

ABSTRACT

Utilizing Mobile GIS for Hydrology and Hydraulics Field Reconnaissance

Jessica D. Baker ¹, EIT, CFM and Noelle Gaspard ¹, CFM

Advances in technology have dramatically improved traditional methods for gathering data in the field. This process was usually time consuming, being recorded by hand with paper and clipboard and then manually entered into GIS databases in the office. Utilizing a mapping grade GPS unit in combination with Mobile GIS software, data is recorded digitally in the field and is ready for use back in the office. Digital maps with streets, stream centerlines, and orthophotography can be used as a reference for collecting data. Existing GIS data can be taken out into the field to be edited or verified based on findings. Forms are programmed so the user can input customized project information such as number of culverts and size. This paper will present examples where Mobile GIS was used for different project applications including Stream Assessments, Floodplain Management Studies, and Hydraulic Modeling Reconnaissance. Moving to a digitally based data collection method greatly increases productivity and minimizes the chance for error in the field reconnaissance process.

¹ Half Associates, Inc., 1201 N. Bowser Road, Richardson, TX 75081 – (214) 346-6200

Utilizing Mobile GIS for Hydrology and Hydraulics Field Reconnaissance

INTRODUCTION

Advances in technology continue to simplify the procedures we go through every day. Traditionally field data collection was performed by a field crew with clipboards, pens and handwritten notes. Data was collected and then had to be sorted through and manually entered into digital format back in the office. Incorporating Mobile GIS and GPS technology into the field reconnaissance process dramatically cuts down on the effort and time spent collecting data.

GEOGRAPHIC INFORMATION SYSTEM (GIS)

A Geographic Information System (GIS) is a collection of computer hardware, software and geographic data used for capturing, managing, analyzing and displaying all forms of geographically referenced material. GIS can integrate and reference any type of data with a spatial component which aids in data organization and allows the user to view multiple types of data at one time. GIS is most often associated with maps. A map, however, is only one way you can work with geographic data in a GIS, and only one type of product generated by a GIS. It can provide a great deal more problem-solving capabilities than using a simple mapping program or adding data to an online mapping tool. Combined with mapping, GIS provides a tool for capturing, storing, querying, analyzing, and displaying various types of data.

GIS is a very powerful tool in water resources engineering. It can help you manage the hydraulics and hydrology of riverine water flow in a timely and cost efficient manner by eliminating data redundancy, automating analysis processes, and increasing data integration. Hydrologic and hydraulic modeling are now integrated through GIS and many H&H software programs work together with GIS to create a spatially referenced model.

The advancement of Mobile GIS software provides field-based personnel with the ability to capture, analyze, and display geographic information with out the use of paper data collection. As more and more traditional processes move into a digital world, Mobile GIS has provided an effective way to collect and utilize data, and streamline our methods of data collection.

GLOBAL POSITIONING SYSTEM (GPS)

The Global Positioning System (GPS) is a constellation of 24 satellites that provides worldwide accurate position coordinates. The 24 satellites that make up the GPS space segment are orbiting the earth about 12,000 miles above us. The first GPS satellite was launched in 1978. A full constellation of 24 satellites was achieved in 1994. The system is owned, operated, and controlled by the US Department of Defense (DOD). GPS was originally intended for military applications, but in the 1980s, the



government made the system available for civilian use. Today, GPS is finding its way into cars, boats, planes, construction equipment, movie making gear, farm machinery, and even laptops.

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.

GPS EQUIPMENT

A variety of GPS equipment is available at both mapping and survey grade levels. For water resources field reconnaissance and data collection, mapping grade equipment provides sufficient accuracy. Half H&H has two separate GPS units: the Trimble GeoXT and the Trimble ProXT paired with a Dell PDA. A Nikon Coolpix digital camera is also used to tie in photos with GPS data.

The Trimble GeoXT handheld combines submeter GPS accuracy with Microsoft Windows Mobile technology. The GeoXT serves as both your data collector as well as your GPS receiver.

The Trimble ProXT is a GPS receiver with submeter accuracy. This receiver works in connection with a field computer of your choice, such as a PDA, laptop, or Trimble Ranger data collector. The ProXT communicates cable-free to your field computer through Bluetooth® wireless technology.



