

## Appendix A

### Technical Tools for Conservation Restriction Stewardship

#### 1. Digital Photography

Digital photography has simplified the process of capturing and managing images, and reduced the variable costs of photo documentation by eliminating film processing. Because the originals are stored in digital form, digital photographs are not subject to physical degradation that can render film prints and negatives unusable over time.

Some practitioners have expressed concerns about the use of digital photography in litigation over a conservation restriction violation. The most common concern is that digital photographs can be easily edited, and so may not be admissible as evidence. However, the same technologies that allow digital photographs to be doctored can also be used to modify traditional photographs. In addition, courts have developed rules to deal with digital evidence of all kinds (text files, email, etc.).

A factor that organizations and agencies should consider in deciding to use digital or film photography is their ability to maintain the digital technology and stay up to date, transferring data to new media as needed in a manner that will maintain the usefulness of the photographs over time and their validity as evidence.

See the web references at the end of this Appendix for more on the use of digital photographs as legal evidence. The proper handling of digital photographs for Baseline Documentation Reports (and monitoring) is discussed in Sections 4 and 5.

**Digital Camera Features:** As with other consumer electronics, the cost of digital cameras continues to decline even as performance and image quality continue to climb. Here are some key features to look for in a camera:





Picture Quality: Digital camera picture quality is measured in megapixels. A 1 megapixel camera will produce pictures with at least one million pixels (square dots), while a 3 megapixel camera will produce a picture with three million pixels. For baseline documentation purposes, a camera with 3 megapixels or more will produce a sharp image even at full-page enlargements.

Display: Liquid crystal displays (LCD) can be difficult to see in bright light or deep shade. In order to accommodate varying field conditions, it is best to use a camera with a traditional viewfinder. Many digital cameras come with both a viewfinder and LCD. The LCD is useful for verifying that the image captured is clear and encompasses your intended field of view.

Storage: Most cameras have removable storage devices (memory cards, memory sticks or disks) that are available in various capacities. A storage device or combination of devices capable of storing more than enough pictures for a day in the field should be selected. To determine the storage capacity needed, consider the size of the property, the length of the boundary, the number of corners, the topography and the number of natural and man-made features that will need to be documented.

Batteries: Over time, rechargeable batteries are far cheaper than disposables. Most good quality cameras come with rechargeable batteries. A second rechargeable battery may be necessary to accommodate a full day of use in the field, particularly during winter months as battery life declines with temperature.

Sound & Date Recording: Many cameras allow a short sound file to be attached to each photo. Sound doesn't take up much digital storage space, and allows each photograph to be annotated as it is taken saving some time in note-taking. A short narrative description such as "View along boundary wall toward northeast corner, restricted area to the left of the wall" provides a means for verifying the written information accompanying each photograph as the photolog is created. Many camera also have a date stamp. If you are using this feature, make

sure that the date is correctly programmed or it may call into question information in the affidavit if the date on the stamp doesn't match the date that the pictures were actually taken.

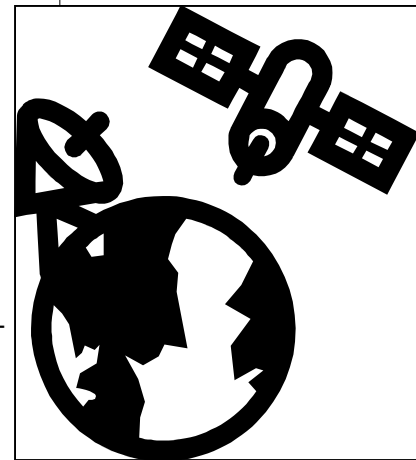
## 2. Global Positioning Systems (GPS)

GPS receivers are used to accurately locate points on the earth by accessing satellites operated by the U.S. Department of Defense. The most common uses of GPS receivers for baseline documentation and monitoring are locating positions where photographs were taken, recording boundary monuments, mapping trails and roads, and locating areas of conservation interest such as vernal pools or unusual natural communities, and recording the route of travel in the field.

