ArcPad

A field user's guide

Jonathan Raper, editor

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Edited by Jonathan Raper

A starting point

In recent years, the rapid growth in the power of mobile devices has made it possible to bring the power of GIS to you whenever and wherever you need it. These developments have dramatically changed the way you can use GIS, since it is no longer tied to the desktop. The long-term implications are profound—you can collect data in the field and enter it directly, you can check out the data you need while you're away from the office and carry it with you, or you can download data over wireless networks when you need to work with it. ArcPad is the software you can use for field mapping applications.

What is mobile GIS?

Mobile GIS means GIS tools that are available to users away from the desktop for a sustained period without access to standard wired communications or mains power **(figure I.1)**. Although laptop computers can be used in some field situations, they are designed for use while sitting down, have high power requirements, and are not usually weatherproofed or used in plastic cases (ruggedized). By contrast, mobile devices like Tablet PCs and personal digital assistants (PDAs) can be held in one hand while using a stylus for data entry, have much longer battery lives, and can be ruggedized.

Mobile devices now support all the wired and wireless communications commonly found on desktop computers, plus you can add multiple gigabytes of data storage. This means that you can use your ArcPad mobile GIS away from the office for hours or even days at a time. When you return to your desk, you can integrate your fieldwork data into your existing GIS system without reentering it or having to merge two incompatible datasets. This way of working has brought many benefits to a wide range of users from foresters to security staff, farmers to engineers, as we will see in this book.

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Figure I.1 *Collaborative decision-making with mobile GIS in the field.*

INTRODUCTION

What is ArcPad?

ArcPad is mobile software in the ESRI ArcGIS family. ArcGIS is a scaleable GIS architecture that can extend from enterprise systems on globally distributed application servers to desktop GIS in the office and mobile GIS on the go. Fully integrated into the ArcGIS architecture, ArcPad software uses the same data formats, user interface, and workflow as its desktop cousins. Easy-to-use ArcPad can run on a range of mobile devices from mini laptops and Tablet PCs to PDAs and can integrate with Global Positioning System (GPS) receivers, range finders, and digital cameras for GIS data collection.

ArcPad: A Field User's Guide is about the things you can accomplish with ArcPad software. The chapters in this book cover the following:

- Defining mobility in terms of GIS
- Putting together a mobile system
- Using positioning technology
- Linking all the steps in your mobile workflow
- Presenting and displaying your work on screen in the field to the best effect
- Customizing ArcPad for your own applications
- Demonstrating the applications of ArcPad using case studies

Though exercises are included, this book is not an ArcPad manual. We cover a wide range of issues and offer ideas on how to benefit from mobile GIS techniques. Think of it as a mobile GIS "cookbook" with a range of recipes to explore.

The mobile GIS experience

Using a mobile GIS can be a powerful experience for the GIS user. This has been brought home to the authors of this book during a year of intensive ArcPad use. Among the various ArcPad projects we conducted was a personal twelve-month tracking experiment. This meant carrying a Bluetooth GPS and ArcPad on a Hewlett Packard iPAQ Pocket PC whenever and wherever we traveled for an entire year. The equipment was set to capture a point every five seconds, so the total set of daily track logs added up to over 100 Mb of data. We now have a huge archive of tracking and other data files, such as those for photo positions, as well as a wide range of map, image, and thematic data that provides essential context to the tracked movements. We've also been using ArcPad for scientific mapping work on professional ruggedized devices in logistically challenging coastal locations.

Carrying a GIS on your belt and having it with you 24/7, whether recording commuting facts or using it for mapping project work, made us realize, again, what a fantastic utility GIS can be. Our ideal is to have it with us exactly when we need it, with exactly the right data at our fingertips, in an easy-to-use package. These are the challenges and promises of mobile GIS, which ArcPad has been designed to support.

So ArcPad can be a practical tool for mapping, inventory, or position fixing, and a geocaching tool for the weekender. If ArcPad is in your pocket or your bag, you are ready for a new way of working: mobile GIS on the go.

CHAPTER 01

The meaning of mobility in GIS

Jonathan Raper, G-ability

Mobile GIS is not simply an office GIS scaled down for mobile devices—it is designed for specific tasks that can only be carried out, or can best be carried out, away from the office. Mobile GIS is an important new element in the family of GIS technologies because some GIS tasks just have to be done on the spot. Examples of these tasks, across a range of application sectors as shown in **figure 1.1**, provide many benefits because

- a worker out in the field can record data in real time;
- an inspector can update records on-site, making asset inventory, asset maintenance, and inspection quick and efficient;
- incidents can be reported and uploaded from the field to the office using wireless communications; and
- decision-making on-site becomes a reality when users have access to data and GIS analysis functionality.

As such, mobile GIS has already found a productive place among professional users in a wide range of application areas, including government, utilities, environment, and public safety.

In this chapter, you will discover what you can do with mobile GIS and how mobile GIS fits in with the wider revolution in mobile information.

TASK	INDUSTRY: Government	INDUSTRY: Utility and Infrastructure	INDUSTRY: Environment	INDUSTRY: Public Safety
Field Mapping	• Recording building footprints • Right-of-way mapping • Base mapping	• Centerline review and mapping • Facility mapping	• Forest boundary mapping • Trail mapping • Geochemical mapping • Volcanic deposit mapping • Wetlands delineation	• 9/11 address mapping • Minefield mapping • Military fieldwork and mapping
Asset Inventory	• Street sign inventory • Municipal assets inventory (GASB34) • Tree survey • Census data collection • Housing condition survey • Cemetery inventory	• Recording installations • Storm water inlet inventory • Storage tank mapping	• Toxic inventory • Mineral exploration • Vegetation survey • Wetland survey • Archaeological site survey	• Aerial survey • Fire perimeter mapping
Asset Maintenance	• Road condition survey • Street light survey • Patient registration	• Power pole maintenance • New equipment installation • Pavement condition assessment	• Crop management • Vacant land condition management • Timber harvest management • Drainage system management	• Locating buried infrastructure • Recording avalanche observations • Facility maintenance survey
Inspections	• Road pavement management • Code enforcement • Health inspection • Housing condition • Water rights enforcement	• Meter reading • Septic system inspection • Documentation • Compliance monitoring • Dam safety inspection	• Habitat studies • Weed abatement • Well sampling • Wildfire sightings	• Damage inspection • Tracking violations • Street sign inspection • Flood risk assessment
Incident Reporting	• West Nile Virus incidents • Public nuisance surveys	• Locating outages • Regulatory compliance	• Animal migration tracking • Oil spill assessment • Radioactive contamination tracking	• Property damage assessment • Accident reporting
GIS Analysis	• GIS data validation • Routing to locations • Property records management	• Locating customers for meter reading and billing • Routing to locations • Tracing networks outages	• Agricultural statistics • Vegetation boundary validation	• Locating customer addresses for investigations • Emergency identification of affected areas • Navigating to accident locations

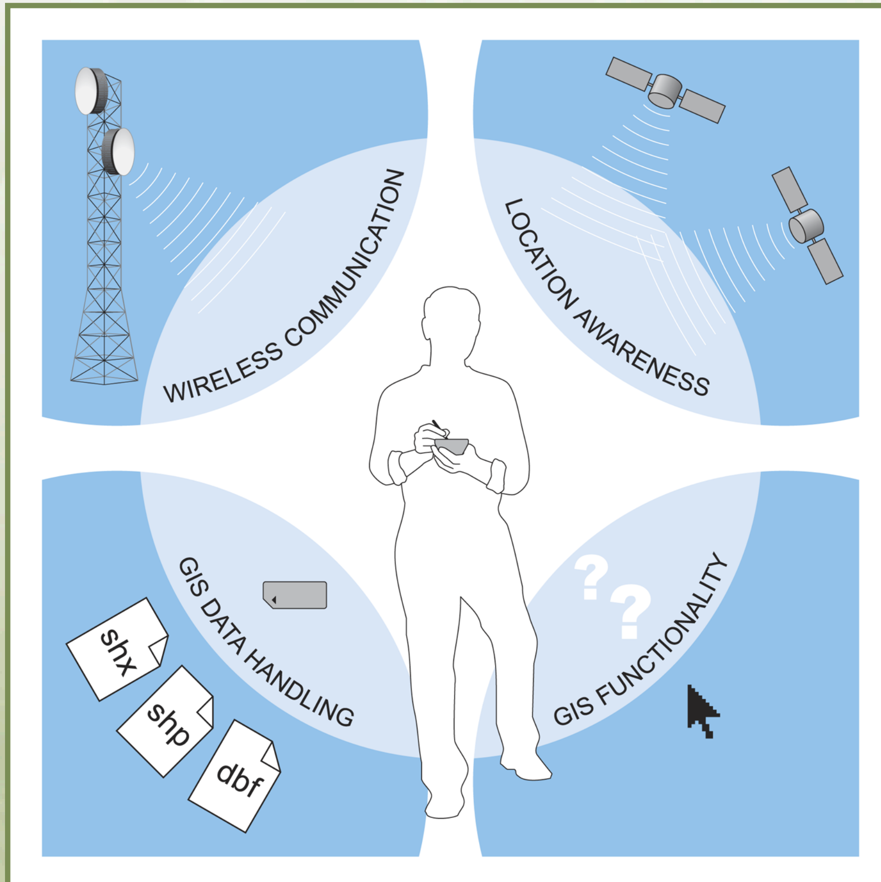
Figure 1.1 *Mobile tasks and application areas.*

Mobile GIS 101

What makes a mobile GIS? **Figure 1-2** shows various defining characteristics, including the following:

- Use of mobile devices with *wireless communications* that can
  - operate away from the desktop for a sustained period;
  - support data entry and device access using a stylus or mobile device joystick;
  - link with other devices like cameras and range finders; and
  - connect to the Internet/enterprise databases.
- Ability to *handle GIS data* in raster and vector formats.
- Availability of onboard *GIS functionality* supporting data capture, editing, and querying of spatial data.
- Integration of *location-awareness* into application development.

ArcPad software meets all of these criteria and is finding wide use as a mobile GIS in many applications. For example, community wardens patrolling the streets in Newcastle-upon-Tyne in England use ArcPad to access municipal databases for maps, aerial photos, maintenance schedules, lists of responsibilities, and records of previous incidents (see chapter 8). The wardens also complete custom forms in ArcPad that they transmit to municipal offices through wireless communications.



Courtesy of Nicholas Garner

Figure 1.2 *Mobile GIS components.*

What's possible with mobile GIS?

Because mobile GIS has expanded the possibilities for how GIS technology can be used, we can rethink the way that some GIS projects are carried out because this new technology relaxes old constraints. For example, now workers can directly update standard GIS datasets checked out of enterprise databases, rather than create files in the field that have to be synchronized later with the enterprise database.

In New Zealand, Delta Utility Services uses ArcPad to monitor the condition of electricity distribution equipment **(see chapter 7)**. Delta engineers use ruggedized mobile devices with long-life batteries to update geodatabase asset records directly into ArcPad, saving time both on preparing before going into the field and on returning to the office. The result is more efficient monitoring of essential electricity assets, leading to higher reliability in electricity provision and lower costs for the operator.

Mobile GIS also opens up new options. For example, with mobile GIS and wireless communications it is now possible to access network GIS servers to download data as needed or to move a copy of collected data back to the office for safeguarding **(figure 1.3)**.

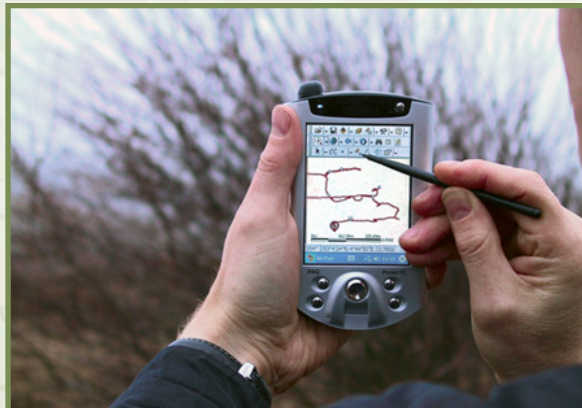


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Figure 1.3 *Mobile GIS in action.*

TIP: Reading the ArcPad case studies available on the ESRI Web site **(www.esri.com)** provides good ideas about how other users have approached their challenges.

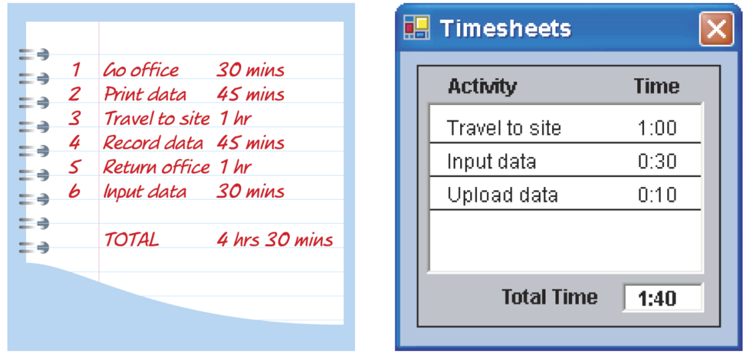
Mobile GIS has been designed to serve a wide variety of functions, but five are the most common:

- *Field data capture*, either by real-time editing of supplied digital maps or by surveying or mapping in the field using GPS input to create new features (e.g., a municipal tax assessor checking the status of vacant lots)
- *Navigation when GPS input is available*, where you can find your current location on a moving map display and use GoTo functions to locate destination points (e.g., an environmental scientist relocating a sample location)
- *Ground truthing*, where maps or imagery is field- or site-checked for validating or updating (e.g., a farm manager checking compliance with a crop plan)

- *Geocoding* land, property, and infrastructure while inspecting assets, then integrating this information with point-of-interest (POI) databases (e.g., a utility inspector conducting an asset audit)

- *Integration with enterprise databases* from the field (e.g., a data librarian updating the location of Wi-Fi hot spots in a database)

To begin to use mobile GIS technology, you first need to identify which of these functions can serve your needs or solve your problem.



Courtesy of Nicholas Garner

Figure 1.4 *A pocket book with a paper-based data collection schedule and a PDA calendar with mobile GIS data collection schedule.*

Benefits of mobile GIS

Mobile GIS benefits are built on the special characteristics of the mobile information experience. These characteristics are the opposite of the desktop GIS experience, which is limited to the office, requires installation in a fixed location, and is dependent on networks, power, and other utility services.

Mobility brings a number of benefits to GIS users, including the following:

- Ubiquitous availability. If you carry the mobile device with you on your belt or in your bag, GIS is available to you wherever you are, making serendipitous GIS use possible.

- True portability. If the mobile device is portable, then it can be used where a GIS has traditionally been unavailable, for example, by an inspector up a utility pole or a scientist climbing a mountain.

- Autonomous use. If the mobile device has a rechargeable power source, positioning services, or wireless access to networks, then the user can extend GIS functionality into remote or hostile environments.

- Data immersion. The real-time integration of human interpretative skills and the streams of data available through the mobile device allow new insights to be gleaned while in the field.

Business benefits can be measured in time and money. Mobile GIS saves time because the work can be done on location without the need to redo much of it once back at a desktop GIS (**figure 1.4**). It also saves money, because decision-making in the field is cost-effective. Mobile GIS also saves on travel by working directly on-site; so project management becomes simpler too.

Mobility in practice

The use of mobile GIS in practice means balancing cost and complexity considerations to ensure that project benefits are achievable **(figure 1.5)**. Low-cost and low-complexity applications characterized by read-only access to data (e.g., weather updates) can best be provided by location-based services on mobile phones or consumer mapping on the Web. Location-based services are information services offered on mobile devices that adapt to the user's real-time location, such as "find my nearest" services. Consumer mapping sites on the Web include sites that offer street maps and those that prepare driving directions.

Higher-cost, higher-complexity data capture or mapping operations characterized by write-only data collection generally require highly accurate datasets and use special data-collection hardware. Mobile GIS can be used to prepare this type of mapping project or help with project management. For example, back-in-the-office project managers can check where and when mapping operations were carried out if the members of the mapping team track their own positions with a GPS during the workday.

At moderate levels of cost and complexity, mobile GIS involves both reading and writing data in applications like asset inventory or incident reporting. This principle

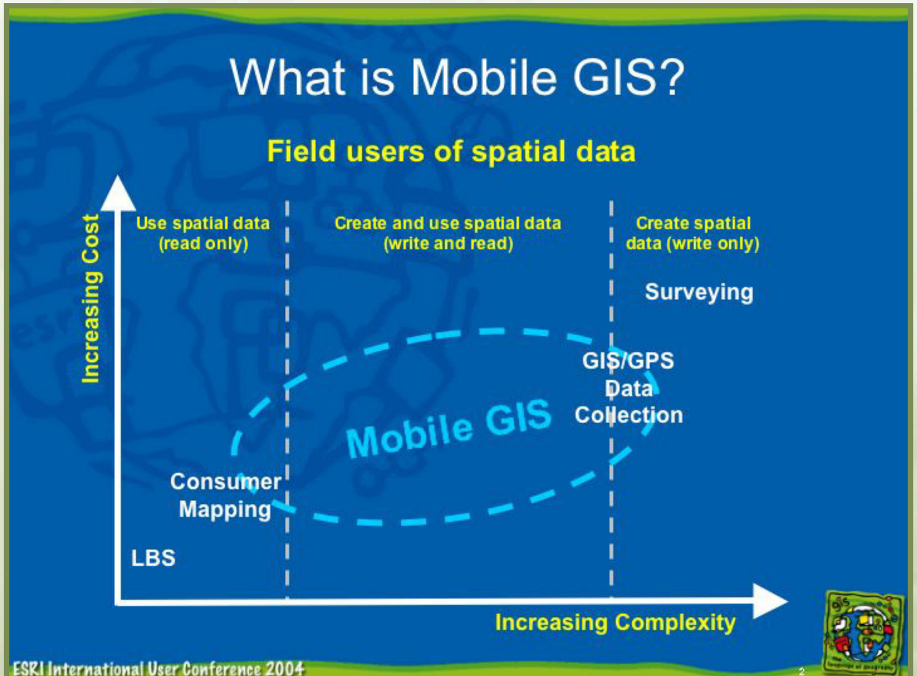


Figure 1.5 *Defining mobile GIS.*

is illustrated by the development of the CropView tool for agricultural survey, which used ArcPad Application Builder to customize the mobile GIS solution. CropView is used by field surveyors to report on crop growth for the Dutch national agricultural database (see chapter 9). By loading digital crop maps into ArcPad in the office then positioning reports and photographs using a GPS connected to ArcPad on-site, the fieldworkers can quickly compile and file their reports via wireless networking through an ArcIMS server. Comparing the

TIP: See the industries section of the ESRI Web site **(www.esri.com/industries)** for a profile of location-based services and how they are being used with ArcGIS software.

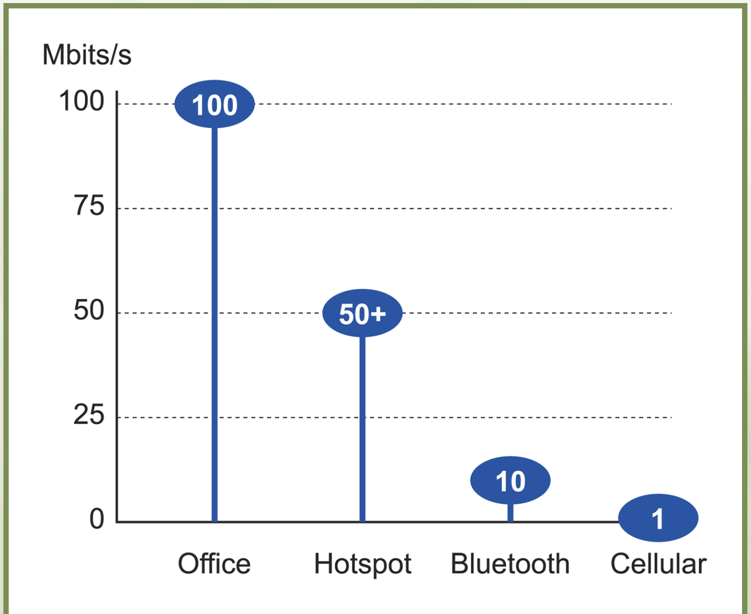
previous paper-based and current ArcPad systems showed a cost saving of 52 percent and a time saving of 35 percent overall on the CropView project. This example also shows that a mobile GIS can effectively communicate with enterprise databases using both desktop connections and an Internet connection while in the field.

Mobile GIS communications

Mobile GIS brings more autonomy, particularly with respect to the network. Since GIS technology involves flows of data from capture to analysis and through updating of databases, the relationship to network data servers can be crucial. In the office of a large enterprise, users likely have a connection to the Internet that operates at a speed of 100 Mbits; small organizations with broadband may have 2-10 Mbit connections.

Outside the office, if your connection to the network uses a wireless local area network (Wi-Fi) hot spot, it is likely to be high speed (10-50 Mbits in use). But this high-speed access will only be available where Wi-Fi service is available. If your connection to the network is through a cellular phone device (using the device-to-device wireless protocol Bluetooth), it is likely to be low- to medium-speed (up to 1 Mbit) but much more widely available. If you do not have access to the network except at the start and the end of the day or trip, the synchronization processes from mobile to desktop will be vital.

The relationship between speed and availability of the network **(figure 1.6)** defines the extent to which your fieldwork will be a stand-alone activity and the way you can design your workflow.



Courtesy of Nicholas Garner

Figure 1.6 *Speed/availability graph for mobile communications.*

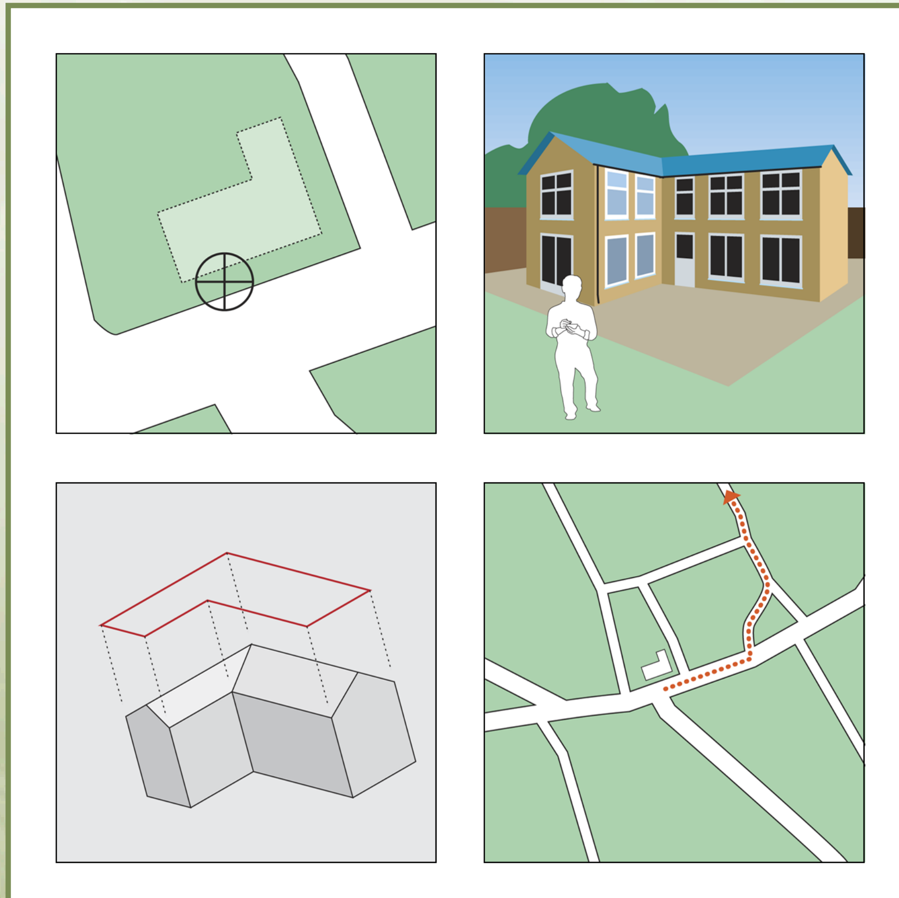
The mobile information revolution

In our increasingly information-driven culture, it is important to ensure that information is sufficiently rich, accurate, and up-to-date to satisfy the need identified. This requires information management processes to produce and sustain information assets.

Many information assets refer to infrastructure, property, transportation, land, and environment, and obviously have a geographic component. Producing and sustaining geographic information means mapping, ground truthing, geocoding, and navigation out on the ground **(figure 1.7)**. While some of these processes, such as mapping, require specialized systems, others such as ground truthing are best carried out with mobile GIS.

The mobile information revolution has also been driven by the need for information to be available anywhere, anytime. Some geographic information management processes are enhanced by access to network resources and online applications, for example, map updates. The costs and benefits of a real-time connection are positive if the information is time-critical, such as vehicle routing, or if the main database needs to be extremely up-to-date.

You should ensure that your geographic information management processes are quality-assured and robust. High-quality data capture must be followed by best-practice information management to protect your data from loss or corruption. Although unglamorous, this is one of the most important steps in the mobile information workflow.



Courtesy of Nicholas Garner

Figure 1.7 *Geographic information management processes.*

Mobile GIS using ArcPad

ArcPad is a full-function mobile GIS system running on a wide range of mobile systems. ArcPad is also fully integrated with the ArcGIS server and desktop data model **(figure 1.8)** and forms part of the ArcGIS Mobile architecture. *ArcPad: A Field User's Guide* covers the following:

- Desktop tools to facilitate the "mobilization" of raster and vector data when it is transferred to ArcPad
- GPS, camera, and range finder support
- Navigation functions when positioning is available
- Comprehensive projection and coordinate systems support
- Querying tools for mobile GIS data
- Data capture and editing tools for the field
- Support for cartographic presentation and sketching
- Integration with online data resources such as ArcIMS servers
- Tools to customize ArcPad, script its behavior, and extend its capabilities

ArcPad is also supported by an extensive user community through online forums, ArcPad templates (arcscripts.esri.com), and sample data and tutorials (www.esri.com).

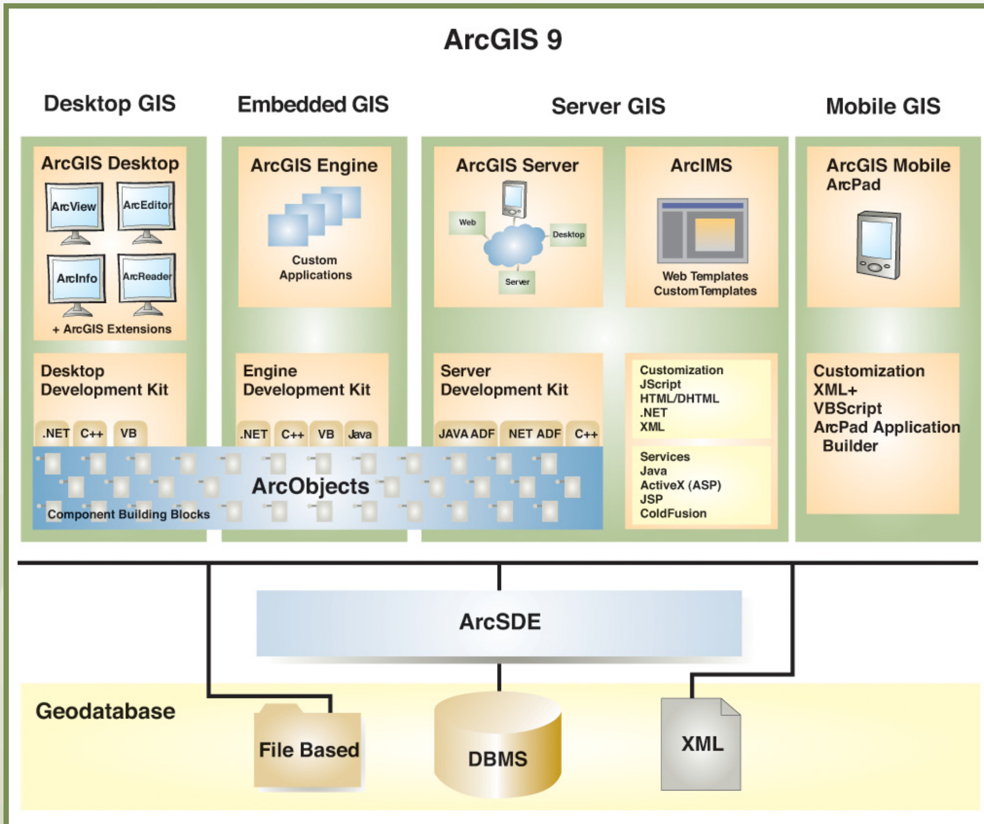


Figure 1.8 *ArcGIS architecture.*

This book is written for ArcPad 6 and ArcPad 7.0, though newer versions have been released (including ArcPad 7.01 through 7.1.1). Sections relating specifically to ArcPad v6 or v7 will be bracketed by these symbols: **V6** or **V7**. In addition, rapid development in mobile technology (including networks, devices, wireless technologies, etc.) means that the latest technology is not covered here.

ArcPad start-up

Since ArcPad can be downloaded for free as a twenty-minute demo from **www.esri.com** in version 6 or 7, you can download and install the application and sample data on any compatible Windows Mobile-based device or Windows-based desktop machine. To install ArcPad on a Windows Mobile device, you will need an ActiveSync connection between the desktop and mobile devices using a cable, cradle, or Bluetooth connection. See the documentation with the ArcPad download for guidance on installation and device compatibility.

Once ArcPad is installed, you can launch it by doing the following:

- Click the ArcPad icon in the Programs folder, which is reached from the Start Menu (Windows Mobile), or
- Select ArcPad from the Start>Programs>ArcGIS menu (Windows desktop)

If you are using the program for the first time, you will be asked for a license number, or you are given the option of continuing with full access for twenty minutes without a license number, after which the program will quit without allowing you to save changes. After the program starts up the following will occur:

V6 ArcPad 6 will open a new empty map **V6**

V7 ArcPad 7 will open the startup screen, which gives you the following options **(figure 1.9a)**:

- Open a new empty map (a frame into which you can load data, then name and save if you wish)
- Browse for data (you can access the sample data)
- Open an existing map or data in a list (if you have ArcPad formatted data on the mobile device). **V7**

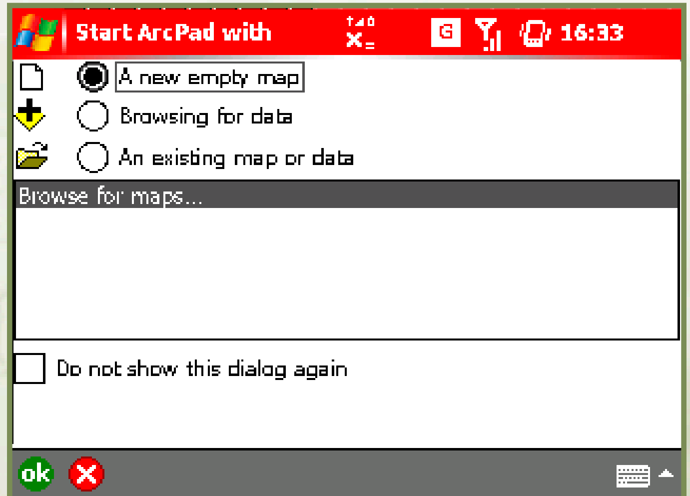


Figure 1.9a *"Start ArcPad with" screen: ArcPad Windows Mobile interface.*

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ArcPad will then open and enter the main user interface that has the following elements (unless previously customized for you):

- V7 The ArcPad application title bar (showing the name of the ArcPad map you are using—“untitled” if new) V7
- The Main toolbar (with open/exit, save, add data, layers, options, and help buttons)
- The Browse toolbar
- A scale bar in the map area
- The Status bar (with coordinate values and current scale)
- V7 The Command bar (with the lock button and input menu—by default a virtual keyboard) V7

Once you have reached this point, you are ready to use ArcPad.

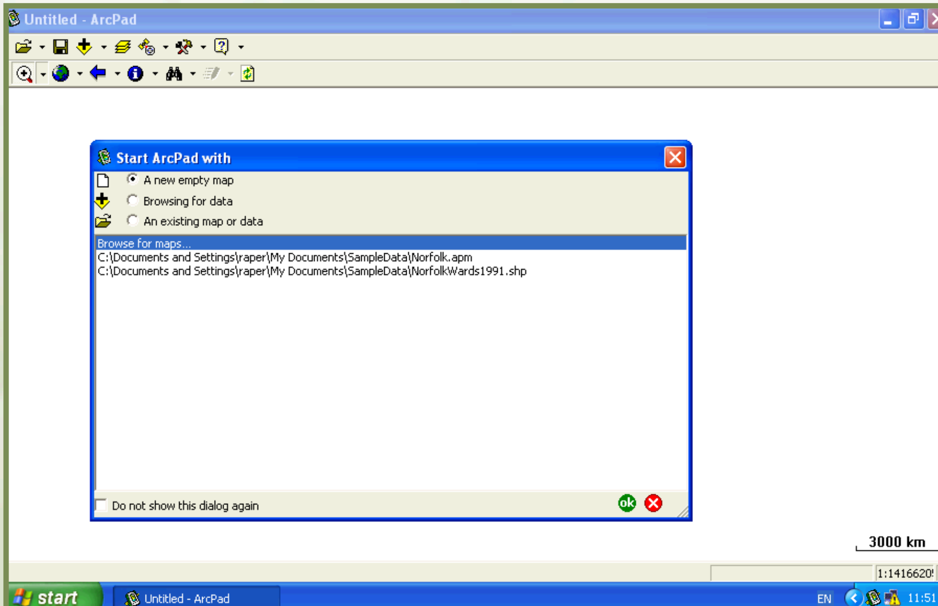


Figure 1.9b *“Start ArcPad with” screen: ArcPad Windows desktop interface.*

Sections of this book relating specifically to devices running desktop operating systems will be bracketed by XP. Sections relating to PDAs, and specifically to Windows Mobile Pocket PC 2003 will be bracketed by PPC; while sections relating to the newer Windows Mobile 5 and 6 operating systems will be bracketed by WM5.

PPC WM5 If you are running ArcPad on a Windows Mobile device, the program window will normally fill your screen with a Start Menu icon at the top left and a program close button (X) at the top right. At the bottom in the middle or to the right, you should see the virtual keyboard icon. You can only switch to another application via the Today screen or through the use of third-party application switchers. PPC WM5

XP If you are running ArcPad on a desktop machine, the program window is a standard system window with minimize, size-toggle, and close buttons at the top right; the Start menu at the bottom left; and the system tray (with settings and any active notifications) at the bottom right **(figure 1.9b)**. You can minimize ArcPad to use just part of the screen if you wish to run another program alongside it. XP

Although you can begin to use ArcPad once the startup sequence is complete, you can customize some aspects of the ArcPad interface to make it easier for you to use. Complete this exercise to try out these features.

Requirements

- ArcPad 6 or 7 on Windows desktop or Windows Mobile

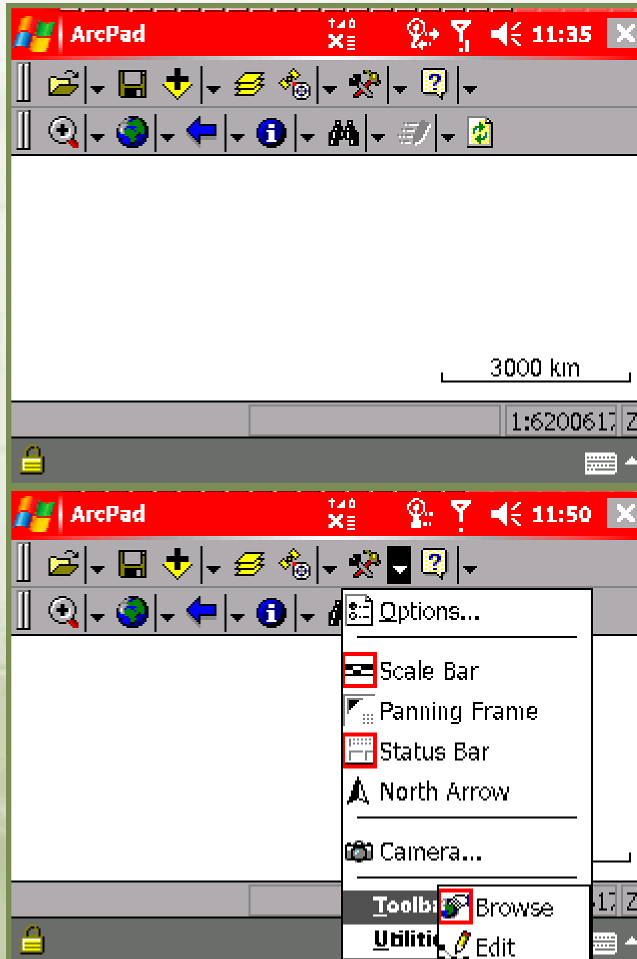
Exercise

1. Open ArcPad in Registered or Demo mode, and, if using v7, select the option "Open a new empty map."

You now see the standard interface with no data loaded, which should look like **figure 1.10a** (the color of the task bar at the top of the screen may vary). If additional toolbars or menu options are visible, then your installer or service provider has precustomized your copy of ArcPad, and you should seek their advice before making further changes.

The first step in optimizing the interface for your use is to reduce all unnecessary use of screen real estate. ArcPad places two toolbars at the top of the screen, Main and Browse, along with a Status bar under the map area (for information such as scale) and the Command bar at the bottom of the screen (with the "Lock screen" button).

2. Use the Options menu shown in **figure 1.10b** to add the third Edit toolbar and to switch on the Panning frame, which provides pan up/down, left/right arrows on the sides of the map window. The map area will now be significantly reduced in size, especially on a PDA.



Top: **Figure 1.10a** *ArcPad interface customization: ArcPad standard interface. Bottom:* **Figure 1.10b** *ArcPad interface customization: ArcPad Options menu.*

To increase the size of the map screen, you can switch off these features (except the Main toolbar and the Command bar); however, you can use a space-saving trick to keep the toolbars switched on without giving up screen space.

3. Click and hold the pair of vertical gray bars at the left end of any toolbar with the stylus or mouse and drag it onto one of the other toolbars. The first toolbar will disappear and an extra pair of vertical gray bars will display at the end of the toolbar you dragged it onto. If three toolbars are displayed, you can drag two of them onto the other until the screen changes from the top to the bottom layout in **figure 1.10c**. By clicking on a pair of vertical gray bars, you restore the hidden toolbar, which replaces the one that was previously active.

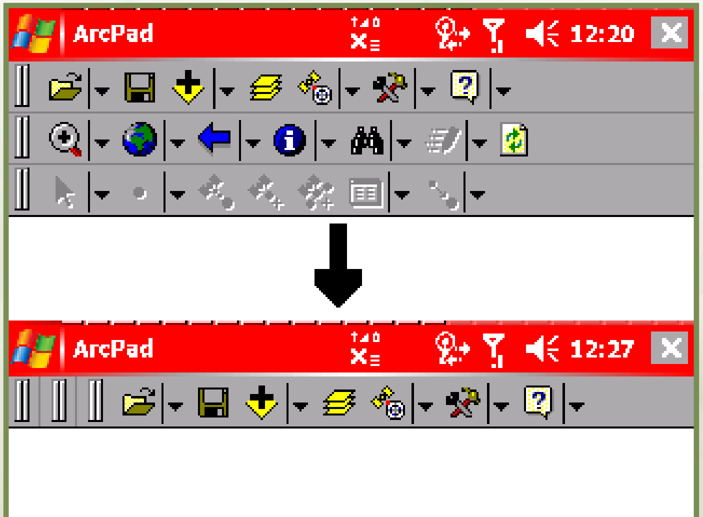


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Figure 1.10c *ArcPad interface customization: ArcPad toolbar hiding.*

Setting up ArcPad to support your application

Becoming familiar with a new program and setting it up to suit your preferences and working methods can be a time-consuming process. Fortunately, the extensive ArcPad user community has already created a range of materials that that you can download and use for free. ArcPad templates are organized in six application areas:

- Health and Human Services
- Infrastructure and Utilities
- Natural Resources
- Public Safety
- State and Local Government
- Urban and Regional Planning

The templates vary from tools to applets to forms, all of which illustrate the practical benefits of ArcPad. The templates aren't designed as complete application solutions; rather, they are a starting point for creating your own ArcPad solution. The ArcPad templates are located on the ArcScripts Web page (arcscripts.esri.com), where you can search for and download a variety of scripts and sample code contributed by the ArcPad user community, for example, the Mobile Fire Mapper applet (**figure 1.11**).

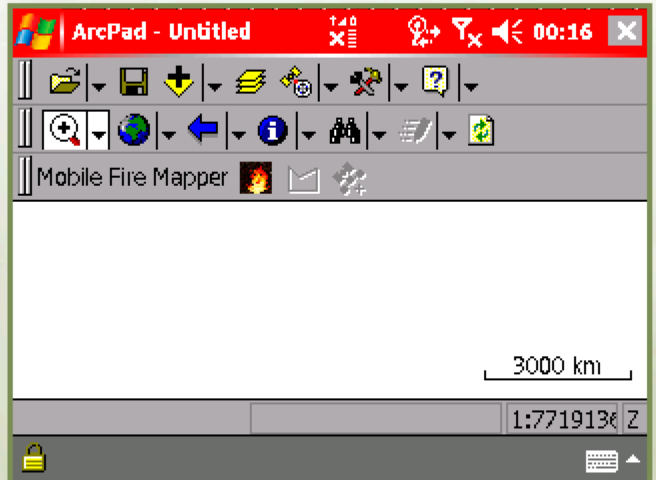

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Figure 1.11 *The Mobile Fire Mapper applet by Craig Greenwald from the ArcScripts Web page.*

Summary

In this chapter, you have discovered what mobile GIS is, what you can do with it, its key benefits, and how mobile GIS fits in with the wider revolution in mobile information. In the next chapter, we will put the entire technical solution together.

CHAPTER 02

Putting your mobile system together

Jonathan Raper, G-ability

Over the past few years, the relentless pace of technological development in computing has brought together high-resolution portable LCD screens, powerful mobile processors, wireless networking, cellular communications, and high-capacity memory in a wide range of mobile devices. The availability of these components has made it possible to design new computing systems in a variety of forms:

- Ruggedized microlaptops
- Tablet PCs
- Personal digital assistants (PDAs), some with phones
- Smartphones
- A variety of embedded devices (e.g., those installed in cars)

All of these devices can now run mobile GIS applications, although, due to memory and interface requirements, ArcPad does not at present run on smartphones or embedded devices.

In this chapter, we will explore the computing hardware you will need for your ArcPad project, concentrating on the decisions you need to make when building your system to use in the field **(figure 2.1)**. Although the pace of change in this area means that the specific hardware models change rapidly, the components, underlying technologies, and device dimensions tend to endure longer.

Figure 2.1 *Mobile computing on a bike.*

The mobile computing hardware issues covered in this chapter can be divided into five areas:

- Mobile computing systems
- Operating systems and software support
- Devices and their peripherals
- Network access
- Linkage with other devices

We will explore the technologies in each of these areas in turn and give you sources to explore for further information.

Mobile computing systems

Mobile devices that can run ArcPad can be divided into two groups:

- Ruggedized microlaptops and Tablet PCs running desktop Windows operating systems (2000 or XP)
- PDAs, PDA phones, and ruggedized PDAs running Windows Mobile operating systems

Remember, sections of this book relating specifically to devices running desktop operating systems will be bracketed by XP. Sections relating to PDAs, and specifically to Windows Mobile Pocket PC 2003 will be bracketed by PPC; while sections relating to the newer Windows Mobile 5 and 6 operating systems will be bracketed by WM5.

XP One way to mobilize your GIS project is to use ruggedized or microlaptops that are very compact and lightweight, and Tablet PCs **(figure 2.2a)** running Windows Desktop systems based on the Windows 2000, Windows XP, or Windows Vista operating systems. This allows you to take your entire GIS solution to the field. While compromises have to be made on device specifications and performance (these devices may not have the fastest processors to cut down power use), the processors and memory of the mobile system will be broadly similar to the systems back in the office.

Laptops and Tablet PCs running any processor compatible with desktop Windows 2000, Windows XP, or Windows Vista operating systems can run ArcPad software, or even the ArcInfo version of ArcGIS Desktop software. To optimize performance, the general rule for such systems is to get the fastest processor and the most memory you can afford for the style of device you want. XP

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ArcPad in use on different devices. Left: **Figure 2.2a** *Windows desktop Tablet PC. Right:* **Figure 2.2b** *Windows Mobile PDA.*

PPC WM5 By contrast, if you want to use PDAs in the field **(figure 2.2b)**, then the device options you have are a bit more complex. The key point is that, unlike laptops and Tablet PCs, operating systems for PDAs are stored in device memory to save power. This means that you cannot always update the operating system, but merely add to it in limited ways. When you choose a PDA, you are effectively deciding on the operating system for the life of the device, which makes it a vital purchasing decision. PDAs with Windows Mobile Pocket PC 2003 or Windows Mobile 5/6 can run ArcPad on devices with ARM-based processors such as the Intel StrongARM and XScale series. See the documentation that comes with the ArcPad software for details on ArcPad-supported processors. PPC WM5

ArcPad can also connect to other devices such as GPS, cameras, and laser range finders, which are discussed in more detail later in this chapter.

TIP: You can check the best combination of software version, hardware, and GPS by going to the mobile GIS pages on the ESRI Web site: **www.esri.com**.

Mobile devices

Choosing a device to run a mobile GIS like ArcPad depends on a range of factors. You need to make decisions about screen size, processing speed and memory size, battery life, communications protocol, and the connectors needed to integrate with other devices. Once you have made your decisions, you need to factor in the budget you have available or the device you have been given. This may then require you to reconsider some of your purchase priorities.

Three typical mobile device types exist:

Microlaptops. Also known as ultramobile PCs, these are now available at a size not much larger than your hand. They provide full PC functionality—running Windows XP or Windows Vista—a stylus pointing device, slide-out mini keyboard and small screen with a resolution of usually 800 by 480. These devices run ArcPad software like any desktop PC would. ***Classic of its kind:*** *the OQO microlaptop.*

TIP: ESRI's online ArcPad user forums **(support.esri.com)** offer plenty of advice on choosing the right mobile device with several discussion threads on this topic.