Trimble GeoXT



**Trimble ProXT in Combination
with Field Computer**

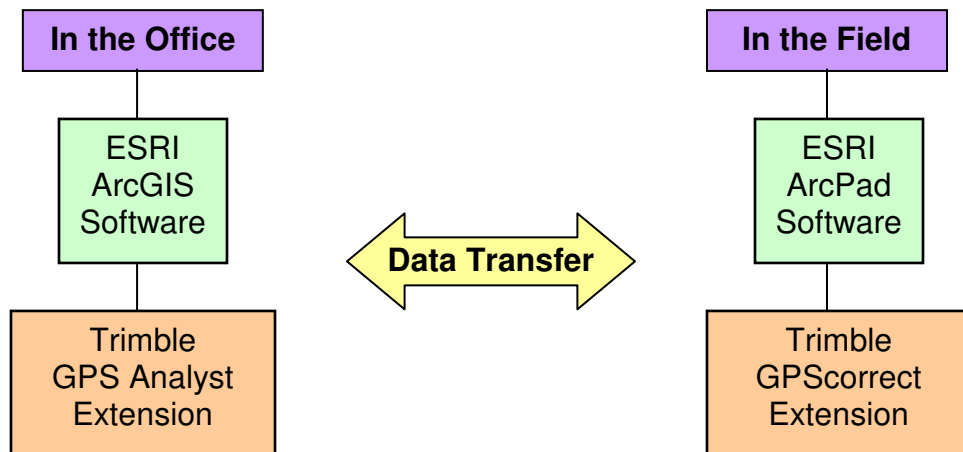
The Nikon Coolpix digital camera series is equipped with built-in WiFi connectivity. Photos that you take are automatically transferred through wireless communication to your field computer.



Nikon Coolpix P1

SOFTWARE FOR USE OF MOBILE GIS & GPS TECHNOLOGY

Several software packages are used jointly to create a smooth process for mobile unit data collection to be transferred for use in the office with desktop applications. ESRI's ArcGIS Desktop software in combination with Trimble's GPS Analyst extension is used in the office for preparing data for field use and post-processing after GPS data is collected. ESRI's ArcPad software in combination with Trimble's GPSCorrect extension is used in the field on a mobile device for GPS data collection and manipulation.



ESRI ArcGIS Desktop is a powerful GIS desktop system for editing and managing geographic data. The ArcGIS suite of applications includes ArcMap, ArcCatalog, and ArcToolbox. ArcMap provides tools for creating visual displays of your data, as well as analysis, editing, and creating data. ArcCatalog is an integrated application used for organizing and managing all of your GIS data. ArcToolbox provides a set of geoprocessing, conversion tools used to edit and manipulate GIS data. The entire suite of ArcGIS applications is helpful for a Mobile GIS project.

ESRI ArcPad is software for mobile GIS and field mapping applications using handheld and mobile devices. ArcPad provides field-based personnel with the ability to capture, analyze, and display geographic information, without the use of costly and outdated paper map books. ArcPad offers reliable, accurate, and validated field data collection while improving the productivity of GIS data collection process.

Trimble GPS Analyst is an extension used with ESRI ArcGIS software. GPS analyst allows you to work with GPS data once you get back to the office. The extension provides tools for differentially correcting GPS data within ArcGIS so that you can improve the accuracy of the data. GPS analyst provides a seamless workflow for checking in and out data from the office to be used in the field.

Trimble GPSCorrect is an extension used with ESRI ArcPad on your mobile device. GPSCorrect records detailed GPS positions and offers real-time differential correction of the data. The extension produces an easy way to manage GPS settings in the field and clearly gives feedback of GPS data including satellite positions and the quality of the data being collected.

Seven Steps of a Successful Mobile GIS Project

Organization and planning out your Mobile GIS project will have a large impact on the ease of data collection in the field.

1. Define your Project

The first step for a successful project must include planning. This includes determining what type of field data you need to collect. Address if your project mainly will involve new data collection or an update of existing data. If you will be doing the same type of field data collection on numerous occasions, this planning will be a one time process. Once your project is set up, the data collection structure can be used over and over for different field reconnaissance trips.