Even inexpensive GPS receivers can often locate points more accurately than traditional methods such as compass and pacing. However, even the most expensive GPS receiver can produce inaccurate results if operated improperly. The discussion below provides an overview of GPS and specific suggestions for maximizing the performance of receivers of all types.

**Overview of GPS:** GPS currently relies on 24 operational Navigation Satellite Timing and Ranging (NAVSTAR) satellites traveling in six evenly spaced orbits. Each satellite orbits the earth every twelve hours. The receiver measures the time it takes for a signal to travel from a satellite to the receiver, and uses this to compute the distance from the receiver to the satellite, assuming that the signal travels at the speed of light. Based on four such distance measurements and the known location of each satellite, the receiver calculates a unique position.

GPS receivers can only access satellites that are above the horizon. The number of satellites above the horizon at a given location and their positions relative to one another — the *constellation* of available satellites — varies throughout the day as the satellites move within their orbits. It may take several minutes for four or more satellites to rise above the horizon and the GPS receiver to calculate a position.



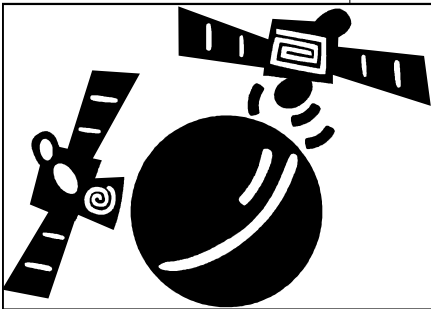
The constellation of available satellites also varies with local site conditions as GPS signals can be weakened by foliage and completely obscured by buildings or terrain. A given receiver may be able to quickly locate the required number a satellites when operated in an open field, but unable to calculate a position under difficult conditions such as under thick tree cover or in a deep ravine.

**Sources of Error:** There are three principal sources of position errors: 1) poor satellite geometry, 2) atmospheric delays, and 3) multipath error.

Satellite Geometry: The probability of calculating a position accurately is highest when the constellation of satellites is relatively widespread across the sky. When the only useable satellites are grouped closely together in the sky or arrayed in a line, they are said to have a high *Position Dilution of Precision (PDOP)*. A PDOP of 4 or less is excellent, and 7 or greater is poor.

Many receivers will display current PDOP, or allow the user to set a PDOP mask so that positions are only calculated when PDOP drops below a certain threshold. For receivers without this capability, it is possible to predict satellite geometry using

desktop planning software and regularly updated information about each satellite's position. Planning software and data are available for download at [www.trimble.com](http://www.trimble.com). This software will generate a chart showing predicted PDOP throughout a given day at a given location.



Atmospheric Signal Delays: A GPS receiver calculates the distance to each satellite based on the time it takes the signal to travel from the satellite to the receiver, assuming that the signal travels at the speed of light in a vacuum. However, these signals are delayed as they travel through the atmosphere, and these delays create position errors. Many receivers eliminate some of these errors using an equation for signal delays.

Errors caused by atmospheric signal delays can't be avoided, but they can be corrected using *differential correction*. By con-

stantly operating GPS receivers at fixed and known locations, it is possible to precisely calculate the position errors caused by signal delay (by comparing the known location with the calculated GPS location). This information is then used to correct positions calculated by GPS receivers in the field in the region of the fixed GPS receiver. These fixed GPS receivers are known as Continuously Operating Reference Stations (CORS). CORS are operated by government entities, universities and private companies across the United States.

Some receivers have the ability to receive and apply these corrections in *real time* while others allow for differential correction at a later date (known as *post processing*). Correction information is broadcast in real time via satellite to subscribers for a fee, and is available free of charge via the Internet for post processing.

Recently, a number of manufacturers have released receivers that are capable of real time correction using the *Wide Area Augmentation System (WAAS)*. WAAS is a program of the Federal Aviation Administration intended to improve the accuracy of GPS for use in commercial aviation. The WAAS system uses geostationary satellites over the equator to broadcast correction information. The position, low on the horizon in the northeastern United States, means that these satellites are often blocked by hilly terrain. The weaker WAAS signal is more likely to be absorbed by dense forest cover as WAAS satellites orbit at more than 22,000 miles versus the 12,500 altitude of the GPS satellites. As a result, the WAAS signal is often unavailable.

