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Geographic Information System Software to Enhance Field-Data Collection and Management of Land Cover Trends Information

By Nathan Wood, Benjamin Sleeter, and Peter Ng

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Introduction

Understanding the rates, driving forces, and consequences of land-use and land-cover change is critical to the study of coupled human-environmental systems and in the ability of land-use managers to effectively manage natural resources (McMahon and others 2005). To support these needs, the U.S. Geological Survey (USGS) Land Cover Trends project seeks to (1) estimate the rates of land-cover change between 1972 and 2000, (2) document the regional driving forces of land-cover change, (3) determine the consequences of contemporary land-cover change, and (4) prepare regional and national syntheses of late-20th century land-cover and land-use change (Loveland and others 2002). Using an ecoregion stratification (Omernik 1987), researchers estimate land-cover change by mapping land cover in randomly selected 10-km by 10-km sample blocks of satellite data for five dates centered around 1973, 1980, 1986, 1992, and 2000 (Loveland and others 2002, Stehman, 2003).

In addition to estimating land-cover change for the sample blocks within an ecoregion, researchers conduct fieldwork to better understand local and regional driving forces and potential consequences of this change. At field sites within each sample block, researchers record qualitative observations in a notebook, collect global-positioning-system (GPS) waypoints, and take photographs. Hardcopy prints of imagery, road maps, and other ancillary geospatial data are used for navigation and for field annotations. Field trips last from one day to one week, with an average length of 5 days. Following fieldwork, researchers spend many hours entering field data, photographs, and map annotations into a digital database summarizing each ecoregion. The final database includes information for each field visit on geographic location, waypoint, sample block number, photograph roll and frame identification, ecoregion identification, and a landscape description.

Field data collection and database management is a significant task for the Land Cover Trends project, due to the national scope of the project and the high number of researchers involved from various USGS science centers. As such, any efforts to increase the efficiency of data collection and accessibility of research findings could have significant research and logistical benefits. Potential areas for increasing efficiency in the Land Cover Trends project include (1) minimizing the amount of hardcopy materials needed in the field while increasing the ability to view spatial data, (2) minimizing the

amount of people required for fieldwork, (3) eliminating potential transcription errors when researchers transfer field notes into digital formats, (4) decreasing the amount of time required for postfieldwork data processing, and (5) increasing the accessibility of collected information for the Land Cover Trends research community.

Purpose and Scope

An extension module to add specialized functionality to geographic information system (GIS) software was created to reduce field logistics and postfieldwork processing in the Land Cover Trends research project. The extension module developed to support the Land Cover Trends project, hereafter called the Trends extension, is designed to be used in the field on mobile computing technology platforms, such as tablet-based personal computers (tablet PCs) for data collection, and in the office on desktop computers for database management. This report summarizes extension installation, methods for its use in the field, and the benefits of its use for researchers.

In addition to supporting the Land Cover Trends research project, this extension was developed to demonstrate the benefits of mobile-computing technology in (1) minimizing logistical and postfieldwork data processing issues related to USGS fieldwork, (2) furthering the use of geospatial information in USGS field research efforts, and (3) in leveraging the existing USGS investment in GIS technology. Logistical issues related to fieldwork and postfieldwork data processing identified in this report are not unique to the USGS Land Cover Trends project and are common issues in many field research efforts of the USGS, We believe integrated packages of GPS, GIS, and mobile-computing technology, like the one described in this report, are applicable to other field research efforts at the USGS, and similar extensions can be developed elsewhere to support USGS research efforts.

Land Cover Trends Extension

Overview

The GIS extension summarized in this report was developed to aid researchers in field-data collection and management related to the USGS Land Cover Trends project. Used in conjunction with tablet PCs, the Trends extension is designed to (1) create a digital forum to collect and store field data while not affecting a researcher's work flow and (2) to create a more efficient information-retrieval system for postfieldwork analysis and documentation. The Trends extension was tested by several users in preparation of this report and software testers felt field-data collection and database management efforts were enhanced by this extension. Specific benefits include:

- The ability to view and query spatial data for navigational purposes instead of referencing hardcopy maps and photos;

- An increase in location accuracy by integrating GPS receivers with the digital database;

- A reduction in postfieldwork processing time by building a digital database in the field;

- The elimination of potential transcription errors in transferring written field notes to a digital database;

- A standard data-collection form and database-management system for multiple users; and

- Greater accessibility of ecoregion findings for the entire research community by archiving and sharing inherently geospatial data in a geospatial database.

Another significant benefit to incorporating this emerging technology into field work is the ability to have a fully functioning GIS environment while at a particular field location. The ability to view and query spatial data in the field may result in better available information about a specific site leading to a broader understanding of the different observed land-cover and land-use changes. Having this data available to the field team in real time could promote more in depth discussions of land-cover and land-use change potentially leading to a more robust understanding of the driving forces of change in the region.

Installation

Before installing the Trends extension, the following must be on the host computer for the extension to work properly:

- ArcGIS 9.0 or higher;

- ArcObjects InterOp libraries [If installed, these libraries would be located in a folder called "DotNet" in the ArcGIS install directory (i.e. C:\Program Files\ArcGIS\DotNet). If the folder is missing, run the ArcGIS installation disc in modify mode to install the libraries for .NET.]; and,

- Microsoft .NET Framework 1.1 (To check if your system has this, go to your desktop taskbar and click Start->Control Panel->Add/Remove Programs and look for an entry for the .NET Framework 1.1.).

Note: If you have .NET Framework 2.0 installed, remove it if it is not needed. The Crystal Reports functionality of the ArcGIS Trends Tool Extension will not work properly if .NET Framework 2.0 is installed. This is because Crystal Reports makes references to ADO.Net dataset at runtime. The version of ADO.Net used in the software code is defined in .NET Framework 1.1.

The installation package for the Trends extension includes a setup.exe, a setup.ini and a setup.msi file. To guarantee that all the necessary assemblies are installed, users should install the extension by opening the "setup.exe" file. Upon opening this file, the user will see the *Trends Extension Setup Wizard* dialog (fig. 1).
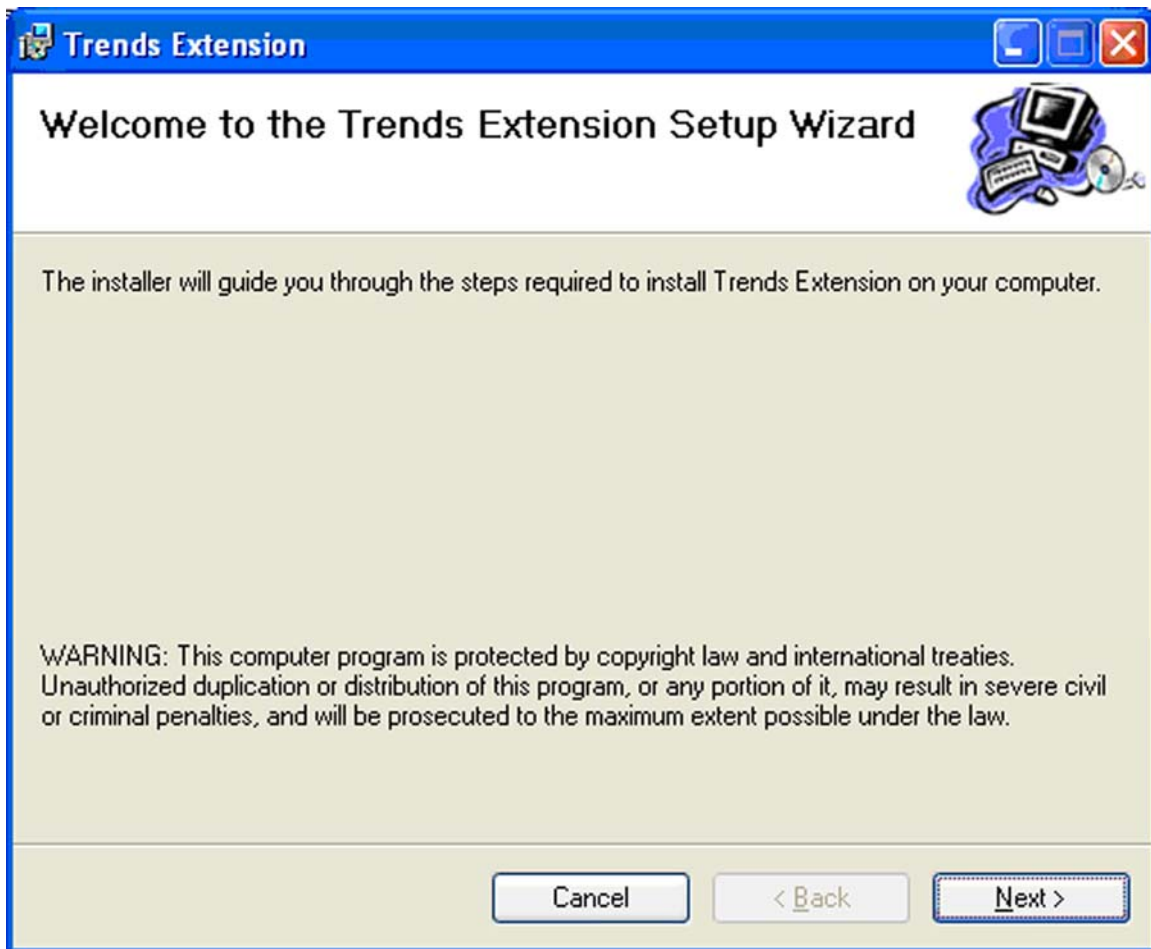
Figure 1. Welcome to the Trends Extension Setup Wizard dialog box.