Tablet PCs. These are designed to be a lightweight, lower-power PC running Windows XP or Windows Vista for tablet devices. Tablet PCs are similar to laptops in specification but with aggressive power management, a stylus pointing device, PC card slots for expansion, and a full-size, foldaway keyboard. They are usually ruggedized to some extent to protect them from rough handling, moisture, and dust, though some are fully ruggedized for extreme environments. These devices run ArcPad software as any desktop PC can. ***Classic of its kind:*** *the Xplore Tablet PC.*

PDAs. These are designed to be held in the hand and controlled using a stylus and a few buttons. While PDAs usually have low specifications for ROM (read-only memory), RAM (random access memory), processing, and screens, they also have long battery life and much greater portability. Like microlaptops and tablet PCs, PDAs have Bluetooth, WLAN (wireless local area network), and sometimes cellular communications, expansion slots and serial or USB connectivity for GPS, cameras, and range finders. Some devices have built-in keyboards; for those that don't, fold-out keyboards can be connected. PDAs come in ruggedized versions. They run ArcPad software on Windows Mobile operating systems, and while the range of PDAs has now become sophisticated, several typical PDA configurations exist, including the following:

- PDA only (Windows Mobile 5 Pocket PC, Windows Mobile 6 "Classic"). ***Classic of its kind:*** *the HP iPAQ Pocket PC.*
- PDA with cellular connection (Windows Mobile 5 Pocket PC Phone Edition, Windows Mobile 6 Professional). ***Classic of its kind:*** *HTC Universal Pocket PC phone.*
- Ruggedized PDA. ***Classic of its kind:*** *Trimble GeoExplorer Series* ***(figure 2.3)***.
- PDA with integrated GPS. ***Classic of its kind:*** *Mio A701 PDA.*

G-ability Ltd. with permission

Figure 2.3 *Trimble GeoExplorer.*

Although ArcPad is the same on these different device types, each of these devices offers you a specific ArcPad experience: the Tablet PC offers large screens (typically 1024 x 768 pixels), which is better for visualization and graphics sketching **(figure 2.4)**, while the PDAs provide excellent communications options. Another key difference is in the memory and processor power available. The Tablet PC can function like a desktop PC, though with a weight to match. By contrast, PDAs have processors and memory resources half that of the Tablet PCs, but they will fit in your pocket or around your neck. In price terms, the microlaptops and Tablet PCs cost three or four times the cost of ArcPad software, while suitable PDAs with accessories cost around the same as ArcPad.

TIP: On PDAs, manipulating datasets larger than 2 Mb (in both vector and raster formats) in ArcPad can be slow even if you have run ArcPad Tools for ArcGIS to "pack" the shapefiles and have compressed the rasters, for example, into MrSID format.

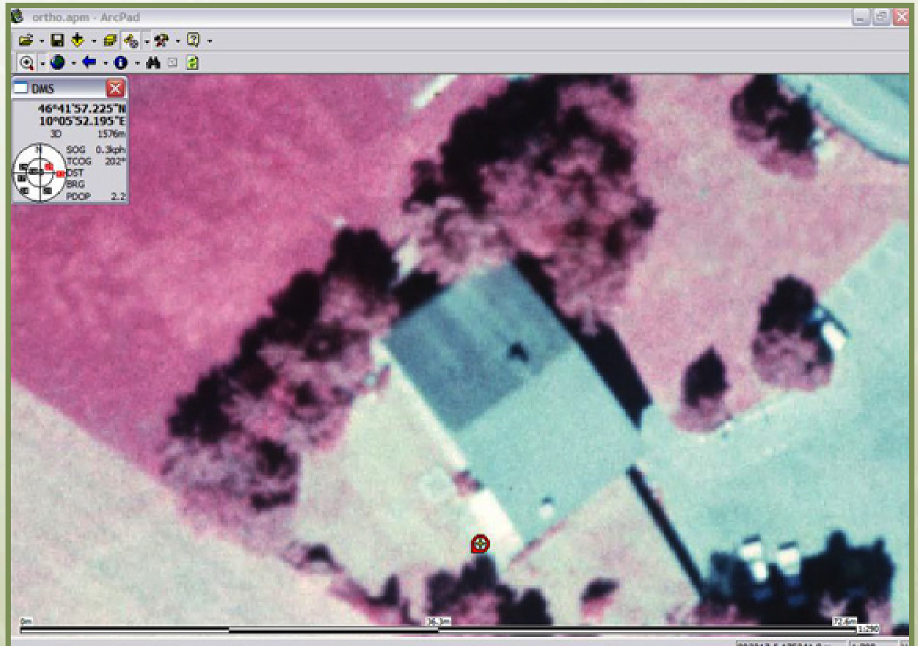

Figure 2.4 *Tablet PC user interface in ArcPad.*

Courtesy of Swiss National Park

The key to selecting the right device is to assess the data you need to work with in the field. If you need your whole project right there with you, then the microlaptops and Tablet PCs are what you need. If you can work with a subset of your raster and vector data with a focus on mapping, assets, incidents, and decision-making, the smaller footprint of the PDA will appeal. The screen size and the availability of power are also important; if weight is not a constraint and power is readily available, then the microlaptops and Tablet PCs are preferable to the PDAs.

Operating systems and software support

After choosing the type of mobile device, your next most important decision is choosing a supported operating system (**figure 2.5**).

HP For microlaptops, the choice is simply between Windows Desktop and Windows with Tablet PC support. Tablet PC support offers pen-based input to the Windows interface, digital ink for graphics sketching and handwriting (supported in ArcGIS Desktop), and voice recognition. ArcPad takes advantage of Windows pen-based input for handheld use. **HP**

V7 ArcPad 7 has a graphics layer where you can use sketching to show plans or annotate features on a map. **V7**

PPC **WM5** On PDAs, the operating system, though Windows-powered, is significantly different from desktop Windows. You need to consider how your project can be supported in Windows Mobile, and this section explains the key differences.

Windows Mobile is a 32-bit, ROM-based operating system that runs on a wide range of mobile hardware, including embedded systems and not just PDAs. Windows Mobile is similar to Windows Desktop in that it

- implements a subset of the desktop Windows (Win32) application programming interfaces (APIs);
- uses the Microsoft foundation classes (MFC) framework;

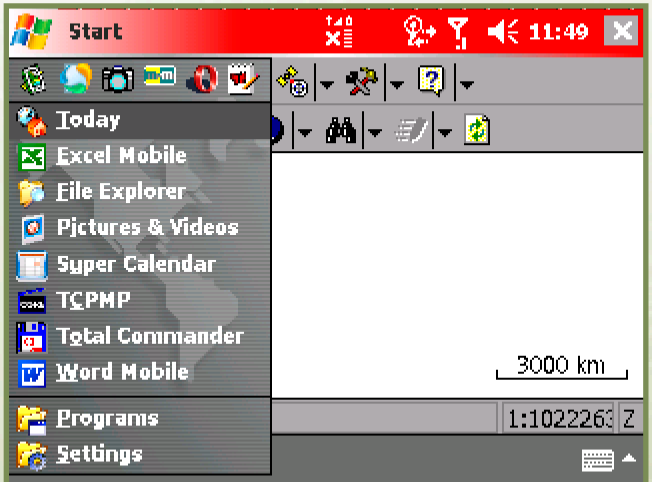

Figure 2.5 *Windows Mobile 5 and ArcPad 7 interface.*

G-ability Ltd. with permission

- supports the (distributed) component object model (DCOM); and
- has a similar graphical user interface (Start menu, etc.).

Windows Mobile and Win32 operating systems have a basic level of compatibility; however, Windows Mobile was designed to support mobile hardware with power, screen size, and memory constraints. This means that

- desktop applications need to be customized to run on Windows Mobile and may use different file formats;
- the file system is different, for example, it allows limited nesting of subdirectories; and
- memory limitations constrain the size of data files that can be manipulated effectively.

Applications need to be designed specifically for Windows Mobile. ArcPad software is available for both Windows Mobile and Win32 desktop versions, with full compatibility for all supported GIS file formats between the two platforms. PPC WM5

Memory management

PPC WM5 Operating systems for PDAs need to be

- low power (dependent on small batteries);
- robust (personal, as the device is often far from support); and
- "instant on" (up and available for use in just a couple of seconds).

In practice this means that the operating system is stored on memory chips and not hard discs, which are too large and use too much power. You will need to choose from two main types of memory chip **(figure 2.6)**:

- Read-only memory (ROM)—used for storing data
- Random access memory (RAM)—used for running programs or storing data

ROM does not need power to remember its contents and consumes little energy when being read or written to. In general, ROM is used for the operating system, though flash ROM can be used for data storage. By contrast, RAM loses its contents without power and consumes more power during use than ROM, though it can be read and written to at higher speed. Note that while the capacity of ROM and RAM installed in PDAs continues to increase, the absolute amount of

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Figure 2.6 *Memory chips for mobile devices.*

storage (up to 128 Mb for consumer PDAs) is still much less than on a desktop PC. PPC WM5

PPC In PDAs running Pocket PC 2003, the operating system is stored in ROM; however, RAM is used both for running programs and for the storage of data. The operating system dynamically adjusts the balance between them, though the user can alter this. Most devices have backup batteries to protect against the loss of power to RAM, but even these run out after a few days without power. When not in use and storing data, PDAs of this kind need to remain plugged in to a power source. Some devices have a little "spare" writeable space in ROM that can be used for data or programs that need to be preserved even if the contents of RAM were to be lost through battery failure. PPC

WM5 PDAs running Windows Mobile 5 or 6 use ROM for storing the operating system and now use flash ROM to store data. So on Windows Mobile 5 or 6, RAM is only used for running programs. WM5

TIP: The Windows Mobile team blog **(blogs.msdn.com/windowsmobile)** is an excellent place to read more about these terms and concepts.

Comparing the specifications of PDAs running Windows Mobile Pocket PC 2003 and Windows Mobile 5 or 6 can be difficult. The amount of RAM is especially important to Windows Mobile Pocket PC 2003, since it used for running programs and data storage. In Windows Mobile 5 or 6, the amount of RAM is usually less than the ROM, since it is only used to run programs. For Windows Mobile 5 or 6 devices, knowing how much of the ROM is available for storing data is important.

Windows Mobile programs

PPC WM5 The Windows Mobile operating systems designed for use on PDAs come with the following applications included on ROM:

- Office software such as Word and Excel
- Web browsers and messaging tools (and phones on some devices)
- Media players (and cameras on some devices)
- Personal information management (PIM) software

Programs are added to the Start menu, but only as many as will fit before scrolling would be needed (**figure 2.7**).

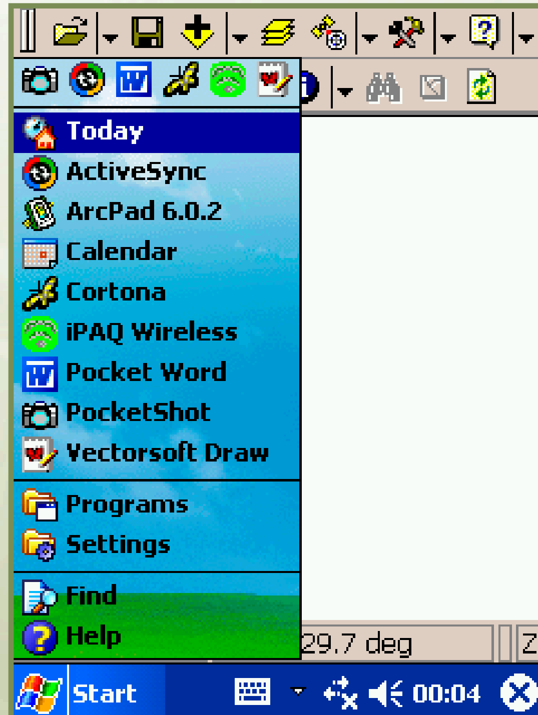

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Figure 2.7 *Windows Mobile 2003 and ArcPad 6 interface.*

Windows Mobile PDAs are designed to be connected to host desktop PCs using serial or USB connectors (often built into a cradle with a power input) or Bluetooth connections.

The privileges for PDA users permit the installation of third-party applications that can read and write to the device, including the following:

- Stand-alone applications like ArcPad
- Java applications (if you install a Java Virtual Machine to carry out the Java instructions and a midlet manager to verify the security of downloadable applets)

TIP: This from bitter experience: if ActiveSync/WMDC is used wrongly, you can easily lose data on your computer. If ActiveSync/ WMDC is set to synchronize whenever connected, and if you delete all of your files in "My Documents" on your PDA when operating independently, ActiveSync/WMDC will promptly delete all of your files in the equivalent synchronization directory on the desktop PC when connected to the PC! Synchronization operates like backup when you are adding files on your PDA, but like spring cleaning when you are deleting them. Don't delete on the PDA thinking that they are still secure in the synchronization directory on the PC: as soon as the device is cradled they will be deleted on the PC too. On the desktop PC, you can get the files out of the trash (whew!); however, on the PDA, the files are gone because no "undo empty trash" operations exist.

Microsoft ActiveSync or, for Windows Vista, Windows Mobile Device Center (WMDC) on both desktop computer and PDA, manages the communications between devices and mounts the PDA on the desktop PC like a disk drive whenever it is connected (you will see it in "My Computer" as "My Mobile Device"). ArcGIS and other programs use the connection that ActiveSync/ WMDC creates between your desktop machine and PDA to send data to ArcPad.

ActiveSync/WMDC can also synchronize the contents of PDA directories (normally "My Documents" by default) with matching directories on the desktop PC whenever connected, or to a schedule. ActiveSync/WMDC can convert data (e.g., from Pocket Word [.psw] to Word document [.doc]) as it is transferred. ArcGIS formats like shapefiles do not need converting because they are supported by all platforms. PPC WM5

Windows Mobile file handling

PPC WM5 Like Windows Desktop, Windows Mobile devices use a standard directory structure (**figure 2.8**). "My Device" is similar to "My Computer" on desktop Windows, but without the separate drives (e.g., C, D), just a single directory structure for all storage. Below "My Device" (\) you will find the following directories:

- Windows directory for system files, most of which are read-only
- Program Files directory, for programs installed on the device

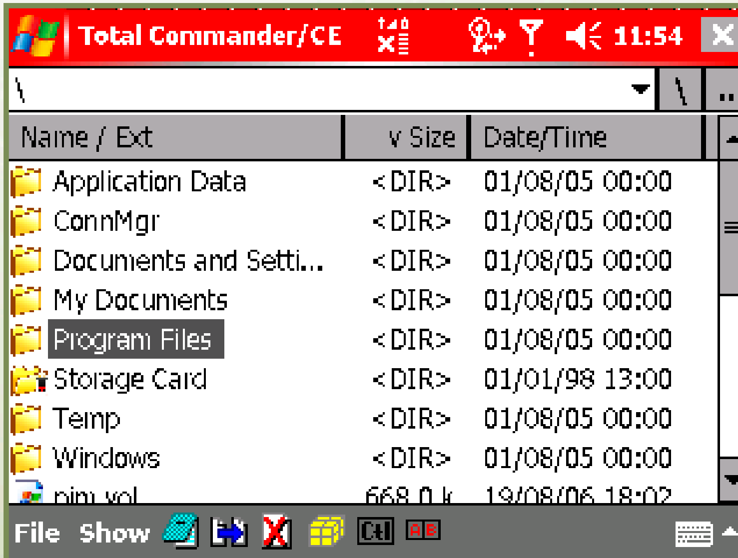


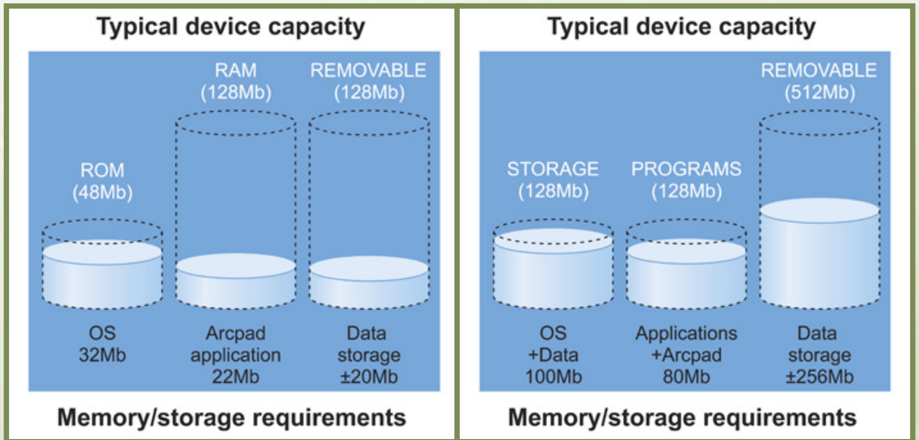
Figure 2.8 *Windows Mobile Directory structure.*

- Documents and Settings folder, for program settings
- My Documents folder, for your data
- Other system directories
- "Storage Card (n)" for any memory cards inserted into the expansion slot(s), where n is 1, 2, etc., if there are more than one.

"Storage Card" is not a directory as such but is another storage location analogous to a separate drive on Windows Desktop. You can install ArcPad software and other programs on the storage card to save storage memory. Note, however, that Windows Mobile dismounts some storage cards, shutting down programs if the device is sleeping for any length of time (in effect, quitting the program without saving changes). Installing ArcPad to "My Documents," therefore, is more reliable.

Use the Windows Mobile File Explorer (analogous to Windows Explorer on desktop Windows) to manage files. However, the File Explorer does not show file extensions, so you can only open and edit files that have Windows Mobile built-in file-to-application associations created when you install a program. Hence, only tracklog.shp can launch ArcPad, not tracklog.shx.

One further limitation of the Windows Mobile file system is that only two levels of subdirectories are recognized by ArcPad. This means that you have to plan your directory structures; you cannot just move Windows Desktop directories over to the PDA if you have more than two directories levels. PPC WM5



Courtesy of Nicholas Garner

Left: **Figure 2.9a** *Windows Mobile 2003—typical memory and storage.*
Right: **Figure 2.9b** *Windows Mobile 5 and 6—typical memory and storage.*

Devices and their peripherals

You need to choose hardware devices to handle data storage and make choices to ensure screen readability and reliable power in the field.

Data storage

Data storage is a low-profile but vital part of computing and is especially important in mobile computing, since you are no longer directly connected to network drives and the Internet. All mobile devices need backup and external data storage solutions for the field to give you peace of mind and flexibility.

XP For microlaptops and Tablet PCs with standard and mini-USB ports, the simple and cheap solution to backup and external data storage in the field is to use a USB key based on flash ROM. These are now available in multigigabyte form allowing for quick and secure copying. XP

PPC WM5 Various types of *removable* flash ROM memory are suitable as external data storage for PDAs, including Secure Digital (SD), CompactFlash (CF), and Memory Stick (MS), that vary in size. In addition to flash memory cards, micro–hard drives are available in multigigabyte sizes. This external storage cannot be used to run the operating system or programs, which still need installed RAM, but can be used to store data and install programs. Some typical memory and storage options are shown for Windows Mobile 2003 in **figure 2.9a** and for Windows Mobile 5 and 6 in **figure 2.9b**.

TIP: Install an alternative file manager to handle files with extensions unknown to Windows Mobile. For example, if you want to copy or create a projection (.prj) file on the device away from your desktop PC, then Word and File Explorer will not allow you to create a text file with a .prj extension, but alternative file managers will. ***Classic of its kind:*** *Total Commander file manager.*

ArcPad requires a minimum of 64 Mb of RAM in the mobile device to run all the necessary operating system services, even though the ArcPad application itself only uses around 2 Mb when running. Loading data into ArcPad uses further RAM, and if ArcPad has to decompress large MrSID image files, the RAM required for ArcPad can exceed 20Mb. PPC WM5

PPC Since installing ArcPad takes up RAM devoted to internal file storage space, and the program can make large demands on RAM for working memory, ArcPad needs a device with as much RAM as possible and a large external storage card for data. PPC

PPC WM5 Mobile GIS operations also need to integrate with the rest of the enterprise database on return from a site or the field. This can be done by

- removing a storage card from the slot and copying the data to PC using a card reader;
- performing a synchronization between the mobile device and a desktop PC using ActiveSync/ WMDC; or
- copying the data onto network servers using wireless data transfer methods. PPC WM5

Power

Power is the fundamental limiting factor away from the desktop for mobile GIS and is likely to be your major worry out of the office. Although battery power has increased for mobile devices, it is unusual to get more than

- 3 hours of battery life with microlaptops;
- 6 hours of battery life with standard PDAs;
- 9 hours of battery life with Tablet PCs; or
- 12+ hours of battery life from ruggedized PDAs.

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Figure 2.10 *Power options for PDAs.*

You have three alternative power strategies in the field or on-site when no power source is available for recharging **(figure 2.10)**.

First and most simply, take spare charged batteries if they can be removed from your device. Regular or extended-life laptop/TabletPC/PDA batteries are expensive but have the advantage of being instantly exchanged, though you may have to reboot (also called soft reset), usually taking 30 to 60 seconds.

PPC WM5 Second, a number of cheap adapters are available for you to power PDAs from additional disposable or rechargeable batteries (e.g., AA type). When the device is off, additional batteries return the internal battery to full charge like an AC source; when the device is on, they usually only recharge the internal battery slowly, as the power is being consumed almost as fast as it is being supplied. PPC WM5

Third, recharge the device battery from an alternate power source. This could include a car adaptor, a fuel cell (available in small disposable forms), or a solar power cell (usually quite bulky compared to a PDA). You can also use cables that charge mobile devices from the USB port on a laptop computer in the field if you are prepared to sacrifice your laptop battery power!

PPC WM5 Battery power for PDAs is quoted in milliamp-hours (mAh). Nonruggedized PDAs have standard batteries with ratings of up to 1,500 mAh and ruggedized PDAs up to 2,200 mAh. Keep in mind that the rating of a battery is usually a guideline and is often not achieved in practice. Battery use by PDAs can be estimated from the consumption of mobile device subsystems **(figure 2.11)**, but experience in using the device in realistic conditions is the best guide. Tools to "underclock" (slow down) the processor can extend battery life further, along with aggressive backlighting reduction, and systems like GPS and phones that draw power can be switched off. PPC WM5

Note that battery power can increase slightly from new as the battery is charged to full capacity and then typically declines very slowly over time. The shape of this lifetime battery curve depends on the battery type. Older NiCd batteries had a "memory effect" that steadily depressed the maximum achievable charge if they were not fully discharged before recharging. Rechargeable lithium ion batteries do not have this problem.

Device subsystem	Power use (mAh)	Typical total (mAh)
Processor (idle to full use)	200–350	275
Screen on backlight minimum	50	50
WLAN (standby to receive mode)	50–250	150
Bluetooth	50	50
Total		***525***

Figure 2.11. *Power availability and use.*

The choice of mobile power for your project depends on how many hours of power you need, whether other sources like cars or laptops are available, and whether you are on the move for more than the time offered by one battery charge. For long periods of use while on the move choose a

- spare battery;
- battery-driven power adaptor; or
- fuel cell.

All of these can be plugged in while the device is in use. For periods of use less than the life of a battery while continuously away from an AC source, take power from a car or laptop, or use a solar charger to recharge as you go.

Screens

Mobile devices now all have liquid crystal display (LCD) screens. LCD screens used in mobile devices are based on active matrix technology, allowing LCDs to render full-color displays. Microlaptops and Tablet PCs offer the same quality of screen display as desktop computers.

PPC WM5 Although LCD technology allows full-color display, compared to desktop devices most PDAs have memory and power limitations, so color displays are usually limited to 16-bit color depth (65,536 colors). This means that many symbols and color schemes designed on 24-bit color-depth displays (16.8 million colors) do not display as expected on PDA screens. PPC WM5

LCD displays for mobile devices are usually transflective, that is, the displays are half-mirrored to allow sunlight or internal backlighting to provide the illumination of the screen depending on where it's used. This means that transflective LCD displays are most readable in either bright sunshine or dim lighting, and that mobile device screens perform least well when outdoors on a cloudy day with low light levels (neither bright nor dark) (**figure 2.12**). Backlighting can be turned off to save power if the screen is not needed (e.g., during some kinds of data capture). By contrast, many laptop screens are very hard to read outdoors. You should always try to test your mobile device screen outdoors before making a purchase.

Mobile devices can also be grouped by screen size: Tablet PCs usually have at least 1024 x 768–pixel XGA screens, PDAs have 320 x 240–pixel QVGA or 640 x 480–pixel VGA screens, and microlaptops have a hybrid screen size of 800 x 480 pixels.

G-ability Ltd. with permission

Figure 2.12 *HP iPAQ Pocket PC screen showing a flat image on a cloudy day.*

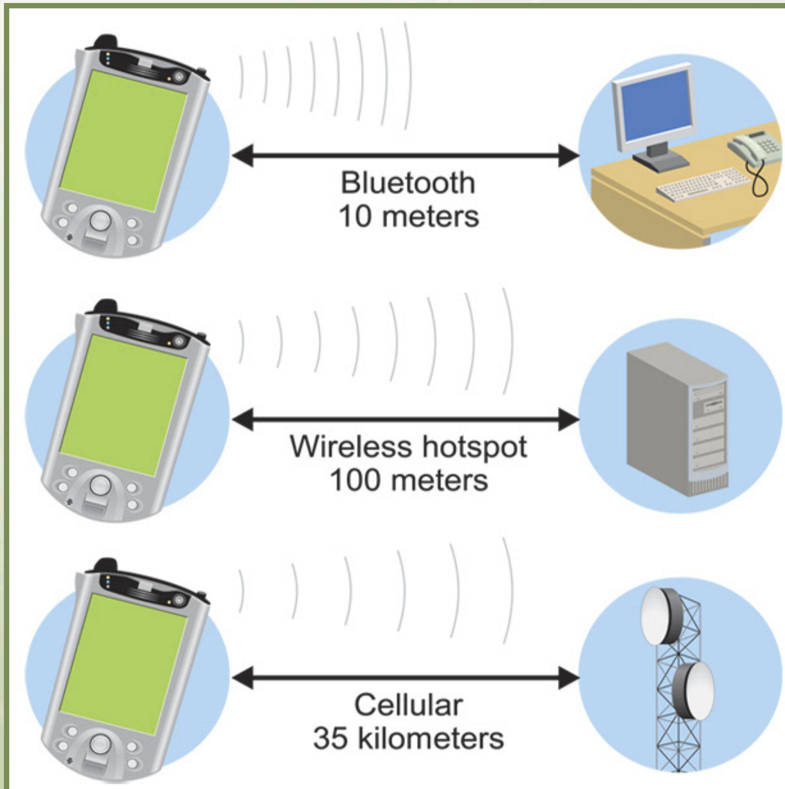
Network access

Mobile devices can be connected to networks as a way to read and write data, to access the Internet, and to access location-based services (LBS). While most mobile devices can be physically connected to a desktop device or a network in the office with cradles, docking stations, or Ethernet cards, there are many benefits to using mobile communications in the field **(see "Mobile GIS communications" in chapter 1)**.

Mobile communications can be divided into the following **(figure 2.13)**:

- Short-range (up to 10 m), for example, Bluetooth peer-to-peer wireless connections from device to Internet-connected device at up to 1 Mbits
- Medium-range (up to 100 m) WLAN connections to Internet/intranet hot spots at up to 50 Mbits
- Long-range (up to 35 km) digital connections from subscriber mobile devices to cellular networks at speeds ranging from 0.1 Mbits up to 1 Mbits

While peer-to-peer Bluetooth bandwidth and some private wireless services are open-access and free, wireless and cellular data services are usually charged by data volume and only available to subscribers. Unless you have an unlimited data plan, charges are set at levels that make large downloads (over 10 Mb) necessitate a good business case. ArcPad can connect to ArcWeb services or enterprise servers this way; data volumes and access methods may need to be planned with cost in mind.



Courtesy of Nicholas Garner

Figure 2.13 *Wireless and cellular connection types and ranges.*

XP For Tablet PCs, mobile communications can be provided by PC data cards that slot into the device and offer data-only cellular services. **XP**

PPC **WM5** PDAs are now being produced in PDA phone configurations where Bluetooth, WLAN, and cellular network access are available built-in, which allows programs like ArcPad to read from the network when connectivity is available. **PPC** **WM5**

Wireless hot spots

The number of WLAN hot spots is growing rapidly because of the low cost of the technology and the flexibility of use that it brings to network access. Since the footprint of a WLAN hot spot is usually less than 50 m, access is only widely available where the density of use is high, such as in cities. If this mode of access to the network is required outside the city, it has to be installed on a specific business case (**figure 2.14**).

Mobile GIS can take advantage of high-speed WLAN connections at commercial hot spots (up to 50 Mbits) to access servers or through community information access. In the former case, a mobile workforce using GIS can upload captured data or obtain datasets from a network server. In the latter case, an information center or community organization can provide geographic information to those with wireless access.

TIP: Many cities are now installing blanket WLAN coverage across large areas of the city to create WLAN "clouds," e.g., San Francisco, Philadelphia, Seoul, and London; you can search for WLAN hot spot locations in a variety of hot spot directories or on Google Mobile wireless service. Private but "open" WLAN connections also "leak out" of houses and can provide serendipitous Internet access too!

Bluetooth connections can be made with other Bluetooth-supporting devices such as desktop or laptop computers, PDAs or smartphones, and Global Positioning System (GPS) receivers in order to access a service they offer. ArcPad on a mobile device, using a Bluetooth connection, can browse and copy data files on nearby devices (e.g., a laptop in a vehicle), add Internet servers from the Geography Network (www.geographynetwork.com), or capture a stream of GPS position data.

Figure 2.14 *Wireless site.*

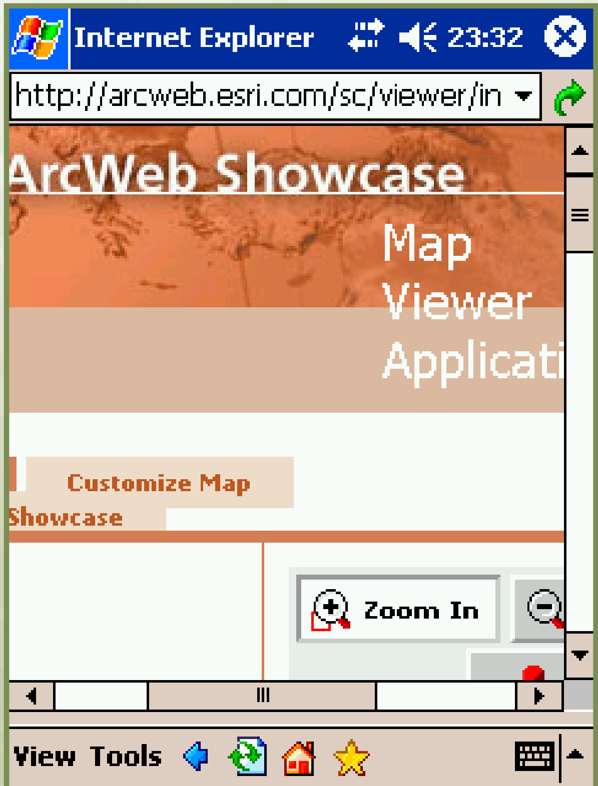
Cellular

Cellular networks, based on second generation (2G) digital mobile telephony standards like TDMA and GSM, now cover over a third of the earth's surface, and typically 90 percent of the population of most developed countries. Data can be carried by these 2G networks at up to 0.1 Mbits using GPRS or 1xRTT protocols or, at higher speeds, using EDGE protocols. The needed hardware ranges from consumer phones with Bluetooth connections to dedicated data cards that can be plugged into laptops or Tablet PCs.

New third generation (3G) digital cellular networks are now being built around the world using WCDMA or CDMA2000 standards that will have more restricted coverage initially, but higher bandwidth. Data can be carried by these 3G networks at around 1 Mbits using High-Speed Downlink Packet Access (HSDPA) and EV-DO protocols.

For applications requiring network communications anywhere on the planet, relatively inexpensive satellite-based solutions such as Iridium or GlobalStar are now widely available at similar bandwidths to 3G cellular services.

Mobile GIS is typically used with these various networks for applications like updating databases, tracking vehicles, and integrating with scheduling and organizer software. It is feasible to connect to ArcWeb services **(figure 2.15)** or the ArcIMS Route Server through a Web browser on the mobile device. These applications require low data volumes that can benefit from access to the network when and where the need arises.



G-ability Ltd. with permission

Figure 2.15 *ArcWeb Services.*

Autonomous deployment

Network access may not be cost-effective or even unavailable for some projects. For tasks such as wilderness data collection **(figure 2.16)**, the need for self-sufficiency is high, where all the data can be carried into and out of the field easily (e.g., on memory cards) or where real-time access to the enterprise database is not essential. In these cases, you will need to configure your mobile GIS to work with datasets transferred from desktop/enterprise systems and uploaded or downloaded at synchronization stops. Alternatively, you can carry out local backups onto external storage devices.

You should also install a backup solution designed for Windows Mobile systems in case the system crashes and loses configuration data. Such programs can run on a schedule and backup system registry settings and configuration files, which can then be easily restored. Note: if you restore to a previous backup file, you may roll the system back to a point before you had installed programs that you now might need to use.

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Figure 2.16 *Mobile device in waterproof bag with Bluetooth GPS.*

Linking to other devices

Mobile GIS also needs to be able to connect to other devices so that you can incorporate measurements or positioning information directly. This allows the capture and verification of a variety of site observations, all at the same time.

V7 ArcPad can integrate data from a number of digital cameras that are

- built-in to Windows Mobile devices; or
- plugged into the mobile device via an expansion slot (PDAs) or USB connection (Tablet PCs).

ArcPad has tools to

- take time-stamped pictures (with no GPS position available);
- take georeferenced pictures (when a current GPS position is available); and
- associate pictures with features such as points in shapefiles.

TIP: If you working with ArcPad away from the office for an extended period or in a hostile environment, ensure that all the applications you take for granted on Windows Desktop are installed on your mobile device, especially your PDA. For example, there is no default installed Windows Mobile program that can read and edit a DBF file with attributes, making it difficult to extract a subset of coordinates captured from a GPS and create a new shapefile.

To use the Camera tool, first select a camera driver in the Camera tab of the ArcPad Options dialog box. The default driver on a PDA is the Windows Mobile Camera; however, your device may also have a device-specific driver that has additional camera controls.

TIP: Since photography uses a lot of memory and some devices do not work reliably with the Windows Mobile Camera driver, check that the camera functions are stable by taking several shots. Restart the device and ArcPad before use to improve Camera performance.

You can access the Camera tool under the Options menu, or under the Picture tab of the Feature properties dialog box for point, line, or polygon (through the camera icon). Selecting one of these options opens a Camera dialog box and displays the camera controls from the driver you have selected. After taking the photo using the Feature properties dialog box, you will see the photo you have taken in the Picture Feature properties. You will see a notification of the file name and path created, which you can view using external photo-viewing software.

ArcPad can map the locations of georeferenced pictures in a Photo layer if latitude and longitude EXIF data is stored in the JPEG image files. ArcPad creates this data with the Camera tool if GPS data is available, otherwise the GPS data can be manually inserted with an EXIF editor such as Opanda or iView MediaPro (**figure 2.17**). When the photo layer is loaded, the latitude and longitude data is

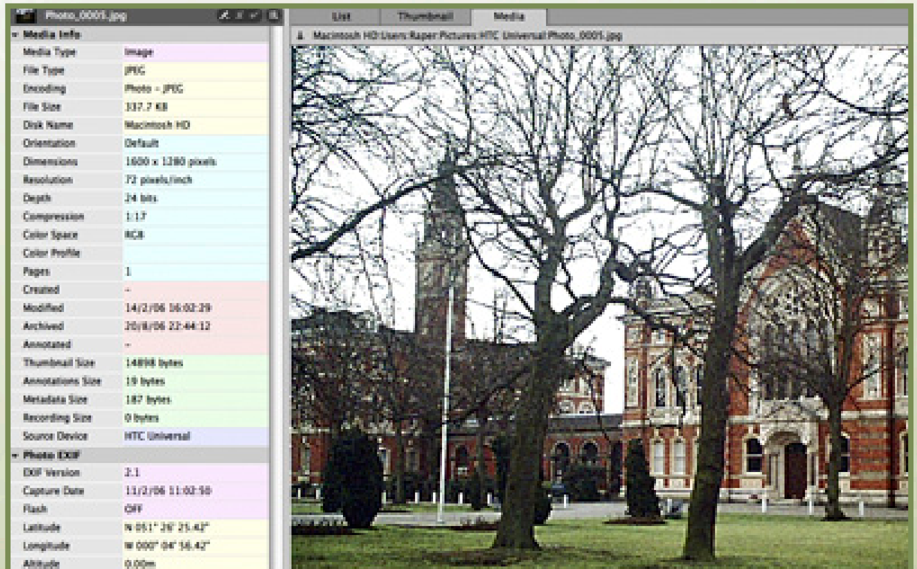


Figure 2.17 *EXIF data with coordinates in Microsoft Expression Media (panel, bottom left) from a photo taken by ArcPad with GPS input.*

projected into the coordinates defined in the ArcPad map in use. V7

ArcPad can also link to GPS for direct data capture and navigation, which is covered in detail in the next chapter.

TIP: In the Camera tab of the ArcPad options dialog box, you can set the file name prefix used by ArcPad as well as the option to include the date and time in the file name.

ArcPad can be used to capture distance, bearing, and inclination data from laser range finders. Range finders bounce a laser beam off a distant object and use the round-trip time to calculate distance. A built-in compass takes the bearing and an inclinometer takes inclination measurements. Basic handheld range finders are available for measuring and recording distance to remote objects. Advanced range finders can record distance, bearing, and inclination while mounted on a survey tripod. You need to make an error assessment for each device before accepting the data collected this way into your enterprise database.

The range finder provides outputs of the measurements as an ASCII message similar to an NMEA (National Marine Electronics Association) GPS message **(see chapter 3)** that ArcPad can display in the GPS/Rangefinder Debug window. You can set the range finder protocol, input data port, and baud speed in the range finder's preferences and activate the range finder from the GPS/Rangefinder menu on the Main toolbar.

Range finders are used principally to measure distance, direction, and inclination offsets from reference points at known locations. For example, if you measure the distance, direction, and inclination values to a target from two reference points, ArcPad can work out where the two target-pointing measurements would intersect and create a point feature there **(figure 2.18)**. The point created can be labeled with measured values or attributes entered when each point is created.

TIP: If cable connections to your mobile device don't work, you can connect a cordless Bluetooth serial adaptor (e.g., from Socket) to the range finder and receive the data input through a Bluetooth serial port.

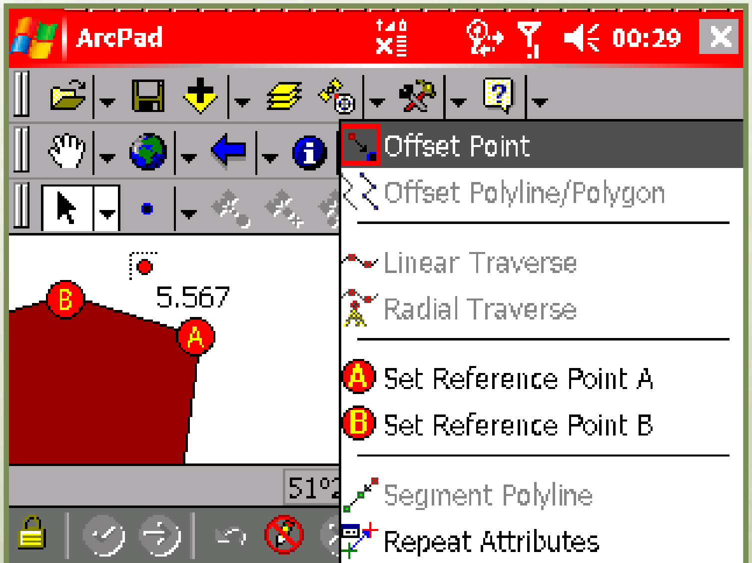


Figure 2.18 *Offset measurement with a range finder.*

EXERCISE
USING THE QUICKFORM WIZARD

When you use ArcPad as a field-mapping tool with connected devices like GPS equipment, cameras, or range finders, you need to be able to capture data quickly and efficiently. The QuickForm wizard is a simple way to set up data capture into a new shapefile. Complete this exercise to try out the wizard.

Requirements

- ArcPad 6 or 7 on Windows desktop or Windows Mobile
- GPS connection (optional)
- Connected ArcPad-recognized camera (optional)
- Georeferenced data for your locality (optional)

Exercise

1. Open ArcPad in Registered or Demo mode. If using v7, select "Open a new empty map." You should now see the basic interface with no data loaded.
2. (Optional step) Check that your camera is connected and working. Choose the Camera tab from the ArcPad Options menu on the Main toolbar and check that your camera appears in the Camera drop-down menu (see the User Guide for details of how to configure your camera). Now take a test photo using the Camera menu on the ArcPad Options menu. ArcPad shows a dialog box to confirm that the photo has been taken and is named or stored in the directory specified in the Camera tab.
3. (Optional step) Connect your GPS and activate it in ArcPad by selecting the "GPS Active" option on the GPS menu (see the User Guide for details of how to configure your GPS). Verify that the GPS data is flowing by displaying the GPS Position window on the GPS menu, and see that the GPS reports a 2D or 3D fix (you will need to be able to see some open sky to do this).

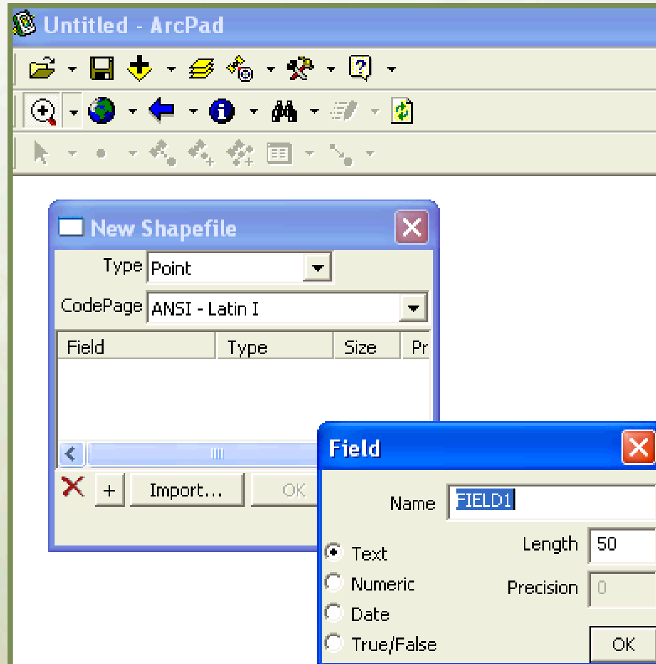
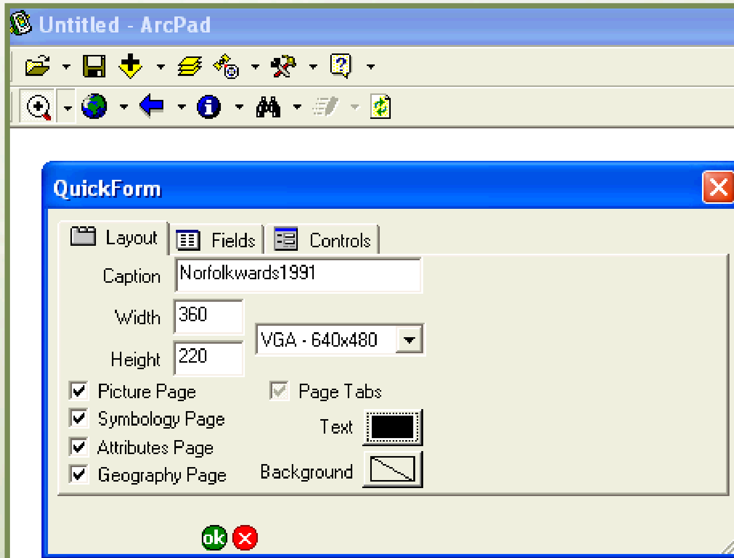
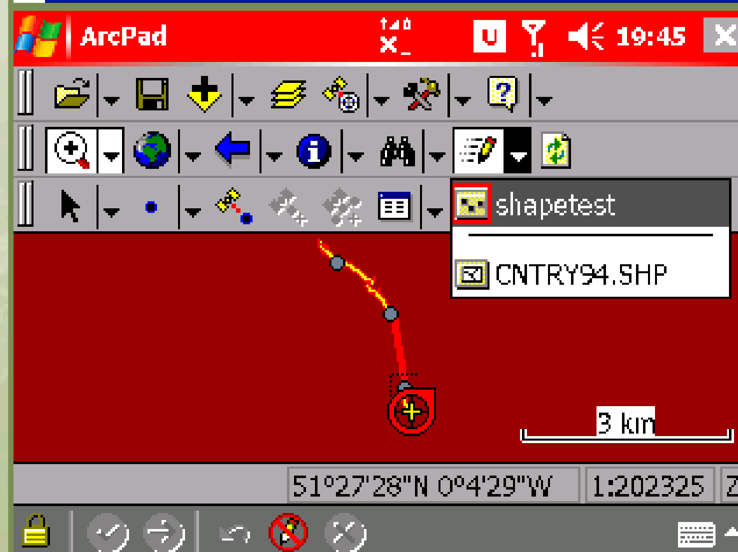


Figure 2.19a *QuickForm wizard: field definition.*

4. (Optional step) Load georeferenced data for your locality using the Add Layer option on the Main toolbar. If you load data with a projection, then the new shapefile will be created with the same projection by default.
5. Create a new shapefile by choosing New > Shapefile from the Main toolbar. Accept the default point type but add an attribute field by either copying it from a preexisting shapefile or by clicking the + button **(figure 2.19a)** and accepting the default name, size, and precision (the default field details will be entered into the field description window). Click OK and, in the file dialog box, choose a name and location for the new shapefile.

6. After clicking Save for the new shapefile, a Create QuickForm dialog box pops up. Click Yes to enter the QuickForm wizard.
7. You can now customize how you collect, in this case, point data into the new shapefile. Start by entering a caption for the QuickForm that will pop up (**figure 2.19b**), and then choose a form size—preferably smaller than the screen size of the device. If you uncheck all the page options at the bottom left and then uncheck the Page tabs check box, the QuickForm will only prompt you for attributes of the fields that you created in the shapefile. If you request pages and page tabs, you will be offered the option to enter all this data when you use the QuickForm. Set the field and control options (or leave them blank) before clicking OK. The QuickForm dialog box will close and you will see a confirmation that the QuickForm has been set up. This ArcPad map and the newly created shapefile can be transferred to any ArcPad platform.
8. You can activate the newly created shapefile by selecting it from the Edit drop-down menu on the Browse toolbar (**figure 2.19c**); it will be the only layer shown if you loaded no data in step 4. You can now capture point data. If you have a GPS data input and a camera connected then you can integrate these streams of data.
9. You can now select the Point tool from the Feature type menu on the Browse toolbar, then click the map where you want to create a new point in your newly created shapefile. The QuickForm pops up. Enter attribute data as appropriate, and then move between the tabs entering information or changing settings as you wish.