Multipath Error: Multipath errors result from satellite signals that are reflected off of obstacles near the earth's surface before they reach the receiver. These signals are delayed by the longer path and so overstate distance, and also can interfere with the straight-line signals. Some high-end receivers have software that filters out multipath signals. Using an external antenna and a *groundplane* will reduce multipath errors on less expensive receivers. The groundplane is a metal plate that attaches underneath the external antenna, and prevents reflected signals from reaching the antenna from below.

**Averaging:** Many receivers have the ability to collect more than one position at a given location, and to average these positions to cancel out random errors. Surveyors seeking accuracy of a few millimeters allow their receivers to operate for long periods at a single point. Collecting one to two minutes worth of data at a sampling rate of one position per second should usually be sufficient for documenting photopoints and capturing boundary locations.

**Comparison of Receivers:** GPS receivers range in price from less than \$100 to more than \$5,000 for mapping grade units. The best-known manufacturers of receivers in this price range are Magellan, Garmin and Trimble. All receivers have the same core capability: tracking multiple satellites and computing distances based on the signals received.

The more expensive units support differential correction in real time or via post processing, allow the operator to set averaging, PDOP and other parameters, and may have multipath elimination software. The least expensive units may not even accept an external antenna. A good compromise for baseline documentation and monitoring is a unit that will average points, allow for a PDOP mask and accept an external antenna that can be fitted with a backplane.

Additional information about purchasing and using GPS can be obtained from the sources identified in the “Resources” section at the end of this Appendix.

### 3. Geographic Information Systems

A geographic information system is a set of computer programs designed to manage, analyze and display spatial data. Spatial data may be thought of as points (e.g., a concrete post at the corner of a property), lines (the western boundary of the town of Marshfield) polygons (the outline of Franklin County) or images (an aerial photograph of Massachusetts).

All of the information in the GIS must be spatially referenced (“*georeferenced*”) as it is entered, typically by longitude, latitude and elevation. This al-



allows the user to overlay data from various sources to create maps (overlying the boundary of Marshfield over an aerial photograph, for example) or for analytical purposes.

**MassGIS:** MassGIS is the Commonwealth's Office of Geographic and Environmental Information, which develops and maintains a statewide database of spatial information for environmental planning and management. MassGIS has a number of datalayers and images that are particularly useful for baseline documentation and monitoring, including

- Hydrography
- Contiguous Natural Lands
- Protected and Recreational Open Space
- Natural Lands Riparian Corridors
- Certified and Potential Vernal Pools
- Biomap Core Habitat & Supporting Natural Landscapes
- Living Waters Core and Supporting Watersheds
- Scenic Landscapes
- Topographic Contours
- Areas of Critical Environmental Concern
- USGS Topographical Maps
- Black and White and Color Orthophotos

MassGIS has created a dataviewer that makes it easy to navigate through the various datalayers. The dataviewer may be used online or downloaded for use with ArcView. These datalayers are also available for download from the MassGIS website or may be ordered on CD-ROM ([www.mass.gov/mgis/](http://www.mass.gov/mgis/)).

A digitized outline of the conserved property boundary, prepared based on photo interpretation or from GPS locations of boundary points (as described in Subsection 4, below), can be used as an overlay on the various MassGIS datalayers to create maps depicting conservation resources, land uses, topography and soils, and hydrology on the land subject to the conservation restriction.

**Importing Data to GIS:** All of the data in MassGIS has been

spatially referenced to a common *coordinate system* (the Massachusetts State Plane Coordinate System) and *datum* (the North American Datum 1983). A coordinate system is a means of specifying locations in space, such as by latitude, longitude and elevation. Each coordinate system specifies a *projection*, a mathematical means of representing the curved surface of the earth as a plane. A datum is a simplified model of the earth, either in the form of an ellipsoid or a geoid.