Clicking the "Next" button in this screen brings up the *Select Installation Folder* dialog box (fig. 2). The user should install the program to the default directory, which is "C:\Program Files\USGS\TRENDS Extension," to ensure proper functioning. The user is also able to determine here whether the extension is accessible to anyone who uses the computer.
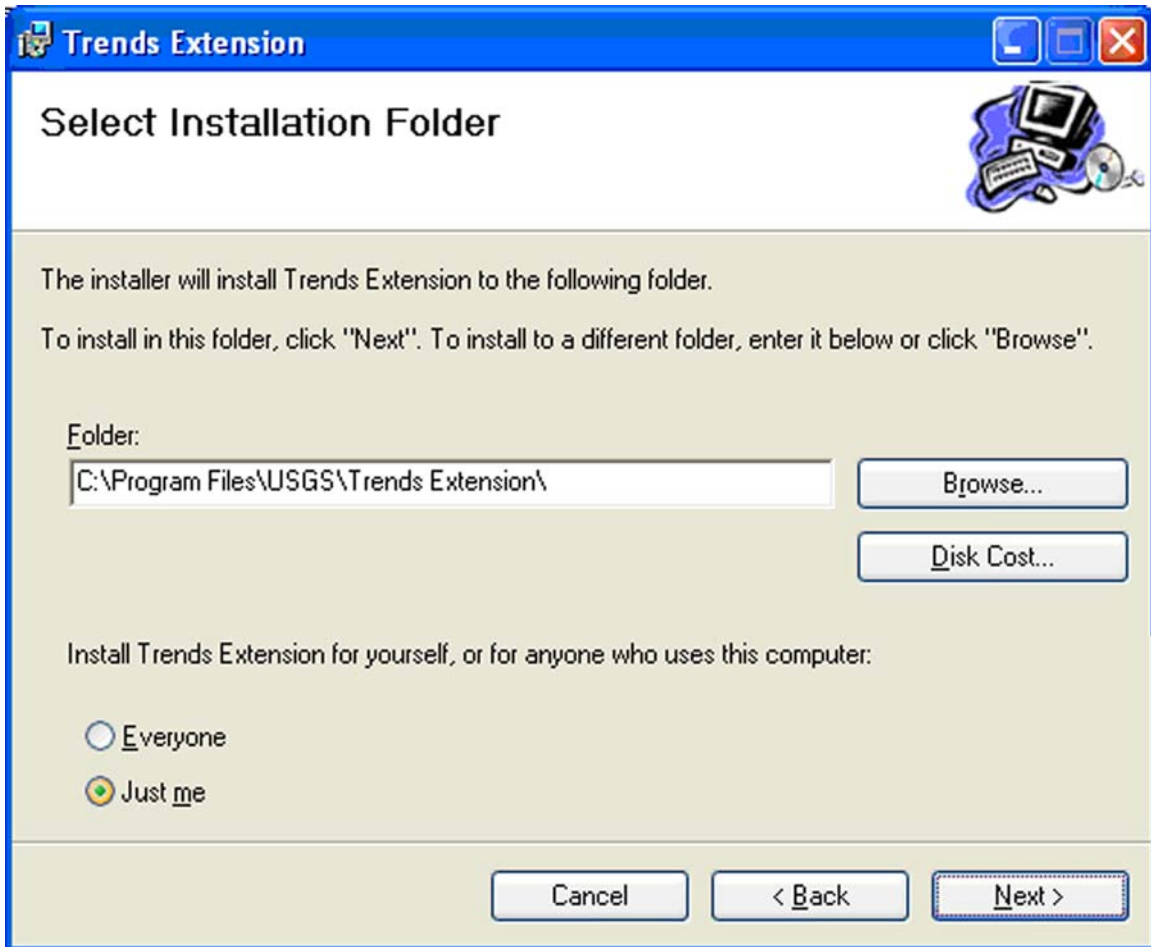
Figure 2. Select Installation Folder dialog box.

Clicking the "Next" button in the *Select Installation Folder* dialog brings up a *Confirm Installation* dialog box (fig. 3). The user clicks the "Next" button to begin extension installation.
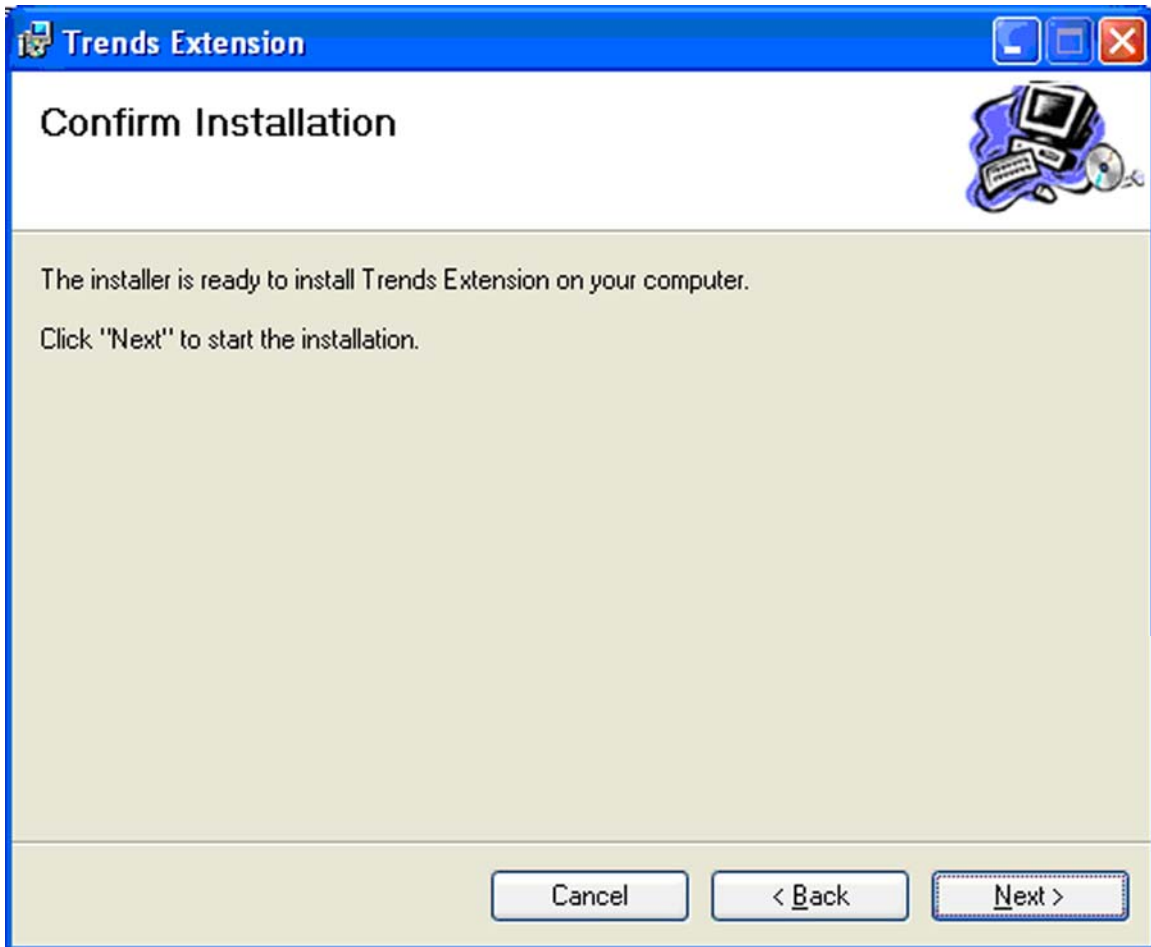
Figure 3. Confirm Installation dialog box.

If the Trends extension is successfully installed, an *Installation Complete* dialog box will appear (fig. 4). The user should then click the "Close" button to close the installation dialog box.

