figure 4-24. Incorrectly-placed Room Corner.

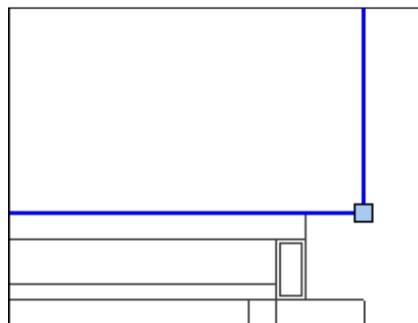


Figure 4-25. Corrected Room Corner.

4.7.3.2. Adding Room Corners

You may find that you missed a corner while drawing a room. In this case, you will need to add a new corner vertex to the room and then drag the new corner vertex to its correct position. The following steps can be used to add a new room corner:

1. Left-click the **Select Object** button on the main toolbar (Figure 4-23).
2. Left-click inside the room on the map to select it. The selected room will be highlighted with light-blue boxes on the corners (Figure 4-26).
3. Left-click directly on a room wall (on the blue line) somewhere near the midpoint of the line to generate a new corner vertex (Figure 4-27).
4. Press and hold the left mouse button on the new corner vertex and drag it to its correct position, then release your mouse button (Figure 4-28).

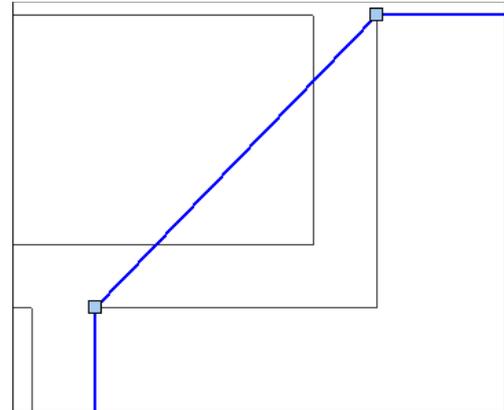


Figure 4-26. Room with Missing Corner.

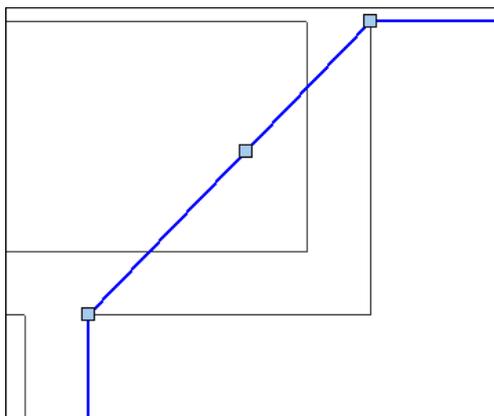


Figure 4-27. New Corner Added to Room Outline.

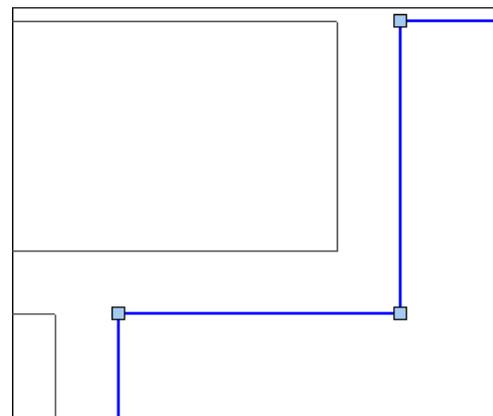


Figure 4-28. New Corner Dragged to Correct Location.

4.7.3.3. Removing a Room Corner

In this exercise, we will remove the vertex in the middle of the straight wall along the left side of Figure 4-29.

Your first task will be to determine the coordinates of the vertex you want to remove. The current location of the mouse cursor within the building is displayed on the status bar below the map (Figure 4-30). Move the mouse cursor over the vertex to be removed and make note of its coordinates.

If it is not already expanded, expand the **Collections** property group of the room by clicking the plus sign (“+”) to its left in the property grid (Figure 4-31). Then click the ellipsis (“...”) button to the right of the **Polygon** property.

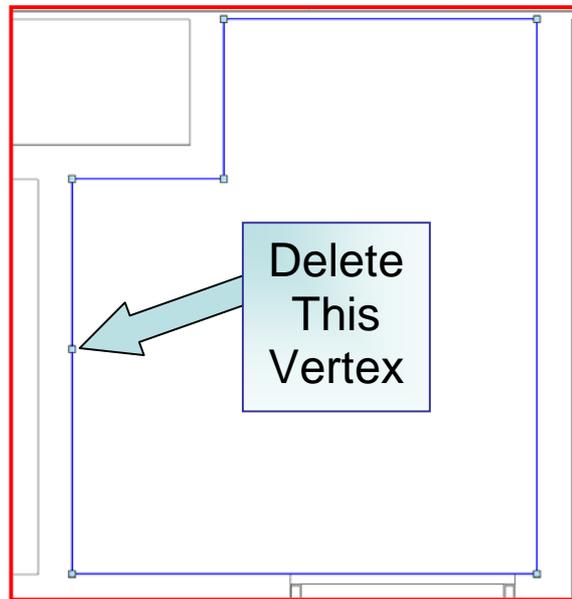


Figure 4-29. Room Vertex to be Deleted.

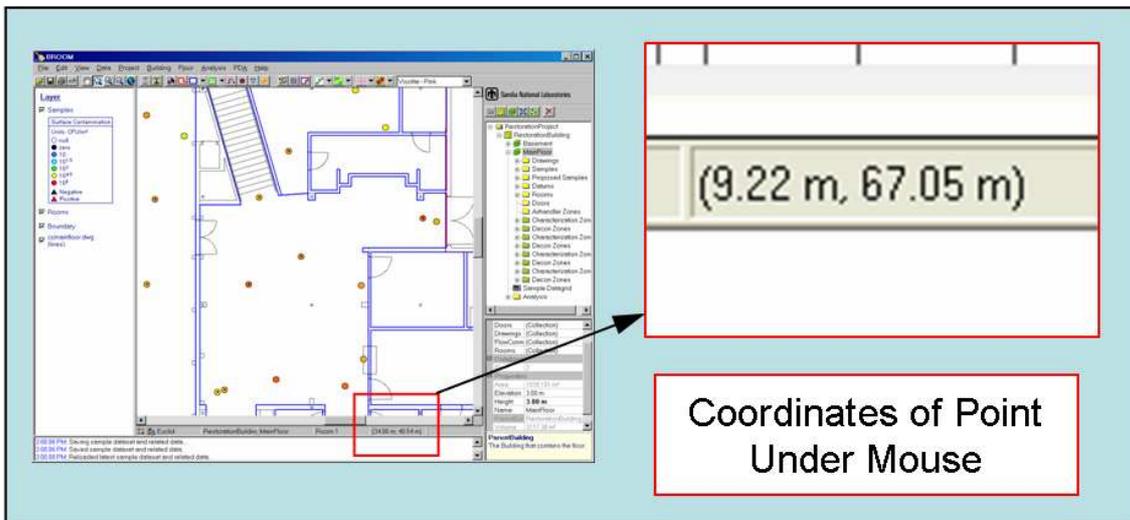


Figure 4-30. Mouse Coordinates on Status Bar.

The *Point Collection Editor* should now be visible. Select the point you want to remove from the list of coordinates on the left hand side of the form (Figure 4-32). Next, click the **Remove** button. Click **OK** to save the change and close the form.

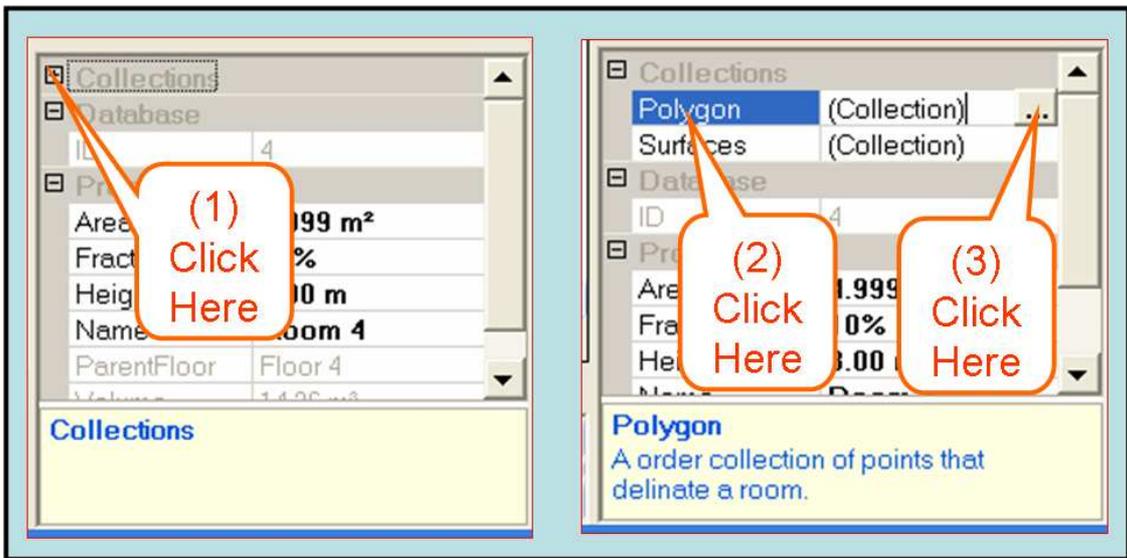


Figure 4-31. Mouse Click Sequence to Access Point Collection Editor.

Once the *Point Collection Editor* form disappears, the currently selected room will redraw itself without the extra vertex (Figure 4-33).

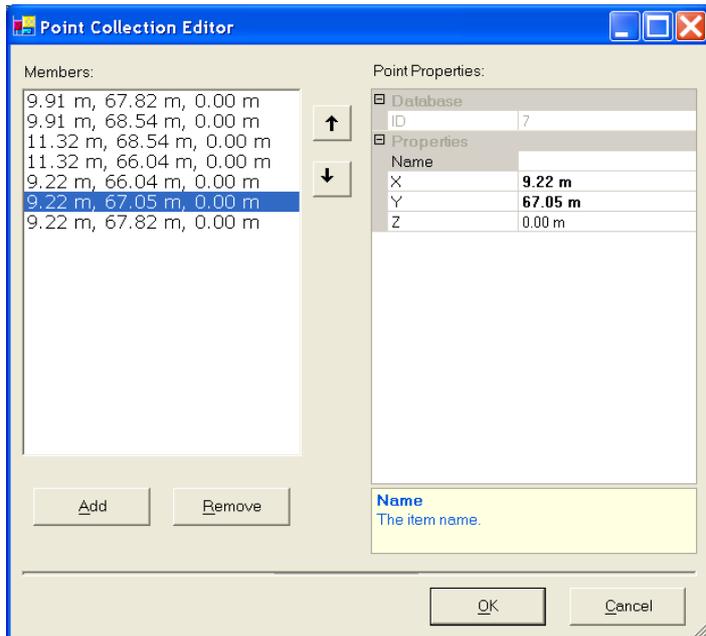


Figure 4-32. Point Collection Editor.

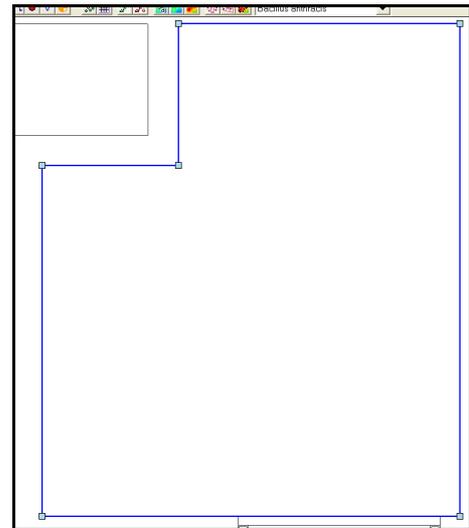


Figure 4-33. Room with Point Removed.

Using these three editing operations of adding vertices, dragging vertices to new positions and removing extra vertices you can create room outlines of practically any shape you need to model rooms in facilities. Editing rooms is a fast operation. However, you may not want to take the time to make every room's geometry perfect, particularly in large facilities with complex, curved walls. Sometimes, quickly drawn, simple outlines work just as well.

4.7.3.4. Troubleshooting Room Edits

Fixing room corners can be difficult when corners of rooms overlap other rooms. When you try to drag a corner that is in another room, BROOM stops the dragging and makes the second room

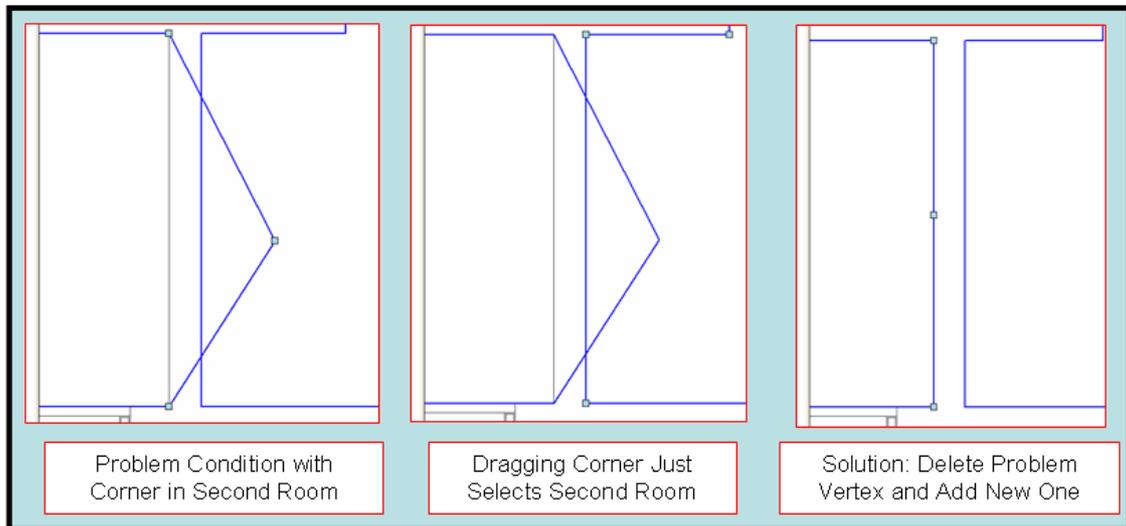


Figure 4-34. Difficulty Editing Overlapping Room Polygons.

the currently selected room (Figure 4-34). To get around this problem, just use the *Point Collection Editor* to remove the problem corner, and then generate a new vertex by clicking on the room outline and dragging the new corner into its proper position.

4.8. Working with Samples

Samples exist as database records in BROOM. BROOM shows samples as circular and triangular symbols on the building map. Sample properties can be viewed and edited via the project tree/property grid and the sample datagrid. In a real-world deployment, samples will primarily be created on and uploaded from PDAs. However, you can manually create samples using the desktop application to explore how you interact with them in BROOM.

4.8.1. Creating Samples

To create a sample, click the **Add Surface Samples** button on the main toolbar (Figure 4-35). When this mode is active, any left-click you make on the map window will create a sample at that position.

As you click on the map, BROOM places samples at those locations (Figure 4-36). These sample locations represent samples that have been taken but not been analyzed by a laboratory.



Figure 4-35. Add Surface Samples Button.

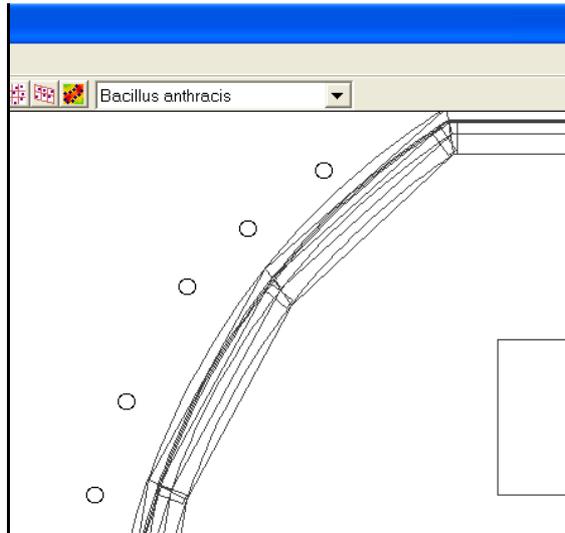


Figure 4-36. Samples Placed on Map.

Looking over to the left side of the BROOM desktop application interface, notice that a colorful legend has been added to the map layer checkbox window (Figure 4-38). This legend shows the colors that will be associated with sample symbols that have various values. Notice that the new samples you have placed on the map have a value of “null”.

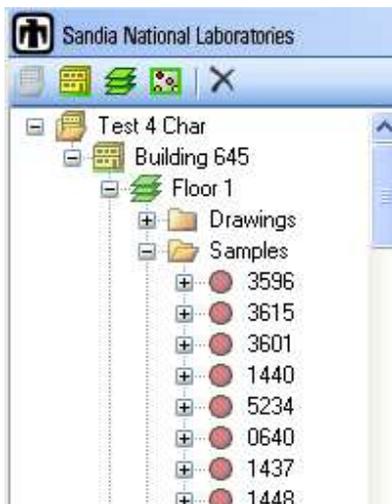


Figure 4-37. Samples on Project Tree.

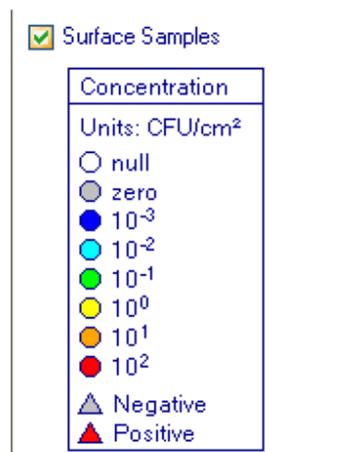


Figure 4-38. Sample Legend.

Now look over to the right side of your BROOM screen. Notice that a series of red dots has shown up on the project tree (Figure 4-37). One sample node is placed on the project tree for every sample that you added to the map. All of the samples on a floor show up in its *Samples* folder. The numbers beside the red dots are the database identifiers for the samples. These identifiers will be replaced by the sample barcodes when they are assigned—samples coming from the PDA will already have a barcode (which will be displayed in the tree).

4.8.2. Editing Sample Properties

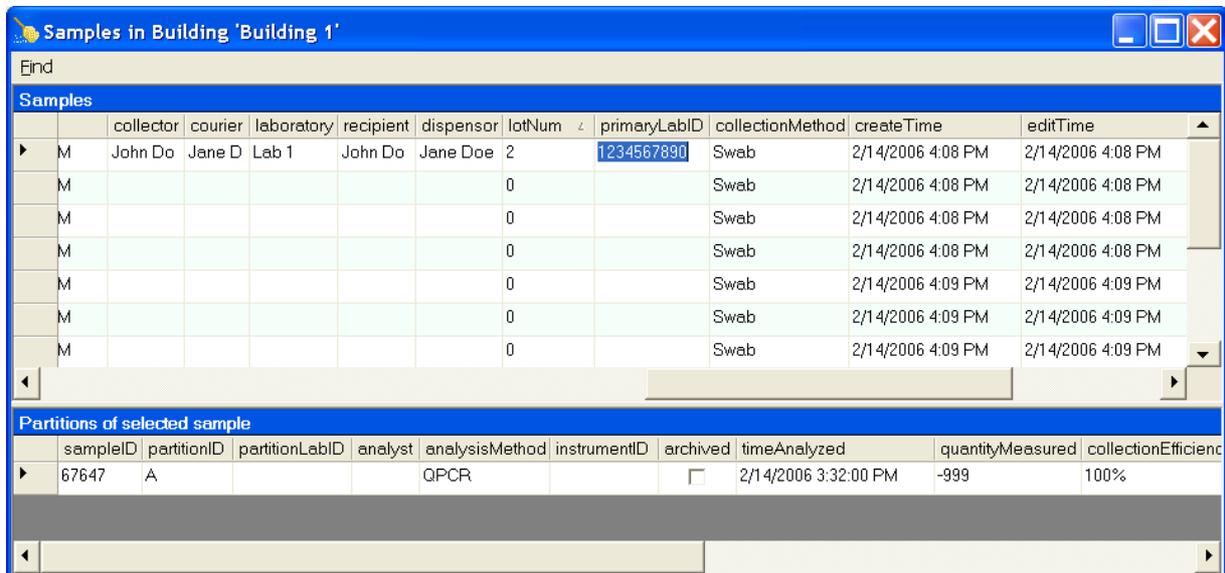
Select a sample on the project tree. Now look below the tree to the property grid; the property grid is now displaying data for the selected sample. Some of the data fields are already filled in with default information. Grayed-out fields cannot be edited.

Sample properties are edited in the same manner as project, building, floor and room properties. Simply place your mouse cursor in the data field space you want to change, click it and then start typing in the new information.

To edit the properties for another sample, click on that sample's node on the project tree (Figure 4-). Alternatively, you may select samples directly from the map window by first pressing the **Select Object** toolbar button (Figure 4-23), then clicking the sample symbol on the map with your mouse.

The sample datagrid provides a spreadsheet-like view of all the samples in your building, allowing large numbers of samples to be quickly examined or edited. The sample datagrid is opened by selecting **Building > Sample Datagrid** on the main menu.

The sample datagrid allows you to view the properties for many samples at one time (Figure 4-39). To edit a value, click on the proper cell and type in the new value. Some property fields have a fixed number of choices of possible values. When you click on these fields in the sample datagrid, a dropdown list of available choices appears (Figure 4-40). At this point, you simply select the one you want and the property value for that cell is changed.



The screenshot shows a software window titled "Samples in Building 'Building 1'". It contains two data grids. The top grid, titled "Samples", lists various sample properties. The bottom grid, titled "Partitions of selected sample", provides a detailed view of the selected sample's partitions.

	collector	courier	laboratory	recipient	dispensor	lotNum	primaryLabID	collectionMethod	createTime	editTime	
▶	M	John Do	Jane D	Lab 1	John Do	Jane Doe	2	1234567890	Swab	2/14/2006 4:08 PM	2/14/2006 4:08 PM
	M					0		Swab	2/14/2006 4:08 PM	2/14/2006 4:08 PM	
	M					0		Swab	2/14/2006 4:08 PM	2/14/2006 4:08 PM	
	M					0		Swab	2/14/2006 4:08 PM	2/14/2006 4:08 PM	
	M					0		Swab	2/14/2006 4:09 PM	2/14/2006 4:09 PM	
	M					0		Swab	2/14/2006 4:09 PM	2/14/2006 4:09 PM	
	M					0		Swab	2/14/2006 4:09 PM	2/14/2006 4:09 PM	

	sampleID	partitionID	partitionLabID	analyst	analysisMethod	instrumentID	archived	timeAnalyzed	quantityMeasured	collectionEfficiency
▶	67647	A			QPCR		<input type="checkbox"/>	2/14/2006 3:32:00 PM	-999	100%

Figure 4-39. Sample Datagrid.

Samples in Building 'Building 1'

End

Samples

id	floorName	roomID	x	y	z	datumID	locationBarcode	locationType	surfaceName	surfaceType	surfaceOrientation
	Floor 4	-1	7.71 m	36.04 m	0.00 m			Wall	Floor	Smooth	Horizontal_Upward
	Floor 4	-1	7.76 m	35.40 m	0.00 m			Floor	Floor	Smooth	Horizontal_Upward
	Floor 4	-1	7.68 m	34.71 m	0.00 m			Wall	Floor	Smooth	Horizontal_Upward
	Floor 4	-1	8.44 m	34.69 m	0.00 m			Supply_Vent	Floor	Smooth	Horizontal_Upward
	Floor 4	-1	8.44 m	34.69 m	0.00 m			Return_Vent	Floor	Smooth	Horizontal_Upward
	Floor 4	-1	9.32 m	35.53 m	0.00 m			Desk	Floor	Smooth	Horizontal_Upward
	Floor 4	-1	10.24 m	35.97 m	0.00 m			Chair	Floor	Smooth	Horizontal_Upward
	Floor 4	-1	10.24 m	35.97 m	0.00 m			Computer	Floor	Smooth	Horizontal_Upward
	Floor 4	-1	9.95 m	34.83 m	0.00 m			Countertop	Floor	Smooth	Horizontal_Upward
	Floor 4	-1	9.95 m	34.83 m	0.00 m			Floor	Floor	Smooth	Horizontal_Upward

Partitions of selected sample

sampleID	partitionID	partitionLabID	analyst	analysisMethod	instrumentID	archived	timeAnalyzed	quantityMeasured	collectionEfficiency
67653	A			QPCR		<input type="checkbox"/>	2/14/2006 3:32:00 PM	-999	100%

Figure 4-40. Dropdown List in a Datagrid Cell.

4.8.3. Exporting and Importing Sample Data

The second method for editing sample data uses Microsoft Excel to manipulate the data for the samples. To use this method, select **Data > Export XML > Sample Lab Data** from the main BROOM menu. This opens up the *Export Sample Lab Data* form which allows you to enter (or browse for) the export file name (Figure 4-41). The sample lab data will be written to this file.

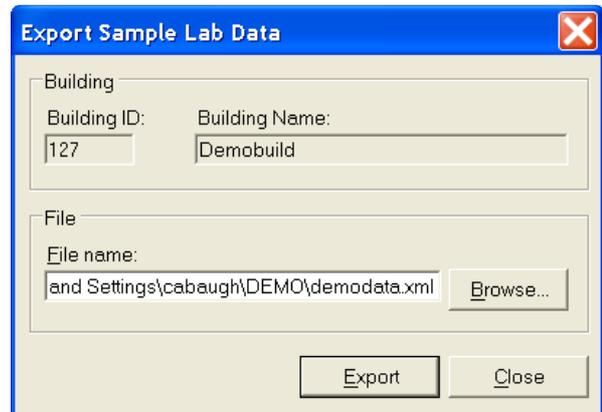


Figure 4-41. Sample Lab Data Export.

Type **Demodata** (or another file name of your choosing) in the **File name** textbox and click the **Export** button. This will create the file containing the BROOM data; this data can now be edited in Excel.

The Next step for you to start Excel open a worksheet with the **File > Open** menu sequence. This will bring up an *Open* form where you can browse for the exported sample data file. Select **demodata.xml** and click the **Open** button.

Next, the *Open XML* window pops up asking you how you want the file opened. Select **Use the XML Source task pane** and click **OK** (Figure 4-42).

In the *XML Source* panel at the right side of the Excel spreadsheet, click on the **Partitions** folder. This highlights every node in that folder (Figure 4-43).

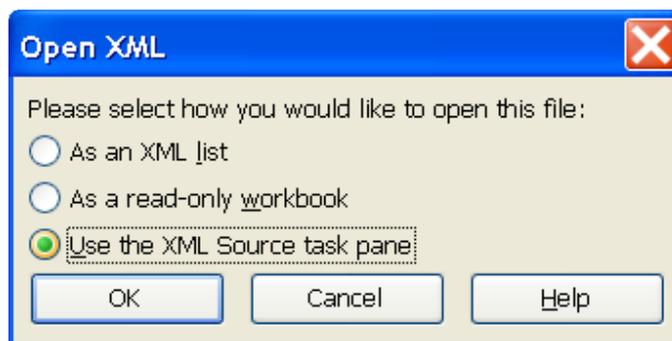


Figure 4-42. Importing XML into Excel.

Drag the **Partitions** folder from the *XML Source* panel to cell **A1** in the spreadsheet (Figure 4-44). This defines the column headings for the data that are to be edited (Figure 4-45).

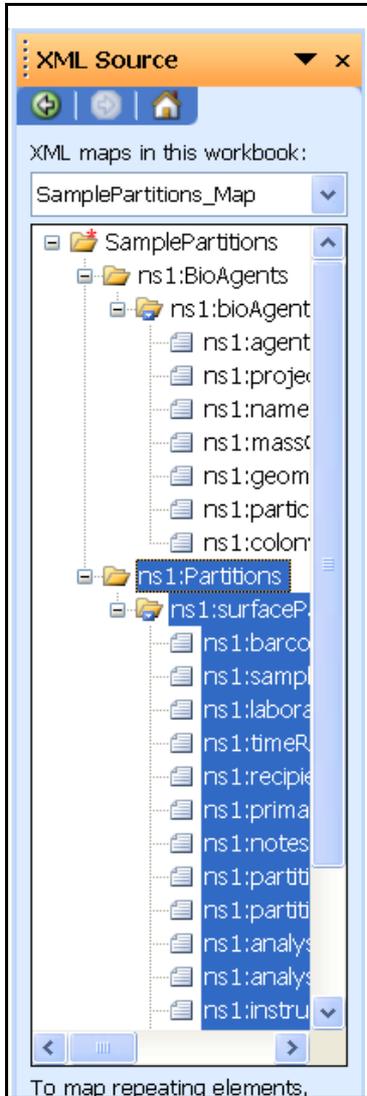


Figure 4-43. XML Source Panel.

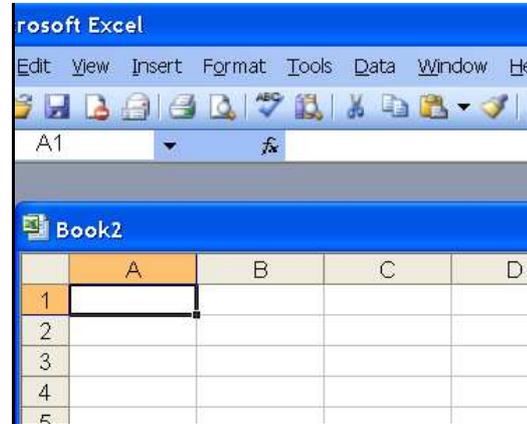


Figure 4-44. Drag the Samples to Cell 1A.

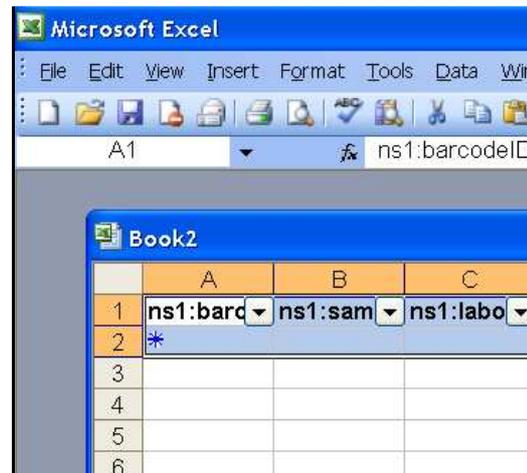


Figure 4-45. Column Headings after Completing Drag Operation.

To load the sample lab data from the file into the spreadsheet, select **Data > XML > Refresh XML Data** from the main menu in Excel. This will populate the spreadsheet with the sample data just like the datagrid in BROOM (Figure 4-46).

	B	C	D	E
1	ns1:sampleID	ns1:laboratory	ns1:timeReceived	ns1:recipient
2	68222		2006-02-20T16:17:00.0000000-07:00	
3	68223		2006-02-20T16:17:00.0000000-07:00	
4	68224		2006-02-20T16:17:00.0000000-07:00	

Figure 4-46. Refreshed XML Data Ready to be Edited.

You may now edit the data in the spreadsheet cells. All standard Excel features such as cell formulas, copy/paste, etc. are available for you to use.

When you are done editing the data, open the **Data > XML** menu and select **Export**. This opens the *Export XML* form. Save the file as an XML file with a different name and then click **Export** (Figure 4-47). This writes the edited data to an XML file which you will import back into BROOM.

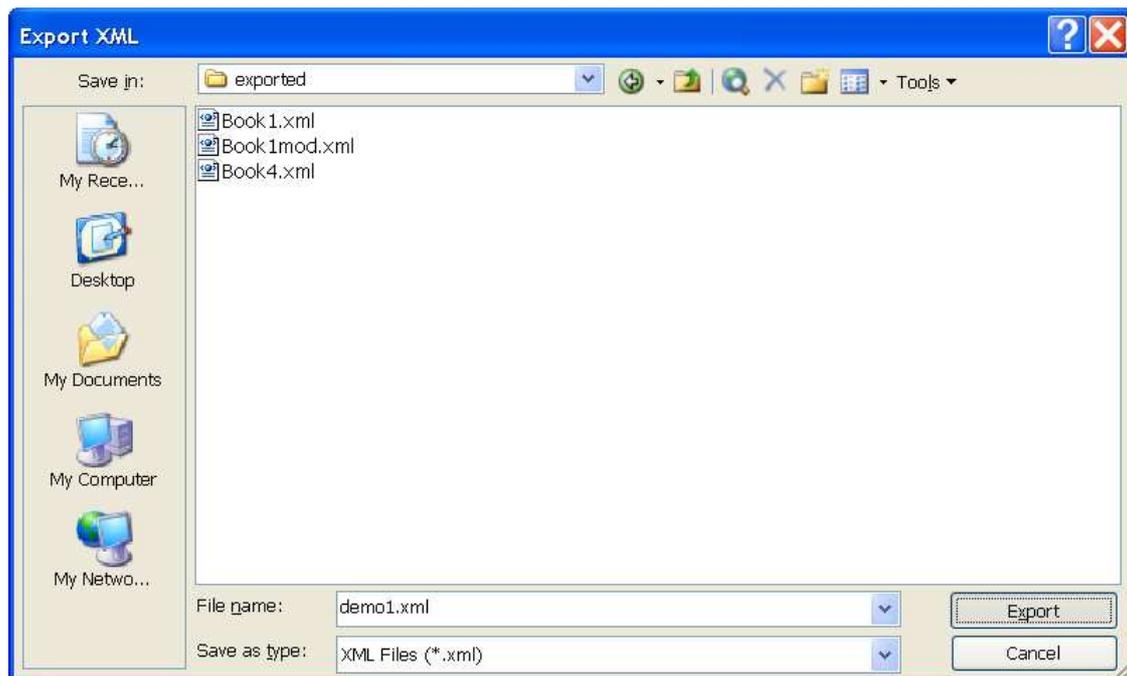


Figure 4-47. Saving the Edited Data as an XML File.

In BROOM, select **Data > Import > XML Sample Lab Data** from the main menu. This opens the *Select XML File for Import* form. Find and select the XML file you exported from Excel and click **Open** (Figure 4-48).

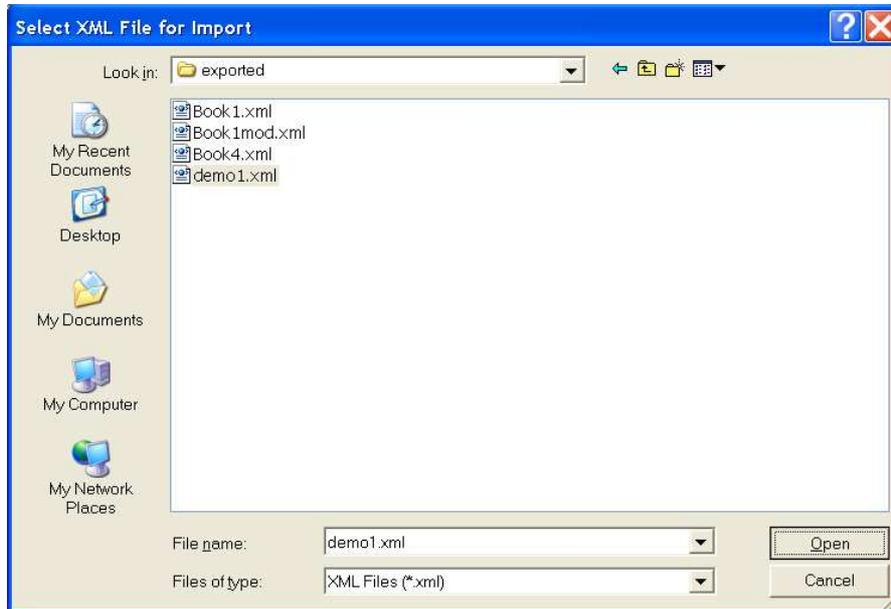


Figure 4-48. Selecting the XML file for Import.

BROOM will now import the data and display a status message when complete.

By selecting different samples in the project tree you can see the data imported from Excel in the property grid (Figure 4-49). The values in the property grid should agree with the values, which you entered in Excel. You can also use the sample datagrid to check the imported values.

Chain of Custody	
BarcodeID	123
Courier	DHL
Dispensor	Jane Doe
Laboratory	Quantico
LotNumber	0
Recipient	John Doe
TimeReceived	2/20/2006 4:17 PM
TimeShipped	2/20/2006 4:17 PM

Figure 4-49. Sample Shown in the Property Grid.

Another method exists to import sample data that is easier than the XML file import. It is a two-step process. First, the sample locations are input, then the laboratory results. To import sample locations the user needs to set up a .csv file. This file can be created in Excel. There should be no header row in the file. The file should contain columns with the following data: Sample ID number, media type (e.g., swab, wipe, etc.), x coordinate, y coordinate, z coordinate. The file should be saved as a .csv file. Next, the user selects Data > Import > Samples (CSV). Then a

pop-up window appears and the user selects the appropriate .csv file to import. Proposed sampling locations can be imported in much the same manner.

To import laboratory results, the user creates an actual Excel file. There can be any number of fields in the Excel file, but the fields of data that may be imported are: Barcode ID, Partition ID, Partition lab ID, Analyst, Analysis method, Date/time analyzed, Quantity measured, Units, Agent/analyte, Notes. Partitions refer to different laboratory analyses (e.g., Sarin, Sulfur Mustard). The Excel file must have a header row to identify the contents of each column of data. The most important parameters that need to be imported are the Barcode ID and the Quantity measured in order to display results in the BROOM interface. The Excel file must be a consistent format with a .xls file extension, not the new .xlsx extension. To import the sample results, select Data > Import Excel Lab Results. A pop-up much like Figure 4-50 will appear. The user selects the file with the Browse button. The Excel worksheet name refers to that worksheet in the Excel file with the laboratory results. The user can type in a laboratory name, or if already in the database, select from the drop-down options.

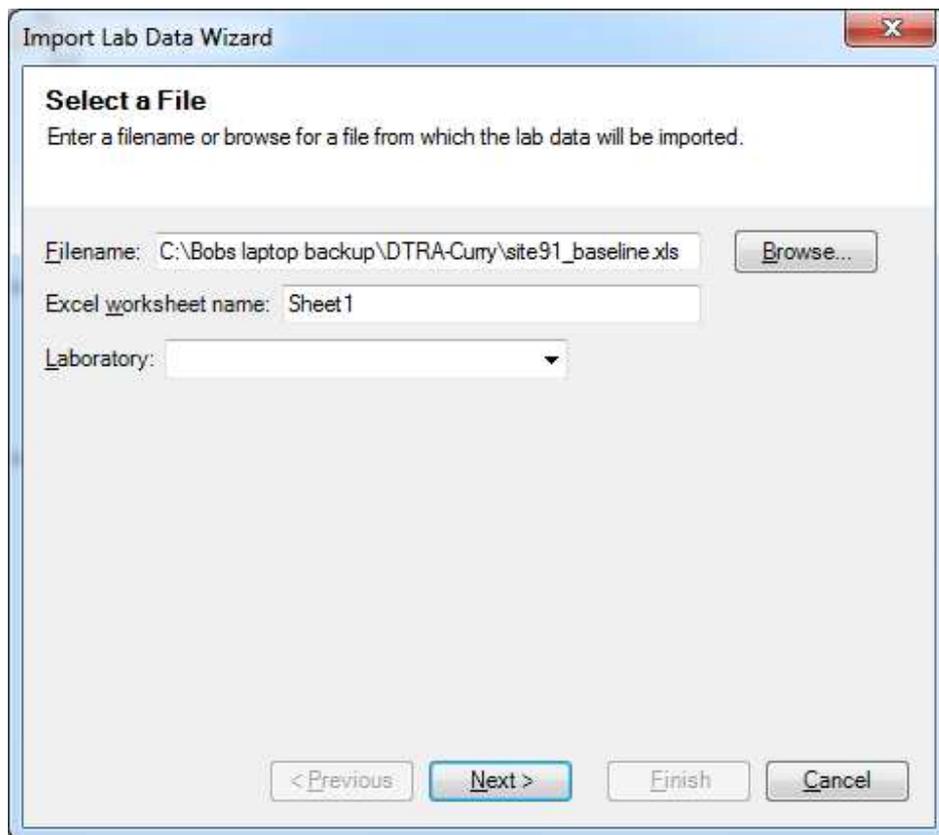


Figure 4-50. Selecting the Excel file for Import.