During this first step, you must address what types of data will be collected (i.e. points, lines, areas). Since data collection is performed using GIS software, you must decide up front if each data type is a point, polyline or polygon feature. Furthermore, you must identify the attributes you need to include. If you are locating street signs, what type of attribute information will be tied to each point – type of sign, height, condition, etc? For each attribute you can pre-set entries; for example type of sign could include Stop, Handicap, No Parking, and Yield. These facts guide the development of efficient data collection forms for ArcPad. Writing out a workflow of all of the data you are going to collect will make the process of building your GIS database much easier.

2. Create Personal Geodatabase

The geodatabase provides the structure for a Mobile GIS project. It is a framework for all of the geographic data and attributes. Even though the geodatabase is not used in the

field by ArcPad, which uses shapefiles, creating a personal geodatabase for use in a mobile GIS project has many benefits. A personal geodatabase is required for you to use the Trimble GPS Analyst extension to process your field data. Using a geodatabase also allows you to check out data from your geodatabase, create or update GIS data in the field, and then check the edited data back in. ArcGIS will determine whether features are new updated, or deleted when ArcPad is checked back in. A geodatabase can support a complex collection of data, including networks, topology, and relationships among feature classes.

3. Prepare Data in ArcMap

Field GIS tasks, mobile devices and field conditions are often different from the GIS tasks, desktops, and conditions in the office. This should be considered when preparing your GIS data for use in the field. For optimum use in the field, consider what tasks will be performed in the field, which data will be edited in the field and what is only needed as reference data in the field. Also, you must consider the field computer's data storage capacity – large orthophotography, and other large files may need to be clipped to only include the area of interest. Symbology and how you want the data to look in the field should be addressed. Light conditions and monitors in the office can support a wide range of color and symbols, where small mobile computers and sunlight limits the number of colors that can be used.

At this point, working in an ArcMap .mxd document, you can prepare your .mxd file exactly as you would like to see it in the field. Add your Geodatabase feature classes into the .mxd, add any reference files that you may need in the field, and specify your symbology for how you would like the colors and symbols to look on the field computer. Also, zoom into the extent of interest. Once your ArcMap .mxd looks like what you would want to use in the field, you are ready to extract the data to be transferred.

4. Get Data for ArcPad

The GPS Analyst toolbar lets you manage transactions between ArcPad and ArcGIS. The “Get Data for ArcPad” wizard on this toolbar extracts data from your map into a checkout folder that will be transferred to the mobile device. This tool will check data out of the geodatabase and convert all feature classes to shapefiles that are compatible with ArcPad. The shapefiles will be in the same projection as the data frame that you are using in the .mxd. All ArcGIS styles are transferred into ArcPad styles as well. It is important that you save the ArcMap .mxd file, and not touch it until data is ready to be checked back in. If the spatial extent or selection set are altered, the check in may not properly bring in all of the data collected in the field. The entire check out folder should be copied over to the mobile device at this time.

5. Mobile Equipment Setup

Now that all data is on your mobile GIS unit, it is a good time to check that you have everything you will need for a field reconnaissance trip. Check that batteries are charged

and that all data has been transferred properly and will open on the mobile device. The effective use of ArcPad depends largely on the field collection settings in both ArcPad and the Trimble GPSCorrect extension on the mobile device. In order to properly connect to the GPS receiver, GPS preferences should be set. Data quality filters like Position Dilution of Precision (PDOP) or Horizontal Dilution of Precision (HDOP) are set. The datum of the incoming GPS positions must be specified. Real-time differential correction should be enabled. You can also enable averaging for GPS fixes when capturing point GPS positions. Averaging multiple GPS fixes tends to improve the accuracy of a point.

6. Data Collection

After setting up ArcPad and GPS settings, it is time to actually collect the data in the field. ArcPad allows for the collection of point, line, and area features. GIS spatial data and GPS collection data is stored in shapefile + ssf file format on the mobile device until it is transferred to an office computer. ArcPad works very similar to ArcMap, with much of the same functionality but on a mobile device. It is easy to add map layers, manage and edit data, and view and move around in your map document.