If the setup.exe fails to install the extension, ensure that the host computer has the required configurations described earlier in this section. In addition to these software requirements, the user will need to have operational knowledge of the GPS functions for ArcGIS, as the Trends extension requires a GPS receiver and connection to obtain waypoint information. Any GPS receiver and connection will work with this extension because the extension reads the ArcGIS GPS connection, not the direct GPS data stream. For more information on how to setup a GPS connection, users should consult ArcGIS Help.
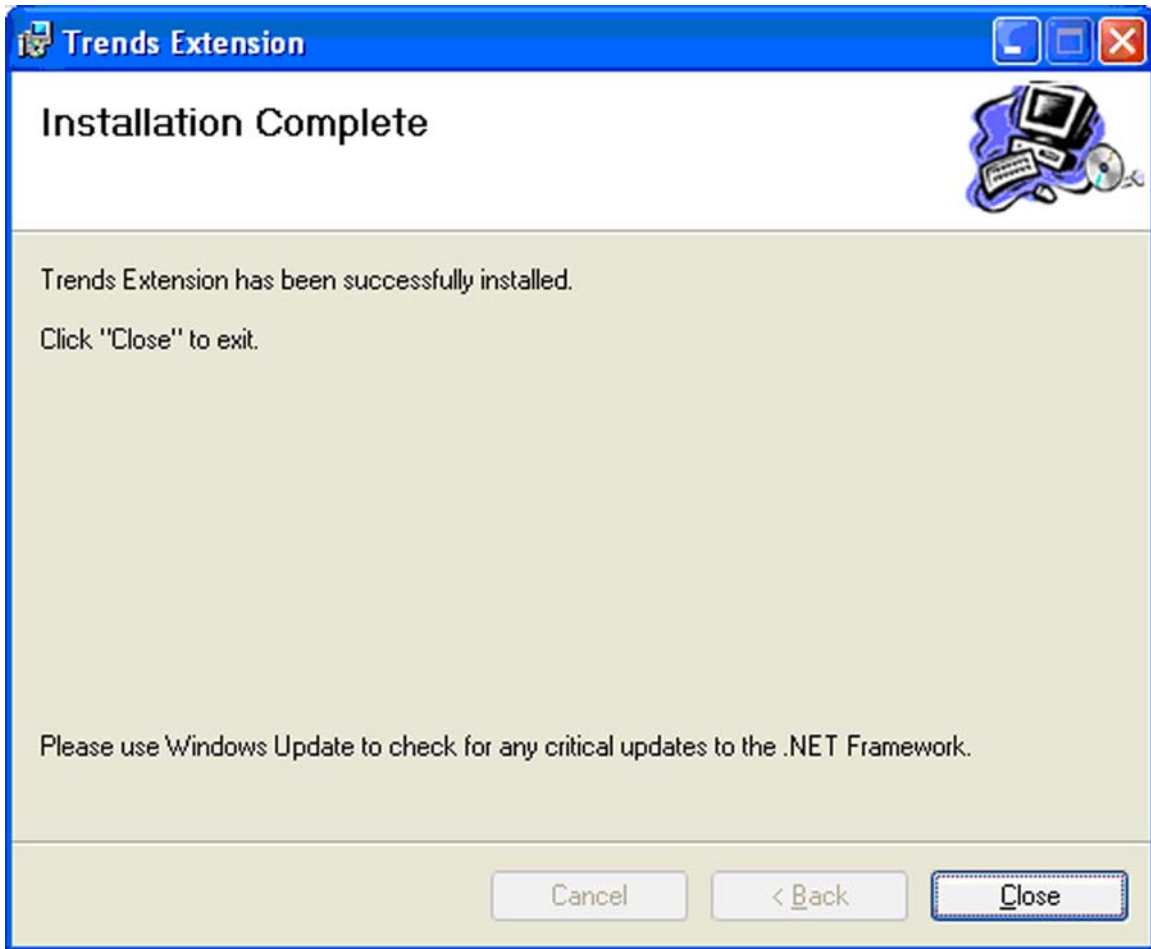
Figure 4. Installation Complete dialog box.

Trends Toolbar

Once properly installed, the extension will register under the Tools/Extensions menu option in ArcMap. The Trends toolbar is made available under the Tools/Customize option or by right-clicking the menu area and selecting "USGS Trends Tools." The toolbar consists of the following features (fig. 5):

- Trends Database setup button;
- Manage Ecoregion button;
- Sample block drop-down list;
- Waypoint drop-down list;
- Add waypoint button;
- Edit waypoint button;
- Add and (or) edit an observation button;
- Add and (or) edit media references button; and
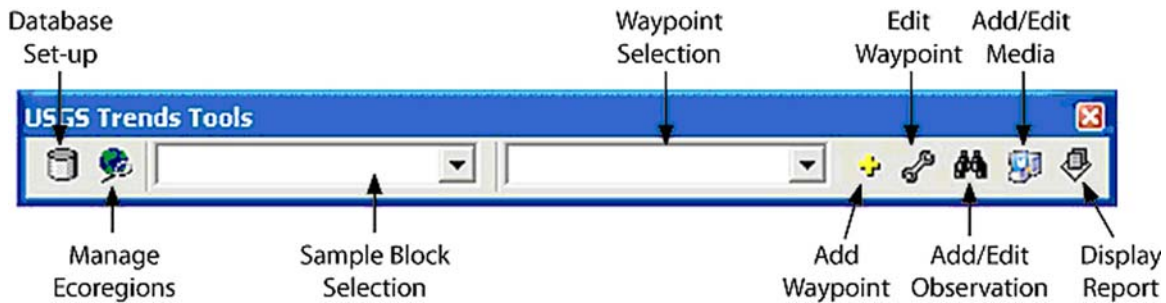- Display field observation report button.

Figure 5. USGS Trends Tools toolbar.

Database Setup

The Trends extension is driven by a trends database that is used for storing and managing data pertaining to each ecoregion, including block, waypoint, observation, and media reference data. A trends database is an ArcGIS geodatabase, which is a type of Microsoft Access database file featuring additional capabilities for storing and managing geospatial data. You can create as many trends databases as desired, but only one trends database can be actively selected at any time.

To select or create a trends database, press the *Setup Trends Database* icon on the trends toolbar (fig. 5). This will open a dialog window that allows you to create a trends database or browse for an existing one. When the user clicks "OK" to exit, the database specified in the dialog window becomes the actively selected trends database. Note, when the trends toolbar is first activated or when an ArcMap application is opened, the *Setup Trends Database* icon will be the only enabled icon in the toolbar. Only after a trends database has been selected via the *Setup Trends Database* dialog window will the other icons in the toolbar become enabled.

Before using the Trends tool, researchers must first set up the database and load ecoregion data. To do this, the user must follow these steps:

1. Once the Trends tool is visible in ArcMap, click the "Database Setup" button on the Trends toolbar (fig. 5)

2. In the *Database Setup* dialog box (fig. 6), click the "Create" button if creating a new database or the "Browse" button for identifying an existing database.

3. After creating or selecting a database, the user must now load ecoregion data. In the *Database Setup* dialog (fig. 6), click the "Load EcoRegion data" button. Multiple ecoregions can be loaded into the database as long as each ecoregion has a corresponding blocks feature layer. It is the blocks feature layer for the ecoregion that is loaded into the database. A set of four tables is created for each loaded ecoregion to store block, waypoint, observation, and media reference data. The names of each of the new tables are prefixed with the name of the ecoregion. For example, if an ecoregion named *Sample* was being loaded, then the four related tables would be *Sample_blocks*, *Sample_waypoints*, *Sample_observations*, and *Sample_media*.
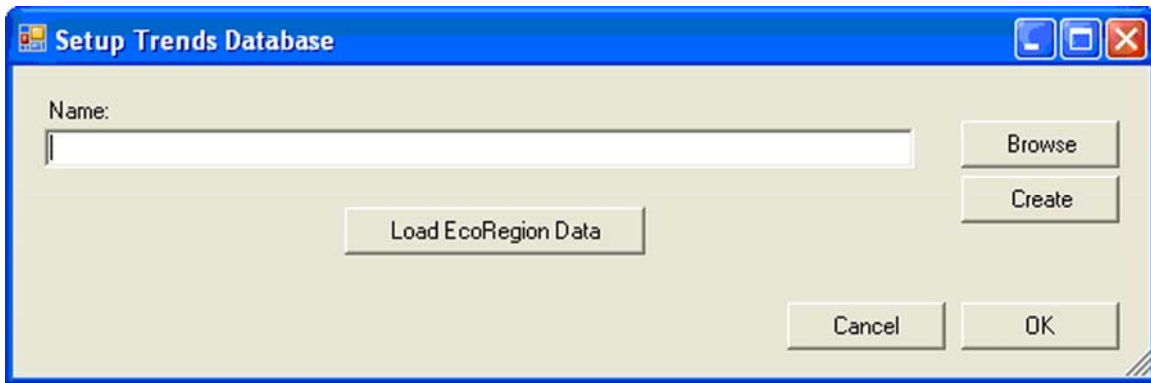
Figure 6. Setup Trends Database dialog box.

4. Once the *Load Ecoregion Data* dialog (fig. 7) opens, browse and select the GIS layer of ecoregion blocks. The *Load Ecoregion Data* dialog box includes data entry fields that will accept input for the location of the ecoregion's blocks feature layer, block id field, name of ecoregion, and a description.
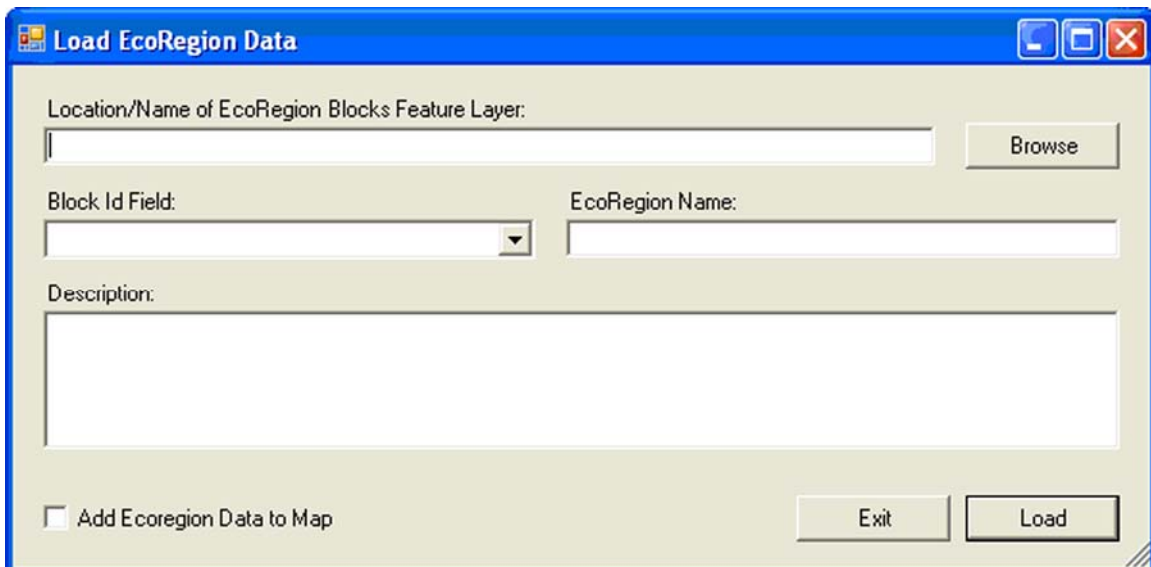

Figure 7. Load Ecoregion Data dialog box

5. Identify the block id field within the layer of ecoregion blocks by using the drop menu under "Block ID field." This drop-down men lists all attribute fields in the identified block layer. The block ID field simply needs to be a unique number identifying each block for that ecoregion.

