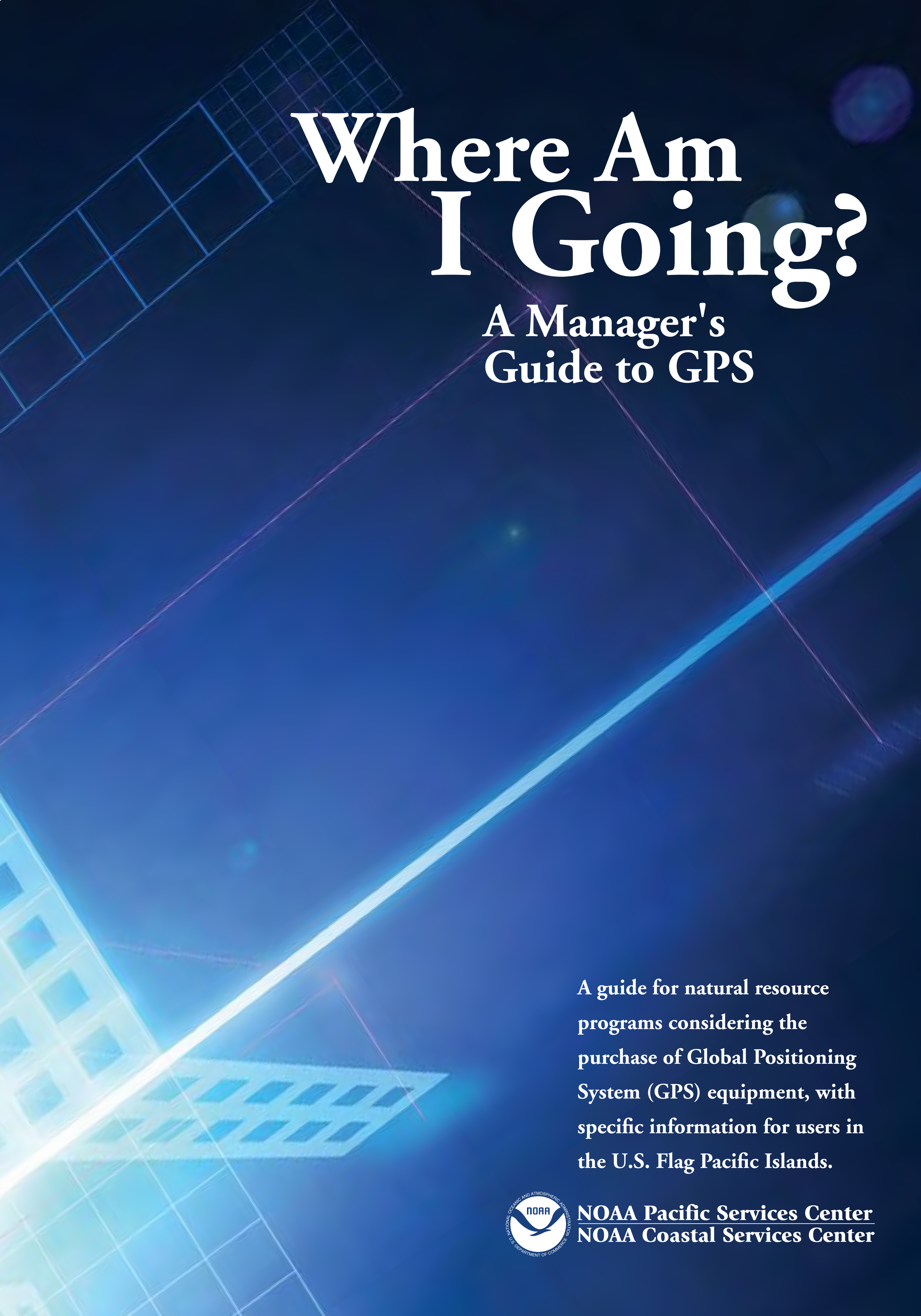

Where Am I Going?

A Manager's Guide to GPS

A guide for natural resource programs considering the purchase of Global Positioning System (GPS) equipment, with specific information for users in the U.S. Flag Pacific Islands.

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This document is intended to be a resource for the coastal and marine resource management community in the U.S. Pacific Islands. It introduces Global Positioning System (GPS) technology, illustrates the benefits GPS can provide, and discusses considerations for purchasing GPS equipment, while focusing attention on important factors specific to the U.S. Pacific Islands.