Once the Select a File option is complete, the user selects Next. Then a pop-up like Figure 4-51 appears. The user selects which row contains the header row identifying the contents of each column of data. When complete, select Next.

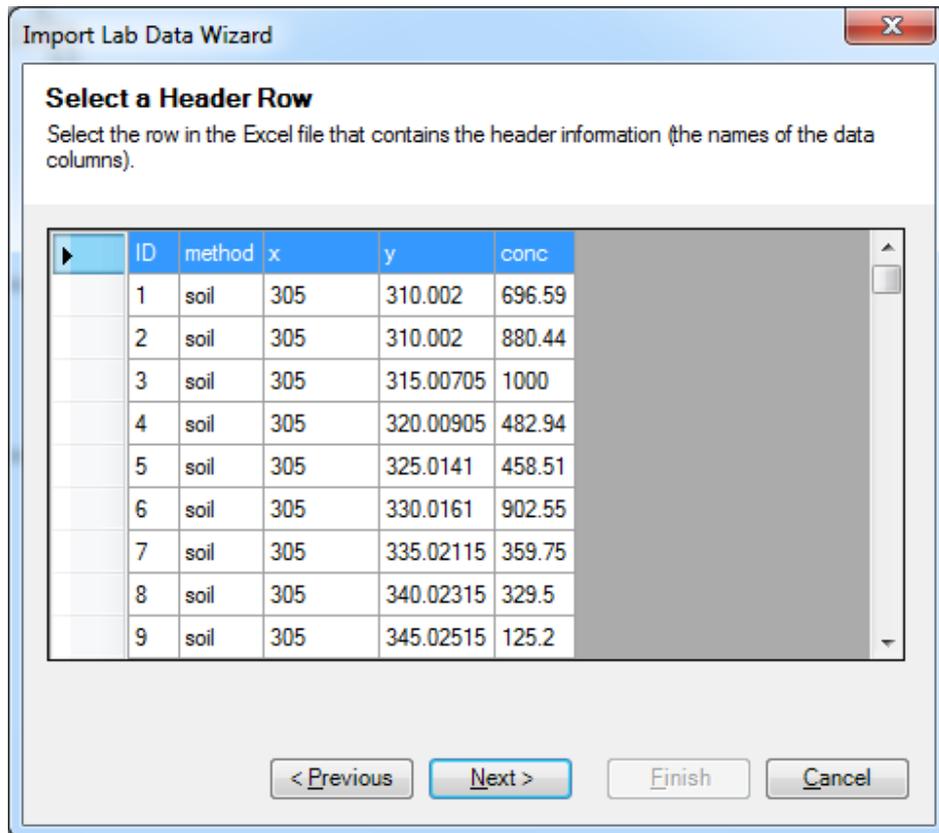


Figure 4-51. Selecting the Header Row for Import.

The next pop-up window should look much like Figure 4-52. In this window the user selects which columns they want to import relative to the data fields allowed for import (e.g., Barcode ID, Quantity measured). Once the mapping of fields to columns is complete, select Next.

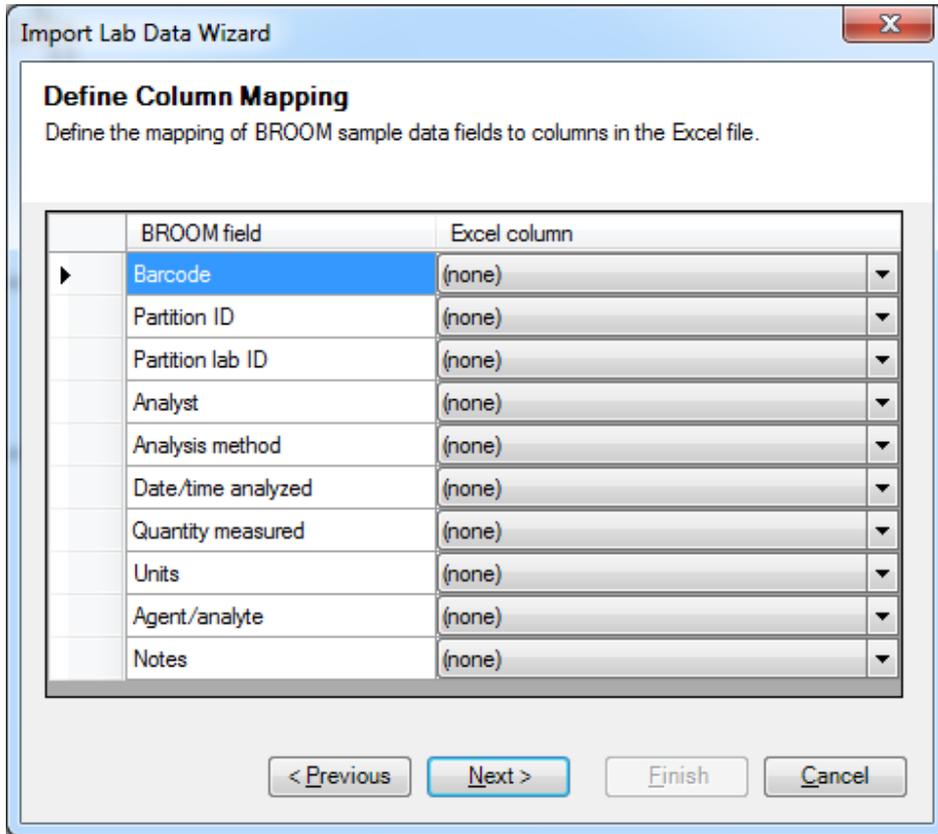


Figure 4-52. Define Column Mapping for Import.

The next pop-up window should look something like Figure 4-53. If the import had not prescribed column inputs for Analysis method, units and Agent/Analyte, then this dialog box will appear.

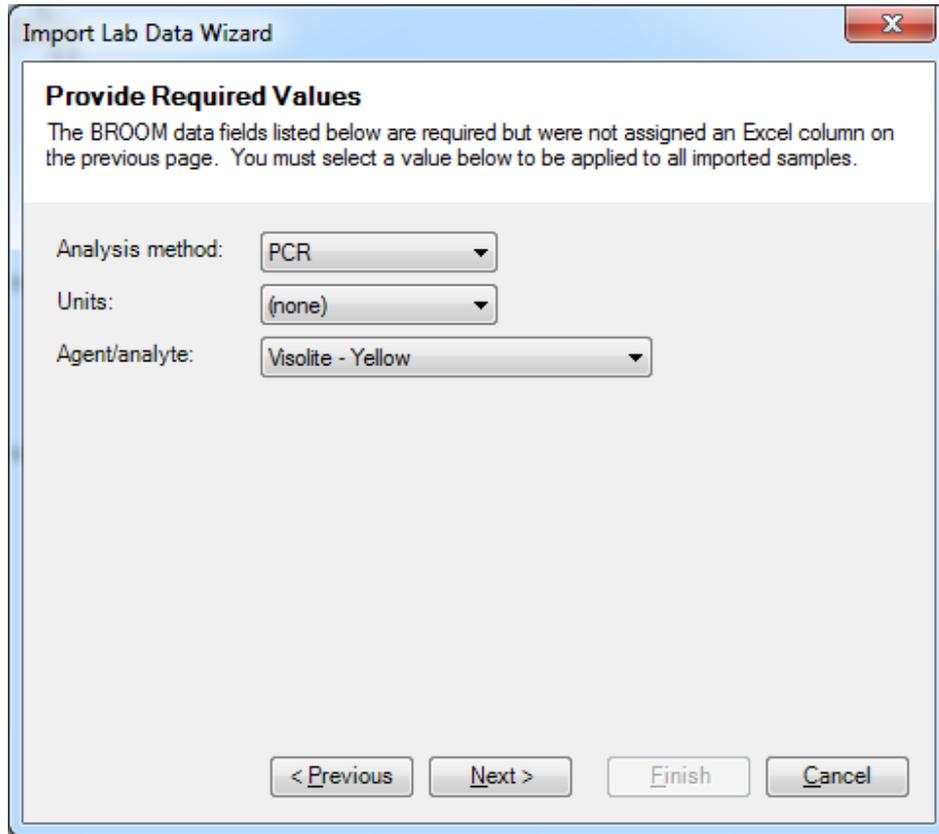


Figure 4-53. Selecting Other Parameter Attributes for Import.

When input to this screen has been completed, the user selects Next. The final screen in the process is shown in Figure 4.54 to Finish the import procedure.

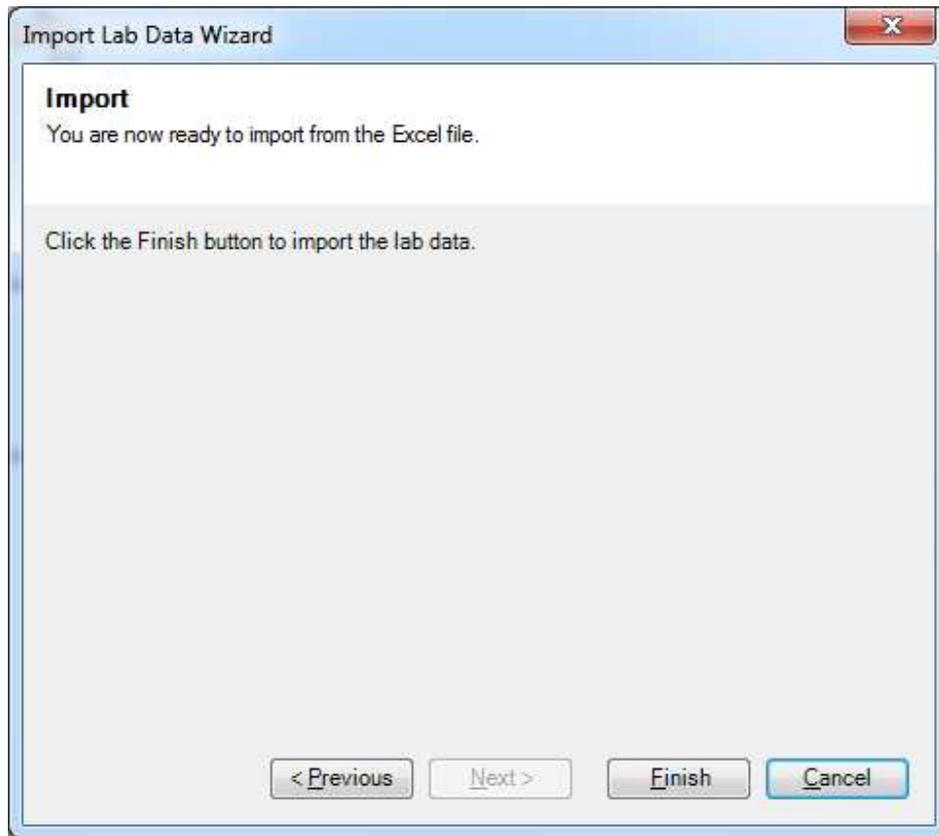


Figure 4-54. Final Screen for Import.

Another option for exporting data which is potentially more comprehensive than the XML export option is listed as Data > Export > BOTE Samples (CSV). The file generated from this option is fairly comprehensive and can be displayed in Excel quite easily.

4.9. Create a Contamination Map

BROOM creates maps of a facility with the sample symbols colored to indicate the measured amount of contaminant. These sample value maps show which samples have high levels of contaminant and which samples have low levels (Figure 4-55, left). Sample value maps show the distribution of samples and help you to understand how the contaminant is distributed.

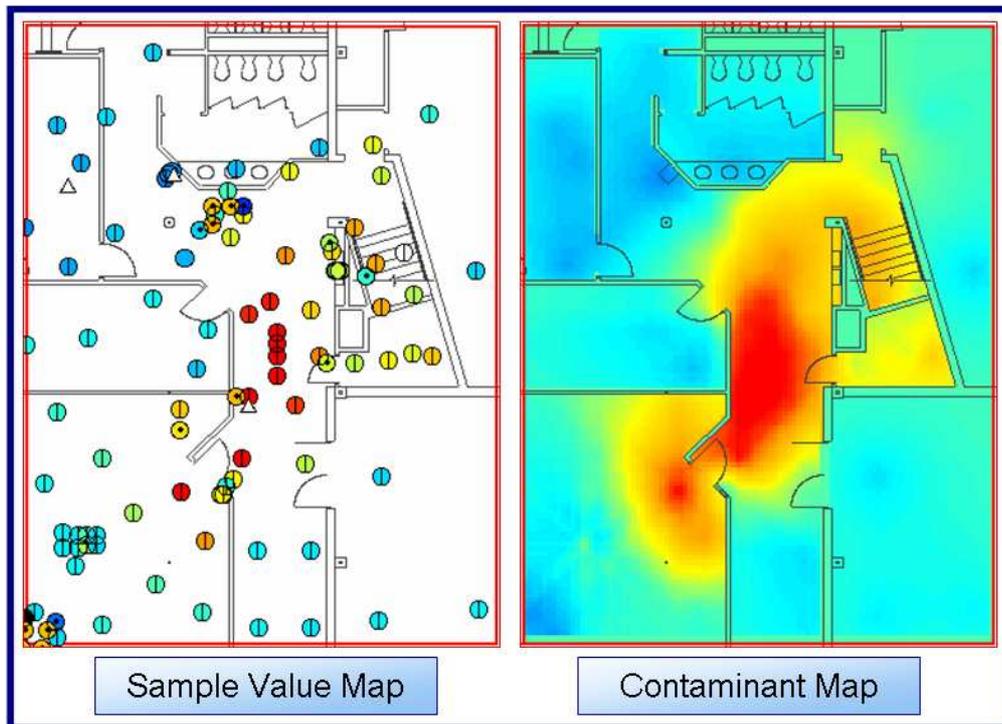


Figure 4-55. Examples of a Sample Value Map and Contamination Map.

Contamination maps extend the coloring to the entire surface of the map (Figure 4-55, right). BROOM creates contamination maps by generating estimates of contaminant levels at all points on the map using known values from the samples. These maps are useful for viewing the extent of the contamination. You can tell from a quick glance where the clean portions of a building are and where the contaminated portions are.

BROOM simplifies the task creating these highly useful contamination maps, but it is still an involved process. Sample value maps are generated automatically by BROOM as values are added to sample locations. Contamination maps require more user interaction, thus they are not automatically generated.

Figure 4-56 shows the order of operations you must perform to create a contamination map. You can access all of the tools you need to make a contamination map from the BROOM toolbar. First, you will need to generate a *Sample*

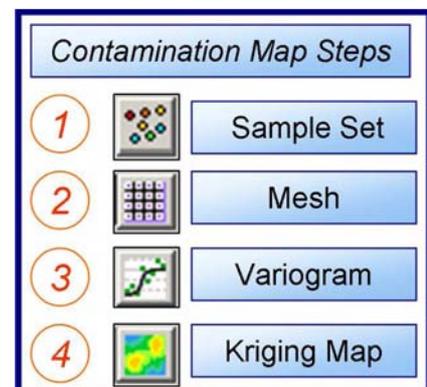


Figure 4-56. Creating a Contamination Map.

Set, which is a subset of the samples that you want to be represented in your contamination map. Next, you will need to decide what part of the building model you want the map to cover and generate a *Mesh* covering that portion of the building. The third step is to construct a *Variogram* that describes the spatial relationships amongst the samples in the sample set. Finally, BROOM generates the final map through the process of *kriging*, making use of the sample set, mesh, and variogram.

4.9.1. Getting Started

To learn how to create a contaminant map, you will first create a new project and building. The procedure for creating a project and building is outlined in Sections 4.3 through 4.7.

4.9.1.1. Create a Basic Building

You will need to create a simple building in your new project. Create a building with one floor (see Sections 4.6 and 4.6.1). The floor does not need to have a drawing associated with it.

Next, add one rectangular room to the floor (see Section 4.7.1). The exact size of the room is not important; just create a single room that takes up most of the screen. Figure 4-57 shows a simple building with one floor and one rectangular room.

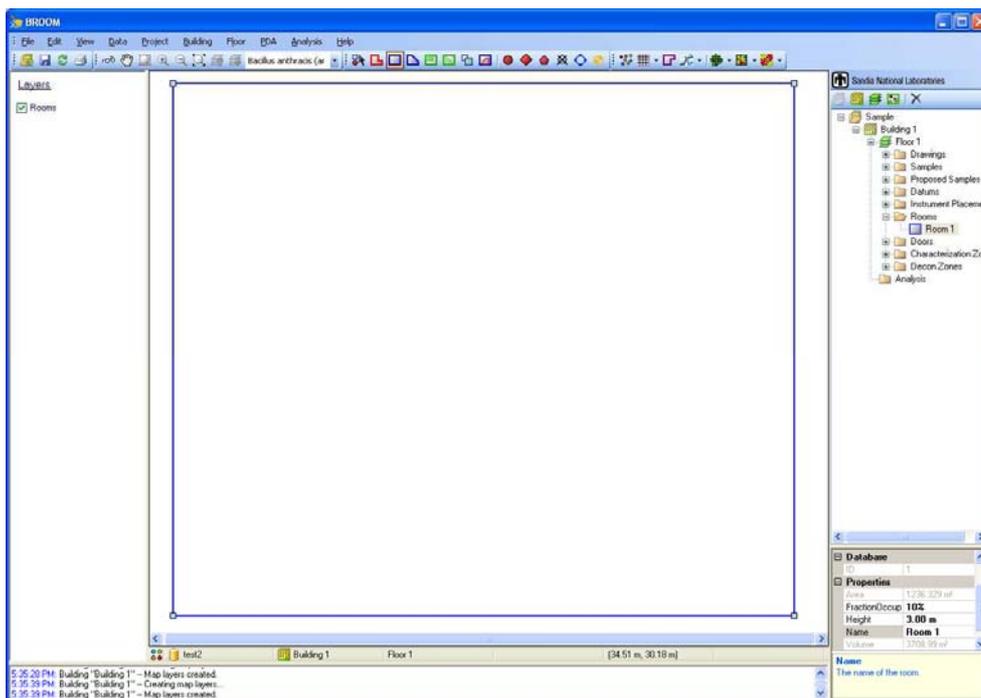


Figure 4-57. Simple One-Room Floor.

4.9.1.2. Configure the Sample Display

The project's sample color scale needs to be configured to properly encompass the sample values we will be using in this exercise. First, select **View > View Options** from the main menu. This will open the *View Options* form shown in Figure 4-58.

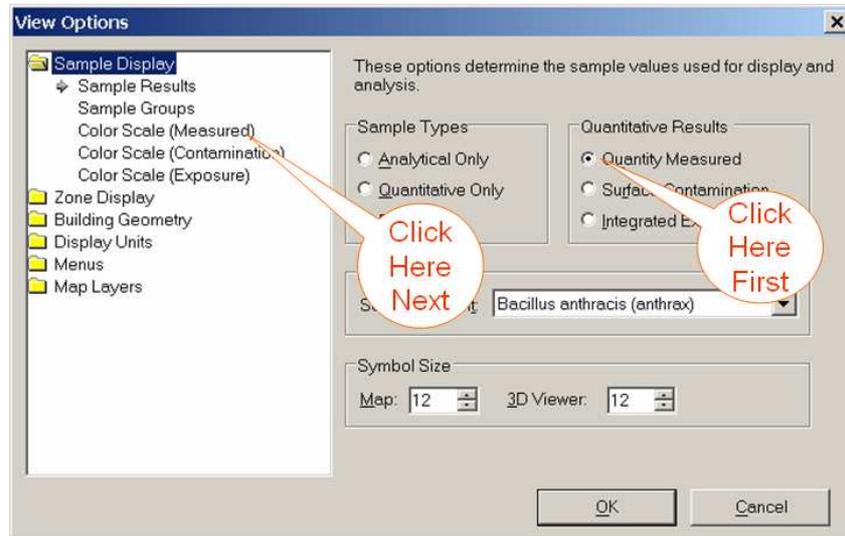


Figure 4-58. *View Options* Form.

Select **Quantity Measured** under *Quantitative Results*. Next, select **Color Scale (Measured)** from the list at the left of the form. The right side of the form will now appear as it does in Figure 4-59. Make the following changes:

1. Select the **Linear** radio button.
2. Set the **Minimum** to **0**.
3. Set the **Maximum** to **1000**.
4. Click **OK**.

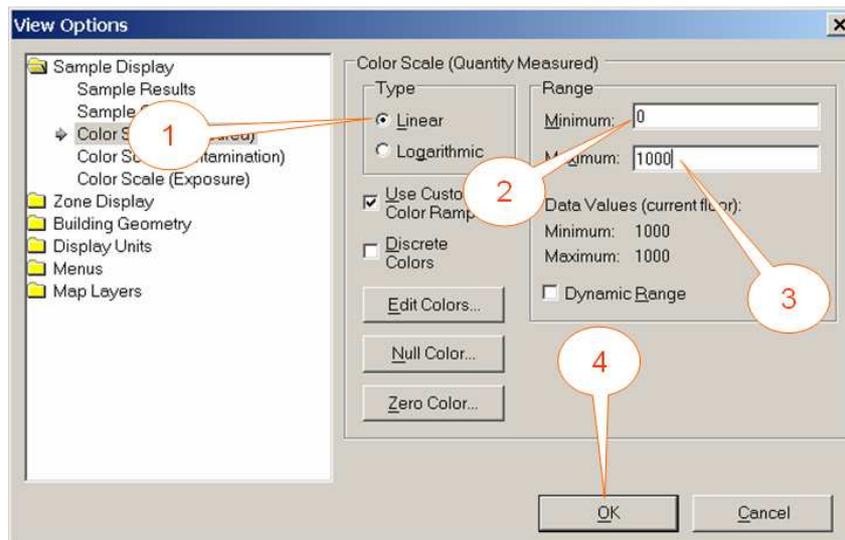


Figure 4-59. *Color Scale Settings*.

Next, select **Data > Options** from the main menu. This will open the *Data Options* form shown in Figure 4-60. Make sure **Enable quick sample entry** is checked. If it is not, click on the checkbox to enable it. When the form looks like it does in (Figure 4-61), click **OK** to save the settings and close the form.

4.9.1.3. Add Samples

Contaminant maps use the values of existing samples to make estimates about contaminant levels in unsampled locations. In this exercise, you will add three samples to your simple room so that the contaminant mapping procedures have initial data to work with.

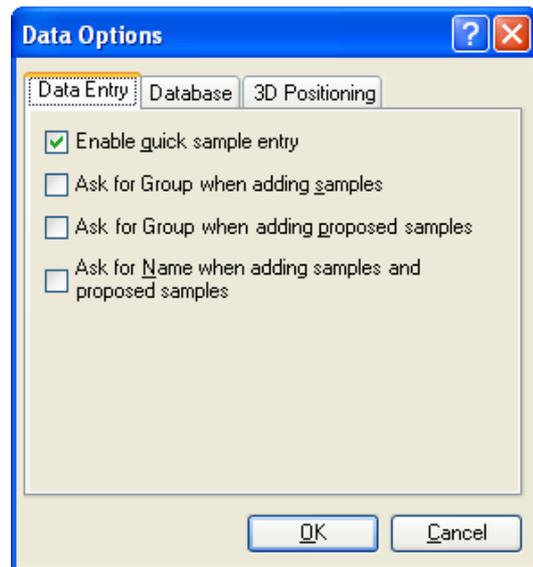


Figure 4-60. *Data Options* Form.

Make sure the **Add Surface Samples** button on the main toolbar is selected. Next, click the left mouse button at about the center of the room that you previously drew in the building. This will create a sample (an empty circle symbol) at that location and open the *Sample Quick-Entry* form (Figure 4-61). Select **QPCR** from the *Analysis Method* list. Next, enter **1000** in the *Quantity Measured* field. The form should look like that pictured in Figure 4-61. Click **OK** to complete the sample entry procedure.

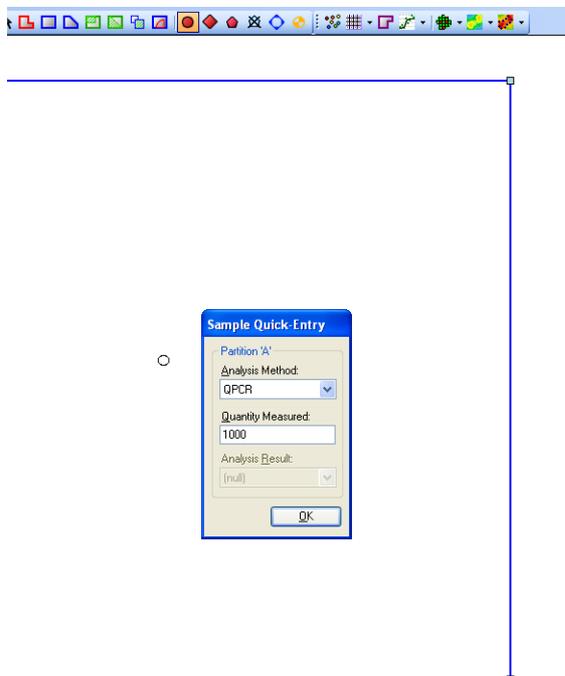


Figure 4-61. Adding the First Sample to Room.

Add two more samples to your room in the approximate locations shown in Figure 4-62. Place the second sample about halfway between the first sample and the blue room outline along the top of the screen. Assign a value of 500 to this second sample. Place the third sample beneath the first sample, but closer to the bottom of the room (Figure 4-62). Give the third sample a value of 200.

Save your project by selecting **File > Save Project** from the main menu.

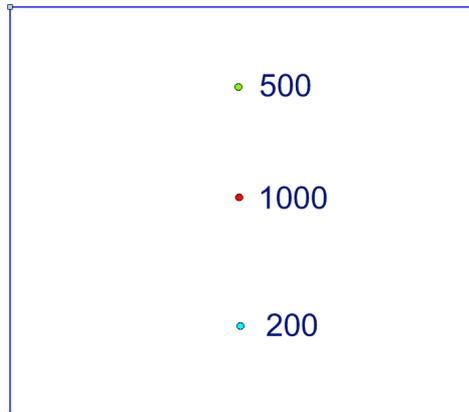


Figure 4-62. Locations of Samples.

4.9.2. Scenarios and Workspaces

Analysis runs and outputs (such as contamination maps) are organized into *scenarios* and *workspaces*. A scenario is a broad, arbitrary category of analyses you are performing on a project. A scenario is assigned a name and description of your choosing. Each scenario is subdivided into one or more workspaces. Workspaces are likewise created and named as you see fit. Simply think of them as folders for organizing your analysis data.

Whenever you generate new analysis results, BROOM needs to know which workspace in which to place the results. When run your first analysis, BROOM will present the form shown in Figure 4-63 (the form will initially be blank). Create a scenario by clicking the **New Scenario** button and entering a scenario name. Next, add a workspace by clicking the **New Workspace** button and entering a workspace name. You may then click **OK** to continue with running the analysis.

If one or more scenarios and workspaces already exist when you run an analysis, there are two ways to specify the workspace to which the analysis will be assigned. If a workspace node is selected in the project tree (or any run or input/output node belonging to a workspace), any analysis you run will automatically be assigned to that workspace. If some other type of node (building, floor, sample, etc.) is selected in the project tree, BROOM does not know which workspace is the “current” workspace. In this case, when you start an analysis you will see the *Select Workspace* form (Figure 4-63) prompting you to select a workspace. You may select an existing workspace or create a new workspace as described in the previous paragraph.

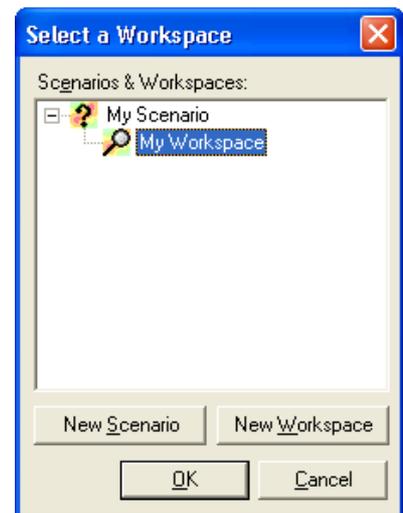


Figure 4-63. Select Workspace Form.

4.9.3. Generate a Sample Set

A *sample set* is a group of samples defined for use in analysis. Creating a sample set is the first step in generating a contamination map. Sample sets can be customized with value transforms and filters for defining which samples will be included in the set.

For this example, you will create a simple sample set that contains all three samples on the floor.

To create a sample set, click the **Create Sample Set** button on the main toolbar (Figure 4-64). This opens the *Sample Set Definition* form shown in Figure 4-. The form has many options for determining which samples are included in the sample set. For this example, leave the form's default values as-is. Click **OK** to generate the sample set. You should then see the sample set show up in the project tree.

Figure 4-64. Sample Set Definition Form.

4.9.4. Generate a Mesh

A mesh is a regular array of points covering the area to be mapped. When BROOM creates a contamination map, it will compute the estimated contamination level for each of the points in the mesh. Meshes can have any number of points in them. The more points there are in the mesh, the better the contamination map will look. Fewer mesh points will result in a more jagged, “blocky” map. More mesh points will result in a longer computation time when generating the map. Generally, meshes with 1,000 to 10,000 points are a good tradeoff between map quality and computation time.

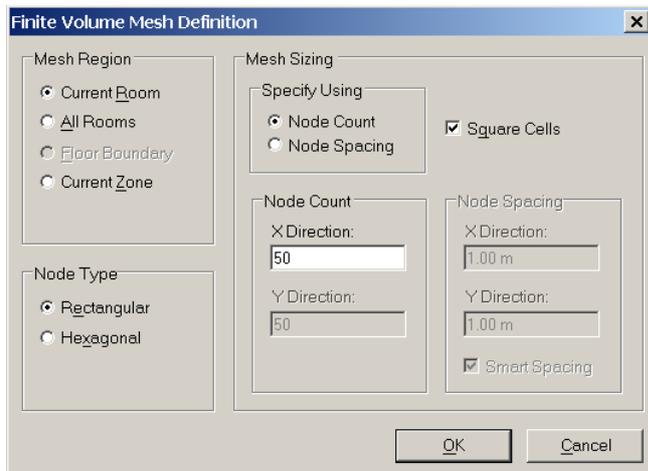


Figure 4-65. Mesh Definition Form.

To create a mesh, click the **Create Mesh** button from the BROOM toolbar (Figure 4-57). This opens the *Finite Volume Mesh Definition* form shown in Figure 4-65. Select the following options:

- **Mesh Region: Current Room**
- **Node Type: Rectangular**
- **Mesh Sizing: Node Count**
- **Node Count: X Direction = 50**
- **Square Cells**

Click **OK** to generate the mesh.

Mesh generation is a very intensive operation and may take a minute or two to complete. The *Accept Mesh* form (Figure 4-66) will appear when the mesh has been generated. This form allows you to name the mesh and to view it on the map before accepting it. You can leave the default name or enter a new name for the mesh. Click **OK** to save the new mesh. You should then see the mesh show up in the project tree.

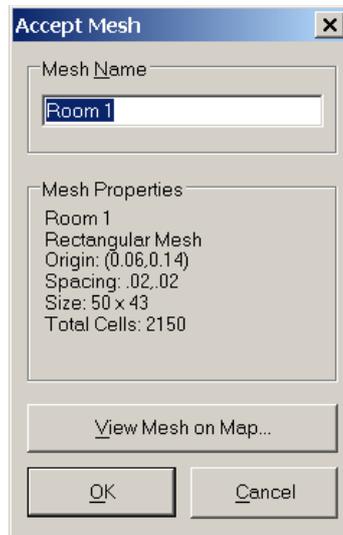


Figure 4-66. Accept Mesh Form.

4.9.5. Create a Variogram

A variogram is the third component required for a contamination map (Figure 4-). A variogram describes how the similarity of samples to one another varies with the distance between them.

To create a variogram, select **Analysis > Variogram > Easy** from the main menu. If the *Select a Workspace* form (Figure 4-63) appears, select a workspace and click **OK**.

Next, the *Easy Variogram Inputs* form appears (Figure 4-67). This form requires you to select a sample set as the input to the variogram generator. In this example, we previously created only one sample set; this sample set appears in the list of *Available Inputs* on the left side of the form. If you had previously created more than one sample set, you would see all of them in the list. Giving the sample sets unique names when they are created makes them easier to identify. The properties of the selected sample set appear on the right side of the form, providing an additional means of identifying the desired sample set.

Properties:	
Location	
BuildingID	4
FloorID	1
Output Type	
CodeName	Sample Set Generator
CreationTime	1/11/2011 5:51 PM
OutputType	Sample Set
Properties	
Agent	Bacillus anthracis (anthra
IndicatorThresho	0
Name	Sample Set
NumSamples	3
SampleTypes	Surface
Transform	None
Type	QuantityMeasured
Units	CFU
ZeroSubstitute	(none)

Name
Name of the Sample Set.

OK Cancel

Figure 4-67. Input Selection Form.

Click on a sample set in the list to select it, and then click **OK**. Note that if you gave the sample set a different name (the default is “Sample Set”), you would see that name appear in the list.

Next, the *Generate Variogram* form appears (Figure 4-68). The form has a graph on the left side and some data input boxes on the right. The vertical axis on the graph displays variability (how similar or different pairs of samples are to one another). The horizontal axis displays the distance between pairs of samples. The red dots on the graph correspond to sample pairs. There are only two dots on the example graph because there are only two pairings of samples (from the three samples in the input sample set).

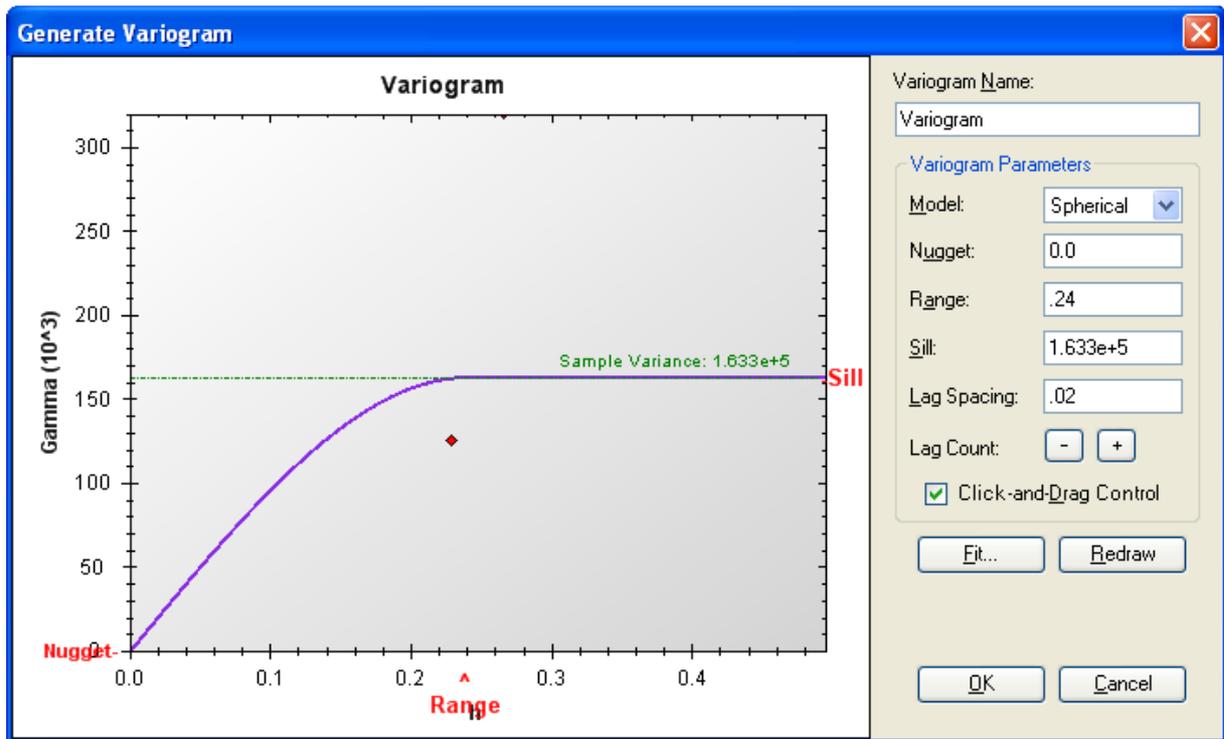


Figure 4-68. Generate Variogram Form.

The purple curve on the graph is the essence of the variogram. This curve will be one of the inputs used when creating the contamination map. The curve should fit the general trend of the red dots while topping off at the horizontal green dashed line. The trend of the red dots in our small example is not readily apparent; however, the trend is typically obvious in a real-world sample set. BROOM automatically generates its best-guess fit. Generally, it is sufficient to simply click **OK** and use the automatically generated variogram.

Verify that your curve (the purple line) looks similar to the one in Figure 4-68. The parameters along the right side may differ, but if the general shape is the same, then the variogram is good. The left end of the curve should intercept the bottom of the graph in this example; if not, drag the red word “**Nugget**” down to the bottom of the graph. This will pull the curve down to the origin. Alternatively, you can simply enter *0.0* in the **Nugget** text box and click **Redraw**. You can also drag the red word “**Range**” along the horizontal axis to change the curve. Try moving **Range** until the curve lines up with a red dot. Once the purple curve looks somewhat like that in Figure 4-68, click **OK** to accept the variogram. You should then see the new variogram show up in the project tree.

4.9.6. Create a Kriging Map

The final step in generating a contamination map is to run the Kriging algorithm (step 4 in Figure 4-56). Kriging uses a sample set, mesh and variogram to generate contamination estimates at each point in the mesh. These estimates are converted into multicolor maps like those seen in Figure 4-55.

To run Kriging and create a contamination map, select **Analysis > Contaminant Map > Easy Kriging** from the main menu. If the *Select a Workspace* form (Figure 4-63) appears, choose select a workspace and click **OK**.

Next, the *Input Selection* form appears (Figure 4-69). On this form, you will select a sample set, variogram, and mesh as inputs for the Kriging.