6. Type in a unique name for the ecoregion where fieldwork will take place in the "EcoRegion Name" window in the *Load Ecoregion Data* dialog (fig. 6). Make sure there are no spaces in the name, and use an underline "_" if a space is wanted in an ecoregion name. Each database created by the Trends extension is capable of handling multiple ecoregions, and it is the unique identifier assigned here that distinguishes between multiple regions.

7. Although not mandatory, you can then type in additional information in the "Description" box.

8. Click "Add EcoRegion Data to Map" in the lower left corner of the *Load Ecoregion Data* dialog box (fig. 6) to add the loaded block and waypoint feature layers to the current ArcMap document.

9. Click "Load" in the *Load EcoRegion Data* dialog box.

10. A *Load Completed* dialog should come up to confirm the process.

11. Click "Okay" to close the *Load Completed* dialog box.

12. Click "Exit" to close the *Load Ecoregion Data* dialog box (fig. 7).

13. Click "Okay" in the *Setup Trends Database* dialog box (fig. 6).

14. At this point, you will see that the Trends extension has created a GIS layer for waypoints and a GIS layer for observations in the ArcMap screen. Both layers begin with the name of the ecoregion assigned in step 6.

15. To begin data collection, Click the "Manage Ecoregion" button in the primary Trends toolbar (fig. 5) to open the *Manage Ecoregon* dialog box (fig. 8).

16. In the *Manage Ecoregion* dialog box (fig. 8), find the appropriate ecoregion name in the drop-down list under "Ecoregion name." If a new ecoregion is needed, click the "Load" button to return to the *Load Ecoregion Data* dialog box (fig. 7). It is also possible to remove an ecoregion from the database by clicking the "Remove" button.

17. After identifying the appropriate ecoregion, all potential block ids in that ecoregion will show up now in the "Block Id" dialog box (fig. 8). When you highlight a block identification number in the "Block Id" list, the computer will zoom to that block in the ArcMap screen (fig. 9).

18. At this point, you are ready to begin data collection. You can either click "Okay" to get back to the primary Trends toolbar or go right to sub-toolbars by clicking on the appropriate buttons in the *Manage Ecoregion* dialog box (fig. 8).
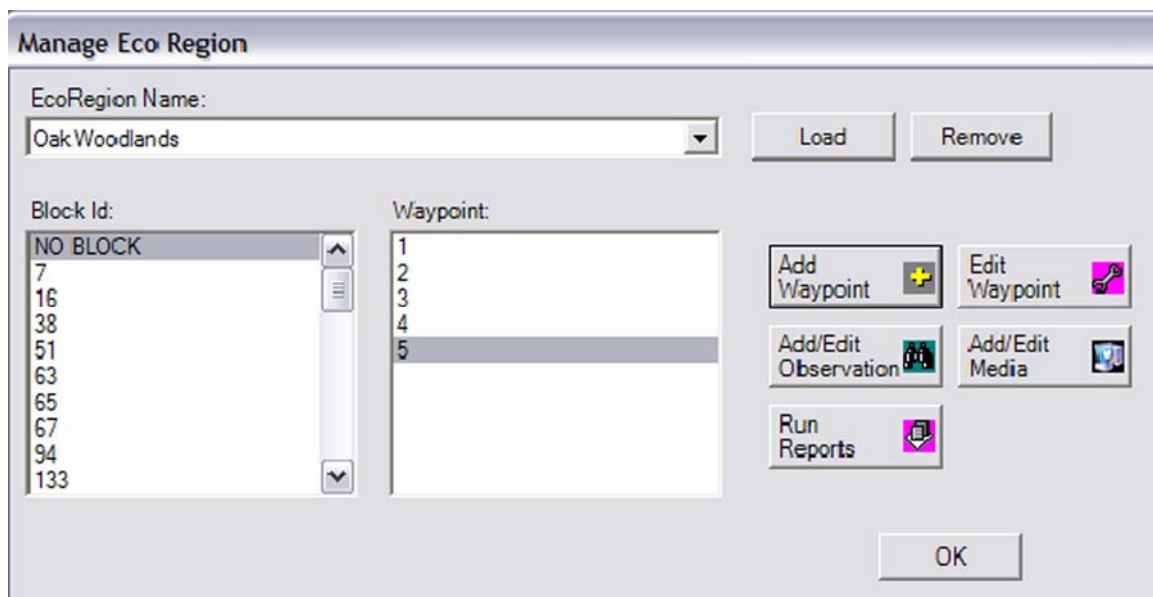

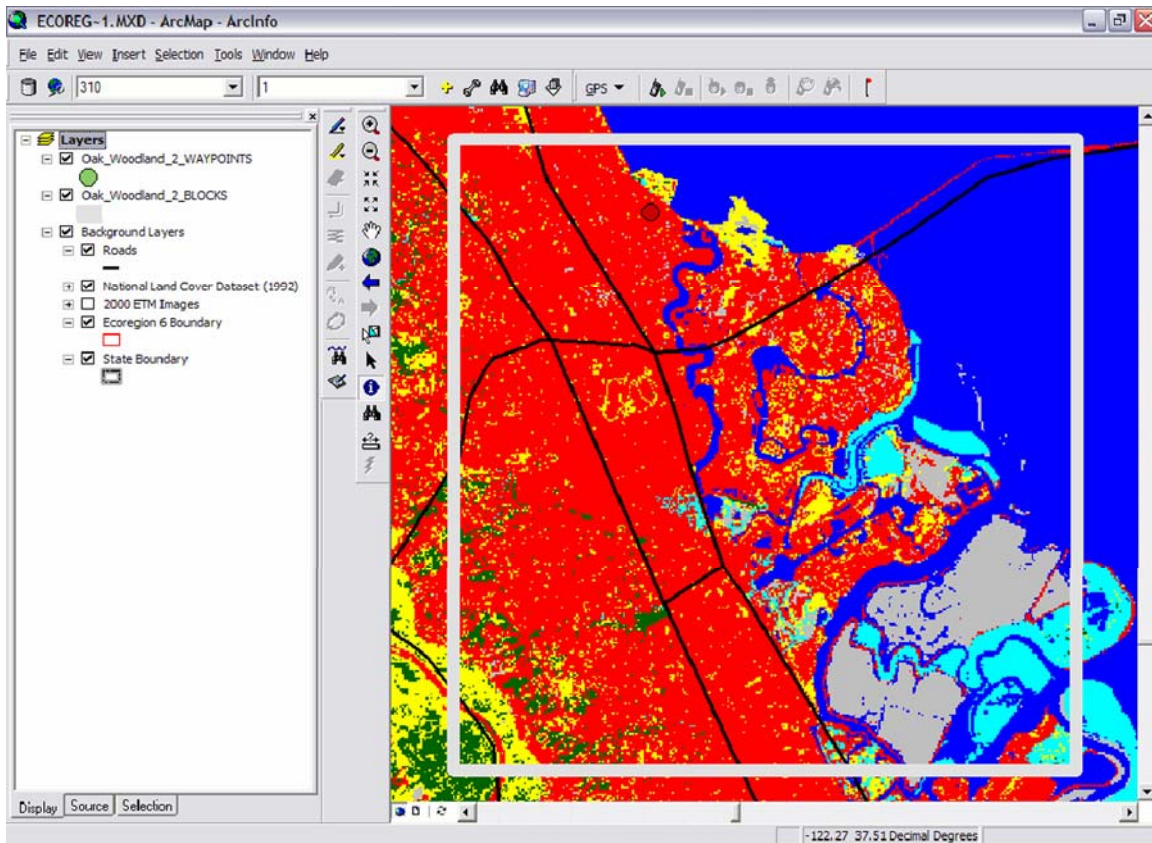Figure 8. Manage Ecoregion dialog box.

Figure 9. ArcMap project with Land Cover Trends extension. The extension zooms to a block identified in the Land Cover Trends toolbar, in this case block 310 of Ecoregion 6.

ArcMap Project Setup

In addition to the Trends database and related layers, certain data sets are useful for Trends researchers during their field trips, both for navigation and data entry. These following layers should be assembled in an ArcMap document prior to going into the field:

- Current land-cover image of sample blocks: If block interpretations have been completed, the most recent vintage land-cover image (circa 2000) is used. If sample block interpretations have not been completed, the 1992 National Landcover Dataset (NLCD) product is used (Loveland and Shaw 1996; EPA 1993; Vogelmann and others 2001).