Top: **Figure 2.19b** *QuickForm wizard: form setup.*
Bottom: **Figure 2.19c** *QuickForm wizard: Edit drop-down menu.*

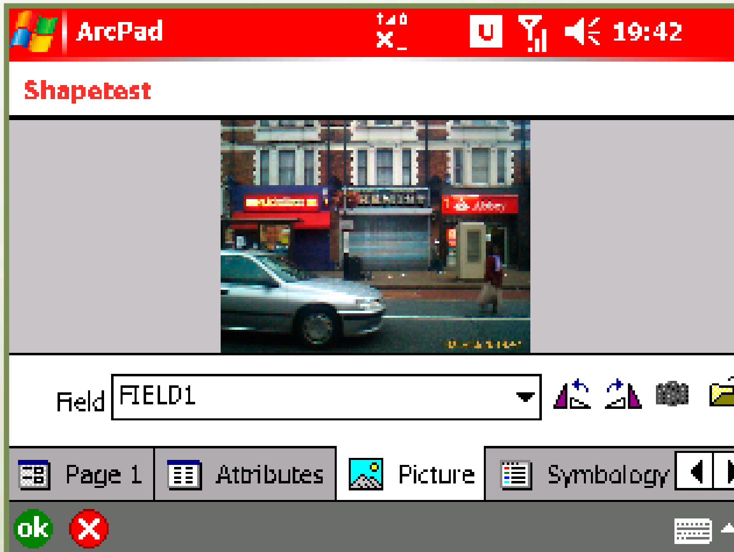
10. Note that if you have a GPS data input, you can use the Capture point using the GPS option on the Edit toolbar to create your point at the current GPS position. The QuickForm pops up. Enter attribute data as appropriate, moving between the tabs to enter information or change settings as you wish.

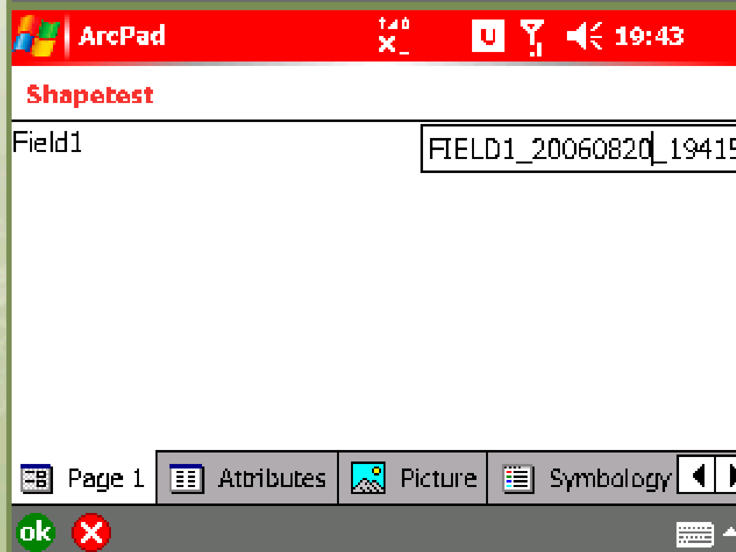
11. If you have a camera connected, you can take a picture by clicking the camera icon in the Picture tab in the QuickForm **(figure 2.19d)**. The picture will be linked to your newly created shapefile and the file name will be entered in the default Field 1. You can see this in the Feature properties option on the Edit toolbar **(figure 2.19e)**.

You have now created a shapefile and a QuickForm to enter data when creating points. If you have a connected GPS and camera, you can add these kinds of data to the created points.

All together, right now

Putting together your mobile GIS is one of the most complex aspects of using systems like ArcPad. The challenges of choosing a mobile device, providing it with power, network access, and storage, and then linking it to other devices or a GPS are significant. However, once configured, systems like ArcPad offer considerable functionality to take to the field, with all the advantages that this brings to GIS projects.





Top: **Figure 2.19d** *QuickForm wizard: Picture tab in the Feature properties dialog box. Bottom:* **Figure 2.19e** *QuickForm wizard: field attributes tab in the Feature properties dialog box.*

CHAPTER 03 Positioning your project

Jonathan Raper, G-ability

Positioning

Whether you are inspecting assets, reporting an incident, mapping in the field, or making decisions on-site, positioning is crucial to your mobile GIS project. Now that it is possible to get a quick, accurate, and inexpensive positional fix on a mobile device using global navigation satellite systems (GNSS), radio navigation (e.g., LORAN), or mobile phone signals, you can accomplish much in the field (**figure 3.1**).

Achieving the full potential of positioning technology requires that you

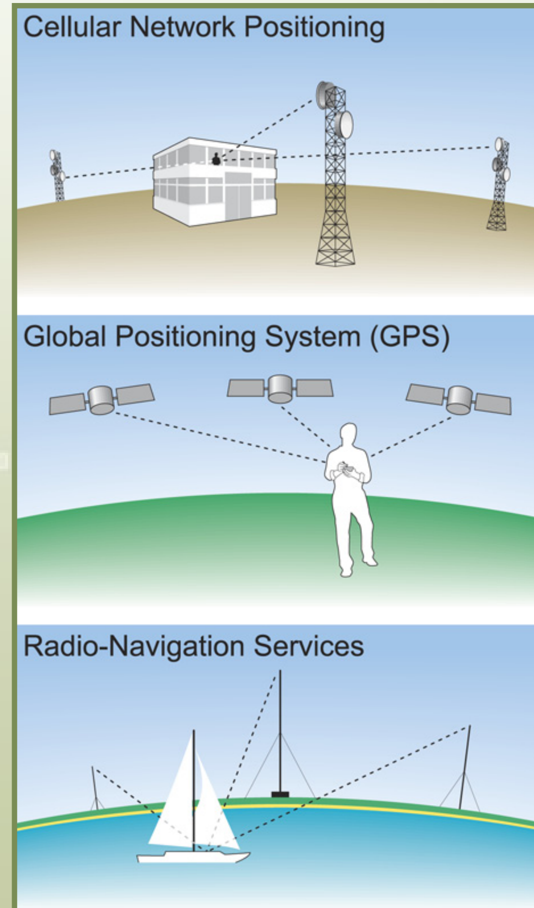
- understand how to acquire data;
- make decisions about display and storage;
- assess the accuracy you are achieving; and
- make choices about integrating positioning with other geographic information.

Of the positioning technologies on the market, GNSS dominate performance and availability, especially the U.S. Global Positioning System (GPS). The current Russian GLONASS and the European Galileo systems are being, respectively, redeveloped or deployed at present and are not yet available for GIS use.

GPS receivers are available as

- stand-alone devices;
- plug-in modules for mobile devices such as PDAs;
- professional surveying systems; and
- mobile phones (with network corrections, called assisted GPS or A-GPS).

Because GPS is free to end-users (the only cost is the device itself) and is universally supported, it is the current positioning tool of choice for mobile GIS. ArcPad allows you to record your path as you move, create new features, navigate, and tag photos with GPS.



Courtesy of Nicholas Garner

Figure 3.1 *Positioning technologies.*

In this chapter, you will discover how GPS works, the different types of GPS receiver, how to acquire and store GPS data, how to integrate GPS data with maps, and GPS navigation techniques. ArcPad is designed to take full advantage of GPS and can interface with a wide variety of GPS receivers.

The Global Positioning System

The Global Positioning System consists of

- satellites in space;
- a number of ground control stations; and
- receivers.

Since control stations do their monitoring and maintenance work behind the scenes, as an ArcPad user, you only need to consider satellite signals and the GPS receiver.

GPS satellite signals are continuously broadcast from the thirty or so satellites orbiting the globe, and they can be picked up by a GPS receiver that has a clear view of the sky anywhere on earth. GPS signals are not affected by darkness, clouds, or weather conditions, but they can be blocked by solid things such as hills, buildings, dense tree canopy, vehicles, and bodies.

Your GPS receiver needs to receive signals from at least three satellites at the same time to compute a basic position. Since between four and twelve satellites are always above the true horizon (at sea level) everywhere on earth at all times, in theory you should always be able to access the three satellites needed to get a GPS position. However, this assumes that

- the signal is not blocked at the receiver, for example, by nearby buildings; and
- you can see to the true horizon in all directions (no hills in the way).

If part of the sky is blocked, the visibility of the four to twelve satellites above the horizon can be reduced significantly. For example, if hills or buildings obscure as much as 75 percent of the sky from where you are standing, then, from the remaining 25 percent of the sky that you can see

- worst case: one out of four satellites and get no position (25 percent of the minimum four satellites);
- best case: three out of the maximum twelve satellites and get a basic position (25 percent of maximum twelve satellites).

TIP: If you place a GPS receiver under the car windshield, attach it to a rucksack strap, or fix it to a tripod, the receiver is almost always able to see more than three satellites, since there is usually much more than the 25 percent open sky than in the example above. In "urban canyons," or if the receiver is covered, the GPS positions are interrupted. The progressive introduction of thirty more satellites from the EU Galileo system and redevelopment of the GLONASS system will allow the next generation of dual-or tri-band receivers to guarantee positioning in almost all circumstances.

So, when you are using GPS, you must always consider whether you can see enough sky to get a position. In some cases you may want to consider planning your GPS capture for a time when the highest number of satellites can be seen. Such planning software is built into professional receivers like the Trimble GeoExplorer series GPS receivers. All GPS receivers that include ArcPad, display a diagram of the GPS satellite positions in the sky (called a skyplot) that can help with this problem **(figure 3.2)**.

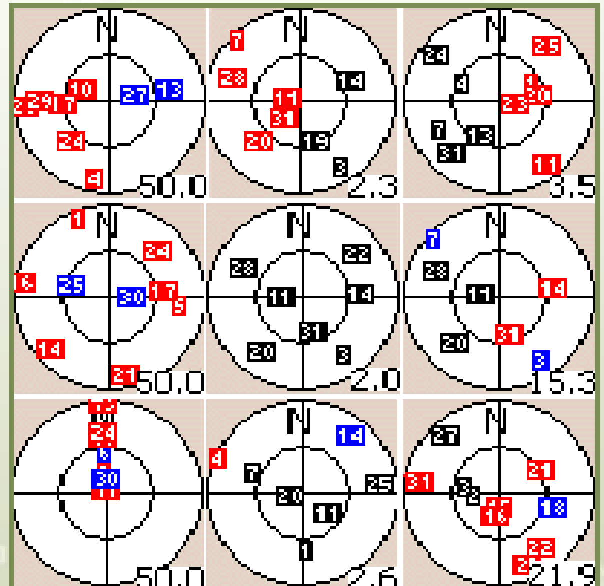


Figure 3.2 *Satellite configurations mosaic using skyplots.*

G-ability Ltd. with permission

To ensure you get a GPS position you can

- turn the device or its antenna in the direction of the visible satellites;
- move to a place that has a view in the right direction; or
- sit on the appropriate side of a vehicle by a window.

You need to continue thinking about this because the satellites move steadily across the sky, changing the ones you can see within hours. In fact, the entire GPS satellite constellation track repeats every twenty-four hours (minus four minutes).

GPS positioning

Once your receiver is receiving signals from the GPS satellites, it can use the following signal properties to compute your position:

- Carrier wave frequency
- Ranging codes
- Navigation messages

Each of these properties, and their importance to the position acquisition process, will be discussed next.

Via *carrier waves*, ranging codes and navigation messages get sent from the satellite to your receiver. The L1 and L2 frequencies used by GPS propagate over vast distances (the GPS satellites are 20,200 km up in space) but are strongly directional and can easily be blocked and reflected as already described.

Ranging codes are used to measure the distance from each satellite to your receiver. Satellites transmit two ranging codes:

- Coarse acquisition (C/A) code on carrier wave L1 (public)
- Precise (P) code on carrier wave L1 and L2 (encrypted for military use)

Ranging codes are repeating code sequences precisely generated from the output of an atomic clock on the satellite. The GPS receiver generates identical repeating code sequences starting at the same time, and when the signal arrives, it compares the received and generated codes. The difference between the codes is equivalent to the time taken for the signal to travel from satellite to receiver, and can be converted to a distance (called a pseudo-range). Civilian GPS receivers can only use the C/A code to calculate pseudo-ranges, which limits their intrinsic accuracy (see below).

TIP: Trimble's **All About GPS** Web site at **www.trimble.com/gps** has an excellent explanation of how GPS works, with animations to explain these concepts.

The *navigation message* contains details about satellite orbit paths around the earth, called the almanac **(figure 3.3)**, ionospheric conditions in the atmosphere affecting the signal speed, and precise time updates. The navigation message gets sent to the receiver using the carrier waves. When a GPS receiver is switched on, it uses the navigation message to check its internal clock, update the almanac, and recalibrate its ionospheric information. Then the receiver begins

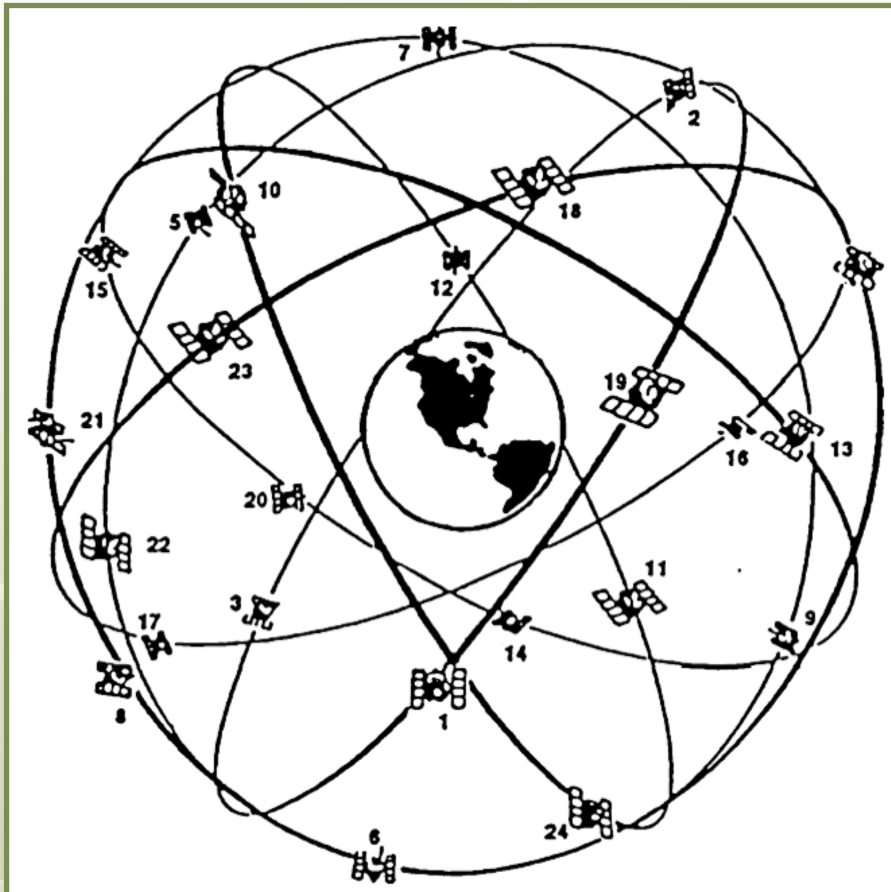


Figure 3.3 *GPS satellite constellation (from the Navstar GPS User Equipment introduction, **www.navcen.uscg.gov/pubs/gps/gpsuser/gpsuser.pdf**).*

generating its own version of the ranging codes to compare to the signal received from the satellites.

From the almanac, the receiver knows the position of each satellite in its orbit relative to the center of a model of the earth's shape (an ellipsoid) with considerable accuracy for any instant in time. When at least three satellite pseudo-ranges are available at the same instant, the receiver is able to calculate its instantaneous position relative to the ellipsoid. The position will be at one of two intersections of three spheres, one generated around each of the three satellites, of radius equal to the pseudo-ranges. One of the two points can usually be rejected as not on the earth, leaving a position on the surface of the ellipsoid we can accept (a so-called 2D fix). If a fourth pseudo-range is available, any clock errors for the original three pseudo-ranges in the receiver can be eliminated, thereby improving accuracy and the height relative to the ellipsoid (a so-called 3D fix).

GPS height

The position obtained by a GPS with at least four pseudo-ranges is expressed as a height above the ellipsoid (sometimes called a spheroid). GPS uses the World Geodetic System 1984 (WGS84) ellipsoid, which is a smooth, almost spherical, best-fit model of the earth's shape **(figure 3.4)**. Unfortunately, the earth's true shape is slightly irregular, and the ellipsoid only approximates it. This means that if you are standing on the seashore, the height shown on your receiver may not be zero. In North America, the Indian subcontinent, and China, the GPS height will be negative because the ellipsoid passes overhead, suggesting you are under water! In Europe and southeast Asia, your GPS height on the seashore will still be substantially above zero, since the ellipsoid lies underground.

The earth's true but irregular shape is usually described by the position of global mean sea level (MSL), that is, the water level in the oceans or where the sea would be if you cut a canal through the

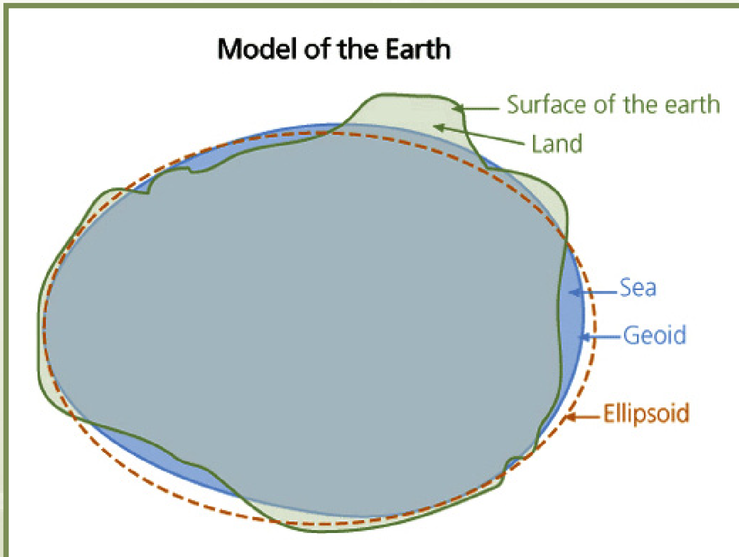


Figure 3.4 *Ellipsoid versus geoid for an exaggerated earth shape www.esri.com/news/arcuser/0703/graphics/geoid1_lg.gif.*

TIP: If the GPS receiver has been switched off for days or weeks before you switch it on (called a cold start), it can take several minutes to acquire a new almanac before any positions can be computed. If you have to quickly change batteries in a GPS receiver, it should be back computing positions a few seconds after switching it on (a so-called hot start). When a GPS receiver has been working that day but not for a few hours, it will take 20 to 30 seconds to start computing positions again (this is a so-called warm start). Keep these start times in mind if you need to get a quick position—and prepare accordingly.

continents. This is because the water level (averaged to remove the effect of tides) is an equipotential (equal gravity) surface hugging the earth's true shape. This global MSL surface is modeled by the geoid. The difference between heights referenced to the ellipsoid (ellipsoidal height) and height referenced to the geoid (orthometric height) is known as the geoidal separation and can be used as a correction factor to convert GPS height into orthometric height. A rough regional geoidal separation can be calculated in real time in the latest GPS receivers, or corrections can be applied by post-processing.

Some GPS receivers have built-in barometers that measure height above MSL by the reduction in atmospheric pressure as you climb above sea level.

TIP: An excellent article on ellipsoids and geoids in **ArcUser Online** (July-September 2003) further explains this subject **(www.esri.com/news/arcuser/index.html)**.

This method can be affected by rapidly changing weather and requires periodic recalibration.

So, it is important to know whether the height output by your GPS receiver is

- ellipsoidal height,
- orthometric height, or
- barometric height.

Orthometric height is preferable, since it is usually very close to the heights shown on maps and is referenced to local sea level.

GPS accuracy

Under perfect operating conditions, a consumer-grade GPS receiver can produce pseudo-range positions with a horizontal accuracy less than five meters most of the time. However, perfect conditions are rare. GPS signals may be reflected (multipath errors), the visible satellites may be aligned poorly (dilution of precision), and receivers may have clock errors, meaning that GPS positions can be 50 meters off under some circumstances. Mitigating each of these problems is discussed next, followed by an alternative GPS positioning method to pseudo-ranging.

TIP: Accuracy is the quality of an observation relative to the true value, while precision is the detail with which an observation is reported. It is possible, therefore, to have a precise GPS position (e.g., to 1 millimeter) that is inaccurate due to one of the problems mentioned here.

Multipath errors

Buildings, water surfaces, and metallic objects can reflect the GPS signal and cause it to travel further than the straight-line distance from satellite to receiver. This multipath error can be mitigated by the following:

- Using a high-quality receiver with multipath filtering
- Using an antenna with an antimultipath design
- Excluding satellites close to the horizon from the position calculations
- Averaging positions over a period of time (not possible when the receiver is moving)

After a multipath error, if an uncorrected GPS is stationary for a few seconds, recorded points will apparently jump around over a radius of 10 to 20 meters **(figure 3.5)**.

Dilution of precision

Although between four and twelve satellites are always above the true horizon (excluding hills) anywhere on earth at any time, they are not always distributed evenly across the sky. The wider the angle between the satellites, the better the accuracy. Satellites clustered in one part of the sky, or lined up in a row, dilute precision, resulting in reduced accuracy. Based on satellite positions, GPS receivers calculate values for horizontal and vertical dilution of position (DOP) and their combination positional DOP (PDOP). A low PDOP value, say less than four, indicates higher accuracy positioning than a high value, say greater than ten. ArcPad can display the selected value of DOP alongside the GPS skyplot and can be set to ignore positions calculated with user-defined “high” DOP values (see **figure 3.2**).

Much better accuracy, say 1 to 2 meters, can be achieved for pseudo-range receivers by using so-called differential GPS correction. This requires two GPS receivers within a few hundred kilometers of each other that are collecting data at the same time. One receiver is stationed at a fixed location known to a high accuracy. By definition, any errors in position calculation at the known location are due to clock, atmospheric, or multipath errors. The distance and direction of the errors can be used to correct the other receiver that roves. The correction can either be broadcast, such as over the radio, and used to correct a roving GPS receiver in real time, or it can be stored and used to correct the roving positions by post-processing the data at a later time. ArcPad reports when the GPS has a differential GPS fix in the Position window.

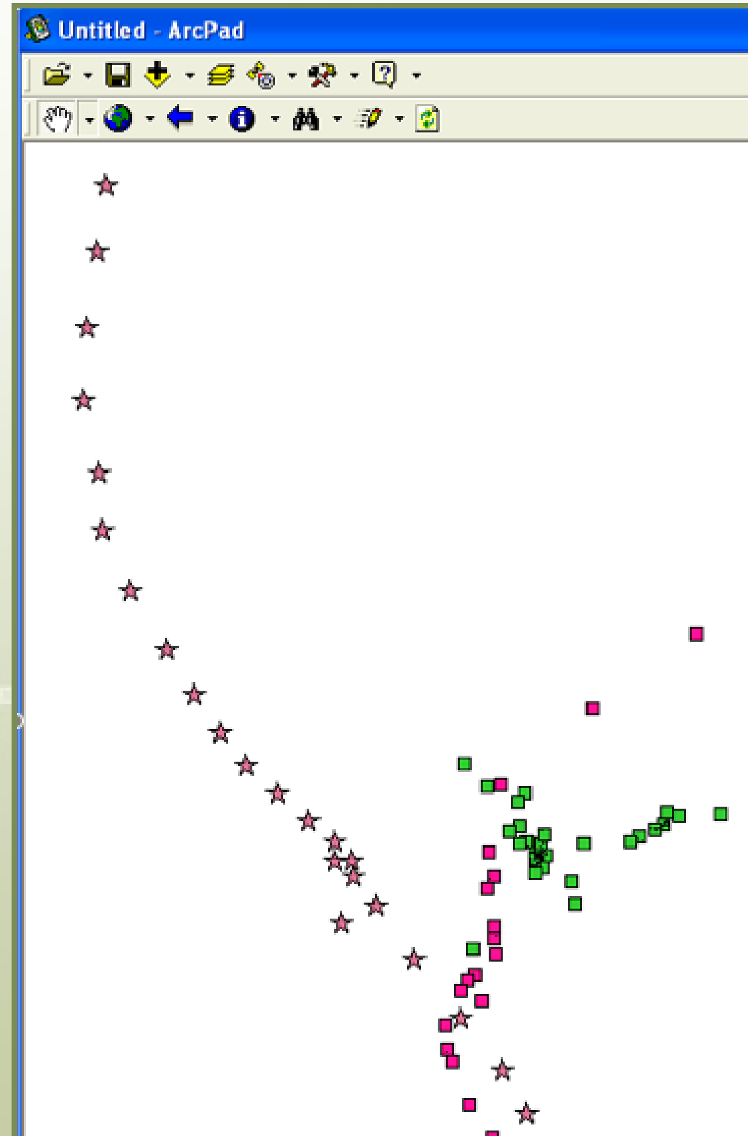


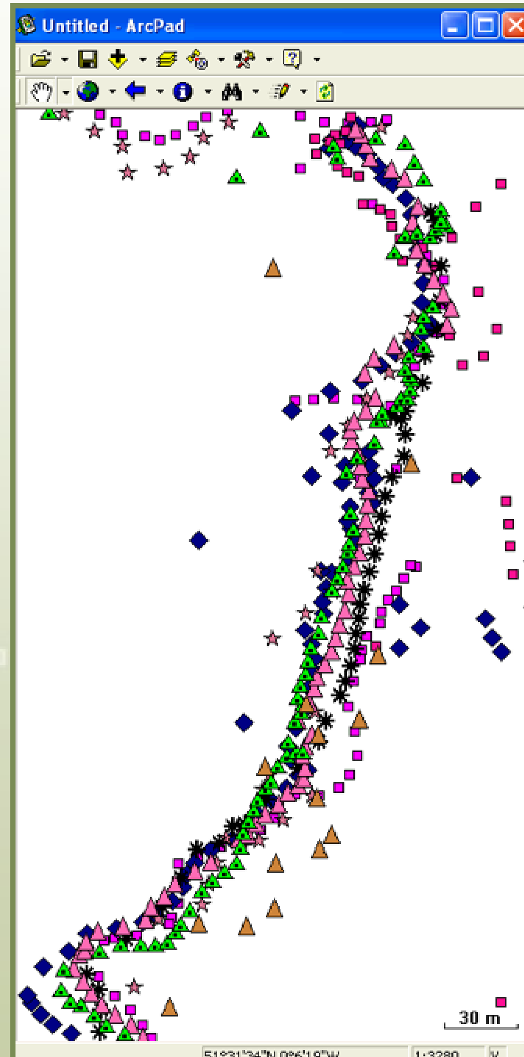
Figure 3.5 *Clusters of points in a GPS track where a stationary receiver experienced variable multipath errors.*

While pseudo-range receivers are normally used for positioning in mobile GIS, GPS can also be used to carry out high-accuracy surveying using carrier phase receivers that measure the distance from receiver to satellite by counting the number of whole wavelengths of the L1 (19 cm) and L2 (24 cm) frequencies between satellite and receiver. ArcPad cannot configure carrier phase receivers, but can read their GPS output.

Some mobile devices with built-in Internet access and GPS receivers can acquire positions even when normal pseudo-range receivers cannot see enough of the sky. Such assisted GPS (A-GPS) receivers replace the missing information from an assistance server on the Internet by periodically downloading the required data. The positions obtained are good enough for many mobile GIS tasks.

TIP: To assess the likely impact of DOP on positioning, study the skyplot in the ArcPad Position window (see **figure 3.2**). In the skyplot you are at the center; the outer circle is the horizon, as if there were no hills around you. The inner circle is 45 degrees above the horizon, and the axes at right angles are a simple compass rose with north at the top. Satellites being used in the current position fix are white numbers in black blocks, those being acquired are in blue, and those unavailable are in red. When you are trying to evaluate the quality of a position fix, imagine a triangle enclosing all the black satellites shown in the skyplot. If the imagined triangle is thin or small then the position is likely to be poorer quality; if it is fatter or larger and covers the majority of the sky, then it is likely to be better.

Until May 1, 2000, nonmilitary GPS receivers could only access the C/A code under selective availability (SA) arrangements and were therefore limited in accuracy to around 100 meters (the C/A code contained semirandom deliberately introduced error). Note that SA may have affected some historical GPS positions. Removal of the C/A code error has now allowed instantaneous stand-alone positioning accuracy for civilian receivers to reach 5 to 10 meters at one-second-update frequency under typical circumstances. See **figure 3.6** for an illustration of the typical achievable accuracy for an uncorrected consumer-grade receiver.



G-ability Ltd. with permission

Figure 3.6 *Many uncorrected GPS tracks collected along the same meter-wide sidewalk (note the scale), which shows the need for differential correction to get an accurate route.*

GPS receivers

GPS positions are only as accurate as the equipment used to collect them (notably the GPS chip and antenna) and the method used to process them. A huge variety of GPS receivers are now available **(figure 3.7)**, including the following:

- High-accuracy survey instruments
- Professional and military receivers
- Navigation devices for car, aircraft, or boat
- Lightweight waterproof sport/hiking/diving units
- Chips in mobile phones or other devices

Each of these devices is designed to collect data at accuracy levels matching their typical applications. Mobile GIS tends to employ professional or military-type receivers, since the survey instruments are complex and not really portable, and the other devices do not have the required accuracy or are closed architecture systems with no output beyond the bundled software.

ArcPad can be used with data from professional and military GPS receivers, which can be divided into four types:

- Handheld GPS receivers with built-in screens that collect GPS data onto a memory card or into internal memory. These devices are usually designed for stand-alone use, though many support differential GPS positioning. They have cable connectors for output or the memory card can be removed and the data copied using a card reader. The software is built-in and this device can only be used as a data collector with ArcPad software. These devices can be ruggedized, as in the case of the military receivers. ***Classic of its kind:*** *Garmin eTrex GPS navigator.*

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Figure 3.7 *Some examples of consumer-grade GPS devices.*

- PDAs with integrated GPS that collects GPS data onto a memory card or into internal memory. These devices are usually professional systems that offer support for differential GPS (real time or by post-processing). PDAs offer wireless, Bluetooth, or USB cable communications to transfer data to desktop systems and support external antenna. ArcPad can run on Windows Mobile PDAs with appropriate specifications, and can be used as the

70 m

tool for data collection and GPS post-processing. These devices can also be ruggedized. ***Classic of its kind:*** *Trimble GeoXT handheld.*

- Stand alone GPS built into type II CompactFlash (CF) and SD cards, which fit directly into the CF/SD expansion slot on mobile devices and some cameras, taking power from the device. These GPS cards have no data storage capability or screen and generally rely on a built-in antenna. ***Classic of its kind:*** *Pharos CompactFlash GPS receiver.*

- Bluetooth GPS devices that communicate wirelessly with Bluetooth-equipped mobile devices, allowing the GPS to be placed in the best position to get a view of the sky, such as on top of a backpack. Bluetooth GPS depends on internal batteries, has no data storage capability or screen, and generally relies on a built-in antenna. ***Classic of its kind:*** *Emtac Bluetooth GPS receiver.*

TIP: Accuracy is strongly related to the size of the antenna on the GPS receiver: larger, more sensitive antennas produce more accurate results. However, antenna size also has an impact on the cost of the device. More expensive devices have more expensive components (e.g., larger antenna, gold connectors, better shielding) and are more accurate. This is the reason that GPS receivers vary in cost from $100 to $3,000. When you consider that a $100 GPS is sold through a retail channel, and that the average mark-up in retail is 100 percent, then retail stores are purchasing this $100 GPS for $50. The manufacturer is making a profit, so the actual components of the $100 GPS probably cost less than $25. You can't get a lot of high-quality components for $25!

Choosing a GPS

The sheer diversity of GPS receivers makes it a challenge to choose one for your project. Although all receivers are designed to read a standard GPS signal (published for civilian use in 1994), manufacturers are free to design their own hardware solutions, making them hard to compare. Add in the fact that there is no certification of civilian GPS receiver operation (except for aviation use), and the challenge of GPS receiver selection becomes even greater. So, when choosing a GPS receiver, you need to narrow down the suitable receivers based on hardware criteria, and then look for testimonials and feedback on receiver operation to ensure you get the performance you want.

Several hardware criteria are important when choosing a GPS receiver, and the most important is *accuracy*. You can assess the accuracy of a GPS receiver either on the basis of specification or by its in-use performance. In specification terms, the more channels, the better, as each channel can be used to track one satellite. Most receivers now have at least twelve channels (the maximum number of satellites above the horizon at any one time). Some have more than twelve channels to allow some capacity to track satellites just on the horizon.

Which GPS chip is used is also important; the number of available correlators is an indicator of the receiver's ability to handle weak signals in buildings, cars, forests, and so on. In-use GPS accuracy is notoriously difficult to measure objectively because of the variation introduced by DOP, multipath error, and interference, which varies greatly according to usage. However, you can consult many sources of simultaneous tests on multiple devices on the Web, for example on the GPS community site **www.gpspassion.com**.

The time to first fix (TTFF) for a cold, warm, or hot start is also important, although most receivers offer similar performance on these measures.

Another hardware criterion for GPS receiver selection is support for *GPS correction technologies*. Most GPS receivers now have built-in support for regional Satellite Based Augmentation Systems (SBAS) broadcast alongside GPS signals. SBAS services provide real-time corrections to the GPS signal, and are especially good at reducing ionospheric errors, which can be significant. SBAS services include the following:

- The Wide Area Augmentation Service (WAAS) in North America
- The European Geostationary Navigation Overlay Service (EGNOS)
- The Japanese Multi-Functional Satellite Augmentation System (MSAS)

By contrast, differential GPS (DGPS) corrections are available from commercial providers via radio signals or over the Internet. Marine agencies such as the U.S. Coast Guard broadcast DGPS corrections free of charge to support marine navigation. DGPS hardware works by sending a correction message to any GPS supporting the RTCM SC-104 protocol (**figure 3.8**), which then allows the GPS receiver to output corrected data. This correction message can be sent internally for hybrid DGPS or GPS receivers, via a cable or over a Bluetooth connection.

TIP: Comprehensive advice on GPS selection, testing, feedback, and testimonials can be found at **www.gpspassion.com**.

DGPS hardware should comply with the International Electrotechnical Commission (IEC) Standard 1108-4. ArcPad can exploit the improved positions derived from SBAS or DGPS.

Also consider power consumption and battery life when selecting a receiver. Most receivers are battery operated but have a range of different power options:

- Internal lithium-ion battery: needs recharging, since it cannot be removed
- Replaceable lithium-ion battery: needs recharging or can be replaced with a spare
- Replaceable AA batteries: needs replacing with spares

Receivers can also be used while recharging from any suitable source, for example, a cigarette lighter socket in a car.

Finally, GPS receivers come in a wide range of forms (see the four types mentioned above) and some are ruggedized. Checking that the receiver can be upgraded when new firmware is available is also of growing importance, otherwise the receiver has built-in obsolescence as technologies change rapidly.

Message header	Station health
Type 3 message	Identity and position of active reference station
Type 5 message	Satellite health indication
Type 7 message	Coverage areas of adjacent reference stations
Type 9-1 message	Pseudo-range corrections at 100/200 bps
Type 9-3 message	Pseudo-range corrections at 50 bps
Type 16 message	DGPS outages known to be occurring

Figure 3.8 *Differential GPS using the RTCM SC-104 (2.1) format.*

Connecting a GPS

Once the mobile device has a connection to the GPS, it can be configured to capture the positional data. The capture process involves the use of serial communications either internal to the device (e.g., PDAs with integrated GPS) or via an external serial port (e.g., Bluetooth receiver). This process is simple for the integrated receivers but can be quite complex when you have to configure an external serial port. Mobile devices have "real" serial ports (hardware connections, often labeled 0 to 8, as in **figure 3.9**) and "virtual" serial ports (extra serial addresses based on real hardware connections, often labeled 9 to 32). GPS receivers usually need real hardware connections, although virtual ports can be used in GPS simulation where a file of GPS data is streamed out of one virtual port and into another.

The easy way to connect a GPS to ArcPad on any device is to switch on the GPS and let ArcPad search for incoming data. For a Bluetooth GPS, this means ensuring that the mobile device has already paired with the GPS receiver, a process handled by the Bluetooth Manager or Bluetooth Control Panel.

V6 To search for incoming GPS data, install the FindGPS extension from ArcScripts. The FindGPS option under the Tools menu allows you to automatically detect incoming data and set the appropriate port. **V6**

V7 To see the available serial ports on your device, open GPS preferences and select the Port drop-down menu. The available real and virtual serial ports will be listed, in some cases with a label such as "COM 1: serial cable." Either select the port your GPS receiver is known to use and set the other preferences, or click the binoculars icon to have ArcPad auto-detect a port for receiving data. **V7**

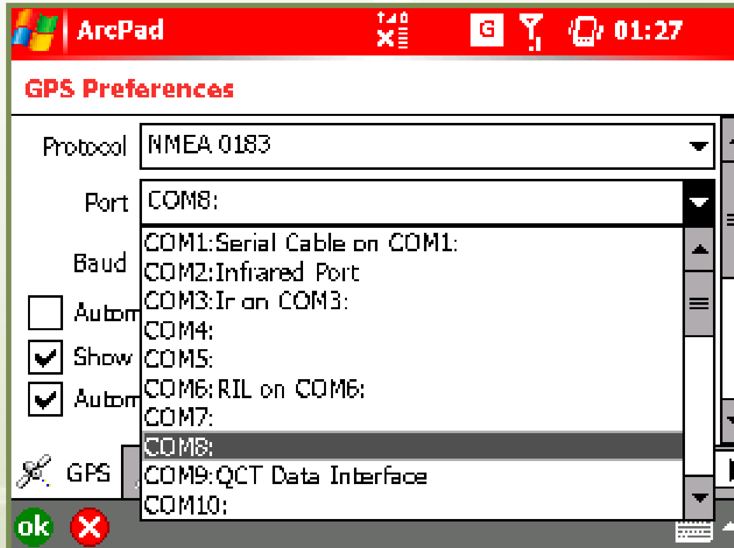

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Figure 3.9 *Typical serial ports and their assignments in the ArcPad GPS Preferences window.*

If the auto-detect methods fail to identify ports with incoming data, you should disconnect the device from any USB connection or cradle, switch the GPS receiver off and on again, and reboot the mobile device. Then reseat the cable, or pair the Bluetooth GPS with the mobile device, and try again.

HP To troubleshoot serial port communications on mobile devices running version of Windows Desktop, locate the "Device Manager" and check the ports listed. You can also use the HyperTerminal application to view data being streamed into any of the ports present on the machine. XP

WM5 On Windows Mobile 5, in the Settings menu, use the Bluetooth Control Panel to set up the ports. If you install the .NET Compact Framework as part of the installation for any GPS-supporting program, a GPS control panel is installed, which allows you to set ports that the GPS can use in any application. WM5

TIP: Use the FakeGPS ArcPad extension to stream a file of GPS data into ArcPad. This may be needed where you have another application (e.g., navigation system) connected to your mobile device that records GPS into a file. FakeGPS can read the GPS file as it is written to by the other application, and then stream the data into ArcPad.

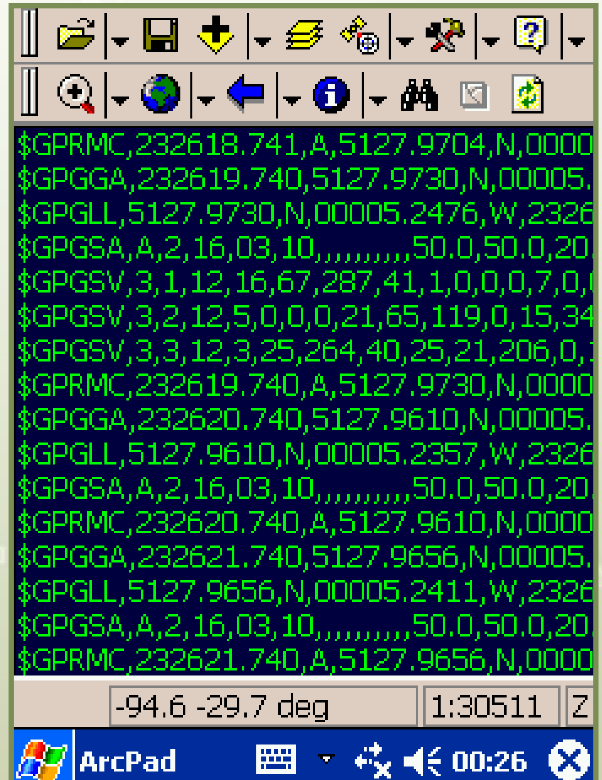

Figure 3.10 *GPS sentences streaming into ArcPad.*

GPS data

Decoding the received GPS data involves setting the correct GPS protocol. ArcPad supports the following protocols for communicating with GPS receivers:

- National Maritime Electronics Association (NMEA) 0183, version 2.0
- Trimble Standard Interface Protocol (TSIP),
- DeLorme Earthmate
- Rockwell Collins Precision Lightweight GPS Receiver (PLGR)

The proprietary protocols are binary formats, whereas NMEA is an ASCII format and much more widely used.

NMEA data is updated once per second with an encoding of 4,800 bps, 8 bits, 1 stop bit, and no parity. GPS data sent from a GPS receiver to ArcPad as NMEA 0183, version 2.0, is divided into a series of "sentences" **(figure 3.10)**:

$GPGGA- position and altitude

$GPGLL- latitude and longitude

$GPGSA- dilution of precision (DOP) and active satellites used

$GPGSV- satellites in view

$GPRMC- basic 2D positional/movement data in one sentence

$GPRRE- residual error

$GPVTG- course over ground

$GPZDA- time and date

Additional hardware-specific sentences are listed, depending on the receiver, some of which can be used to control the GPS output. In ArcPad, use the incoming NMEA data to display the current position via a GPS cursor and to populate the GPS Position window with satellite data.

V7 You can customize the GPS cursor bitmap by editing the settings in the ArcPad Configuration file (ArcPad.apx). **V7**

GPS tracklog

In ArcPad, a red line known as the GPS tracklog represents the stream of positions in the NMEA data (**figure 3.11**). From the GPS menu, you can switch this option on and off as required. Sometimes gaps in data collection occur; missing sections are joined by straight lines. When switched on, the GPS tracklog is stored by default as a shapefile in \My Documents\Tracklog.shp. From the table of contents, you can access the Tracklog Layer Properties dialog box to configure the storage location.

The GPS tracklog is a special layer in ArcPad, always lying on top of other layers, and displayed as a red line even though the produced tracklog file is a point shapefile. Though the NMEA data is received and displayed once per second, you can store positions at a defined interval in seconds (in the table of contents, set it in the Layer Properties for GPS tracklog). This is necessary in long data collection sessions because the GPS tracklog becomes so large that it can take several seconds to redraw.

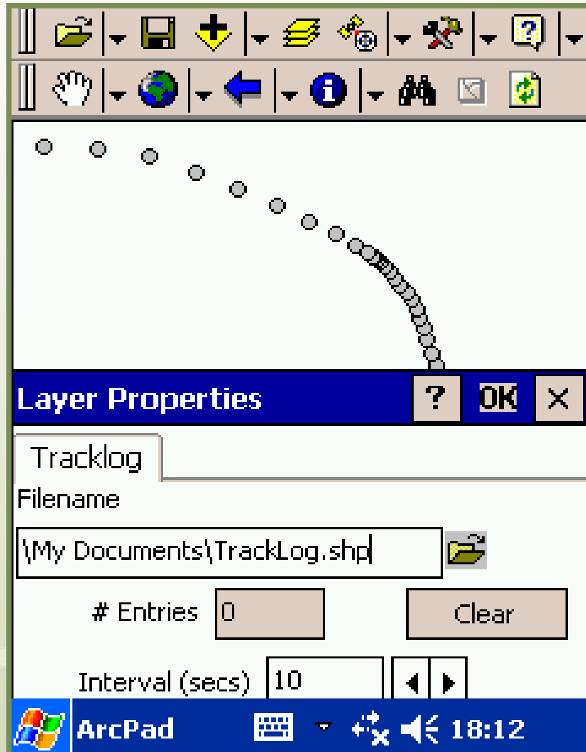

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Figure 3.11 *Tracklog showing a change in the capture interval time from 10 to 5 seconds at the same underlying speed.*

TIP: A five- to ten-second interval is a good compromise between data volumes and resolution where you need full movement details. If the speed for updates is greater than ten seconds, the tracklog begins to cut off corners and ceases to follow your route precisely. You can change the interval at any time; **figure 3.11** shows a tracklog with gray point symbols showing a change in sampling interval from 10 to 5 seconds (moving left to right at the same underlying speed).

The produced tracklog file is populated with twenty-three attributes derived from the NMEA including the following:

- 3D position in latitude and longitude
- 3D position in projection units (if a projected map is loaded)
- UTC time
- Speed and course over ground
- Error assessments
- Fix type and satellite numbers used in position
- Differential GPS information
- Other sensor information, especially marine

The tracklog file is a shapefile with four constituent files saved to disk:

- Shapefile (stores geometry)
- Spatial index file (stores spatial index)
- Database file (stores attributes)
- Projection file (stores projection data if using georeferenced mapping)

If the tracklog file remains in its default location, ArcPad will continue to add to it by default. The entries in the GPS tracklog can be cleared in the Layer Properties for GPS tracklog. If you want to keep a separate tracklog for each GPS data capture session, you should rename the four tracklog files or move them into another directory. The GPS tracklog can also be set to record only the positions meeting quality rules based on PDOP (again in the Layer Properties for GPS tracklog).

TIP: The attributes of the tracklog file are written in dBASE IV format. Although dBASE files are read by Excel software on the desktop, the Windows Mobile version of Excel does not read dBASE files. You will need an application like Soft Expert DBF View (a free utility available online at **www.soft-expert.ro/dbfview.htm**) to read the tracklog attributes in table form on a mobile device like a PDA, since ArcPad only allows you to read attributes for individual features with the Information tool.