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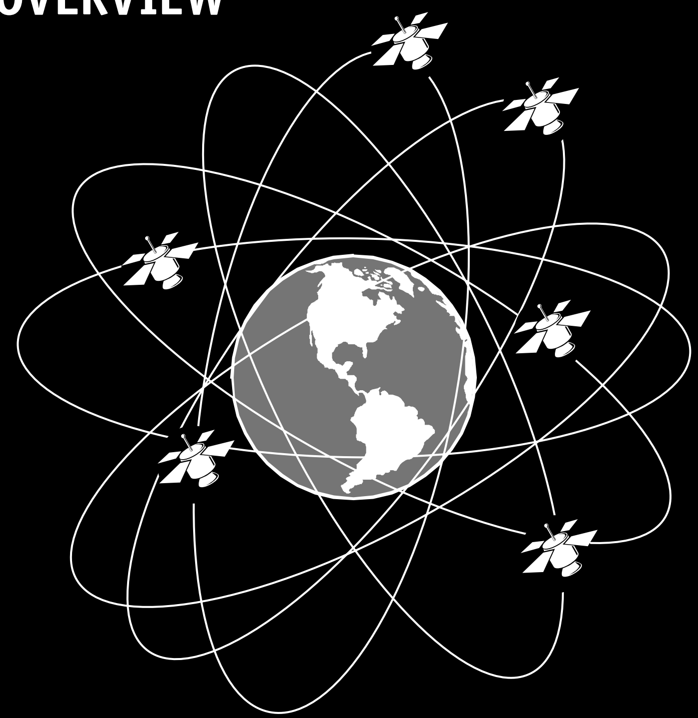
GPS OVERVIEW



What is GPS?

Global Positioning System (GPS) technology allows you to measure or estimate a location or position anywhere on the surface of the Earth at all times of the day. With GPS, you can determine one location or a series of points that make up a line or area. You can also use GPS to return to a known position at a later time, such as a research plot or monitoring site. Although originally developed for military use, GPS has proven invaluable in natural resource applications. It can be used to locate critical habitats, define marine boundaries, record locations of research observations, track movements of animals or monitoring equipment, and collect spatial data quickly and accurately for use in a geographic information system (GIS).

The U.S. GPS is a satellite-based radio-navigation system developed and operated by the U.S. Department of Defense (DoD). It is a constellation of at least 24 satellites orbiting the Earth at an altitude of about 12,500 miles and traveling at a speed of just over 8,600 miles per hour. These satellites are positioned around the Earth in such a way that five to eight satellites are accessible at any time of the day from anywhere in the world. Since its inception in 1978, GPS has expanded to many diverse civilian applications. The use of GPS has enabled the collection of accurate positional measurements, increased mobility in the field, and provided increased opportunities for spatial data creation.

How does GPS work?

A GPS receiver uses signals transmitting from at least four GPS satellites to determine its location on the surface of the Earth on any day, at any time, in most weather, and from any location. The first step in determining where a GPS receiver is located on the Earth is to establish the distance between the receiver and a GPS satellite. When a GPS receiver is turned on, it begins to search for any of the GPS satellites above the horizon. The receiver locks onto the strongest signal and starts to collect data. By timing how long it takes the satellite's radio signal to reach the receiver, the receiver determines its distance from that satellite. Once the distance from the receiver to one satellite has been calculated, the next step is to use this value together with the distance values from three other satellites to compute the three-dimensional position of the receiver (that is, latitude, longitude, and altitude or elevation) on the surface of the Earth.

GPS Basics

GPS equipment relies on a simple mathematical principle called **trilateration** to determine a three-dimensional position (latitude, longitude, and altitude) on the surface of the Earth.

GPS equipment must first receive a radio signal from four or more GPS satellites, which explains where the term **GPS receiver** comes from. Each radio signal includes the satellite's location and the precise time the signal left the satellite.

By timing how long it takes each signal to arrive, the GPS receiver can determine the distance to each satellite.

Once the distance to each satellite is known, the GPS receiver uses mathematical formulas to "triangulate" its own horizontal and vertical position.

How can GPS benefit my program or project?

Coastal and marine resource programs throughout the Pacific are taking advantage of the benefits provided by GPS. The collection of accurate GPS locations documents the position of important features in marine and terrestrial environments. This work can translate into precise shoreline delineations, safe maritime navigation, rapid critical habitat identification, or well-defined marine managed area boundaries.