- Circa 2000 Landsat Enhanced Thematic Mapper Plus images are helpful for comparing spectral properties with ground observations and land cover.

- Topographic maps (digital form; for example, Digital Raster Graphics).

- Detailed Street Maps for field navigation in and between sample blocks (for example, ESRI "StreetMap").

- Aerial photography (for example, Digital Orthophoto Quads) or high-resolution aerial photography for extracting detail not available in satellite imagery.
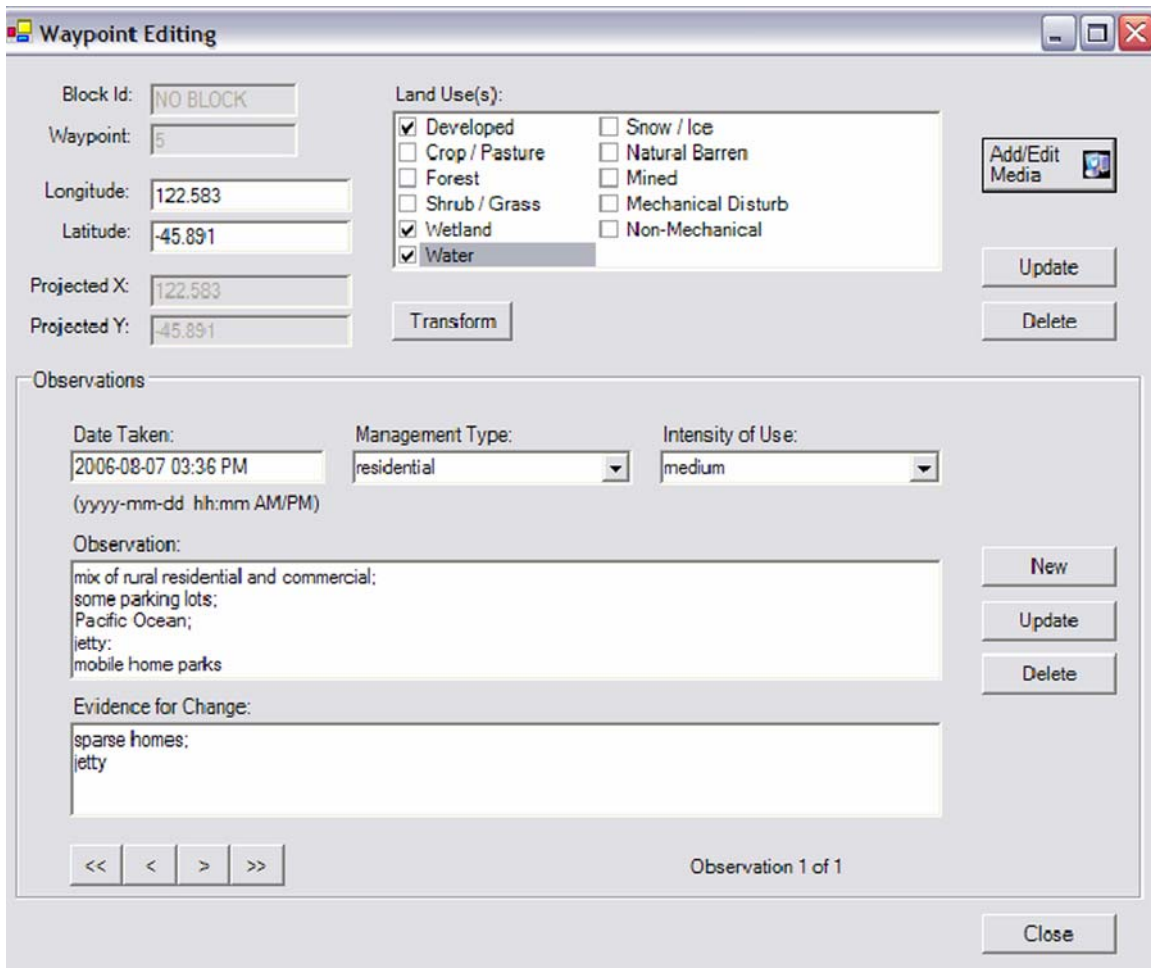
- Other data sets that would prove useful in the field may include digital elevation models and terrain data (hillshade, slope, and aspect), point and feature data (Geographic Names for information such as mines and quarries), land ownership data, wildfires, hydrography, and high-resolution data, such as planning and zoning maps.

In the field, it is helpful to have the sample-block GIS layer overlaid on top of these various geospatial layers. This ability is an improvement over past fieldwork procedures where multiple hard-copy prints of each layer were needed.

Waypoint Entry and Editing

When in the field, researchers identify the drivers of land-cover and land-use change by documenting the observed land cover and land use, management type, intensity of use, and evidence of change in each 10-km sample block. At each field stop, researchers record a waypoint and take landscape photographs. To add a waypoint, the user clicks the "Add Waypoint" button in the Trends toolbar (fig. 1). Doing so will open the *Waypoint Editing* dialog box (fig. 10).

Every time a user clicks the "Add Waypoint" button, the Trends tool automatically records positional information from the connected GPS unit and the time of the recorded observation. It also performs an overlay function to determine what sampling block, if any, the user is in when recording a waypoint. If the user is in a predetermined sampling block, this information is automatically noted in the *Waypoint Editing* dialog box (fig. 9). The Trends tool is capable of pulling positional information (for example, latitude and longitude) from a connected GPS receiver, or the user has the option of manually entering geographic coordinates through the same interface. If using the GPS data, the geographic coordinates will automatically appear in the "Projected X" and "Projected Y" fields in the *Waypoint Editing* dialog box (fig. 10). If opting to enter coordinates manually, the user should do so in the "Latitude" and "Longitude" fields in the *Waypoint Editing* dialog box followed by pressing "Transform." The "Transform" button transforms the collected latitude and longitude data into the projected X and Y coordinates for the ArcMap project coordinate system.

Figure 10. Waypoint Editing dialog box.

After the Trends tool automatically enters the block number, waypoint number, time and latitude/longitude coordinates, the remaining information in the dialog box must be added by the user. First, the user enters land-use information for the sampling block. To do this, the user checks the boxes to the left of each land-cover or land-use type for a specific waypoint in the "Land Use" check-box list of the *Waypoint Editing* dialog box (fig. 10). The user can check more than one land-cover/land-use type and then must then press the "Save" button to save these inputs.

After saving land-use inputs, the user can add observation data for a given waypoint. Adding observation data for a given waypoint is slightly different than applying a land-cover/land-use classification for two reasons. First, there can be more than one observation for a waypoint. Second, the observations do not follow a preexisting classification scheme. The user is not able to add data for an observation until the waypoint (for which the observation data is to be added) is written to the database. Thus, adding observational data remains unavailable until the user presses the "Save" button for a new waypoint. Each observation must be added separately. To add an observation the user must:

1. Select or type a Management Type description in the **Management Type** drop-down list.

2. Select or type an Intensity of Use description in the **Intensity of Use** drop-down list.

3. Type in their observation to the **Observation** multiline textbox.

4. Type in their observations as evidence of change in the **Evidence of Change** multiline textbox.

5. Press the "Save" button.

All distinct entries for **Management Type** and **Intensity of Use** are written to drop-down lists to speed data entry. This means that although the user is always able to manually enter new text, commonly entered text is available in the drop-down lists. With this feature, nothing will initially show in the drop-down list until text is entered. Once the descriptions are entered for an observation, they should be saved to the database by pressing the "Save" button to the right of the Observation multiline textbox. To add a second observation, the user clicks the "New" button to the right of the Observation multiline textbox. The user can also delete an observation by clicking the "Delete" button to the right of the Observation multiline textbox. The user may also navigate between observations for editing using the navigation buttons below the observation pane.

To edit previous waypoint, the user clicks the "Edit Waypoint" button either in the *USGS Trends Tools* toolbar (fig. 5) or the *Manage Ecoregion* dialog box (fig. 6). Pressing this button in either dialog box will open the *Waypoint Editing* dialog box (fig. 10) and any data can be edited at this point. To save edits in the *Waypoints Editing* dialog box, the user must click the "Save" buttons for both the waypoint and the observations. Edits will be lost if the "Save" button is not clicked and the dialog box is closed. Users can now add media references by clicking the "Add/Edit Media Reference" button.

Adding a Media Reference

In addition to entering field observations, Trends researchers take pictures at each waypoint. To link photographs to the digital database, the user should click the "Add Media Reference" button in the *USGS Trends Tools* toolbar (fig. 5), the *Manage Ecoregion* dialog box (fig. 6) or the *Waypoint Editing* dialog box (fig. 10). Doing so opens the *Add Media Reference* dialog box (fig. 11). In this dialog box the user can enter photographs, as well as video or audio records, to the ecoregion database. To add a new media reference, click the "New" button at the bottom of the dialog box. Doing so will allow the user to enter additional details of the collected media.