There are many different coordinate systems and datums in common use today. Before datalayers from multiple sources are used together to create maps or for analysis, they must be *reprojected* – converted to a common coordinate system and datum. Most GIS programs have utilities that allow a datalayer to be reprojected into a new coordinate system and datum. Information about a given datalayer’s spatial references is typically contained in a “metadata” file available from the data vendor. The metadata contains information on how and when the data was gathered, where it comes from, and any limitations on its use.

**Importing GPS Locations to GIS:** By importing GPS data into a GIS, it is possible to quickly create maps of photopoints, boundaries, roads and trails. An outline of the conserved property boundary can then be used as an overlay on the various MassGIS datalayers to depict conservation resources.

GPS data must be reprojected to be consistent with other GIS datalayers. Most GPS receivers compute position using the World Geodetic System 1984 (WGS 84)/Geodetic Reference System 1980 (GRS 80) datum, although they may be set to display coordinates in various coordinate systems and datums.

GPS data can be reprojected as it is exported from the receiver, or as it is imported to the GIS program. Trimble software allows the data to be reprojected as it is exported. There are various export programs available for Garmin and Magellan receivers. Some allow for reprojection, while others simply extract the “raw” data in a form suitable for export to GIS. A free utility for Garmin receivers is available from the Minnesota Department of Natural Resources ([www.dnr.state.mn.us](http://www.dnr.state.mn.us)).

#### 4. Aerial Photography

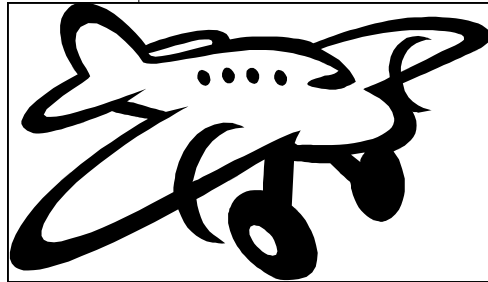
Aerial photographs are available from public agencies and private vendors in a wide variety of scales, resolutions and formats (e.g., black and white, color, color infrared). In baseline documentation and monitoring, aerial photographs are used to document property conditions at the time the restriction is recorded, identify changes to the property, identify vegetation community types, and as a backdrop in GIS to digitize property boundaries.

**Digital Orthophotographs:** A digital *orthophoto* is a digitized aerial photograph that has been “orthorectified” so that it is a planar representation of the subject area as if it were totally flat. This means that it has been corrected for the distorting effects of the ups and downs of the topography on the ground.

Orthophotos can be used for digitizing property boundaries as described below. A digital orthophoto that is georeferenced using the same datum and coordinate system can also be used with other GIS datalayers.

MassGIS offers a number of digital orthophotographs. The most useful for baseline documentation and monitoring are the statewide 1:5,000 Color Ortho Imagery and the 1: 5,000 Black and White Digital Orthophoto Images, both with ½ meter ground resolution (i.e., each pixel represents ½ meter). The most recent photos are available for downloading from the MassGIS web site or can be used online to make a map using their Online Data Viewer at [www.mass.gov/mgis/mapping.htm](http://www.mass.gov/mgis/mapping.htm).

**Digitizing Boundaries:** Aerial photographs have a number of cues that can be used to digitize property boundaries in GIS. First create a rough polygon of the property boundaries using whatever map or property description is available. Using an aerial photograph as a backdrop, the corner and lines of the polygon may be edited to conform to features such as roads, structures and clearings. The edited polygon can then be used to delineate the property boundaries on topographical maps and aerial photographs for the initial site visit. GPS locations collected during the visit can later be used to correct the polygon.