Image copyright DigitalGlobe

Monitoring shoreline change in Guam with GPS

For example, the Government of Guam Coastal Management Program is using GPS to monitor coastal erosion at multiple sites around the island. By returning to the same areas to collect GPS positions of the shoreline, coastal resource managers are able to track changes in the shoreline. This information is being used to guide both long-term planning and short-term response to erosion problems. In Hawai`i, the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service uses GPS to determine if commercial vessels are fishing in restricted areas. Each vessel in the longline fleet has a vessel-monitoring system (VMS) on board. This system includes a GPS receiver and a radio transmitter that broadcasts the vessel's location, course, and speed to a fisheries enforcement control center. These diverse examples demonstrate the wide range of potential GPS applications. Other current applications in the U.S. Pacific Islands include mapping critical facilities, road networks, and endangered species habitat, and collecting on-the-ground positions for satellite imagery acquisition and processing.

Choose the Equipment to Meet Your Needs

Are there different types of GPS receivers?

GPS receivers come in many different varieties with a large range in cost and functionality. Your project needs, study area location, and accuracy requirements will determine which functionality options are most important for your organization. The following discussion will cover the range of common receiver types, from the simple recreational-grade to the more complex mapping- and survey-grade receivers.

GPS surveying on Saipan, CNMI

Recreational-grade receivers are good for camping, hiking, boating, and uses that do not require more than 10 to 20 meters (33 to 66 feet) of accuracy. They are typically the lowest in cost and offer the most limited functionality. They usually do not provide a connection to a computer, and if they do, only certain data sets or maps can be uploaded and limited data can be downloaded. Positions usually cannot be easily downloaded to other software packages.

Choose the Equipment to Meet Your Needs

continued

Mapping-grade receivers are the most diverse in terms of features, prices, and possible applications and can obtain 1- to 10-meter (3- to 33-foot) accuracy. The most common breakdown of mapping-grade receivers is based on the method of **differential correction**. Differential correction is the process by which GPS positions are corrected for errors. Differential correction uses a base station on the Earth to record the same GPS signals from the satellites as does your handheld or roving receiver. The base station's location on the ground is known to a very high degree of accuracy. Its positional values also are continually collected from the GPS satellites. The difference between the base station's known and satellite-measured locations is caused by error in the signal. Because the same satellites are used by both the base station and a receiver in the field, the errors in the signal are the same, and the base station corrections can be applied to your receiver.

Mapping wetlands on Rota, CNMI

Post-processing differential correction

There are two types of differential correction: post-processing and real-time. For **post-processing differential correction***, a base station computes the errors between its real and estimated location during a specified period of time and creates a difference file. Using GPS software, the difference file is applied to the receiver's positions after the field data have been collected. The result, after differential corrections have been applied, is an accuracy of 1 to 5 meters (3 to 16 feet), compared to a field accuracy of 10 to 20 meters (33 to 66 feet). Because these corrections are applied with a supporting computer after the fieldwork is over, the process is termed "post-processing" correction. The National Geodetic Survey (NGS), an office of NOAA's National Ocean Service, operates a series of base stations called* **continuously operating reference stations (CORS)** *throughout the U.S. Pacific Islands. More information on using CORS data for post-processing differential correction can be found at www.ngs.noaa.gov/CORS/.*

Real-time differential correction

Real-time differential correction *uses the same base station concept. However, instead of a base station computing the correction and writing the values to a file, the corrections are continuously broadcast out to your receiver via radio or cellular networks. The accuracy of real-time differential correction can be sub-meter to 2 meters (6.5 feet). Because these corrections are applied in the field as the data are collected, the process is termed "real-time."*

Obtaining ground control for satellite images in Hawai`i

Survey-grade receivers, which are the most costly, are used to determine positions within an accuracy of 5 centimeters (2 inches). Survey-grade receivers track a different portion of the GPS signal than do the mapping-grade receivers and therefore require specific situations in which to collect data. Unlike mapping-grade receivers, which can record data in somewhat obstructed or wooded areas, the survey-grade receiver requires an unobstructed view of the sky. Survey-grade receivers also require a longer time at each position, generally 20 to 30 minutes compared to 1 second to 5 minutes for mapping-grade receivers.

The widespread use of handheld computing devices such as personal digital assistants (PDAs) has given rise to a number of alternatives to the traditional GPS hardware options discussed above. **GPS-enabled PDAs** provide the functionality of a PDA along with a GPS receiver. There are two types of GPS-enabled PDAs: 1) **GPS-integrated PDAs** that include an internal GPS receiver and 2) **component systems** that rely on an external GPS receiver. External GPS receivers require either a physical (wire or card) or short-range wireless connection to communicate with a PDA.