If entering a photograph, the user selects "Photo" in the **Medium Type** panel and then whether the photograph is either analog (film) or digital. If the "Analog" button is selected, the user can then enter the roll identification, the frame number and a directional bearing in integer form (for example, cardinal degrees). The user can then type in a description of the photograph in the "Description" box. Once film is developed and a digital version is available, the user can link the final photograph to the database by using the folder button in the "File Path" box to identify the file path. If using a digital camera, the user is still able to enter a bearing, description, and file path for the photograph. The user can also enter an "Original Source Name" in the field to identify the file name assigned by the digital camera. The Trends tool will automatically link a photograph

reference to a sample block (if location of waypoint is within a block) or will assign a value of "0" to indicate the photo and corresponding waypoint is located outside of any sample block. The user must click the "Save" button after each photograph to add to the database. If there is a file path identified for a photograph, the digital version will be displayed in the upper-right dialog box.
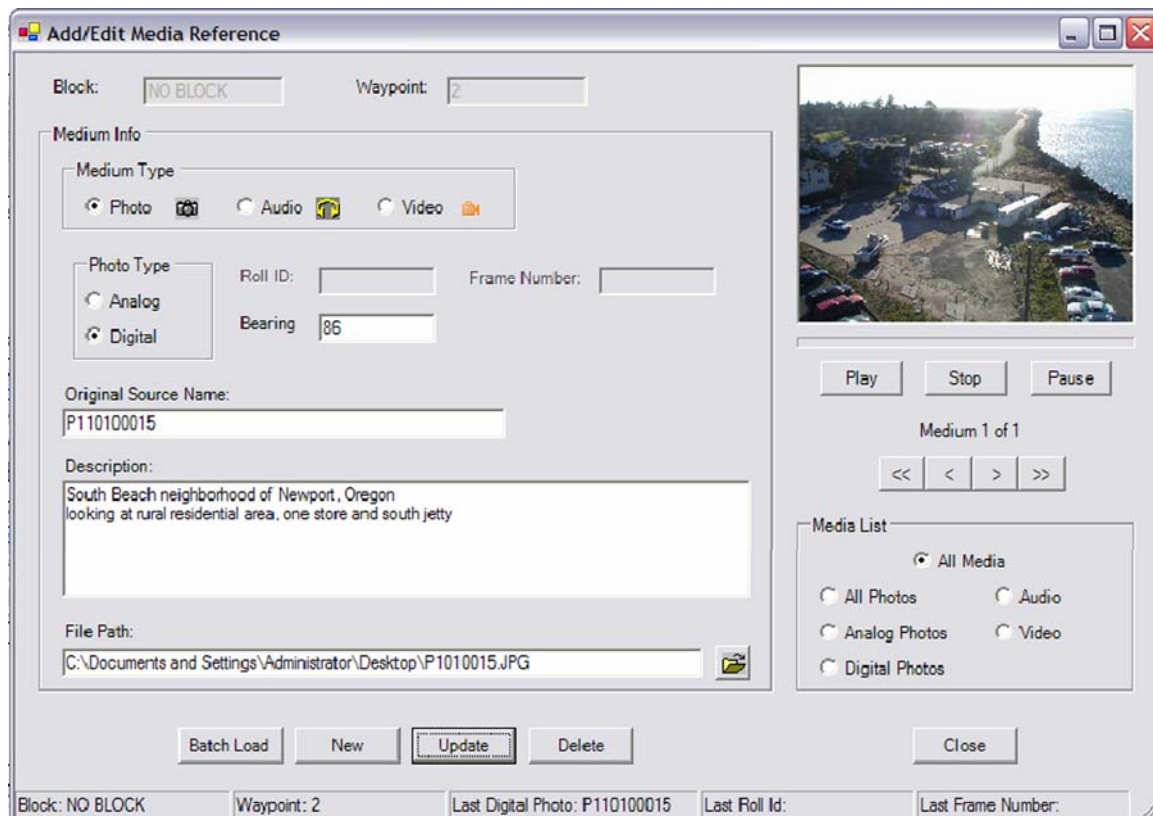

Figure 11. Add/Edit Media Reference dialog box.

In addition to adding photographs to a database, the Trends tool also provides user with the ability to link audio and video files to waypoints while in the field. Audio files can be generated by the microphone internal to the computer or an external microphone. Video files can be created by an external hand-held digital video camera and then transferred to the field computer. To create an audio or video reference, the user must press the "Add/Edit Media" button in the *USGS Trends Tools* toolbar (fig. 5), the *Manage Ecoregon Data* dialog box (fig. 8) or the *Waypoint Editing* dialog box (fig. 10) to open the *Add/Edit Media Reference* dialog box (fig. 11). Here, the user enters the filename and a description of the contents of the audio and (or) video file. Loaded audio and video files can be played by clicking the "Play" button in the upper right-hand section of the *Add/Edit Media Reference* dialog box.

If a researcher has a folder of multiple media files to add to a Trends database, it is possible to add them all at the same time, instead of having to add each file individually. To do so, the user clicks the "Batch Load" button at the bottom of the *Add/Edit Media Reference* dialog box and then identifies the folder where the multiple media files reside. This then automatically creates a record in the database for each media
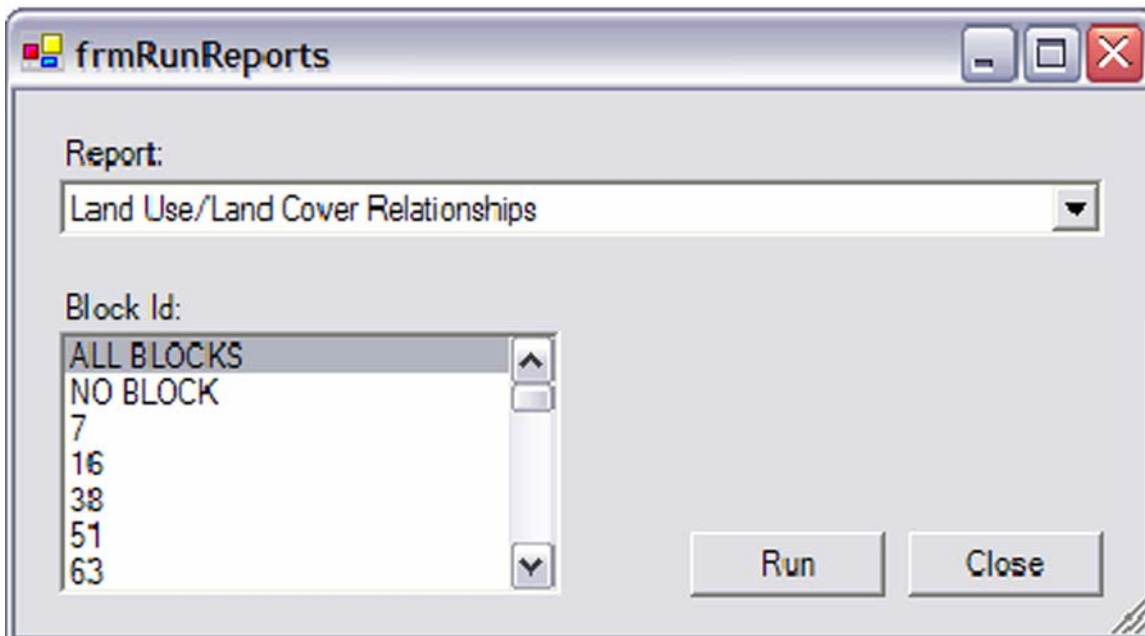
file in the folder. The user can then retrieve each new record and add in information such as bearing or description, ensuring to click the "Save" button after each edit is complete.

Once there are multiple media files in the database, the user is able to scroll through the multiple files using the arrow buttons on the right side of the *Add/Edit Media Reference* dialog box. The double-left arrow will show the first record of the batch and the double-right arrow will show the last record of that batch. To only show media files of a certain type (for example, audio, video), the user clicks the appropriate type in the **Media List** section. Selecting a subset of media types will reduce the files available when using the arrow buttons to scroll through the media references. Also, if there are not multiple media files in the database, the **Media List** box will be grayed-out and unavailable to the user. Finally, *Add/Edit Media Reference* dialog box (fig. 11) also comes with a status bar at the bottom of the dialog box that summarizes current media and location information.
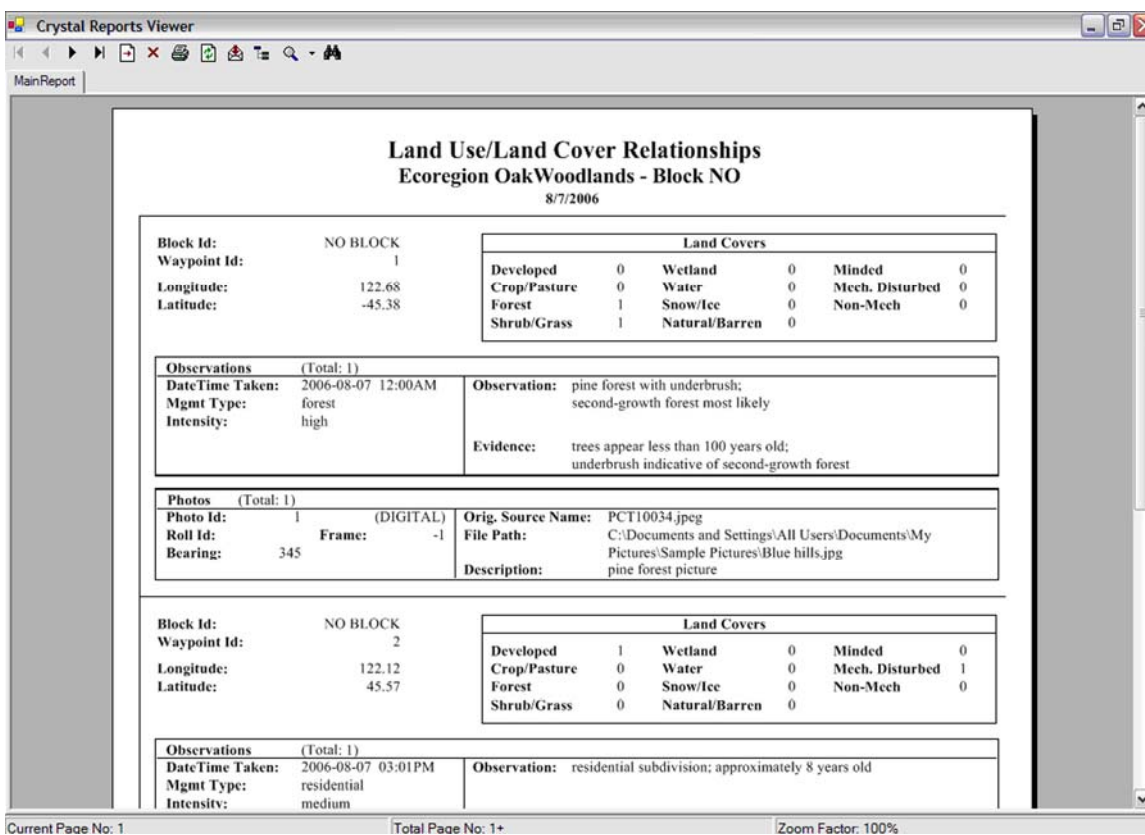
Displaying the Final Field Report