	<p>Note that it is not unusual for parcel lines created on aerial or orthophotos to not fit precisely on topographic maps (and vice versa). Remember that a map like this is an approximation of the boundaries and not a substitute for the actual survey plan.</p> <p><b>Other Aerial Photography Sources:</b> The oldest MassGIS aerial photographs date back to 1992. Earlier photos for conservation restrictions granted prior to 1992 are available from The Aerial Photography Field Office of the US Department of Agriculture (<a href="http://www.apfo.usda.gov">www.apfo.usda.gov</a>) and a number of commercial vendors, including Col-East, Inc. (<a href="http://www.coleast.com">www.coleast.com</a>), Eastern Topographics (<a href="http://www.e-topo.com">www.e-topo.com</a>), James W. Sewall Company (<a href="http://www.jws.com">www.jws.com</a>), Chas. H. Sells, Inc. (<a href="http://www.chashsells.com">www.chashsells.com</a>) and National Aerial Resources (<a href="http://www.nar.com">www.nar.com</a>).</p> <p>Most vendors will supply aerial photography in either digital format or hard copy. Hard copy prints can be digitized using a desktop scanner set to the appropriate resolution. Note that while digitized photographs can be imported into a GIS, they cannot be used with other datalayers unless they are georeferenced.</p> <p>Another sources of very low level oblique aerial photographs can be found on the web at <a href="http://www.local.live.com">www.local.live.com</a>. New sources are regularly available, so it is worth your time to do some searching for aerials of your area.</p> <p><b>Satellite Imagery:</b> Aerial photographs are particularly good for baseline documentation and monitoring as they are taken at relatively low heights (hundreds of feet versus hundreds of miles) and have high resolution. However they are generally taken at infrequent intervals. The potential advantage of satellites is that images of a given area are captured and made available on a regular basis.</p> <p>Until very recently, commercial satellite images were only available at low resolutions. Resolution is important as it determines the minimum size object that may be seen in an image. A 30-meter resolution satellite image would be comprised of pixels (picture elements) 98 feet square. At this resolution any object smaller than 98 feet on a side would be invisible even if it fell in the center of a pixel.</p>
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Now there is high-resolution satellite imagery with ground resolutions of a meter or less, comparable to aerial photographs. On a per acre basis, the costs are quite low (\$26.00 per square kilometer for some satellite images from one vendor ([www.OrbView.com](http://www.OrbView.com)) However, the individual images are very large and, as a result, so are the minimum order requirements and the cost: the minimum archival order for OrbView is 64 square kilometers, for a minimum order of just under \$1,700. This begins to approach the cost of hiring an aerial photography company to fly custom photographs.

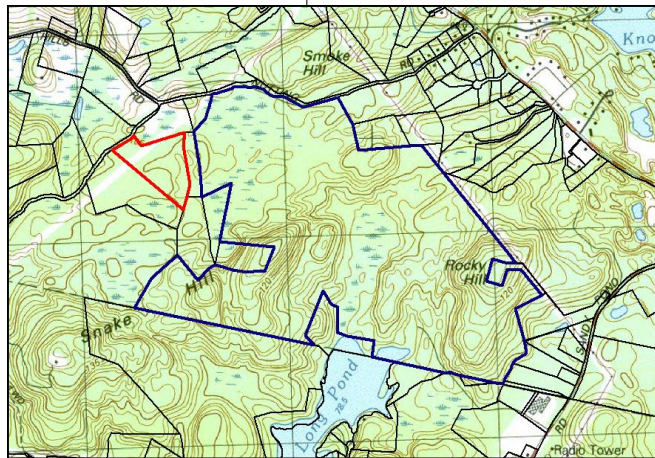
### 5. Topographical Maps

Topographical maps use contour lines (lines of equal elevation) to depict land forms, and show natural and manmade features of the landscape, including areas of vegetation (shown in green), water bodies (blue), developed areas (gray or red) as well as trails, roads, utility lines, and other infrastructure, and major buildings. Topographical maps thus contain lots of information that is useful for determining boundary location in the field, and in characterizing a property in the Baseline Documentation Report.

United States Geological Survey (USGS) topographical maps are available in various scales. The most useful for baseline documentation and monitoring are the 1:24,000 scale maps (or metric versions at a scale of 1:25,000).

These maps are also referred to as 7.5 minute quadrangles as each encompasses an area 7.5 minutes of longitude by 7.5 minutes of latitude. One inch equals 2,000 feet on these “large scale” maps. The USGS also produces smaller scale maps at 1:100,000 and 1:250,000.