To provide mapping capabilities, GPS data collection software can be installed on most PDAs. However, before purchasing hardware and software for mapping applications, you must ensure that the accuracy of the receiver and the possible method(s) of differential correction meet your mapping needs. Most GPS-enabled PDAs are equipped with recreational-grade receivers, while a few incorporate mapping-grade receivers that may or may not provide real-time differential correction. Lastly, when purchasing either a GPS-integrated PDA or assembling a component system, be sure to investigate compatibility between the PDA, the GPS receiver, and the data collection software. Most GPS-enabled PDAs can be purchased for under $800, not including data collection software.

Considering Equipment Options

When it comes to purchasing a GPS receiver, what options do I need to consider?

Now that you have an idea of how you can apply GPS in your agency or organization and you have been introduced to the different types of GPS receivers, it's time to start thinking about purchasing your GPS equipment. The options discussed here are not all that are available in the marketplace but are some of the more common ones. To help with your purchase, there are many commercial vendors happy to speak with you about your requirements, and this will help with comparing alternatives. You may also want to speak with colleagues in your agency or organization, or in a related field, to ask about their recommendations and experiences. Local GPS, GIS, and surveying user groups are a great place to start. To avoid feeling overwhelmed, keep in mind that both the needs of your project or organization and the funds to purchase the equipment will dictate which features are essential and which can be overlooked.

Do I need real-time differential correction?

Not all receivers have real-time differential correction. Deciding if this feature is needed for a project or organization is very important. If a high degree of accuracy is needed *in the field*, then real-time differential correction is required. If the data will not be used as they are collected, but only afterward in the office, then a standard post-processing-capable receiver will suffice. Aside from the basic difference in technique, the biggest difference between receivers' differential correction capability is price. Receivers with real-time differential correction can cost substantially more than standard post-processing receivers.

Surveying cultural resources with GPS on Saipan, CNMI

If I do need real-time differential correction, is it readily available in my study area?
In the U.S. Pacific Islands, the only publicly available network of radio towers transmitting real-time differential correction information is the U.S. Coast Guard (USCG)-operated **Maritime Differential GPS (DGPS) Service**. This system consists of a network of beacons set up in coastal areas to provide real-time information. Unfortunately, there are currently no DGPS network beacons providing real-time differential correction in Guam, the Commonwealth of the Northern Mariana Islands, or American Samoa. In Hawai`i, real-time differential correction via the USCG DGPS network is only possible on the main eight islands.

If real-time differential correction is not readily available in my study area, what can I do?
If real-time differential correction is required outside the coverage area of an existing real-time differential correction network, a **real-time kinematic** (RTK) system can be established. An RTK system requires two receivers, one stationary receiver (the base station) located at a known horizontal and vertical coordinate like a benchmark, and another that can

Wide Area Augmentation System (WAAS)

The Wide Area Augmentation System (WAAS), developed and maintained by the U.S. Federal Aviation Administration (FAA), is a real-time differential correction system for GPS designed to provide precision flight approaches for aircraft in the U.S. Although specifically designed for aviation applications, WAAS corrections are publicly available, providing civilians with an additional source for real-time differential correction.

WAAS uses a network of 25 monitoring stations, two ground reference stations, and two geostationary satellites to monitor, calculate, and broadcast a differentially corrected message in real time to WAAS-enabled GPS receivers. The full correction message accounts for both horizontal and vertical positioning errors. Horizontal errors are caused by GPS satellite orbit and clock drift, and vertical positioning errors are introduced by signal delay from atmospheric and ionospheric interference. To receive the full correction message, your GPS receiver must be WAAS-enabled, within the WAAS satellite footprint, and within close proximity to the continental U.S. The following Web sites provide maps with real-time snapshots of the extents of the horizontal and vertical corrections available with WAAS.

www.nstb.tc.faa.gov/npa.html

www.nstb.tc.faa.gov/vpl.html

In Hawai`i, WAAS-enabled GPS receivers are able to receive the WAAS horizontal corrections broadcast from the WAAS satellites but are not within distance of the ground reference stations located on the U.S. West Coast to receive the full WAAS correction. Thus, WAAS-corrected positions in Hawai`i are not expected to be as accurate as those corrected with WAAS within the continental U.S. According to the WAAS satellite footprint, the horizontally corrected signal reaches American Samoa, but reliable signal reception could not be confirmed. As of publication, the WAAS signal was not available in Guam or the Commonwealth of the Northern Mariana Islands.