Once fieldwork is completed, Trends researchers return to their offices to organize and enter their field notes into a computer database. Hardcopy notes and annotated maps of each waypoint are retained and kept in a summary binder for the ecoregion.

With the Land Cover Trends extension described in this report, no postfieldwork data organization or entry is required. A Land Cover Trends report can be instantly generated through the Crystal Reports report function of this extension. By pressing the "Create Report" button in the Trends toolbar (fig. 5), the user will open a dialog to determine what type of report to create and which blocks to include in the report (fig. 12). The only report type currently available in the drop-down list is "Land-Use/Land-Cover Relationships" and should be selected prior to clicking the "Run" button. After selecting the report type and the blocks to be included and clicking the "Run" button, the user will be shown a Crystal Report document (fig. 13). Digital reports can be edited or printed using the toolbar at top of the Crystal Reports Viewer. Using the "Export Report" button, reports can also be exported into .pdf, .xls, .doc and .rtf file formats. For additional backup, it may be wise to print out a hardcopy version of the database. Finally, because an Access database is used to store waypoint information, custom queries and reports can be made in Access via the trends.mdb database located in the c:\Program Files\USGS\Trends Extension\Data directory.

Figure 12. Report Creation dialog box.

Figure 13. Crystal Reports Viewer

Added Functionality of a Tablet PC

Although the Trends extension can be run from a laptop, there are additional benefits to the researcher if it is run from a tablet PC in the field. The two main functions that immediately help field researchers include the Microsoft Tablet PC Input Panel with handwriting pad and the Pen/Ink tool within the ArcGIS environment. For illustrative purposes, specific references to tablet PC functionality are based on a HP TC1100 Tablet PC; however, these features are common to all Tablet PCs. Please refer to the user's manual for other types of Tablet PCs to find the corresponding button.

The first benefit of using a Tablet PC is the ability to directly input information using a digital pen instead of typing it in with a keyboard. Although keyboards are available with tablet PCs, researchers may not be comfortable typing in a moving vehicle or while on foot. Therefore, in addition to keyboards (many detachable), tablet PCs have input panels that allow users to enter data using a digital pen, either by tapping keys on an onscreen digital keyboard or by handwriting notes into the Trends Extensions forms. This is useful for Trends researchers entering field notes as they travel by car and by foot throughout a study area. To access the Input Panel, press the "e" Microsoft Tablet PC Input Panel button on the upper left corner of the Tablet PC frame (fig. 14).
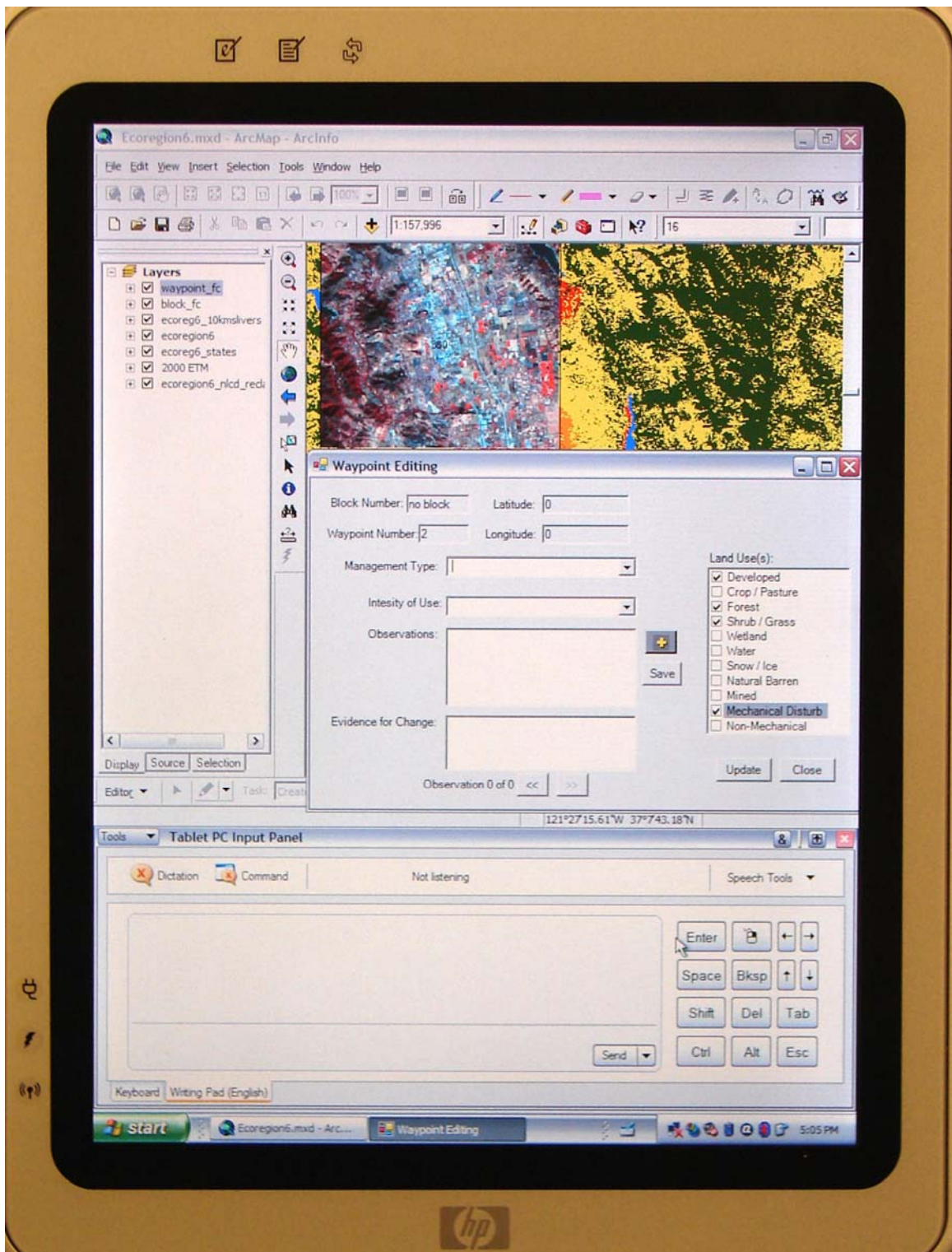
Figure 14. Opening the Microsoft Tablet PC input panel

Once the onscreen keyboard or handwriting pad is open, the user should place the cursor in the field where information is to be entered. This could be in a word processing file, an attribute field of a GIS layer, or an input field in the *Waypoint Editing* dialog box