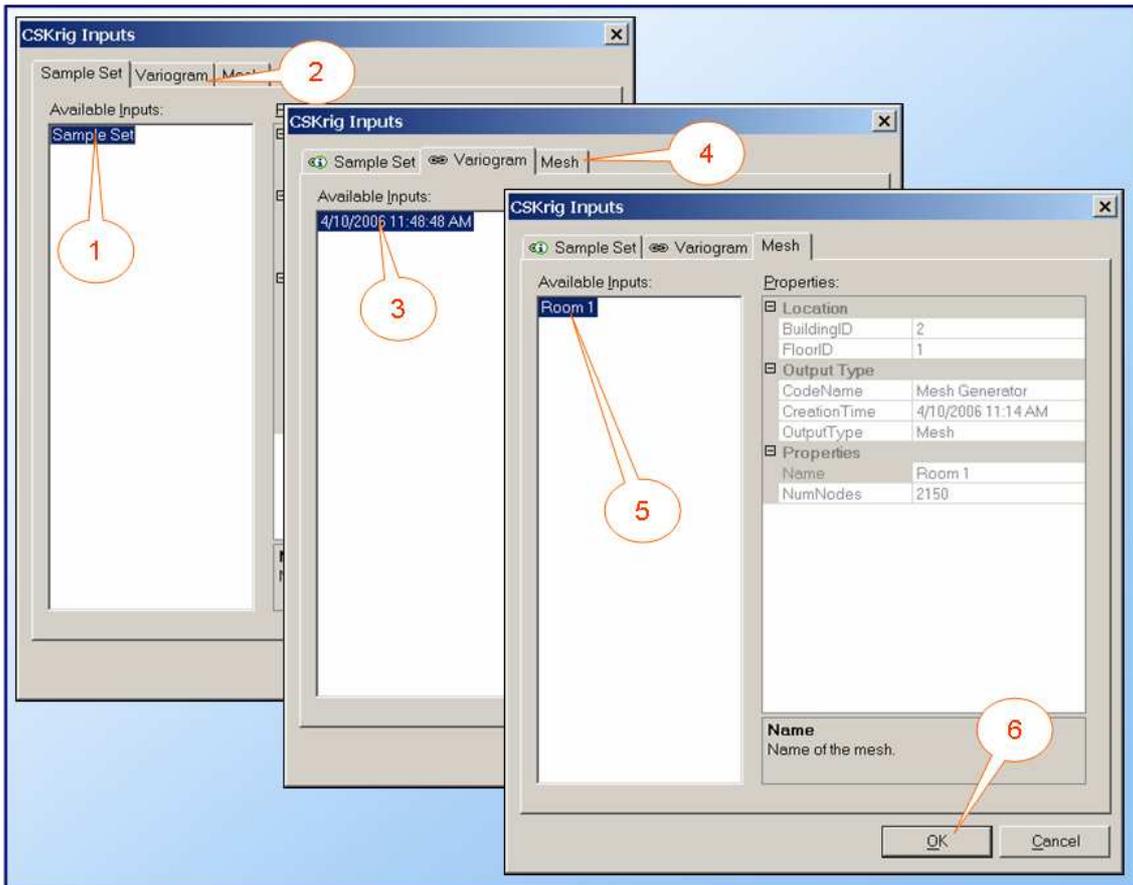


Figure 4-69. Selecting Kriging Inputs.

Figure 4-69 and the following list describe the steps for selecting the inputs:

1. Select our example sample set in the *Available Inputs* list.
2. Click on the **Variogram** tab.
3. Select our example variogram in the *Available Inputs* list.
4. Click on the **Mesh** tab.
5. Select our example mesh set in the *Available Inputs* list.
6. Click **OK**.

Technically, you could skip step 1; when you select the variogram in step 3, the sample set from which the variogram was generated is automatically selected on the *Sample Set* tab.

After you click *OK*, the kriging algorithm will begin generating the map. This can take a few minutes, depending on the size of the mesh. When complete, BROOM displays the *Map Preview* form (Figure 4-70). This form provides a preview of the map before it is finalized and added to the project. You can specify how the map is colored and how it is rendered. For this exercise, select **Current Sample Colors** for the *Map Color Scale* and **High Quality** for the *Map Layer Type*. Then click **OK** to save your choices and display the map.

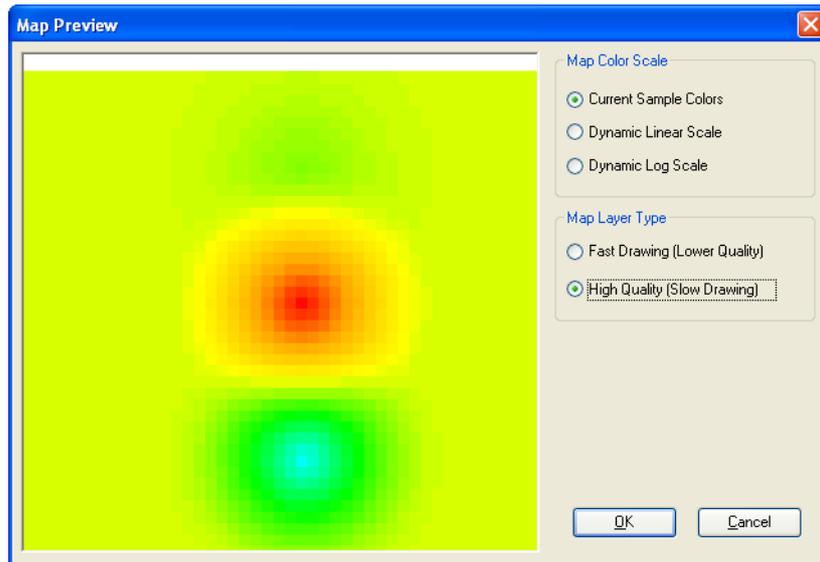


Figure 4-70. Map Preview Form.

The contamination map will appear in the map window and show up in the layers panel as the *Estimate* layer (Figure 4-71).

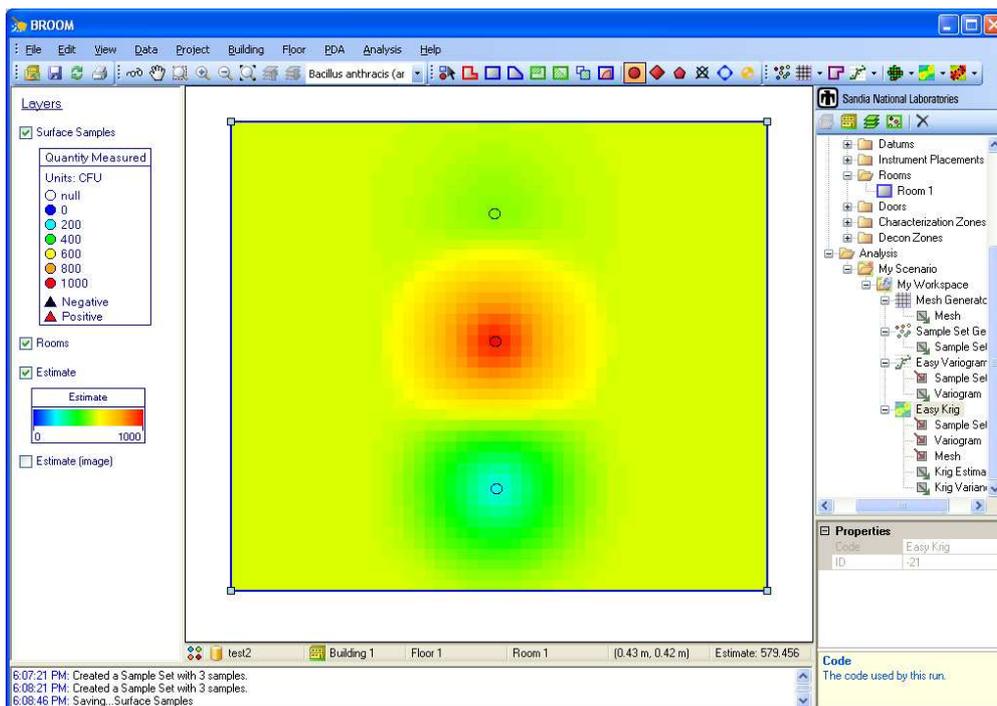


Figure 4-71. Completed Contamination Map.

4.9.7. Contamination Estimates

The displayed contamination map (see the previous section) can now be used to determine estimated contamination levels anywhere in the room. First, make sure the map is in **Select Object** mode (Figure 4-). Now hold your mouse cursor over one of the three samples on the map. A small tooltip window will pop up with information about that sample (Figure 4-72).

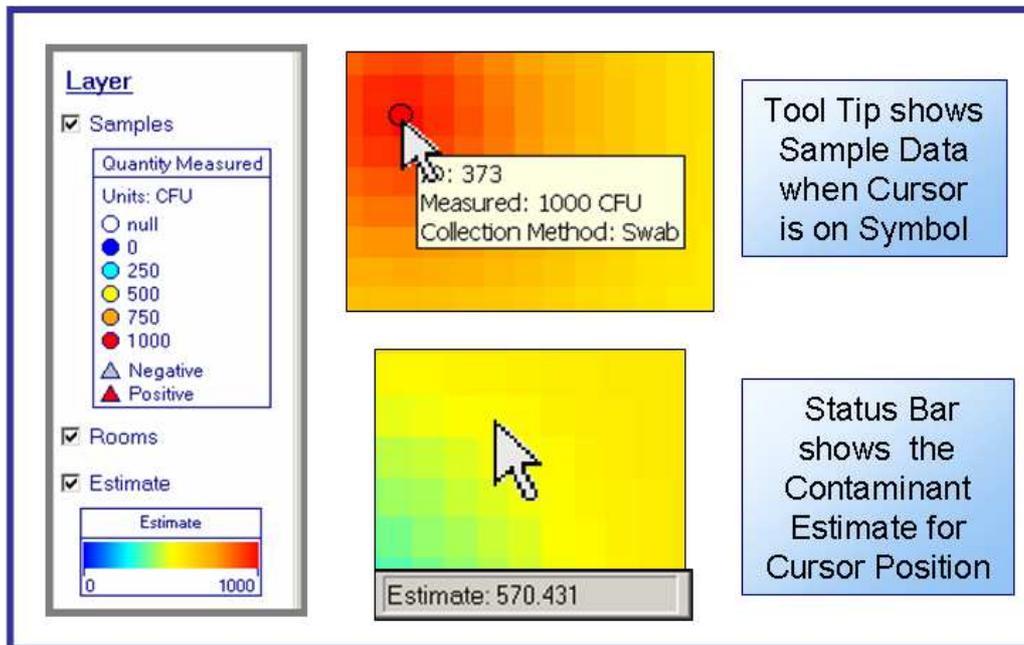


Figure 4-72. Obtaining Contamination Estimates.

Now, slowly move your mouse cursor around within the room while watching the status bar directly below the map. In particular, watch portion of the status bar that is labeled *Estimate*. You will see this value change as you move the mouse around. The displayed estimate value increases when the mouse is over a red area and decreases when the mouse is over a blue area. The displayed value is the estimated contamination level that BROOM has calculated for the portion of the room under the mouse cursor (Figure 4-72).

4.10. Generate Maps for the PDA

PDA's have much less memory and processing power than desktop and laptop systems. Therefore, it is necessary to create smaller, more efficient building maps for the PDA application.

There are two types of maps that can be generated for the PDA: "Image maps" and "CAD maps." Image maps are bitmap graphics images of what is being displayed in the desktop application's map area at the time the PDA map is generated. The advantage to using an image map is that you can incorporate various map layers into the image (the CAD layer combined with the contaminant map layer, for example). CAD maps have the advantage of high detail and fine resolution but can be generated only if there is a CAD map loaded in the desktop application.

Typically, you will want to generate both image maps and CAD maps for the PDA. To do so, first check or uncheck various map layers to achieve the desired appearance for the image map. Then select **PDA > Create All PDA Maps for Current Building** from the main menu. It may take a few minutes for the maps to be created, especially if the CAD layer contains a complex map. The maps you just created for the PDA will reside as files on the local computer.

Some points to keep in mind when dealing with PDA maps:

- If you have multiple buildings in your project, you must repeat the above steps for each building.
- If you change a building (add floors, change floor maps, etc.) you must regenerate the PDA maps.
- If you regenerate the PDA maps, remember the PDAs will still have the old maps until you re-download them into the PDAs.

5. USING THE PDA

5.1. PDA Basics

The BROOM system has two main components: the desktop application, which runs on a standard Microsoft Windows computer, and the PDA application, which runs on a Pocket PC or Windows Mobile PDA (earlier versions of Windows Mobile were called Pocket PC). The PDA acronym stands for “Personal Digital Assistant” and refers to small hand-held computers. Pocket PC and Windows Mobile are special variants of the Windows operating system designed for PDAs. “PDA” is the most generic term for these devices, whereas “Pocket PC” and “Palm Pilot” refer to PDAs built for competing operating systems, much like “Windows” (or “PC”) and “Mac” refer to different platforms.



Figure 5-1. iPAQ Pocket PC.



Figure 5-2. Trimble Nomad.

5.1.1. Text Entry

The standard method of interacting with a PDA is via its touch screen. Text entry may be performed using the standard “input panel” control. This control is activated by tapping on the small keyboard, stylus, or handwriting icon in the bottom-right corner of the screen (see Figure 5-3). This will pull up a keyboard, handwriting recognizer, or put the PDA in “transcriber” mode. Tapping the icon again will close the control back down. These modes are selected by tapping the up arrow next to the icon, as shown in Figure 5-4. Note this icon may not always be present—it is up to the running application to make it available and is typically not shown on screens that do not require text input.



Figure 5-3. Text Input Mode Icons.

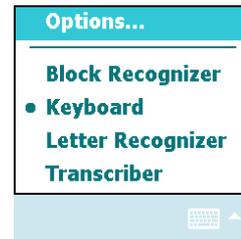


Figure 5-4. Text Input Menu.

Keyboard mode provides an on-screen keyboard and is the simplest mode to use. This mode is shown in Figure 5-5. Text is entered on the screen simply by tapping the keyboard with the stylus. This is the simplest but slowest method for entering text.

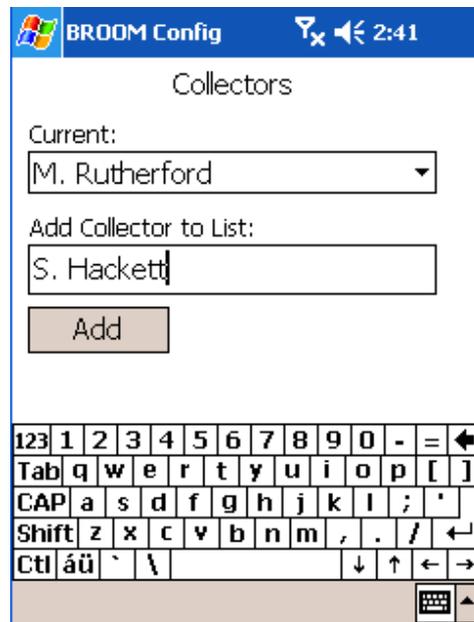


Figure 5-5. Keyboard Input Mode.

The block recognizer and letter recognizer are represented by the stylus icon. The block recognizer interprets characters drawn on the input panel (see Figure 5-6). This mode recognizes characters drawn in a style developed for older Palm Pilot PDAs. A better alternative is the letter recognizer (see Figure 5-7). Letter recognizer mode recognizes characters drawn in a more

natural manner. Letters should always be drawn in lower case, however where they are drawn on the control (the “ABC,” “abc,” or “123” section) determines how they will be interpreted. These modes are slightly more difficult to learn than the keyboard, but once the user is proficient

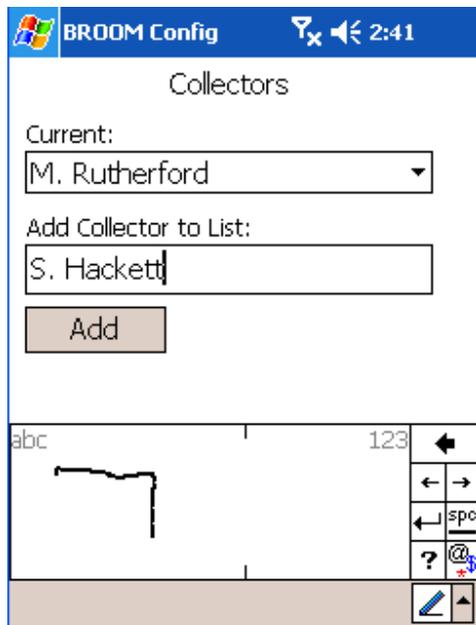


Figure 5-6. Block Recognizer Input Mode.

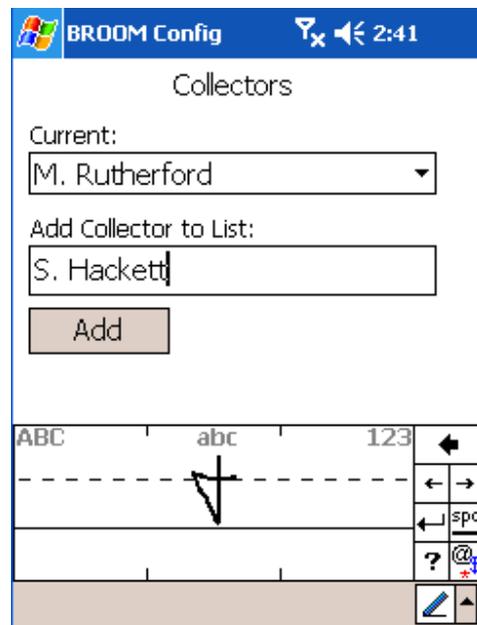


Figure 5-7. Letter Recognizer Input Mode.

they are faster than using the keyboard.

The transcriber mode (see Figure 5-8) recognizes characters written anywhere on the screen and offers many options for fine-tuning its behavior. It allows the user to write an entire word at a

time before it interprets the text. This is the fastest and most powerful method for text entry, but it can also be initially frustrating and has a bit of a learning curve.

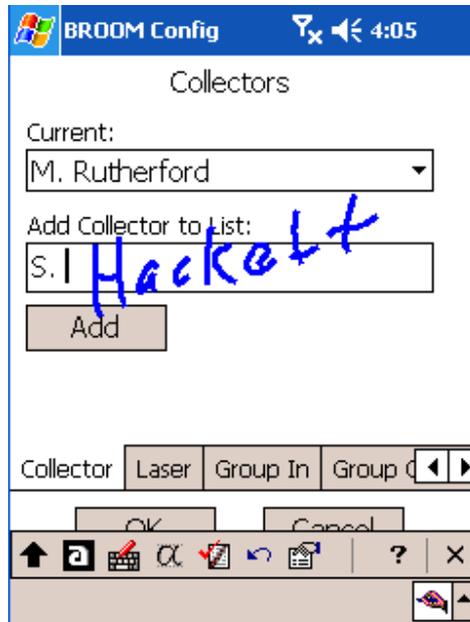


Figure 5-8. Transcriber Input Mode.

Some PDAs, such as the Trimble Nomad series, provide hardware buttons that can be used for



Figure 5-9. Trimble Nomad Keypad.

entering numbers (see Figure 5-9).

5.2. Wireless Network

The PDA and the desktop application communicate via a standard 802.11b or 802.11g wireless network using standard off-the-shelf equipment (PDAs do not typically support 802.11a or 802.11n). It is assumed that the individual responsible for establishing the network has some degree of familiarity and experience with such matters.

In this section, the term “server” refers to the desktop/laptop computer running BROOM with which the PDA communicates. It does not refer to the database server (which may or may not be the same computer).



Figure 5-10. Commercial Wireless Router.

5.2.1. Wireless Router Configuration

Recommended network configuration:

- **Static IP addresses:**
A static address is recommended for the desktop computer acting as the server for the PDAs. The user must initially enter the server’s IP address when configuring BROOM on a PDA, thus it is simpler when the server has a static IP address. Static addresses are also recommended for the PDAs themselves to alleviate any confusion when troubleshooting network connections.
All devices should be on the same subnet for all BROOM features to function properly. That is, all devices should be assigned addresses in the form of aaa.bbb.ccc.ddd where the first three octets (aaa.bbb.ccc) are the same for all devices and the fourth octet (ddd) is unique to the device.
- **Encryption:**
Network encryption is strongly recommended. Encryption helps prevent unauthorized users from intercepting data and from becoming a member of the network. Use the strongest encryption supported by the PDA. At a minimum, most (if not all) PDAs support 64-bit WEP encryption. However, WEP can be cracked and defeated easily and is effectively useless in protecting your network. WPA2 encryption is far superior to WEP. The Trimble Nomad PDAs support WPA2 with a pre-shared key (also known as “WPA2 PSK” or “WPA2 Personal”) and both the TKIP and AES algorithms. A WPA2 key (password) must be between 8 and 63 alphanumeric characters; the more characters the stronger the protection. Furthermore, common sense dictates the use of obscure and/or random keys – don’t use “password” for your key. Use a mixture of upper and lower case characters, numbers, and symbols.

5.2.2. PDA Network Configuration

The PDAs must be configured to connect to the SSID (network name) defined by the router and to work with its encryption settings (e.g., WEP or WPA2 and the network key/password). Static IP addresses are recommended (but not required) for the PDAs.

5.2.2.1. Trimble Nomad Configuration

Network configuration involves two main steps. First, the PDA's IP address must be configured. Then we will configure the wireless network settings.

1. If using a dynamic IP address (DHCP), this step may be skipped. Otherwise, to assign a static IP address, tap **Start** > **Settings** > the **Connections** tab > **Network Cards** > the **Network Adapters** tab (“Start” refers to the Windows logo in the upper left corner). Tap **Marvell SDIO8686 Wireless Card**.

Select **Use specific IP address** (Figure 5-12). Enter a unique **IP address** on the same subnet as the router. Set the **subnet mask** to 255.255.255.0 and set the **default gateway** to the IP address of the router. Tap OK (upper-right corner) to save the changes.

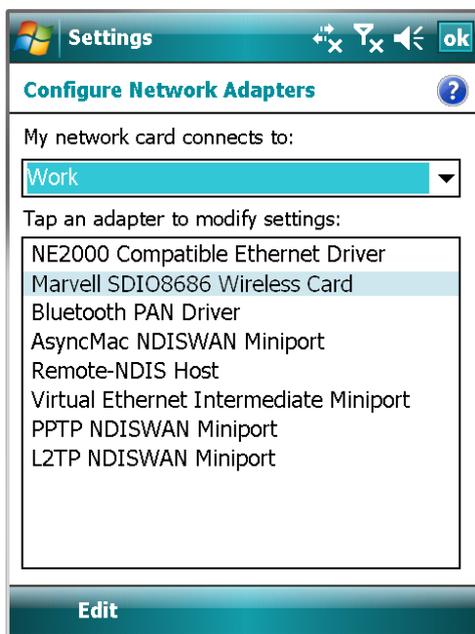


Figure 5-11. Network Devices.

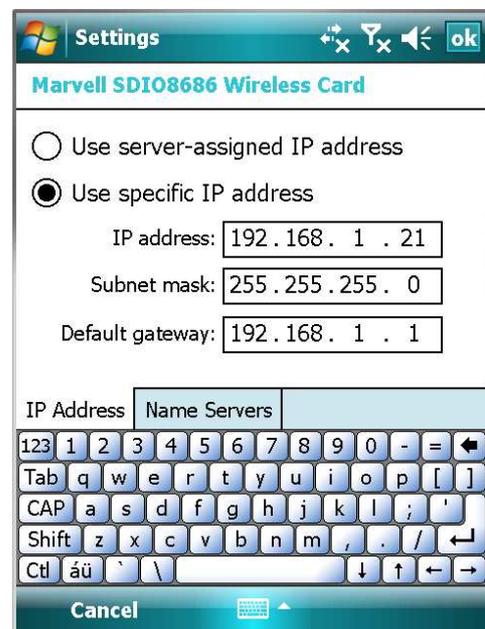


Figure 5-12. Static IP Address.

2. To edit the wireless network settings, tap **Start** > **Settings** > the **Connections** tab > **Network Cards**. Tap **Add New** to bring up the *Configure Wireless Network* screen. Enter the network name (the SSID) and then tap **Next**. Select the authentication and encryption methods per the wireless router's chosen configuration. Typically the authentication will be **WPA2-PSK** and the encryption will be **TKIP**, but again this depends on the settings that the network is using. Also enter the network key (password) and then tap **Next**. Then just tap **Finish** on the final screen.

5.2.3. Desktop/Laptop Network Configuration

The server computer must be configured to connect to the SSID (network name) defined by the router and to work with its encryption settings (e.g., WEP or WPA2). A static IP address is recommended (but not required) for the server. Assigning a static IP address to the server makes

it simpler to know which address to enter when telling the PDAs which computer to connect to when transferring data to/from the server.



To configure a wireless network connection in Windows XP, click the **Start > Run**. Type “ncpa.cpl” and click **OK** (Figure 5-13).



Figure 5-13. Accessing the Network Connections Control Panel.

The *Network Connections* window should appear. Double-click **Wireless Network Connection** (or similar). You should now see the *Wireless Network Connection* window (Figure 5-14).

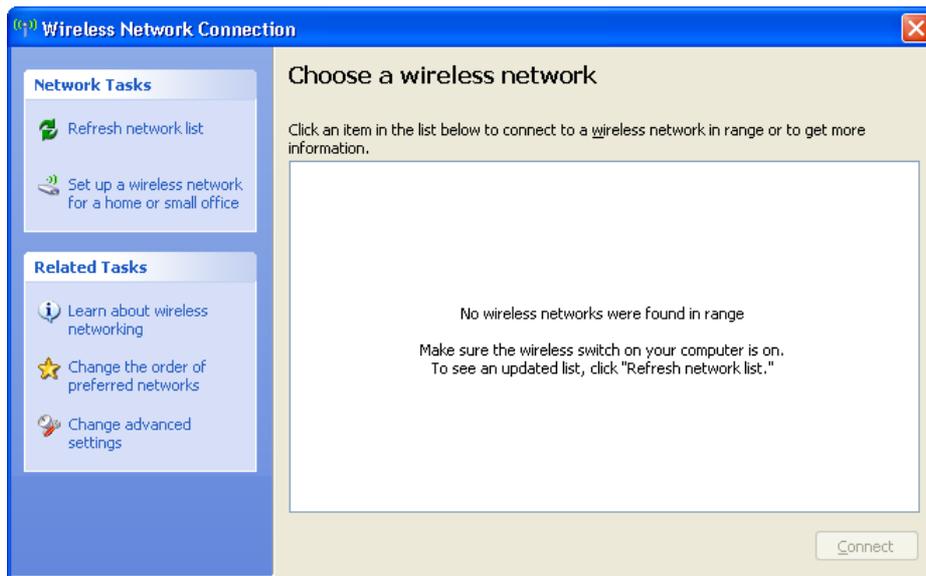


Figure 5-14. Wireless Network Connection Window.

In the *Wireless Network Connection* window, click **Change advanced settings**.

The *Wireless Network Connection Properties* window (Figure 5-16) should now be displayed.

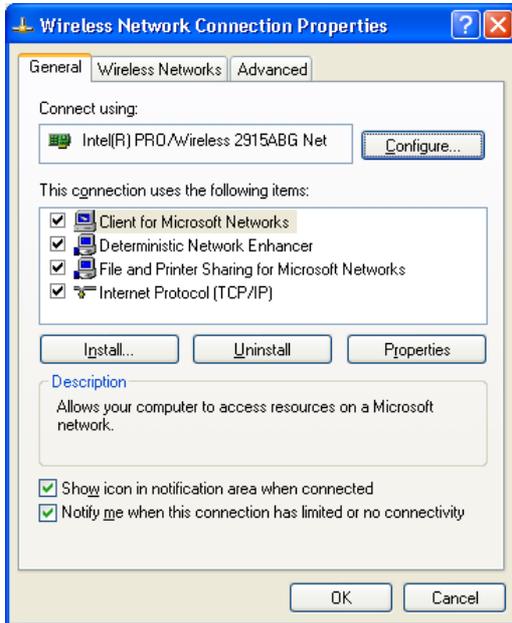


Figure 5-16. Network Connections.

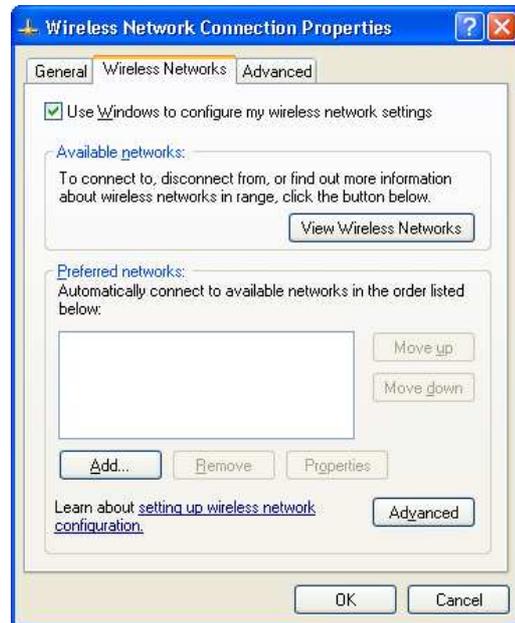


Figure 5-15. Wireless Networks.

Click on the **Wireless Networks** tab (Figure 5-15) and click **Add**. The *Wireless network properties* window will appear (Figure 5-17). Enter the **Network name (SSID)** as determined by the wireless router's settings. Set **Network Authentication** to *WPA2-PSK* and set the **Data encryption** to *TKIP* (or other settings based on the actual network configuration). Enter the **Network key** defined in the router's settings. Flip to the *Authentication* tab and make sure *Enable IEEE 802.1x authentication* is NOT checked. Click **OK** to save your changes and close the window. Click **OK** again to close the previous window.

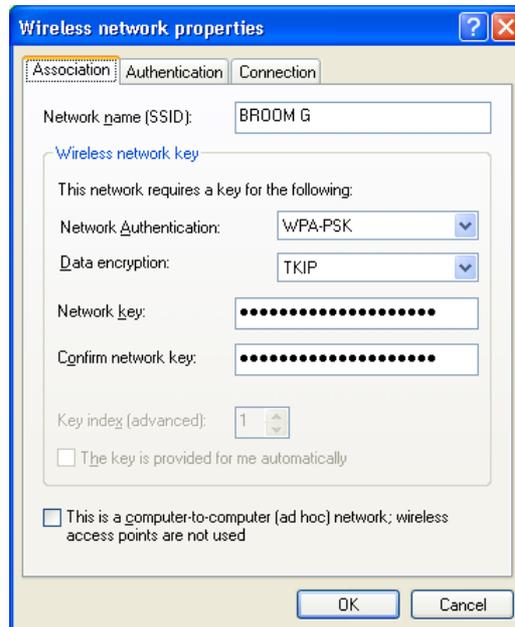


Figure 5-17. Network Properties.

5.2.4. Network Coverage

Complete wireless coverage (i.e., no dead spots) is not necessary for normal operation. There are two types of data transfers that take place between the PDA and desktop server: building/sample transfers and current position updates.

Building/sample transfers are the explicit upload and download operations initiated by the PDA operator and can only be performed when the wireless connection is present. These operations cannot be performed when the PDA is in a dead spot with no network coverage. The PDA operator may also wish to move to an area of better coverage before performing an upload or download in the outer fringes of the network.

The PDA broadcasts current position updates whenever the user updates their position on the map (via manual mode or the laser rangefinder). These updates will reach the server only if the PDA is in an area with network coverage. However, there is no harm done if there is no coverage—the server simply will not receive the updates and the PDA’s current position won’t be shown on the server’s map.

5.2.5. Firewalls

Software firewalls (such as Symantec™ or McAfee®) will interfere with PDA-server network communications. At a minimum, the following ports should be opened for the BROOM application running on the server:

- TCP: 50880, 50881
- UDP: 50882, 50883, 50884

You may need to make additional changes to your firewall if you have additional desktop/laptop computers connecting to the database over the wireless network. The firewall on the computer running SQL Server must be configured to allow all network communications for SQL Server. Some firewalls also may have “intrusion prevention” settings that need to be altered. Symantec, for example, must be configured to stop watching for “MSSQL Null Packet DOS” attacks. In general, it is advisable to consult your tech support for assistance with your specific configuration.

5.2.6. USB Cable / PDA Cradle

In lieu of a wireless network, a USB cable or PDA cradle may be used for data transfers. Building/sample uploading and downloading is possible through the USB cable connected to the server. However, position updates will not function through the cable. To use the cable with a Windows XP machine, make sure Microsoft ActiveSync 4.5 is installed on the server. To use the cable with a Vista or Windows 7 machine, make sure the Windows Mobile Device Center (WMDC) is installed on the server. When the PDA is connected to the cable, ActiveSync or WMDC may pop up on the server and ask whether to establish a standard or guest partnership. Either is acceptable, but guest is much simpler. This connection must be established (i.e., the above question must be answered) before the PDA and server can communicate.

Note when connecting the Trimble Nomad, the USB cable must be plugged into the “mini-B” port (the small trapezoidal port) rather than the “standard-A” port (the larger rectangular port) on the PDA.

If the PDA and laptop server do not want to transfer data (e.g., maps), check that a setting on the PDA is set appropriately. From the Start menu in the upper left of the PDA screen, select Settings. Next, select the Connections tab at the bottom of the Settings screen. Next, tap on the USB to PC icon on the screen. The check box labeled “Enable advanced network functionality” should not be checked when communicating with a USB cable.

The BROOM application running on the PDA must be configured to connect to a server IP address of 192.168.55.100 (regardless of the server’s actual IP address). This special IP address allows the cable and ActiveSync to mimic a real network connection. The PDA itself will receive the address 192.168.55.101, but will appear to the server as 127.0.0.1, regardless of the PDA’s wireless IP address.

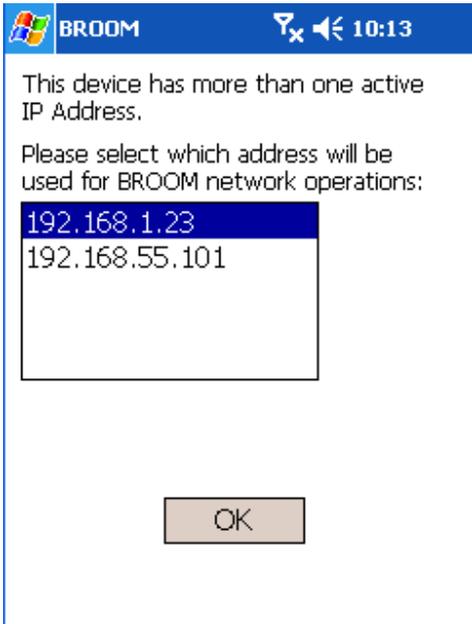


Figure 5-18. Multiple IP Addresses.

When the PDA is in the cradle it will typically have two IP addresses: its wireless address and the special cradle address mentioned above. When BROOM is started on the PDA, it will recognize this situation and ask which IP address to use (Figure 5-18). It does not matter which address is selected in this situation.

5.3. Traveling with the PDA

Most PDAs will turn on not only when the power button is pressed, but will also often turn on when *any* button is pressed. This increases the chances that the PDA will turn on while inside a suitcase during travel. If the PDA is on long enough it will drain the batteries. To prevent this from happening, the PDA should be configured to automatically turn off after some period of time. During normal usage—especially when using BROOM—this feature will generally be disabled.



Power

> **Settings** > the **System** tab > **Power** > the **Advanced** tab. Check or uncheck the **turn off device if not used for** option for battery power (Figure 5-19). Check this box to enable the feature for travel and then uncheck the box when you are ready to use the PDA at your destination. Tap **ok** to save the changes.

To enable or disable the auto-shutoff feature, tap **Start**

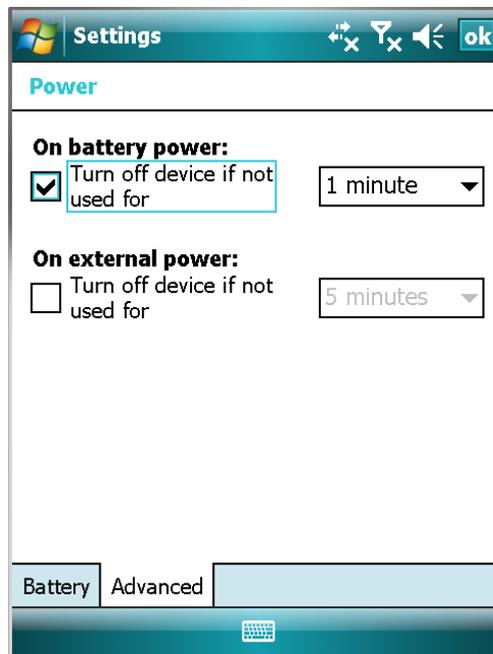


Figure 5-19. Power Settings.

6. USING THE PDA APPLICATION

In this section, the term “server” refers to the desktop/laptop computer running BROOM with which the PDA communicates. It does not refer to the database server (which may or may not be the same computer).

6.1. Starting BROOM

Initially the *BROOM* program icon does not appear on the *Start* menu. BROOM can be started by tapping **Start > Programs > BROOM** (Figure 6-1). It will take about 10 seconds for BROOM to start.

You may want to add the BROOM program icon to the Start menu. You can do this by tapping **Start > Settings > Menus**. Scroll down the list until you see *BROOM* and check the box next to it. Tap **ok** in the upper-right corner, and now the BROOM icon should appear on the Start menu (Figure 6-2).

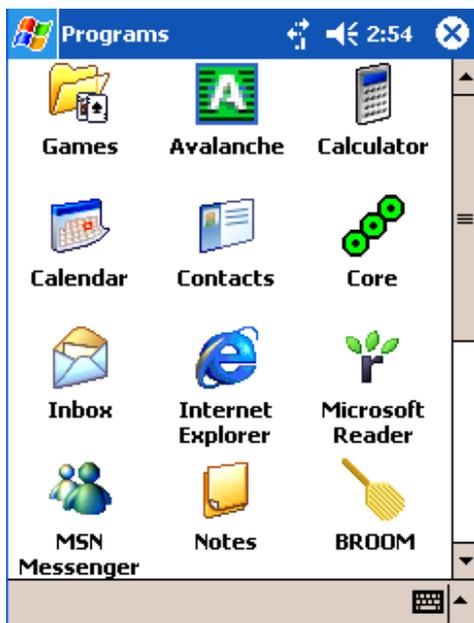


Figure 6-1. Programs.

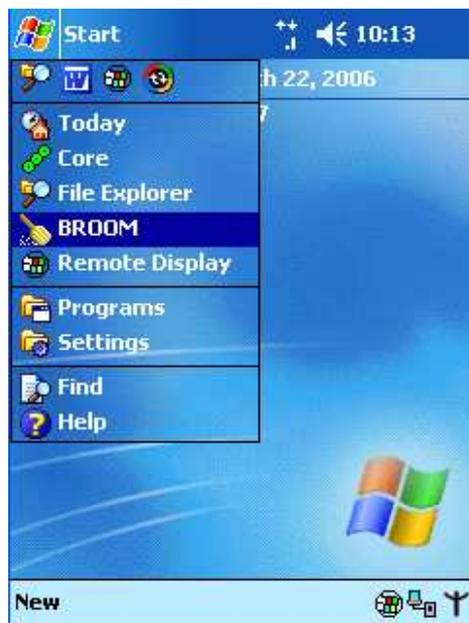


Figure 6-2. Start Menu.