Comparison of GPS Receiver Options

	Recreational Grade	Mapping Grade	Survey Grade
Cost	$	$$$	$$$$
Number of Channels	6 to 12	6 to 12	9 to 12
Accuracy	3 to 10 meters	1 to 10 meters	~ centimeter
Real-Time Capability	Yes	Yes	Yes
Post-processing	No	Yes	Yes
Data Logging	Simple	Advanced	Advanced
Complex Data Logging	No	Yes	Yes
Data Streaming	Yes	Yes	Yes

move to collect data (the rover). The two receivers communicate via radio beacons or cellular telephones connected to the receivers. The corrections to the GPS signal are determined by the base station and transmitted to the rover in real time. A disadvantage of using a radio signal in an RTK system is that the link seldom extends beyond 6 miles. The use of a cellular telephone network in an RTK system permits GPS data collection anywhere a cellular signal can be received. These systems require trained personnel to operate and are expensive because of the additional equipment costs.

What options or features are important in a GPS receiver if the data are to be used in a GIS?

In addition to the difference in differential correction capabilities, another common difference between receivers is their **data-logging capabilities**. The ability to log descriptive information (attributes) about a feature with each position is very important. This option allows the collection of more spatial or GIS-ready data and separates lower-end from higher-end receivers. Having data-logging capability can also improve and control data as they are collected, rather than having to rely on field notes back in the office. The data log allows users to determine what attributes or information is included about a feature, provide a location for supplemental information to be stored, and require users to enter needed information about various features. Data logging allows features being mapped to be described not only as locations, but also as information that can be used in a GIS.

If your work does require data logging, you will want to consider compatibility to external software. **External software** works with the receiver to transfer data to a computer, allowing the user to review, edit, print, and export the GPS data. Many software packages provide the ability to export the GPS positions to data formats appropriate for importing into GIS or CAD software. You will also want to consider the different methods for **entering alphanumeric data**, such as via a keypad or touch screen. Depending on your application, you may also need to consider the **amount of memory** required for working with large data sets.

How can I compare the accuracy of different receivers?

The **number of channels** in a receiver determines how many satellites a receiver can read at once. The more satellites a receiver can read, the more accurately it can measure a position. Six-channel receivers usually get 10- to 15-meter (33- to 49-foot) accuracy in the field, while 12-channel receivers can get 5- to 10-meter (16- to 33-foot) accuracy before any differential correction. In addition, a manufacturer-specified positional accuracy of a GPS receiver may be given as a **Root Mean Square** (RMS) value. This value typically is based on a 68 percent confidence level. A receiver with a particular RMS accuracy specification can expect to calculate a position within that specified distance 68 percent of the time. For example, if a receiver has a 10-meter accuracy specification and a user collects 100 points, then 68 points are likely to be within 10 meters of the true location, while 32 positions are likely be outside a 10-meter distance.

What other options are there to consider?

Other options common to GPS receivers are the **amount of disk space** on the receiver and **real-time data streaming**, which allows for the instant transfer of data from your receiver to a computer or handheld device. These options may come as standard or extra features on different receivers. **Manufacturing standards** for reliable use in extreme environments are also important to consider. If your receiver will be exposed to high humidity, high altitudes, extreme temperatures, potential water immersion, or wind-driven rain, sand, or dust, you may want to consider its manufacturing specifications.

What about all the accessories and hardware options?

In addition to decisions about receiver functionality, there are many GPS accessories and other hardware options to consider. **Power source options**, including battery life, battery weight, and the power demands of your receiver, are important considerations if you will be working away from an electrical outlet. You may want to consider adapters for connecting your receiver to alternate power sources such as a car cigarette lighter, solar power, or AC power. Your receiver's **antenna configuration** is another important consideration. If you plan to use your receiver under cover of a car roof or a thick vegetation canopy, you will need the capacity to use an external antenna. If you are only using the receiver from inside a vehicle or from the bridge of a ship, you may want to consider a fixed-mount unit with a mountable external antenna. If your unit is not a fixed-mount, you will need to consider the many options for working hands free. Having your hands free and being comfortable is important for collecting data in the field for long periods of time or over long distances.

What if my project or organization doesn't have the funds to meet my GPS requirements?