USGS maps are prepared from a variety of sources including stereoscopic aerial photographs and ground surveys. They are highly accurate: the National Map Accuracy Standards require that 90% of all field-verified points on a 1:24,000 map be within



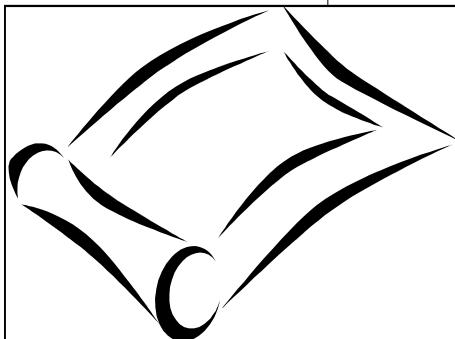
40 feet of their mapped locations horizontally, and within one-half of a contour interval vertically (e.g., within 10 feet if the contour interval is 20 feet).

USGS maps are generally available at many bookstores and outdoor recreation stores. They are also available for downloading from the Mass GIS web site and other commercial online sources such as [www.topozone.com](http://www.topozone.com).

## 6. Boundary Location

**Boundary Description:** The property description in the conservation restriction is generally found at the end of the restriction. It can take many forms, including citation of deeds or plans (by registry book and page numbers or land court document number), reference to town tax maps, or recitation of metes and bounds (i.e., distances and directions). Sometimes a plan is recorded that is prepared specifically for the conservation restriction. This is often done when portions of a property have been excluded from the conservation restriction or if there are building areas reserved within the restricted land.

The property description in the conservation restriction may not be sufficiently detailed to be used for boundary location in the field and additional research may be required. The appropriate county Registry of Deeds or Land Court will have copies of any plans or deeds cited in the conservation restriction. Cited deeds and earlier deeds from prior sales of the subject property may contain useful plan references. Most of the Registries in Massachusetts are now accessible on line, and many allow for viewing and printing of plans and deeds. Town offices frequently have plans on file in the offices of the town clerk, assessor, town engineer or planning department. Note that tax assessor's maps should not be used for boundary location themselves as they are prepared at very large scales, and are often not accurate at the parcel level (see Section 3 of this Manual for more information in researching land ownership).



Metes and bounds property descriptions should be converted into a map for ease of use in the field. This can be done by hand using a protractor and ruler, or

using GIS. The Norcross Wildlife Foundation/Massachusetts Department of Environmental Management Data Editing Extension is a free extension for ArcView that produces maps from metes and bounds descriptions (see <http://www.state.ma.us/dem/programs/gis/de/pe.htm>).

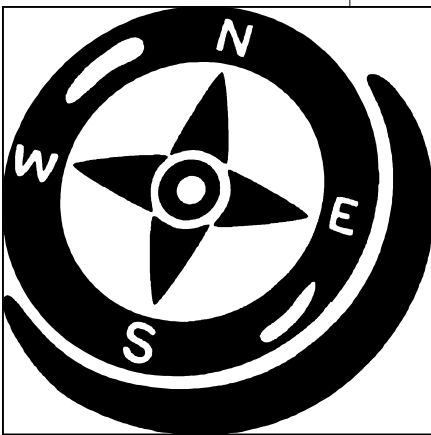
If there is no map or description of the property, it is possible – but very time consuming – to compile a property map using plans or metes and bounds descriptions of abutting properties where these are available. Use the town tax map to identify abutters by tax map and lot or deed book and page, then search the appropriate Registry, Land Court and town offices for plans.

**Boundary Location in the Field:** Using whatever property descriptions are available, annotate a copy of a map or prepare a sketch that shows every corner and line monument by type, and the distance and direction from each monument to the next. Monuments will be identified by type in the metes and bounds property description and on the survey plans. The most common types are stone bounds (SB), concrete bounds (CB), iron pipes (IP), or rods (or even musket barrels), stonewalls and rock piles. Rock and concrete monuments often have drill holes to precisely locate a corner or line.