7. Data Processing & Use

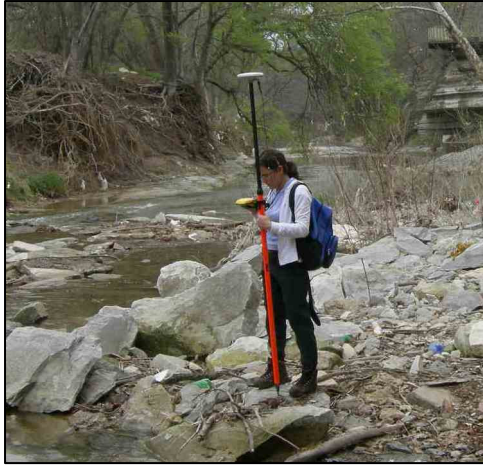
Once you have collected all data in the field, the mobile device is connected back to the office computer. The folder that was copied to the mobile device should then be copied back to the office computer and replace the existing check out folder. Open the .mxd that was originally used to check out the data. Using the GPS Analyst toolbar “Check In ArcPad Shapefiles + SSF files” button, the updated field data is checked into the geodatabase where it was originally. The new data appears in your ArcMap session. Data can be differentially corrected to improve the accuracy of the GPS data. Post-processing through the GPS Analyst toolbar can significantly improve the GPS positions accuracy. GPS feature validation provides an indication of the quality of GPS positions collected and if the features meet your accuracy requirements.

Mobile GIS Project Applications

The uses and applications for Mobile GIS are endless. A variety of field-workers already use this technology including engineers, scientists, firefighters, police officers, utility workers, inspectors, soldiers, census workers, and more. In any situations where data is collected out in the field, Mobile GIS provides a solution for time consuming older methods of collecting and storing data. Below are a few examples of how Mobile GIS can be used in the field of water resources engineering.

Stream Assessments

Mobile GIS was an excellent tool for a recent stream assessment project that covered over 70 miles of stream. The field assessment was structured to follow protocols similar to the Unified Stream Assessment (USA), which is a continuous stream walk that



systematically evaluates conditions and identifies restoration opportunities within the urban stream corridor. It will help to create stream management plans that will govern the level and types of development permitted in the catchment areas around them.

The assessment was based on continuous stream walks upstream to downstream, performed by teams composed of an Environmental Engineer, a Water Resources Engineer and a Geomorphologist/Hydrologist. The data was gathered using a GPS unit and a PDA.

Eight impact assessment forms were programmed for ArcPad and were used to collect basic data on the location, condition, and restorability of individual problems encountered within the stream corridor (Outfalls, Channel Modification, Severe Erosion, Impacted Buffer, Stream Crossing, Trash & Debris, Utilities in the Stream Corridor, and Reach Level Assessment).

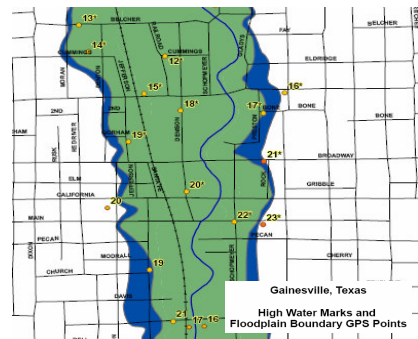


This ArcPad toolbar was customized for this project, so that for each stream assessment condition, you could select the appropriate button, which leads to a customized form. Each of the customized forms prompts you for data specific to that stream condition. For example, the Outfall forms below, ask for data on the type, size and condition of the pipe. Another page of this form asks about the type of flow and location.

At the end of the project, we had shapefiles for each stream assessment condition, which were spatially referenced. With all of the data in GIS, you can query, for example, where are all Outfalls in poor condition. Almost all of the time was spent in the field, with very little to do back in the office other than summarize the findings. Mobile GIS data collection allowed for a much more productive process for gathering data.

Floodplain Management Applications

Mobile GIS can be an important tool for a floodplain manager. Often after a large flood, there is a large amount of data to be collected in a short amount of time. Using Mobile GIS and GPS technology greatly improves current data collection procedures. After a flood, often high water marks and flooded structures must be identified. With Mobile GIS, the data is collected and stored much easier than previous methods of collecting field data and then spending time manually entering it in a GIS system back in the office.



The location and photos of high water marks are important data for a community that has flooded. Post flood evaluations are needed to update and/or validate the existing hydraulic models. A community could use Mobile GIS to keep a database of all high water marks updated over time so that when needed all data is in a consistent format and stored together.

Using Mobile GIS would help with keeping a good record of structures located in the floodplain. This data is often needed during a flood, and if a database is updated regularly, the information will be readily available when it is needed. This technology also could help a floodplain manager locate properties that are flooded during a storm, and then analyze this information, identifying where the most flooded structures are located, if they are in a Special Flood Hazard Area, and how much damage occurred.