When BROOM is done initializing and is ready to use, you will see the main menu (Figure 6-2).



Figure 6-3. Main Menu.

The following functions are available on the main menu:

- **Take Samples** allows the user to enter data for new samples. The user is guided through a sequence of forms for entering data such as the sample location and barcode.
- **Set Collector** allows the user to specify who is collecting the samples.
- **Select Floor/Select Zone** allows the user to select the current floor or zone. This dictates which map is shown by the *Take Samples* function.
- **Download** allows the user to download building information (maps, proposed samples, etc.) from the server.
- **Upload** allows the user to upload new samples to the server.
- **Setup** allows the user to edit various configuration settings.
- **Exit** terminates the application.

6.2. Downloading Building Information



The first step in using the PDA application is to download the building maps and proposed samples. This data transfer takes place over the wireless network (or USB cable—see Section 5.2.6); it is therefore necessary for both the PDA and server to be connected to the network. Note that it is necessary for the PDA to be connected prior to starting the application (likewise, the server should be connected before its application is started).

The PDA will communicate with BROOM running on the server; the server's application must be running and have the desired project loaded. The PDA will have access to data for any of the buildings in the server's project.

Before the PDA can download maps, the server must first generate special maps for the PDA. These maps are in a smaller, more efficient format than those used by the desktop application (and in some cases, they are broken up by zone). Refer to Section 4.10 for instructions on how to create the maps for the PDA.

To connect to the server and begin the download process, tap **Download** on the main menu. This will open the *Building Download* form (Figure 6-5). There are two components to this form: the upper half allows the user to scan the network for BROOM servers; the lower half (shaded light blue) specifies the network address of the desired server. If no server IP address has previously been specified, the window shown in Figure 6-4 will appear. Tapping **Yes** will search the network and populate the *Servers found on network* list. This can also be performed by tapping **Scan for Servers**. Tap an address in the list and then tap **Select** to copy this address into the blue *Server IP address* fields. Alternatively, an address may be manually entered by tapping in the first of the four address text boxes (to place the cursor) and then using the text entry control (the keyboard or stylus icon at the bottom of the screen (see Section 5.1.1)). Note that if no servers are found during a network scan it does not necessarily mean they are not there. It may be necessary to repeat the scan a time or two. Also, verify that both the server and PDA are connected to the network and have a reasonably strong wireless signal. The scan feature is merely provided as a convenience—if necessary simply enter the server IP address manually.

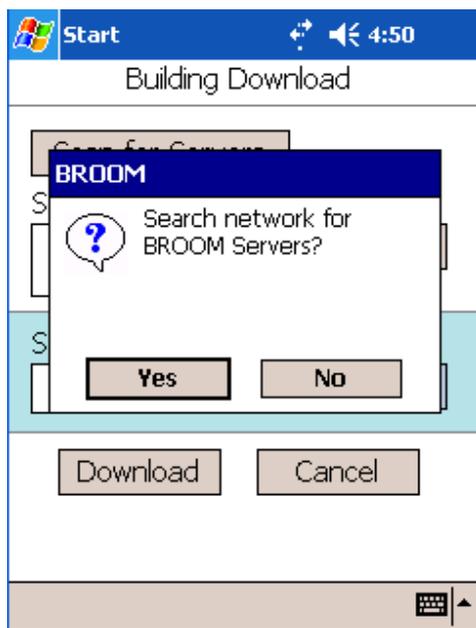


Figure 6-4. Server Search.

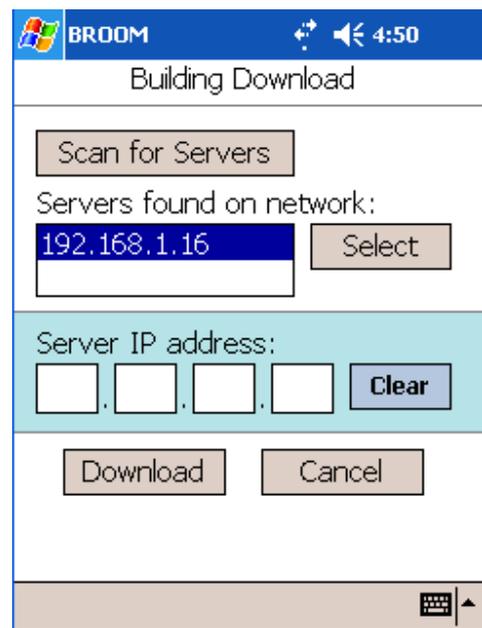


Figure 6-5. Server Address.

Tap the **Download** button to request the initial building information from the server. A few moments will pass while the data is being transferred over the network, and then the *Available Downloads* form (Figure 6-6) should appear. Tap the **Building** dropdown list to select a building (if more than one is defined in the server's project). There are two options governing the maps that will be downloaded. The default is to download maps for the entire floors. Optionally, if zones are defined in the building, the user may select specific zones and download only the

subsets of the map for the areas defined by the selected zones. Large and complex maps can slow down the PDA's performance; it may be advantageous to download only the zones of interest. To do this, select **Selected zones** and then tap the checkboxes for the desired zones (Figure 6-7).

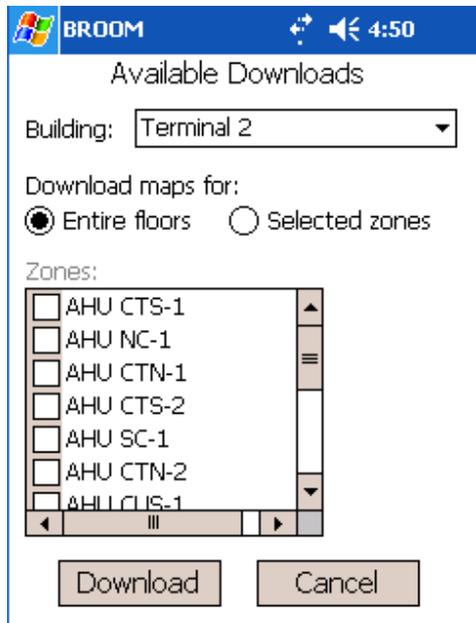


Figure 6-6. Available Downloads.

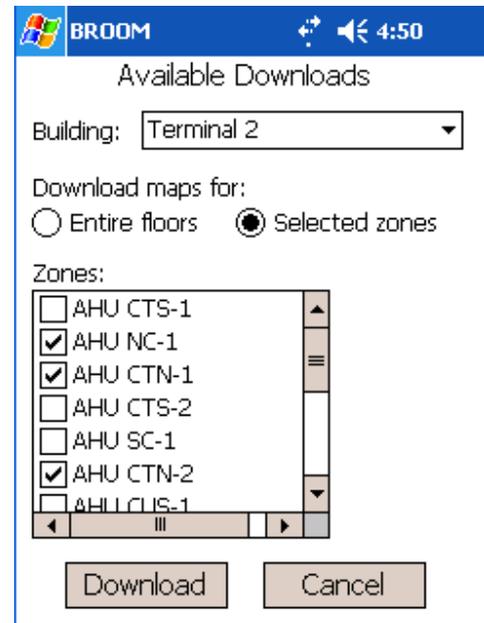


Figure 6-7. Selected Zones.

Tap **Download** to request the maps from the server. The maps (and other data such as proposed samples) will now be transferred across the network. This may take as long as several minutes depending on the complexity of the maps and the wireless signal strength. A message will appear when the download is complete (Figure 6-8). Tap **OK** to acknowledge the message. The PDA will now store the data in its local memory—this may take another minute or two. The main menu will appear when the process is complete.

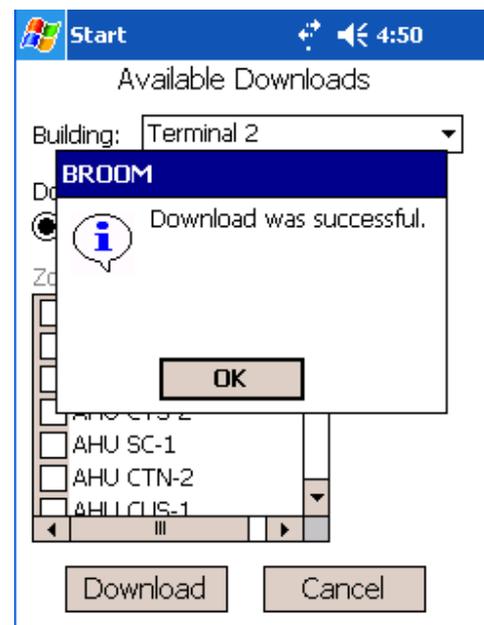


Figure 6-8. Successful Download.

6.3. Specifying the Collector



The collector is the person performing the sample collection. The application tracks the name of the collector and stores it as a part of the sample data. To change or enter a new collector, tap **Set Collector** on the main menu. Initially there are no defined collectors.

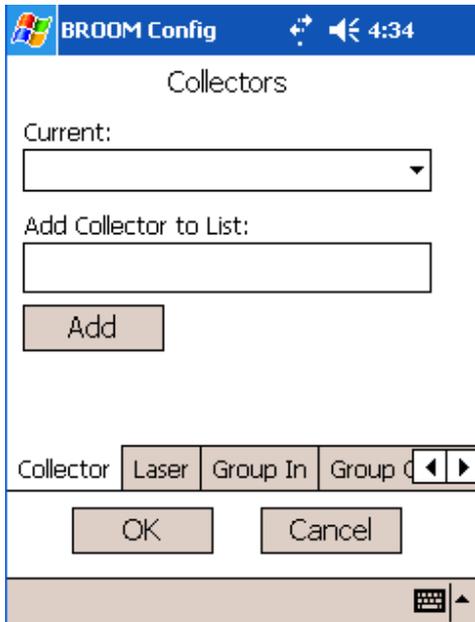


Figure 6-9. Collectors Form.

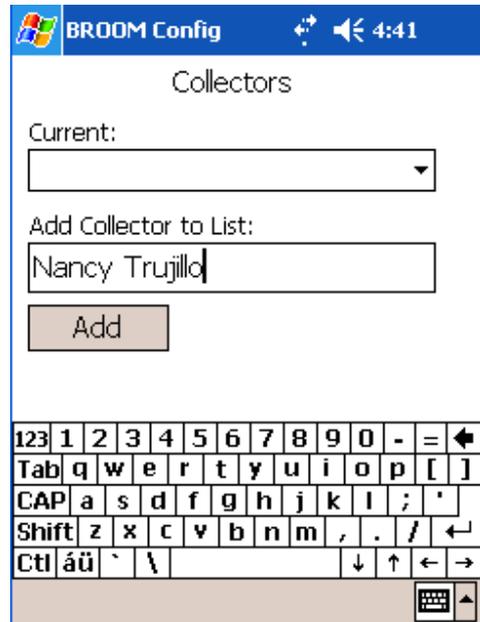


Figure 6-10. New Collector.

To add a new collector, tap inside the **Add Collector to List** text box (Figure 6-10) and use the text input control (see Section 5.1.1). Once you have entered the new name, tap **Add** and the collector will appear as the *Current* collector. If multiple collectors have been added, tap the

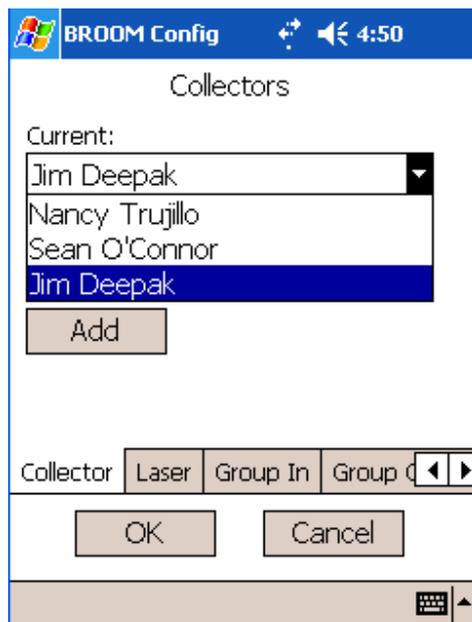
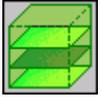


Figure 6-11. Existing Collectors.

Current dropdown list and choose from the existing collectors (see Figure 6-11). Tap **OK** to save the selection and close the form.

6.4. Selecting a Floor or Zone



The PDA application has a concept of the “current floor” (or zone). The current floor (or zone) determines what map is displayed when collecting samples. Furthermore, new samples are assigned to the current floor when they are created.

The type of maps (whole-floor or zone-specific) downloaded from the server (see Section 6.2) determines whether the user will be selecting a “current floor” or a “current zone.” If whole-floor maps were downloaded, the *Select Floor* button on the main menu will allow the user to select the current floor. If zone maps were downloaded, the same button will be labeled *Select Zone*. Selecting a zone is a two-stage process—first a floor is selected and then a zone is selected from that floor.

To select a floor (when whole-floor maps have been downloaded), tap **Select Floor** on the main menu. Tap on the **Current Floor** dropdown list to select one of the floors in the current building (see Figure 6-12). Tap **OK** to save the selection and return to the main menu.

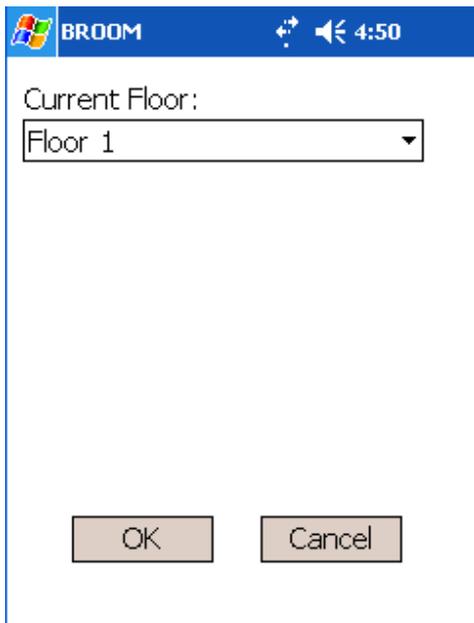


Figure 6-12. Floor Selection.

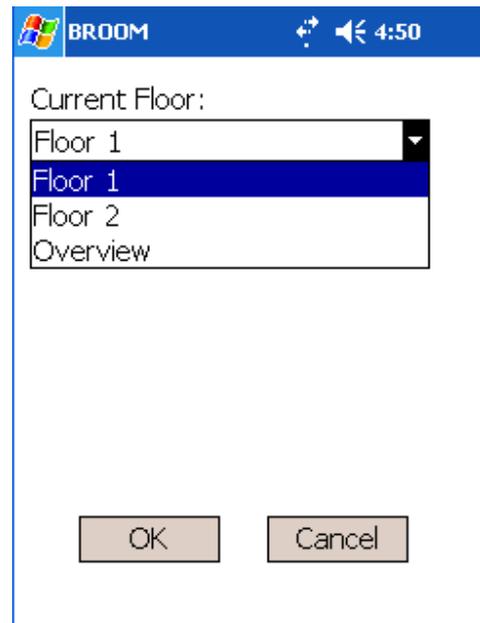


Figure 6-13. Floor Selection.

To select a zone (when zone maps have been downloaded), tap **Select Zone** on the main menu. Tap on the **Current Floor** dropdown list to select one of the floors in the current building (see Figure 6-14). Of the downloaded zones, those that have boundaries on the selected floor appear in the “Current Zone” list. Tap on a zone name to select it. Tap **OK** to save the selection and return to the main menu. Note it is possible that there may be no zones listed for a particular floor; the downloaded zones might exist only on certain floors.

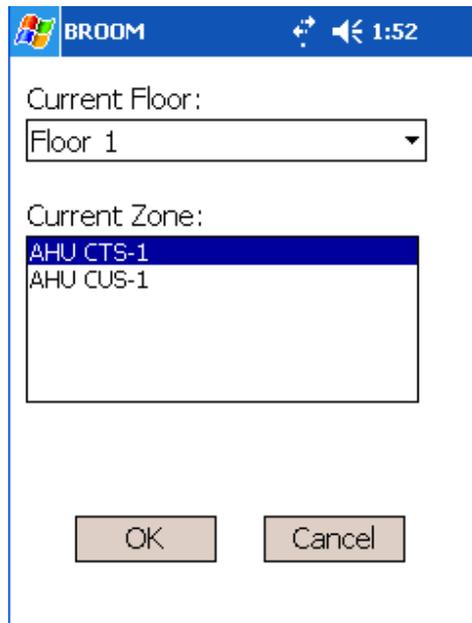


Figure 6-14. Zone Selection.

6.5. Collecting Samples



Tap **Take Samples** to begin the process of collecting a sample. This will initiate a sequence of forms for entering the data associated with a sample. There are six screens in this sequence:

- Map
- Position (details)
- Collection Method
- Sample Surface
- Sample Bar Code
- Sample Notes & Photo

6.5.1. Map / Sample Position

The first sample collection form is for the sample position (the location within the building). This is actually a combination of two forms: one shows the text of the x, y, and z coordinates and the other displays a map. Initially the first form appears as it does in Figure 6-15. This text form is primarily used for entering a z coordinate (the elevation of a sample off the floor, such as the height of a tabletop). Otherwise, the map form is used for determining the sample position. Tap **Show Map** to display the map. Before doing this, however, it is recommended to check the **Automatically display map** option (see Figure 6-16); this will cause the map to automatically appear rather than requiring you to tap the **Show Map** button for each new sample from this point on. With this option checked, the next time you tap **Take Samples** on the main menu the map will appear rather than the text form.

Figure 6-15. Sample Position Form.

Figure 6-16. Sample Position Form.

The map form is shown in Figure 6-17. The displayed map will of course depend on the map downloaded from the server. Initially the map will be zoomed out; generally the user will have the map zoomed in to some degree (see Section 6.5.1.2.3). The orange crosshairs (near the bottom left of the map) represent the origin of the map's coordinate system (0,0). The red crosshairs (near the center of the figure) indicate the position of the sample being taken. The red crosshairs will move about the map as a result of various kinds of user input. The map can be panned, zoomed in and out, and various types of data can be displayed or hidden. The toolbar buttons (along the bottom of the form) control these functions and are explained in the following sections.

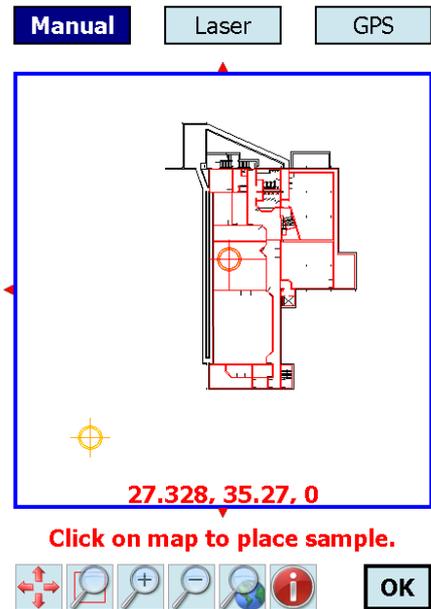


Figure 6-17. Map Form in Manual Position Mode.

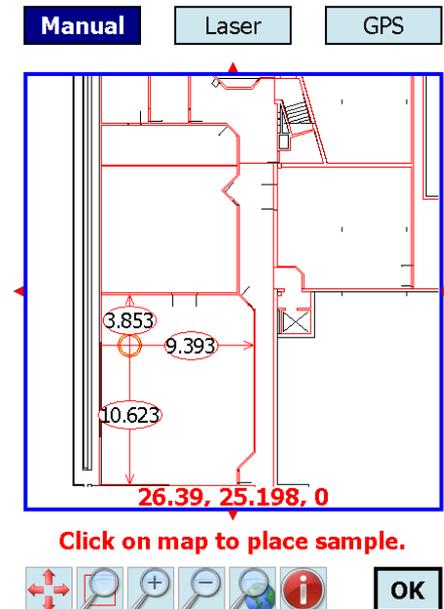


Figure 6-18. Manual Position Mode, Zoomed In.

6.5.1.1. Manual positioning mode

The **Manual** button at the top left places the map in manual positioning mode. This mode allows the user to tap on the map to indicate the sample’s position, as shown in Figure 6-18 (the map shown has been zoomed in somewhat—zooming is explained in Section 6.5.1.4 “Navigating the Map”). Note the thin black box outlining the button as well as *Manual Position Mode* appearing just above the toolbar. The arrows extending from the red crosshairs display the distances to the walls (in meters).

You may repeatedly tap on the map to adjust the sample position. Tap **OK** in the lower right corner to accept the position and return to the *Sample Position* text form.

6.5.1.2. Laser positioning mode

The **Laser** button at the top center places the map in laser positioning mode. This mode allows the user to use a Leica Disto Plus, Leica Disto D8, or TruPulse 360B laser rangefinder to determine the sample’s position within a room. There is some setup required prior to selecting this mode. Section 6.5.1.2.1 describes the initial setup procedure. Section 6.5.1.2.2 describes how to use the laser rangefinder.

6.5.1.2.1. One-time Laser Rangefinder Setup

The PDA communicates with the laser rangefinder via a Bluetooth wireless connection. Before using the rangefinder, some one-time setup must be performed to make the PDA aware of the rangefinder as a Bluetooth device. Note these steps and screenshots are geared for the Trimble Nomad PDA and may vary depending on your specific PDA. To perform this setup, tap the **Start** button (the Windows logo in the upper-left corner) > **Settings** > the **Connections** tab > **Bluetooth**. Then go to the **Mode** tab and turn on Bluetooth (Figure 6-19). Next, go to the **Devices** tab (Figure 6-20). Now, before attempting to connect to the rangefinder, we must turn on the rangefinder and enable its Bluetooth capability.

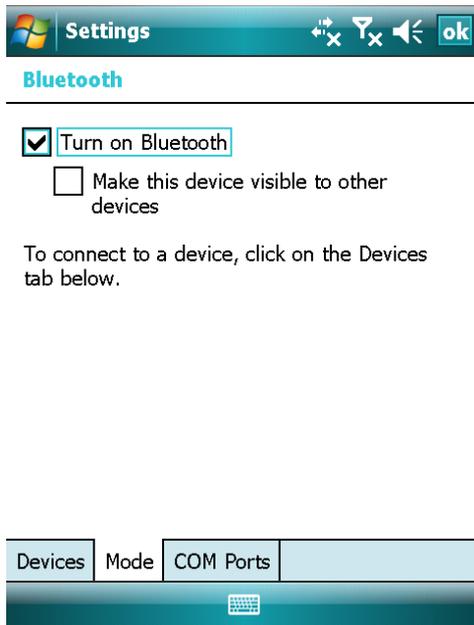


Figure 6-19. Turning Bluetooth On.

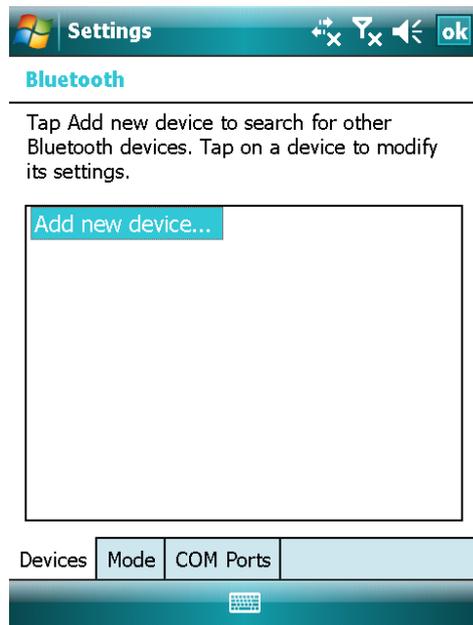


Figure 6-20. Bluetooth Devices.

If using the Leica Disto Plus or the Disto D8 rangefinder, turn it on and press its Bluetooth button (Figure 6-21). A flashing Bluetooth icon should appear on the display. At this point you have 2 minutes to complete the remaining configuration and connect to the PDA or the rangefinder will turn its Bluetooth back off. If it does automatically turn off, simply press the button again to turn it back on.

If using the TruPulse 360B rangefinder, first turn it on by pressing the **FIRE** button. Next, look through the viewfinder and press and hold the down arrow key until “Units” appears. Release the key and then apply one short press of the same down arrow key so that “bt” appears. Press the **FIRE** button to select bt. Now either “btoff” (Bluetooth is off) or “bt_on” (Bluetooth is on) will appear. If “btoff” is shown, press the down arrow key to change to “bt_on.” In either case, press the **FIRE** button to accept the displayed setting. Tap **Next** on the PDA to begin searching for Bluetooth devices.



Figure 6-21. Leica Disto Plus Buttons.



Figure 6-22. TruPulse 360B Buttons.



Figure 6-23. Bluetooth Passcode.



Figure 6-24. Bluetooth Serial Port.

Now return to the PDA and tap **Add new device** (Figure 6-20). The PDA will spend about 15 seconds searching, and then the rangefinder should appear in the list of devices (Figure 6-23). It will be called “DISTO nnnnnnnn” or “TP360B-nnnnnn” where *n* is the rangefinder’s serial number. Select this device by tapping on it in the list and then tap **Next**. You will now be asked to enter a passcode to connect to the rangefinder (Figure 6-23). Enter 0000 for the Leica Disto Plus and Disto D8 or 1111 for the TruPulse 360B. Tap **Next** after entering the passcode.

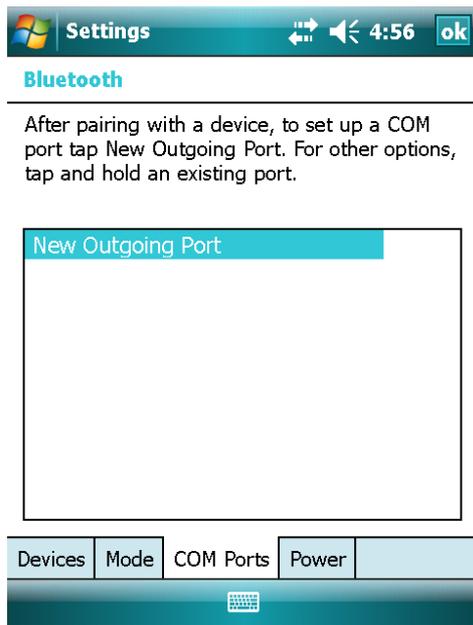


Figure 6-25. Outgoing Port.

On the *Partnership Settings* screen (Figure 6-24), check the box next to **Serial Port** and then tap **Finish**. At this point you will return to the main Bluetooth settings screen (Figure 6-20). Go to the **COM Ports** tab and tap **New Outgoing Port** (Figure 6-25). Next, you will see the *Add a Device* screen. Select the name of the rangefinder device and tap **Next**. Now, on the screen seen in Figure 6-26, make sure **COM8** is selected and make sure **Secure Connection** is NOT checked. Now tap **Finish** and then tap **ok** in the upper right to exit the Bluetooth configuration.

The PDA is now configured to use the specific rangefinder used in these steps. Imagine several PDAs—each with their own rangefinder—being used simultaneously. Because each PDA is wirelessly communicating with its rangefinder, each PDA must know specifically which rangefinder to talk to. It is for this reason that the PDA is configured to work with a single, specific rangefinder. To use a different

rangefinder, repeat these steps to establish a new link between the PDA and rangefinder.

6.5.1.2.2. Using Laser Positioning Mode

Laser positioning mode allows the user to easily determine the sample's position by firing the laser at two walls of a room. Given the current room and the two distance measurements, the application can determine the position within the building. SNL was granted a patent for this functionality.

The **Laser** button (top center) places the map in laser positioning mode. The PDA will attempt to connect to the rangefinder the first time the laser toolbar button is tapped. Prior to selecting laser positioning mode, the rangefinder must be turned on with Bluetooth enabled. On the Disto, the Bluetooth indicator will flash while Bluetooth is enabled but not yet connected (Figure 6-26). It is important to note that the rangefinder will turn off Bluetooth if no connection is established within two minutes. If this happens, simply turn Bluetooth back on by pressing the button on the rangefinder. The TruPulse lasers are simpler—as long as the initial configuration (Section 6.5.1.2.1) was successful, the TruPulse merely needs to be powered on.



Figure 6-26. Rangefinder Buttons.

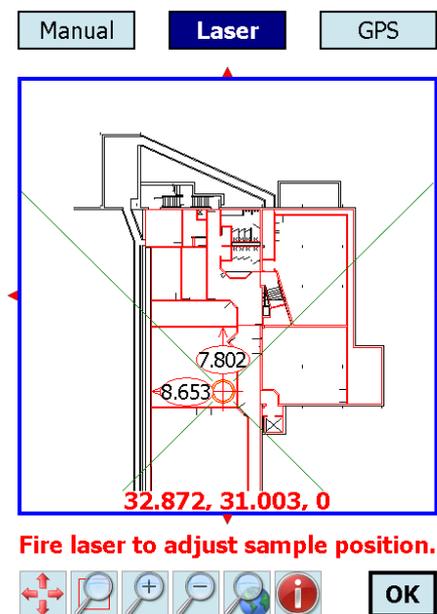


Figure 6-27. Laser Positioning Mode.

To connect the PDA to the rangefinder, select laser positioning mode by tapping the **Laser** button. After a few seconds, the screen will indicate a successful connection. This connection will remain in effect until BROOM is exited. The Leica rangefinders are under the control of BROOM and cannot be turned off until the connection is broken. The TruPulse rangefinder is not explicitly controlled by the PDA, like the Leica, but does transmit distance data to the PDA.

The map should now be in laser positioning mode (see Figure 6-27). Note *Fire laser to adjust sample position* appearing just above the toolbar.

The next step is to manually place the red crosshairs in the room in which you are standing by tapping in the room (see Figure 6-28). It is a good practice to place the crosshairs at a rough approximation of the sample position. It is necessary to place the crosshairs in the correct room in order to translate the rangefinder's measurement to the correct position on the map.

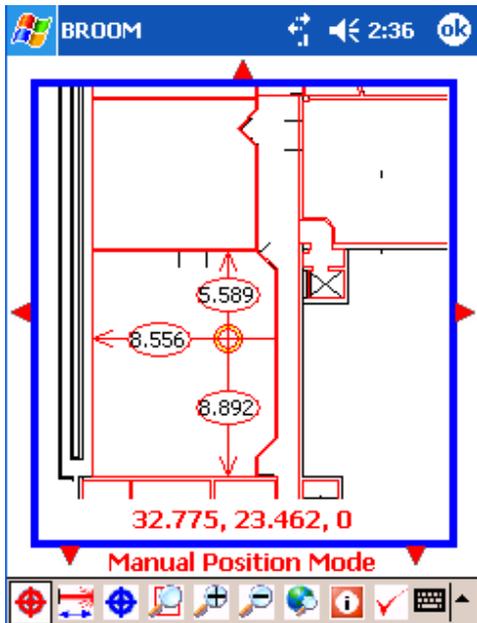


Figure 6-28. Laser Room Selection.

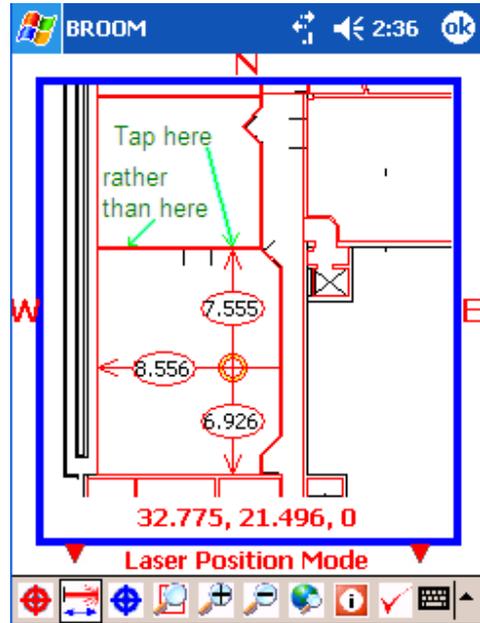


Figure 6-29. First Laser Measurement.

The following narrative discusses the use of the Leica laser system. Now return to laser positioning mode (tap the laser mode button). To take the first distance measurement, aim the laser at a wall and tap that same wall on the map. To ensure the application correctly interprets

your wall selection on complex maps, it is a good practice to follow the arrow coming from the crosshairs and tapping where it meets the wall as shown in Figure 6-29. In this example, the laser was fired at the wall to the north of the crosshairs. Note the new position of the crosshairs, now 7.555 meters from the north wall.

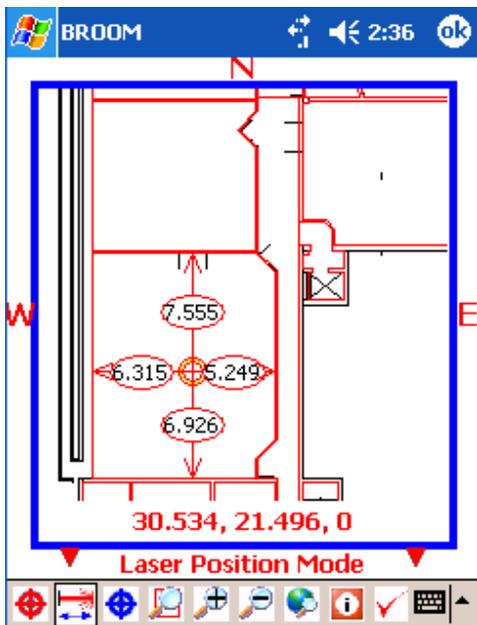


Figure 6-30. Second Laser Measurement.

Next, establish the position along the other axis by selecting a perpendicular wall and taking the second measurement. In Figure 6-30, the laser was fired at the west wall. Note the distance from that wall has changed to 6.315 meters.

You may take as many measurements as necessary to establish the sample position. When the rangefinder takes a measurement, you will see the red laser dot momentarily appear on your target surface. Watch for this to ensure you hit your intended target; sometimes the laser is not aimed exactly where you intended and you will have to retake a measurement. You may accidentally hit a column rather than the wall behind it,

for example. Also, be aware of windows and reflective surfaces (especially mirrors). The laser will likely just go through a window. Hitting a mirror will extend the measured distance to whatever object the laser hits after bouncing off the mirror.

When you are satisfied with the measured position, tap **ok** in the upper right corner to accept the position and return to the sample position text form.

6.5.1.2.3. Leica Laser Control Modes

There are three different modes for controlling the rangefinder:

- **Single Shot/1-Pick:** this is the default mode. To take a measurement, tap a wall on the map to fire a short laser burst. This mode is fast and simple but can make it difficult to visually verify where the laser actually hit.
- **Point and Shoot/2-Pick:** this mode requires two screen taps to take a measurement. First, tap anywhere on the map to turn the laser on. The laser remains on, allowing you to aim the beam to the intended target. Once the beam is aimed, taps a wall on the map to take the measurement.
- **Continuous Shot/Multi:** this mode provides a periodic live update of the current distance from a wall. Taps a wall on the map to turn on the laser. The rangefinder will continually take periodic measurements and update the position of the red crosshairs on the map. You can then walk towards or away from the wall until at the desired position. This mode is useful when trying to line-up with some predetermined position (such as a proposed sample). To turn off the laser and stop the updates, tap the screen.

There are two ways to set the laser control mode. From the map, set the mode via the **Map Options** (see Section 6.5.1.5). From the main menu, set the mode via the **Setup > Laser** menu (see Section 6.7.3).

6.5.1.2.4. TruPulse Operation

The TruPulse laser rangefinder functions more simply than the Leica lasers. Once the user has tapped the **Laser** button on the PDA map, then they should pan/zoom to the room they are taking samples in. By tapping in the confines of the room the target icon appears and the distances in meters to each wall are displayed on the map. Next the user positions the TruPulse over the location that is being sampled and fires the laser at a wall. It is advisable to look through the viewfinder of the TruPulse to determine where the device is being aimed. The TruPulse contains an infrared laser, which is not visible to the naked eye. Therefore, caution must be exercised in firing the laser at the appropriate target on the wall, such that the laser is not aimed at some other object like a desk or bookshelf. The TruPulse laser has a directional compass built in to the device and transmits this information to the PDA as well. The PDA determines which wall has been shot with the laser and updates the location on the PDA map. Therefore the user does not have to indicate on the PDA which wall is being shot. Next, the user turns the laser 90° to an adjacent wall and fires the laser again. This in turn updates the location of the sample. When satisfied with the positioning of the sample, the user taps the **OK** icon. The next screen is a summary of the coordinate information and has an icon to return to the map (see Figures 6-15

and 6-16). The user may now enter a z height for the sample if desired. By tapping on **Edit** a pop-up will appear with a number keypad to enter values. Alternatively, when using the TruPulse, the device can be tilted downward and the user pushes the fire button to take a height measurement. The TruPulse has a tilt meter that allows it to sense when in a vertical position for this height measurement.

6.5.1.3. Proposed Samples

Proposed samples are locations where a sample should be taken. These come from the desktop application at the same time that the maps are downloaded into the PDA. Proposed samples appear on the map as blue dots. To enable or disable the display of proposed samples, tap the “i” toolbar button to open the *Show on Map* screen (Figure 6-32). Then check or uncheck the

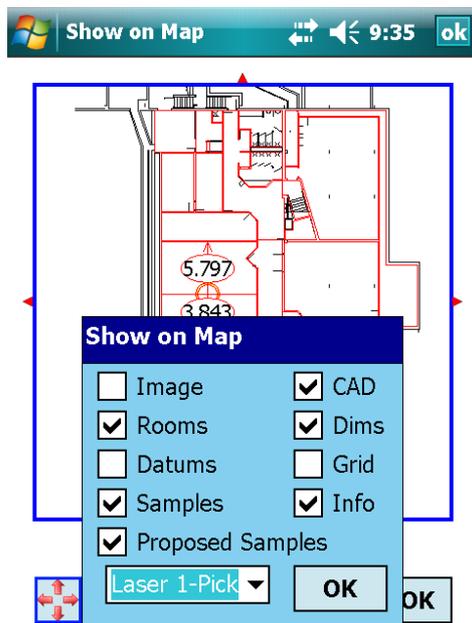


Figure 6-32. Proposed Sample Option.

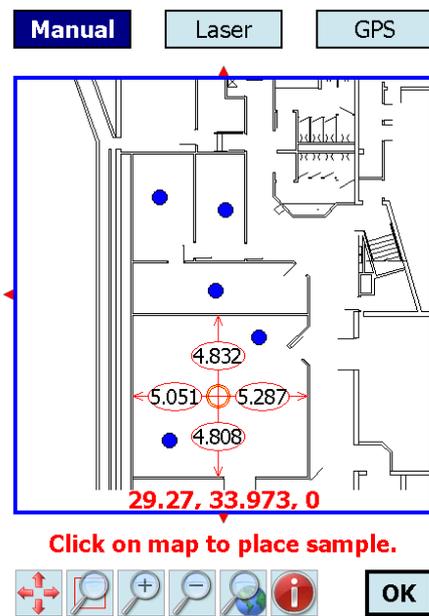


Figure 6-31. Proposed Samples On Map.

Proposed Samples box and tap **OK**.

6.5.1.4. Navigating the Map

The map may be zoomed in and out and panned in the four cardinal directions. The following sections describe these features.