A map may refer to pre-existing boundaries as “found” or “existing” (e.g. “found concrete bound”), and those established or to be established at the time the map was made as “set” or “to be set” (“set iron pin”, “iron pin to be set”). It is not uncommon to find that boundaries labeled as “to be set” were never actually put in place.

Wooden stakes near a boundary line may indicate where a permanent boundary was to be set, or could simply be a temporary marker used by the surveying team. Similarly, flagging and areas of cleared vegetation left over from a prior survey may be on or off a boundary line, and may even extend into adjacent properties – particularly in the case of wetland flagging.

The most efficient way to accurately locate property boundaries is to methodically move from one monument to another, following the bearing of the boundary line with a hand compass and keeping track of the distance traveled along the way.



Blazes: Often boundary lines will follow stonewalls or the remains of an old wire fence. Absent these features, it is common to blaze and paint trees on or near the boundary line. A blaze is made by removing a small area of bark with a drawknife or hatchet to expose the wood underneath. The blaze is usually painted to make it visible at a distance.

Trees that are on the property line are blazed in the center on both sides, so that an imaginary line drawn through the blazes would point along the boundary line. *Quartering blazes* are often made on trees that are within three feet of the line. These are similar to the property line tree blazes, but are offset to the side of the tree closest to the line. Trees three to six feet off of the line are blazed once, on the face that points toward the line. Trees are also blazed to indicate corners. Three or more “witness” trees around a corner monument are each blazed on the side closest to the marker. This makes it easier to locate the marker, and makes it possible to replace it if it is disturbed.

Even absent boundary markers, walls, wire or blazes, it is possible to follow boundaries based on cues on the ground. Often there will be a noticeable difference in vegetation on one side of a boundary line due to differing historical uses (e.g. pasture versus cultivated field, managed woodlot versus uncut forest). Other cues include the distinctive mark of healed tree blazes, or persisting scars and burls on trees from fence wire long rusted away.

Following a Bearing: Boundary line bearings may be given in *azimuth* or in *quadrants*. Bearings in azimuth simply use the clockwise angle of deflection from north, with north being 0 degrees, east 90 degrees, south 180 degrees and west 270 degrees. In the quadrant system, the compass is divided into four sections (quadrants): northeast, southeast, southwest and northwest. Directions are given with reference to these quadrants so that northeast is “north 45 degrees east”. The table on the next page compares these two systems:

	<b>Degrees</b>	<b>Quadrant</b>
<b>Northeast</b>	45	N 45 E
<b>East</b>	90	N 90 E, or S 90 E
<b>Southeast</b>	135	S 45 E
<b>Southwest</b>	225	S 45 W
<b>West</b>	270	N 90 W or S 90 W
<b>Northwest</b>	315	N 45 W

Compass bezels (the outer ring that turns) are marked in degrees, quadrants or both degrees and quadrants. Using quadrant bearings with a compass marked in degrees is relatively simple. First set the compass to north or south according to the quadrant bearing, and then turn it the specified number of degrees toward east or west. For example, to set a degree compass for the bearing S 45 W, set the bezel to south (180 degrees) then turn it 45 degrees toward the W mark on the bezel (to 225 degrees).

Bearings may be given with reference to *magnetic north* – the direction of the force lines of the earth’s magnetic field – or true north – toward the earth’s geographic north pole. The difference between the direction of magnetic north and true north is referred to as *declination*. Declination varies from location to location, and over time. The current declination in Massachusetts is approximately 16 degrees west (i.e., magnetic north is 16 degrees west of true north), whereas it is 16 degrees east in Idaho. Current local declination is printed on USGS topographical maps. In Massachusetts, to convert a magnetic reading to true north, subtract 16 degrees. Many compasses can be set to compensate for declination, allowing readings to be made directly in true north.

The polarity of the earth has completely and abruptly reversed itself several times over geological time scales. Magnetic north wanders east and west over much smaller time frames, and so the declination at a given location changes as a result. The table on the next page shows the declination for Worcester

Massachusetts at the beginning of each of the last ten decades, and the annual average change in declination for the decade (calculated using the USGS web site declination calculator).