Low Water Crossings are often the cause of many deaths during a flood. Drivers frequently do not understand the severity of water covering the road during a flood event. A community could utilize Mobile GIS to locate low water crossings and how they should be barricaded during a flood. If the data is available spatially in GIS, then at the time of a flood event, emergency responders have the information they need to quickly barricade roads to prevent the loss of life.



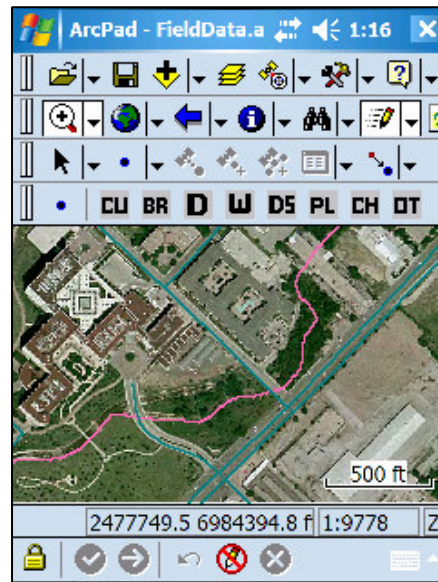
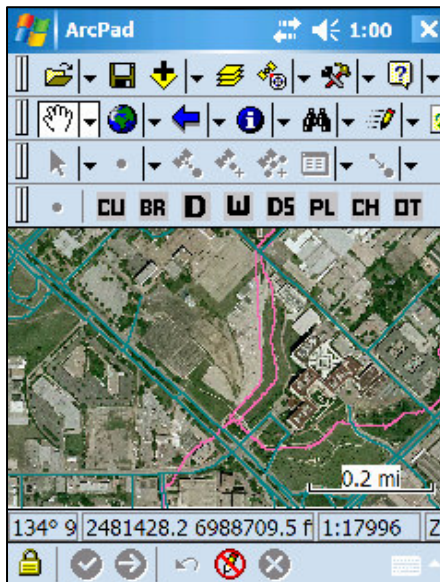
Hydraulic Modeling Field Reconnaissance

For a detailed hydraulic analysis of a stream, a large amount of time can be spent on field reconnaissance so that the stream is accurately modeled. Often, for structure crossings and some channel cross sections a detailed survey is required. Mapping grade GPS units are not a replacement for this detailed level of survey. Survey is expensive though, and often project budgets do not allow for new survey of every structure crossing. Using a mapping grade GPS unit along with Mobile GIS, good GIS data can be collected to enhance the accuracy of a hydraulic model.

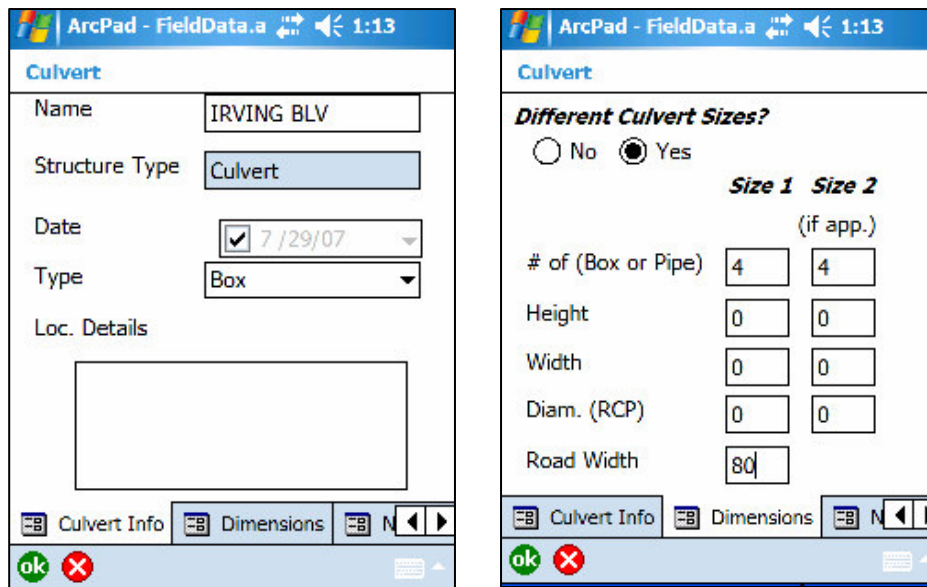
We looked at what type of data and information we were collecting during a typical field recon trip. At structure crossings we wanted to know, what type of structure is this – culvert, dam, bridge? At a culvert, what shape and size? At a bridge, how many piers and what size? At a channel cross section, what is the roughness value in the channel and in the overbanks? A custom toolbar in ArcPad was created with a button for each situation you typically come across during a Hydraulic Field Recon trip. Custom forms were created for Culverts, Bridges, Dams, Weirs, Drop Structures, Pipeline Crossings, Channel Sections, and then an Other category.