6.5.1.4.1. Window Zoom



The *zoom window* button places the map in a mode that allows the user to draw a red box/window around a region to zoom in to. Note the thin blue box outlining the button as well as *Drag stylus to define zoom window* appearing just above the toolbar when selected (Figure 6-33).

To draw the zoom window, place the stylus at the upper-left corner of the desired region. Drag the stylus to the lower-right corner of the region and then lift the stylus. The map will zoom in to this region. Figure 6-33 shows a zoom window (red square) drawn around the southern portion of the building map. Note this is a “single use” button, meaning you will no longer be in *zoom window* mode after performing the zoom. Tap the button again if you wish to zoom again.

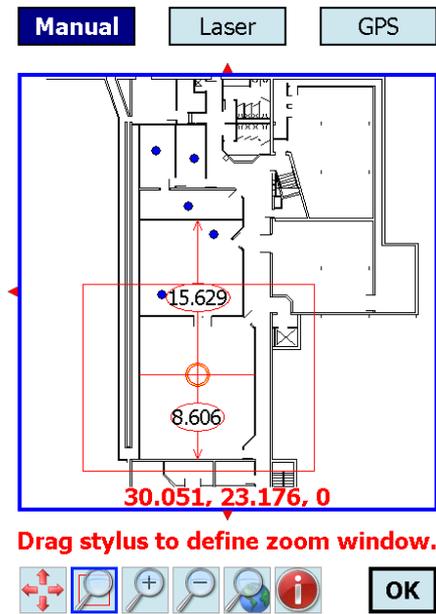


Figure 6-33. Zoom Window Mode.

6.5.1.4.2. Zoom In and Zoom Out



The *zoom in* and *zoom out* buttons zoom in or zoom out one step. They are not modes, meaning the buttons perform one-time actions and do not stay selected.

6.5.1.4.3. Zoom World



The *zoom world* button zooms all the way out to show the entire map. It is not a mode, meaning the button performs a one-time action and does not stay selected. This button is useful if you have become disoriented or zoomed-in too far on the map.

6.5.1.4.4. Panning



The *panning* mode allows you drag the map with the stylus in order to adjust which portion of the map is visible. Note the thin blue outline surrounding the button when selected, as well as the *Drag stylus to move map* visible just above the toolbar. Unlike the other toolbar buttons, this one remains selected until you tap it again to deselect it and exit the mode. Also, note that you may pan the map up, down, left, or right at any time regardless of the map mode by tapping just outside the map in the desired direction.

6.5.1.5. Map Options



The *map options* button allows the user to control what is and is not shown on the map. Tapping the button brings up the form shown in Figure 6-34.

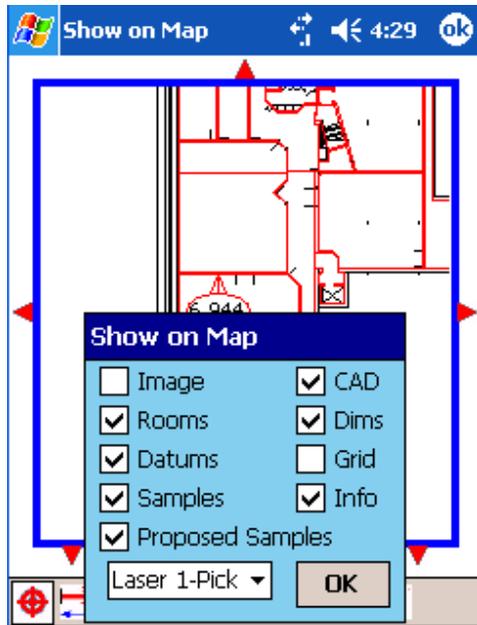


Figure 6-34. Map Options.

- **Image** controls the visibility of the map image received from the server.
- **CAD** controls the visibility of the CAD drawing received from the server. The CAD drawing will only be available if the server’s map is CAD-based.
- **Rooms** controls the visibility of the room definitions provided by the server. Room outlines show up as red on the map.
- **Dims** controls the visibility of the “distance arrows” that extend from the red crosshairs on the map. When Dims are enabled, the distance of the sample position from each wall is shown.
- **Datums** controls the visibility of datums on the map (datums are very rarely used).
- **Grid** controls the visibility of a 1-meter grid overlay on the map.
- **Samples** controls the visibility of samples that have been taken but not yet uploaded. Samples appear as red dots on the map.

- **Info** is no longer used and can be ignored.
- **Proposed Samples** controls the visibility of proposed samples. Proposed samples appear as blue dots on the map. Proposed samples can be filtered by groups via the main menu, as described in Section 6.7.1.
- The laser control mode can be set with the dropdown list to the left of the **OK** button. See Section 6.5.1.2.3 for a description of these modes. These modes apply only to the Leica Disto Plus laser.

6.5.2. Collection Method

The *Collection Method* form (Figure 6-35) is reached by tapping **Next** on the *Sample Position* form (if you are on the map screen, you must hit **OK** at the bottom right to return to the *Sample Position* form).

Tap one of the icons to select the collection method. The selected method is highlighted blue with bold text. *Swab* is the selected method in Figure 6-35.

Tap **Next** to accept the collection method and advance to the *Sample Surface* form.

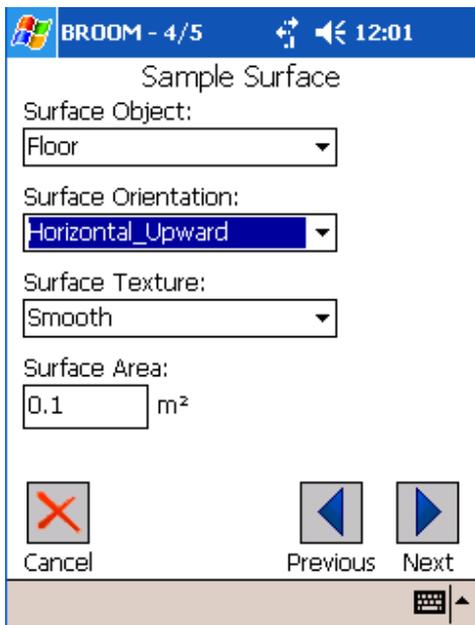


Figure 6-35. Collection Method Form.

6.5.3. Sample Surface

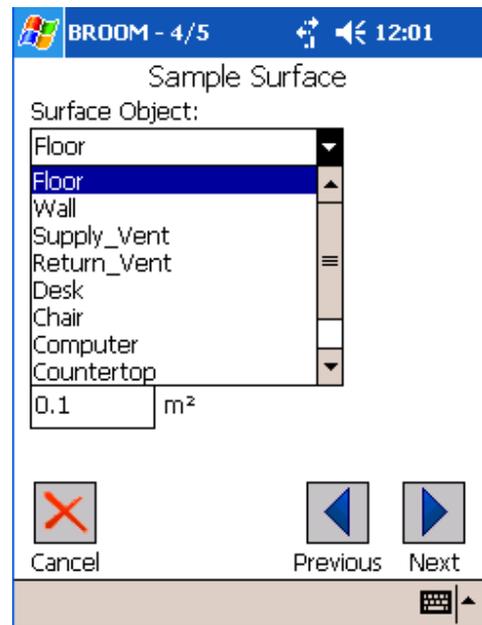
The *Sample Surface* form is reached by tapping **Next** on the *Collection Method* form. This form allows the user to specify the type of object being sampled (floor, desk, etc.), the orientation of the surface (horizontal upward-facing, vertical, etc.), the surface texture (glass, carpet, etc) and the size of the area sampled. Tap the **Surface Object**, **Surface Orientation**, or **Surface Texture** box to drop down a list of possible selections. The **Surface Area** can be edited by tapping in the text box and then using the text input control (see Section 5.1.1).

Tap **Next** to accept the selections and advance to the *Sample Barcode* form.



The screenshot shows the 'Sample Surface' form on a mobile device. The title bar at the top reads 'BROOM - 4/5' and '12:01'. The form contains four fields: 'Surface Object:' with a dropdown menu showing 'Floor'; 'Surface Orientation:' with a dropdown menu showing 'Horizontal_Upward'; 'Surface Texture:' with a dropdown menu showing 'Smooth'; and 'Surface Area:' with a text input field containing '0.1' and a unit 'm²'. At the bottom, there are three buttons: 'Cancel' (with a red X icon), 'Previous' (with a left arrow icon), and 'Next' (with a right arrow icon). A keyboard icon is visible in the bottom right corner.

Figure 6-36. Sample Surface Form.



The screenshot shows the 'Sample Surface' form with the 'Surface Object:' dropdown menu open. The list of options includes 'Floor', 'Wall', 'Supply_Vent', 'Return_Vent', 'Desk', 'Chair', 'Computer', and 'Countertop'. The 'Floor' option is currently selected and highlighted in blue. The other fields and buttons remain the same as in Figure 6-36.

Figure 6-37. Surface Object List.

6.5.4. Sample Barcode

The *Sample Barcode* form (Figure 6-38) is reached by tapping **Next** on the *Sample Surface* form. This form allows the user to enter the sample's barcode, either by using a scanner or by manually entering the text.



Figure 6-38. Barcode Form.



Figure 6-39. Scanned Barcode.

The Trimble Nomad PDA (certain models) has an integrated barcode scanner. To scan a barcode, hold the barcode about 6 inches from the scanner (at the top of the PDA) and press the Windows logo hardware key at the top left of the hardware keypad. The laser will read the barcode and populate the text box on the screen (Figure 6-39) (or the laser will give up after 3 seconds if no barcode is found – just press the key again to try again).

If the barcode scans successfully but doesn't appear on the form, make sure the cursor is blinking in the *Bar Code* text box. Tap inside the text box and then try scanning again.

The **Clear** button can be used to erase the *Bar Code* text box.

If necessary, a barcode can be manually entered by using the text input control (see Section 5.1.1).

Tap **Next** to accept the barcode and advance to the *Sample Notes & Photo* form.

6.5.5. Sample Notes & Photo

The *Sample Notes & Photo* form (Figure 6-40) is reached by tapping **Next** on the *Sample Barcode* form. This form can be used to enter any notes concerning the sample. The notes might contain anything unusual about the sample or a justification for taking it, for example. The text is entered using the text input control (see Section 5.1.1). You may also use this form to take a photograph of the sample location. Tap the **Take Photo** button to switch to camera mode. You will see a live preview on the screen. Press the enter key (↵) on the hardware keypad to take the photo. You will then see the frozen image on the screen. Press the enter key again to return to the *Sample Notes & Photo* form. The photo is now part of the sample record.

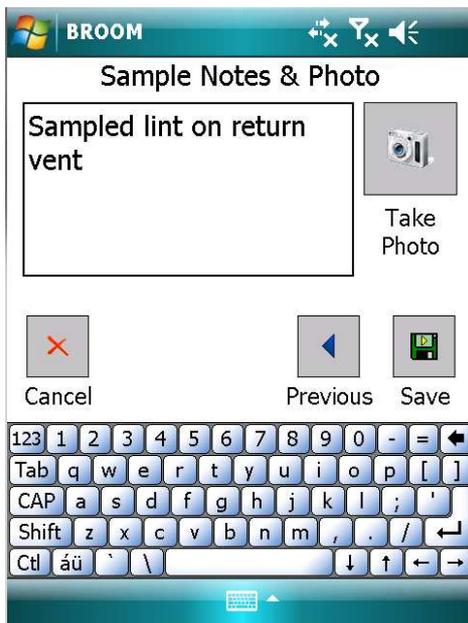


Figure 6-40. Sample Notes Form.

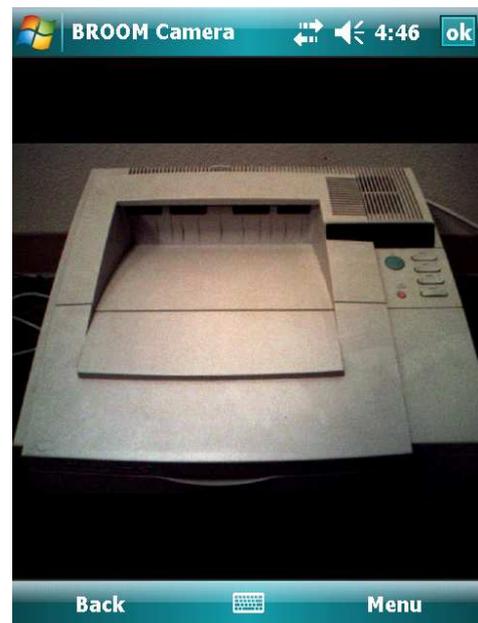


Figure 6-41. Sample Notes.

Tap **Save** to store the sample locally on the PDA. The sample will not be sent to the server until an upload is initiated by the user (see Section 6.6). Once the sample is saved, the sampling screen sequence restarts; the *Sample Position* or map form will appear for a new sample to be taken. To exit to the main menu at any time, tap **Cancel**. If the map form is being displayed, it must first be closed (tap **ok** in its upper-right corner) to be able to see the *Cancel* button on the *Sample Position* form.

6.6. Uploading Collected Samples



To upload new samples to the server, tap **Upload** on the main menu. The *Upload to Server* form (Figure 6-42) will appear.

This form displays information about the upload operation. The first two lines show the number of data items that you have collected that are ready to be uploaded. For the example in Figure 6-42, no datums and two samples have been collected and are ready to be uploaded to the BROOM server. Beneath the blue box, the server address is listed. Double check this value; it should agree with the server address you used when you downloaded the building and sample information at the beginning of the sampling sequence.

Before you can upload the sample data, you must sign your name in the white rectangular space inside the light blue box with the stylus. Your signature in the box attests that you collected that data that you are about to upload. Creating your electronic signature is simple; just write your name inside the box. You'll find that it may take a few times to get a recognizable signature. To erase your signature and try again, just tap the **Clear** button. Once you have a satisfactory signature, tap the **Upload** button to begin the upload process.

The PDA establishes contact with the BROOM server and then attempts to upload the sample data. If the upload is successful, a small alert window pops up telling you that the upload is complete (Figure 6-43, center). After tapping on the **OK** button, the upload form is changed to reflect the successful upload status (Figure 6-43, right). Notice that the signature box has been removed because your signature has already been transmitted. Also, the quantity of samples that had shown up in the *Ready* list is now in the *Sent* list. The green check mark next to the sent sample total confirms that those samples did make it to the server. Since everything went through successfully, tap the **Close** button to return to the main menu.

	Ready	Sent
Datums:	0	0
Samples:	1	0

Sign here: **Clear**

Collector: Tom Scholz

Server address: 192.168.55.100

Review **Upload** **Close**

Figure 6-42. Upload Form.

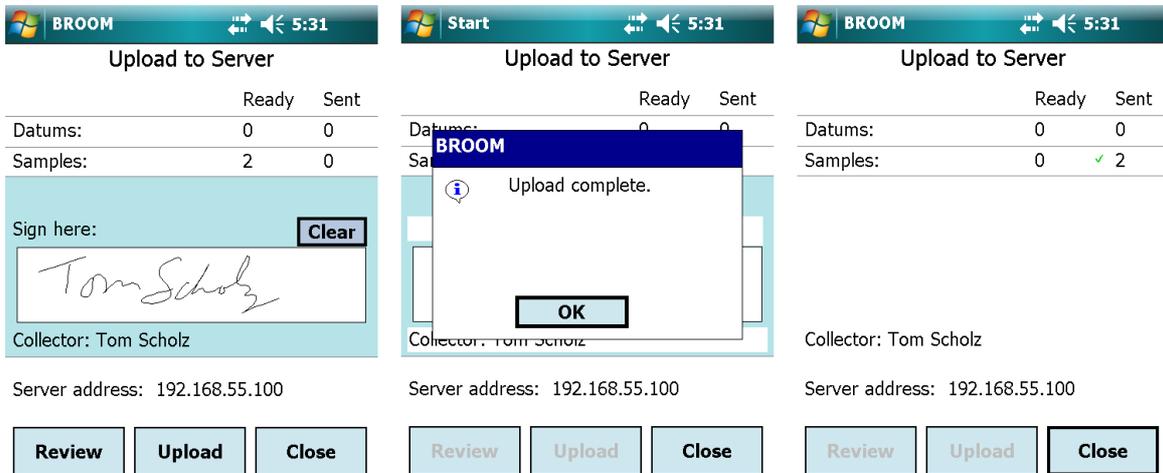


Figure 6-43. Upload Screen Sequence.

6.6.1. Troubleshooting Uploads

In the event of an error during the upload process, and alert such as the one shown in Figure 6-44 will appear. The most likely cause of a failure is the loss of the wireless network connection. In larger buildings, wireless coverage can be spotty, so it is often a good idea to upload from a location where you know that the wireless signal strength is high. Usually, the best location with the best wireless signal strength is very close to the wireless router. If you do get an error alert such as that shown in Figure 6-44, first try walking to a location close to the router and repeating the upload procedure. Once wireless connectivity is re-established the upload should progress normally.

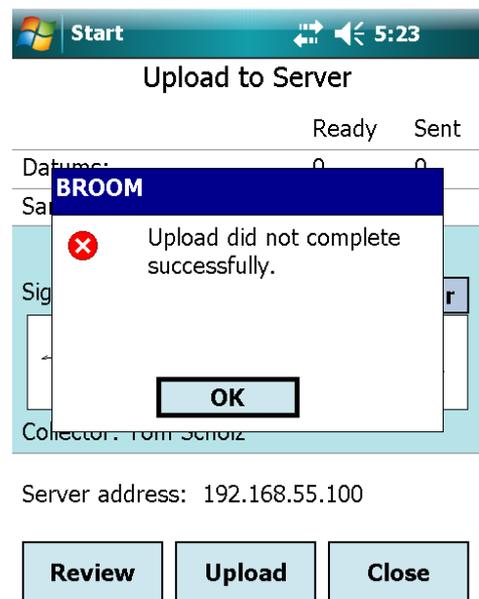


Figure 6-44. Upload Error.

6.7. Miscellaneous Configuration

There are several configuration options available from the main menu. They are accessed by tapping the **Setup** menu at the bottom-left of the main menu (Figure 6-45).

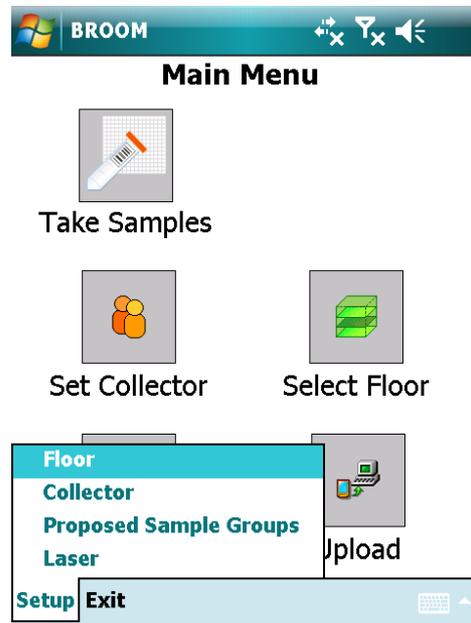


Figure 6-45. Setup Menu.

6.7.1. Proposed Sample Groups

To filter the proposed samples that appear on the map, select **Proposed Sample Groups** from the **Setup** menu on the main menu. The *Proposed Sample Groups* form (Figure 6-46) allows the

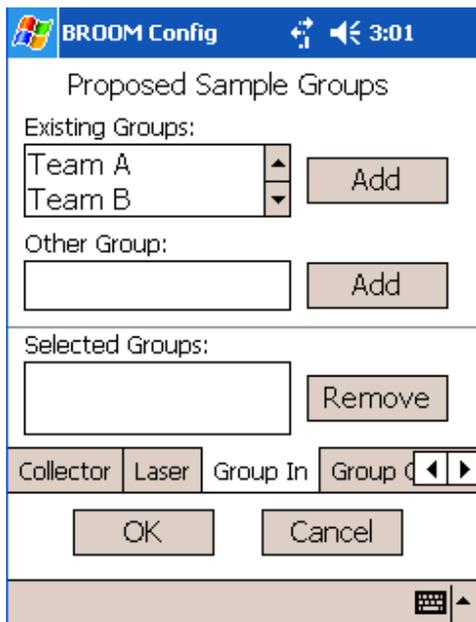


Figure 6-46. Proposed Sample Groups Form.

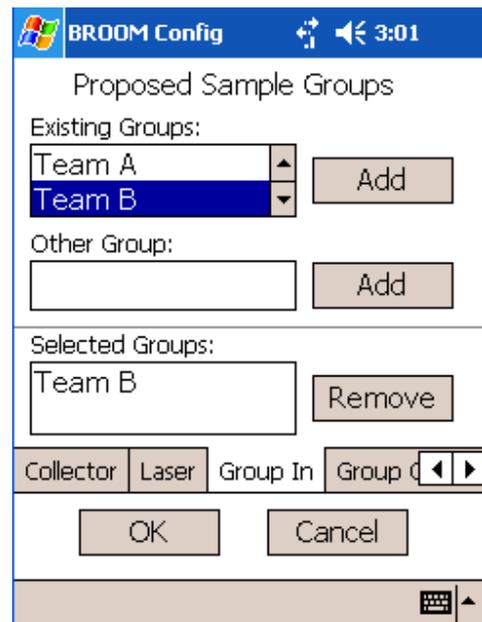


Figure 6-47. Selected Groups.

user to select which groups will be visible. The *Existing Groups* list contains all of the groups defined in the proposed samples received in the last download from the server. By selecting a group in *Existing Groups* and then tapping **Add**, the group will be added to the *Selected Groups* list. Proposed samples belonging to groups in the *Selected Groups* list will be visible on the map. To remove a group from *Selected Groups*, select the group name and then tap **Remove**. Figure 6-47 shows that group “Team B” has been added to the *Selected Groups* list. The *Other Group* text box allows the user to add a nonexistent group to the *Selected Groups* list. The user may wish to do this in anticipation of a proposed sample group that will be downloaded at a later time.

Note that proposed samples with no assigned group (a blank group name) will always be visible on the map.

Tap **OK** to save the changes (or tap **Cancel** to abort) and return to the main menu.

6.7.2. Outgoing Sample Group

The *Outgoing Sample Group* can be configured to assign a sample group to new samples as they are created on the PDA. Tap the **Setup** menu from the main menu, and then tap **Proposed Sample Groups**. Then tap the **Group Out** tab (to the right of the *Group In* tab) to display the *Outgoing Sample Group* form (Figure 6-48).

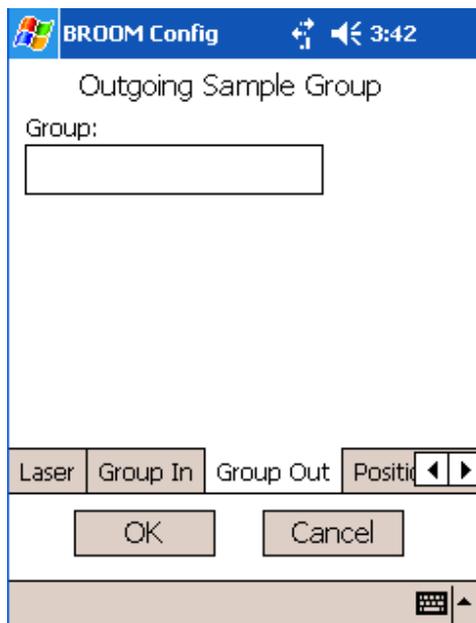


Figure 6-48. Outgoing Sample Group Form.

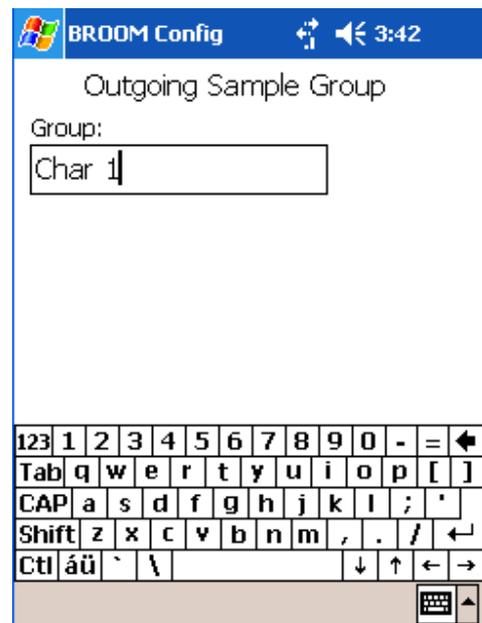


Figure 6-49. Outgoing Sample Group.

Tap in the *Group* text box to enter the group name using the text input control (see Section 5.1.1). Close the text input control (tap on the keyboard, stylus, or handwriting icon in the bottom-right corner) and tap **OK** to save the changes (or **Cancel** to abort) and return to the main menu.

6.7.3. Laser Control Mode

Tap **Setup** > **Laser** from the main menu to configure the laser control mode. Note this setting pertains only to the Leica Disto Plus laser. The three modes are described in Section 6.5.1.2.3. Tap **OK** to save the change (or **Cancel** to abort) and return to the main menu.



The screenshot shows a mobile application window titled "BROOM Config" with a status bar at the top displaying the time "10:38". The main content area is titled "Laser Rangefinder" and contains a "Mode:" label above a dropdown menu currently set to "Single Shot". Below the main content area is a navigation bar with four tabs: "Collector", "Laser", "Group In", and "Group C", with the "Laser" tab selected. To the right of the "Group C" tab are left and right arrow icons. Below the navigation bar are two buttons: "OK" and "Cancel". At the bottom right of the window is a keyboard icon and an upward-pointing arrow.

Figure 6-50. Laser Configuration Form.

7. ADVANCED ANALYSIS USING BROOM

7.1. Overview

BROOM provides a rich variety of integrated analysis tools. These tools provide the means to: (a) better understand the extent and magnitude of the contamination event and (b) generate operational recommendations for number and location of samples that need to be taken.

The tools provided can be categorized into four main groups:

1. Enabling tools: Generate sample sets and spatial constructs that are used by other tools
2. Mapping tools: Generate estimates of contaminant concentration at locations where no samples were taken. These estimates are then plotted on maps.
3. Conventional Sample Design Tools: Create sampling plans and proposed sample locations based on traditional statistical approaches
4. Optimized Sampling Design Tools: Apply machine-learning methods to define the best possible sample sites based on prior results.

A major strength of the BROOM analysis tool suite lies in its tight coordination with other BROOM components. The tools are tightly integrated with the sample dataset and the building model for input. Output can be viewed immediately by use of the BROOM visualization system of maps and graphs. Finally, analysis input, output and metadata are stored seamlessly in the BROOM database.

7.2. Enabling Tools

The sophisticated mapping, statistical and optimization functionality exposed by the analysis tool suite relies on simple common data collections to describe samples and areas of the building. BROOM provides easy to use enabling tools which construct these simple data structures which are used by more advanced analysis tools.

7.2.1. *Sample Sets*

A Sample set is a snapshot of the locations and values of samples used in an analysis. BROOM provides interactive user controls to filter the full sample dataset to produce sample sets that meet particular criteria. Sample sets maintain historical validity even if samples locations are later recomputed or sample values are analyzed again and found to be different. Once generated, the sample locations and values of a sample set become disassociated with the BROOM sample dataset. That is, an edit or deletion of a sample's location of laboratory value after a sample set is created does NOT retroactively alter values in the sample set.

7.2.1.1. *Sample Set Filters*

Filters can be defined to create sample sets which are smaller than the current floor's entire sample dataset. BROOM supports four methods of filtering sample sets. The sample set filters are additive, if more than one method is defined, samples must pass through all active filters to remain in the sample set.

7.2.1.1.1. Collection Method Filter

Any combination of sample collections methods may be specified in constructing a sample set (Figure 7-1). The accompanying filter shows a collection method filter being defined to include samples collected with wipes and mini vacuums. This filter will exclude any samples collected with any of the methods shown in Figure 7-1 which are not checked. Collection method filters are particularly useful when dealing with scenarios for which the factors used to normalize quantity measured sample values to surface contamination are not well constrained. Surface contamination normalization may not produce consistent values in instances where samples are being collected with non-standard media, or over unusual surfaces, or being tested with a laboratory which cannot supply extraction and detection efficiency factors. In such cases, applying a collection method filter and analyzing the data for a single collection method in isolation can obviate the negative effects of these interferences.

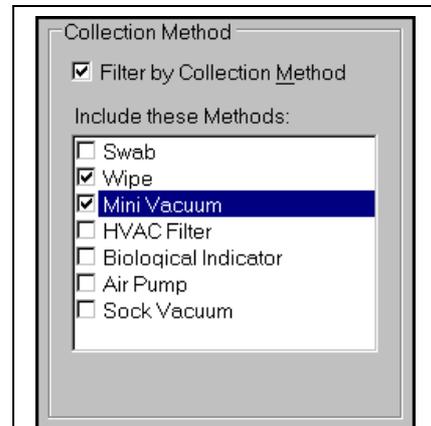


Figure 7-1. Collection Method Filter.

7.2.1.1.2. Sample Group Filter

A sample set may be defined by specifying the sample groups. Each sample's database record has a *group* attribute. A *sample group* is the set of samples having a common value in the group attribute. As with collection methods, a sample group filter can be defined using multiple possible matches for group attribute (Figure 7-2).

Sample group filtering is a principal means of restricting the population of a sample set. The group attribute of a sample is automatically populated when it is collected. Users can interactively edit the group attribute through the property grid to quickly identify samples with certain characteristics to be included or excluded from analyses. The list of available groups is dynamically updated by BROOM as new group attribute values are added to the sample dataset.

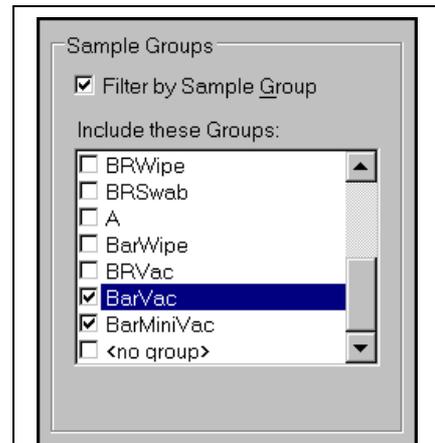


Figure 7-2. Sample Group Filter.

7.2.1.1.3. Sample Values Filter

Sample sets can be filtered based on the numeric values they represent. Samples with values below a lower limit and sample with values in excess of an upper limit can be excluded from a sample set (Figure 7-3).

This filter option is particularly useful for analysis codes which do not explicitly support input filtering by value. Often sample datasets contain analysis blanks or other spurious items to be filtered. Additionally, this option is well suited to eliminating outliers or questionable values. When a lower limit and an upper limit are both included in a sample values filter, the effect is additive. That is, the filter defines a *between* condition where samples greater than the lower limit *and* less than the upper limit are included in the sample set.

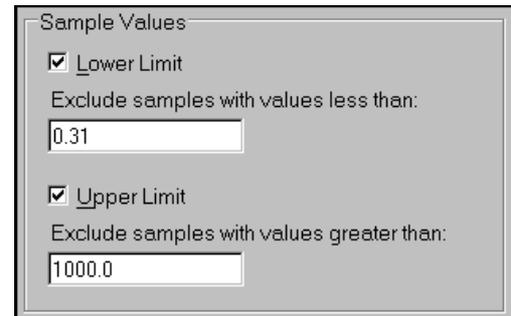


Figure 7-3. Sample Value Filter.

7.2.1.1.4. Zone Sample Filter

Characterization and decon zones define regions within the current building bounded by polygons. Zone sample filters select samples which are located within the polygons belonging to specified zones (Figure 7-4). Since zones can be defined with arbitrary shapes, the zone sample filter can be used to define ad-hoc spatial filters. Temporary zones can be drawn to match the requirements for a unique sample set for a given analysis. Applying a zone sample filter to this temporary zone then allows samples from arbitrarily shaped regions to be included or excluded from an analysis.

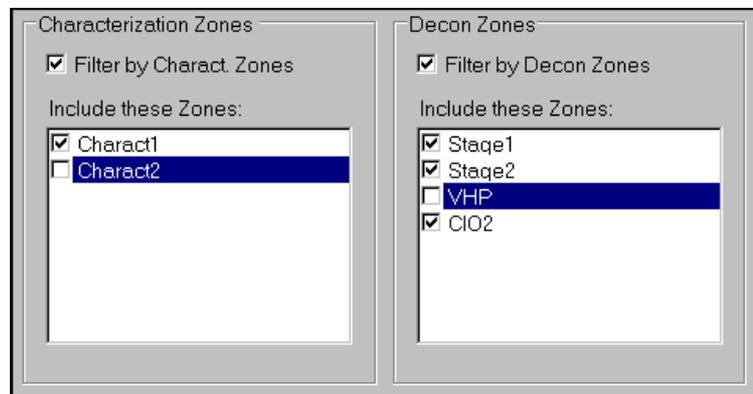


Figure 7-4. Zone Sample Filter.

7.2.1.2. Sample Set Value Operators

The quantity that is stored as the numeric value for each sample in the sample set is user configurable. The sample set retains knowledge of the nature of the numeric values associated with each sample for later use by analysis and display processes.

7.2.1.2.1. Value Source

The value saved in the sample set can come from any of the three available sample value types:

- Quantity Measured: Contaminant level in the sample as reported by the laboratory
- Surface Contamination: Quantity measured corrected for surface area and sampling efficiency
- Integrated Exposure: Surface exposure corrected for differential settling rates

7.2.1.2.2. Value Transform

The value associated with each sample in a sample set can be transformed from the value that occurs in the sample dataset (laboratory results). The available transform options are:

- Log10: Calculates the log10 result of the sample laboratory value and records that result as the sample set value.
- Indicator: Calculates a binary (0 or 1) value based on whether the laboratory value of a sample is above or below a user definable threshold level. This binary value is then assigned to the sample set.

7.2.2. Meshes

Map-based analysis methods entail making estimates at a large number of regularly spaced locations within a building. Simple rectangular grids are simple to generate and define, but real-world buildings are irregularly shaped. The mesh generation tool in BROOM creates regular sets of points for analysis codes to operate on when making estimates. The meshes also define the small polygons around the estimation points to assist the BROOM visualization system in creating accurate and pleasing maps of the analysis results. An example of a floor-wide mesh is shown in Figure 7-5.

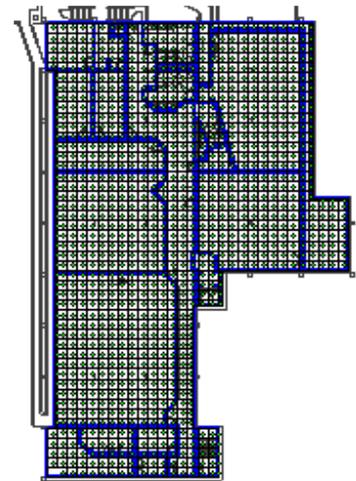


Figure 7-5. Mesh Covering a Floor.

7.2.2.1. Mesh Parameters

Meshes are defined interactively by specifying the region the mesh is to cover, the size of the individual mesh cell and the shape of the mesh cell (Figure 7-6).

7.2.2.1.1. Mesh Region

Meshes must be limited to polygonal regions. A single mesh can be defined by multiple polygons, and the polygons need not be contiguous. Free hand, interactive sketching of mesh bounding polygons is not supported in BROOM. Instead, meshes are defined based on the geometry of pre-existing building components (Figure 7-6). Mesh regions can be based on:

- The currently-selected room
- All rooms on the current floor
- The bounding polygon of the current floor
- The currently-selected zone

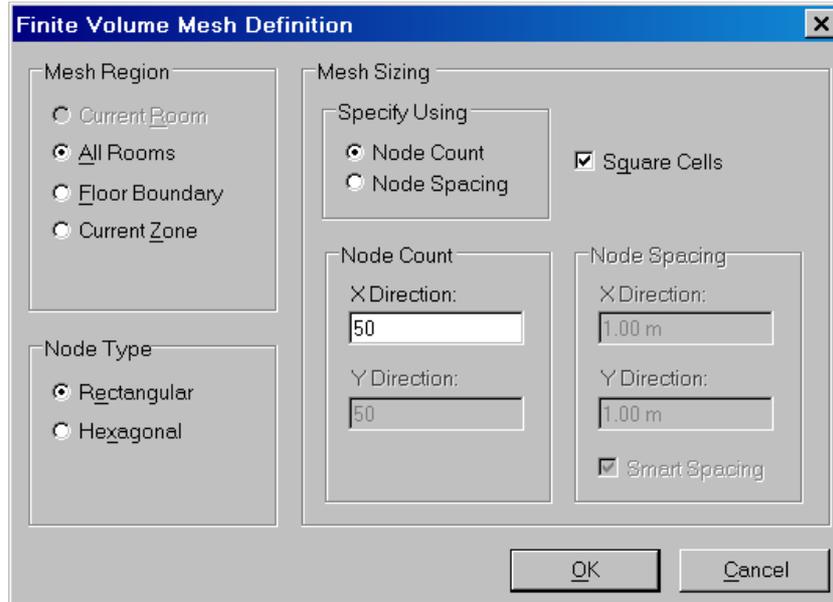


Figure 7-6. Mesh Definition Form.

Of these options, only the *All Rooms* and *Current Zone* selections permit disjoint collections of polygons to define a single mesh. Note that the mesh points within the wall cavities on the mesh created with the *Floor Boundary* option, but the mesh points are limited to the rooms leaving the cavities open when the *All Rooms* option is selected (Figure 7-7).

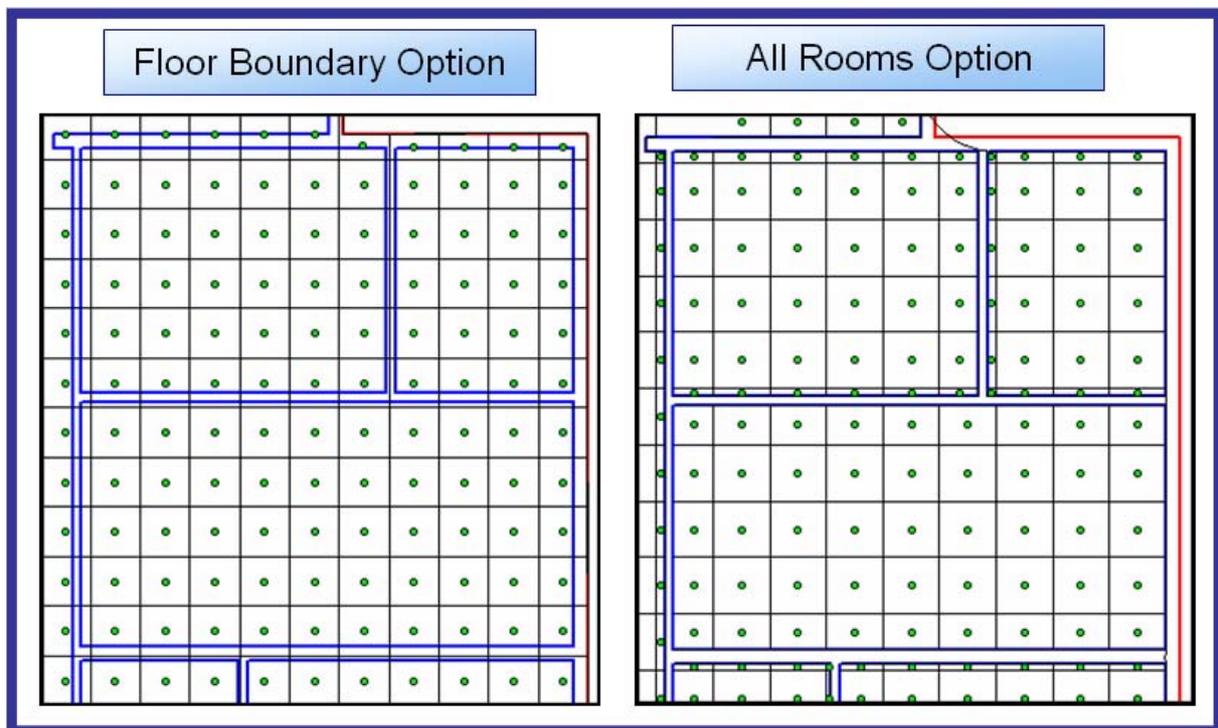


Figure 7-7. Meshes Created with Different Region Options.