Plotting GPS data on maps

The real value of the GPS tracklog is only realized when it is plotted over a background map, yet this can be a demanding task if unsupported by a desktop GIS. Plotting the GPS tracklog over a map in ArcPad requires a map source of the area georeferenced using ESRI conventions:

- Vector data in shapefile format, or raster data in a format supported by ArcPad—GIF, JPEG, JPEG2000, MrSID, PNG, TIFF (including GeoTIFF and LZW compression), Windows Bitmap, and CADRG raster maps
- Vector data must have projection information in an auxiliary file (created by ArcCatalog) or an ArcGIS projection file (.prj) (these can be copied from c:\Program Files\ArcGIS\Coordinate Systems\Projected Coordinate Systems\ on a desktop ArcGIS installation)
- Raster data must have georeferencing information in an auxiliary (.aux) file (created by

ArcCatalog) in the header of a GeoTIFF file or in an ESRI World file

ArcPad Tools for ArcGIS provide methods to export datasets from desktop GIS or enterprise GIS that meet these requirements. At the other extreme, the minimum requirements for georeferencing background raster mapping "in the field" with a PDA are

- a raster map in an ArcPad supported image format;
- an ArcGIS projection file (.prj) for the projection associated with the coordinate system in use; and
- coordinates of the top left corner of the raster and resolution of the raster in coordinate system units for the World file **(figure 3.12)**, for example, TIFF World file (.tfw).

If you create your own projection file and ESRI World files, you will need a tool to rename these files so they have the same file root as the raster image or shapefile.

TIP: Image manipulation tools for Windows Mobile allow you to convert most image formats into an ArcPad-supported one. File management tools for Windows Mobile like Total Commander (shareware available at **www.ghisler.com**) allow you to change file root (the part of the name before the '.') and suffixes (the three letters after the '.' in the filename) for projection files and ESRI World files. Text editors (not Word Mobile) allow you to create the six-line ESRI World basemap data and save it with the appropriate suffix for the type of image.

```
10 resolution in coordinate units in x
0 rotation for row
0 rotation for column
-10 resolution (-ve) in coordinate units in y
(usually x=y)
00000 x coordinate of centre of top left pixel
00000 y coordinate of centre of top left pixel

tfw= TIFF World File
jgw= JPEG World File
bpw= BMP World File
pgw- PNG World File
```

Figure 3.12 *ESRI World file structure.*

If ArcPad has a projected map or image loaded before the GPS is activated, the GPS tracklog attributes will include both latitude and longitude (unprojected geographic) coordinate values and (on-the-fly) projected coordinate values. This is a boon because it prevents any need to later reproject either geographic coordinates to projected coordinates or vice versa. It also permits the replotting of the projected coordinates in the tracklog file over any projected mapping or imagery in the same projection.

If you want to replot the tracklog data over maps as a projected shapefile, you need to extract the projected coordinates from the Tracklog.dbf file (e.g., in Windows Desktop Excel) and save them as a comma-separated value (CSV) file. Then you can convert the projected coordinates into a shapefile using the Add X,Y Data tool in ArcGIS on the desktop. Keep in mind that whenever the tracklog file is moved or renamed, it is dismounted from a projected ArcPad map and you can reload it only by changing the Tracklog Layer Properties dialog box (accessed from the table of contents) to the new location. Also note that adopting a particular projection to use in your GPS capture commits you to using a particular ellipsoid (spheroid), with all attendant implications for GPS height and geoidal separation **(figure 3.4)**.

GPS data capture

GPS receivers can be used for different types of data capture, depending on the receiver set up and the operating conditions. You can set up the professional and military GPS receivers supported by ArcPad to do the following:

- Free-standing data collection
- Differentially corrected data collection in real-time
- Differentially corrected data collection with post-processing

Typical operating conditions for mapping include the following:

- Conditions that allow some dwell time at a location for data collection
- Conditions that require more or less constant movement

The combination of these setup and operating conditions can define the quality of the positioning achieved in the survey.

For example, for nondifferential data capture with some "dwell time" at each point, you can use ArcPad's "Enable averaging" option to improve accuracy for GPS data collection. This function takes a user-specified number of vertices or points and computes the mean position, which reduces the effect of multipath errors in particular. Research shows that, with averaging, errors are almost halved in five minutes (300 positions), reduced to less than a third in fifteen minutes (900 positions), and by up to twenty times in an hour of averaging (3,600 positions).

V6 In ArcPad's Options dialog box on the Capture tab, you can also choose the streaming vertices interval. **V6**

V7 In the GPS Preferences dialog box, Capture Tab, you can also choose the position and distance interval. **V7**

TIP: If you set the tracklog location in the layer properties to the location of an existing tracklog, ArcPad will then translate the on-the-fly projection of the tracklog in geographic coordinates into any ArcPad map.

When you use the "Add GPS vertices continuously" tool, you can specify how frequently ArcPad uses the incoming GPS coordinates when creating vertices. For example, a position interval of "2" means that ArcPad will use every second-incoming GPS coordinate value when creating vertices. The default position interval is "1." A distance interval of "2" means that ArcPad will only use the incoming GPS coordinate when the distance from the last coordinate is two meters or more.

By contrast, a differentially collected survey can be in constant motion without affecting accuracy, since the corrections will reduce the effects of all errors. However, for real-time differential corrections, the RTCM SC-104 protocol via radio signal or Internet connection must be received continuously to ensure higher accuracy.

ArcPad also allows you to use the GPS position like a cursor to edit a layer. You can record the vertices of a new line using an active GPS input by clicking the "Add GPS vertex" button on the Edit toolbar.

V7 You can also edit features by using the "Insert Vertices" and "Append Vertices" buttons on the menu below the "Feature Properties" button on the Edit toolbar. **V7**

In ArcPad, you can create, capture, and name specific GPS points, known as waypoints **(figure 3.13)**. You can record new points with an active GPS input by clicking the "GPS point" button on the Edit toolbar. Waypoints are stored as features in a new point shapefile layer. When the capture of a point, line, or polygon feature with GPS input is complete, you are prompted to enter any attribute values.

V7 Feature properties can include a photo that can be taken by your device if there is a camera present and a driver is available. When you have finished inserting or appending vertices on a feature, the Command bar at the bottom of the ArcPad Window allows you to complete a GPS-drawn polygon by clicking the green right arrow. Click the green tick to "Commit geometry." **V7**

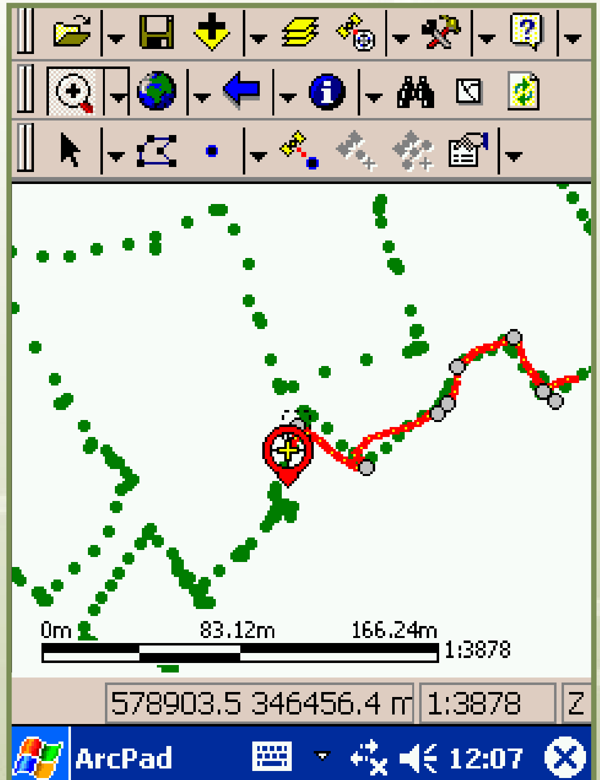

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Figure 3.13 *ArcPad being used to revisit the locations of previous surveys. The green points are known as waypoints.*

Creating new features with ArcPad

Mobile GIS gives you the advantage of mapping features in the field, which you can do either by hand on a background map or by using GPS input.

U7 If you select a shapefile to edit from the Start/Stop Editing drop-down list, you open the Edit toolbar. Use the "Capture a feature" button to choose between the following feature types: point, line, polyline, freehand line, rectangle, polygon, ellipse, circle, and freehand polygon. You can use the mouse pointer on Windows Desktop or the stylus on Windows Mobile to create features with any of these tools. When you have completed polyline or polygon features, use the "Proceed" button (right-pointing green arrow) on the Command bar at the bottom to confirm that data capture is complete (this will close a polygon). When the capture of a point, line, or polygon feature is complete, you are prompted to enter any attribute values required. Until you press the "Commit" button (green tick) on the Command bar, you can use the "Undo" button (left-pointing blue return arrow) to reverse editing actions. Committing changes means changing the stored shapefile. This kind of editing is usually carried out when a background map allows accurate feature creation in context.

ArcPad also allows you to use GPS positions like cursor or stylus input when creating point, polyline, and polygon features. By selecting the "GPS point" button on the Edit toolbar, you can create a point feature in the active layer at the current GPS position (using point-averaging or not). If you select a polyline or polygon feature using the "Capture a feature" button on the Edit toolbar, you can use GPS input to create the feature directly. With the "Add GPS vertex" button, you can use the current GPS position to create a vertex in a polyline or polygon feature. The "Add GPS vertices continuously" button streams GPS positions into polyline and polygon features. If you use GPS to draw a polygon, then committing the collected data (green tick icon) will close the polygon from the penultimate point to the first point, not the final GPS position.

You can edit features by using the "Insert Vertices" and "Append Vertices" buttons on the menu below the "Feature Properties" button on the Edit toolbar (**figure 3.14**). **U7**

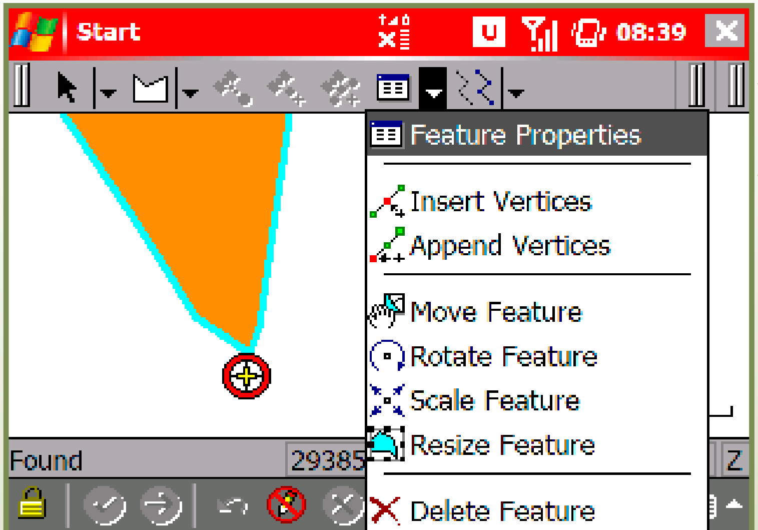

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Figure 3.14 *Creating a polygon using continuous GPS input in ArcPad and the properties of the completed feature.*

TIP: If you need to capture features that are inaccessible or for which GPS positions cannot be obtained, you can use Offsets to move the cursor in a specified direction or distance before the feature is created. Use Offsets in conjunction with range finder devices or by measuring distance and direction in other ways.

Navigation with ArcPad

ArcPad offers several navigation tools along with an active GPS input. The simplest is the GoTo tool on the Browse toolbar, which allows you to set a navigation destination by clicking the map (shown as "Mark"). In the GPS Position window, the skyplot shows the distance (DST) and bearing (BRG) to the mark from your current position **(figure 3.15)**. Clicking the skyplot once toggles the display to the compass; the bearing to the mark from your current position is shown with a red line.

ArcPad also allows you to use the Find or Advanced Select options to locate features (including points within polylines or polygons) by setting them as navigation destinations.

TIP: ArcPad allows you to manually or automatically rotate a map depending on current direction from an active GPS input. Auto rotate can lead to dramatic fluctuations of direction when you stop moving or are moving slowly due to the positional volatility of a nondifferentially corrected GPS receiver, as noted above.

TIP: When you are moving, you can display the compass to show your current direction of movement relative to true north, next to the bearing to the mark. Given the positional volatility of a nondifferentially corrected GPS receiver, it requires some skill to navigate more precisely than ±30 degrees, and you should also expect the distance to fluctuate rapidly. This means that when searching for a point (e.g., in geocaching) getting closer than 25 meters using the GPS exclusively requires low DOP values (ideally less than 6 degrees) and many satellites.

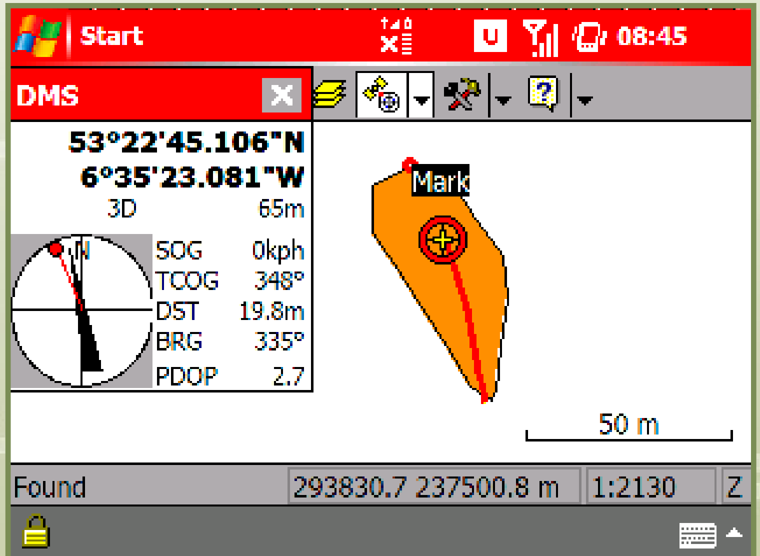


Figure 3.15 *ArcPad navigation display on the Position window compass.*

EXERCISE
GPS TRACKLOG

Since GPS position data provides important input to ArcPad, this exercise familiarizes you with the GPS tracklog that ArcPad creates when capturing GPS. The tracklog is a point shapefile drawn as a red line (with tiny yellow position dots within it) on top of all other layers **(figure 3.13)**. If georeferenced data with a projection file or World file is loaded, the tracklog is projected on the fly into the map coordinates. Complete this exercise to explore this feature.

Requirements

- ArcPad 6 or 7 on Windows Desktop or Windows Mobile
- GPS connection

Exercise

1. Open ArcPad in Registered or Demo mode, and, if using V7, select the option to Open a new empty map. You will now see the basic interface with no data loaded.
2. Open the GPS tab at the bottom of the GPS Preferences menu option **(figure 3.16a)** and set the GPS protocol, port, and baud for your GPS. (See the user guide for details of how to configure your GPS.) If you plan to display the GPS position over a map as you move then check the "Automatically Pan View" option. If you want to log all the GPS data in raw NMEA form (this can take 12K of space per minute) instead of or as well as recording the tracklog, then check this option. Double-click the Log check box to set the file name.

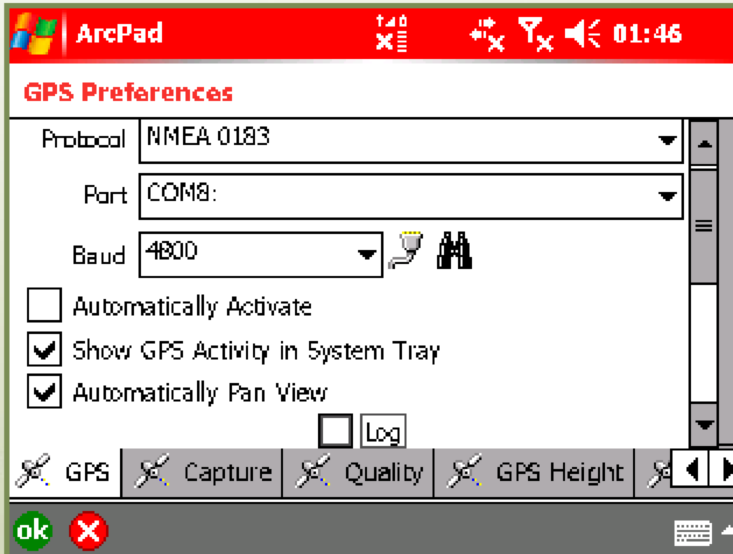
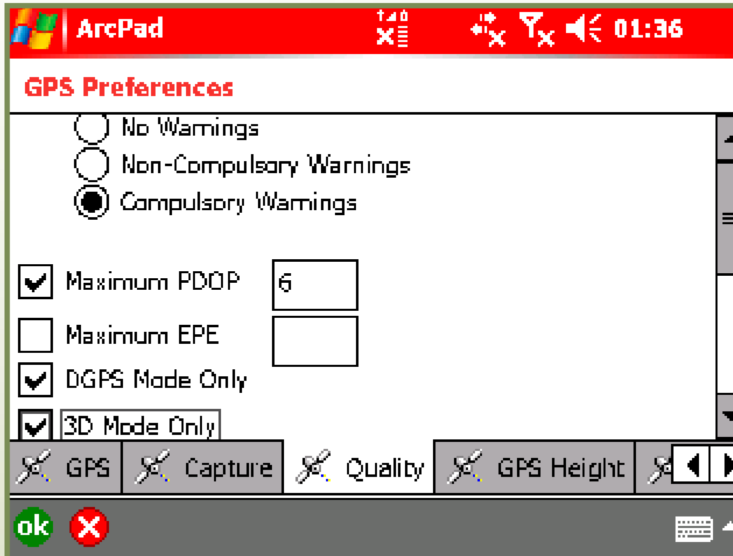


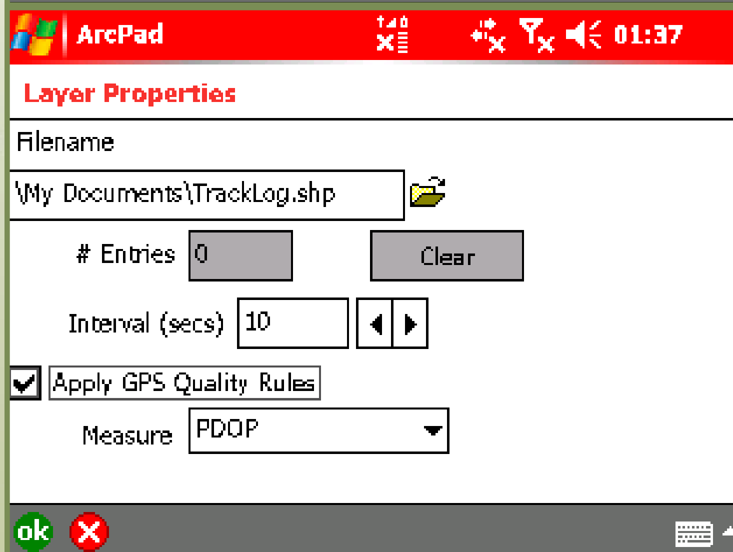
Figure 3.16a *ArcPad tracklog: GPS tab of the GPS Preferences.*

3. Now open the Quality tab on the GPS Preferences dialog box **(figure 3.16b)** and decide whether you need to set limits on the quality of position recorded in the tracklog (in positional dilution of precision units, PDOP). Theoretically, you cannot set a PDOP quality limit, but many experienced users accept 6.0 as a good quality cutoff. Check the "DGPS only" and/or "3D Mode only" if you want to restrict data capture to these modes. These quality limits can be warnings or compulsory restrictions depending on the radio buttons that you check at the top of this settings tab. Click OK to close the GPS Preferences menu option and accept all the changes made.

4. The tracklog data capture is configured in the Tracklog Layer properties accessed from the table of contents **(figure 3.16c)**. Set the name and path of the file name you want to capture, and check the Apply GPS Quality rules box if you want to use the selections you made in step 3. Set the interval to the number of seconds between GPS positions that you wish to be stored. Note that if this is set to 1 then the tracklog will grow at more or less the same rate as the NMEA log mentioned in step 2. You can review the number of positions collected at any time by revisiting the Tracklog Layer properties, and change the sampling interval (see **figure 3.11** for the effect of this).

5. Now turn on your GPS and activate it in ArcPad by selecting the GPS Active option on the GPS menu. To verify that the GPS data is flowing, display the GPS Position window on the GPS menu and make sure that the GPS reports a 2D or 3D fix (you will need to be able to see some open sky to do this). Choose the GPS Tracklog option on the GPS menu to activate GPS position recording into the tracklog. Note that unless the Log box is checked in the GPS tab of the GPS Preferences menu option, no GPS positions will be captured unless you activate the GPS tracklog, even though the GPS position window shows that you have a fix.





Top: **Figure 3.16b** *ArcPad tracklog: Quality tab of the GPS Preferences. Bottom:* **Figure 3.16c** *ArcPad tracklog: Layer properties for the GPS tracklog.*

6. Load georeferenced data for your locality using the Add Layer option on the Main toolbar. If you load data with a projection, the new tracklog will be projected into the same projection on the fly by default.

7. Move around for a few minutes over a distance of a few hundred meters to capture GPS data. Clear the selected GPS Tracklog option and study the data collected. Note that if you clear the GPS Active option then the GPS Tracklog button is automatically not selected.

8. The tracklog is drawn over projected vector data (if a projection file is present) or raster image (if a World file is present) by on-the-fly projection. This red line with tiny yellow dots is lost if you quit ArcPad and reopen it again; however, if you reopen the same ArcPad map file and both reactivate your GPS and reselect the GPS Tracklog menu option, then you will see the tracklog drawn again.

9. Note that the tracklog is a point shapefile, and so when you load it into ArcGIS or back into ArcPad, it displays as a point set. The tracklog is treated as geometry in unprojected geographic coordinates (latitude/longitude). This means that it won't plot back over any projected map that was used during data capture when it is reimported as a layer. However, if you open the Tracklog.dbf file and save it as a CSV file (only possible with third-party tools on Windows Mobile, so copy to a PC), then you can add it back into ArcGIS as an X,Y file (Tools menu) in projected map units by selecting the easting (X) and northing (Y) fields **(figure 3.16d)** as the coordinate values. Now the layer has projected coordinate values in the geometry.

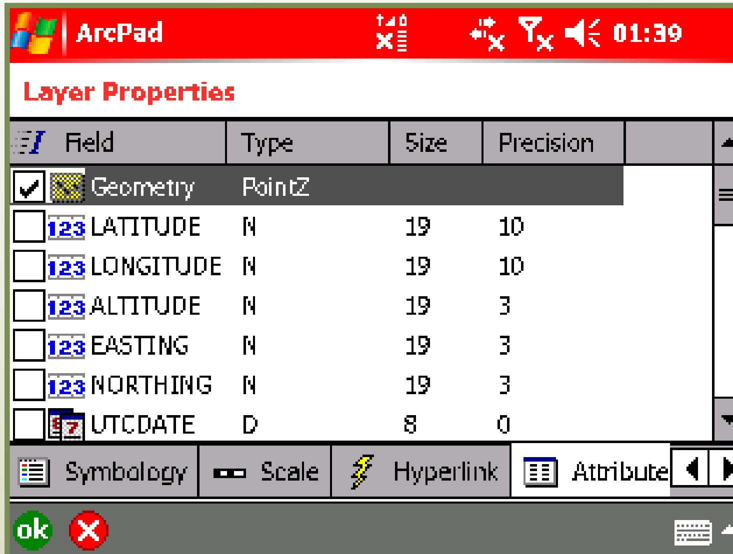


Figure 3.16d *ArcPad tracklog: Layer properties for a tracklog layer reloaded into ArcPad.*

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Summary

Understanding and deploying positioning technologies is one of the most crucial parts of mobile GIS. In addition, understanding the accuracy of positioning and the kind of data collected is vital to ensure you meet your objectives.

CHAPTER 04

Linking up the mobile workflow

Jonathan Raper, G-ability

Integration

Mobile GIS usually only makes sense as an element within a larger GIS project. It is rare for a project to be conducted entirely on a mobile device, since data acquisition, analysis, and presentation all require higher data capacities, more processing power, better screens, or greater access to peripherals than usually available in the field (see **figure 4.1** for an extreme environment). As such, mobile GIS has been designed to play a specialized role within the GIS project as a whole, and ArcPad has evolved to serve mobile workflows. This means that linking up the office-based and field-based elements in your workflow is a key question when planning your mobile GIS project.

The type of linkage issues you will face depend on the wider context of the project. Although all mobile GIS systems share some generic elements in the mobile GIS workflow, more complex aspects only arise in corporate environments. This chapter covers both general workflow integration issues and some features of corporate integration processes.

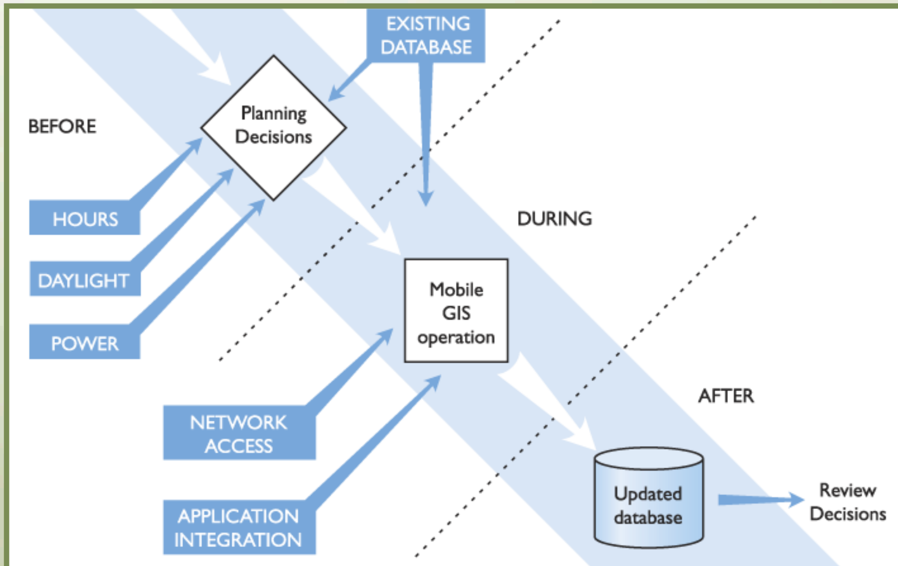
Figure 4.1 *Mapping in the Swiss Alps (lead author left, with PDA in protective holder) with ArcPad.*

Mobile GIS workflows

A GIS workflow marks out the pathway through which your data moves and identifies all connections to other systems **(figure 4.2)**. Mobile GIS workflows need to be carefully planned, as mobility demands more of you, your system, and your data. In particular you need to

- make the best use of time in the field—consider hours of operation, and the availability of daylight and power (logistics);
- check that all the data required will be available and that the needed data is designed for use on the mobile device (data preparation);
- plan how the mobile GIS could access data and services on any available network and on other systems if needed (interoperability);
- check how the mobile GIS will link with other applications on the device (application integration) and with third-party extensions and scripts (extensibility); and
- ensure that the mobile GIS can efficiently update the enterprise database after the site work (information management).

This section goes into more detail about how to consider these five issues—logistics, data preparation, interoperability, application integration and extensibility, and information management—in your mobile GIS workflow.



Courtesy of Nicholas Garner

Figure 4.2 *Mobile GIS workflow.*

TIP: Note that the cost of time out of the office is often much higher than back at base due to the special support required, thus making it especially important to plan mobile GIS thoughtfully.

ArcGIS architecture

ArcPad is part of the ArcGIS integrated GIS software architecture consisting of four interrelated parts:

- ArcGIS Desktop, includes the ArcMap, ArcCatalog, ArcScene, and ArcToolbox applications, and many extensions such as 3D Analyst, Spatial Analyst, and so on
- ArcGIS Embedded, a component GIS toolbox that allows developers to produce stand-alone applications for Windows with GIS functionality
- ArcGIS Server and ArcIMS, a tiered client-server architecture that allows users to access enterprise processing resources from thin clients like Web browsers or thick clients like ArcPad
- ArcGIS mobile, a set of tools for mobile devices, including ArcPad and ArcWeb Services

ArcGIS architecture is designed around database access, either directly when you use geodatabases or indirectly when you use ArcSDE to allow access to database management systems, including SQL Server, Oracle, DB2, and Informix.

The key roles of mobile GIS are to deliver new data or updates to the desktop or server GIS and to allow data browsing away from the desktop. To fulfil these roles, mobile GIS systems focus on the database part of the broader GIS architecture and address three overlapping functions (**figure 4.3**):

- Geodatabase storage, where a wide range of georeferenced data can be stored, including raster and vector data, tabular data, imagery, terrain models, temporal data, network data, and mapping observations, each topologically structured by layer, as necessary
- Geoprocessing, where transformations and analysis can be carried out, and where models can be designed and run
- Geovisualization, where the results of the geoprocessing of data in the geodatabase can be explored and visualized

Mobile GIS software such as ArcPad continues to extend its reach into all of these areas as the power and capacity of the devices improves, for example, through Tablet PCs.

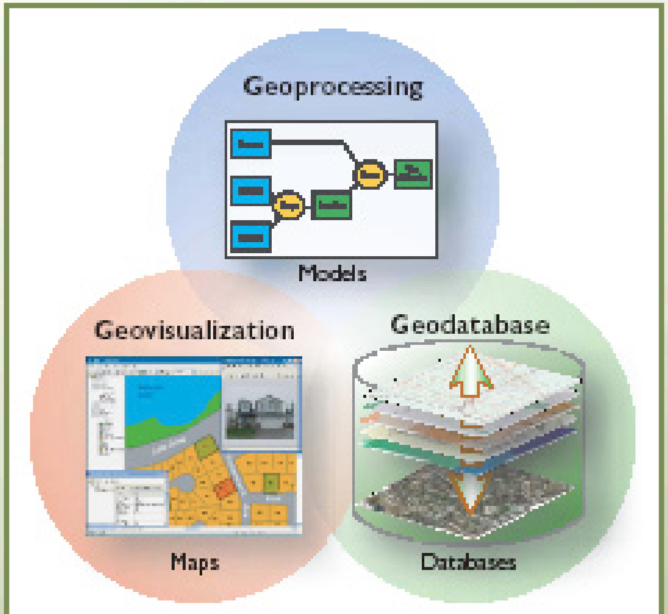


Figure 4.3 *Three functions of GIS.*

Logistics

All field data capture involves logistical planning to make the most productive use of time, ensure safety, and work within the operating envelope of the mobile device (i.e., how long the device can work and what conditions it can work in.)

Using time in the field productively usually depends on the environment and access. The environment includes such things as lighting conditions and visibility. LCD screens are easy to read in low light levels and sunny conditions, but require strong backlighting in overcast conditions. The more backlighting needed, the shorter the battery life. Most survey and ground-truthing operations require good screen readability; hence, fog, glare, or high winds reduce productivity **(figure 4.4)**.

Users working on mobile devices need to be aware of increased risks of trip and collision hazards while concentrating on the screen and even possibly increased exposure to crime. Appropriate training and assessment can mitigate these risks.

Although mobile devices can tolerate vibration, rain, dust, and a wide range of operating temperatures (typically 0° to 40°C or 32° to 104°F), they do not work well in subzero temperatures despite the heat they generate, nor can they keep working after becoming soaked in water. In these conditions, waterproof housings are necessary for standard devices or ruggedized devices can be used—though they are larger and heavier.

Figure 4.4 *Fieldworkers working with a mobile device in the rain.*

TIP: Many Windows Mobile devices stop access to memory cards at 10 percent battery power. After this point, you cannot back up your data onto permanent storage, and so you run a higher risk of losing data. Planning for power usage is an important logistical step in mobile GIS.

Data preparation

Mobile GIS is not simply standard GIS software running on mobile devices. Mobile GIS includes streamlined versions of desktop programs with several inherent limitations in their capacity and performance away from the desktop. For success, the desktop and mobile environments must be linked in a workflow that optimizes productivity both in the office and in the field (**figure 4.5**).

Although ArcPad is capable of reading several standard raster and vector data formats, you want to use moderate file sizes to secure reasonable performance from a mobile device. The processor speeds and memory available on a mobile device mean that raster or vector data files over 1Mb lead to progressive performance degradation, especially on PDAs.

PPC On Windows Mobile Pocket PC 2003, you can handle large data files by increasing ArcPad's available program memory at the expense of storage memory. If you use external storage for files (e.g., on a SD card), you can give up almost all the storage memory to ArcPad as program memory. **PPC**

WM5 On Windows Mobile 5, the device's memory is predivided between program memory and storage memory. When you buy the device, make sure you will have all the program memory you are likely to need. **WM5**

The ArcPad toolbar for ArcGIS Desktop offers conversion tools for layers created on a desktop machine that are to be used on a mobile device. The "Get Data for ArcPad" tool in ArcMap is a wizard that allows you to choose layers, select the attributes to be exported, and choose the spatial extent of the exported layers. The tool creates an ArcPad map file (.apm) that references the exported data, thereby making it easy to open all the data in ArcPad with a single click. The export can also be limited to the features in each layer's definition query.

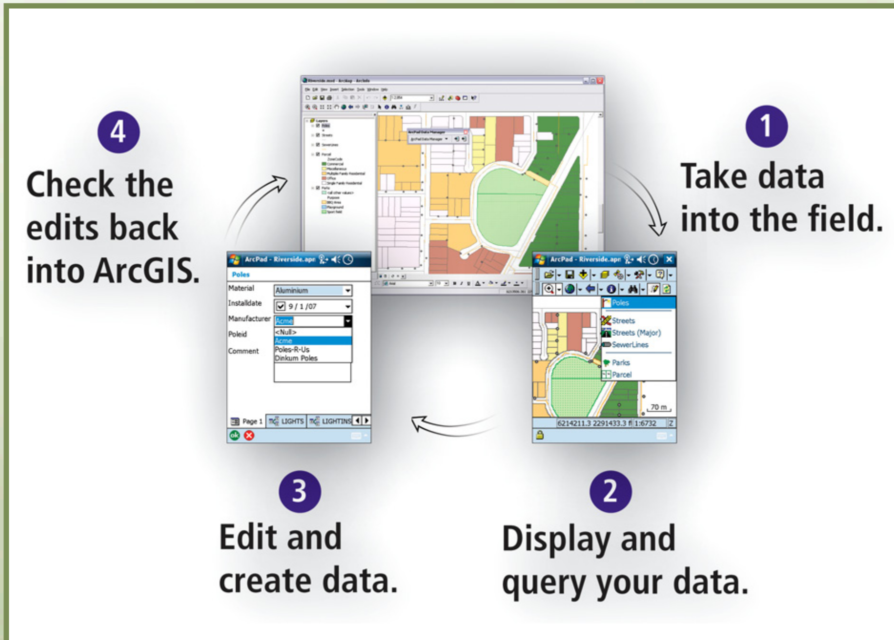


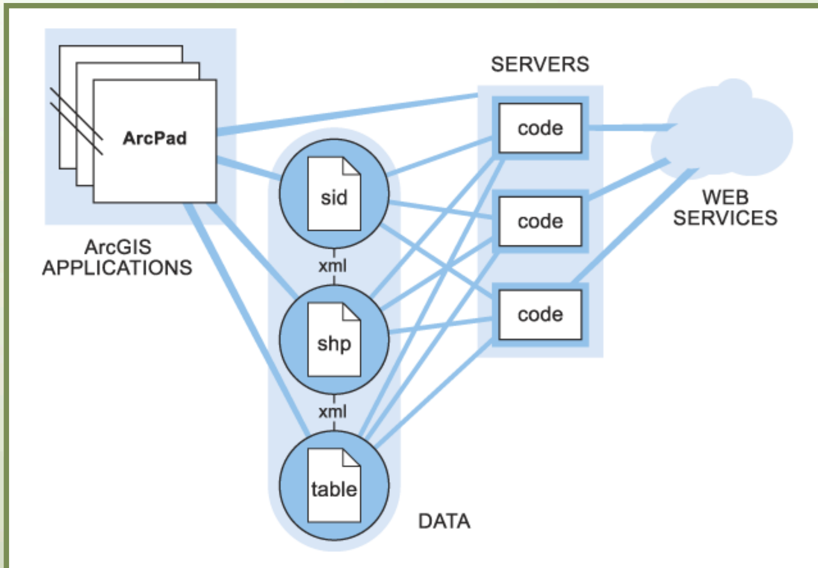
Figure 4.5 *ArcPad desktop tools concept.*

V7 To use the ArcPad 7 tools for ArcGIS Desktop, you need to have ArcGIS Desktop, version 9 or higher. **V7**

V6 ArcView 3.x has several tools for working with ArcPad in the ArcPad 6 tools extension. The "Export to ArcPad Map" tool works in the same way as the "Get Data for ArcPad" tool in ArcMap, except it defaults to all active layers and has no clipping options. You can simplify symbology from that using the "Export Layer Symbols" tool in the desktop software to the specification of the fonts installed and color depth supported on the mobile device. With the "Export View Screenshot to GeoJPEG" tool, you can capture the current state of the view (layers displayed, zoom level, symbology, etc.) as a georeferenced screenshot that can be displayed as an image in ArcPad. Finally, the "Pack Active Theme Shapefiles" tool allows you to recover the space used by deleted items in the file to ensure they are as small as possible.

TIP: You can use a definition query to exclude or include features in a layer based on a SQL statement in the Query Builder. You can find the definition query for a layer in the Properties dialog box.

The ArcPad 6 tools extension is designed for ArcPad 6 software, though the data produced by the "Get Data for ArcPad" and the "Export View Screenshot to GeoJPEG" tools can be read by ArcPad 7. **V6**



Courtesy of Nicholas Garner

Figure 4.6 *The key elements of interoperability, including applications, data formats, remote systems, and Web services.*

Interoperability

Interoperability describes all the connections that your system has to other systems, whether through *data exchange* or through *remote server usage*. True interoperability has rarely been achieved, even within one vendor's software and hardware, and it remains a long-term goal of standards bodies, vendors, and users alike. The point of improving interoperability is to enable better integration between systems and to allow each system to specialize in what it does without becoming an island. To improve interoperability requires integration between applications like ArcPad, data and the formats in which it is stored, server processing, and Web services **(figure 4.6)**.

For ArcPad, data exchange is a question of

- geographic information formats supported by ArcPad, including shapefiles (vector) and TIFF, JPEG, JPEG2000, CADRG, BMP, GIF, MrSID, and PNG (raster) formats plus DBF tabular data; and
- availability of metadata (data about data) that allows you to assess sources before downloading and importing into ArcPad.

ArcPad can use catalog portals such as the Geography Network **(www.geographynetwork.com)** to find and assess datasets that could serve your project needs.

Remote server usage allows ArcPad to make use of the processing power available on the enterprise network, but depends on

- available network connections on your mobile device;
- protocols for online access supported by ArcPad;
- the way ArcPad is integrated into your enterprise client-server environment; and
- the nature of any online database storage.

In the following sections, we explore interoperability through catalog portals then client-server environments.

Catalog portals

In GIS, catalog services store and index metadata records for datasets uploaded to the service, and provide Web-based search tools in the catalog portal.

You can use ArcCatalog to create metadata records for ArcGIS-compatible datasets, which you can then publish to an ArcIMS Spatial Server using either of the following:

- Federal Geospatial Data Committee (FGDC) Content Standard for Digital Geospatial Metadata, or
- International Standards Organization (ISO) 19115 Metadata standard.

The National Oceanic and Atmospheric Administration (NOAA) ArcView Metadata Collector Extension can be used to publish metadata from ArcView 3.x.

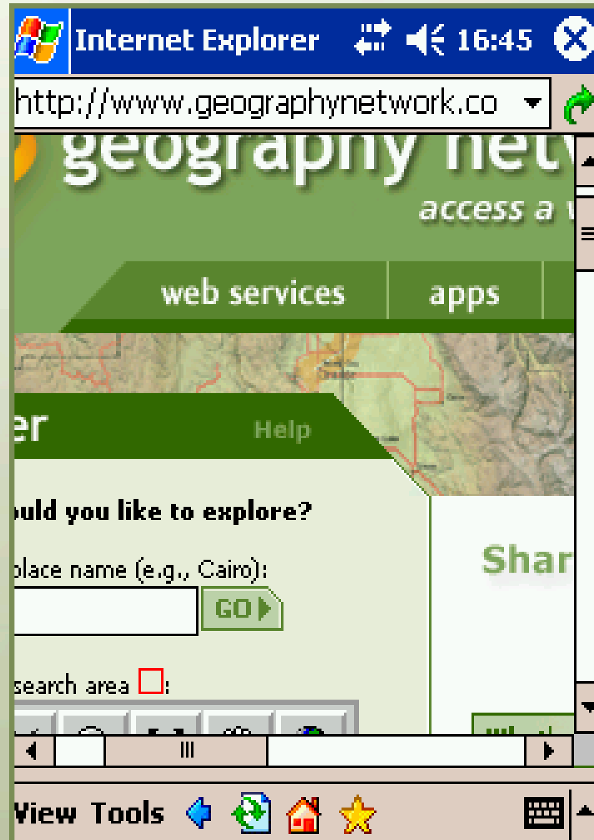


Figure 4.7 *Geography Network catalog portal.*

The Geography Network **(www.geographynetwork.com)** is an ESRI catalog portal **(figure 4.7)** that gives users access to multiple catalog services, including those for locating downloadable data in formats that ArcPad can use, maps, and images that you can view in a browser on your mobile device.

You can also use the Geography Network to publish and share your ArcGIS-compatible datasets and search for datasets with both spatial and nonspatial criteria. ArcPad can access Geography Network servers whenever a network connection is available to search for datasets and display or query them.

TIP: The Opera Mobile browser offers the widest range of browser functions for PDAs and many more functions than the built-in Pocket Internet Explorer.

XP The Web browsers available on Tablet PCs give access to the full range of Geography Network services, including dynamic maps. XP

PPC WM5 The Web browsers available on PDAs don't always support the full range of Geography Network services. PPC WM5

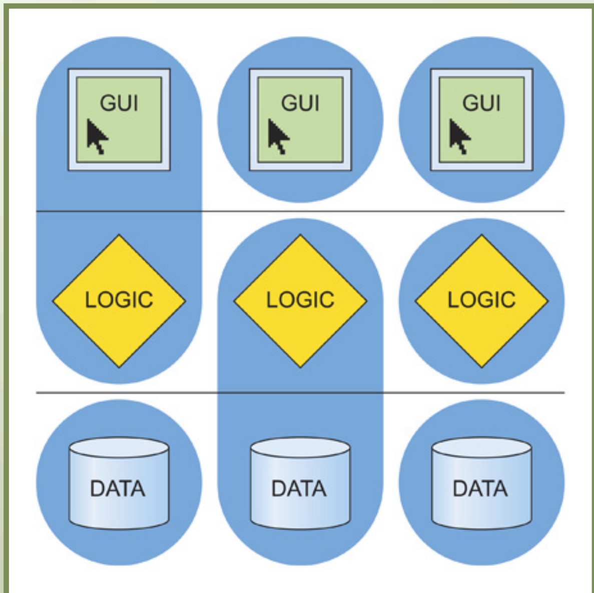
Client-server integration

Mobility, data exchange, and remote system connections bring a greater complexity to data usage. In stand-alone applications, local file management is simple and efficient, since only one program is reading and writing your data from the storage. However, with multiple applications distributed over networks, a client-server approach helps to handle all the communications between data storage and programs. Client-server architectures have a tiered design where the logical (software) and physical (hardware) elements are increasingly independent of each other (**figure 4.8**). A client-server approach gives mobile GIS greater flexibility in the provision of data access.

A tiered client-server architecture is composed of three elements:

- Data storage in a database management system (DBMS)
- The application, or business, logic, and associated middleware communications between DBMS and interface
- The presentation through a graphical user interface (GUI), whether that be a stand-alone application like ArcPad, a Java applet or MIDlet, or Web browser.

A spectrum of possible physical implementations ranges from all three elements running on one machine to each of the three elements running on separate



Courtesy of Nicholas Garner

Figure 4.8 *Client-server "tiering" showing three different ways in which GUI, logic, and data can be grouped on individual machines (shown as blue patches).*

machines. N-tier architecture partitions the logic or data elements onto multiple machines when this is required to handle the processing load. In the ArcGIS client-server architecture, a DBMS such as Oracle can provide data storage, ArcGIS Server or ArcIMS can manage the logic tier, and ArcPad can be the GUI. In this approach, ArcPad is the front end to a powerful enterprise system that can be accessed whenever network connections are available.

TIP: You can find out more at **www.arcwebservices.com.**

Serving geographic information to mobile users

Since ArcPad can be a client to ArcGIS Server or ArcIMS, when you have network connectivity on your mobile device, you can access data held in remote GIS databases. You can establish a connection to a server running an image service from the "Add Internet Server" menu in ArcPad **(figure 4.9)** and store a Geography Network Definition (.gnd) file reference locally. Once the connection is established, you can add layers to an ArcPad map with a compatible projection and query them across the network using the ArcPad Identify tool. Layers downloaded are cached as JPEG images for offline access or refreshed when the network is available.

In the ArcGIS architecture, the client-server logic tier dealing with requests from clients like ArcPad consists of a Web server (e.g., Microsoft Internet Information Services), server communication connectors (e.g., Java servlets), application servers, and a spatial server. A variety of spatial servers is available, including those offering image (raster), feature (vector), geocoding, and metadata services, although ArcPad supports only image services. This system gives you the flexibility to access, cache, and use remotely-stored data while on the go, with all the advantages of real-time access to the database.

Mobile users can also access spatial data through ArcWeb services. The ArcWeb Mobile Toolkit allows you to develop Java Micro Edition Mobile Toolkit (J2ME) applications for PDAs and smartphones. These Java applications can send requests for maps, geocoding, routing, address mapping, and searches for nearby locations such as restaurants or banks using ArcWeb Services.

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Figure 4.9 *ArcIMS access from ArcPad.*

Application integration

Since GIS can be used as a lookup tool for other information (e.g., a map can be a visual index to a property gazetteer), a GIS client can be used to hyperlink geographic features to other datasets and multimedia content. A mobile GIS client like ArcPad is an ideal way to create a handheld map-based index to spatially distributed content.

In ArcPad you will find the hyperlink tool under the Information tool on the browse toolbar **(figure 4.10)**. Clicking a hyperlinked geographic feature with this tool automatically opens the linked file and switches to the appropriate application. In Windows Mobile a hyperlink uses the default application to open the link, hence Pocket Internet Explorer or the Opera Mobile browser is used for HTML files, Pocket Word is used for text files, Acrobat is used for PDF files, and Windows Media Player is used for video and audio files. You will need to manually return to ArcPad by closing the viewer application you opened with the hyperlink.