Purchasing the right GPS equipment to meet your needs can be a significant financial investment, and it is often the case that an organization's GPS requirements extend beyond its budget. This may be an excellent opportunity to develop partnerships with other agencies or organizations possessing the capacity you require. Because developing partnerships may take time and may not address immediate needs, it is always possible to rent GPS equipment or contract GPS services. Renting and contracting, however, are often not viable long-term solutions.

As daunting as the investment in GPS technology may seem, once you define your budget and begin to identify your most critical needs, the process becomes more about preferences and less about requirements. The following pages contain additional sources of information about GPS technology, training opportunities, and on-line resources. For more information on this guidebook or to request a printed or digital copy, please contact the NOAA Pacific Services Center at (808) 532-3960 or via e-mail at *psc@noaa.gov*.

Additional
Information Resources

National Oceanic and Atmospheric Administration (NOAA) Pacific Services Center (PSC)
PSC provides GPS training and technical support to the coastal and marine resource management communities in the U.S. Pacific Islands. Formal courses are scheduled via the NOAA Coastal Services Center on an as-needed basis. PSC also has a dedicated technical support staff for providing timely project support and also houses the National Geodetic Survey Pacific Region geodetic advisor, who is available for general and technical inquiries. You can find out more information by contacting PSC via e-mail at *psc@noaa.gov*.

NOAA Coastal Services Center
The NOAA Coastal Services Center offers regularly scheduled training courses to support the nation's coastal resource management programs. A three-day course, *Coastal Applications Using ArcGIS,* contains a training module called *Overview of the Global Positioning System* that provides a general understanding of the GPS system, positional determination, sources of error, correction methods, applications, and receivers. Skills taught include the creation and implementation of a field-data-collection plan and the creation of a data dictionary. More information, including scheduled courses, can be found at *www.csc.noaa.gov/training/*.

NOAA National Geodetic Survey (NGS)
NGS coordinates two networks of continuously operating reference stations (CORS): the National CORS network and the Cooperative CORS network. Each CORS site provides Global Positioning System (GPS) carrier phase and code range measurements in support of three-dimensional positioning activities throughout the United States and its territories. CORS data can be downloaded at *www.ngs.noaa.gov*.

U.S. Fish and Wildlife Service National Conservation Training Center (NCTC)
The NCTC trains and educates natural resource managers to accomplish the goal of conserving fish, wildlife, and plants, and their habitats. NCTC offers training and education opportunities to its employees and others. On-line courses include *GPS Overview for Natural Resources, GPS Introduction for Natural Resource Field Personnel,* and *GPS Advanced Applications for Natural Resources.* Course descriptions can be found at *http://training.fws.gov.*

U.S. Geological Survey (USGS) Global Positioning System Page
The USGS GPS page contains resources for general GPS information, training, services, and use in the USGS and the Department of the Interior. It is located at *http://biology.usgs.gov/gps/home.html.*

Natural Resources Conservation Service (NRCS) GPS Web Site
The NRCS GPS pages provide support for GPS technology and applications for U.S. Department of Agriculture NRCS personnel. The site provides active links to general information, announcements, publications, presentations, and other resources: *www.ncgc.nrcs.usda.gov/products/gps/*.

U.S. Coast Guard Navigation Center of Excellence (NAVCEN)
NAVCEN operates the Coast Guard Maritime Differential GPS (DGPS) Service and the developing Nationwide DGPS Service, consisting of two control centers and over 60 remote broadcast sites, including three in the Hawaiian Islands. More information can be found at *www.navcen.uscg.gov.*

American Samoa Geographic Information System (ASGIS) Users Group
The ASGIS Users Group consists of representatives from various agencies and organizations in the U.S. Territory of American Samoa. Meetings are held bimonthly at participating agencies on a rotational basis. These meetings are held to discuss GIS-related issues, activities, and initiatives. More information can be found at *http://doc.asg.as/Default.htm*.

Pacific GPS User Group
The Pacific GPS User Group is a group of professionals in Hawai`i and the Pacific sharing GPS experiences and knowledge. You can sign up for the user group e-mail list to exchange tips, tricks, and technical information with other GPS users in Hawai`i and the Pacific at *http://groups.yahoo.com/group/gpsusergroup*.

GPS World
GPS World is a monthly publication and on-line magazine delivering content on innovations and best practices for employing global positioning technologies. *GPS World* provides news and analysis of business and technology developments, marketing trends, and policy issues affecting the GPS community. The publication's annual buyer's guide can be found at *www.gpsworld.com.*

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