7.2.2.1.2. Mesh Cell Type

BROOM meshes can be defined using rectangular or hexagonal cell shapes. Different analysis codes into which the mesh feeds often require rectangular or hexagonal mesh inputs (Figure 7-8).

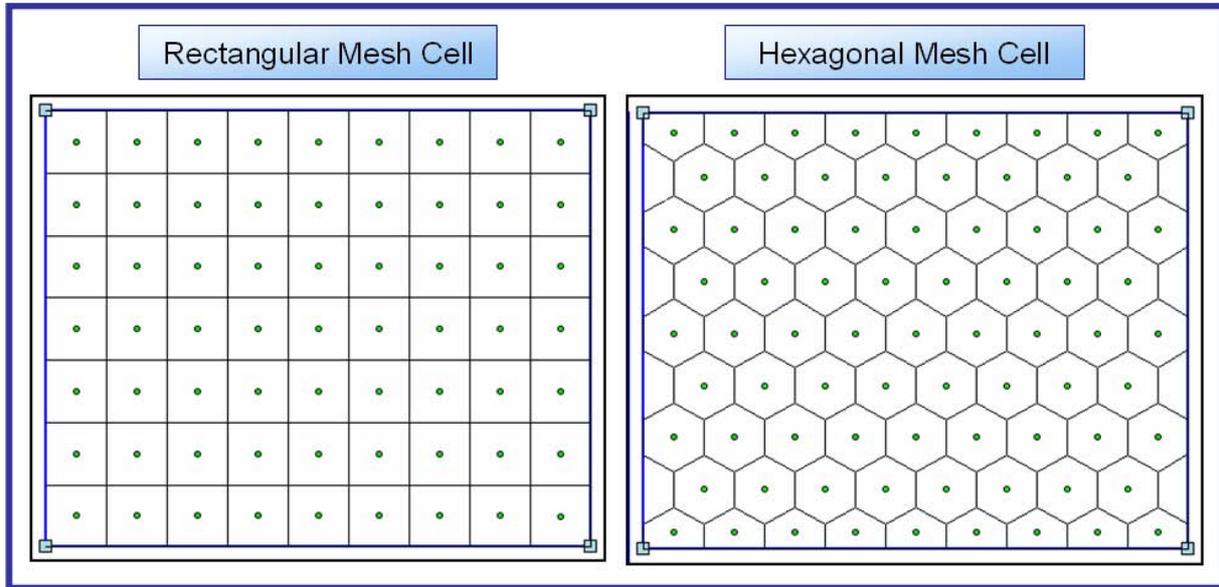


Figure 7-8. Mesh Cell Shapes.

7.2.2.1.3. Mesh Sizing

The spacing between the mesh points or nodes can be specified either by count or by physical spacing. The *Node Count* option subdivides the area covered by the mesh so as to make the maximum horizontal extent of the mesh contain the specified count of nodes. If the *Square Mesh* option is enabled, the node spacing calculated for the horizontal dimension of the mesh is automatically applied to the vertical dimension. The *Node Spacing* option simply takes the entered value and forces the nodes to be exactly that distance apart.

7.2.3. Regions

Many analysis codes require an area as an input, but not with the subsidiary nodes contained in a mesh. Regions provide a general-purpose polygonal input for these analysis codes.

Regions inherit pre-existing geometry (Figure 7-9). Regions may be defined from:

- The currently-selected room
- All rooms on the current floor
- The bounding polygon of the current floor
- The currently-selected zone
- The currently-selected boundary of a multiple-boundary zone

Many analyses which generate proposed sample locations or other point-based output utilize region inputs.

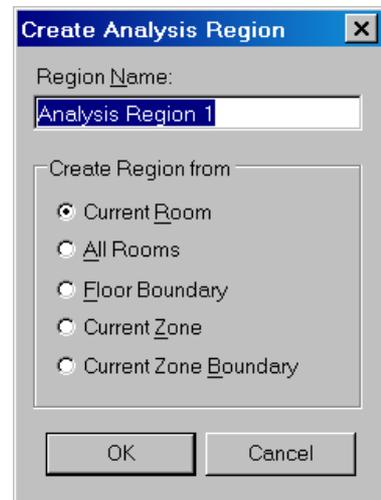


Figure 7-9. Region Options.

7.3. Mapping Tools

BROOM provides sophisticated methods for estimating contamination levels in a building based on existing samples and presenting those estimates as contaminant maps. The three mapping methods offer different levels of automation and user interaction. The available mapping methods are:

- Inverse Distance: Fast contaminant maps requiring minimal user input modeling
- Kriging: Higher quality maps requiring some knowledge of spatial correlation
- Shortest-path kriging: Advanced method optimized for building interiors, requiring additional user inputs and considerable user training.

7.3.1. Inverse Distance Mapping

The inverse distance mapping tool provides a very fast method and reliable means for generating a contaminant map. The technique generates a usable map with minimal user interaction.

7.3.1.1. Inputs

The inverse distance mapping tool (IDW) requires a sample set (see section 7.2.1) and a mesh (see section 7.2.2) as inputs. These inputs are selected from the analysis inputs dialog in a manner consistent with all other BROOM analysis codes.

7.3.1.2. Inverse Distance Map Preview

Although a minimal number of inputs are needed to get a serviceable map using inverse distance, often the map is fine-tuned by altering some parameters. BROOM provides an interactive dialog which displays an image of the inverse distance map created for the specified sample set and mesh along with three main controls. These controls permit fine adjustment of the map image by interactively adjusting the parameters.

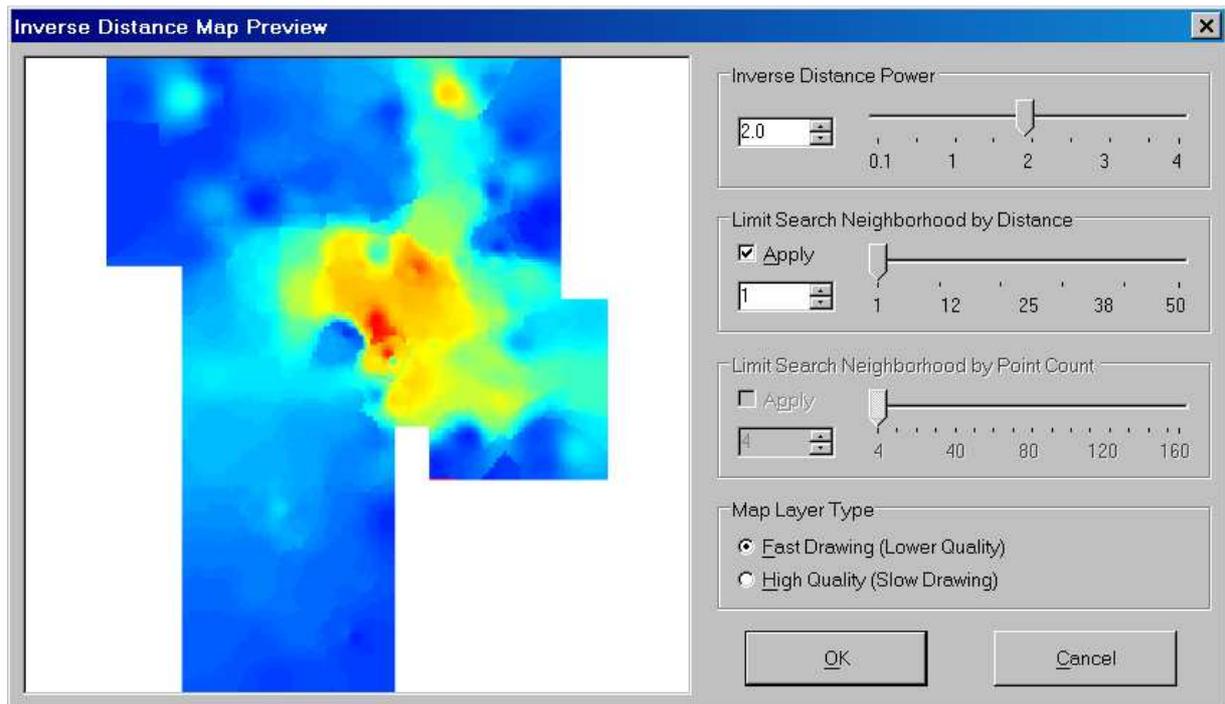


Figure 7-10. Inverse Distance Map Preview Form.

7.3.1.2.1. Inverse Distance Power

Adjusting the *Inverse Distance Power* affects the contribution of sample points distant from the estimate point. Powers higher than two (the default) tend to increase the contribution of closer points while minimizing the effects of more distant points. Power values less than two make distant points relatively more influential. Values near zero generate a map with uniform values near the mean value the samples. In practice, power values between 2 and 3.5 seem to generate the most useful maps.

7.3.1.2.2. Search Distance

Changing the search distance (the *Limit Search Neighborhood by Distance* option) can improve map quality when an inverse distance map is looking “spotty” with strong concentric coloration patterns around samples. Often the spottiness results from too large of a search distance. The default search distance for the inverse distance mapping tool is the full spatial extent of the sample set. Decreasing the search distance restricts the estimation calculation to samples within a smaller radius of the estimation point. This often makes the spottiness or other artifacts disappear.

7.3.1.2.3. Point Count

Another method to force the estimation procedure to focus on sample points close to the estimation point is to restrict the number of sample points that it uses for calculating each estimate. This is accomplished by modifying the *Limit Search Neighborhood by Point Count* option. The default point count is the total count of points in the sample set. By decreasing the

allowed point count to, say, 7 allows only the seven samples closest to the estimate point to be included in the estimate calculation.

7.3.1.2.4. Output controls

The remaining controls on the map preview dialog are simple output controls which determine the type of map plotted in the BROOM map window.

7.3.2. Traditional Geostatistical Kriging

7.3.2.1. Variograms

Generally speaking, the level of contamination found at two samples is going to be similar for two samples near each other and less similar for two samples distant from one another. A variogram is a model of this spatial correlation between samples. An example of spatial correlation is shown in the contamination map in Figure 7-11. Notice that for two points next to each other, their values (represented as a color) are similar. Yet, at greater distances, two points chosen at random typically have larger differences in value.

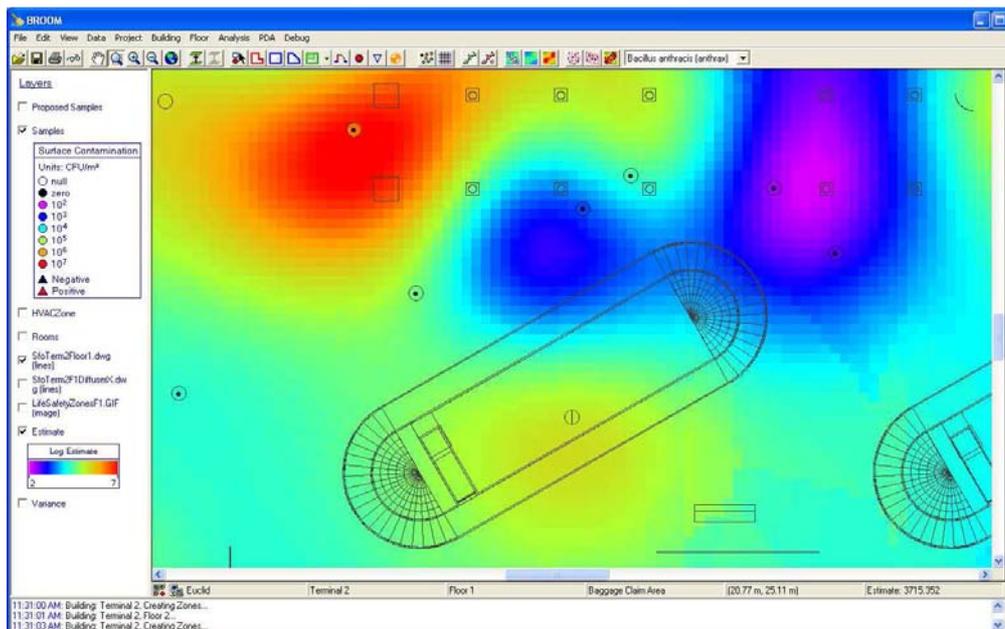


Figure 7-11. Contamination Map.

7.3.2.1.1. Easy Variogram

When analyzing a contaminated area for spatial correlation amongst the known samples, BROOM employs a tool called Easy Variogram for generating and fitting variograms. Easy Variogram allows the user to describe how areas of contamination are related to each over a given space.

The Easy Variogram GUI is designed to facilitate the geostatistical analysis and correlation modeling of spatial data sets. It is a separate application that is launched from within BROOM. Easy Variogram computes empirical variograms of gridded or irregularly-spaced data.

A variogram requires one input, a sample set. The space over which the variogram is generated is specified by the sample set. See section 7.2.1 for more details about sample sets. All other

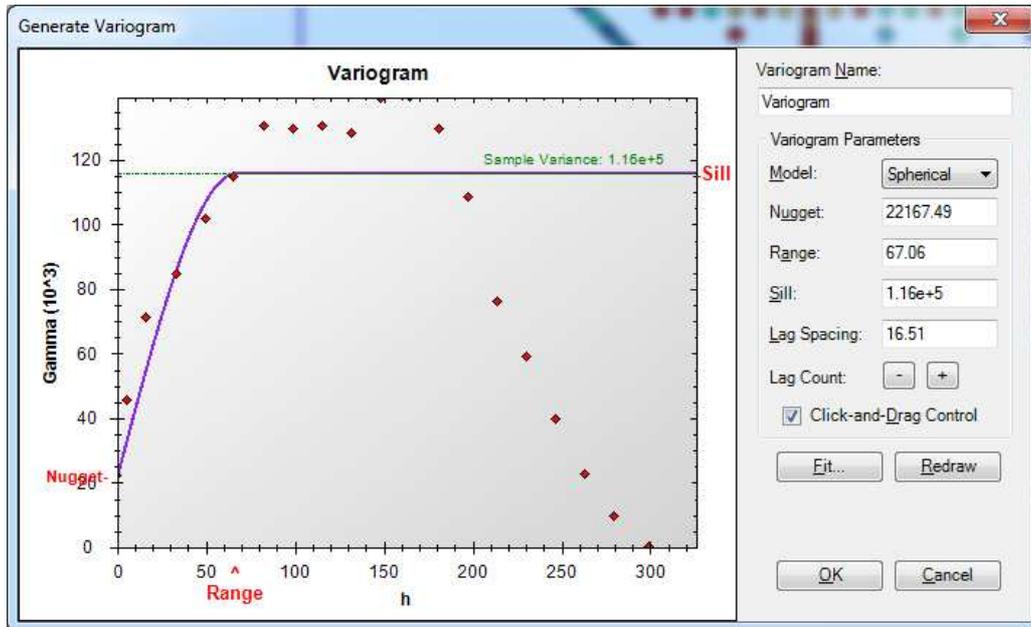


Figure 7-12. Easy Variogram GUI.

necessary inputs are automatically generated; however, they can be edited once the Easy Variogram GUI has launched. A more detailed description of each parameter can be found in the next subsection. The variogram modeling analyses may be conducted in 1, 2, or 3-dimensional space. Typically, the user will limit the modeling to one dimension for simplicity (effectively saying that the spatial correlation is the same in all directions), which is assumed to be the case for the Easy Variogram module.

The input parameters (e.g., nugget, range and sill) for the variography have a significant effect on the predicted outcome of the spatial model. Easy Variogram plots a variogram curve (the blue line shown in Figure 7-12) against the variogram calculated data points. To make a long story short, this plot consists of points which will typically show a fairly apparent trend. The user's task is to fit a curve to these points, as shown in Figure 7-12. The user can manually change the fit of the curve to the data in two distinct ways. On the right side of the Variogram window are numerical inputs for the key parameters to a spatial correlation model (e.g., nugget, range, sill, lag spacing). There are three types of spatial correlation models to choose from: spherical, Gaussian, and exponential). Each of these spatial correlation models has a unique, characteristic shape for the variogram. The second manual method to fit the curve is a click-and-drag technique. On the graph on the left side of the variogram window there are three of the parameters listed in red text, which are the Nugget, Range and Sill. The user can click on one of these parameters and drag the arrow to change the shape of the curve. The plot also shows the

overall sample variance as a horizontal line on the graph and the numerical value for the variance in green text. The Sill parameter should typically be set to the sample variance value.

In addition to the manual manipulation of the spatial correlation curve fit, the Easy Variogram has an option to automatically fit the three spatial correlation models to the spatial data. Figure 7-13 shows an example of this curve fitting option with the three curve fits in three different colors on the graph. The legend in the graph shows the correlation coefficient for each curve fit (e.g., a goodness-of-fit indicator).

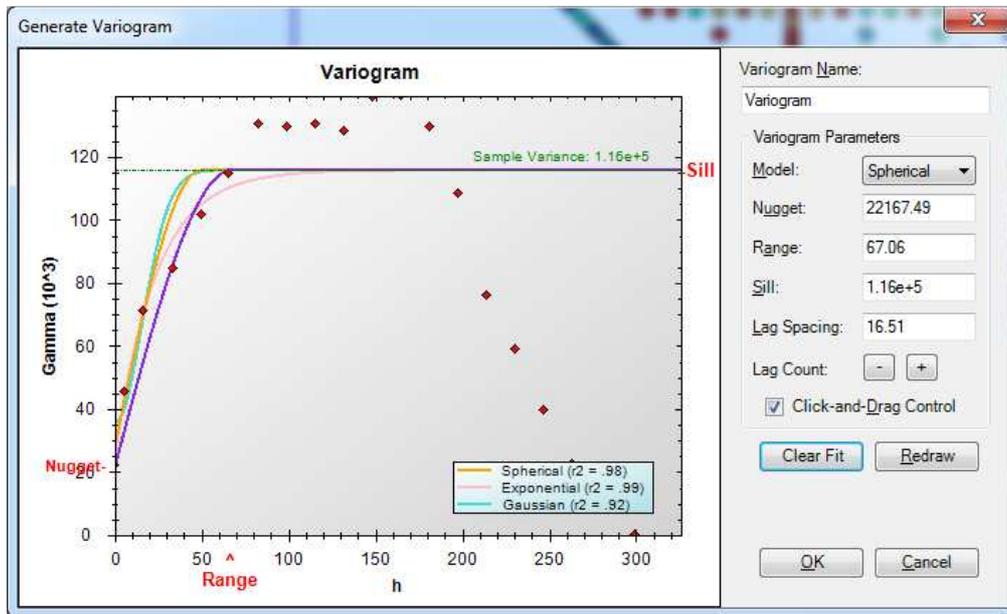


Figure 7-13. Spatial Correlation Model Fitting

7.3.2.1.1.1. Easy Variogram Inputs and Outputs

- **lag spacing:** the unit lag separation distance.
- **nugget:** the y-axis intercept of the spatial correlation model, a parameter that relates to the amount of uncertainty in close proximity to existing data points.
- **sill:** the asymptotic tail end of the spatial correlation model, a parameter that relates to the variance of the data set.
- **range:** the point on the x-axis where the spatial correlation model changes in slope to the asymptote, a parameter that relates to the distance over which samples tend to be correlated in the data set.

7.3.2.2. Easy Kriging

Kriging is a regression technique used in geostatistics to approximate or interpolate data. Easy Kriging is a kriging package that allows BROOM to characterize a target region by generating a contamination map and uncertainty map. The contamination map provides a color-coded display of the amount of contamination over a region. Corresponding with the contamination map is an uncertainty map that provides the amount of certainty in the contamination estimates.

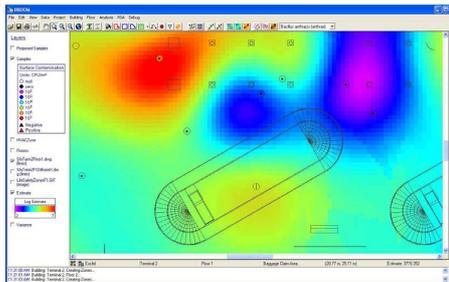


Figure 7-14. Contamination Map.

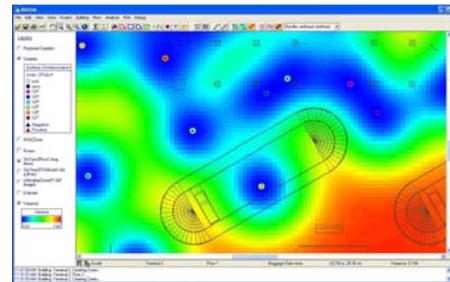


Figure 7-15. Uncertainty Map.

The contamination map shown in Figure 7-4 displays areas of highest contamination in red and lowest in blue and violet. This map is generated from a sample set and the variogram describing the spatial correlation amongst those samples. A mesh is the third input for kriging. The mesh defines the boundary and resolution of the contamination and uncertainty maps.

The uncertainty map shown in Figure 7-15 displays, like the contamination map, areas of high uncertainty in red and low uncertainty in blue. Note how the areas immediately surrounding each sample are blue—the closer you are to a known sample, the more confidence you can have in contamination map's value at that point. The further away you are from a known sample, the more uncertain you become.

The space over which the kriging maps are generated is specified by the sample set, variogram, and mesh tabs, as seen in the figures above. The mesh may be derived from an assemblage of the room polygons, the boundary polygon, or a characterization zone polygon. Section 7.2.2 describes the options for generating a mesh. Several parameters will control the size and shape of the mesh for generating contamination and uncertainty maps. The number of nodes has a profound effect on the clarity of the color contour definition and how pixilated it might appear. The greater the number of nodes the smoother the color transitions and display but with the trade-off that it takes longer to process the geostatistical model calculations. Generally speaking, a node count of 150 in both the x and y directions yields smooth looking contamination maps. The Easy Kriging GUI is designed to facilitate the process of generating kriged data sets in 2 dimensions.

7.3.3. Shortest Path Kriging

Kriging is an interpolation method used to generate contaminant maps from point samples. Kriging relies upon the distances separating samples to establish their spatial correlation which in turn is used to estimate contaminant values at unsampled locations. In obstructed

environments, like the interior spaces of most buildings, the true distances between samples are not straight-line or line-of-sight distance. Shortest path kriging is a new method which applies a graph algorithm to a bitmap image of the building interior to calculate the true distances between the samples. Shortest path kriging can generate contaminant maps that more accurately represent contaminant levels in unsampled locations.

7.3.4. An Example Dataset

Samples of possible contaminants are collected at point locations within buildings. Analytical results from these samples give an indication of what areas of the building are contaminated and to what extent. When sufficient number samples have been analyzed, plotting the results on a map enables trends and hotspots to be spotted (Figure 7-134). In the model building dataset shown below, high levels are observed in the east and north portions of the building and low values in the northwest and southeast rooms. The points displayed in Figure 7-136 represent a random subset of 20,000 points which constitute a simulated release of a bio-agent (Figure 7-147).

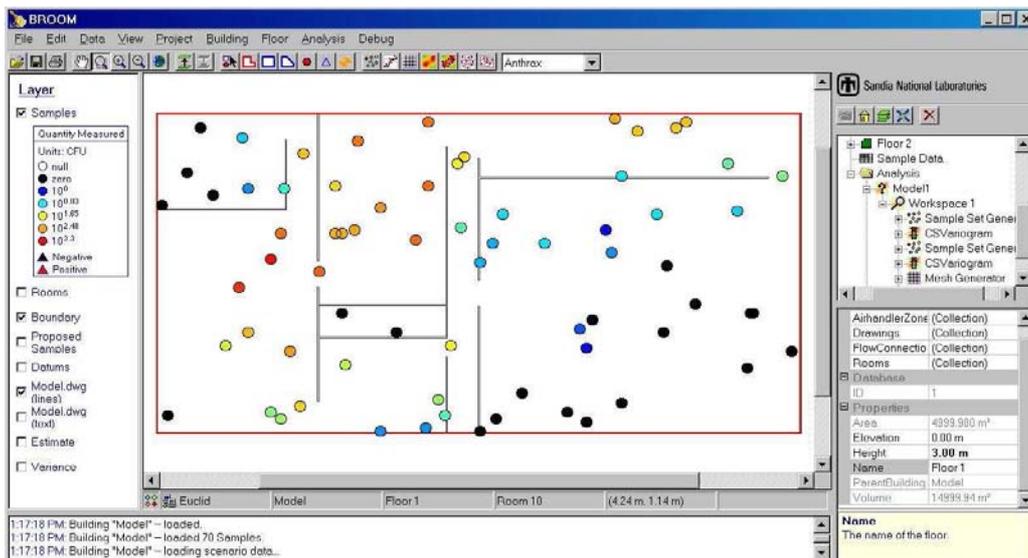


Figure 7-136. Map with 70 Color-Coded Samples.

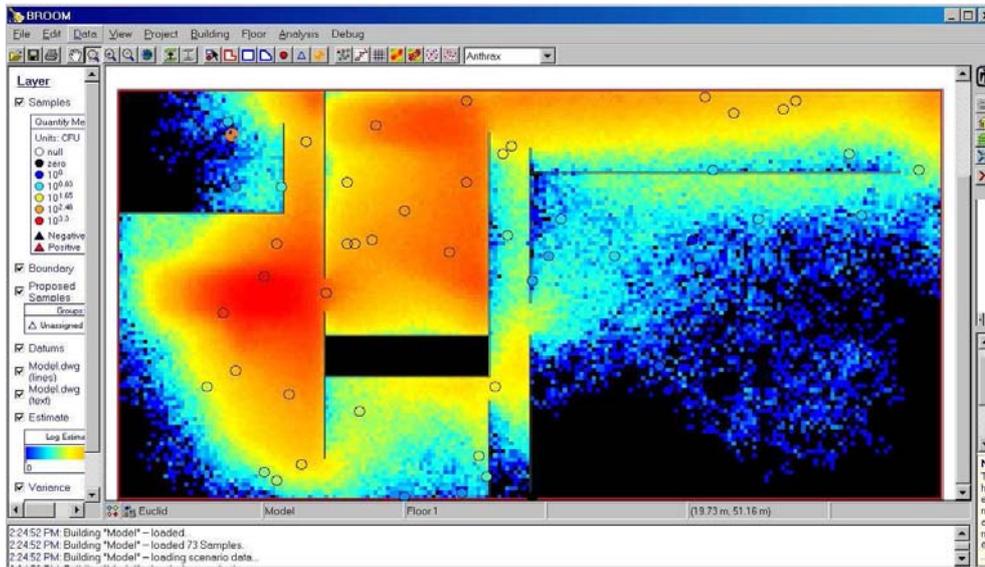


Figure 7-147. Map Showing 20,000-point Dataset (Ground-Truth).

7.3.4.1. Applying Traditional Methods to a Dataset

Kriging is a geostatistical method which generates estimates of levels at locations at which no samples were taken. Kriging numerically estimates not only the expected value of the quantity of interest, but also the variance of the measurement, giving us an indication of the uncertainty associated with the estimate. Applying traditional kriging to a 70-point subset of the model dataset (Figure 7-136) produces a contamination map showing the extent of the contamination (Figure 7-8). The field of the map is composed of approximately 20,000 square cells each measuring 50cm on a side. Each cell is assigned a value corresponding to the amount of the contaminant that the kriging calculation determines is most likely to be present at that location given the spatial configuration of the sample points.

Generating kriging maps represents a step forward in ease of interpretation from the color-coded dots in Figure 7-136. Additionally, the interpolation maps allow deposition patterns to be more readily visualized.

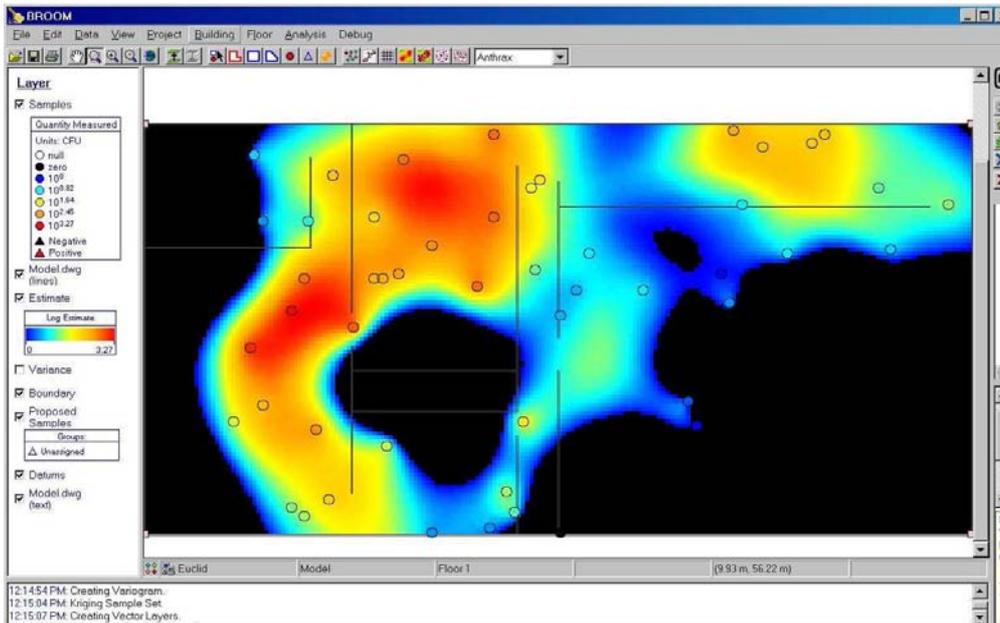


Figure 7-18. Traditional Kriging Map (Ignores Walls).

7.3.4.2. Challenges in Applying Kriging Indoors

While kriging generates useful maps of indoor contamination levels, indoor building geometry complicates their interpretation. Geostatistical analyses such as kriging rely upon the distance separating sample points to determine their spatial correlation. This spatial correlation in turn determines the values assigned to cells for which sampled values are not available. Building interiors are challenging environments for geostatistical analysis since walls, doors, and ventilation systems introduce spatial non-uniformity.

The problem can be thought of as finding the distance between two locations in two adjacent rooms (Figure 3). The resultant true shortest path distance must include the distance from the first point to the door of the first room, the distance between the doors of the two rooms and the distance from the door of the second room and the second point. A traditional kriging estimation involving the two green points in Figure 7-19 would use the length of the red line as the distance used to determine the effect of a measured value at one green dot to an estimate being calculated at another green dot. Using the true shortest path distance, the length of the blue path, should give a more realistic estimate of the true spatial relationship of the two green points and thus a higher quality estimate.

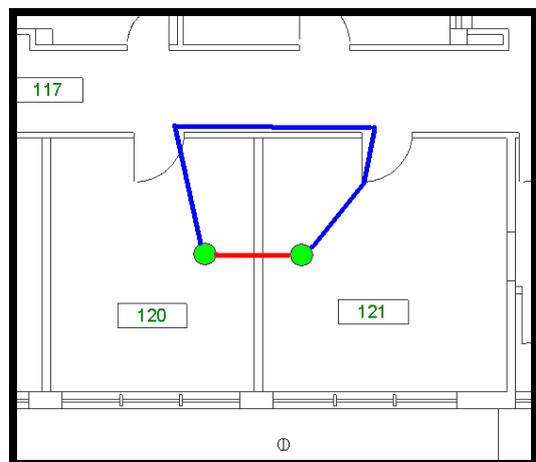


Figure 7-19. Distance Relationships Between Samples.

7.3.4.3. Shortest Path Kriging Methods

We have developed methods to calculate these non-Euclidean distances in building models. The methods rely upon Dijkstra's algorithm, one of the foundation algorithms of graph theory. In our application, a bitmap image of the floor plan of the building model is used as "Distance Mask" (Figure 7-20). The graph algorithm operates between sample points on this bitmap image to determine the shortest paths which do not cross building components such as walls and partitions. The distances along these computed shortest paths can be substituted for the simple straight-line distances traditionally used by geostatistical methods such as kriging to generate contamination maps.

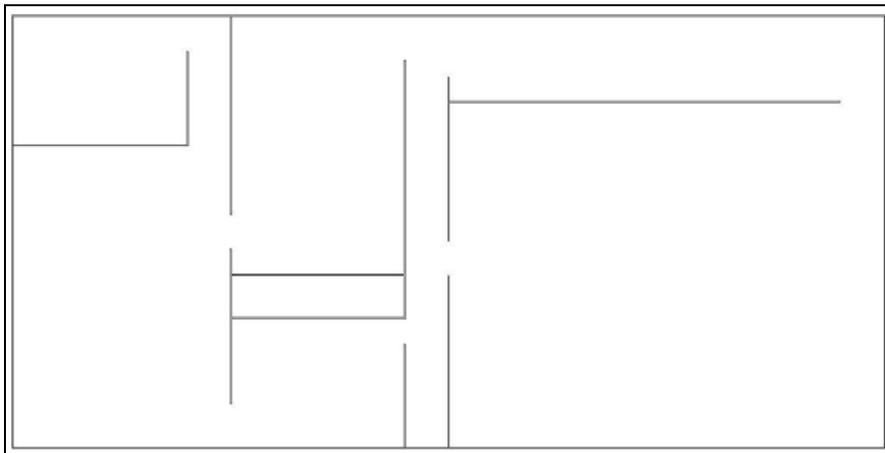


Figure 7-20. Floor Plan Used as a Distance Mask.

When these corrected distances are fed into the kriging processes, a much different map is generated (Figure 7-21). The non-Euclidean distances produce color gradations that respect the interior arrangement of the interior partitions. In particular, the small room in the northwest corner of the building shows distinct offset of the color gradients across its southern partitions. Similarly, the small room in center-southwest portion of the map which has no door to connect it to the rest of the building is shown to be isolated from the rest of the building, with estimates of zero inside the building and greater than zero outside.

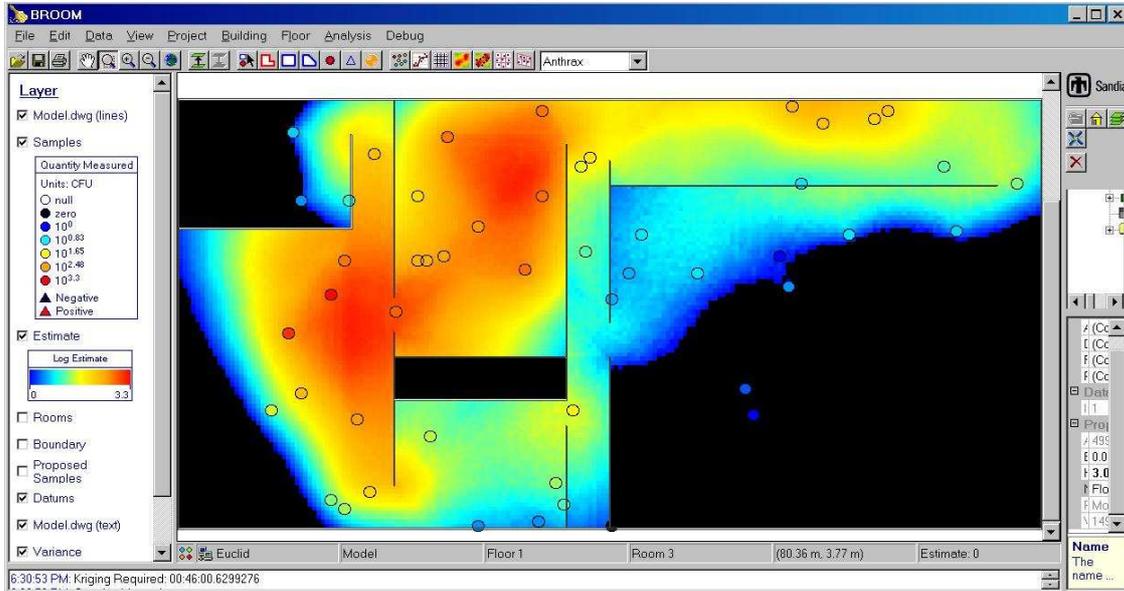


Figure 7-21. Shortest Path Kriging Map.

Maps generated from shortest path distances visually agree with expectations for contaminant level patterns in and around impermeable interior partitions. The deposition patterns represented in Figure 7-21 are qualitatively plausible; contaminant levels vary sharply across walls, but smoothly across open doorways.

7.3.4.4. Shortest Path Variance Maps

Variance maps show the influence that correcting distance values for building geometry has upon the uncertainty of estimates. The standard kriging variance of the model data set is shown in Figure 7-22.

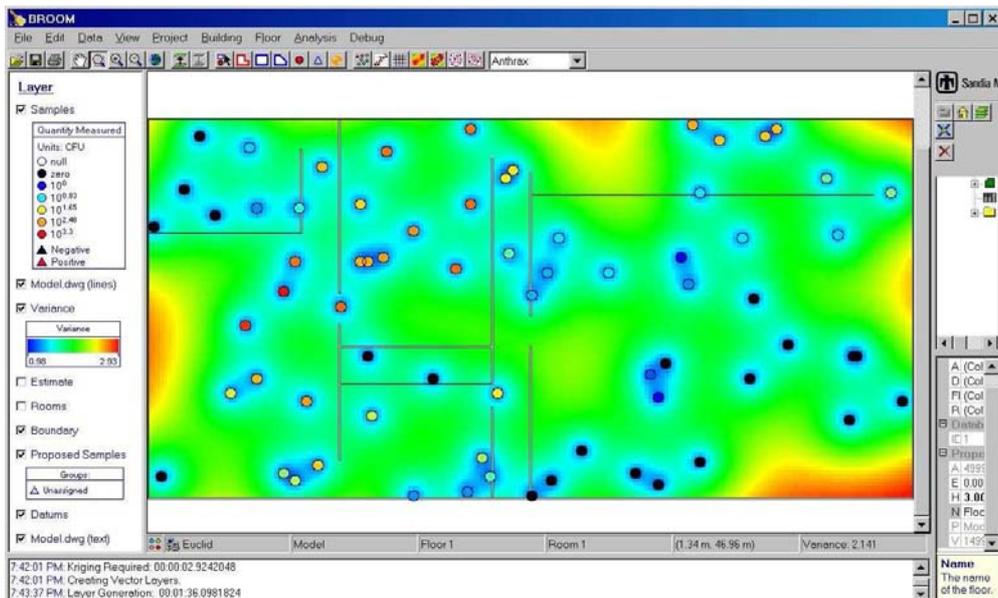


Figure 7-22. Variance Map Created by Traditional Kriging.