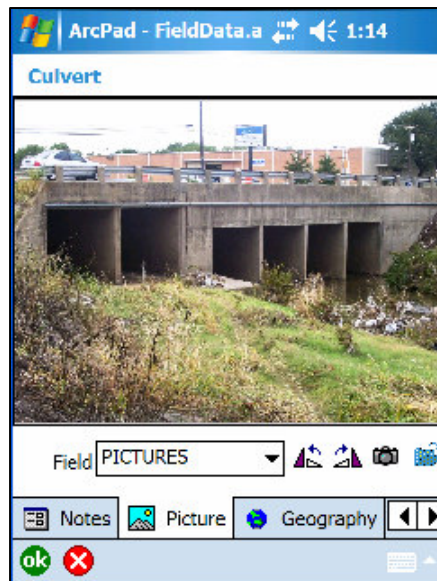
A stream centerline file, roads files, and orthophoto image were added to the document as reference files. While out in the field it is helpful to be able to use reference data like this to have a better feel for your location. Below is the ArcPad interface that you would work with on your mobile unit.



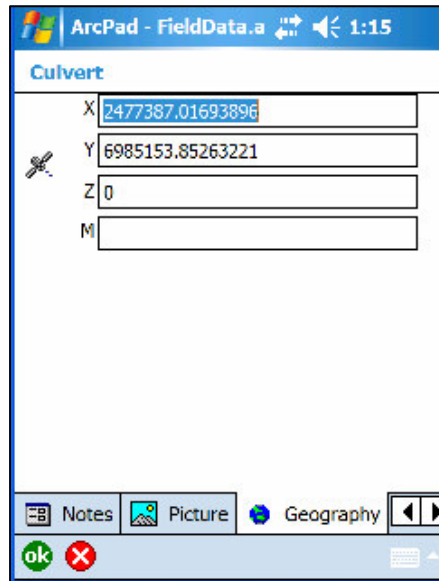
The forms below for a culvert demonstrate the type of information collected during a field recon trip. For a culvert, information such as Name of the Structure, Type of Culvert, and Size of Culvert were collected.



Using a Nikon Coolpix WiFi Camera, pictures taken in the field are transferred to your mobile computer, and then can be added into your data collection process as an attribute. Below you can see that a picture of the culvert was attached along with other data collected.



A Geography tab is included for each feature. This is where you can get your GPS position. If you are collecting new data, then you touch the satellite button to record your spatial location. You can also take existing data out in the field and using this satellite button on the Geography tab, update the location of a feature.



References

ArcPad 7 for Mobile GIS Training Guide, Trimble Navigation Limited, September 2006.

Trimble GPS Tutorial, Trimble Navigation Limited, 2007. Available at the following website: <http://www.trimble.com/gps/index.shtml>

Trimble Products and Solutions, Trimble Navigation Limited, 2007. Available at the following website: <http://www.trimble.com/productsaz.shtml>

NikonUSA product information, 2007. Available at the following website: <http://www.nikonusa.com/template.php?cat=1&grp=2&productNr=25534>

Dell Axim X51v Product Details, 2007. Available at the following website: http://www.dell.com/content/products/productdetails.aspx/axim_x51v

Environmental Systems Research Institute, Inc. (ESRI) website, Redlands, California, 2007. Available at the following website: <http://www.esri.com/index.html>

Turn Around Don't Drown logo, National Weather Service, Southern Region Headquarters, Fort Worth, Texas, 2007. Available at the following website: <http://www.srh.noaa.gov/tadd/>