TIP: Take care to make sure that the features have symbolization large enough to make it easy for users to click them with the hyperlink tool.

In ArcPad, hyperlinking requires adding a valid path to the attributes of the layer that identify the file to be opened. You can add this to any layer created in ArcPad or to preexisting layers created in ArcGIS. If the files are in the same directory as the layer, the path is simply the file name.

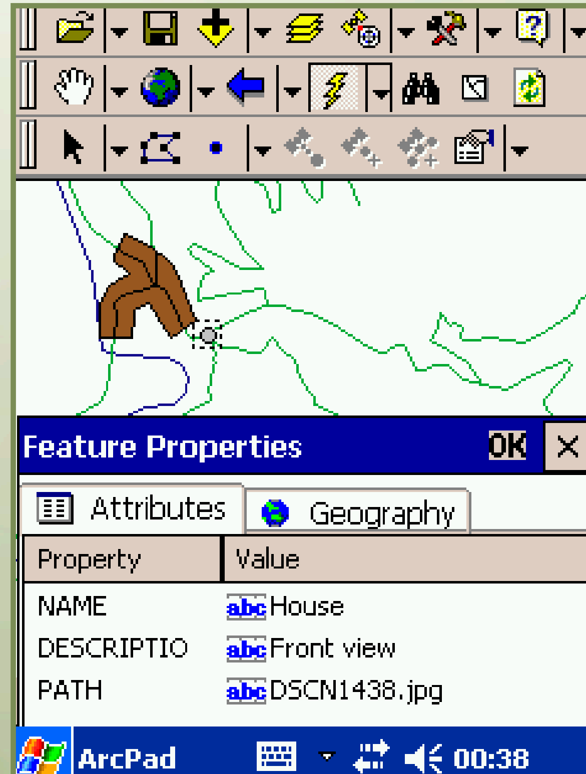

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Figure 4.10 *Hyperlinked feature showing file name in feature properties.*

Extensibility

ArcPad can be extended in a variety of ways so you can customize how you use the software. Using ArcPad Application Builder and VBScript, Jscript, or Microsoft Visual Studio and C++ (see chapter 6) you can create applets to do the following:

- Hide or create toolbars and configure the status bar
- Create new tools for built-in or user-defined commands
- Design custom forms for data input

You can also alter the default customization file ArcPad.apx that defines the way ArcPad looks when you start it up.

By contrast, extensions allow developers to add new functionality to ArcPad, including support for

- new data formats;
- new data input devices; and
- new coordinate systems and projections.

As an example, the FakeGPS Extension simulates a GPS by sending ArcPad position data from a file **(figure 4.11)**.

TIP: Sample extensions and applets can be obtained from the ArcScripts Web site **(arcscripts.esri.com)**. Once downloaded they should be unzipped and saved in their respective folders (ArcPad\Extensions or ArcPad\Applets) before starting or restarting ArcPad.

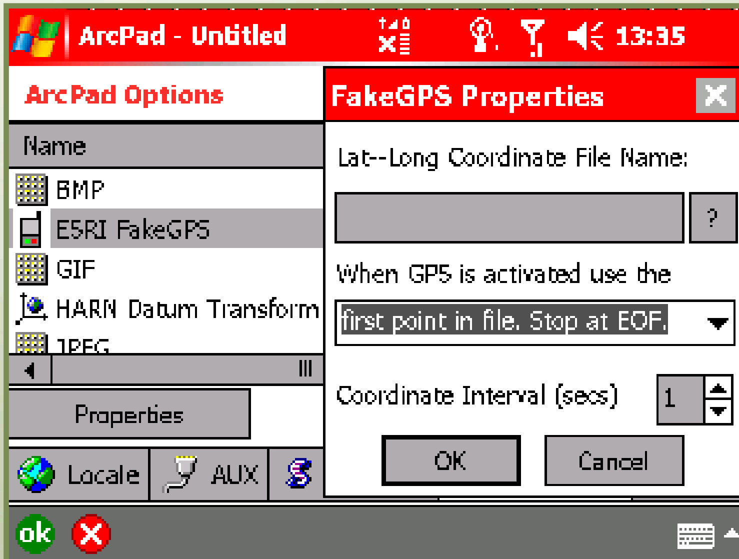

Figure 4.11 *FakeGPS extension.*

Information management

ArcGIS offers the mobile GIS user several methods for managing data checked out of the enterprise database for update in the field. These methods depend on whether the data is stored as a shapefile or geodatabase, which ArcGIS software license you have (ArcInfo, ArcEditor, or ArcView), and whether you will use ArcPad. ArcPad users can only edit vector data and not rasters.

The following methods are available:

- HP When your data is stored in a multiuser geodatabase such as Oracle, you can check out a local geodatabase version. You can edit features on your mobile device such as a Tablet PC. On completing the editing, you can check the edits back into the multiuser geodatabase and any differences can be resolved (this is known as disconnected editing). HP
- When the data is stored in a personal geodatabase, you can use the ArcPad toolbar in ArcGIS to check out data to ArcPad by conversion to shapefiles **(figure 4.12)**. You can check the edits back into the geodatabase with the ArcPad toolbar for ArcGIS, with manual reconciliation of changes.
- You can also send shapefiles in ArcView to ArcPad where they can be edited and the whole shapefile returned to ArcView to replace the original.

Editing existing data and creating new data requires careful planning to ensure that information management processes are documented and checked.

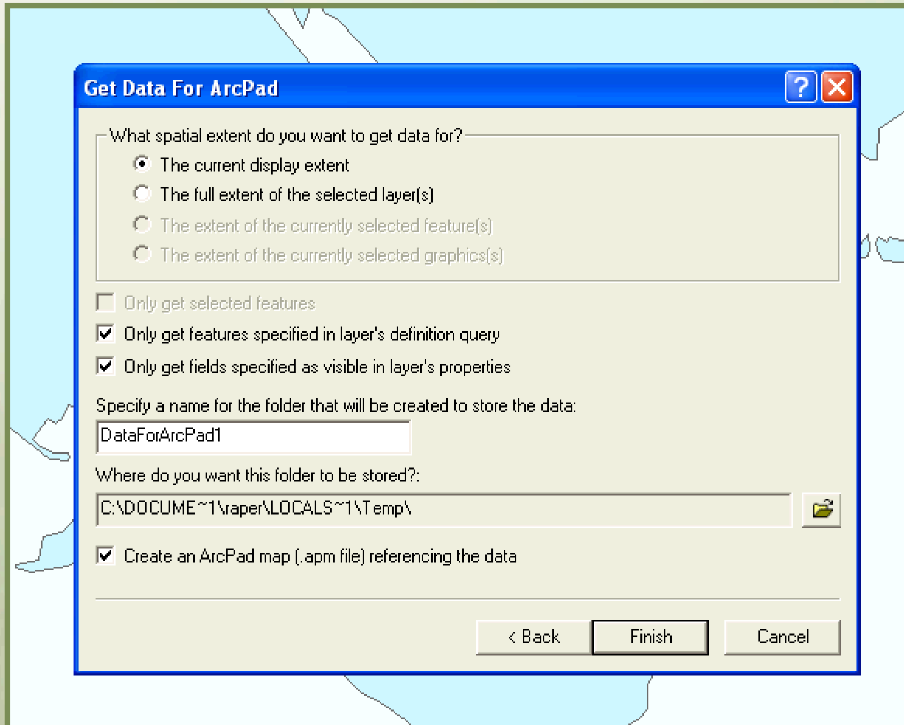

Figure 4.12 *Checking out data from ArcGIS to ArcPad.*

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EXERCISE
ADD INTERNET SERVER

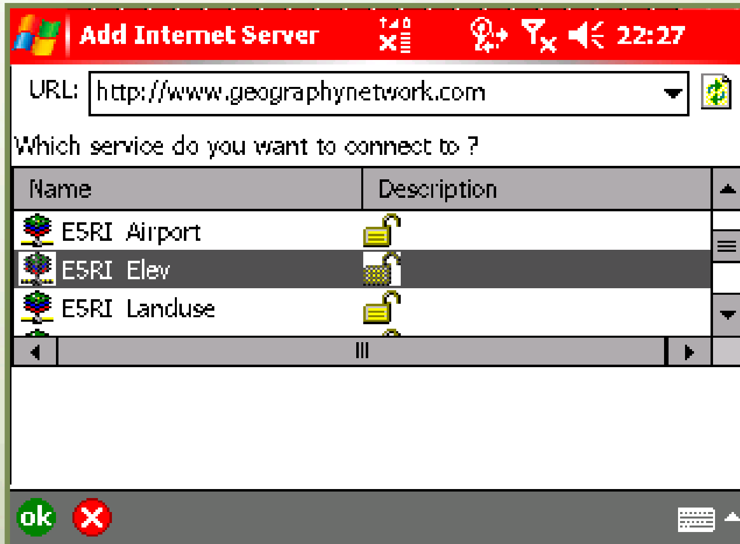
If you have Internet access through an ActiveSync/WMDC, Wi-Fi, cellular, or Bluetooth connection then the range of datasets available to you in ArcPad can be greatly expanded when you connect to Internet servers that provide geographic information. Complete this exercise to explore this feature.

Requirements

- ArcPad 6 or 7 on Windows desktop or Windows Mobile
- Internet connection on your mobile device

Exercise

1. Open ArcPad in Registered or Demo mode, and, if using V7, select the option Open a new empty map. You should now see the basic interface with no data loaded.
2. Select "Add Internet Server" from the Add Layer menu on the Main toolbar. In the window that opens you should specify the name of a service that returns ArcGIS layers. Accept the default of **www.geographynetwork.com** or add your own such as **www.mapdex.org**. Then click the Refresh button to the right of the URL box and wait for ArcPad to retrieve a current list of the layers available **(figure 4.13a)**. Select a layer and click OK, then choose the location to download it to. If the data is online, it will be loaded and displayed like any other layer. You will also be able to see the layer in the table of contents **(figure 4.13b)**. If the layer is password protected, you can enter a user name and password in the ArcIMS tab of the ArcPad options dialog box.

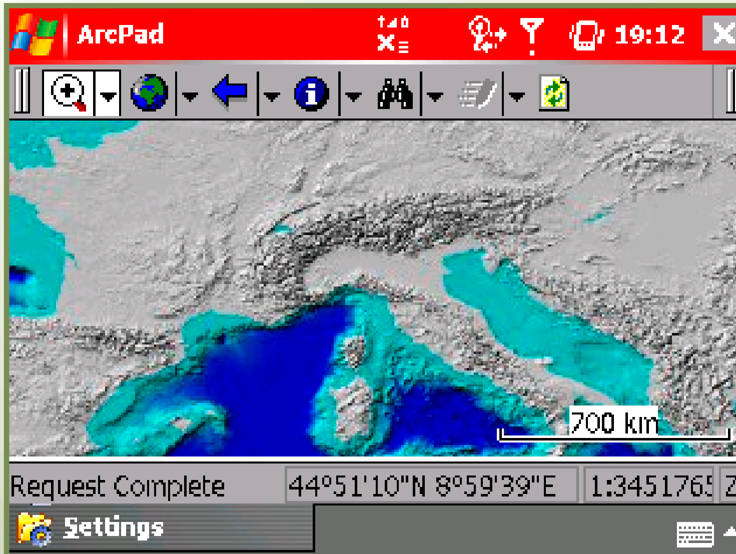


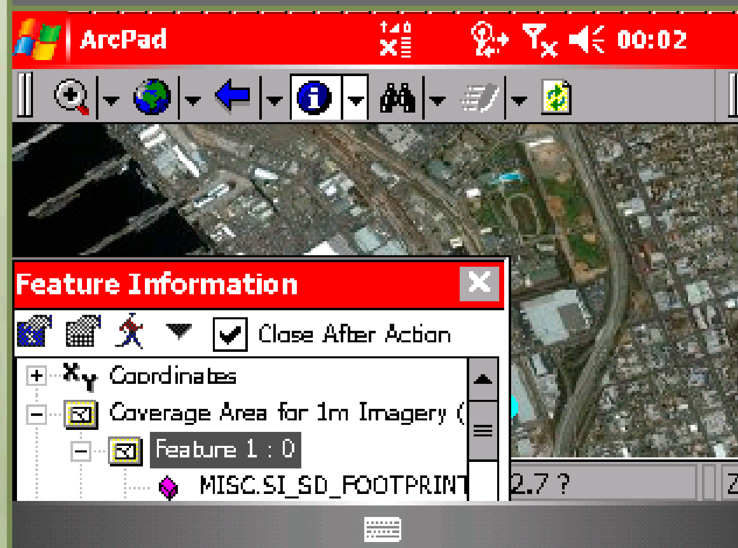
Top: **Figure 4.13a** *Add Internet Server: Add Internet Server dialog box. Bottom:* **Figure 4.13b** *Add Internet Server: Table of contents with ArcIMS layer loaded.*

3. Each layer is cached on your device at the location you chose with a geography network definition (GND) file to record the source of the data. If the option to automatically refresh is checked in the ArcIMS tab of the ArcPad Options dialog box, then as you pan and zoom the layer is reloaded from the server **(figure 4.13c)**. This also means that you can remove the layer from the table of contents and add it back again later from the cache you have stored locally.
4. For layers that have associated vector layers on the server, you can use the Identify tool on the Browse toolbar to query features **(figure 4.13d)**. Select the Identify tool and click the feature of interest; the feature Information dialog box will pop up with attribute details required.

ArcPad integration

This chapter looked at the mobile GIS workflow and the different ways it links up with other systems and processes. Although you may simply consider ArcPad a stand-alone tool for collecting and browsing GIS data in the field, with useful GPS and navigation tools, it is capable of much more. ArcPad becomes more powerful when it is integrated with databases, networks, and server-based processing. Combining these functions makes ArcPad into the definitive integrated mobile GIS.





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Top: **Figure 4.13c** *Add Internet Server: ESRI Relief layer loaded from geographynetwork.com. Bottom:* **Figure 4.13d** *Add Internet Server: ArcIMS layer loaded and queried using the Identify tool.*

CHAPTER 05

Geopresentation on the move

Elsa João, University of Strathclyde, **and Jonathan Raper,** G-ability

Because ArcPad provides a tool for working away from the desktop, data presentation in field conditions needs to be effective. Field conditions include unfavorable lighting and a small display screen. At typically 320 by 240 pixels (quarter VGA screen), a PDA mobile device has a screen with only one eighth of the screen real estate of a typical desktop or laptop—this imposes some potentially severe presentation limitations for GIS data. **Figure 5.1** shows a Tablet PC screen outlined in black compared to a desktop screen, demonstrating the limited area available for display.

Figure 5.1 *Relative sizes of PDA and desktop screens.*

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This chapter introduces some key concepts of "geopresentation," focusing on symbolization, styles, photos and graphics, scale, and labeling. Given the constraints of field use, enhancing how ArcPad presents your data can make a huge difference in usability and, ultimately, the success of the endeavor.

Scope of ArcPad geopresentation

ArcPad can present the following kinds of georeferenced data:

- Symbolized, labeled vector shapefiles
- Image files, with transparency and color-map properties
- ArcIMS image layers loaded from the network
- Graphics layers with annotations, text, points, lines, and polygons for annotation and sketching
- Tracklog layers with inputs from GPS receivers
- Photo layers to show photo locations and attributes
- A map grid for use as a reference frame

Because the viewing screen is small, you will need to do some planning and design work to prevent these elements from interfering with each other **(figure 5.2)**.

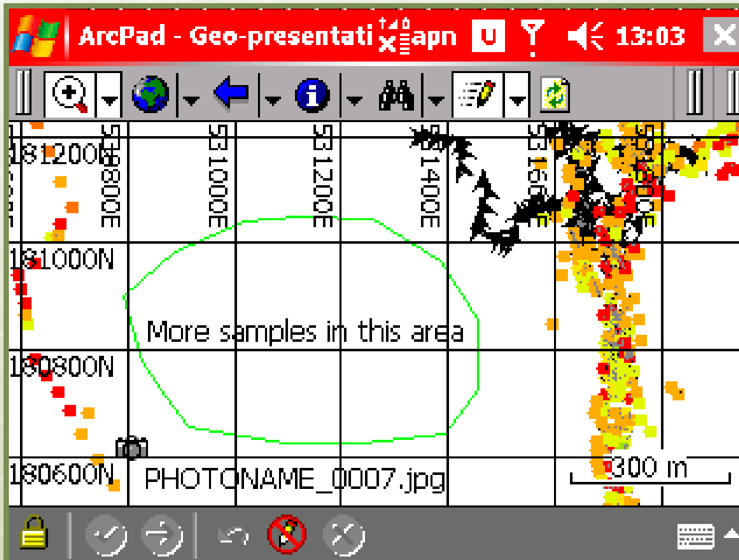

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Figure 5.2 *A collage of confusing and mutually interfering geopresentation elements.*

The first consideration in geopresentation is precedence of layers: the layers can be rearranged in order to suit your geopresentation aims. In the table of contents, you can move a layer higher or lower by selecting the layer and using the up and down arrows at the right. Constraints exist—the tracklog is always on top, followed by the map grid. Note that raster image layers obscure layers below them in the table of contents if they are drawn as opaque layers, which is the default.

TIP: In a raster layer's Properties dialog box, change the transparency value on a range from 0 to 100 percent so you can see through a raster image layer. This setting is stored with the ArcPad map.

When doing field editing, your next consideration is map design. If you are simply field-checking layers with no on-site editing, then you can export a full set of layers from ArcGIS. You can use graphic annotations in ArcPad to mark issues for correction later in the office. However, if you are editing or collecting data in the field, a sparse presentation design works best so that the created features can be seen without frequent and time-consuming changes in layer visibility and order.

Using geopresentation tools generates additional ArcPad XML files (we discuss this in detail in this chapter), which must be kept together with the layers they reference. These files are either produced by ArcGIS tools for ArcPad when exporting or by ArcPad itself. The XML files must be included in any backup strategy for your field data capture.

Symbolization in ArcPad

Symbols are graphic elements that represent either real features that exist on the ground, such as a river, or defined features, such as a state boundary. The process of choosing or creating graphic symbols to represent different features effectively on a map is known as symbolization and forms part of cartographic design. GIS software applies a default symbolization when the data is loaded (e.g., into ArcPad); however, users should assign symbols, based on standard cartographic practice **(figure 5.3)**.

The choice of symbols depends upon how many different feature types you need to represent, the purpose of the map, and the characteristics of the display. The symbols need to be meaningful; for example, it makes sense to represent a river with the color blue and a road with the color brown rather than vice versa. Symbols also need to relate to all of the other map elements so that they fit with related features and their symbols. Finally, the type of symbols you choose depends on the display technology, especially the available colors on screen or printout.

In vector map layers, symbols can be points (e.g., to indicate the location of signs or cities, depending on the scale), lines (e.g., to show the shape of roads or rivers), or polygons (e.g., to indicate the shape and size of land parcels or lakes). In ArcPad, points, lines, and polygons are represented in different vector layers since each layer can only have one type of feature. ArcPad can read ArcGIS symbology or you can create symbology in the layer's Properties dialog box.

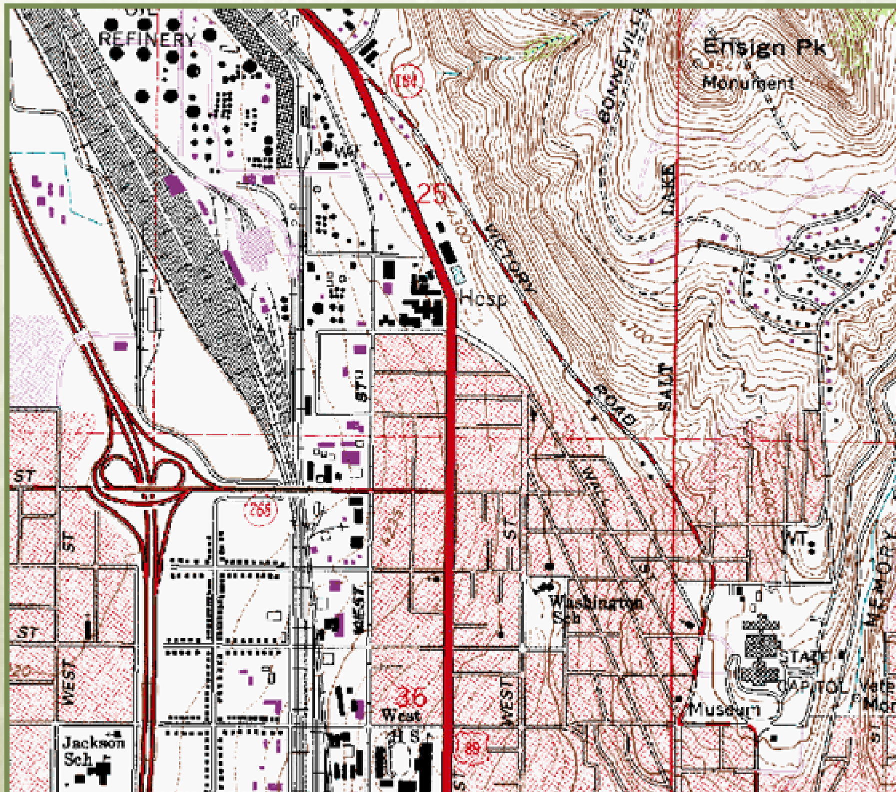

Figure 5.3 *Symbol types illustrated in a USGS 1:24,000 quadrangle map for Salt Lake City.*

Raster layers are symbolized by a color scheme related to the cell values, depending on whether they are red/ green/ blue (RGB) images or raster maps. RGB images are usually symbolized using an RGB composite where red, green, and blue colors are assigned to the values in the red, green, and blue input values (e.g., selected bands in a satellite image). Raster maps can be symbolized several ways:

- As color ramps (e.g., from white to shades of gray to black)
- By classifying the values into color ranges
- By using a color map where the cell value corresponds to a particular feature (e.g., blue means "sea").

ArcPad cannot read RGB images, so ArcPad tools for ArcGIS convert the image to a raster with one value per cell. Note that some rasters have "no data" values: you can set the color to be used for "no data" values (e.g., transparent) in the ArcPad layer feature properties dialog box.

Simple ArcPad symbology

ArcPad supports two levels of vector symbology:

- Simple symbology controlling shape, size, and color
- Complex symbology produced in ArcGIS and converted for ArcPad use

V6 Simple ArcGIS symbology can be created in ArcPad 6, and limited types of complex symbology can be exported from ArcGIS to ArcPad 6 using the ArcPad 6 tools for ArcGIS 8 or the ArcView 3.x ArcPad extension.

Simple vector symbology can be specified in ArcPad for points, lines, and polygons as follows (**figure 5.4**):

- Points. Simple symbology means you can use only circle symbols, which can be filled or unfilled, have different sizes, and have different outline or fill colors chosen from the device's palette.
- Lines. You can choose either a solid or a dashed line, then choose the thickness and the color of the line from the device palette.
- Polygons. You can choose to show polygons with either a solid or dashed border, which may be filled or unfilled; however, all filled polygons in a layer must have the same color.

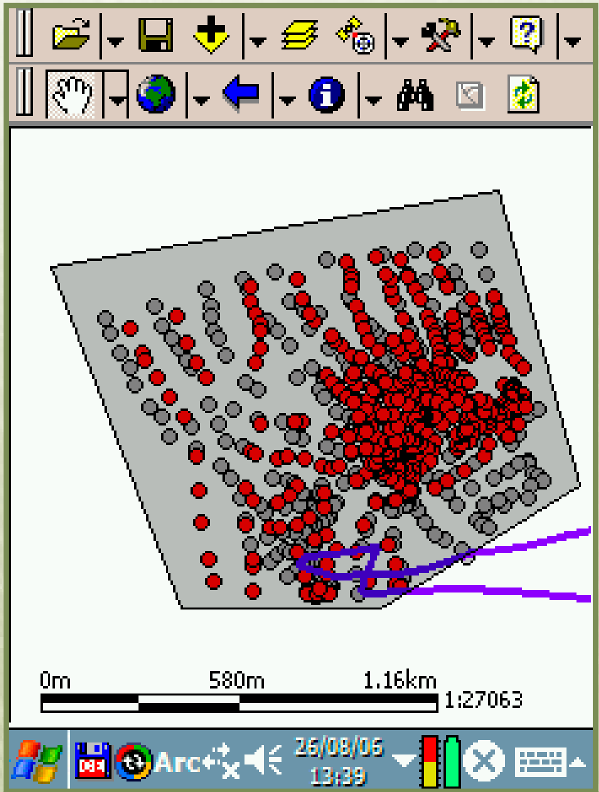

Figure 5.4 *Simple symbology in ArcPad 6.*

The ArcPad 6 tools for ArcGIS can only convert symbology to ArcPad 6-supported types. For point layers, ArcPad supports both simple TrueType font symbols and bitmap symbols. Plus it supports point symbol rotation angle and reference scale, though not composite or color symbols. If you want to use TrueType fonts, you must load them onto your mobile device. For line layers, ArcPad supports line color, style, thickness, and symbol reference scale. For polygon layers, ArcPad supports simple raster and bitmap fills. **V6**

Complex ArcPad symbology

V7 ArcPad 7 can display almost all of the symbology produced by ArcGIS, including that based on features (e.g., line dashing), categories (based on attributes), and quantities (e.g., proportional symbols). You can export all symbology from ArcGIS to ArcPad using the ArcPad 7 tools for ArcGIS **(figure 5.5a)**.

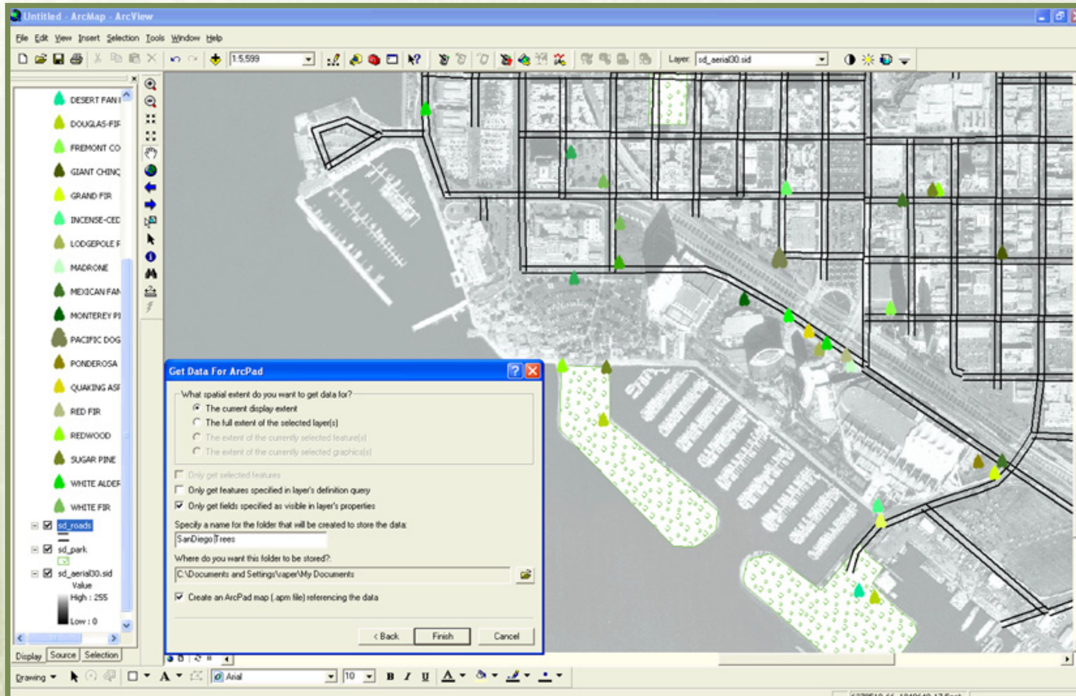

Figure 5.5a *Using ArcPad tools for ArcGIS to export complex symbology.*

For complex symbology, both abstract and pictorial point symbols are available. Abstract point symbols may be any geometric shape, such as an arrowhead to represent a direction. In contrast, pictorial point symbols look like the features that they represent (a tree, a windmill, or a fire hydrant).

A variety of cartographic line symbols is supported by ArcPad 7, including specific hatch designs, casements (linear features represented by parallel lines), and lines with periodic symbols along them (e.g., to signify the number of a bus route).

You can shade or symbolize polygons by attribute in ArcGIS and then export them to ArcPad (**figure 5.5b**). Within ArcPad you can shade polygons using a range of crosshatch, stipple, or fill styles, or you can fill by any color supported by your mobile device display. You can also set polygon outline types, thicknesses, and colors in ArcPad.

ArcPad has an optional setting, called greeking, that allows you to simplify feature symbols by reducing the number of pixels used to draw them. This can improve performance when ArcPad has to draw large and complex datasets. **V7**

TIP: You can turn greeking for points, lines, polygons, and multipoint features on or off in the Display Quality tab in the ArcPad Options dialog box. You can edit the threshold feature size in pixels to determine whether greeking will be used for each of these feature types in the ArcPadPrefs.apx file.

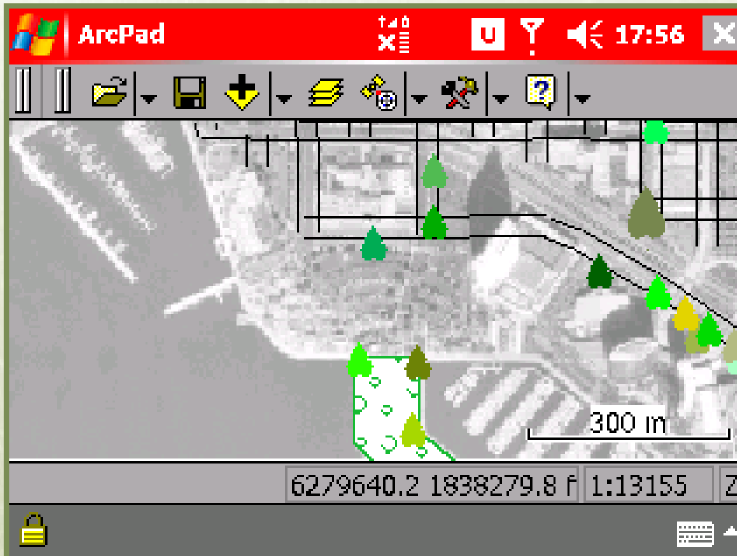

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Figure 5.5b *Complex symbology viewed in ArcPad 7.*

ArcGIS styles and ArcPad

V7 In ArcPad 7, complex symbology support is based on ArcGIS style sheets, which are sets of predefined symbols for point, line, and polygon features. The style sheet called ESRI.style supplied with ArcGIS has 18,000 predefined symbols, most of which are also available in the default ArcPad 7 style file (.aps). This allows you to pick symbols from standard sets and maintain consistency of presentation across distributed projects in both the office and the field. You can also create your own styles using the ArcGIS Style Manager (on the Tools menu of ArcGIS) by right-clicking any style.

You can make ArcGIS styles available to other ArcGIS users either by circulating a style file or by embedding them in an ArcGIS map template file (.mxt). You can also import styles used in any available ArcGIS layer via Properties > Symbology tab > Import in ArcGIS.

You can export to ArcPad styles you use in ArcGIS either by exporting

- the entire style file in ArcGIS to an ArcPad 7 style file (.aps) via Tools > Styles > Export Referenced Style(s) for ArcPad **(figure 5.6)**; or
- a particular style used in an ArcGIS layer to an ArcPad layer definition (.apl) file using the Export Symbology tool in the ArcPad 7 tools for ArcGIS.

In ArcPad, once you have applied a style to a layer, the symbolization options are recorded in the .apl file alongside simple metadata for the layer. So, once defined, the symbology is portable with the layer.

You can access both simple and complex symbologies from the Symbol properties page (access from the legend or the Symbology tab of the Feature properties dialog box). The Styles tab gives you access to any complex symbology you have chosen. If you switch to the Point/ Line/ Polygon style tab you will see the simple symbology options. These options will be grayed-out if you are using complex symbology; clicking the "Set to default style" button will remove complex symbology and allow you to revert to simple symbology. **V7**

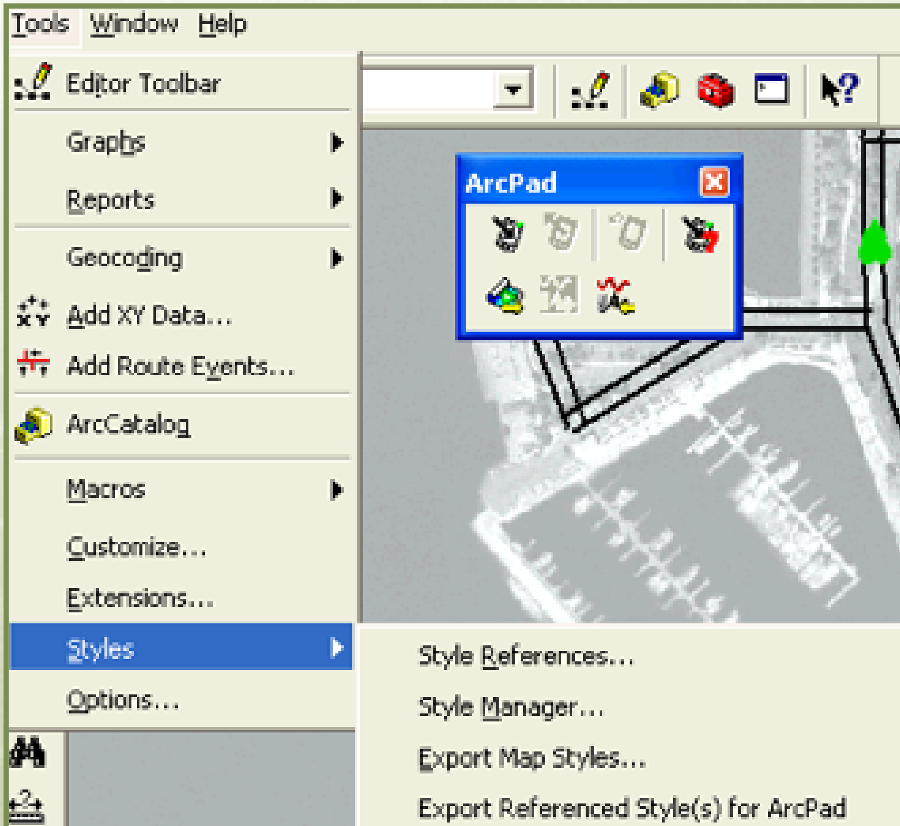

Figure 5.6 *The "Export Style for ArcPad" tools.*

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Photos and graphics in ArcPad

U7 ArcPad offers two special layers designed to support mobile geopresentation: a graphics layer and a photo layer.

A graphics layer is designed to allow you to create georeferenced annotations or to enter small numbers of features using the graphic tools provided. The features can be point, line, or arrows, polyline, freehand line, rectangle, polygon, ellipse, circle, and freehand polygon. The graphics produced are not the same as geometric features in shapefiles, although you can convert them to features using third-party extensions like Xtools Pro or TypeConvert.

You can create graphics layers in ArcGIS or ArcPad: Active Page Generator APG script (.apg) files are XML files produced are self-contained and include projection information. To create a graphic feature in ArcPad, you need to make a graphics layer editable and select the type of feature you want to create from the Edit toolbar. Once you have drawn the feature, you can access the full range of edit tools from the Feature properties menu on the Edit toolbar, including inserting or appending vertices, moving, rotating, scaling, resizing, and deleting features. You can label graphic features through the Feature properties menu using styles or using standard font and color options.

You can create photo layers so that they point to folders containing georeferenced photos; then they can be displayed in ArcPad. Digital photos in JPEG format with GPS coordinates in their EXIF headers will be projected into the reference frame of the map and drawn (by default) in the Photo layer with camera symbols. You can enter GPS data into the EXIF header by doing the following:

1. Taking a picture with a GPS-equipped camera (e.g., Ricoh Caplio Pro G3 camera);
2. Using ArcPad to take a photo with a mobile device camera when a GPS is connected;
3. Entering the GPS coordinates manually (e.g., using Opanda or iViewMedia Pro software).

TIP: Because the created points are very densely packed, before you try to edit a freehand graphics feature, make sure you zoom to a large scale using the “Zoom to a selected feature” option on the Selection menu on the Edit toolbar.

Refer to the ArcPad User Guide for more details about cameras connected to ArcPad.

You do not need to create photo layers before taking the photos. Wherever they are created on the device, ArcPad gathers up and displays any JPEG files with GPS EXIF data located in the same directory. So that they are always visible, the camera symbols remain the same size on the map as the map scale. They are labeled with the file name.

If you have a mobile device running ArcPad connected to a camera and a GPS, you can use the "Capture point using GPS" button on the Edit toolbar to create a point feature with an associated picture (see chapter 3). The point feature is created from the GPS data. You are then prompted for attribute values and to take a picture. It is worth noting that if you are moving during this procedure, the point feature is created some seconds before the photo is taken, putting it in a different place. If you create a photo layer to map these photos, the camera symbol for the photo and the symbol for the point feature may lie slightly apart, as in **figure 5.7**. Both picture and point can be labeled; in figure 5.7 they are labeled with the file name and an expression to show the photo direction (Azimuth = n degrees), respectively. A graphics layer has been created to draw arrows showing the photo azimuth. V7

Figure 5.7 *Graphics layer (arrows showing photo direction) and photo layer (camera symbols) in ArcPad.*

Symbolization principles

To differentiate between geographic features, symbols need to be visually distinct from one another. Map symbols can differ in many ways such as size, shape, color, or orientation, used either in isolation or in combination. A combination of size and type can be particularly effective for linear features, by using, for example, width to denote importance, and line ornamentation to show the difference between individual features. The ESRI-style symbol set (located in ArcGIS Desktop at \Program Files\ArcGIS\Styles\) contains a range of linear styles of this kind for covering road classifications.

Symbols can represent both qualitative and quantitative information. Qualitative data allows you to distinguish between different types of features only. For example, ArcPad allows you to assign a symbol to every point in a set to show the category that it belongs to (as specified in an attribute field). Quantitative data can indicate either quantity or relative status by specifying both the amount and the kind of feature. Using symbology in ArcPad you can present a graduated symbol map, where the size of the symbol varies according to rank or progression value (e.g., cities can be represented by large circles while towns can be represented by small circles).

ArcPad can also show symbols like arrows rotated according to the value in a field (complex symbology exported from ArcGIS) and can rotate labels based on field values **(figure 5.8)**.

Symbolization and lighting

Using complex symbology in ArcPad, you can view a range of sophisticated symbol color schemes, placements, and labels. These options make the most of the mobile device available, so that on a PDA they use 16-bit color and ClearType fonts optimized for LCD screens. However, you may not be able to get the most out of this geopresentation when you are away from the relatively low lighting of the office.

TIP: It is well worth the effort to define bookmark views in advance of fieldwork so that zooming in and out of the data is quick and easy. Bookmarks can be defined on the "Previous/next extent" menu on the Browse toolbar. You can move bookmarks between ArcPad installations by copying the ArcPadBookmarks.apx file.

When choosing symbolization options for use in ArcPad, it is important to take into account the likely lighting conditions in the field. For a small computer LCD screen in the field, contrast is high in strong sunlight (if tilted toward the light) and high in low light (with some backlighting), but contrast is low in cloudy weather **(figure 5.9)**. Unless you can guarantee high contrast lighting conditions (and remember that backlighting uses more power)—consider what symbolization will work best under typical working conditions. Viewing options are even more limited if the mobile device is placed inside a waterproof wallet, which reduces contrast.

Top: **Figure 5.8** *Points symbolized with arrows rotated to show direction of movement. Bottom:* **Figure 5.9** *Low contrast on a cloudy day makes the screen hard to read.*

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To make it easy to use the device in low-contrast lighting, we recommend using a limited number of bright colors. Instead, distinctive symbols are more effective for displaying the data. It is also better to zoom into the dataset to a large scale so that the symbols are distinct from each other.

Symbolization and scale

Scale profoundly affects map symbolization. The question of what type of symbolization to use for a particular feature is a question of the scale at which it needs to be viewed.

For raster maps, the map designer makes symbolization decisions when choosing resolution, and this cannot easily be changed by the user. When zooming into the map, a point is reached when the individual raster cells become evident. It is sometimes appropriate to have a variety of raster maps loaded so that the appropriate ones can be displayed at the appropriate scales. ArcPad can define the display scale ranges to be used for a layer so that you see the appropriate raster at all scales **(figure 5.10)**.

TIP: Use a graphics layer to represent any small number of features at a small (zoomed out) scale. Design a symbol using the graphics tools, with text if needed, and set the graphics layer display scale accordingly.

Map designers also symbolize vector maps, but these maps can be changed in ArcPad. Choosing points, lines, and polygons to represent geographic features is not an absolute choice, but you need to choose relative to scale and the characteristics of the feature being represented. For example, an airport may be represented on a detailed map by a polygon symbol showing the layout of the airport and all its runways. However, at a less-detailed map scale, the same airport may be represented instead by a pictorial point symbol of an airplane. In less-detailed maps, other features will also be represented by point symbols instead of by their real shape and extent, for example, cities or hospitals.

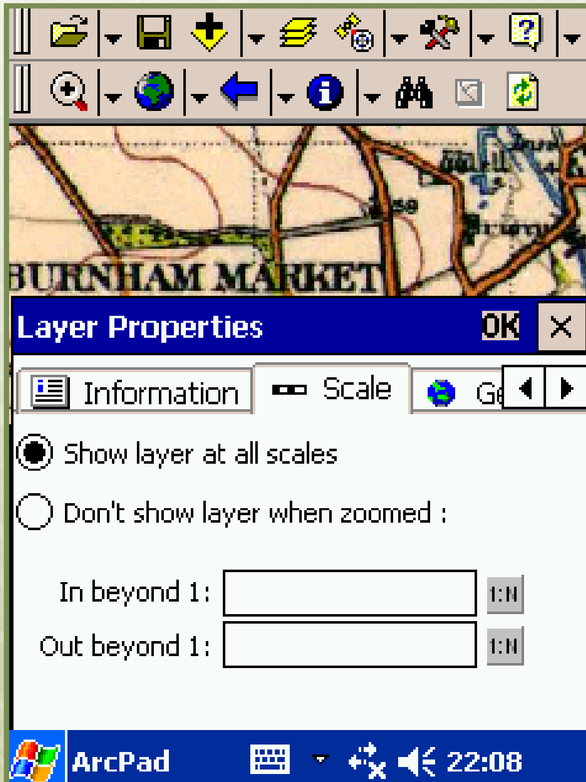

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Figure 5.10 *Setting the display scales for a raster map.*

Scale

By definition, any ArcPad representation of your data must be smaller than the land it portrays, and the map scale tells us how much smaller. The map scale is the ratio between a specified distance on the map and the actual distance this represents on the ground.

ArcPad provides three main ways to show the map scale **(figure 5.11)**:

1. As a bar scale. A line is used to measure distances on a map marked like a ruler in the prevailing units of measurement (e.g., meters or kilometers). In ArcPad a fixed length bar scale is switched on and off from the Options menu on the Main toolbar. As the scale changes, the distance represented by this bar is updated.
2. As a representative fraction such as 1:25,000. This implies that one unit on the map is the equivalent to 25,000 similar units on the ground. Therefore, if a stretch of river measures one centimeter on a 1:25,000-scale map, in reality it has a length of 25,000 centimeters (or 250 meters) on the ground. In ArcPad, the representative fraction can be found in the Status bar, which is switched on/ off from the ArcPad Options menu on the Main toolbar.
3. Through the use of a map grid. ArcPad can display a map grid superimposed on a map at a regular spacing (generated automatically). Switch the ArcPad map grid on or off in the table of contents.

Each of these scale indicators is useful in different situations.

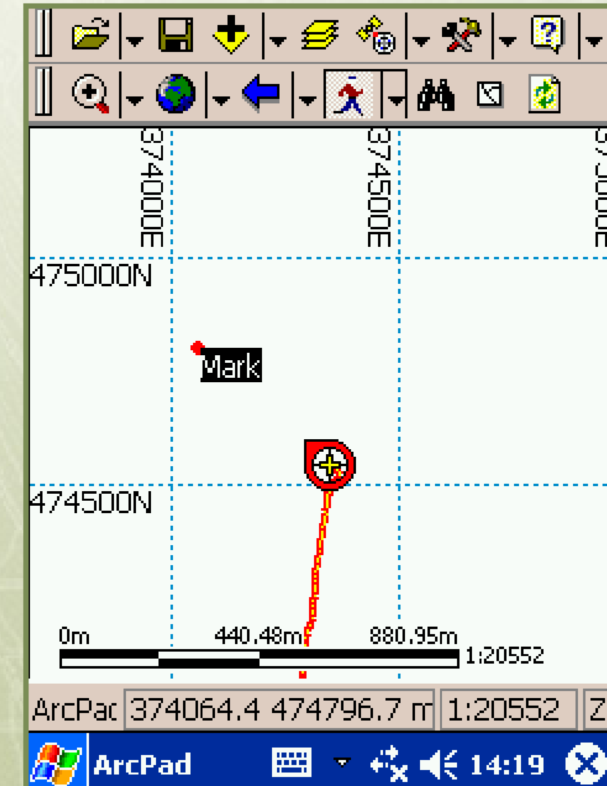

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Figure 5.11 *Scale bar, representative fraction, and grid in ArcPad.*

Map scale and display

In cartographic terminology, 1:100,000 is a smaller-scale map than 1:50,000. However, in day-to-day language we often refer to large and small scale in the reverse sense. We say that large-scale maps cover a large portion of the earth's surface, albeit with small detail. So it is important to always clarify the use of the terms large and small scale or, alternatively, to talk instead about "more detailed" (e.g., 1:5,000) and "less detailed" (e.g., 1:100,000) scales—the strategy adopted here.

Paper maps are designed and produced at a fixed scale—1:50,000 or 1:250,000, for example. This scale cannot be changed, since the data usually comes from a fixed scale source like aerial photography. However, when this map is scanned into digital form, you can choose any scale by zooming in and out. Take care to select an appropriate scale to display this digital map data because

- at more detailed scales, the map may become unreadable because the individual pixels become evident; and
- at less detailed scales, the map may become unreadable because the text is too small to read.

Sometimes you will need to use raster maps when details are unreadable (e.g., when zooming out to get an overview of a GPS track), but you will probably prefer to have other maps available.

Raster maps such as scanned USGS quad maps should always be crisp and clear when displayed at their original scale. However, it is not always the case that the scanning was done at this scale, and so the limits to zooming need to be independently established for each raster map by manual inspection **(figure 5.12)**.