(fig. 15). Once the cursor is in the appropriate place, the user simply taps or writes with the digital pen and clicks the "Enter" button on the Microsoft Tablet PC Input Panel. By doing so, the information will be entered in the appropriate field or file. The example in figure 15 shows the phrase "pine forest" written in the Input Panel Writing Pad field and then automatically entered by the computer in the **Observation** box in the *Waypoint Editing* dialog box. A similar process is used if the digital keyboard input panel is used. A third option for entering data is to use the speech-recognition software available on most tablet PCs. However, this is only an option if the user has extensively trained the speech-recognition software to recognize his or her individual voice, and this training must be done by each user wanting to use this feature.
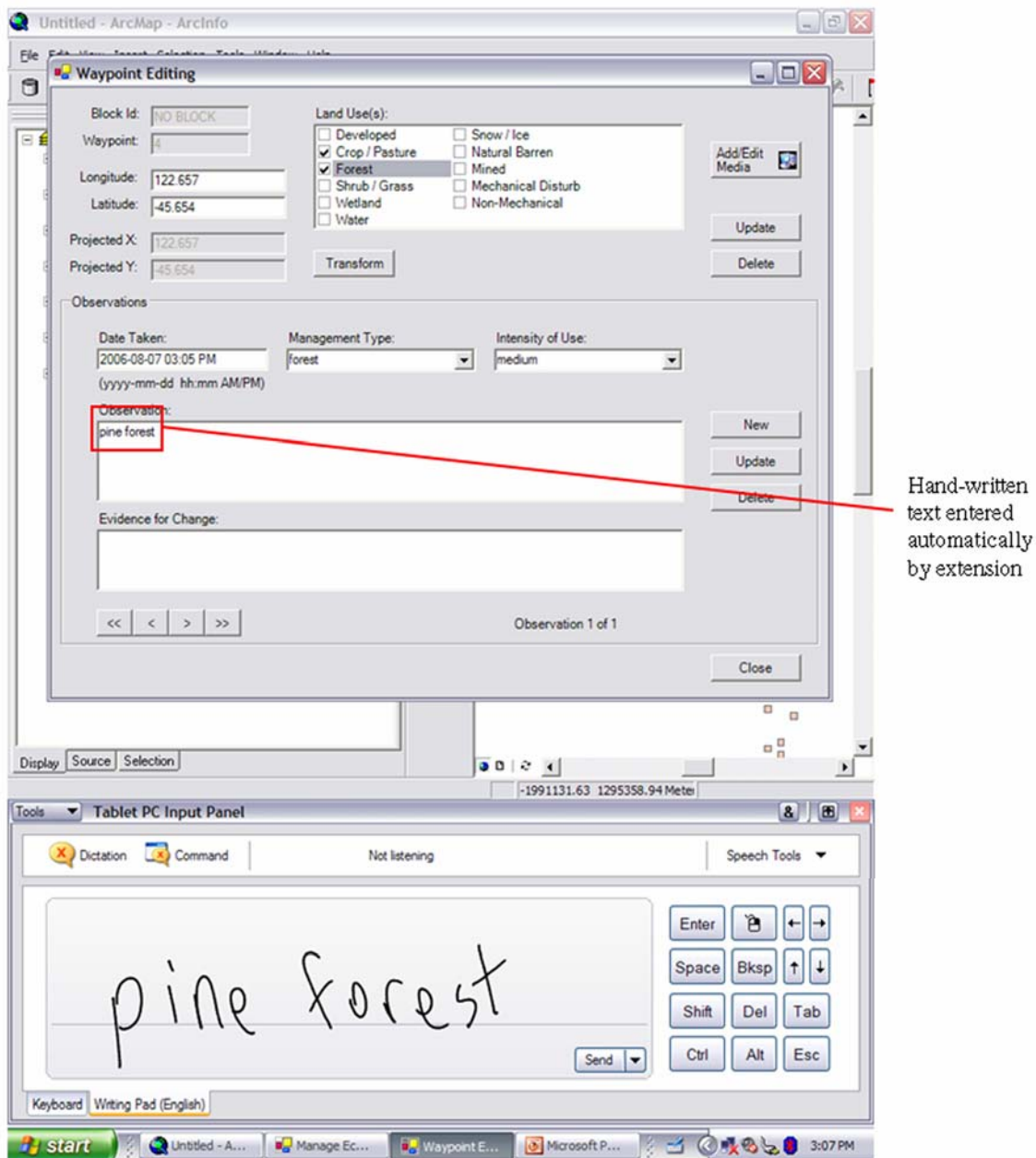

Figure 15. Input panel for Tablet PC.

A second benefit of using a Tablet PC is the ability to use the digital pen to directly annotate maps and images. Currently, Land Cover Trends researchers annotate paper maps with pens and markers. They then need to keep the multiple maps and images organized so that information could be transferred to the appropriate place once back in the office. Using the extension described in this report and a Tablet PC, researchers can eliminate this need to annotate and organize multiple paper maps and images. This is done by using the Tablet toolbar within ArcGIS, a tool developed by ESRI to support Tablet PC for ArcGIS. Using the Tablet toolbar, Land Cover Trends researchers are able to make notes directly on their ArcMap documents (fig. 16). The Table toolbar creates graphics on the annotation of the target layer (set via the Draw toolbar). This tool is useful when finding areas that may need reclassification back in the office, or for noting interesting features. The Pen/Ink Tool is located on the Tablet PC toolbar and additional information on this tool can be found in ArcGIS Help.
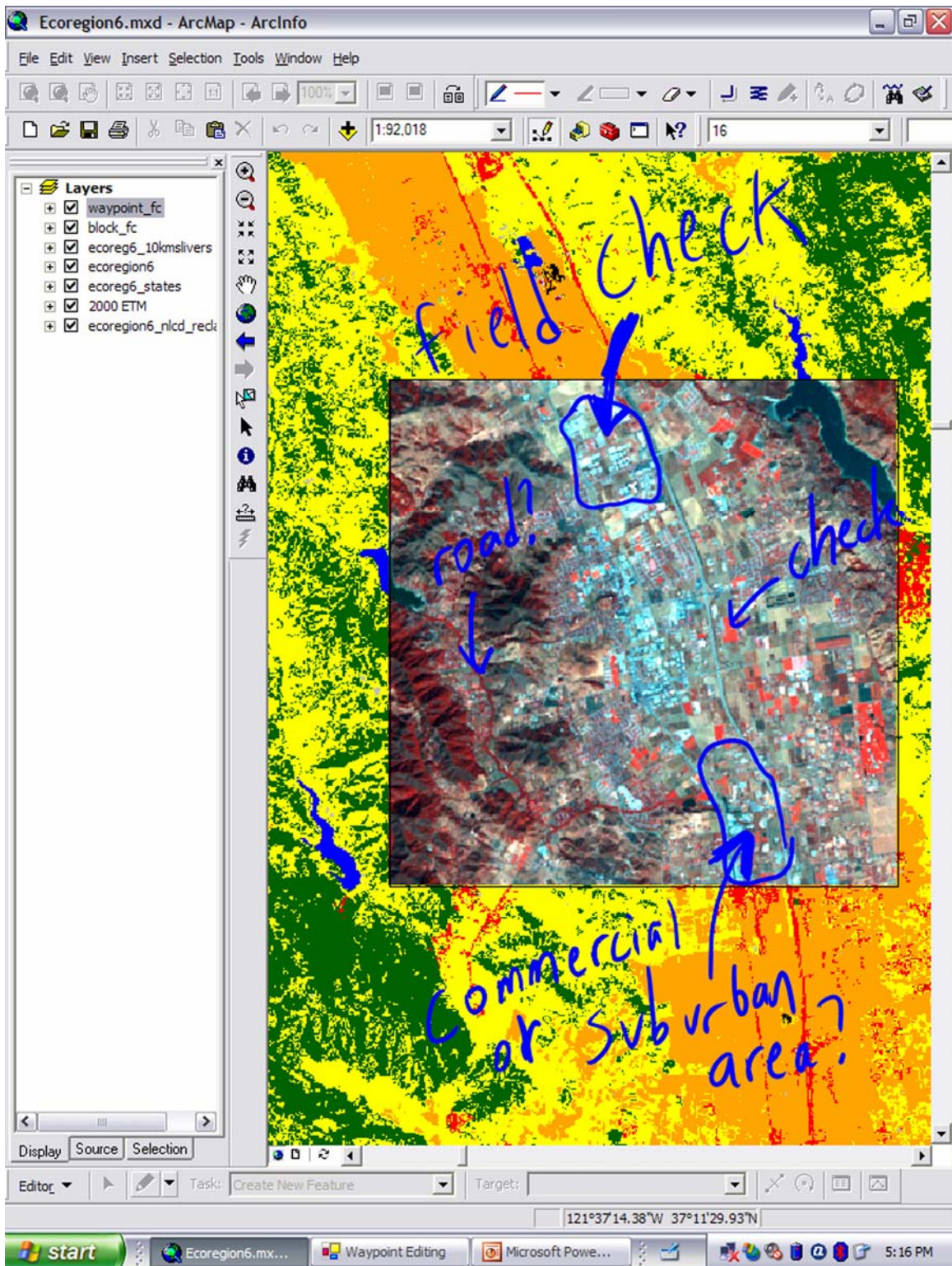
Figure 16. Map annotation using Tablet PC digital pen technology

Summary

The objectives of this GIS software extension are (1) to support Land Cover Trends researchers in their efforts to synthesize land-cover change rates and consequences in the United States and (2) to demonstrate the utility of mobile-computing technology. This software extension could increase the productivity, ease, and efficiency of Land Cover Trends fieldwork and decrease the amount of postfieldwork to organize data. More data could ideally be obtained in the field, data collection errors could be reduced and data access could be easier after fieldwork. Primary benefits of the Land Cover Trends extension include (1) the ability to view and query spatial data in a fully functioning GIS environment for navigational and observational purposes, (2) a reduction of postfieldwork processing time by building a digital database in the field, (3) the elimination of potential transcription errors, (4) a standard database-management system, and (5) the potential for greater accessibility in sharing ecoregion databases. Although the extension can be used on normal laptops or personal digital assistants (PDAs), the use of tablet PCs provides researchers with the portability of a PDA, the large viewing screen and full GIS software functionality of a laptop, as well as features unique to tablet PCs, including the ability to annotate digital maps and to digitally record information by digital pen or voice.

Although this GIS software extension focuses on the Land Cover Trends project, we show how mobile computing technology could further the use of geospatial information in other USGS field research efforts and leverage the existing USGS investment in GIS technology. The integrated package of GPS, GIS, and mobile-computing technology described in this report is applicable to other field research efforts at the USGS and similar extensions can be developed elsewhere. We believe that the development and use of this extension, in addition to the results of a bureauwide assessment of researchers' mobile-computing technology needs (Wood and Halsing, 2006) will generate further discussions within the bureau on the development and use of mobile-computing technology at the USGS.

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