Applying corrected distances yields a somewhat different picture of estimated uncertainty. Figure 7-153 shows the variance map for the model data set obtained by shortest path kriging. Zones of elevated variance are shown in a corner of the large southwest room, in the corner of the north-central room adjacent to the sealed room and at the south end of the central hallway. These areas of high uncertainty are all characterized by having samples close to them, but on the opposite side of a partition.

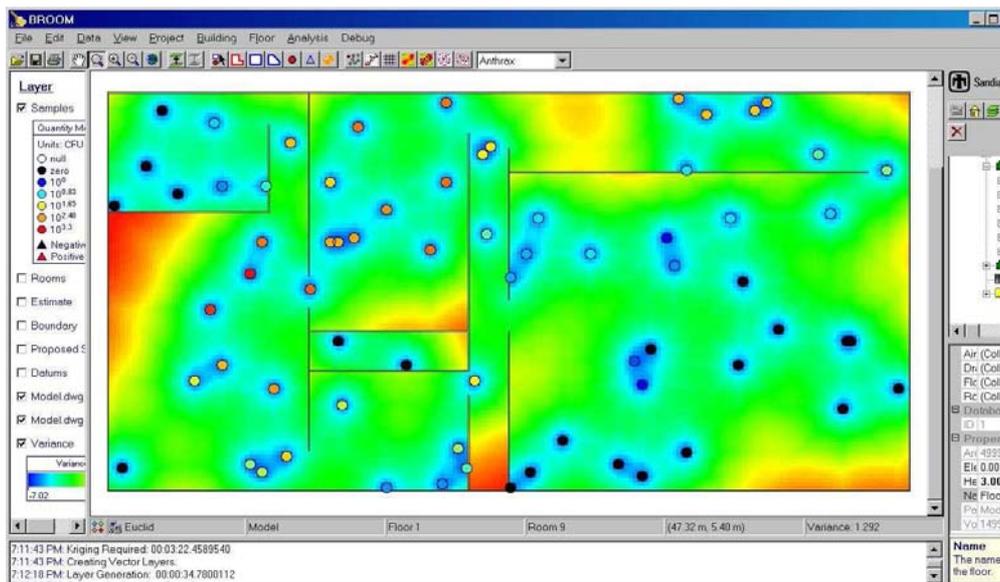


Figure 7-153. Variance Map Created by Shortest Path Kriging.

The capacity of shortest path kriging to delineate these zones of elevated uncertainty could have implications to sample placement considerations. When using a map of kriging variance to guide optimum sample placement, standard kriging variance maps may overstate the confidence with which estimates are known in areas where interior partitions are found.

7.3.4.5. Mass-Balance Calculations

The geostatistics-based analysis system in the BROOM system permits estimated values to be assigned to unsampled areas cells within a building. The contaminant values in each of these cells can be summed to give an estimate of the total amount of contaminant present in the facility. Since this building model represents a sampled subset from a synthetic dataset, we can compare the kriging methods in BROOM to see how well each reconstructs the actual amount of material present in the model (Table 7-1).

Table 7-1. Integrated Contaminant Estimates.

Model	Max Cell Value	Mean Cell Value	Standard Dev	Integrated Total	Accuracy vs Ground Truth
Ground Truth (Figure 1)	2,367	122	280	613,000	100%
Standard Kriging (Figure 2)	1,234	60	147	300,000	49%
Large Distance Mask (Figure 5)	1,510	94	221	470,000	77%
Small Distance Mask (Figure 6)	1,852	208	258	537,000	88%

In this example, all kriging methods underestimate the amount of contaminant present in the building. Of the methods, the two shortest path methods came closest to the ground-truth values. Surprisingly, the method with the integrated total closest to the ground truth was run with the smaller distance-mask bitmap.

It is notable that the integrated totals for all kriging methods are as close to the ground-truth value as they are, given the size of the dataset. The 70 samples selected represent 0.35% of the 20,000 cells of the ground-truth dataset.

7.3.4.6. Comparison of Kriging Methods

The maps generated with shortest-path kriging follow the interior building geometry more closely than the maps generated by standard kriging techniques and thus would appear to produce more accurate estimates of contaminant levels.

To test the quality of the kriging estimates, maps were generated from the model data set using both methods. Randomly selected sample sets of 50, 62, 70, 125, 250, 500 and 1,000 data points were extracted from the model dataset. Each sample set was mapped with each kriging method. The estimates obtained in each of the 20,080 cells of the map were then compared with the ground truth values. Mean square error, average error, and correlation coefficients were calculated to show how well traditional kriging estimates agreed with ground truth and how well shortest path kriging estimates agreed.

Results for the correlation coefficient are is graphed in Figure 7-164. These results suggest that estimates obtained from the shortest path method maintain their agreement with actual values better at lower sample counts than do estimates obtained from standard kriging methods.

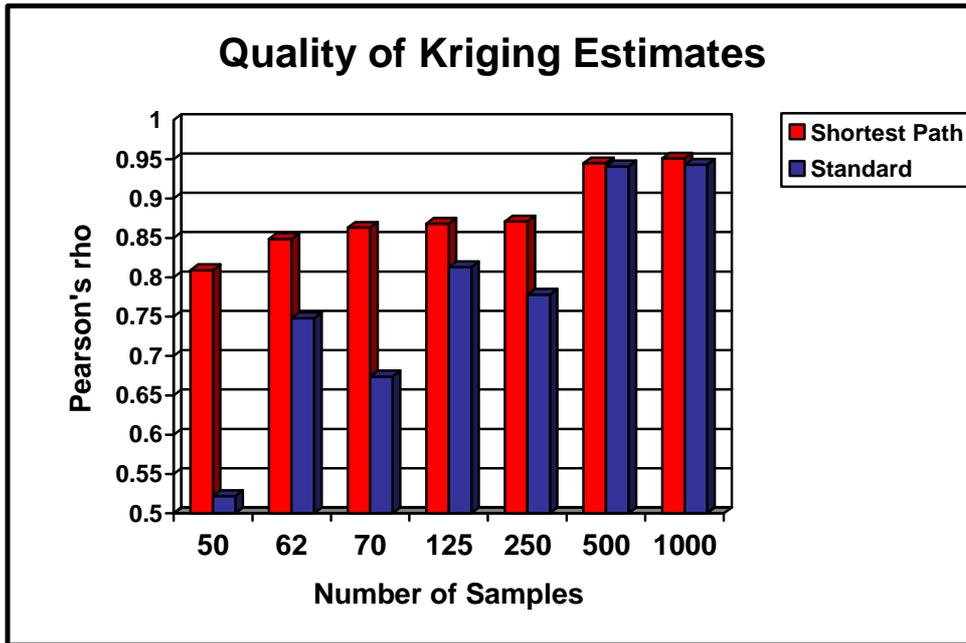


Figure 7-164. Correlation Coefficient Values of Estimated and Actual Values.

An alternate view of the estimates made by the two methods is shown in the plot of average estimation error in Figure 7-175. The magnitude of the average error generally decreases with larger number of samples. At smaller sample numbers, shortest path kriging appears to generate estimates which are closer to the true value.

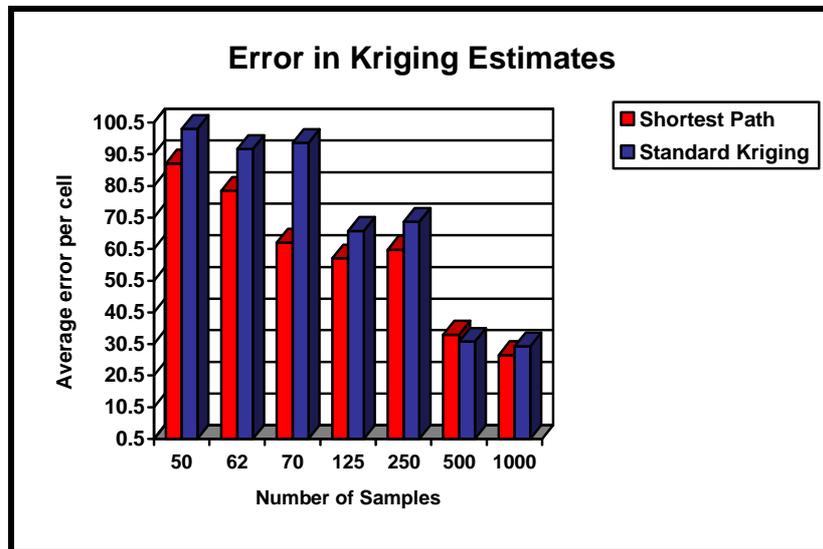


Figure 7-175. Average Kriging Estimate Errors.

Shortest path kriging shows promise of increasing the accuracy of estimated contaminant levels inside buildings. Applying simple graph algorithms to the floor plans of buildings permits true distances separating the samples to be calculated. The contamination maps generated from this

model data set indicate that shortest path kriging produces maps that are more accurate than maps produced by standard kriging methods.

7.3.4.7. Distance Mask

The distance mask used in shortest path kriging is a simple bitmap image file. Any available image file which pictures the facility of interest can be used for the distance map. Supported formats include jpg, gif and bmp. The convention used for interpreting a distance mask image is that a white or light colored area is open space and a black or dark area is a barrier. Thus, a black line across a white area can model a wall separating two open rooms. An open doorway can be created in the wall by simply erasing a segment of the line where the door is located.

As an alternative to importing bitmap images files of the facility, BROOM can generate distance mask image files interactively by capturing the current map panel display on screen. The distance mask user interface contains a button for generating the image directly from BROOM. The dialog also presents controls to allow editing of the image (Figure 7-6). These interactive editing features for distance masks are quite useful for quickly modeling the potential effects of changes in configurations of a facility. The effects of opening and closing doors, movable partitions, on contaminant distribution patterns can be evaluated by editing the distance map bitmaps to add or delete the features of interest and then running the shortest path kriging analysis on the modified distance mask.

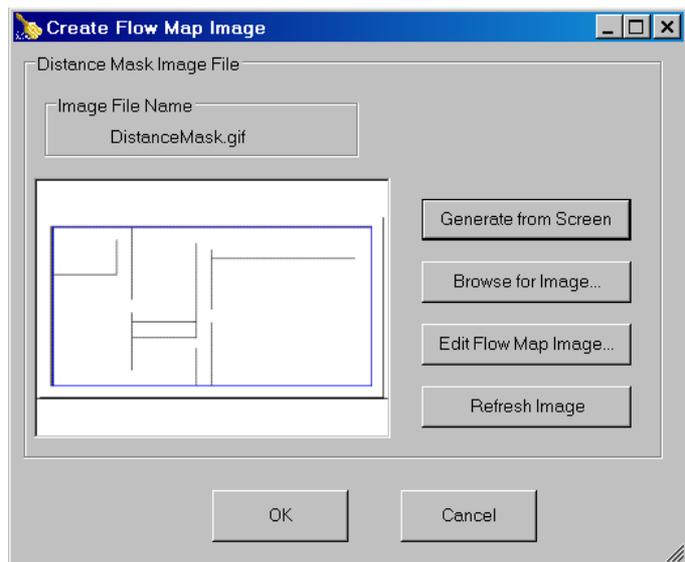


Figure 7-26. Distance Mask User Interface.

Figure 7-26 shows an example of how simple editing of a distance mask changes the map generated from shortest path kriging. When no black lines exist within the building outline as shown in the upper left example, the map generated shows concentrations changing smoothly across the map (lower left). When the interior walls are drawn in the distance mask, but no communicating passageways exist (upper center), concentrations change smoothly within each room, but sharp estimated concentration differences are seen between rooms. In the third example, the distance map was modified by adding two doorways. The map in the lower right of Figure 7-7 shows that estimated concentrations in the southern part of the northeast room have increased substantially compared to the map with no doorways (lower center). With no doors, all estimates within the northeast room were based only on the two relatively low-level samples within the room. Once the doors to the room are open, the kriging procedure can use the higher values from samples in adjacent rooms when estimating the most likely contaminant levels within the northeast room.

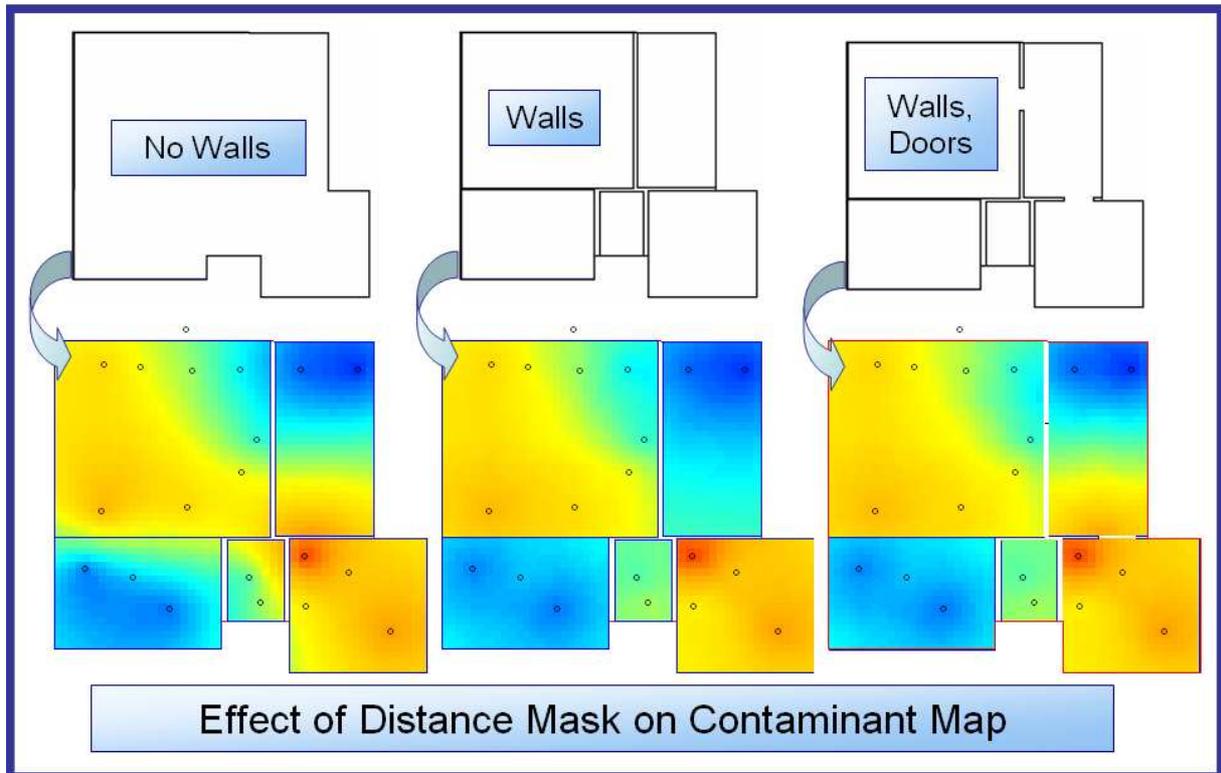


Figure 7-27. Distance Mask Effects on Contaminant Map.

7.4. Sample Design Tools

BROOM includes a number of tools to facilitate design and implementation of sampling plans for a contaminated facility. Statistical methods exist to determine how many samples are needed to adequately characterize a facility to a given confidence level. Most of these methods make assumptions about the samples or the distribution that may not be applicable. BROOM provides a conservative nonparametric procedure which to generate the number of samples. Once this minimum number of samples is determined, BROOM provides interactive tools to quickly lay out the samples across the facility.

7.4.1. One-Sample Sign Test

BROOM uses the one-sample sign test to determine a suggested minimum number of samples to be taken from a particular part of a facility. The one-sample sign test makes no assumptions about the distribution of sample values being normal or symmetric. The one-sample sign test does assume that the contaminant is not present in background (Reference to MARSSIM).

7.4.1.1. Inputs

The sign test procedure requires inputs that may be specific to the site and to the contaminated facility. Allowable error levels are independently set for Type I (false positive) and Type II (false negative) errors (Figure 7-8). The action level corresponds to the level at which the area or zone as a whole is considered to be contaminated. The lower bound corresponds to the

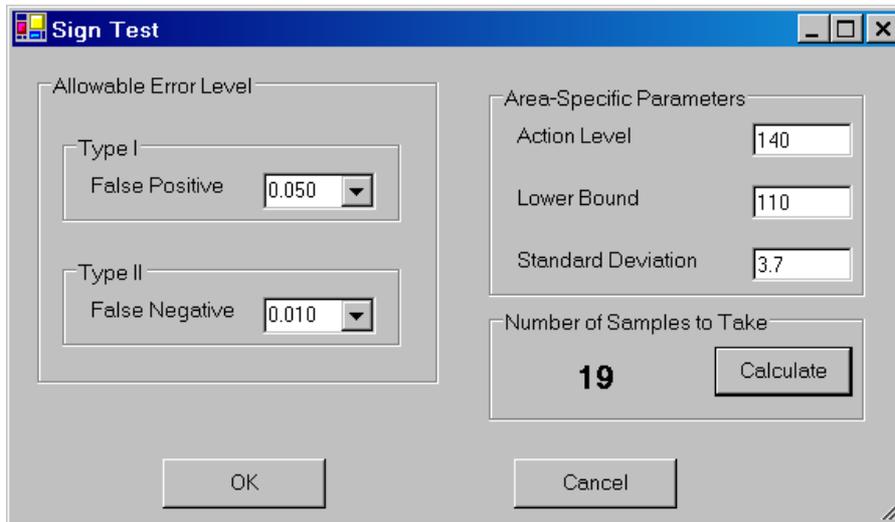


Figure 7-28. Inputs to MARSSIM Sign Test.

permissible amount of contaminant allowed. This parameter is open to some interpretation (marsim gogolak reference). The lower bound parameter has often been set to one-half of the action level. Another reasonable value for the lower bound is the detection limit of the collection of laboratory method being used to generate the sample values. The standard deviation value can be derived from previous work with the chosen method, or by blanks, spiked samples, or closely-spaced sample arrays collected during initial phases of sampling. The procedure calculates a minimum number of samples required to meet the parameters entered.

7.4.2. Random Sample Layout

BROOM provides an easy-to-use tool to generate randomized layouts of prospective sampling locations. The inputs are simply a BROOM region describing the area to cover with the samples and the number of samples desired. Proposed sample locations are randomly generated as specified. These locations can be viewed on the map and sent to the PDA for collection by the sample teams.

7.4.3. Grid Sample Layout

Many sampling strategies require a regular pattern of samples. BROOM helps generate regular samplings grids at user specified densities. Users may choose many alternative grid layouts before committing on one to apply to a sampling plan (Figure 7-).

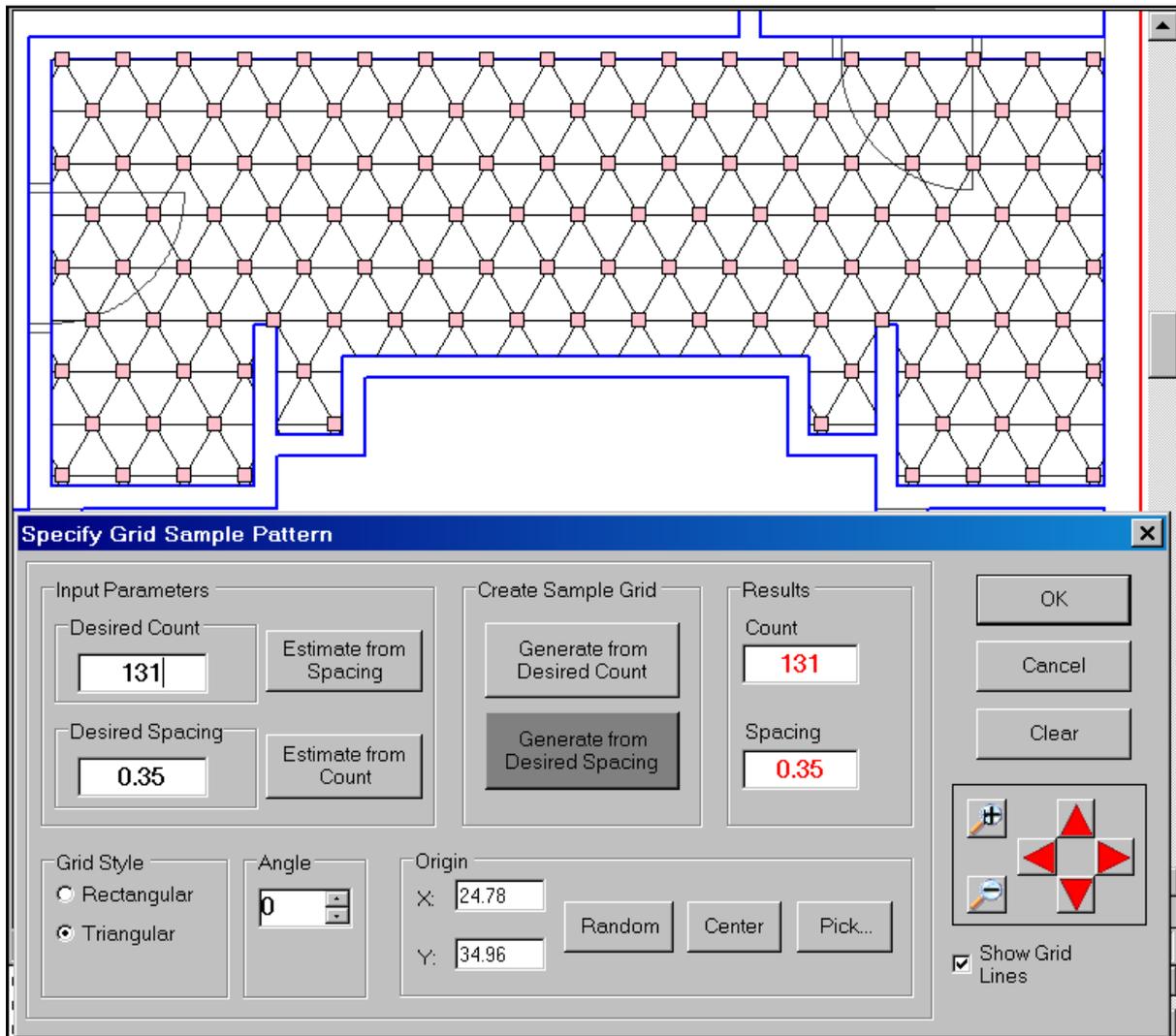


Figure 7-29. Grid Sample Layout Interface.

7.4.3.1. Inputs

The principal inputs to the grid sampling tool concern grid geometry and density. Triangular and rectangular grid styles are available. Density can be specified as either the count of desired samples within the sampled region, or as the desired spacing between samples. By default, the sample grid's origin is centered in the sampled region. Alternative placement options, such as random origin or user-defined sample origin permit flexibility in laying out the grid. The angle of the grid can be adjusted by the user to account for building components which are not aligned orthogonally with the building model axes.

7.4.3.2. Sample Grid Generation

The tool provides two methods for generating the sampling locations based on the input parameters. The *Generate from Desired Spacing* option creates a grid based on the current

spacing, angle and origin inputs. This option efficiently creates a grid which is displayed as pink points on the map. The count and spacing of the resulting grid are displayed on the dialog in red (Figure 7-).

The grid sampling tool applies an optimization to the sampling grid when the *Generate from Desired Count* option is selected. With this option, the tool varies the grid spacing in an attempt to create a grid with exactly the number of samples matching the current desired count input. Often, no grid exists which will place the exact desired count of samples in the sampled region using the current settings for grid origin and grid angle. In this instance, the optimizing routine will create a grid with a count as close as possible to the desired count.

Regardless of the method used to generate the grid, choosing a new origin or angle creates a new grid. Entering new values for the grid angle or origin triggers the tool to automatically recalculate the grid and display it on the map. Often, if the first attempt at generating a grid with the desired count of samples in a region is not successful, simply choosing a new random grid origin will create a grid with the desired configuration.

7.4.4. *Stratified Random Sample Layout*

Random sample layout often generates patterns with large areas of the sampled region not covered. Stratified random sampling combines elements of gridded methods and random methods to generate randomized sampling designs which have more regular and predictable spatial coverage than simple random approaches.

Stratified random sampling first subdivides the sampling region into an array of discrete areas or strata which are evenly distributed throughout the region. Then a sample location is located at a random point within each stratum. This approach guarantees samples are relatively well distributed throughout the sampling region, but not requiring the rigid periodicity of the gridded approach.

BROOM's stratified random sample layout user interface (Figure 7-) closely resembles that for grid sample layout (Figure 7-). The concepts governing the size and placement of the strata are similar to those needed to specify a sampling grid. The grid lines drawn on the map during interactive stratified random layout delineate the boundaries of the strata. The pink dots occupy random locations within the strata.

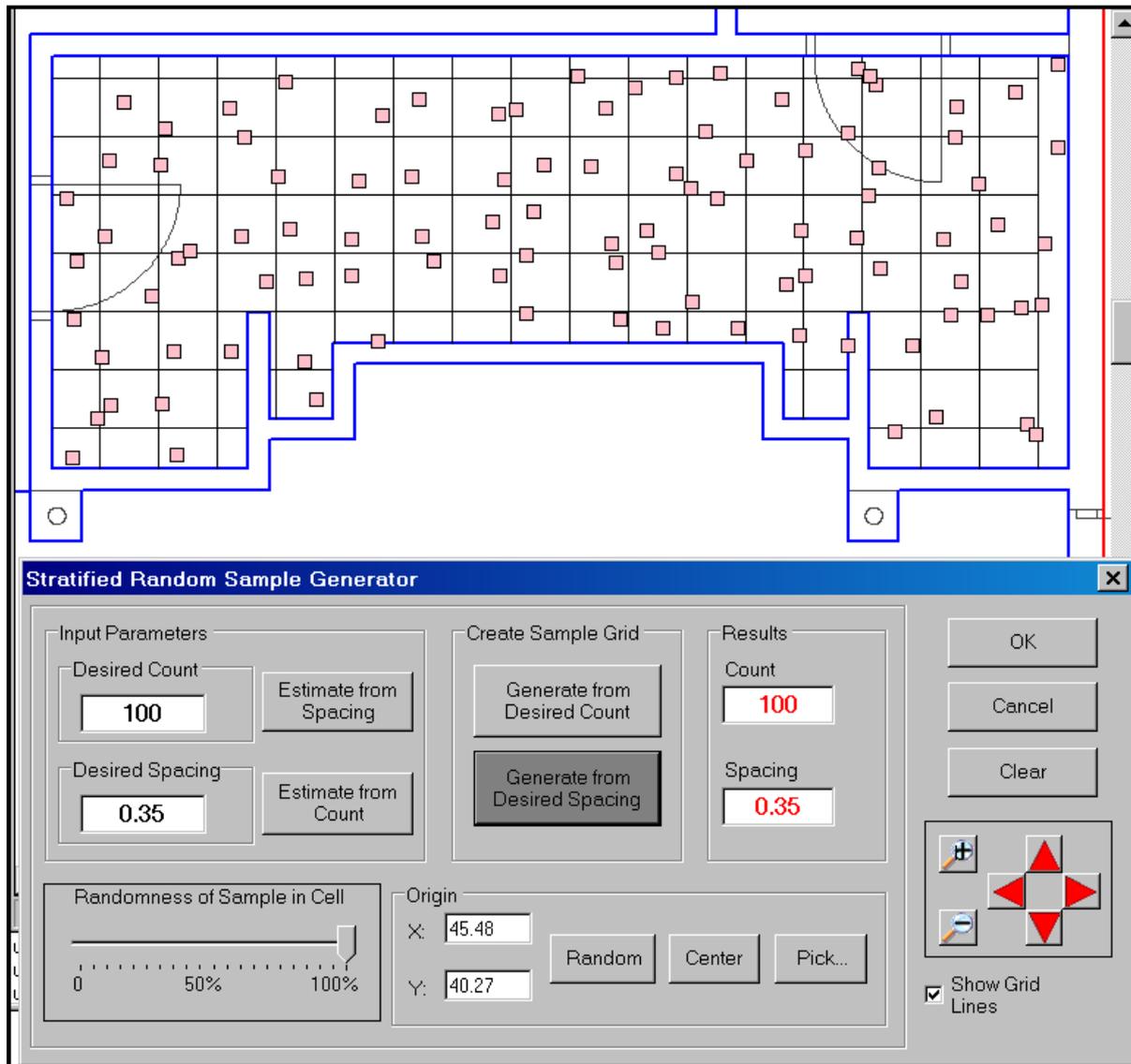


Figure 7-30. Stratified Random Sample Layout Interface.

The degree of randomness of a sample point within a stratum can be assigned by the user. At 100% randomness, the sample is equally likely to end up anywhere within the stratum. At zero percent randomness, the sample is placed in the exact center of the stratum (Figure 7-). At intermediate values, the sample is randomly placed within the stratum with a variable degree of central tendency. The sample location is determined by a Gaussian normal distribution; increasing the randomness value with the dialog control corresponds to broadening the distribution by increasing its standard deviation. The schematic probability plots in Figure 7- show that the probability function for the sample placement within a stratum with a 0% randomness setting is a spike at the center of the stratum cell indicating that the probability of placement at the center of the cell is 1.0. At the other extreme, the 100% randomness schematic probability plot shows that the probability of sample placement is the same anywhere across the width of the sample stratum. At 50% randomness, samples are more likely to be placed near the

center of the stratum cell, but a finite probability exists that a sample can be placed near the edge of a stratum. This range of pattern choices gives the analyst flexibility to balance the needs for spatial cover and randomness when designing the sample plan for a specific facility.

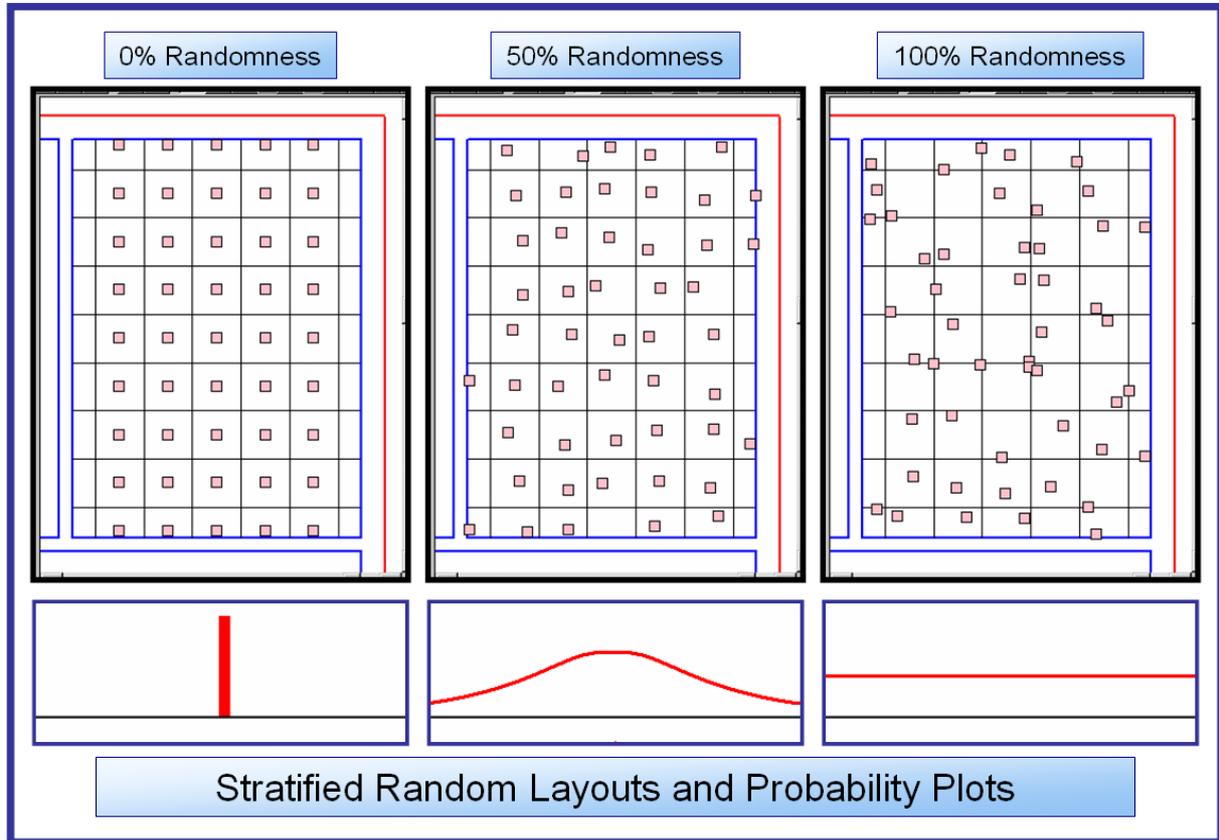


Figure 7-31. Effect of Randomness on Stratified Random Sample Layout.

7.4.5. Sampling Optimization

The sampling design tools within BROOM are based on the concept of adaptive sampling where some information has already been collected and the locations of additional samples need to take into account that existing information. The geostatistical mapping features within BROOM can provide spatial estimates of concentrations, uncertainty inherent in those estimates and/or the probability of exceeding a specified threshold concentration at any location. These spatial estimates are maps that serve as input to the optimization tools. As an example, additional samples could be acquired in areas of high estimated concentration and high uncertainty through the definition of an objective function that incorporates these two objectives: identify high concentration areas and sample where the uncertainty is the greatest.

The BROOM software provides two different options for creating an optimal sampling design. Here, sampling design is defined as the spatial arrangement of the samples within the building and does not directly address the choice of the sample type (e.g., vacuum vs. swab) or the type of analyses done on those samples. Optimal sampling designs are those that minimize some quantifiable objective function. Within BROOM, different objective functions can be created to achieve different sampling goals and these objective functions can be combined for multi-objective optimization. Two different optimization schemes, simulated annealing (SA) and the Probabilistic Adaptive Sampling Technique (PAST), are included within BROOM. Each optimization scheme is a heuristic optimization tool in that the final sampling design(s) are not mathematically provable as being the optimal designs. However, the final designs do meet some user-specified thresholds defining the degree to which the initial value of the objective function has been decreased or the total number of different sampling designs that have been evaluated.

In general, the major differences between the SA and PAST algorithms are that SA optimizes a single design at a time while PAST optimizes a population of designs simultaneously. SA is typically applied to discrete optimization problems (e.g., the spatial arrangement of samples on a predefined grid). PAST utilizes Monte Carlo simulation to address uncertainty in the mean, variance and probability fields. As implemented in BROOM, the SA algorithm uses previously calculated maps as the input and does not change these during the simulation. These maps can be thought of as response surfaces for providing input to the function evaluations. Within BROOM, the PAST module has been coded to work with the Sequential Gaussian Simulation (SGSim) geostatistical simulator.

7.4.5.1. Simulated Annealing

Simulated annealing (SA) is a generic probabilistic algorithm for completing combinatorial optimization. Different from gradient-based optimization algorithms, SA optimizes the combination of a finite number of objects in a large, but discrete, configuration space. SA is a good approximation for locating the global optimum of a given function in a large search space. Within a given SA method, each point of the search space is compared to a state of some physical system, and the objective function to be minimized is interpreted as the internal energy of the system in that state. This energy is a numerical analogy to the free energy in a physical melt where the goal is to cool the melt slowly such that the optimal crystalline configuration is reached. Numerically, the goal is to bring the system, from an arbitrary initial state, to a state with the minimum possible energy. In sampling design, the goal is to find the optimal configuration of N samples on a grid containing 1000's of potential sample locations on a predefined grid. Typical optimization goals are to simultaneously reduce uncertainty and to bound the extent of contamination that exceeds some threshold value.

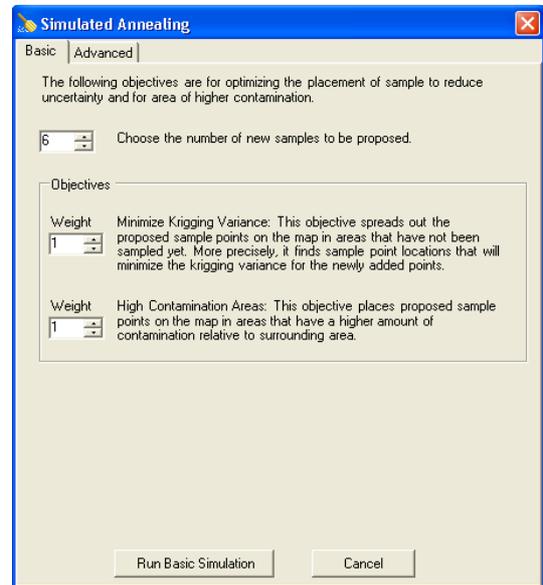


Figure 7-32. Simulated Annealing Interface.

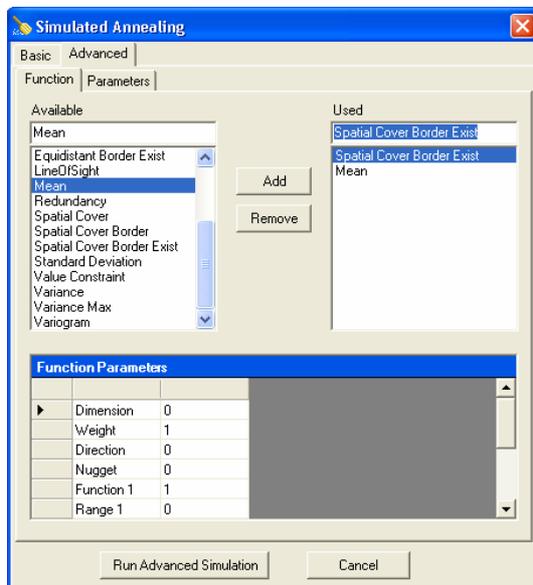


Figure 7-33. Simulated Annealing Interface.

At each step, the SA algorithm considers some neighbor of the current state s . SA then makes a probabilistical decision between moving the system to the new state s' or staying put in the current state s . The probabilities are chosen so that the system ultimately tends to move to states of lower energy. Typically, this step is repeated until the system reaches a state that is good enough for the application, or until a given computation budget has been exhausted. The probability of making the transition from the current state s to a candidate new state s' is a function of the energies of the two states, and of a global time-varying parameter T called the temperature.

The SA user interface provides two tabs for defining conditions for optimization: *Basic* and *Advanced*. The *Basic* tab allows the user to select the number of newly proposed samples, as well as the weights (corresponding to importance) for

minimizing kriging variance and finding high contamination areas. The *Advanced* tab allows many objective functions to be defined, which are described in more detail below.