ArcPad allows you to specify a reference scale in Map, Layer, and Feature or Label properties. When you specify a reference scale, the symbol and label text size will change as you zoom in or out from this scale. Specification of a reference scale at the feature or label level overrides settings at layer level, which in turn overrides settings at map level. If you set no reference scales, the symbols are drawn in

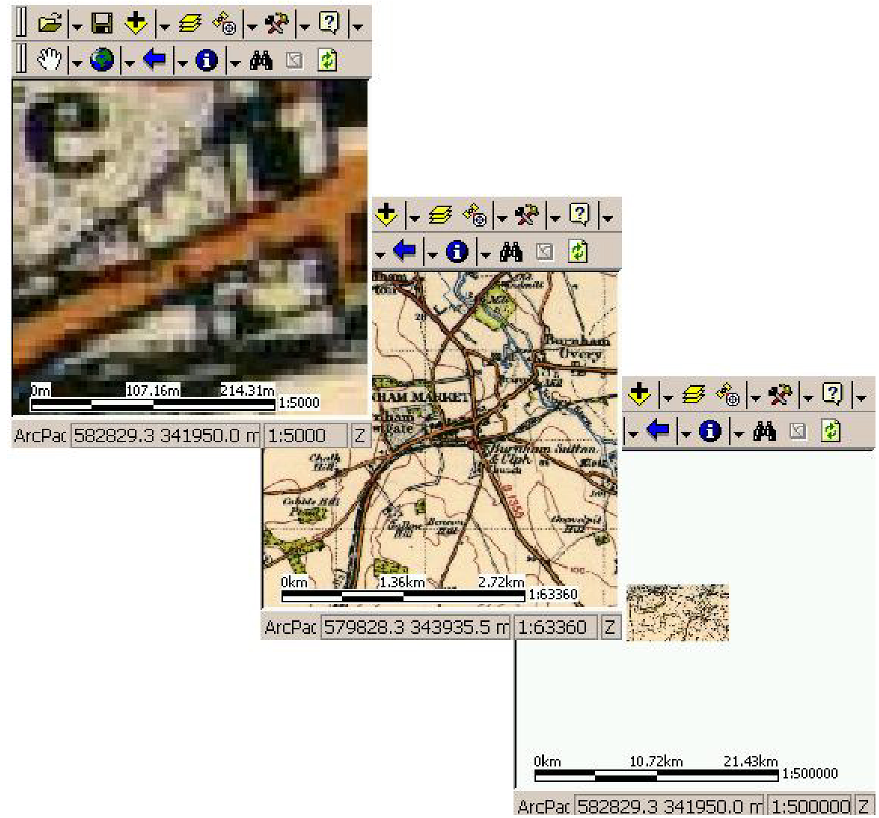

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Figure 5.12 *Suitable and unsuitable scales for map viewing.*

the point size set in the symbol properties. The problem is that at less-detailed scales, many labels and symbols drawn in a very small area can lead to potentially unreadable displays.

Map scale and generalization

Independently of the *display* scale used, you must also record and consider the original *source scale* of the data because the source scale affects the type and quantity of features represented. The amount of detail that can be shown on a map depends on the scale. Even at a very detailed scale, not all features that appear on the ground can be shown.

As the scale becomes less detailed, fewer numbers of features can be shown and the representation of features has to be generalized. Generalization is the process applied to real world features represented on a map at a given scale in order to maintain clarity. Some features will have been combined with others (e.g., several houses may be combined into a single residential block, or even omitted altogether). It is also possible that essential features, such as a lake in an area with scarce water resources, are enlarged or exaggerated with respect to their true size.

Another important effect of generalization is that as scale is reduced, line length (or the perimeter length of polygons) changes. As a line gets generalized, it will tend to lose part of its "wigglyness." As it gets straighter, it will also become shorter.

When using ArcPad, generalization effects are most evident when bringing together datasets derived from different source scales. **Figure 5.13** shows a vector coastline that matches poorly with a raster map when zoomed in. If necessary, the vector coastline can be edited using the Resize option on the Feature properties menu.

Figure 5.13 *Overgeneralization of the vector coastline has led to a poor fit with the underlying image.*

Labeling in ArcPad

ArcPad can label point, line, and polygon features using the contents of an attribute field. Labels are controlled from the Layer properties, Labels tab where all properties can be set. Labeling can be

- direct, when the values are taken straight out of a field; or
- V7 computed, when the values are taken from an expression (e.g., one numeric field divided by another).

Computed label values are limited to a single line of code using the current ArcPad scripting language (e.g., VBScript), which is set in the Scripting tab of the ArcPad Options menu. V7

V6 The Labels tab describes size, color, and scale ranges for the label display. V6

V7 The Labels tab contains labeling options including the following:

- No labels
- Labels using field [choose field]
- Labels using an expression (e.g., for the ArcPad tracklog, the expression "PDOP " & [PDOP] will place a label like PDOP=10.5 as in **figure 5.14**)

Access the Symbol Properties by clicking the red A to the right of the "no labels" option (not active if the "no labels" option is selected). The symbol options include the following:

- Style choice from the available style sheets
- Color and background color
- Font and character set if not ANSI (e.g., for Arabic or Chinese)

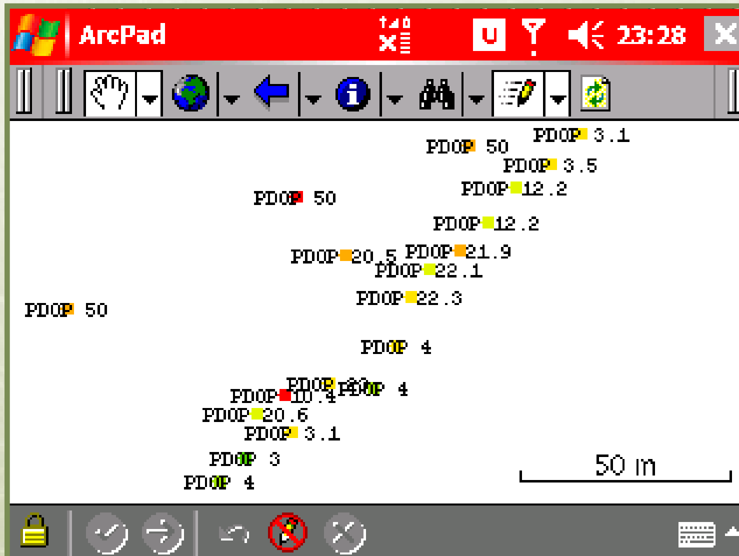


Figure 5.14 *Labeling example using an expression.*

- Placement choices for a point label (8 compass points around the symbol or a central position that overwrites the symbol) or a line label (vertical and horizontal positions)
- Scale limits on the display of the labels. V7

TIP: By manipulating the label expression, the font, and symbol, you can achieve some advanced placement effects. Using the "PDOP" expression above, you can fit a color point symbol into the space, with PDOP on one side and the value on the other.

EXERCISE
GRAPHICS LAYER

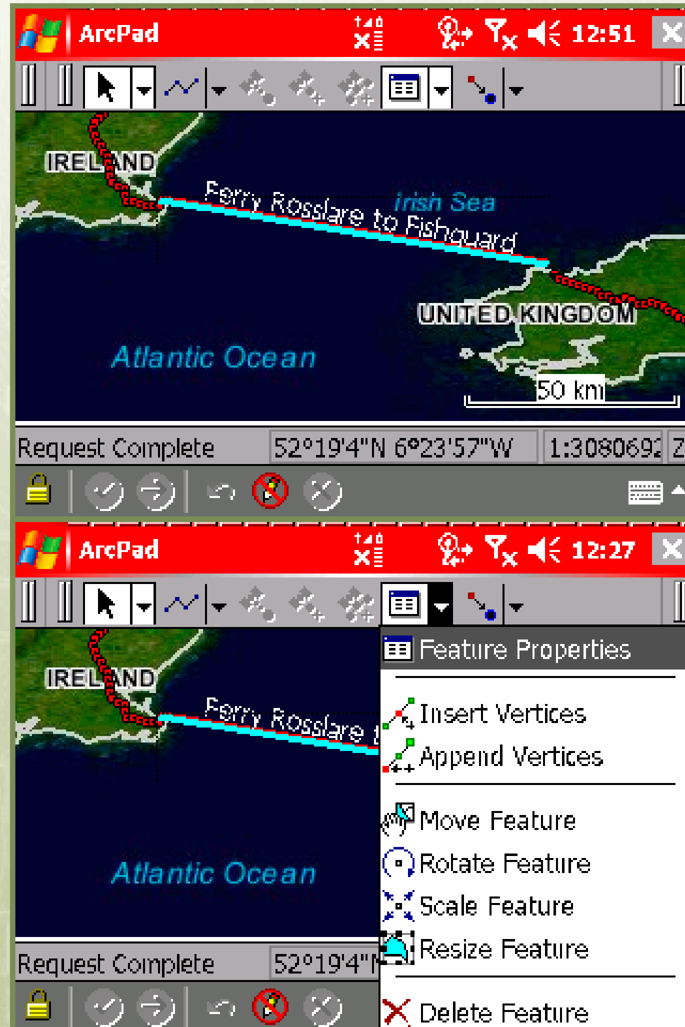
Using graphics layers is a useful way to create georeferenced features when you need to digitize small numbers of features from imagery or when you need to construct features using geometric shapes. These features can then be imported into ArcGIS as a graphics layer. Complete this exercise to explore this feature.

Requirements

- ArcPad 7 on Windows desktop or Windows Mobile

Exercise

1. Open ArcPad in Registered or Demo mode and select the option Open a new empty map. You should now see the basic interface with no data loaded.
2. This exercise shows you how to create a graphic feature to complement existing geometric data. To illustrate this process, you can load a layer from the Main toolbar: choose Add layer > Add Internet Server. Now you can draw a graphic feature or use any other suitable georeferenced source. In this case **(figure 5.15a)**, an unmapped ferry journey was drawn as a graphics line to join two terrestrial tracklogs.
3. Now that you have chosen the layer you will use as a source for the drawing, you need to create a new graphics layer from the New menu on the Main toolbar. Once created, you will notice that it is named and selected in the Edit menu on the Browse toolbar, and that it has an .apg extension. You can also access all of the tools on the Edit toolbar, including the drawing tools.
4. Select a drawing tool and draw a graphics feature. You can move, rotate, scale, or resize the feature as drawn, and you can also append or insert vertices **(figure 5.15b)**. Under Feature properties you can label the feature and control the symbology.



Top: **Figure 5.15a** *Drawing a graphic feature to join two disconnected tracklogs. Bottom:* **Figure 5.15b** *Editing options for a graphics feature.*

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5. To save the contents of the graphics layer you need to select it again in the Start/Stop Editing drop-down menu on the Browse toolbar: this will save the edits you have made and switch the editing state to inactive. Now copy the APG file you have created onto a device running ArcGIS (e.g., using ActiveSync/ WMDC or Bluetooth).
6. In ArcGIS you need to activate the ArcPad toolbar (View>Toolbars>ArcPad) and select the option Import an ArcPad Graphics layer document into the Graphics layer. This opens a file dialog box from which you can choose the APG file you created in ArcPad. Once you have imported the file, it will be drawn in the current ArcGIS data frame over any data you have loaded there **(figure 5.15c)**.
7. ArcGIS graphic features can be converted to shapefile features using third-party extensions like Xtools Pro or TypeConvert software.

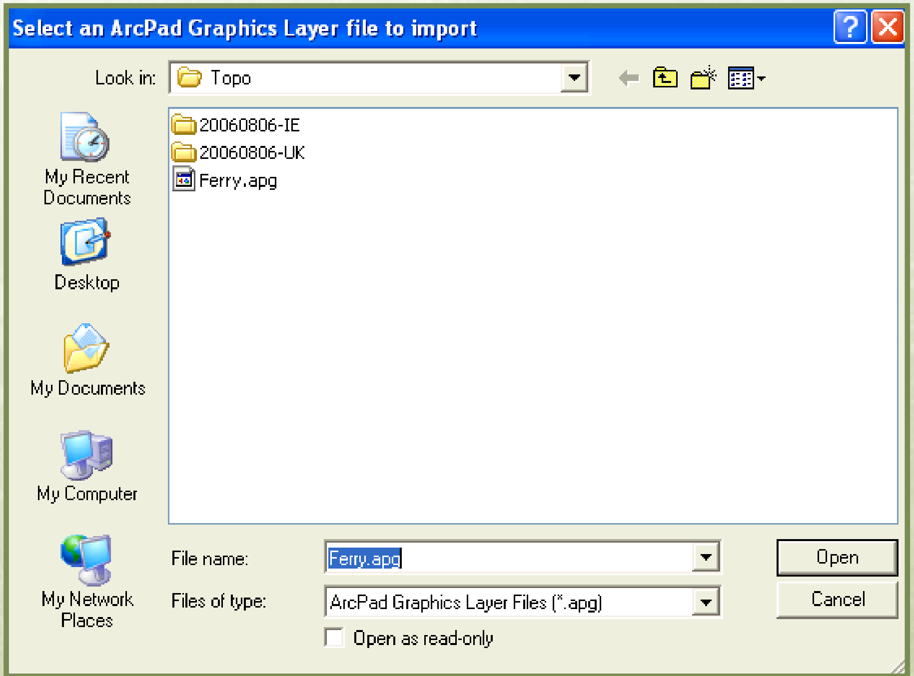

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Figure 5.15c *Importing an ArcPad graphics layer into ArcGIS.*

Presenting data in context

Effective geopresentation involves making design decisions about symbolization, styles, photos and graphics, scale, and labeling, all of which require special consideration on mobile devices. The advantage of getting field geopresentation right is that you can see and understand your data in context by being immersed in it.

Presenting data in its geographic context is a key requirement of mobile GIS projects, since you typically need to capture data and make decisions in real time. In ArcPad, the ability to display GPS tracks over georeferenced datasets and to keep the display centered on the current position allows real-time verification of location, speed, and progress toward an objective. Geopresentation should never be neglected: it provides a range of techniques for speeding up mobile GIS and for improving the effectiveness of its operations.

CHAPTER 06

Customization for mobile applications

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This chapter describes how you can customize the ArcPad environment to create a user-friendly interface for collecting data. Collecting data in the field is one of the primary uses for ArcPad across a wide range of industries such as public and private utilities, local government, and environmental consultancies. This chapter describes how mobile GIS technology has been used in the Swiss National Park (SNP) **(figure 6.1)**. The requirements and solution are unique in terms of location and organization, yet the principles of customization for data collection are broadly applicable wherever and whatever your situation.

As you customize ArcPad, you create an environment that is less a generic mobile GIS and more a made-to-order tool designed for a specific job. Customization of the interface can hide higher-level functionality that the intended user will not require and add tools that they will need. Custom tools can be created, using a little scripting, to extend the functionality of ArcPad beyond its out-of-the-box capabilities. You can create forms and link them to editable data layers to store information collected in the field. Back at base, this information can then be transferred and used without the need for conversions, seamlessly integrating mobile and desktop GIS.

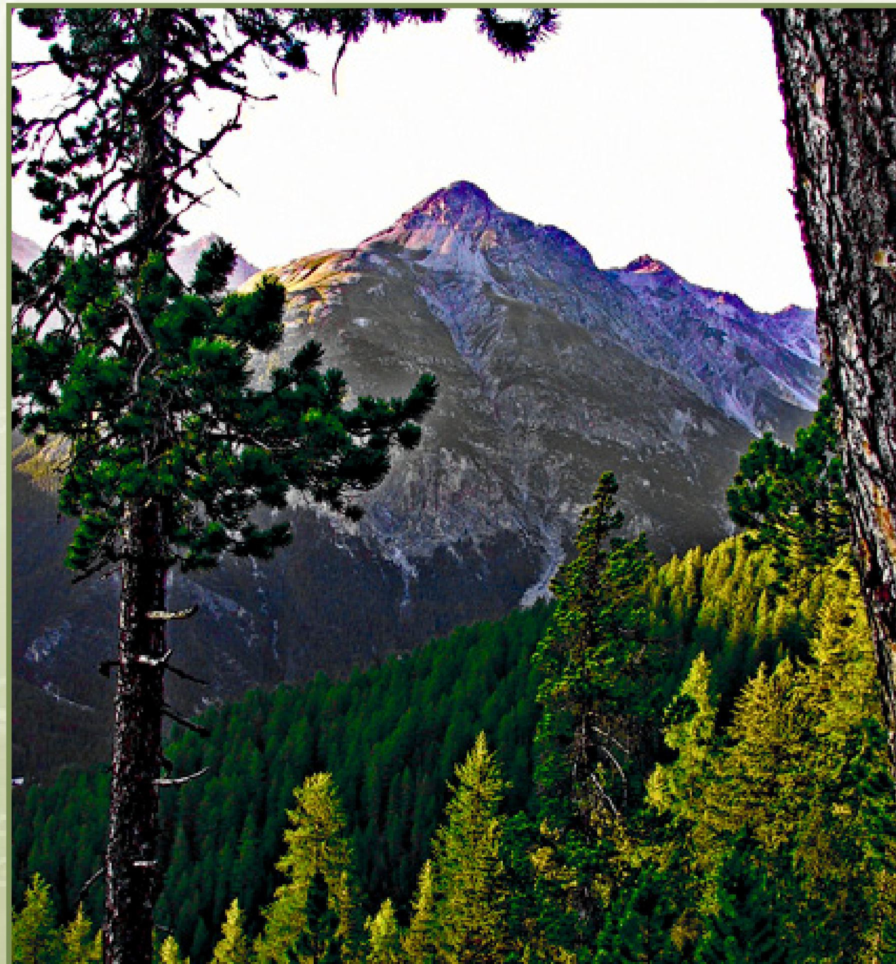

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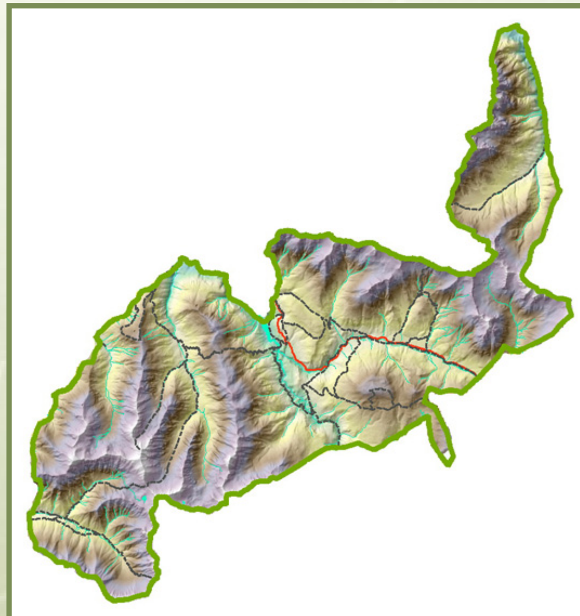
Figure 6.1 *The Swiss National Park—a protected alpine nature reserve on the Swiss-Italian border.*

Animal observation in the Swiss National Park

The Swiss National Park (SNP) is a protected alpine nature reserve on the Swiss-Italian border. Visitor access to the park is restricted to a network of trails and a primary aim of the park administration is to ensure that human impact is kept to an absolute minimum. Within this environment, the flora and fauna are left to their natural development, thus providing researchers opportunities to make wildlife observations. This chapter will consider how to customize ArcPad to collect observations in the field and create a database that can be used for administrative, tourism, and research purposes.

The need for animal observation in national parks

The SNP **(figure 6.2)** has close ties with academia and the park often makes the stored data available to academic researchers. For example, researchers have studied variations in the distribution of animals over time and compared this pattern to possible causes such as annual changes in the availability of food and vegetation cover for concealment. From these observations, researchers can also study the impact of visitors, for example, the annual and diurnal variation of animal ranges compared to the volume and location of visitors.



Courtesy of Swiss National Park

Figure 6.2 *The dramatic topography in the Swiss National Park (gray= high ground, yellow= low ground) and the network of trails (shown as broken gray lines).*

GPS tagging: Researchers devote a great deal of time and effort to collecting data that describes the movements of animals within the SNP. For larger animals, they have introduced a GPS tagging program that can eliminate some of the sampling bias associated with human sightings. Because radio GPS units are expensive to buy and attach, they cannot be fitted for all animals—they are reserved for a sample of the ungulates (deer) in the park. This GPS monitoring occurs in conjunction with human observation, which can reveal more about the group dynamics of animal behavior.

This research helps us to understand animal behavior and has led to many publications about the relationship between animals and their environment. For the park administration, the results can indicate where and when visitors are potentially having adverse impacts on wildlife, prompting administrative actions to alter this. To achieve this level of understanding, we need precise and accurate datasets with a uniform set of attributes that describe the times and locations of animal observations.

Animal ages: The SNP uses different age categories for different animals based upon the easiest way to discern age in the field. For female red deer, only two age categories are defined ("1 year old" and "2 years or older"). The age category for mature males is based upon the number of "crowns" (antlers with three tips) that the deer possesses, either none, one, or two. All deer less than a year old are classed as "juveniles" and no gender is specified.

Drawbacks of the paper-based approach

Paper-based field observations have a number of drawbacks, such as limited locational accuracy, since the data collector may be unable to describe the position with the required degree of precision. This could be due to unfamiliarity with the environment or a limited ability to interpret maps from inexperience or adverse weather conditions. Potentially, data collectors could introduce errors when finding the grid reference associated with a point on a map, and the precision of the reference will be limited by the scale of the map used. With the transfer of information from paper to the digital environment, the risk of transcription errors exists. This risk is increased if the person entering the data into the database is not the person who originally recorded the observation. At this stage, we may find that different collectors have interpreted a paper-based form in different ways; hence, not all records have a standard set of fields. Manually entering paper-based records into a database results in a time lag, so the database may not be up-to-date.

The ArcPad customization solution

Using mobile GIS can overcome many of the problems just described. Integrating a mobile GIS running on a personal digital assistant (PDA) with a global positioning system (GPS) leads to less opportunities for errors associated with reading a grid reference from a map—and the error of the GPS signal is typically less than 20 meters (differential correction can reduce this to a meter). Observers are also able to visualize their positions on the map displays on which the PDA assists navigation.

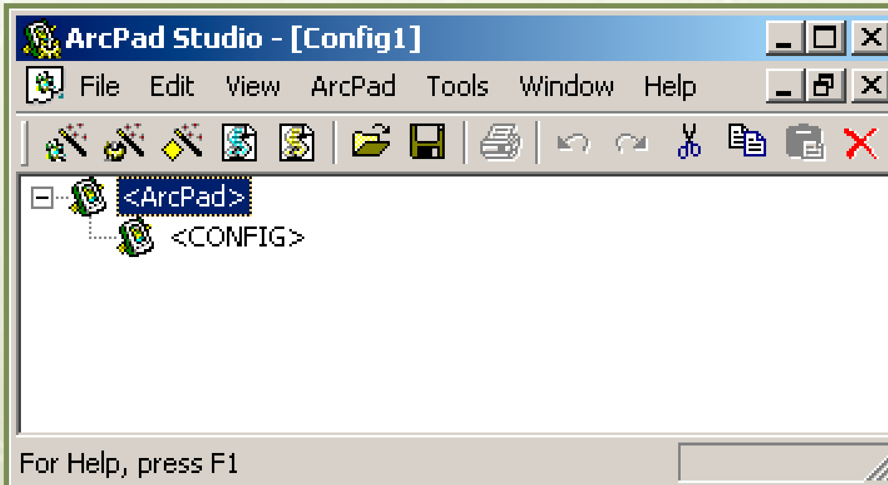
Data recorded in the field can be transferred to the desktop environment rapidly to eliminate transcription errors and reduce time lags.

This chapter describes how these benefits can be achieved by doing the following:

- Planning the hardware and software environments
- Integrating the mobile GIS with desktop GIS
- Customizing the mobile GIS environment to perform specific tasks using ArcPad Studio (an application included with ArcPad Application Builder)
- Handling GPS data within ArcPad

The real-life solution described in this chapter was implemented using a PDA with 64 MB RAM running Windows Pocket PC 2003. For positioning, a GPS receiver is connected to the PDA via a serial port connection. The software required on the PDA is ArcPad version 7, plus any drivers needed to establish a connection between the PDA and GPS. On the desktop, ArcPad Studio (Application Builder) version 7 is used for the ArcPad customization **(figure 6.3)** and ArcCatalog to manipulate spatial data.

You can customize ArcPad using ArcPad Studio, a desktop application that is part of ArcPad Application Builder, a development product for customizing the ArcPad environment.



G-ability Ltd. with permission

Figure 6.3 *ArcPad Studio Application Builder.*

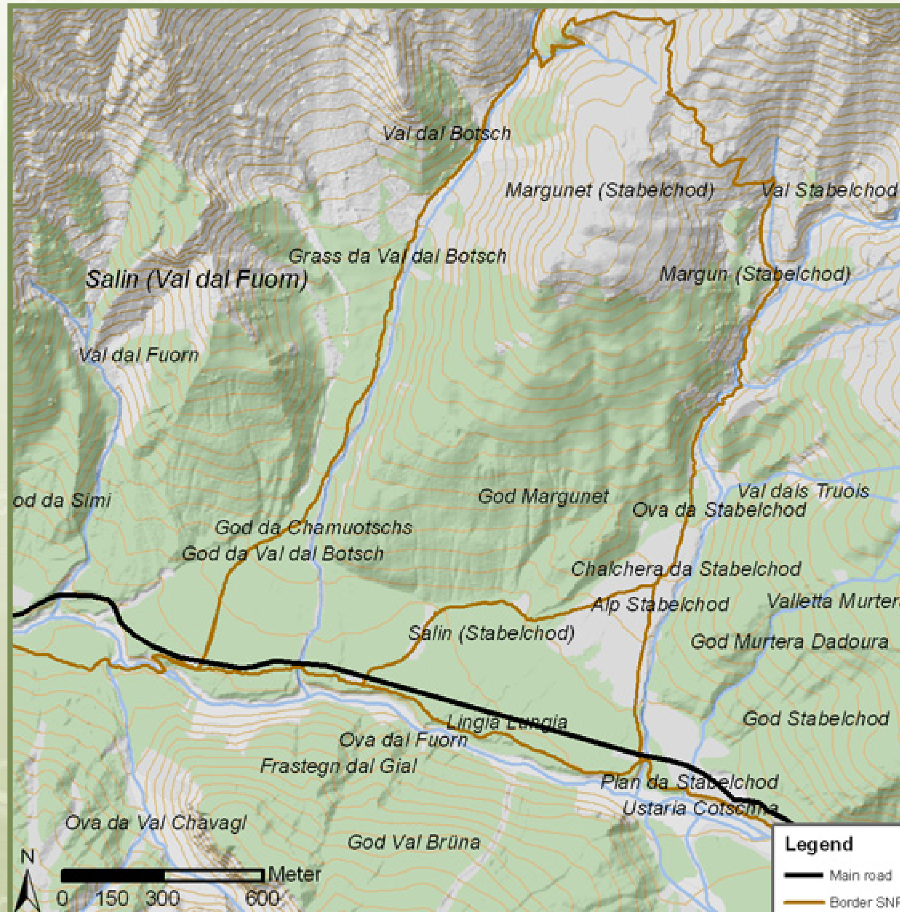
Our animal observation application needs to be able to do the following:

- Load all required datasets at once, including a data layer that stores the observations
- Have a form associated with the data layer that allows the observer to enter the observation attributes
- Record the observation time and location automatically, as well as information about the observation
- Make the interface more intuitive by removing unwanted functionality and implementing custom tools

Each of these tasks will now be considered in detail.

Defining layers

To record animal observations in the field, we need at least two data layers. The first is an existing topographic basemap **(figure 6.4)** that covers the area over which data will be collected. The observer uses this layer to identify the exact location of each observation. The second layer is an editable point shapefile used to store the location, times, and attributes of the observations themselves.



Courtesy of Swiss National Park

Figure 6.4 *Topographic basemap of the SNP used by the data collectors to orientate themselves and position animal observations.*

We create the second storage layer as a new point shapefile in ArcCatalog by selecting File > New > Shapefile. Then we define spatial reference properties explicitly or import them from the basemap as shown in **figure 6.5**. This layer will store not only the spatial location of the observations, but their attributes as well. By double-clicking the shapefile in ArcCatalog and selecting the Fields tab, we can add the required attributes by entering a field name and selecting the appropriate data type.

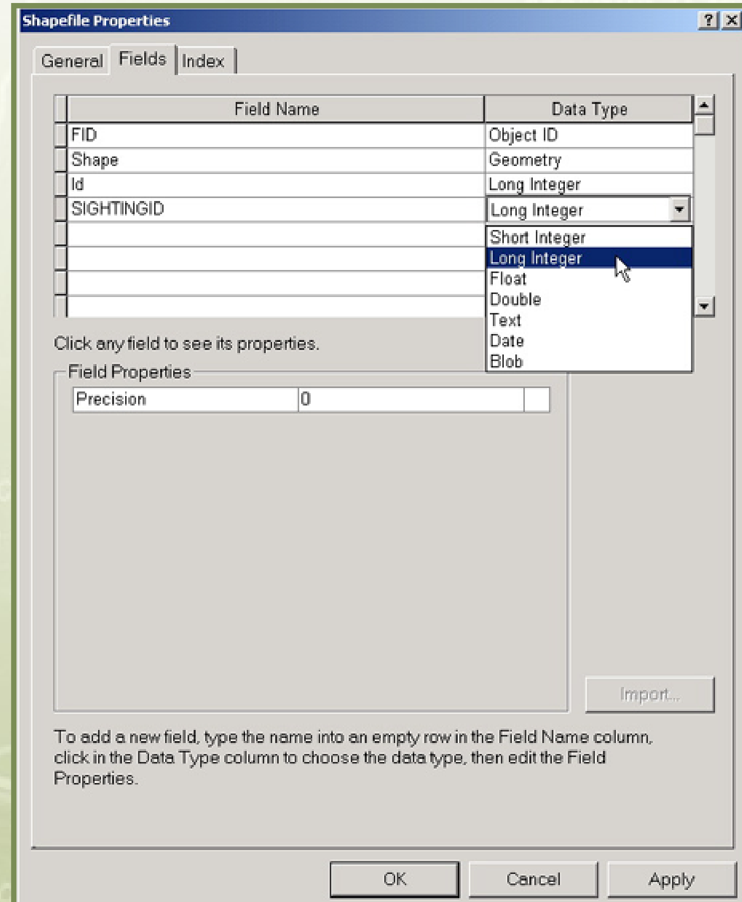
For recording animal observations, the following attribute fields are required:

- Observation (sighting) ID
- Date and time of the observation
- Observer (ranger) ID
- Observer's location

Finally, we add a series of fields that record the number of each category of animal seen. Each of these fields represents a different combination of species, gender, and age (e.g., Red Deer, female, 2 years or older).

We created the fields to meet the requirements outlined above; however, it may not be until the form used for data collection has been finished that the final fields are known. ArcCatalog allows you to delete a shapefile's fields and add new ones so the fields created at this stage need not be final.

Now that the two required layers have been defined, they can be grouped together as a single ArcPad map document. To do this, open ArcPad, select the Add layer tool, select the basemap and point shapefile



Courtesy of David Mountain

Figure 6.5 *ArcGIS dialog for adding new fields to a shapefile.*

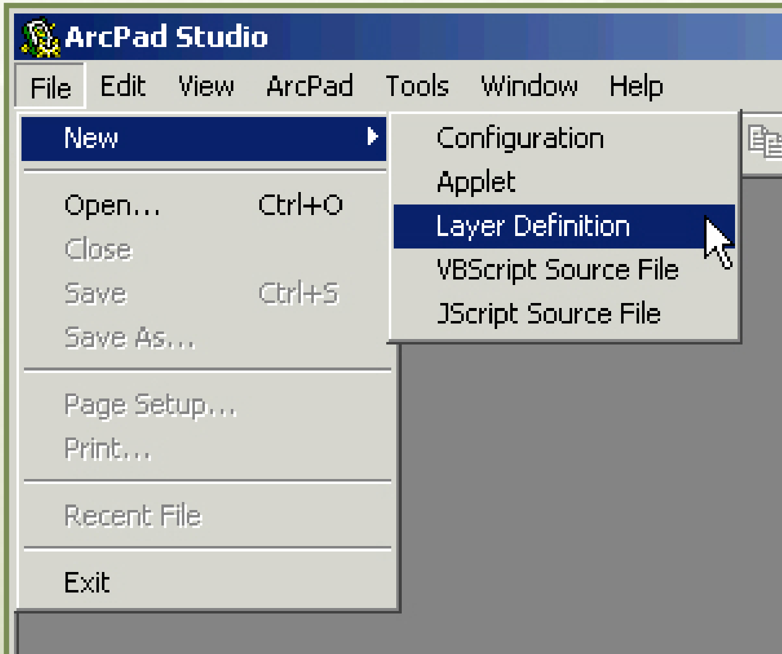
layers, then select "Save the map" and choose an appropriate name and location. In the future, instead of adding each layer individually, all required layers will be loaded when the map document (.apm) is opened.

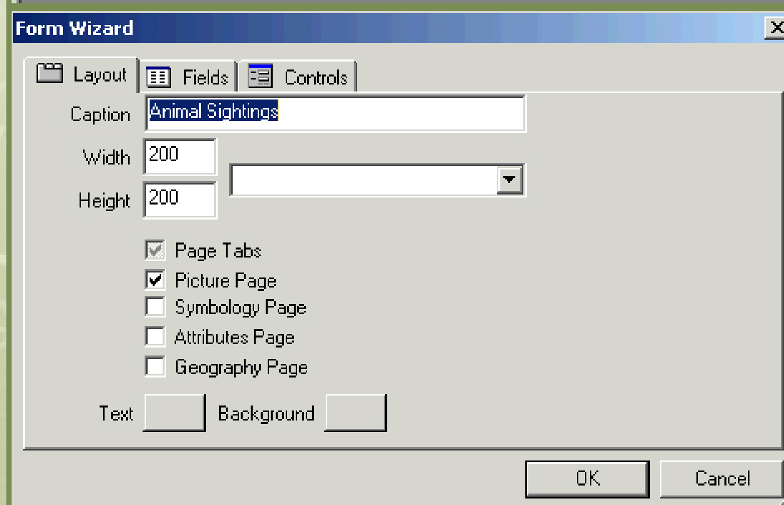
To ensure that the links to the different layers and the ArcPad map work on the PDA as well as the desktop, they should be in the same relative location in both places. The easiest way to do this is to store all data layers (and associated layer definition files and scripts created subsequently) along with the ArcPad map document in a single directory.

Creating a form for adding observations

Now that a point shapefile exists to store the animal observations, we use ArcPad Studio to create the form the observer will use to store individual records. In ArcPad, a form allows a user to enter attribute information via text fields, combo boxes, and other graphical user interface (GUI) components. Each form can consist of several pages to overcome the size limitations of small screen devices. A layer definition file is used to associate a form with a specific shapefile **(figure 6.6)**, so that the data entered by an observer can be stored directly to that shapefile's attribute (.dbf) file. The layer definition file can also associate other customizations with the shapefile, such as Visual Basic scripts, described later in this chapter.

We created layer definition files in ArcPad Studio where we specified the layer's associated shapefile (the point shapefile created in ArcCatalog). The layer definition file has the same file name as the shapefile with the extension .apl. Use the Form Wizard to create a default form **(figure 6.7)**: first define the form caption and size. You will be asked for the screen resolution of the target device, and can additionally specify the dimensions of the form window. For long or complex forms,



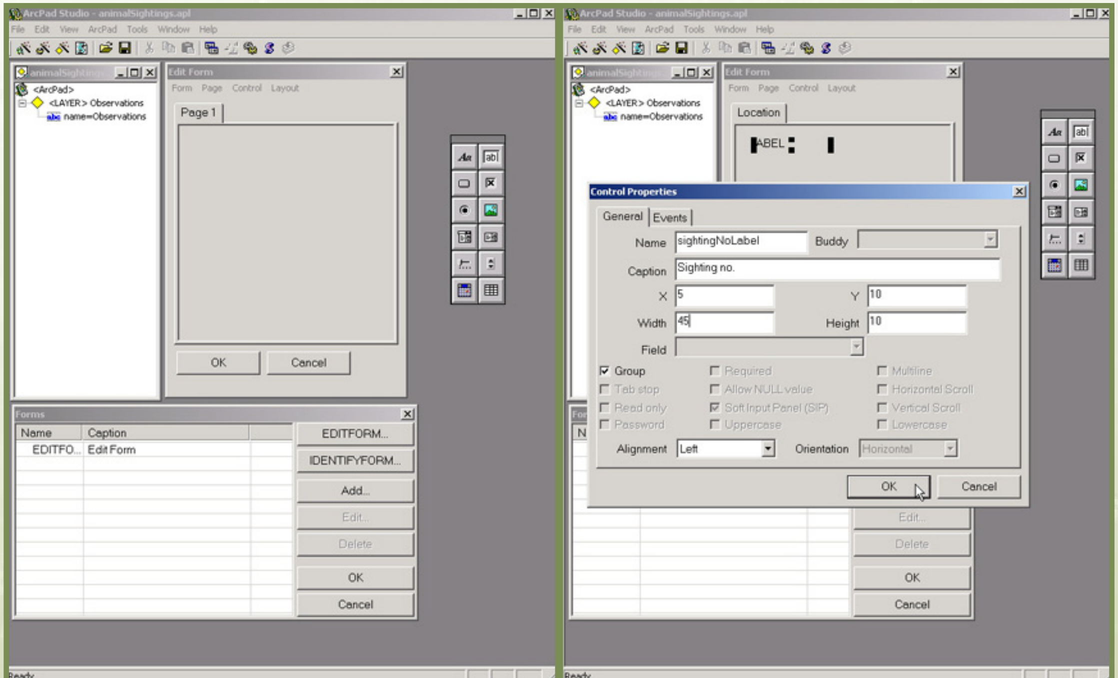


Top: **Figure 6.6** *Creating a new Layer Definition file (.apl).*
Bottom: **Figure 6.7** *The ArcPad Studio form wizard interface.*

Courtesy of David Mountain

you may need to increase the default width and height to a size that fills more of the available screen space.

By selecting the Fields tab in the Form Wizard, you can select or deselect the fields that will appear in the form. By default, all selected fields will be included in the form, over a series of pages. This works fine for very short forms where perhaps only two or three fields are required; however, to make complex forms more usable for the field data collectors, you may need to override the default wizard and design the form layout yourself.



Courtesy of David Mountain

Left: **Figure 6.8** *Editing a new form in ArcPad Studio. Right:* **Figure 6.9** *Editing a form control in ArcPad Studio.*

To design a form from scratch, the first step in the Form Wizard is clearing the checkboxes next to all of the fields—this will produce an initially blank form. After clicking OK to complete the wizard, you can see the new layer in ArcPad Studio in the form of a hierarchy, listing associated forms and scripts.

Adding basic controls to the blank form

You can edit the default form created by the wizard by selecting the Forms button from the ArcPad Studio toolbar and clicking on the EDITFORM button. You can modify the single-paged blank form created by the wizard using the controls (labels, text boxes, and other GUI components) available from the control palette **(figure 6.8)**. Use the Page menu to edit a page's name and caption and to add new pages to the form.

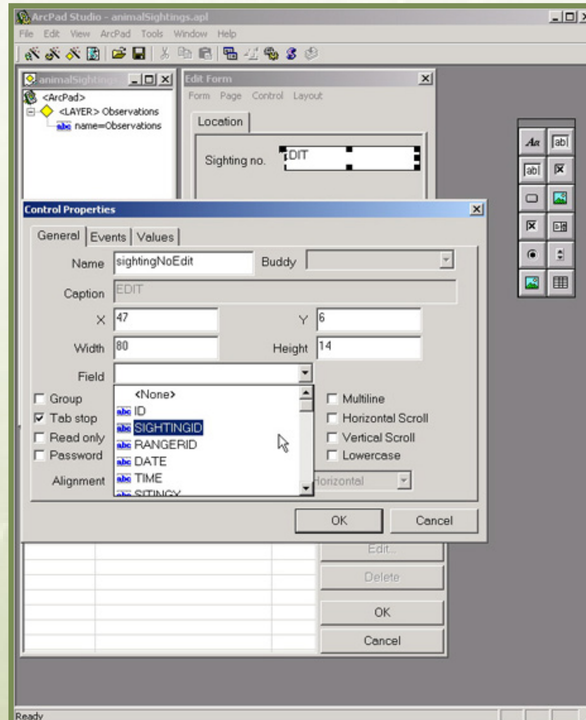
In ArcPad Studio, you can add a control by dragging it from the control palette to the page. When you release the mouse button, a dialog box will pop up. Here you specify the control's name, caption, and precise location, for example for a label **(figure 6.9)**. Labels simply annotate the page; however, for the controls where the user enters observation data (such as text boxes), this information must be saved to one of the fields in the layer's data table. For the animal observations application this is the editable point shapefile's attribute table (DBF file). The value provided by the user through the control can be linked to a field. When you save the form in ArcPad by clicking OK, the contents of the edit box will be stored to this field in the shapefile **(figure 6.10)**. If no suitable field exists at this stage, one should be created as described in "Defining layers" section above.

For some controls, the observer may be allowed to enter any text values, such as field notes. Others may need to be more restrictive. Dates and times can be written in various ways (e.g., 23 Nov 1974, 23/11/74, or 11-23-1974), and it is easy to make errors typing these by hand. A DATETIME control is available to allow the user to enter times and dates in a standardized way. You can set a control or, as we describe in the next section, write a Visual Basic script to take the present time and date taken from the system clock.

Controls with restricted options

For other controls where the available options should be restricted, you can predefine a set of options for the observer to choose from in a combo box or drop-down menu. To do this, you create an attribute file that specifies the captions to be shown in the drop-down menu and the associated values to be stored; most spreadsheet and database software can perform this task **(figure 6.11)**. Whenever the observer enters the numbers of any one type of animal seen, the options can be limited to between 0 and 9 for most practical purposes. The contents of the attribute file require that the captions be stored as text and the values as integers.

Now that the captions and values have been defined, you can add a combo box to the form. The appropriate attribute file can then be selected (under the List Values tab) so that the values and captions fields are set automatically. Selecting "Limit to List" prevents the user entering other values, and a default value for the list can be added under the Values tab.



Courtesy of David Mountain

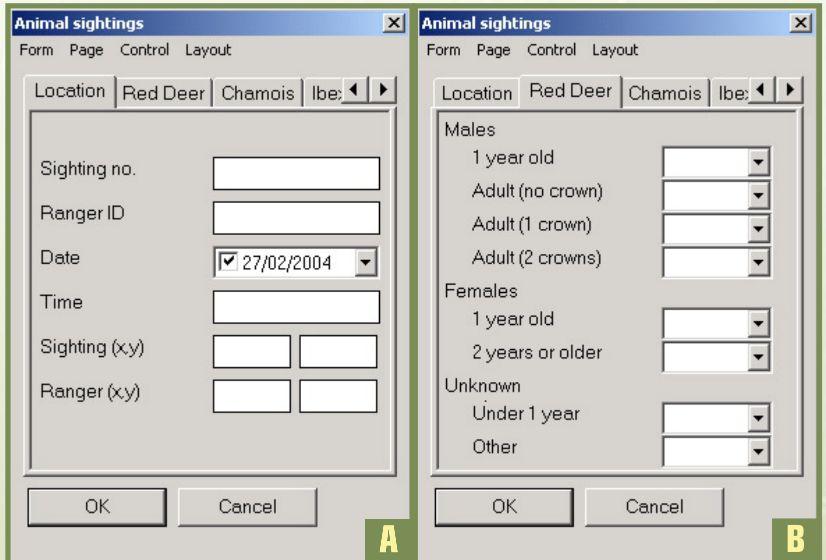
Above: **Figure 6.10** *Linking the control's value to a field in the layer's data table in ArcPad Studio.*
Below: **Figure 6.11** *The contents of a DBF file opened in a spreadsheet editor.*

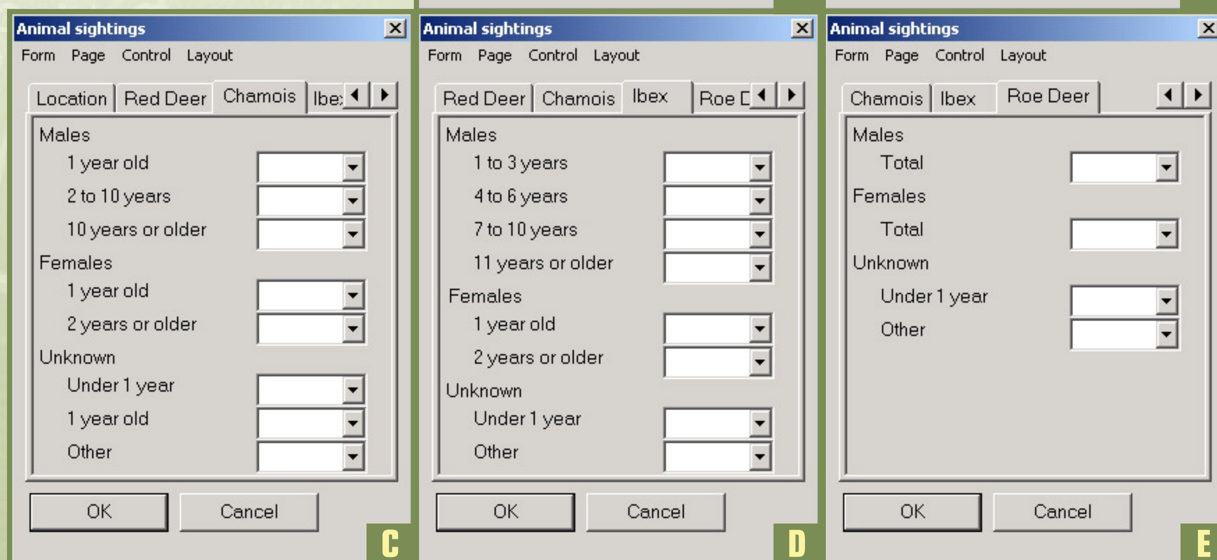
	A	B
1	NTEXT	NINT
2	0	0
3	1	1
4	2	2
5	3	3
6	4	4
7	5	5
8	6	6
9	7	7
10	8	8
11	9	9
12		

In this way, you can build the form until all the required pages and controls have been defined for the data-collecting task. The five pages created for collecting animal observations in the SNP are shown in **figure 6.12**. The user selects the number of each category of animal sighted from the combo box. For many of the fields on the first page however, it is more efficient and accurate to set the values automatically. For example

- The observation number should be unique and can be calculated automatically by adding "1" to the last observation.
- It would be time-consuming for observers to have to enter their IDs for every observation; this can also be read from the last observation and modified if necessary.
- The date and time can be set from the system clock.
- The location of the observation can be taken from the user's click on the map.
- Finally, the location of the observer can be taken directly from the GPS data.

The next section will discuss scripting in Visual Basic, and how a little programming can increase the efficiency and accuracy of data collection.





Courtesy of David Mountain

Figure 6.12 *The five-page form for recording animal observation in the SNP: (a) Spatial, temporal, and ID information; (b) Red Deer sightings; (c) Chamois sightings; (d) Ibex sightings; (e) Roe Deer sightings.*

Custom functionality using scripts

Scripting allows developers to further customize the ArcPad environment by accessing the ArcPad object model. Various development languages are available, although not all are supported on all platforms. One of the most popular approaches for developers is customizing ArcPad using Visual Basic scripts (VBScripts), snippets of which will be provided throughout the remainder of this chapter. JScript is another, increasingly popular, approach to customizing ArcPad, and both VBScript and JScript samples can be downloaded from the ArcScripts Web site.

ArcScripts: For potential developers who have never used a scripting language before, the ESRI support center provides a large number of free scripts to use **(arcscripts.esri.com)**. If an existing script is not a perfect match, it can often be used as a template, and minor adjustments can make it suitable for specific data layers and application requirements.

You can view the full object model by selecting "Object Model Diagram" from ArcPad Studio's Help menu. The model consists of groups of objects that give you control over the application itself (including the map and layers), geometric objects (such as points, lines, and polygons), forms, and other objects such as an incoming GPS stream. With a small amount of scripting, the customized application can launch forms automatically, retrieve coordinates from the map or GPS stream, get the time and date from the system clock, or query a shapefile to enter some form values automatically.

Customizing the interface

So far we have dealt exclusively with the layer file associated with a particular shapefile. This allows us to design forms and to associate scripts with the layer, but it does not allow us to customize the ArcPad interface. In order to do this, we must define a new configuration file. In ArcPad Studio, select File > New > Configuration to create a new configuration. To add a new tool to this configuration, first create a custom toolbar by clicking the Toolbars button. By default, the Main and Browse toolbars are already available to the user, but the Edit toolbar is not. Create the new toolbar by selecting Add and entering a name and caption. Save the configuration file with the file name ArcPad.apx in the ArcPad system directory: this is usually Program Files\ArcPad\System on both desktop and PDA. In the future, whenever ArcPad starts, it will use this new configuration. If you want to return to the previous configuration, keep a copy of the original ArcPad.apx file. Next, we will write a script that will be associated with this configuration file and link it to a custom tool.

Custom toolbars: For the animal sightings application, the user is allowed access to all the functionality provided in ArcPad's Main and Browse toolbars. However, these toolbars can be hidden and the required, existing ArcPad functionality added to a custom toolbar. This presents a simpler interface for less experienced users.

Adding scripts

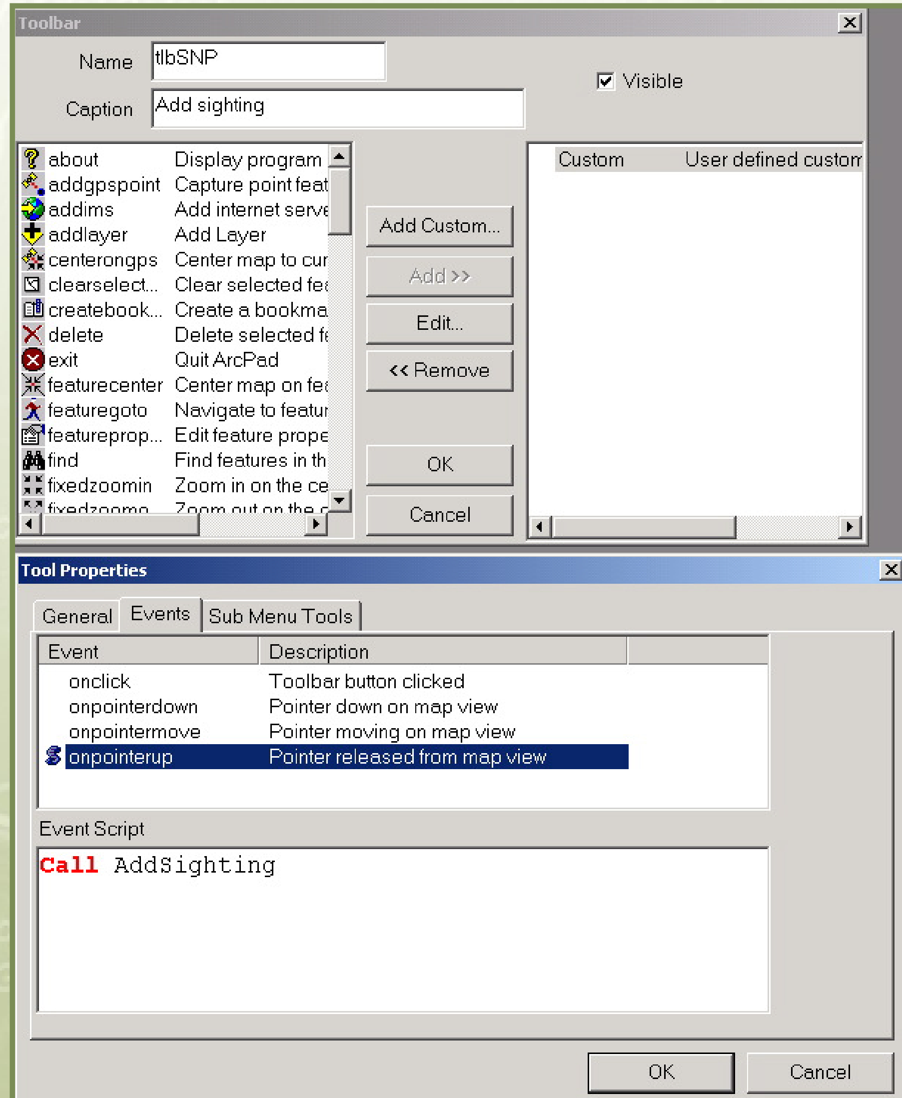
The first script we consider here has a subroutine (Visual Basic code describing a procedure), called AddSighting, that runs whenever the observer selects a custom tool and clicks the map (**figure 6.13**). AddSighting checks that the required data layer is present, gets a location (in the coordinate system of the map) described by a user's onscreen click, and brings up the form to allow the user to enter attribute data.

Figure 6.13 *Code sample: The AddSighting VBScript.*

```
Option Explicit

' Checks that the required layer is present,
' and adds spatial and attribute data to the
' shapefile by utilising a form

Sub AddSighting

 'Get a reference to the tool button object
 Dim objToolButton
 Set objToolButton = ThisEvent.Object

 ' blnLyrExists stores whether Animal Sightings is
present (true) or not (false)
 Dim blnLayerExists
 blnLayerExists = False
 Dim objLyr
 For Each objLyr in Map.Layers
 If StrComp (objLyr.Name, "animalSightings", 1) = 0
Then
 blnLayerExists= True
 Exit For
 End If
 Next

 ' If Animal Sightings layer does not exist:
 ' Notify the user, return the tool button to its
original state, and exit.
 If Not blnLayerExists Then
 MsgBox "The Animal Sightings layer is not present in
the current map.", vbExclamation, "Layer not present"
 objToolButton.Click
 Exit Sub
 End If

 'If the Animal Sightings layer does exist:
 'Get the coordinates of the map where the user
clicked
 Dim dblX, dblY

 dblX = Map.PointerX
 dblY = Map.PointerY

 'Get a reference to the Animal Sightings Layer object
 Dim objLayer
 Set objLayer = Map.Layers("animalSightings")

 'If the layer can be made editable, make it editable
 If objLayer.CanEdit Then
 objLayer.Editable = True
 ' Add a new sighting (point feature) at the clicked
location (dblX,dblY)
 ' The 'True' value states that the edit form should
be shown
 Call Map.AddFeatureXY(dblX,dblY, True)
 ' Return button to "off" state
 objToolButton.Click
 End If

End Sub
```

To add scripts, click the "Edit Script" tool button, enter the code that comprises the VBScript (in this case, to add an animal sighting, and close the window choosing to save changes. Once done, a script "ArcPad.vbs" should be visible under the <SCRIPT> tag in the configuration file. Some of the specifics of this code will be discussed later; however, first we will link the script to the tool so it is launched when the user clicks the button.

To add a custom tool to the new toolbar **(figure 6.14)**, select the Edit toolbar icon once more then choose to edit the new toolbar. Clicking on Add custom adds a tool to the toolbar. Specify a name and select a button



Courtesy of David Mountain

Figure 6.14 *Adding a custom tool in ArcPad Studio.*

icon (in the form of a bitmap file); some icons are available within ArcPad, but any suitable bitmap files can be used. The Events tab defines what happens when the user clicks the button on the screen. For the SNP animal sightings application, the subroutine should be called when the user takes the stylus off the screen (the end of a click). This is specified by selecting "onpointerup" and, in the Event Script panel below, typing **Call** (a Visual Basic key word), then the name of the subroutine (AddSighting) that you wish to run when the button in pressed **(figure 6.15)**.

Figure 6.15 *Code sample: the Animal Sightings VB Script, which fills many of the fields that are predictable (such as the Observer ID and Sighting ID), time-consuming to enter, or a likely source of errors (such as timestamps and locations).*

```
Sub InitializeForm
 Dim objEFPageOneControls, objEditForm
 Set objEditForm = ThisEvent.Object
 Set objEFPageOneControls = objEditForm.Pages("timePlace").
Controls
 If objEditForm.Mode = 3 Then

 'Initialize DATE and TIME to current timestamp
 objEFPageOneControls("datDate").Value = Now
 objEFPageOneControls("txtTime").Value = Time

 ' Get the sighting (x,y) from the user click
 objEFPageOneControls("txtSightingX").Value = Map.PointerX
 objEFPageOneControls("txtSightingY").Value = Map.PointerY

 ' Set the observer's (x,y) from the GPS stream
 If GPS.IsOpen = True Then
 objEFPageOneControls("txtRangerX").Value = GPS.X
 objEFPageOneControls("txtRangerY").Value = GPS.Y
 Else
 MsgBox "No GPS position available! Check connections and
coverage", vbExclamation, "Check GPS!"
 End If

 'Get the animal sightings layer's recordset
 Dim objAnimalSightingsRS
 Set objAnimalSightingsRS = Layer.Records
 ' Set observation ID
 objEFPageOneControls("txtObsNo").Value = ReturnNextID
(objAnimalSightingsRS, "SIGHTINGID")
 ' Get the default ranger id from the last entry
 objEFPageOneControls("txtRangerID").Value = ReturnRangerID
(objAnimalSightingsRS, "RANGERID")
 End If

 'Free up objects
 Set objEFPageOneControls = Nothing
 Set objEditForm = Nothing
 Set objAnimalSightingsRS = Nothing
End Subv
```

Checking that required layers are present

The subroutine AddSighting performs checks to ensure that the required data layer is available. A Boolean (true/ false) variable (`blnLayerExists`) stores whether the layer is present **(figure 6.16)**. Initially set to false, it checks each of the layers in the map (`Map.Layers`) to see if one of them has the required layer name (`'animalSightings'`). If one of them does then `blnLayerExists` is set to true. If the layer is not present a warning is presented to the user, the subroutine is ended at this point (`Exit Sub`), and the form is not presented to the user.

Getting coordinates from user interaction

Within the ArcPad object model, the location of the onscreen click (in map coordinates) is given by the properties `Map.PointerX` and `Map.PointerY`. If the required layer is present, the user's onscreen click is captured using these properties and used as the point geometry for a record that is added to the editable data layer. The call to the AddFeatureXY method of the Map object in the line `Call Map.AddFeatureXY(dblX,dblY, True)` stores the point location to the data layer shapefile. By specifying 'true,' the form associated with the layer is displayed, allowing the user to define further attribute information before the point observation is saved.

Figure 6.16 *Code sample: Checking that required layers are present.*

```
' blnLyrExists stores whether the animalSightings layer is present
(true) or not (false)
 Dim blnLayerExists
 blnLayerExists = False
 Dim objLyr
 For Each objLyr in Map.Layers
 If StrComp (objLyr.Name, "animalSightings", 1) = 0 Then
 blnLayerExists= True
 Exit For
 End If
 Next

  ' If Animal Sightings layer does not exist:
  ' Notify the user and exit.
 If Not blnLayerExists Then
 MsgBox "The Animal Sightings layer is not present in the current
map.", vbExclamation, "Layer not present"
 Exit Sub
 End If
```

Getting coordinates from a GPS data stream

All the code discussed thus far has related to the AddSighting subroutine stored in the ArdPad.vbs VBScript file with the ArcPad.apx configuration file. This subroutine is stored with the configuration file because it is associated with a button on the toolbar. Hence, ArcPad needs some default behavior to use when the user presses that button. The remaining scripting discussed here is only relevant to the Animal Sightings layer, and so this is where the remaining scripting is stored.

A new VBScript can be stored with a layer definition file (.apl) by clicking the "Edit script" button; this brings up ArcPad's script editor where code can be entered. This script will automatically fill some of the fields in the form so the observer can avoid repetitive tasks and transcription errors. We will consider some lines of this example VBScript in more detail.

When ArcPad has a connection to a GPS data stream, a VBScript can access this information via the ArcPad object model **(figure 6.17)**. A preliminary check to perform is that GPS data is being received using the GPS.IsOpen property; further checks could be performed here, such as checking the GPS.IsValidFix property. If the GPS position is not available or invalid, this event must be handled in some way, for example, by entering a null value or getting the user to define the position manually. If the GPS "is open" then the form text fields storing the observer's (ranger's) location can be set to the location received from the GPS. Using the GPS.X and GPS.Y values, the GPS coordinates are automatically converted to the map coordinates. The unconverted GPS latitude and longitude are available using the GPS.latitude and GPS.longitude properties.

Figure 6.17 *Code sample: Using a GPS stream to set form values to the observer's location.*

```
' Set variable to the first page controls,
Dim objEFPageOneControls
Set                  objEFPageOneControls                  =
objEditForm.Pages("timePlace").Controls

 ' Get the observer's (x,y) from the GPS stream if there is a GPS
stream)
If GPS.IsOpen = True Then
objEFPageOneControls("txtRangerX").Value = GPS.X
objEFPageOneControls("txtRangerY").Value = GPS.Y
End If
```

Figure 6.18 *Code sample: Setting the date and time from the system clock.*

```
'Initialize DATE and TIME to current timestamp
objEFPageOneControls("datDate").Value = Now
objEFPageOneControls("txtTime").Value = Time
```

Getting the date and time

You can write code that takes the date and time from the system clock and enters it into the relevant form fields **(figure 6.18)**.

Getting values from a layer's record set

Finally the layer's record set can be queried to find previous observations entered via the form. The record set object represents the entire set of records from a layer's database table. In the case of a shapefile, this is stored in the database file. The record set can be retrieved as shown in **figure 6.19**.

Figure 6.19 *Code sample: Getting the layer's record set.*

```
 'Get the animal sightings layer's recordset
 Dim objAnimalSightingsRS
 Set objAnimalSightingsRS = Layer.Records
```

Getting the default observer ID

A unique observer ID is required for most sightings, and the observer is likely to be the same as the one for the previous record. The subroutine in **figure 6.20** shows how to find the value of a field from the *penultimate* record of a record set. The *final* record will be created by the form that is being edited now, which contains mostly null values; hence, the one before this is required. The subroutine requires two input parameters, the layer's record set, and a string representing the name of the field containing the observer's ID in that record set.

Figure 6.20 *Code sample: Getting the default observer ID.*

```
'Returns the default observer ID (from the previous observation)
Function ReturnRangerID (objRS, strFieldName)
 Dim rangerID
 'Get the previous record
 objRS.MoveLast
 objRS.MovePrevious
 'Initialize the value to the first record
 rangerID = objRS.Fields(strFieldName).Value
 ReturnRangerID = rangerID
End Function
```

Setting the value of a control

The subroutine in **figure 6.21** can be called to return a string representing the observer's ID. This string can be used to automatically set the value of a control in the form via the ReturnRangerID subroutine.

Figure 6.21 *Code sample: Using the ReturnRangerID subroutine to set the value of a control.*

```
' Get the default ranger id from the last entry
 objEFPageOneControls("txtRangerID").Value = ReturnRangerID(objAni
malSightingsRS, "RANGERID")
```

Transfer between desktop and mobile GIS

To ensure that data transfers correctly between the desktop and mobile GIS software, users should customize the application.

Setting up customization on the PDA

For the animal sightings application, the two configuration files are ArcPad.apx, which is the default configuration file, and its associated VBScript stored in ArcPad.vbs. Both of these files must be stored in ArcPad's system directory on the PDA, usually Program Files\ArcPad\System. Note that saving ArcPad.apx will overwrite the existing configuration file.

Usually considerably more layer files than this are involved. The files can be stored anywhere on the PDA; however, for the ArcPad map document (.apm) to point to the correct layer files, the relative location of the files should remain the same as on the desktop. To ensure this, first transfer all of the files associated with the basemap from desktop to PDA. Next, move the point data layer and form that will store the observations. In the case of the animal sightings application, the layer consisted of files with the same file name stem but different extensions. The shapefile itself is composed of four files with the extensions .dbf, .prj, .shp, .shx, but the layer also requires the layer definition files (.apl) and the associated VBScript (.vbs). Also required are any further database files used to define the values of the combo boxes in the form and the ArcPad map document itself (.apm), which links all the layers together.

Retrieving data collected in the field

Retrieving data collected in the field using this customized version of ArcPad is a straightforward task (**figure 6.22**). Upon returning from the field, you can synchronize the PDA with the desktop in the normal way, usually by placing it in its cradle. The device should be available in Windows File Explorer as "Mobile Device." You can then transfer the data layer by dragging all the files that comprise the shapefile from the mobile device to the desktop, or by a standard synchronization. Then you can view, edit, merge, and analyze this shapefile as necessary, enjoying the full functionality of ArcGIS without any need for further file conversions.

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Figure 6.22 *Two rangers take a break from observing animals in the Swiss National Park.*

Developing a customized application shows how the power of ArcPad can be harnessed for mobile field-workers without requiring lengthy training or the dispatch of technical staff to the field.

Mobile GIS applications: Delta Utility Services, New Zealand

Jonathan Raper, G-ability

Background

Delta Utility Services **(www.4delta.co.nz/AMProfile/AM.htm)** was formed from Dunedin Electricity (now Aurora Energy) in 1998 when the Electricity Industry Reform Act required the separation of electricity delivery and asset servicing in New Zealand **(figure 7.1)**. Delta took on the responsibility of managing the Dunedin electricity distribution network for Aurora, and later expanded into several new territories by purchasing existing electricity delivery businesses. Delta now has responsibility for 4,100 km of electricity lines and over 5,000 substations across New Zealand's South Island.

Asset management on this scale requires information systems that support the reporting and monitoring functions required by engineering operations and the electricity regulator. GIS is a key component of these information systems because utility networks are geographically dispersed and spatially complex. Around the world, utility companies have achieved considerable productivity improvements in asset management by using GIS to create asset databases. However, asset management is a year-round, ongoing job, and continuous updating of the database is necessary. Mobile GIS is increasingly seen as the optimum way to update the core database on the basis of cost and ease of use. ArcPad is Delta's chosen system because of how it integrates with ArcGIS in the office.

G-ability Ltd. with permission

Figure 7.1 *Delta offices, Dunedin, New Zealand.*

The solution involving ArcPad

Each year Delta Engineering Services inspectors need to visit all their substations to read the maximum demand indicators and carry out an asset inspection **(figure 7.2)**. This monitoring is used to assess where overloading occurs and to schedule repair work. The process involves a huge number of inspection sorties and collecting large quantities of data. Originally, the inspection data was recorded on paper and then keyed into the database back at the office.

Delta uses mobile devices with ArcPad to carry out asset inspections. The shapefiles are downloaded to ArcPad at the office, updated by the engineers on-site, and then uploaded to the GIS database in the office again. Once in the GIS database, GIS technicians update the existing layers. A manager then checks this work before it is committed to the GIS database.

Delta Utility Services with permission

Figure 7.2 *Power line and substation assets to be mapped.*

The Delta technology environment

The Delta information systems department operates a variety of databases, including Oracle and ArcGIS Server. The Oracle database contains the maintenance history of the assets, while ArcGIS looks after the land information, power networks, and other asset data. The GIS is a hybrid system, being distributed between the enterprise database, desktop platform, and mobile device.

The information systems at Delta were redesigned completely in 1999–2000 when two smaller electricity asset businesses were purchased, each with GIS that were incompatible with Delta's. These other GIS systems were closed down, a new ArcGIS system was commissioned, and all the data was converted and stored in an enterprise GIS database. The design of the new system by Eagle Technology focused on ease of use, integration, and licensing concurrency.

For the mobile component, ArcPad was specified on HP iPAQ Pocket PC hardware **(figure 7.3)**, although later this was migrated to ruggedized Symbol devices that have greater battery life and are more suitable for inspecting assets in the field.

Delta Utility Services with permission

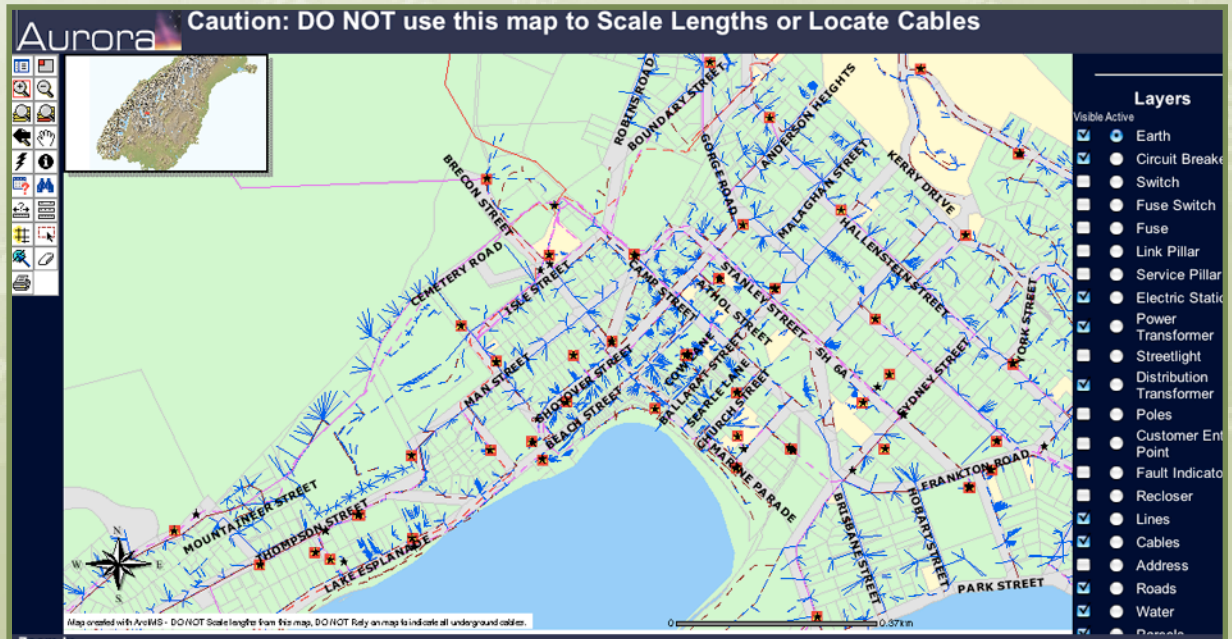
Figure 7.3 *HP iPAQ Pocket PC with Delta datasets for Dunedin.*

The Delta GIS environment

The Delta GIS environment is based on ArcGIS Server that includes ArcSDE technology acting as the GIS gateway to spatial data stored in an Oracle database. The GIS back office uses ArcInfo for asset data entry, ArcEditor for land management data, and ArcView for analysis work. Delta also runs Telvent Miner & Miner ArcFM as a utility asset manager solution with an integrated data model and interface.

To ensure that the GIS data is available to all staff and offsite contractors, Delta installed ArcIMS on all desktops with the HTML Viewer client. This same ArcIMS system is packaged on the Internet as "Maps & More" **(figure 7.4)** that Aurora customers use to look up asset details **(www.electricity.co.nz/GIS.htm)**.

As already stated, ArcPad is used in the field on asset inspections. Using ArcPad Application Builder, Delta customized the ArcPad interface to allow form-based data entry into the attribute fields of shapefiles from the enterprise GIS database.



Delta Utility Services with permission

Figure 7.4 *Maps & More public Internet assets portal,* ***www.electricity.co.nz/GIS.htm****.*

Spatial data environment

Delta has developed a GIS data model and database schemas to suit the rapidly changing database that it needs to maintain.

On the mobile devices, data management for ArcPad depends on the use of solid state memory cards (CompactFlash card). Once the inspections are complete, a CompactFlash card is sent to the office for uploading **(figure 7.5)**. This has proved more practical than synchronization (the device may not return to the office each day) or mobile communications (which may be expensive). For some important updates, mobile communications linked to the mobile device have been used to view and update asset information in real-time from the field.

Each working day, data technicians edit the uploaded data, and the data administrator checks and validates the edits. Then layer versions are refreshed once they are in ArcGIS.

Delta Utility Services with permission

Figure 7.5 *Communications from the field to the GIS.*

The ArcPad workflow

The Delta ArcPad asset inspection workflow consists of three main steps. First, the user downloads the appropriate shapefile data to ArcPad. The shapefile data can be acquired from ArcMap using the ArcPad extraction tools in ArcGIS. Choosing the "Get data for ArcPad" tool in ArcMap opens a wizard **(figure 7.6)** that allows the user to choose

- the geographic area from which to export the data;
- the layers to include; and
- how the layers will be returned to the GIS database.

In the Delta asset inspection application, the layers are shapefiles, which are updated in the field and then copied back to the GIS database as new versions.

Next, asset inspectors in the field use ArcPad to enter information and update the attributes of the downloaded shapefiles. In the field, the inspection engineer may be in a vehicle, climbing an electricity pole, or at a substation—so the mobile device must be rugged and usable in a variety of lighting conditions. The engineer uses menu options to fill in customized forms. Location is established on the displayed street map and GPS is not used.

Finally, the engineer updates the shapefiles on the CompactFlash card and uploads them to the GIS database, where they are checked and committed.

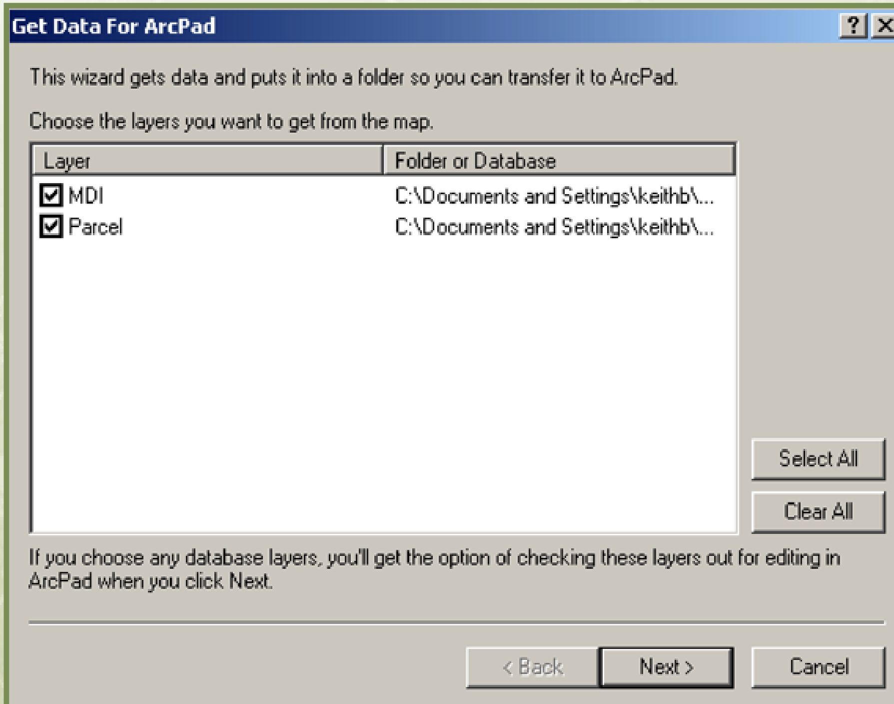


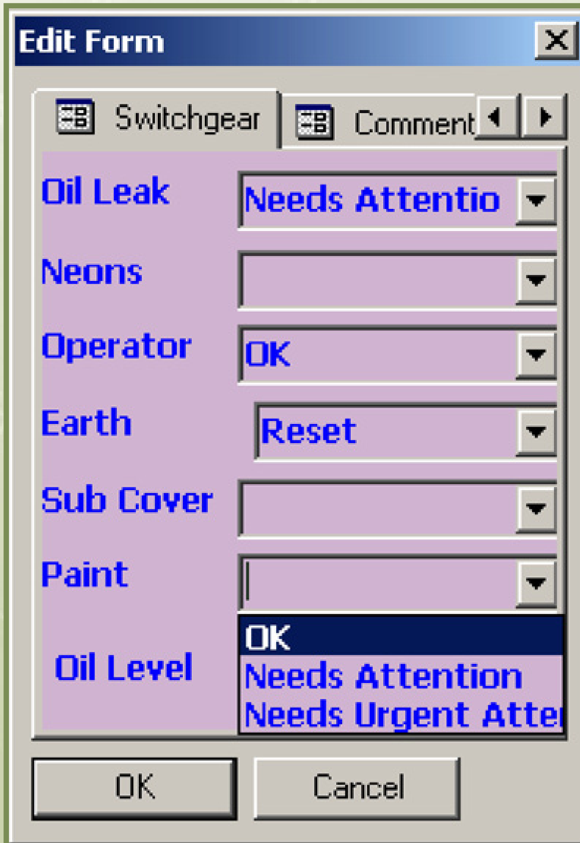
Figure 7.6 *"Get data for ArcPad" tools used by Delta.*

ArcPad customization

Effective use of ArcPad in the field involves careful customization of the application. This customization takes place at three levels:

- First, the data must be prepared to ensure that it is readable on the mobile device. This primarily involves simplifying symbology and planning color use to suit the limited palette of the mobile device screen.
- Second, the interface needs to be appropriate for the circumstances of use. Removing or simplifying the toolbars helps the user avoid unintended button clicks. Removing unneeded toolbars can provide an extra 15 percent of screen real estate.
- Third, data input needs to be fast and easy. Forms with drop-down menus and space for limited comments are easy and quick to use (**figure 7.7**).

In the Delta asset inspection application all these levels of customization are present and used effectively.



Delta Utility Services with permission

Figure 7.7 *Delta data entry forms for ArcPad.*

Business benefits of ArcPad at Delta

The business benefits of the ArcPad application can be divided into information efficiency and workflow savings.

The ArcPad application brings information efficiency over comparable paper updating systems because it eliminates rekeying of analog data into the enterprise database. However, there are also ancillary benefits: being able to complete the inspections more quickly means that it is less likely that a potential asset failure will go undetected **(figure 7.8)**.

Workflow savings are also valuable. Using the ArcPad application means that an entire service area uses a common methodology for asset inspection. The engineers who carry out the inspections gain the benefit of additional training and reduced time in the field collecting data.

Figure 7.8 *Asset repair ground markings.*

CHAPTER 08

Mobile GIS applications: Byker Street Wardens, United Kingdom

David Fairbairn, University of Newcastle-upon-Tyne

Background

On the northeast coast of England, Newcastle-upon-Tyne, with a population of around 300,000, is a generally prosperous city. However, some inner urban areas are decayed and suffer the effects of antisocial behavior. Activities such as scrawling graffiti, gathering in youth gangs, petty pilfering, littering, and other public disorder have the potential to inflict fear on local communities and degrade the local environment **(figure 8.1)**. The Newcastle City Council decided to tackle such problems by reaching out to the community, listening to residents and traders at a local level, and responding to specific needs on the streets.

The city council has appointed neighborhood wardens to interact with citizens, undertake patrols in specific areas, liaise with the police, and report back to the city's civic government. These wardens are able to communicate to the council recommendations for immediate environmental improvement work (e.g., collect fly-tipped litter, repair streetlamps, erase graffiti), report problems with municipally owned housing stock (e.g., needed roof repairs, unruly neighbors, neglected gardens), and record accounts of criminal behavior (intimidation by local youths, burglary, and vehicle crimes). The wardens are on duty from 2 PM to 10 PM, seven days per week in six wards across the city. The project was tested in the inner city area of Byker, a closely knit community with a mixture of public and private housing, retail centers, indoor and outdoor leisure and recreational facilities, various educational institutions, and small-scale factory units.

Courtesy of David Fairbairn

Figure 8.1 *Street wardens have been appointed to tackle antisocial behaviour such as graffiti.*

Overview of the solution involving ArcPad

The City Council considered a range of possible hardware, software, and data provision combinations to furnish the neighborhood wardens with a means of carrying out their duties in the community **(figure 8.2)**. The critical issues to address were the following:

- Location dependence. They needed a method of identifying, recording, and using the position of the warden.
- Task dependence. The wardens needed to be able to note, record, and transmit information related to incidents they witness or are informed about. In addition, they may require access to records of previous incidents or to people who can assist them.
- User dependence. The people employed as wardens are not IT experts and therefore require a relatively simple interface for their data-handling tasks.
- Hardware dependence. Any devices used by the wardens needed to be portable and discreet, yet allow for interactivity and considerable functionality.

Courtesy of David Fairbairn

Figure 8.2 *Street warden in Byker: Problems in view?*

Hardware and software for the solution

Advisors chose the HP iPAQ Pocket PC for the neighborhood wardens to use on the street. They made this choice because the PDA offers versions of standard Windows applications (notably Word and Excel), application-specific programs, handwriting recognition, and voice recording. In addition, Internet connections through a Bluetooth modem are possible, and a GPS card inserted into the iPAQ Pocket PC can give positional intelligence. Wardens are also equipped with mobile telephones and a panic alarm via the PDA's GPS functionality **(figure 8.3)**.

Because ArcPad is compatible with the city's enterprise GIS system, the neighborhood wardens have direct access to the enterprise database, which includes maps and images from various sources, including the Ordnance Survey (OS) national mapping agency. ArcPad can be easily installed, and users can display, query, capture, and modify spatial and nonspatial data.

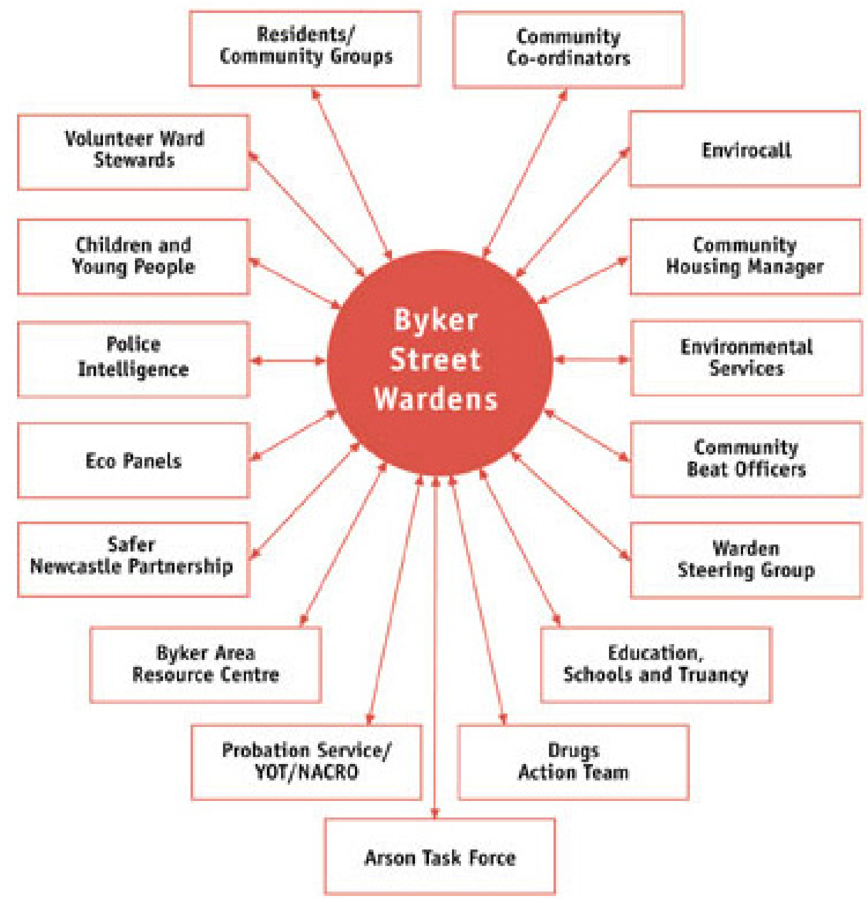
Source: Newcastle City Council

Figure 8.3 *Street wardens working on-site.*

GIS environment into which ArcPad is integrated

City staff uses an enterprise database that includes both spatial and nonspatial data (**figure 8.4**). ArcGIS and Oracle software mounted on an enterprise server support the GIS application in a number of council departments. The central server allows access to data via metadata and map interfaces and ensures that decision-making is supported by GIS capabilities.

Digital spatial data is the basis for all GIS work and map presentation. The street warden application uses large-scale Ordnance Survey Mastermap cartography of the entire area, available at a scale of 1:1,250. The maps are supplemented with city-specific information, such as street lighting, planning applications, and service information, such as refuse collection and library facilities. A number of departments on a variety of different platforms use the spatial data. The organization has a distributed workforce (in refuse collection, grounds maintenance, traffic management, etc.) and distributed assets (street furniture, educational and leisure buildings, public housing stock), and mobile technologies are regarded as significantly supportive to their efforts.



Source: Newcastle City Council

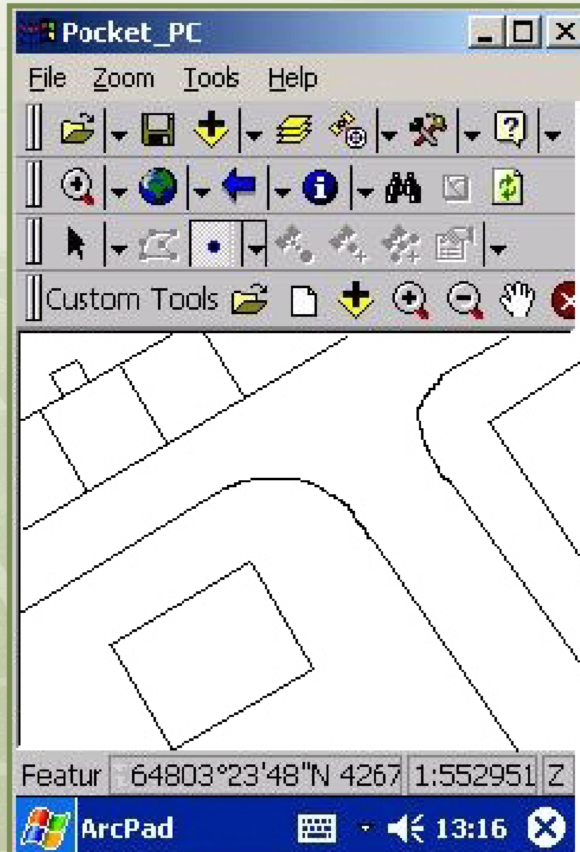
Figure 8.4 *The flows of information available to the street wardens.*

Workflow from the user's perspective

The Xtools Pro extension for ArcGIS extracts digital maps of the Byker area from shapefiles on the enterprise Oracle database. Xtools Pro "cookie cuts" the geometry to the Ward boundary. Using ActiveSync, the data is loaded onto iPAQ Pocket PCs in the main council offices. If necessary, data can be transferred using mobile communications. Available layers of shapefile data include the Ordnance Survey basemap information, along with the council's data. Additionally, remote users are able to handle raster data such as rectified aerial photography, though this has not yet been implemented. Wardens can view all displays at variable scales using the zoom and pan tools in ArcPad.

The detailed map data displayed on the mobile units **(figure 8.5)** allows the wardens to position themselves to a fairly high degree of precision (say, 10 meters). Though the PDAs have GPS receivers attached, the accuracy of a stand-alone GPS is not yet sufficient for legal enforcement recording. The addition of council-specific information allows for maintenance schedules, lists of responsibilities, and records of previous incidents to be accessed and discussed by wardens and local residents. The wardens can retrieve and fill in standard report forms digitally. The mobile communications link ensures that the wardens can make remote reports to the main administrative center.

When the wardens return to base, they use ActiveSync to upload the attribute data they have collected (the dBase part of the shapefile) to corporate data storage. The files are appended so that each warden's data is combined and a custom Java program enters it into the Oracle database.



Source: Newcastle City Council

Figure 8.5 *Street Warden application in ArcPad.*

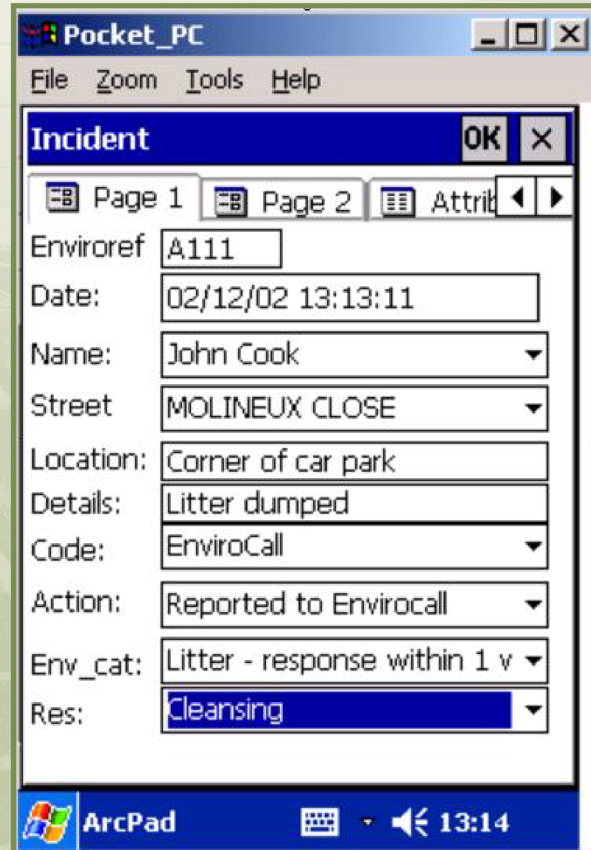
Customization of ArcPad

The system needs a degree of customization to ensure a user-friendly interface, access to the required datasets, and applicability to the tasks to be performed. Using ArcPad Application Builder, new toolbars were created to produce an appropriate screen layout for the wardens containing built-in and custom tools.

Custom forms have also been designed to allow for easy prompting and recording of information, and data collection in the field can be streamlined using predetermined procedures. To report an incident, wardens complete a multipage form **(figure 8.6)** that identifies the problem and the agency that should respond.

Further development of applets using VB Script has allowed for interactive data validation and the automation of certain operations.

The council is also testing the use of TC Technologies' Go-Sync for its ArcPad solution, which integrates with Trimble GPScorrect extension (v.2). This will allow automatic bidirectional synchronization with the enterprise Oracle database each time the PDA is cradled.



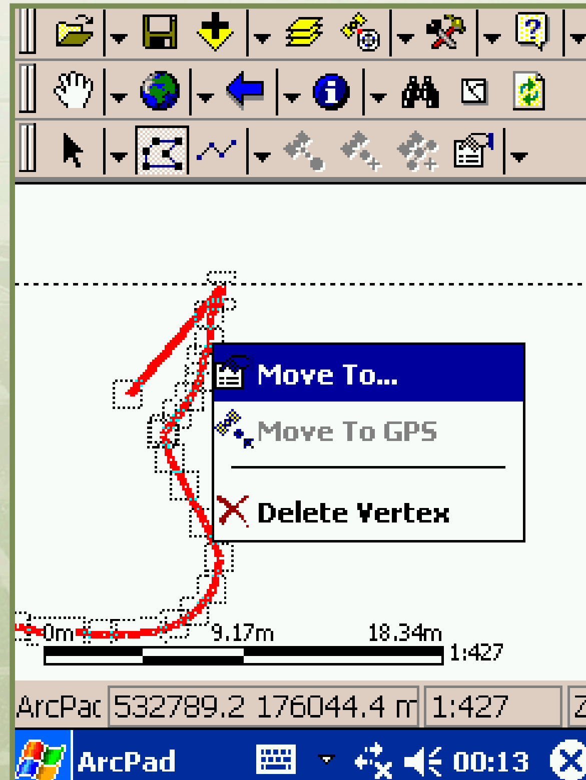
Source: Newcastle City Council

Figure 8.6 *ArcPad form to be completed by street wardens.*

Integration with GPS

Integrating GPS capability with the mobile device is simple to implement. The Byker warden solution uses a CompactFlash GPS card from HAiCOM with integral antenna and receiver. The card outputs data using the NMEA protocol, and users can select appropriate communication parameters such as baud rate, parity, data bits, stop bits, and COM port using the Options dialog box in ArcPad. In addition, users must select correct georeferencing options, including projection, datum, and spheroid so that conversion from GPS-derived locations to local map coordinates can take place.

Users can capture positional data using three different GPS tools in ArcPad **(figure 8.7)**: the "Capture Point Using GPS" button, the "Add GPS Vertex" button, or the "Add GPS Vertices Continuously" button. Data can also be edited once entered. Due to the nature of the urban environment within which the wardens operate (i.e., poor GPS reception, the 5-10 m precision of the GPS card, and the large number of point locations to be recorded), the tendency is to operate in Capture Point mode. This mode uses position averaging to obtain the most precise locational fix.



Source: Newcastle City Council

Figure 8.7 *GPS capture and edit functions in ArcPad.*

Accuracy, data capture, and future developments

Tests were undertaken in the pilot project to determine the accuracy of matching the GPS position to mapping based on the British National Grid. The worst-case scenario was eight meters off, but more typically the accuracy was three to four meters. These accuracies are in two dimensions; currently there is no height information on these large-scale maps, and it is unlikely to be a useful supplement to the data handled by the wardens. In practice, collecting locational data in areas with little map detail is more accurate using GPS, while clearly defined map details (such as wall junctions and building corners) are more precisely positioned using the coordinates taken from the map. Using GPS to navigate to a map location is straightforward.