7.4.5.1.1. SA Objective Functions

- Angle: The angle objective is minimized by placing samples around a center location (Center X, Center Y) such that the differences in the angles formed between adjacent points and the center location are minimized.
 - Center X: X-axis coordinate of the center location.
 - Center Y: Y-axis coordinate of the center location.
 - Weight: is a constant multiple applied to this objective function
- Covariance Max: The Covariance Max objective is maximized when the weighted average of the map data within the elliptical variogram surface (defined by the parameters below) is maximized. The weights applied to each map value are derived from the complement of the variogram function and are the spatial covariance values. Points falling within the variogram ellipse, but outside of the map boundaries are set to the lowest value in the map domain. In application, covariance max function is minimized by taking 1/max. Its opposite objective function is Covariance Min. More information on the variogram parameters can be found in Deutsch and Journel, 1998.
 - Anis: Range*Anis is length of the minor axis of the ellipse
 - Dimension: the index of the map column that defines the data set
 - Direction: gives the orientation/rotation of the major axis of the ellipse (0 north – 180 south)
 - Function: Defines the variogram function: 1-spherical, 2-exponential, 3-gaussian, 4-power
 - Range: length of the major axis of the ellipse
 - Sill: Sill1+Sill2+Nugget = 1.0 define the height of the ellipse at different distances from the center.
 - Weight: is a constant multiple applied to this objective function
- Covariance Min: The Covariance Min objective is minimized when the weighted average of the map data within the elliptical variogram surface (defined by the parameters below) is minimized. Points falling within the variogram ellipse, but outside of the map boundaries are set to the largest value in the map domain. More information on the variogram parameters can be found in Deutsch and Journel, 1998..
 - Anis: Range*Anis is the length of the minor axis of the ellipse.
 - Dimension: the index of the map column that defines the data set
 - Direction: gives the orientation/rotation of the major axis of the ellipse (0 north – 180 south)
 - Function: Defines the variogram function: 1-spherical, 2-exponential, 3-gaussian, 4-power
 - Range: length of the major axis of the ellipse width of oval
 - Sill: Sill1+Sill2+Nugget = 1.0 define the height of the ellipse at different distances from the center.
 - Weight: is a constant multiple applied to this objective function
- Difference: The difference objective is minimized when sample locations are chosen such that the difference between the map values at those locations and a prescribed value are minimized. .

- Dimension: the index of the map column that defines the data set
 - Value: the constant target value constant to which other points will be compared.
 - Weight: is a constant multiple applied to this objective function
- Difference Over Area: The difference over area objective is minimized when sample locations are chosen such that the difference between the average values within a given radius around the sample locations and the prescribed value are minimized. This is essentially the same as the Difference function, but operates on a simple spatial average centered on each sample location, not just the actual sample point.
 - Dimension: the index of the map column that defines the data set
 - Radius: the radius of the circle that defines which points to be averaged
 - Value: the constant target value to which other points will be compared
 - Weight: is a constant multiple applied to this objective function
- Distance: Similar to spatial cover, but without the edge boundary condition. The distance objective is minimized by maximizing the sum of Euclidian distances between all points.
 - Weight: is a constant multiple applied to this objective function
- Equidistant: Similar to spatial cover, but only to nearest neighbor. The equidistant objective is minimized by maximizing the sum of Euclidian distances to the nearest neighbor (nearest point or border of domain).
 - Weight: is a constant multiple applied to this objective function
- Equidistant Border Exist: This objective is minimized when oval shaped variograms (defined by function, range, sill) overlap most with the smallest values on the map. Points outside the map are set to the largest value in the domain
 - Anis: $\text{Range} \times \text{Anis}$ is height of oval
 - Dimension: the index of the column that defines the data set
 - Direction: gives the orientation/rotation of the oval (0 north – 180 south).
 - Function: 1-spherical, 2-exponential, 3-gaussian, 4-power
 - Range: width of oval
 - Sill: $\text{Sill1} + \text{Sill2} + \text{Nugget} = 1.0$
 - Weight: is a constant multiple applied to this objective function
- Line of Sight: The line of sight objective requires that topographic elevation be one of the map data columns. This objective is minimized by constructing a minimum spanning tree where the edge weights in the tree are determined by line of sight connections. The edge weight is equal to minimized if the two locations have a line of site connection and equal to the amount of land above the straight-line connecting the two points if they do not have line of site connection. . When all points have line of site communication, the objective is minimized. Edge weight between two points, P1 and P2, is calculated by integrating the area above the straight line.
 - Dimension: the index of the map column that defines the data set
 - Weight: is a constant multiple applied to this objective function
- Mean: The average value of a data set (defined by dimension) is minimized. This is equivalent to choosing the minimal values of a data set.
 - Dimension: the index of the map column that defines the data set
 - Weight: is a constant multiple applied to this objective function
- Redundancy: This objective ensures that line of sight connections are maintained in the case of partial failure (removal) of one or more sample locations. This objective only ensures that each node has multiple line of sight links to adjacent nodes. It does not

ensure that global line of sight across all sample locations will be maintained in case of sample failure (removal). An Example of failure is with two strongly connected sub-graphs with a bridge between them.

- Dimension: the index of the map column that defines the data set
- MinSight: the minimum number of line of sight connections between each data point and others
- Weight: is a constant multiple applied to this objective function
- Spatial Cover: Similar to distance, but with edge boundary condition. The spatial cover objective is minimized by maximizing the Euclidian distance from each sample location to all other sample locations points and the nearest location of the domain edge boundary.
 - Weight: is a constant multiple applied to this objective function
- Standard Deviation: The standard deviation of a data set (defined by dimension) is minimized.
 - Dimension: the index of the column that defines the data set
 - Weight: is a constant multiple applied to this objective function
- Value Constraint: Ensures that points are bounded by the low and high value in a defined data set (defined by dimension). While labeled as a constraint, this is actually an objective where the objective is minimized by keeping all sample locations within the High/Low limits defined.
 - Dimension: the index of the column that defines the data set
 - High: the maximum value for each sample data point
 - Low: the minimum value for each sample data
 - Weight: is a constant multiple applied to this objective function
- Variance: The variance of a data set (defined by dimension) is minimized.
 - Dimension: the index of the column that defines the data set
 - Weight: is a constant multiple applied to this objective function
- Variogram: The variogram objective places an elliptical variogram surface at the center of each sample location. This function is minimized when the amount of weighted (by the covariance) overlap between adjacent sample points is minimized. This objective has similarities to the Covariance Min and Covariance Max objectives.
 - Anis: Range*Anis is length of minor axis of ellipse
 - Dimension: the index of the map column that defines the data set
 - Direction: gives the orientation/rotation of the major axis of the ellipse (0 north – 180 south).
 - Function: Defines the variogram function: 1-spherical, 2-exponential, 3-gaussian, 4-power
 - Range: length of minor axis of ellipse
 - Sill: $Sill1+Sill2+Nugget = 1.0$ define the height of the ellipse at different distances from the center
 - Weight: is a constant multiple applied to this objective function

7.4.5.2. Probabilistic Adaptive Sampling Technique - PAST

The primary benefit to the PAST method for optimizing characterization sampling is the application of a geostatistical analysis method. Unlike traditional statistical methods, geostatistics can be used to model the spatial correlation of existing data, thereby producing a representation of spatial variability throughout the domain of interest. Some amount of data is

needed to begin an analysis using geostatistics. It is recommended that at least 20 or 30 randomly placed samples be collected prior to beginning a geostatistical analysis.

Once a set of data is acquired, a variogram analysis is conducted that models the spatial correlation of the data. There are several common spatial correlation models available to fit to the observed data. These include spherical, Gaussian, and exponential models. A spherical model works well most of the time. Figure 7-34 shows an example of a variogram fitting analysis. It is also possible that the data may need to be transformed to obtain a reasonable variogram fit to a spatial correlation model. Log transformations may be employed when the range of the data is over multiple orders of magnitude. At times, the data are not spatially correlated, and the variogram analysis will not provide a good fit to the observed data. In these instances, it may not be advisable to use a geostatistical approach because the data are not correlated.

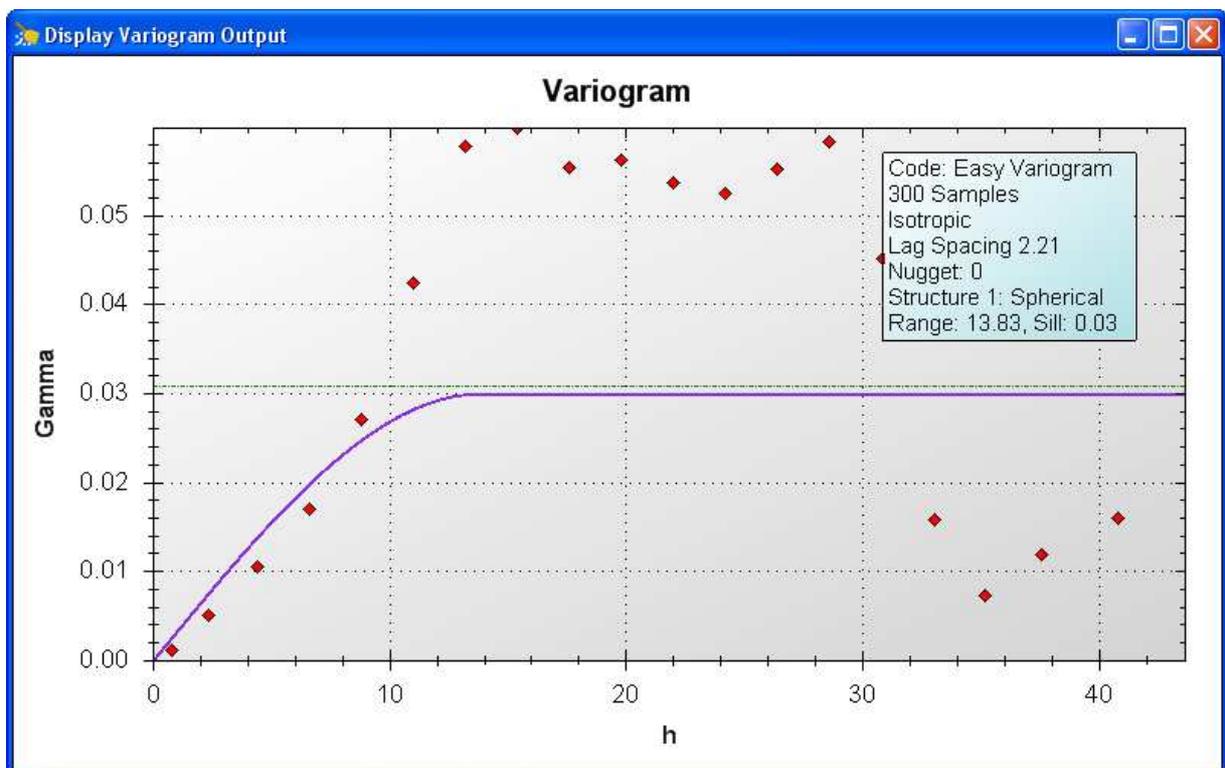


Figure 7-34: Example of a Variogram Analysis

Once a variogram analysis has been completed, a geostatistical model is employed to estimate the spatial distribution. There are many options for geostatistical models. The most common application of a geostatistical model is kriging. Kriging estimates the mean spatial distribution of the data as well as a variance estimate (i.e., a measure of uncertainty). Another geostatistical technique that can be used involves simulation. This method is called Sequential Gaussian Simulation, or SGSim. With SGSim, the user specifies a number of realizations to simulate and the code produces those variations of the spatial distribution. Each realization honors the values of the known data points but projects a different spatial distribution between data points that still meets the variogram specifications. With SGSim the user can get an appreciation for the amount of variability that might exist in the spatial distribution between known data points. From the

multiple realizations produced by an SGSim analysis, an estimate of the spatial distribution of the variance can be made. In addition, if the user specifies a concentration of interest, a probability of exceeding that concentration can be estimated throughout the area of interest. A probability plot is quite useful when evaluating the variability and uncertainty in the cleanup area, if the concentration specified was a preliminary remediation goal based on a risk assessment. The PAST method employs the SGSim model to take advantage of the probability estimates, as well as the variance. Many of the geostatistical models are available from Deutsch and Journel (1998).

The optimization algorithm developed for the PAST method is designed to reduce the uncertainty in the area defined by a user-specified concentration threshold (e.g., a cleanup guideline). The user needs to supply several parameters associated with the objectives of the optimization. First the user defines the concentration threshold of interest. Next the user defines a probability of exceedance range within which a search routine will function. By example, the user might specify a probability band of 0.70 to 0.99 to conduct a search, meaning that the spatial distribution of contamination is 70% to 99% likely to exceed the specified concentration threshold. The user then supplies a distance measurement that corresponds to a minimum distance between adjacent sampling points. This is a constraint objective. The intent of this objective is to prohibit the search algorithm from specifying a dense congregation of sampling points that would not add significant value to the spatial distribution prediction. The reason that the search algorithm could return densely populated sampling locations is that it is searching for the locations where the variance is highest, which implies that the uncertainty is highest. The PAST method seeks to reduce uncertainty, so locating samples where the variance is highest will reduce uncertainty. Finally, the user specifies the number of potential sampling sites that will be identified for this round of the iterative sampling protocol. At the end of each sampling iteration, the geostatistical tools are used to estimate the cleanup area defined by the user-specified concentration threshold. A standard deviation of the cleanup area is also calculated. The user then decides whether to do another round of sampling based on the difference in the cleanup area and its uncertainty from the last iteration of sampling. The user may decide that a 5% difference is acceptable and that no further improvement in the estimate of the cleanup area is warranted, and a decision based on this state of information can be made. Figure 7-35 shows decision logic for implementing the PAST method. In summary, the PAST method is searching for a specified number of new sampling locations that will reduce the uncertainty in the spatial distribution of the user-specified concentration threshold.

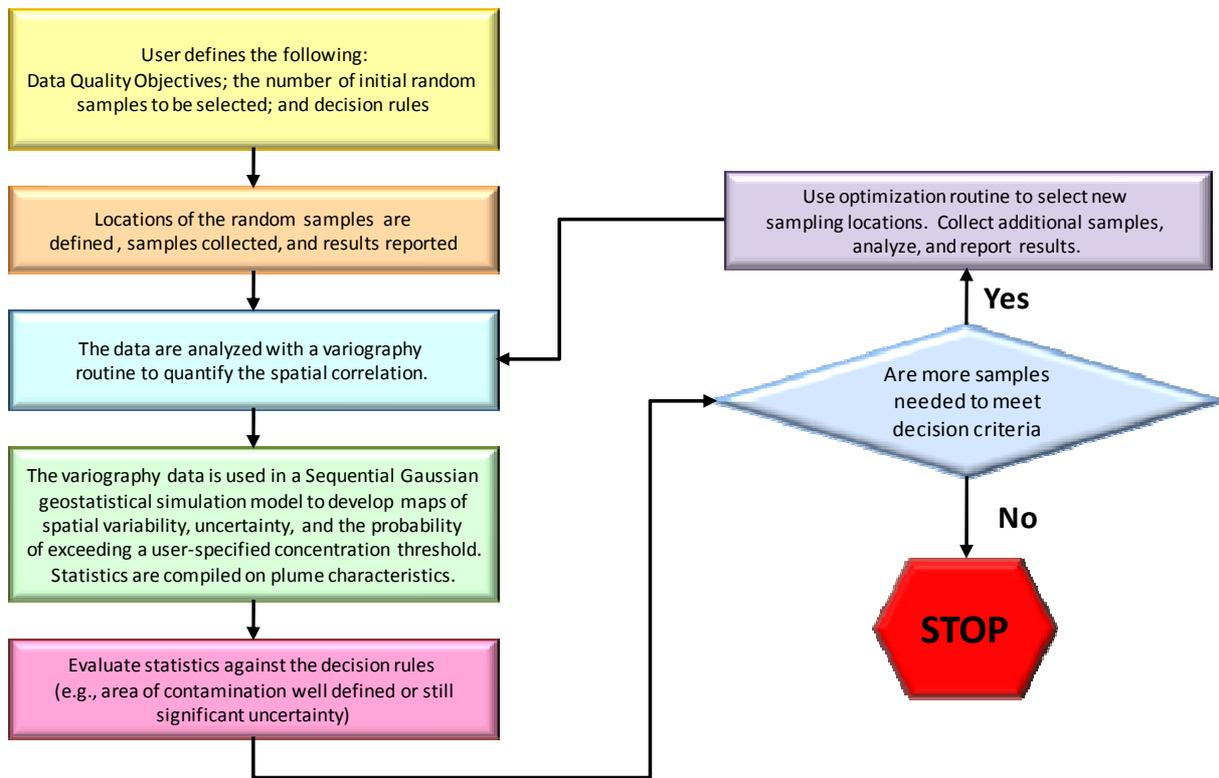


Figure 7-35: Decision Logic for PAST

In order to demonstrate the application of the PAST method, a case study was needed. A lead contaminated site at SNL was selected to evaluate the PAST method. The site was characterized extensively under regulatory oversight from the EPA, thereby providing a good comparison to the proposed PAST method. The site was approximately 5 acres in size. The EPA prescribed 2 rounds of sampling: a star pattern and a grid pattern. The EPA was not satisfied until 350 samples were collected. No statistical measures were employed at the time to define the adequacy of sampling. Figure 7-36 shows the sampling results from the EPA endorsed sampling scheme.

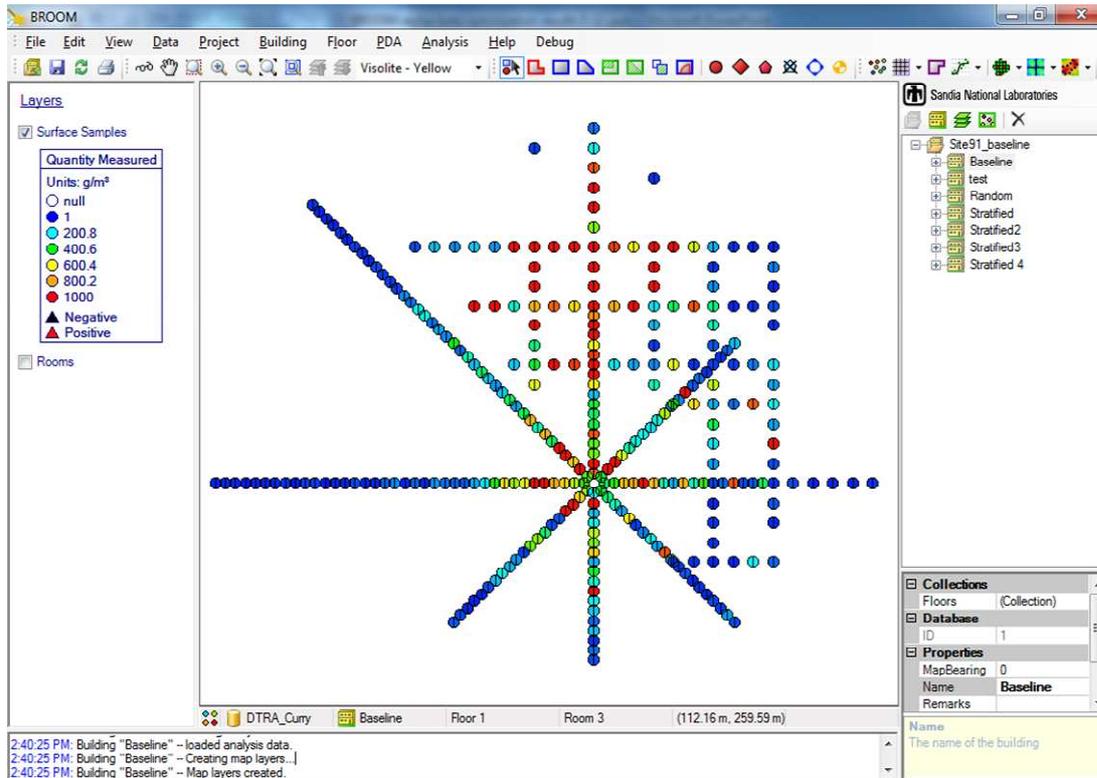


Figure 7-36. Sampling results for lead contaminated site

A geostatistical analysis was performed on the lead site data on a 12 meter grid resolution. The spatial concentration map (Figure 7-37) was assumed to be a baseline for querying concentration data for the PAST evaluation.

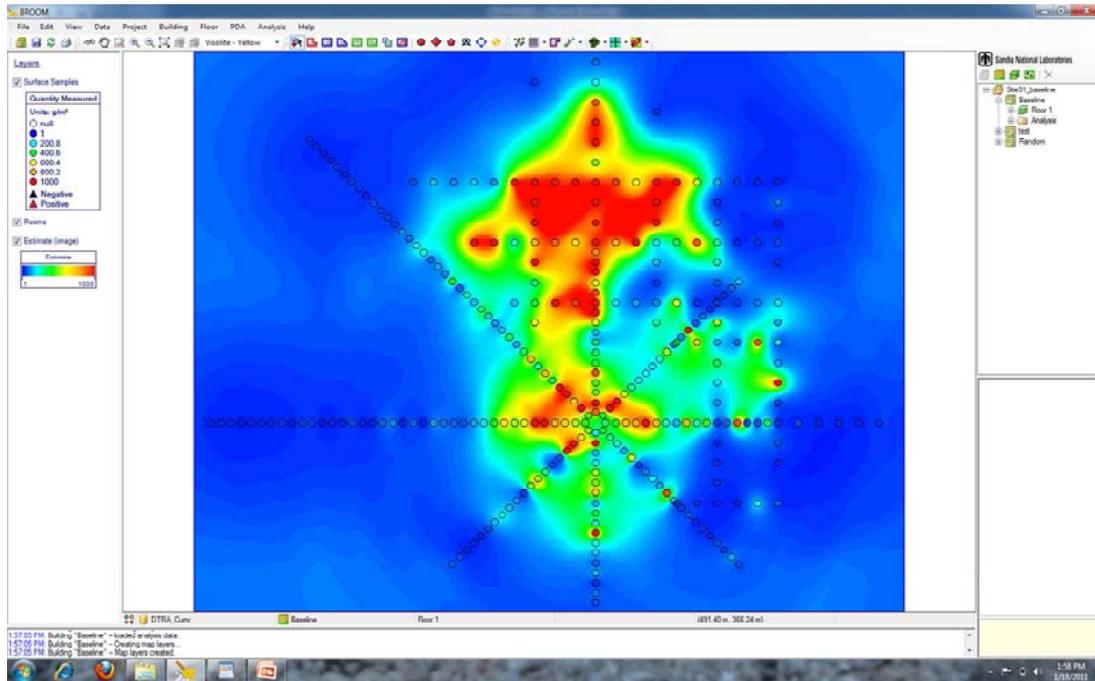


Figure 7-37. Geostatistical mapping results for lead contaminated site

The PAST method begins with a prescription for an initial round of sampling. Twenty five (25) samples is generally considered a minimum dataset to begin a spatial analysis. A stratified random approach was used to designate the locations for the first 25 sampling points, whereby a grid is established and within each grid cell a random location is selected. The baseline spatial dataset is queried for the concentrations at each of the 25 sampling locations. Next, a variography analysis is performed to model the spatial correlation of these data. Sequential Gaussian Simulation (SGSim) is performed to predict the concentration distribution and variance distribution. A risk-based concentration threshold of 300 parts per million (ppm) has been established by the EPA, which is used to estimate a probability map for the PAST method. The user also specifies a minimum distance between sampling points when estimating new sampling locations.

Next, the user specifies the number of samples they want to collect for the next round of sampling. Because the SNL robotics platform can only collect 6 samples at a time, the number of samples for each sampling round was set to 6 to evaluate the burden on the robotic deployment. Each round of sampling is culminated with an analysis of the data and a prediction of the next round of sampling locations. The area of contamination that is greater than the concentration limit for lead in soil was used as the metric to evaluate the performance of the method.

The baseline dataset has an area of 14,800 m². PAST uses the variance distribution and a user-specified probability band to select new sampling locations. Figure 7-38 shows the variance distribution (an expression of uncertainty) and Figure 7-39 shows the spatial distribution of the probability of exceeding the risk-based threshold, 300 ppm.

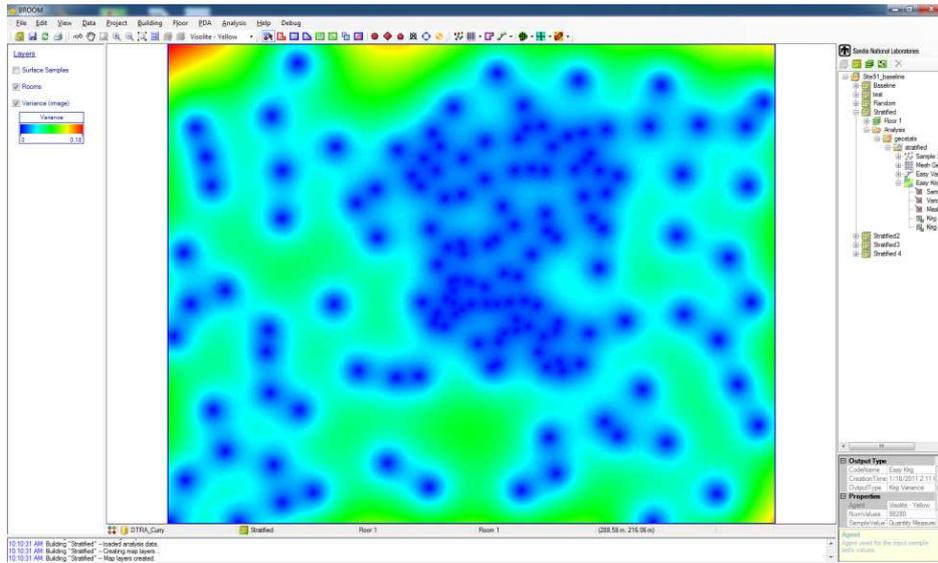


Figure 7-40. Variance mapping results for lead contaminated site

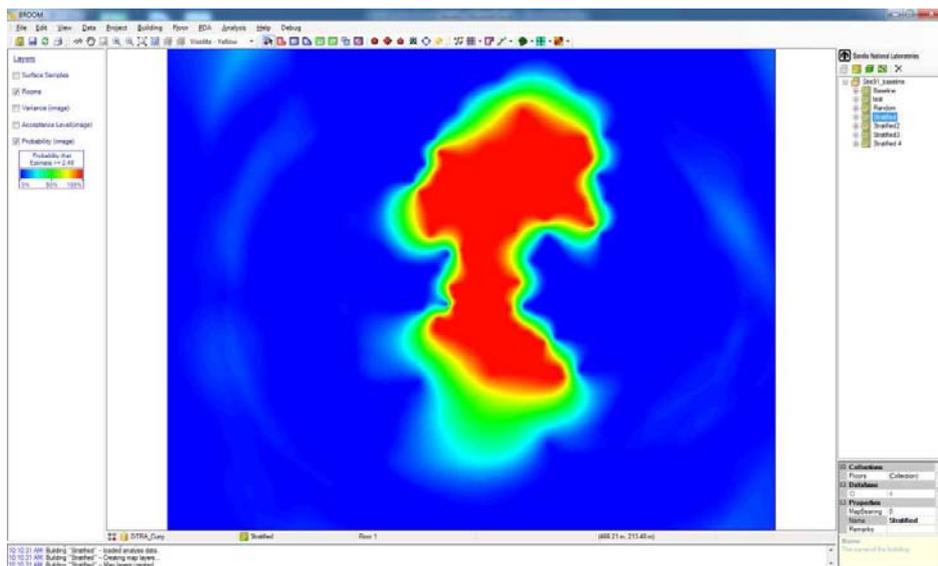


Figure 7-39. Probability mapping results for lead contaminated site

The iterative procedure for evaluating new rounds of sampling was continued until a total of 140 samples were collected. Figure 7-40 shows results of the estimated area that is greater than or equal to the 300 ppm concentration limit for each round of sampling.

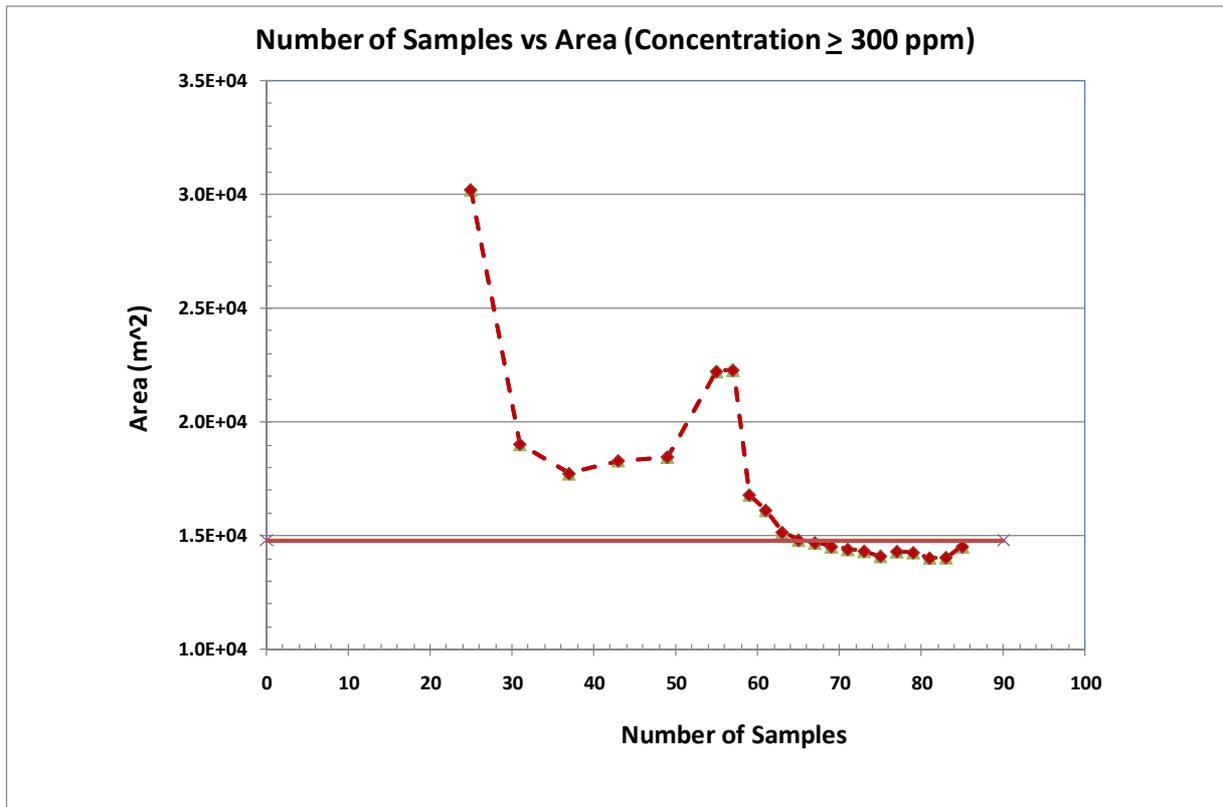


Figure 7-40. Plume statistics for sampling iterations for lead contaminated site

The PAST method defined the extent of contamination within the risk-based limit with ~60 samples compared to 350 samples with a conventional EPA approach. Clearly the PAST method has the ability to optimize sampling requirements. Figure 7-41 shows the final results of the plume mapping with 60 samples.

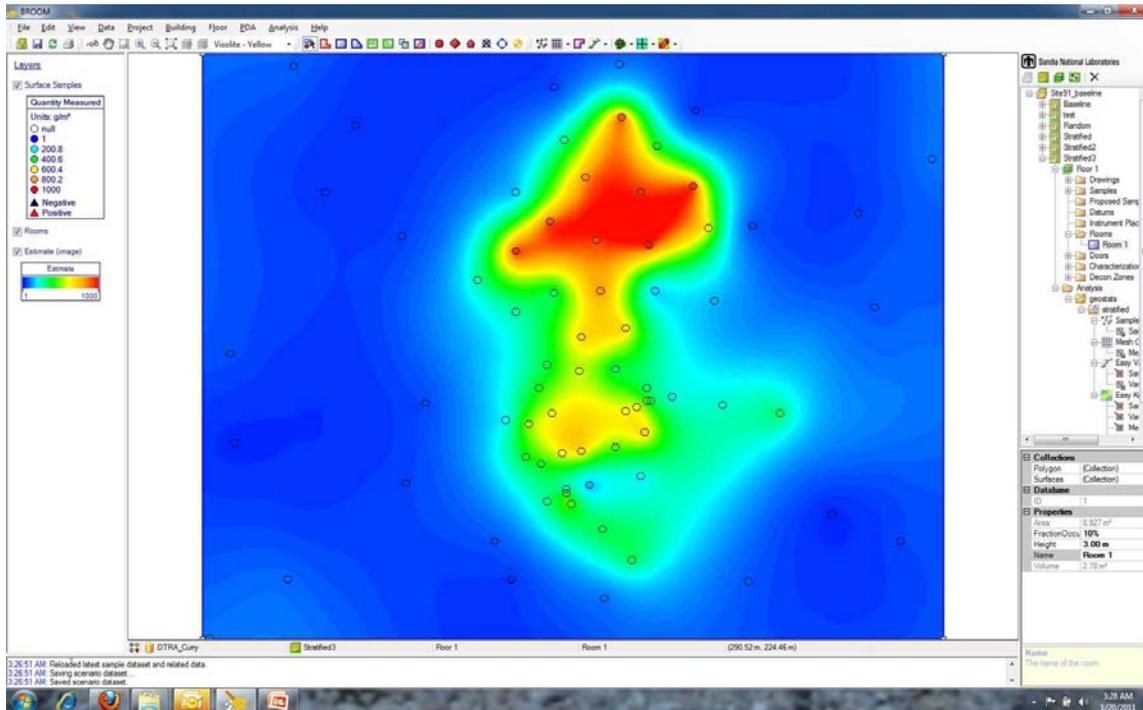


Figure 7-41. Geostatistical mapping results using PAST for lead contaminated site

The geostatistical simulation technique estimates concentrations in a grid. A mass estimate can be derived for each grid cell based on the predicted concentration for each grid, then summed to get a total mass estimate. This estimate is dependent on an assumption of the thickness of the contaminated soil. Assuming a 1 inch thick layer of contaminate soil, this test site has approximately 1M kg of lead throughout the whole area, and about 0.8M kg that is over the 300ppm limit.

7.4.5.2.1. PAST Functionality in BROOM

In order to use the PAST routine in BROOM, the user must first create a rectangular characterization zone of interest in which they wish to have the sampling optimization performed. Once a characterization zone is defined, it is recommended that a stratified random sampling design be invoked to establish the locations of the first round of samples. A stratified random approach distributes samples throughout the zone of interest, which should lend better to establishing the spatial correlation attributes of the data and to preclude any areas from exclusion. To be statistically representative, a minimum of twenty five (25) samples is recommended for the first round of sampling. Once those samples have been collected, analyzed, and the results imported into BROOM, a Sample Set should be created within the characterization zone. The user may want to consider transforming the data (e.g., log transform) and setting a zero substitution value of some minimal value in order to have the variography and geostatistical simulations perform better. Once the data set has been created, a mesh needs to be defined for the characterization zone. The mesh needs to have square cells. Next, the user should perform a variography analysis with the Easy Variogram routine.

The PAST method within BROOM utilizes a different geostatistical routine than the kriging methods available to the user, so therefore the kriging model does not need to be invoked in order to run PAST. It uses a geostatistical simulator called SGSim. SGSim will perform multiple realizations of the concentration distribution while honoring the variogram and data from the data set. The user selects the PAST option and is queried for the appropriate Sample Set, mesh, and variogram. Next, the user must input parameters that influence sample optimization. Figure 7-44 shows the pop-up window to prescribe the necessary parameters for the optimization routine.

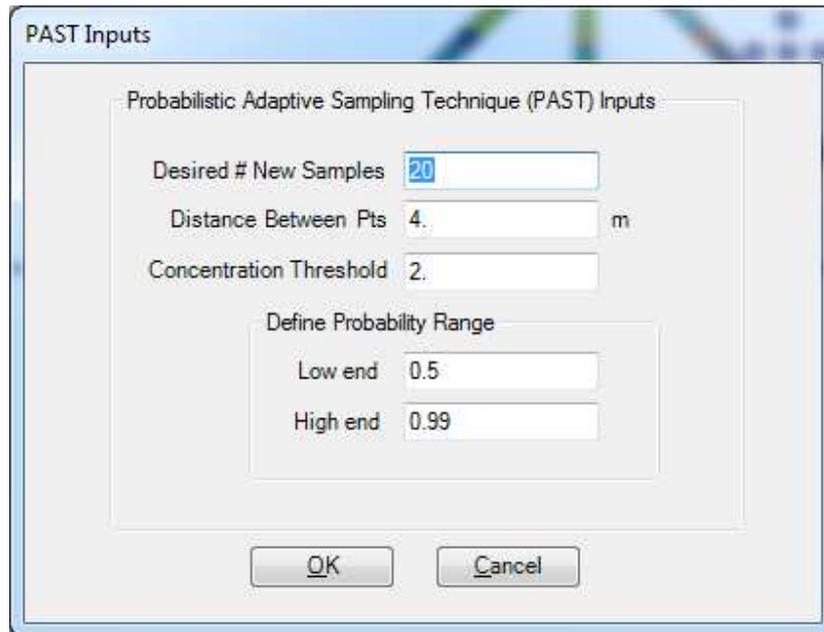


Figure 7-44. Input parameter screen for the PAST module

The user specifies the number of samples that they wish the PAST module to produce. The PAST module may not produce that many sample locations, because of the criteria for selecting new sample locations which may be limited by the prescription for an off-set distance between existing and proposed sampling points, the concentration threshold, and the probability range. The concentration threshold is an important parameter. This is the concentration value around which the user wants to optimize the sampling locations in order to define the distribution of contamination that is greater than or equal to this prescribed amount. The probability band determines how tight spatially the new sample locations are likely to be around the concentration threshold. Once these parameters are set the user clicks the OK button. It may take several minutes or more to perform the optimization due to the fact that PAST is running a Monte Carlo type simulation with many realizations of the SGSim geostatistical simulator.

On the right side of the BROOM screen in the Analysis folder, PAST will have created several output fields. One allows the user to display the proposed new sample locations. Other options allow the user to display the mean concentration distribution, a variance distribution and a probability distribution. There is also a capability to create a KML file that can be viewed in Google Earth.

8. CASE STUDY

BROOM has been instrumental when deployed on a number of release tests facilitating data acquisition, data management and data analysis. Summaries of these case studies will be provided in a later edition of this User's Manual. Several references may be of use to the user to see the overall use of the BROOM software on several of these tests.

Knowlton, Robert and Brad Melton, 2010, "Data Collection and Analysis of the HUMBLE YUCCA Release Test Using the BROOM System", Sandia Report #SAND2010-7511, Sandia National Laboratories, Albuquerque, New Mexico, .

Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD), 2008, "Evaluation Report, September 2007: Indoor Field Evaluation of Sample Collection Methods and Strategies at Idaho National Laboratory", May 2008, Prepared for the Department of Homeland Security, Science & Technology Directorate, Washington, DC 20528, and Joint Program Executive Office for Chemical and Biological Defense, 5203 Leesburg Pike, Skyline 2, Suite 1609, Falls Church, Virginia 20147, 140 p..

Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD), 2008, "Evaluation Report, September 2008: Indoor Field Evaluation of Sample Collection Methods and Strategies at Idaho National Laboratory II", December 2008, NSTD-09-0163, Prepared for the Department of Homeland Security, Science & Technology Directorate, Washington, DC 20528, and Joint Program Executive Office for Chemical and Biological Defense, 5203 Leesburg Pike, Skyline 2, Suite 1609, Falls Church, Virginia 20147, 264 p..

9. REFERENCES

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