The wardens often need to capture data in the streets, usually recording their own position, an alteration or addition to the spatial dataset, or an observation by a resident **(figure 8.8)**. They upload real-time data using a mobile communications in conjunction with the Bluetooth-enabled PDA. This requires a network connection that ensures an efficient and low-cost transfer of data. Future improvements may also include serving and retrieving spatial data using Internet protocols.

Courtesy of David Fairbairn

Figure 8.8 *Street warden using ArcPad on-site.*

Business benefits achieved

The benefits achieved by the trial project are quantifiable and sufficiently worthwhile for the scheme to be extended into other inner city areas of Newcastle. Wardens made a total of 2,825 reports during the first year of operation. In the Byker area, overall levels of crime have been reduced. Crimes against property have fallen along with crimes affecting people, and the environment is less visually degraded. Fewer public housing units are empty—people actually want to come and live in Byker **(figure 8.9)**. The wardens themselves feel that their work and applying the data they acquire is helping to improve the look of the area and the attitude of the residents.

Courtesy of David Fairbairn

Figure 8.9 *Street warden in Byker: Solutions in sight!*

CHAPTER 09

Mobile GIS applications:

CropViewer Surveying, Netherlands

Alfred Wagtendonk, Nils de Reus, Euro Beinat, Spatial Information Laboratory, Vrije Universiteit Amsterdam; ***and Paul van der Voet,*** Vexcel Corp.

Background

Every year Vexcel Corp. produces a digital crop map of the Netherlands. The map shows what crops are grown on every parcel of agricultural land in the country (see a sample parcel in **figure 9.1**). The map is used by a wide range of organizations, including local and national government bodies, water authorities, and agribusinesses. Its uses include yield forecasts, disease and crop protection management, land administration, environmental quality monitoring (e.g., estimation of pollution loads), and manure management.

Source: Photograph Alfred Wagtendonk
Spatial Information Laboratory (SPINlab), Vrije Universiteit Amsterdam

Figure 9.1 *Two crop plots showing the difficulty that surveyors have locating themselves in flat agricultural landscapes.*

The digital crop map is compiled from interpretations of optical and radar satellite images collected at different phases of the growing season. This automatic phase is usually complemented by fieldwork to validate the results and to complete data acquisition where satellite images are insufficient. In general, the automatic interpretation of images needs to be validated on the ground for quality control reasons.

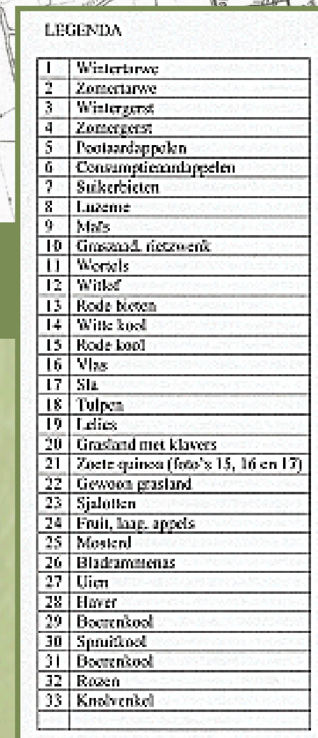
Specialized fieldworkers with skills in mapping and crop identification visit areas to ground truth the data, in other words to make sure that the information collected remotely is correct on location. They validate the image interpretation and, in some cases, when the field boundaries cannot be extracted from satellite images, update crop area boundaries. Vexcel Corp. releases a final map every fourth quarter of the year.

Overview of the solution involving ArcPad

Until recently, the fieldworkers relied on paper maps **(figure 9.2a)** and input forms (see the legend in **figure 9.2b**). Since the areas to be covered by fieldwork are large (about 10,000 parcels, or 1 percent of the total), this work can be time-consuming and expensive. Crop identification can also be difficult at times, especially at some stages of the plant life cycle and when the fieldworker has limited experience.

Determining the exact position in the field when no landmarks such as roads or houses are visible was not always straightforward. After fieldwork results were available, office workers manually copied the field data into a GIS database, which was a time-consuming, expensive, and error-prone process.

For these reasons, the governor of Wageningen (a municipality and historical town in central Netherlands) decided to introduce, first in the form of a pilot project, a new way of carrying out fieldwork based on mobile computing. The goals were to reduce the time required by data collection, to reduce the post-processing effort, limit the chance of error, and introduce a real-time link between the fieldworker and the office. The choice was made to use a solution based on ArcGIS software, both on the server and client sides, with mobile users equipped with ArcPad. The application was called CropView.



LEGENDA

1	Wintertarwe
2	Zomertarwe
3	Wintergerst
4	Zomergerst
5	Pootaardappelen
6	Consumptieaardappelen
7	Suikerbieten
8	Luzerne
9	Maïs
10	Graszaad, rietzwenk
11	Wortels
12	Witlof
13	Rode bieten
14	Witte kool
15	Rode kool
16	Vlas
17	Sla
18	Tulpen
19	Lelies
20	Grasland met klavers
21	Zoete quinoa (foto's 15, 16 en 17)
22	Gewoon grasland
23	Sjalotten
24	Fruit, laag, appels
25	Mosterd
26	Bladrammenas
27	Uien
28	Haver
29	Boerenkool
30	Spruitkool
31	Boerenkool
32	Rozen
33	Knolvenkel

Above: **Figure 9.2a** *Paper crop maps for field-workers.*
Right: **Figure 9.2b** *Crop legend for paper map.*

Source: SYNOPTICS - Integrated Remote Sensing & GIS Applications

Hardware and software environment for the solution

For this application, a mobile device needs to include the functions of PDA, GPS receiver, and GPRS (General Packet Radio Service) modem for Internet access. During project trials, the three combinations shown in **figure 9.3** were evaluated.

None of these solutions is completely ideal. The first solution, a PDA with external GPS, uses a handheld with integrated Internet connection (and phone) but requires a cable connection to an external GPS receiver, as there is no built-in data card slot. The second solution integrates the three items in a single package, which makes it heavy and voluminous. The third solution simply uses three separate devices that are connected to each other via Bluetooth, a short-distance high-bandwidth radio connection, making it a little unwieldy.

Based on the trials, and confirmed by growing evidence from the field, this third combination appeared the most suitable. The phone is usually small and can be carried in a pocket. The GPS device is also small and light and can be worn, for instance, on a jacket. The disadvantage of carrying multiple devices is counterbalanced by the fact that during fieldwork the only device in the hands of the user is the small and light mobile device. Meanwhile, after the project trials, PDA devices appeared on the market that combined both GPRS and GPS in one compact integrated device (like the HP iPAQ Mobile Messenger) for this type of work.

Fieldworker equipment	Handheld	GPS receiver	GPRS device
1 - PDA with external GPS	XDA (Pocket PC handheld with integrated phone and GPRS)	External received, connected with cable	n.a. (integrated in the handheld)
2 - PDA with integrated GPS and GPRS	HP iPAQ Pocket PC	Flash-card mounted GPS receiver	GPRS sleeve for HP iPAQ Pocket PC
3 - PDA with external phone and GPS	HP iPAQ Pocket PC or Fujitsu-Siemens handheld with Bluetooth connection	Bluetooth GPS	GPRS phone with Bluetooth

Figure 9.3 *Hardware options for CropView.*

GIS environment into which ArcPad is integrated

CropView allows fieldworkers to view a high-resolution satellite map of the fieldwork area. The area displayed on the device is centered on the GPS position of the user. The user can insert a "crop point" on the map (an editable shapefile) and then associate information with it and the surrounding parcel, such as crop type or description. Through an Internet connection, each point added can also be sent to a central ArcIMS Web server in real time (using the POST method), which can then be displayed on a background map.

In some cases, when the field boundaries do not match those derived from satellite images, the user can sketch the correct boundary as observed in the field by using the digitizing functionality of ArcPad **(figure 9.4)**. The application is able to add the coordinate position of the fieldworker to the crop point information. This position may not be the crop point, for example, when the fieldworker stands on a road and verifies fields at the roadside. This information is stored in the attribute table of each crop point and is used for data validation and quality control.

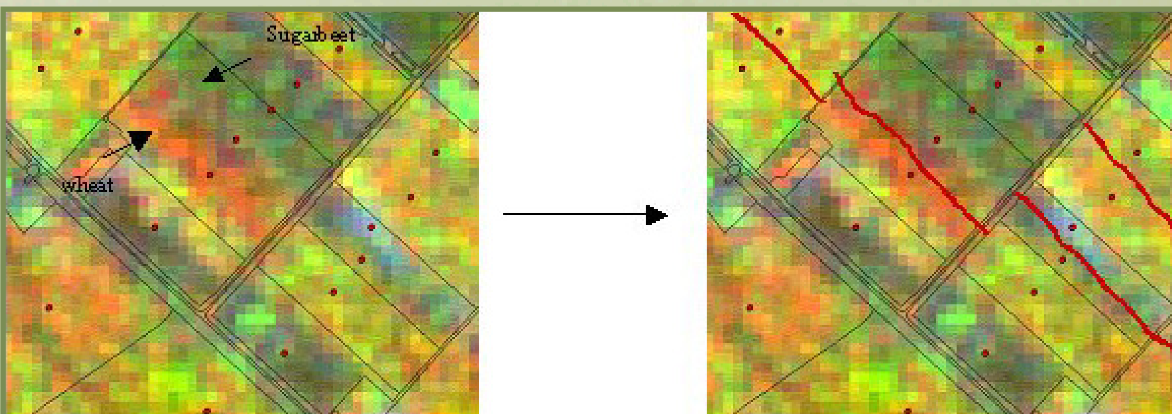


Figure 9.4 *Screen digitizing of corrected field boundaries.*

Source: Spatial Information Laboratory (SPINlab), Vrije Universiteit Amsterdam; background image SYNOPTICS - Integrated Remote Sensing & GIS Applications

On the server side, a Windows 2003 Server runs ArcIMS. Incoming HTTP POST data is received by an ASP script on the Web server and stored in a Microsoft Access-based database table. Subsequently, a conversion utility updates a shapefile with the data from the table. A script invokes the command line Java tools for ArcIMS and refreshes the Web mapping service, forcing it to use the newly updated version of the shapefile. To execute the conversion scripts, the solution requires a Java runtime environment for ArcIMS command line tools and a Python environment. The interval between the addition of a crop point and the availability of the updated data on the server is only seconds.

The application relies on a good registration of geographical coordinates to locate the position of the user and the location of the fields to be mapped. As the mapping takes place outside urban areas with clear sky view, accuracies are always better than fifteen meters and are usually around five meters **(figure 9.5)**.

Source: Photograph Alfred Wagtendonk
Spatial Information Laboratory (SPINlab), Vrije Universiteit Amsterdam

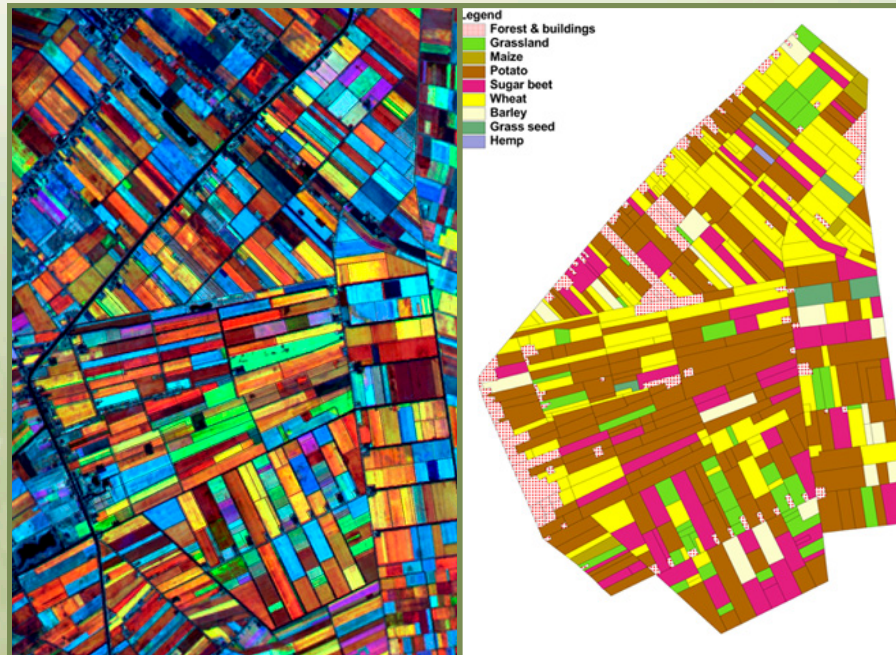
Figure 9.5 *Data collection and recording crop information in the field with ArcPad.*

Data and database environment for the solution

The application uses two methods for data storage. The first collects data on the handheld device, which can be transferred to a central GIS at the end of the fieldwork. To prevent data loss caused by battery failure or technical malfunction of the mobile device, the application saves data on a removable memory card.

The second method uses remote data storage. Via the Internet, users can send the information collected about each crop point to a remote database. In this case, the information is stored both locally and remotely. Even though this feature is not mandatory, it does make it possible to exchange data remotely between different field teams and the office.

Datasets loaded into ArcPad include the most important features from the 1:10,000 topographic map (roads, canals, houses, etc.); satellite imagery (e.g., Landsat TM or Envisat radar, depending on the time of year—see **figure 9.6a**); and field boundary polygons. All maps and images are georeferenced to the Dutch national coordinate system, called the Rijksdriehoekstelsel. Thus the final crop map (**figure 9.6b**) is delivered as a shapefile that is compatible with the standard 1:10,000 topographical vector map of the Netherlands.



Left: **Figure 9.6a** *Satellite image used as a base for the crop mapping.*
Right: **Figure 9. 6b** *Final crop map.*

Source: SYNOPTICS - Integrated Remote Sensing & GIS Applications

Workflow of the solution

The application workflow **(figure 9.7)** begins with the preparation of the appropriate background maps in the office. Once in the field, the fieldworker starts an ArcPad session, activates the GPS, Bluetooth connections, and the Internet connection.

When in proximity to a crop field, the user first needs to identify the crop, using the crop information list on the mobile device if necessary. If this is not sufficient, the user can use the device to take a picture of the crop on the device (if a camera is built in) and associate it with the crop point for later identification or send it to the office for assistance. When adding a crop point, the fieldworker stands on the road halfway along the field. The crop point is placed inside the field, approximately five to fifteen meters from the road to ensure they are stored inside the correct field.

Once recorded, the point is stored on the removable storage card and, optionally, sent directly to the Web server if the connection is active. A confirmation message is received from the server if the point data has been received correctly, or, if not, the application will attempt to send the point again. Once all data collected by different teams is integrated into a central database, the resulting map is checked for consistency errors.

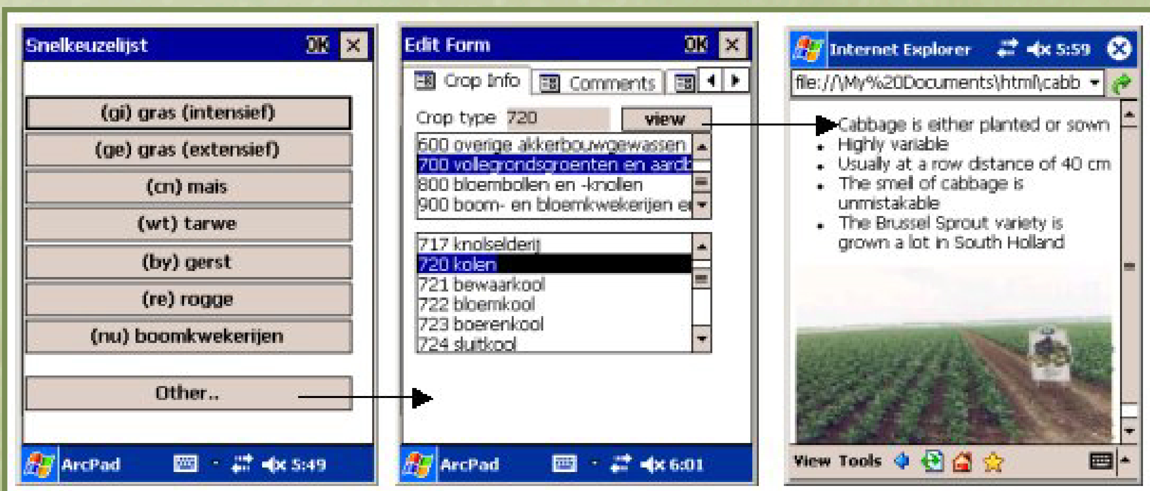


Figure 9.7 *CropView input process.*

Source: Arcpad application and screenshots: Spatial Information Laboratory (SPINlab), Vrije Universiteit Amsterdam; content application database (texts and photographs of selected crops): SYNOPTICS - Integrated Remote Sensing & GIS Applications

Customization of ArcPad

To streamline data entry, the application requires customization of the ArcPad interface, created with ArcPad Studio **(figure 9.8)**. After customization, when a fieldworker adds a point by tapping on the screen, a map entry form pops up to assist crop identification and specification. The form shows seven of the most prevalent crops in the fieldwork area to help the fieldworker identify the crop. This list is based on the frequency of each crop type in past fieldwork.

If the observed crop is not among the top seven, the user can visualize a comprehensive list of crops, classified into crop families. Visual and descriptive information for each crop is also available, and can be used by less experienced fieldworkers to facilitate crop identification. The user can also record comments and text information, or add a picture taken in the field if the mobile device has a built-in camera.

Figure 9.8 *CropView interface.*

Source: Photograph Alfred Wagtendonk
Spatial Information Laboratory (SPINlab), Vrije Universiteit Amsterdam

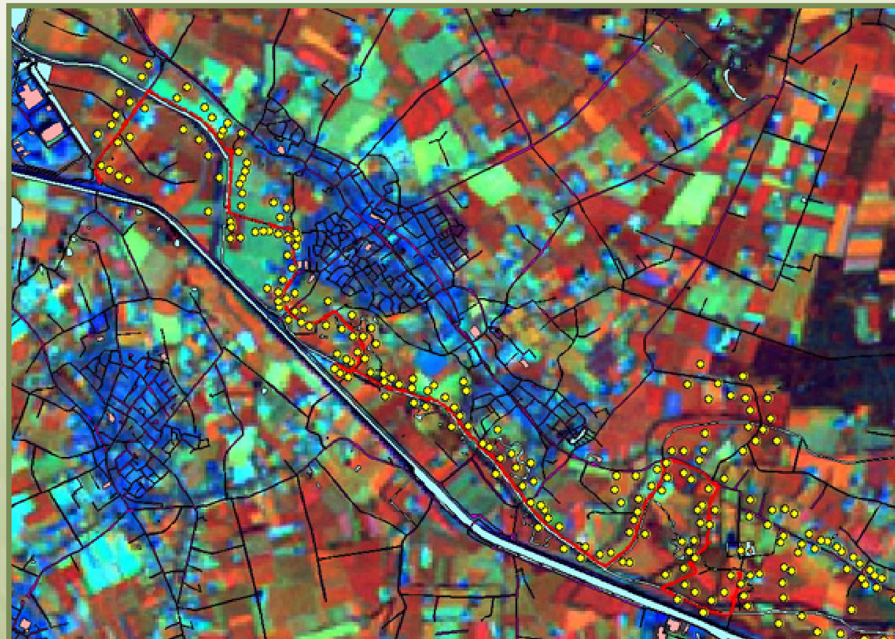
Integration with GPS

GPS data helps the fieldworker navigate and provides position and timing data for the ground truthing work. Accordingly, the GPS tracklog was stored so that data collection strategies can be analyzed and possibly improved. GPS data quality indicators are also stored (DOP) so that accuracy can be controlled.

To simplify the GPS connection process at the start of each survey, we used the FindGPS extension for ArcPad (available from **arcscripts.esri.com**) to automatically find the right port, baud, and parity settings for the GPS.

GPS devices can be mounted on the vehicle being used (from bike to tractor!) with specialized mounts that cushion the device and supply power.

A sample of the field data collection as a tracklog with crop points is shown in **figure 9.9a** along with part of the GPS data file in **figure 9.9b**.



Source: Spatial Information Laboratory (SPINlab), Vrije Universiteit Amsterdam; background satellite image: SYNOPTICS - Integrated Remote Sensing & GIS Applications

Above: **Figure 9.9a** *GPS tracklog and crop points from CropView.*
Below: **Figure 9.9b** *Part of the GPS data file from the CropView survey.*

PROJNUM	MAPSHEET	CROPTYPE	COMMENT	GPSX	GPSY	GPSZ	GPSSATS	GPSHDOP	GPSQUAL	TIME	DATE	PICTURE	AGENT	CROPNAME	SENT
Test 3	45DN	608		159944,4097	407147,446	66,6	6.0	1.3	1	15:58:32	11/20/2003		Karin	gras (intensief)	TRUE
Test 3	45DN	160		159732,116	407223,265	63	0.0	0.9	1	16:02:08	11/20/2003		Karin	mais	TRUE
Test 3	45DN	609	beeldentuin	159273,995	407500,987	81,1	8.0	1.8	1	16:04:24	11/20/2003		Karin	gras (extensief)	TRUE
Test 3	45DN	943		155516.4794	409308.723	53	4.0	2.4	1	16:07:37	11/20/2003		Karin	vruchtbomen	TRUE
Test 3	45DN	983	wild stukkie	159510.342	406689.603	61	4.0	7.3	1	16:15:12	11/20/2003		Karin	natuurontwikkeling	TRUE
Test 3	45DN	421		158641.8927	408746.338	54	7.0	1.1	1	16:19:28	11/20/2003		Karin	suikerbieten	TRUE
Test 3	45DN	982		158644.4270	408749.492	41	7.0	1.2	1	16:23:15	11/20/2003		Karin	naaldbos	TRUE

Business benefits achieved

From the user's perspective, the main criteria for assessing the suitability of the application were twofold:

- Improvements in crop-point collection speed, i.e., the number of points collected per hour
- End-to-end cost saving for the entire process, i.e., from the start of fieldwork to the integration of the data collected into the crop map

Other, softer criteria included the increase of data quality, the reduction of collection and transcription errors, and the availability of fieldwork planning information to optimize the scheduling and location of field work.

Figure 9.10 compares the traditional method with the CropView method. With the latter, fieldworkers are significantly more efficient and are able to operate around 35 percent faster. This is a sizable benefit that can be translated directly into cost savings.

On the other hand, CropView introduces some cost, such as for the mobile devices, software licences, and Internet connections. It also requires lengthier preparation, including device preparation, data loading, and tests. Overall, however, these increases are compensated by the reductions in the fieldwork and post-processing time, leading to savings of half the original costs.

CropView introduces other benefits, such as the possibility of employing less-expensive fieldwork labor, an increase in quality control in the fieldwork, and better management of the various fieldwork teams. These benefits are achieved because the mobile solution actively supports crop recognition in the field, monitors fieldworker position with GPS, minimizes position errors, and verifies the progress of separate teams in real time.

Activity	Traditional	CropView
Fields per day	400	550
Costs	Traditional	Digital
Fieldwork	39%	28%
Coordination	7%	4%
Fieldwork preparation	3%	12%
Postprocessing of field data	51%	0%
Mobile equipment	0%	4%
Total	***100%***	***48%***

Figure 9.10 *CropView cost savings compared to traditional survey.*

CHAPTER 10

Mobile GIS applications: Intend Logistics, Germany

Moritz Wurm, Intend Geoinformatik

Background

Sugar beets are one of Germany's most important crops, being grown on 4 percent of the country's arable land. The cultivation of sugar beets in the country yields 26 million to 28 million tons annually, from an area of 450,000 ha (17,375 square miles). The crops are sown in the spring, mature during the summer, and are harvested in September or the following months. During the harvest, crops are stored in piles alongside the fields **(figure 10.1)**. Finally, the beets are loaded onto trucks and transported to refineries.

The harvesting and transportation of sugar beets puts logistics to the test, as it requires a considerable amount of planning and cooperation between a variety of players with different stakes and jobs. Using an integrated GIS enables a fully digital dataflow between all the players and system components in the process.

Courtesy of Mortiz Wurm

Figure 10.1 *Sugar beet harvesting.*

Overview of the solution involving ArcPad

To improve the planning and hauling processes, Pfeifer and Langen, one of the leading sugar producers in Germany, together with Zutra, one of its subsidiaries, have introduced the use of ArcPad. The ArcPad solution is designed to be used by the companies that organize loading and transporting sugar beets.

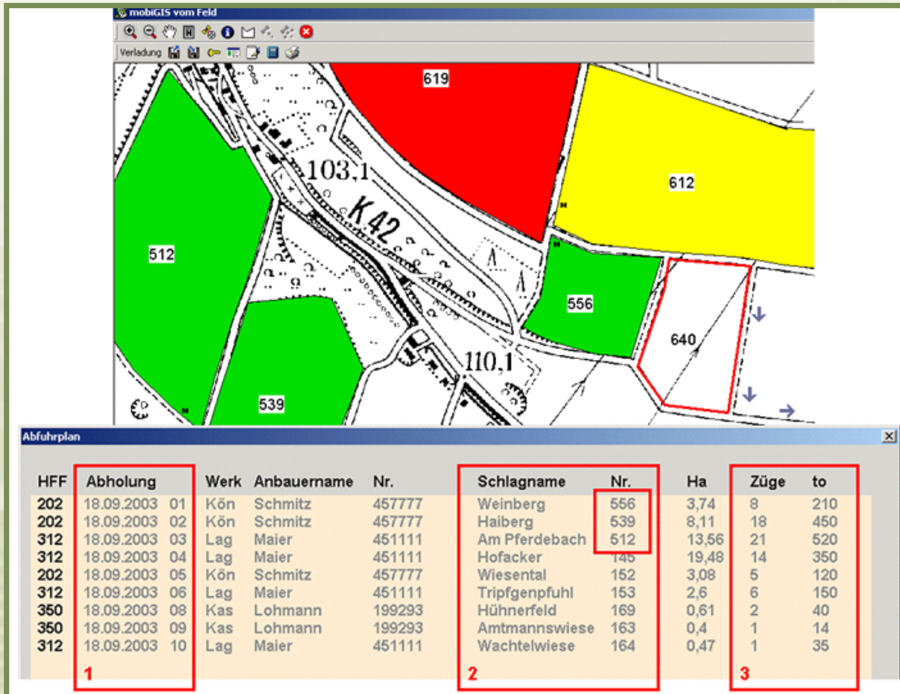
The ArcPad solution needed to do the following tasks:

- Collect and update data from producers about agricultural plots
- Geometrically represent the plots as polygons on digital topographical maps for planning purposes
- Enhance navigation by using GPS positioning
- Create an integrated digital data flow between both headquarters and distribution, and headquarters and loading

ArcPad is also used as an audit tool in the transportation of crops to the sugar factories for farmers, transporters, and processors of the crop.

In the collection schedule shown in **figure 10.2**, the plots for each day are listed in the order of

- their collection;
- plot number and name; and
- number of trucks with the amounts to be loaded.



HFF	Abholung	Werk	Anbauername	Nr.	Schlagname	Nr.	Ha	Züge	to
202	18.09.2003 01	Kön	Schmitz	457777	Weinberg	556	3,74	8	210
202	18.09.2003 02	Kön	Schmitz	457777	Haiberg	539	8,11	18	450
312	18.09.2003 03	Lag	Maier	451111	Am Pferdebach	512	13,56	21	520
312	18.09.2003 04	Lag	Maier	451111	Hofacker	145	19,48	14	350
202	18.09.2003 05	Kön	Schmitz	457777	Wiesental	152	3,08	5	120
312	18.09.2003 06	Lag	Maier	451111	Tripfgenpfuhl	153	2,6	6	150
350	18.09.2003 08	Kas	Lohmann	199293	Hühnerfeld	169	0,61	2	40
350	18.09.2003 09	Kas	Lohmann	199293	Amtmannswiese	163	0,4	1	14
312	18.09.2003 10	Lag	Maier	451111	Wachtelwiese	164	0,47	1	35

Courtesy of Mortiz Wurm

Figure 10.2 *Transportation planning sheet and map showing projected harvest month (September = green, October = yellow, November = red).*

Plots 556, 539, and 512 in the map are due to be loaded next according to the schedule (green = September). The beets in plot 612 should be loaded in October (yellow), and those in plot 619 in November (red). Plot 640 has already been cleared.

Hardware and software environment for the solution

ArcPad can be used on both desktop and mobile Windows platforms, which offers great versatility for sugar beet logistics **(figure 10.3)**. At headquarters, ArcPad is installed on standard office PCs. The distributors use Windows Mobile devices such as HP iPAQ Pocket PCs. The connected GPS receivers are mostly Pretec CompactFlash GPS card or Crux II BTGPS by Bluetooth.

On the loading vehicles, Tablet PCs or laptops are used instead of Windows Mobile computers. These devices have to be very robust, as they are exposed to dust and vibrations. In addition, the display needs to perform well in bad visibility. A report printer is connected to the device's parallel port and a data key controller to the serial port. For the data exchange between vehicle and headquarters, PCMCIA cards or CompactFlash memory cards are used.

ArcPad was chosen because of the range of platforms it works on and with and its support for many raster and vector data formats. Another valuable feature is the ability to customize ArcPad to the user's needs by means of VBScript and ArcPad XML. Since most users are not familiar with GIS, the application must include a user-friendly interface with customized dialog boxes. Last but not least, the low license fees per device are a positive feature for an agricultural logistics tool.

Courtesy of Mortiz Wurm

Figure 10.3 *Loading sugar beets.*

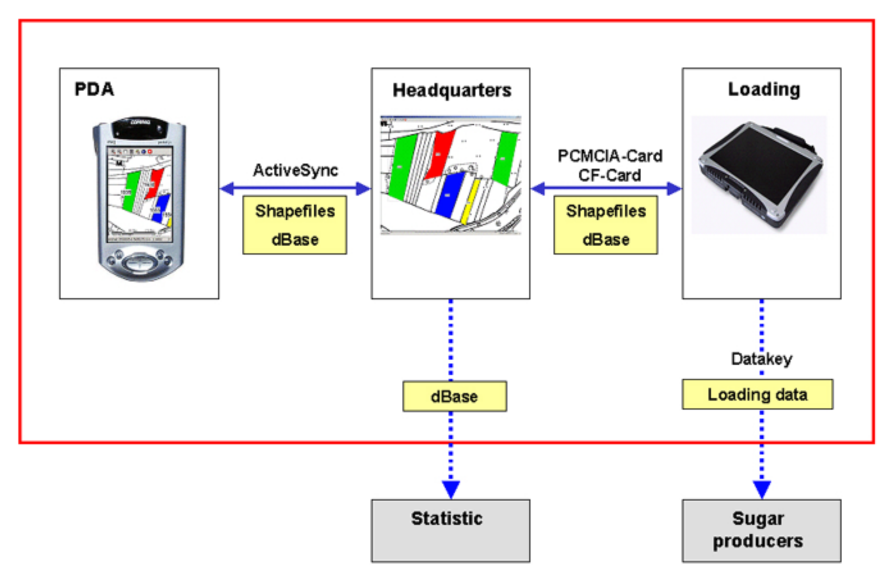
GIS environment into which ArcPad is integrated

The overall GIS solution has been designed to share data across different devices used in three specific locations:

- At headquarters (PC)
- In the field on mobile data input (PDA)
- Loading vehicles (Tablet PC or laptop)

The ArcPad applications used in each of these different locations vary in some respects. Basic functions such as the entering and editing of surveying and attribute data, various zoom and search functions, and the system settings are the same in all applications and can be accessed by customized toolbars and dialogs. However, in the headquarters and loading vehicles applications, a second toolbar provides additional functions.

All space-related data is kept in shapefile format. That means the registered agricultural plots are represented as polygons, routes can be recorded as line objects, and points of interest as point objects. Moreover, each loading operation is saved as a point object on the loading vehicles.



Courtesy of Mortiz Wurm

Figure 10.4 *Workflow for the ArcPad solution.*

Data and database environment for the solution

Other than the spatial data, the rest of the attribute data is saved in plain dBase tables. This includes data about the farmers that cultivate the plots and information on the sugar factories, the trucks, and the loading vehicles. Editing these tables can be done in ArcPad itself.

The workflow for the solution is shown in **figure 10.4**. Both the shapefiles and the dBase tables are kept in a database at headquarters. The central ArcPad application is responsible for processing and distributing data to the other system components. For this system the data transfer is achieved by data replication via ActiveSync and memory cards.

To plan the harvest activities, PDAs are used for mobile capturing and editing of data. At headquarters, the necessary shapefiles and dBase tables are copied to a target directory, such as the ActiveSync replication directory. The data is then transferred to the PDA at the next replication point. If changes are made in the field then the changed records are marked and updated in the central application's replication directories.

In the central application's consolidation process (explained in detail below), users can verify any changes made to geometry or attribute data. This approach enables several clients to work with the same shapefiles, since only the changed records are overwritten. However, identical objects cannot be processed simultaneously.

The workflow between the office PC and the device on the loading vehicle is organized in much the same way. The only difference consists of the transfer mode, for which memory cards are used. On the loading vehicles new data is generated at each loading of sugar beets. This is passed on to the factories by a data key.

Workflow of the solution from the user's perspective

The workflow solution includes doing preparatory work at headquarters, collecting data during beet harvesting, loading, and transporting, then consolidating the data back at headquarters.

Controlling activities at headquarters

Before September each year, the various harvest activities have to be planned. In the headquarters' ArcPad application, the plots are digitized using existing grid data. The next step is inputting attribute data used in the planning process. For each area, planners estimate the expected harvest date and yield, then they make decisions about which factories the crops will be hauled to and how the total amount will be split among them. Besides these field-related items, planners enter additional data about the farmers who cultivate the plots, along with details about the trucks and other loading vehicles.

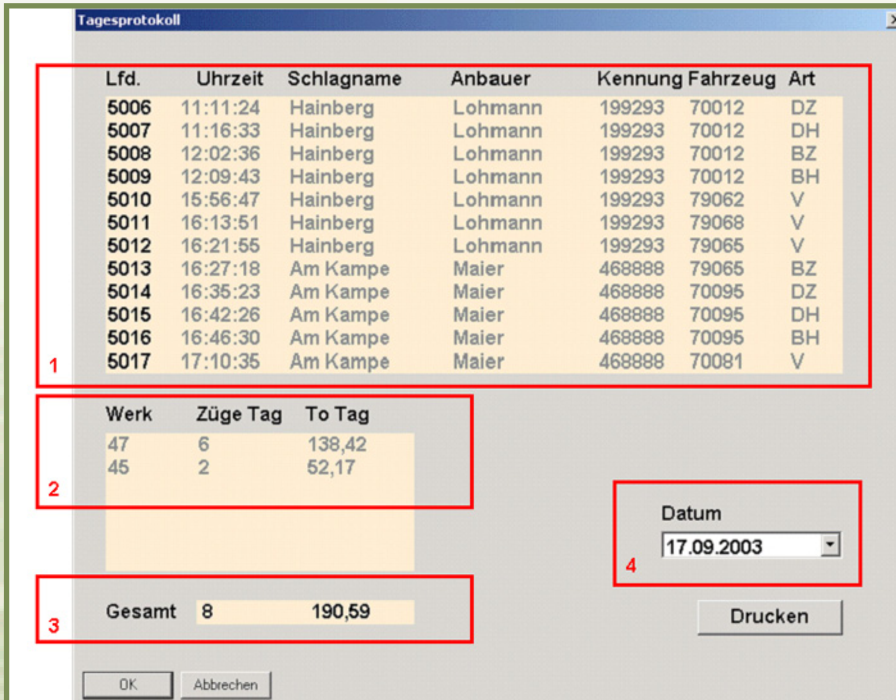
Planners also need to determine where the harvested sugar beets are to be deposited on the plot, and for this information, they created a point layer. The storage places are marked on the map and thus the drivers of trucks and loading vehicles can easily find them. In many cases the driving directions along the tracks to be used are also prepared and displayed as an additional object on the map. The drivers can use the directions for their route planning.

The planning process doesn't only take place inside the office. All data can be transferred to Windows Mobile clients and taken into the field. There the distributors complete the input and add further details. In addition, new plots can be surveyed using GPS.

As soon as the sugar beet harvest has started, the first transport schedules are drawn up at headquarters. For each area, three different collection dates are fixed. As large quantities of crops have to be hauled in one day, prioritizing the fields is possible.

The application allows the coordinator to list all areas with collections for a certain date and print them. Managing collection schedules is considered a dynamic process that constantly needs changing and adapting. For instance, unpredictable weather conditions can delay or damage the harvest, thereby forcing collection dates to be rearranged.

The data stored during planning is saved on a memory card that is given to the loading vehicles' drivers who then have access to the current planning data.



Courtesy of Mortiz Wurm

Figure 10.5 *Loading activities for a particular day for integration with ArcPad.*

Data capture during loading

An ArcPad application is also installed on the loading vehicles. Having logged in to the Tablet PCs or laptops, the vehicle's driver can feed the data from the memory card into the system, after which he can start working. The transport schedule clearly indicates those fields where sugar beets have to be loaded and the sequence of activities can be retrieved easily. With this information, the digital map, and the GPS position, the driver has everything needed to precisely locate the crop storage points.

For each loading operation, the system produces a documentation record consisting of a point object at the vehicle's current GPS position. As shown in **figure 10.5**, all loading activities for a particular day are listed (1), and the date can be selected (4). For each loading operation, the plot name (Schlagname) and the IDs of the farmers (Anbauer) and the trucks (Fahrzeug) are displayed. Moreover, the amount of beets loaded (To Tag) per refining factory (2) and the total amount of beets loaded are also shown (3).

This data is also written on a data key carried by most of the trucks, which can be read and processed at the sugar factories. The data key thus ensures the integrity of the data flow from the ArcPad application on the loading vehicle through to the factory.

The vehicle's driver can access the daily results through predefined queries. Another query returns the current total for each plot. For those farmers present during the loading, a report containing all loading details can be printed out. With this, farmers can prove which amounts were hauled from their fields. All data stored in the system during loading is saved on the memory card that is returned to headquarters at the end of the day.

Data consolidation at headquarters

Throughout the harvesting season, data is continuously being consolidated at headquarters. By processing the loading vehicles' memory cards, the current status on each plot can be retrieved. After an area has been cleared, it is deleted from the processed data. All data can be exported from ArcPad in dBase format and can be processed in other programs (e.g., Microsoft Excel). This is particularly helpful for billing and statistics.

Customization of ArcPad

A major prerequisite for using GIS in sugar beet logistics is user-friendly software. Particularly in the field, under difficult conditions, and with users not accustomed to working with IT systems, ease of use is essential. For this reason, ArcPad's standard user interface had to be customized for all system usage contexts. A further reason for customization was the need to implement additional features. The system underwent the following changes:

- Customization of the user interface (ArcPad applet)
- Integration of data key technology
- Creation layer edit forms and symbology (layer definition files)
- Printing functions (VB DLL)

The interface was complemented by an applet (APA file) with respective VBScript files. In the applet, ArcPad's standard toolbars are replaced by a user-specific one. Thus, most of the functions are hidden, and the user can access important commands via buttons and special dialogs. Certain functions like switching layers into edit mode have been automated. A second toolbar that provides specific needed functions has also been implemented for the headquarters' applet and the loading vehicle's applet.

Drivers on the loading vehicles need to be able to read and write data keys. The data key requires a data key controller, which is connected to the serial port. ArcPad manages the data flow between computer and data key controller. Communications are realized by the auxiliary programming interface. Generally, this allows the exchange of clearly defined datagrams. The data key controller acknowledges each datagram that ArcPad sends. ArcPad then reads the reply datagram's characters from the buffer and reacts accordingly. In this way, specific inputs from the data key can be addressed. Since every truck holds its own key, ArcPad is able to identify each truck. The loading details are written to predefined areas on the data key so they can be read in the sugar factories.

The actual display of layers is controlled by layer definition files (APL files). Moreover these layer files contain the data input forms.

A printer is connected to the computers on the loading vehicles at the parallel port. Since the current ArcPad object model does not support a print interface, the printout was realized through a DLL file called by VBScript. The DLL file then sends data to the parallel port using the parameter values.

Integration with GPS

A compelling argument for using ArcPad in sugar beet logistics is its GPS interface. ArcPad is able to communicate with a wide variety of GPS receivers with little configuration. Numerous functions for GPS data entry are a standard feature in ArcPad and the GPS position window constantly monitors GPS reception.

GPS has been integrated in the process of planning and operating at several points so that it provides a useful tool, especially since the open field conditions support rather precise GPS positioning.

Starting with the planning, distributors use GPS to survey land not yet registered and points where crops are stored before onward transportation. Even truck routes can be entered on a special line layer.

The GPS coordinates for each load of sugar beets are saved on the data key, making it possible to track the load back to the field. Sugar factories can use this information for quality control. In order to save plot data on the data key, at each loading, the current GPS position is automatically matched with the corresponding plot. ArcPad is then able to access all attribute data referring to the selected area.

Business benefits achieved

Overall, using ArcPad ensures a high level of data security and makes data transfer much easier. A constant replication of central and field data keeps all participants updated. People in the field have access to the most current data, thereby minimizing difficulties caused by a lack of information. In addition to these benefits, the use of GIS data in combination with GPS supports navigation in the field. Mobile GIS has proved to be the key instrument for controlling logistics.

CONCLUSION

The future of mobile GIS

Jonathan Raper, G-ability

This book has focused on the technologies and tools you need to make your mobile GIS project a success using ArcPad. It has covered mobility, platforms, positioning, integration, presentation, and customization, in detail, to bring you the experiences and success factors that are really critical to effective ArcPad use. Fieldwork with finite time and resources is inherently challenging: this book aims to help you fully prepare for your ArcPad project before you leave the office.

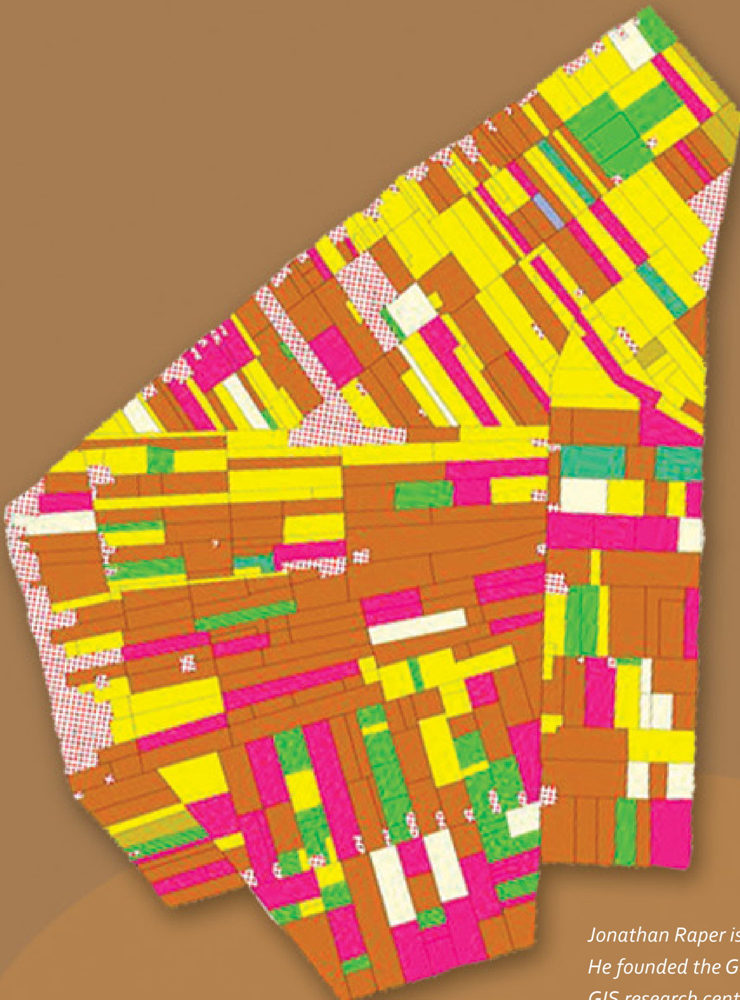
The benefits of mobile GIS are considerable: this has been recognized by the U.S. Census Bureau, whose thousands of field enumerators will use a customized version of ArcPad to follow-up nonresponse address assignments for the 2010 Census. ArcPad is also in use across the globe in forestry, land surveying, transportation, logistics, infrastructure management, and security assessment among others. All of these users share the key benefit of mobile GIS: the functionality of GIS can be deployed—and adjusted in real time if necessary—right there on-site where the action is happening.

Although we have distilled much experience of ArcPad use into this book, many other sources of information are available for you to consult. The ESRI User Forum for ArcPad, the ArcScripts library, and the Knowledge Base for ArcPad are all accessible from **www.esri.com**. These sources have now been joined by the ArcPad team blog at **arcpadteam.blogspot.com** and the ArcPad World site **(www.frappr.com/arcpadworld)**, where you can exchange experiences with other ArcPad users. We wish you all the best in your own projects!

The future

Mobile GIS is set for huge growth as the capabilities of mobile devices improve and as it becomes possible for you to integrate devices, connect to networks, and capture large data volumes securely in the field. Alongside these technical advances, expect increasing sophistication in mobile data management with intelligent synchronization and seamless access to Web services. Further on, expect mobile GIS to integrate with wireless sensor networks and to become a GIS ecosystem. For now, the real limit to mobile GIS is the humble battery: neglect it at your peril!

Category: Technology/Software Applications/GIS/Geographic Information Systems



ArcPad: A field user's guide

Take GIS with you wherever you go!

ArcPad: A Field User's Guide tells you how to use ArcPad—one of ESRI's feature-rich mobile GIS applications—to manage data and perform GIS analysis away from your desktop GIS. With ArcPad, you can download data over wireless networks and carry it with you, and add new data collected in the field. Running on a variety of portable devices such a mini laptops, Tablet PCs, and personal digital assistants (PDAs), ArcPad allows you to take GIS with you everywhere!

With ArcPad, you can extend GIS capability from an enterprise system on an application server to a desktop GIS in the office to a mobile GIS in the field. *ArcPad: A Field User's Guide* helps you set up an ArcPad system and describes how businesses around the world use ArcPad. Chapters include the following:

- Putting together a mobile system
- Using positioning technology
- Linking steps in a mobile network
- Presenting and displaying data on a small screen to good effect
- Customizing ArcPad for your applications

Jonathan Raper is professor of geographic information science at City University, London. He founded the Geographic Information Centre (giCentre.org) there in 1999, a leading GIS research center. In 2003, Raper and Geraldine Garner founded G-ability, a London-based consulting firm specializing in geospatial publications and location-based services.

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