Year	Declination (west)		Annual Change (minutes)
	Degrees	Minutes	
1930	14	20	2 west
1940	14	35	0
1950	14	27	0
1960	14	29	0
1970	14	32	0
1980	14	46	3 west
1990	15	10	2 west
2000	15	11	2 east

This is the reason true north is often used in maps – it is a fixed reference point. If your map is old and the bearings are given in magnetic north, you may need to compensate for subsequent changes. For example, the magnetic north bearings from a 1930 map would be some 50 minutes off of magnetic north in the year 2000.

Note that *Grid north* appears on many recent maps, including most topographic maps. Grid north is the reference north of coordinate systems that depict the curved surface of the earth as a plane, such as the Massachusetts State Plane Coordinate system described in Section C above. While the difference between grid north and true north is significant near the poles, in our mid latitudes the difference is too small to matter when using a hand held compass.

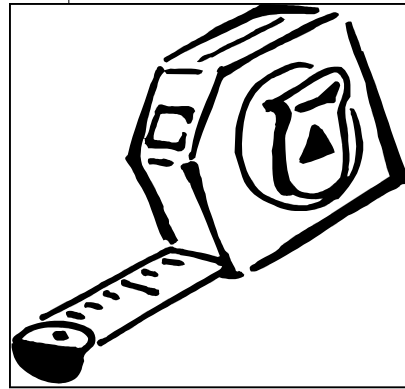
Most professionally prepared maps include a compass rose that indicates the basis for the given bearings. A north arrow with a star is true north, an arrow with an “N” is magnetic north, and an arrow with “GN” is grid north. If the map doesn’t specify in writing or symbolically, pick a prominent line feature on the map (e.g., a road or a wall) and compare its given bearing with a compass reading made on site.

Traditionally, bearings found on maps or in metes and bounds descriptions were given in *degrees, minutes and seconds*. There are 360 degrees on the compass bezel. Each degree is divided into 60 minutes, and each minute into 60 seconds. 45° 12' 50" stands for 45 degrees, 12 minutes and 50 seconds. Bearings may also be given in *decimal degrees*. Decimal degrees express the minutes and seconds as decimal fractions. To convert from degrees minutes and seconds to decimal degrees, the equation is: degrees + minutes/60+seconds/3600. In decimal degrees, 45 12 50" would be expressed as 45.2139 (calculated as 45 degrees +12 minutes/60 minutes + 50 seconds/3600 seconds)

When using a hand held compass, round up to the nearest degree. Minutes and seconds are only meaningful when using a staff-mounted compass or surveying instruments. Set the bezel to the specified direction, then rotate the compass until the arrow aligns with north. Note that large mineral deposits, power lines, electric fences and electronic equipment such as GPS receivers or cameras can cause the needle to deviate from magnetic north. Hold the compass level at about waist height, and well away from electronic devices. Pick a visible landmark (a snag or a tall tree, for example) that is in line with the direction indicated and use it as a guide. When following a boundary line that is not well marked (i.e., no fence or blazes), hang small pieces of flagging at head height periodically, then back sight on these with the compass to maintain the bearing.

Measuring Distance: When setting monuments surveyors use steel tapes and lasers to measure distances to within a small fraction of an inch. Fortunately, following these surveyor's measurements to relocate boundaries doesn't require nearly the same level of accuracy.

*Pacing* – measuring distance based on stride – is an efficient way to measure distance between boundaries. To determine the length of your pace, measure out a distance of 100 feet on level ground and walk it several times. Divide the distance by the average number of paces (each pace is two steps). Adult paces range from less than 4ft. to more than 6ft.





**For Further Reading:**

**Digital Photography:**

The Admissibility of Digital Photographs in Court, Seven B. Staggs— [www.crime-scene-investigator.net](http://www.crime-scene-investigator.net)

Digital Photography as Legal Evidence, Roderick T. McCarve [www.seanet.com/~rod/digiphot.html](http://www.seanet.com/~rod/digiphot.html)

Mapping Systems General Reference, Trimble Navigation Limited, 645 North Mary Avenue, Sunnyvale, CA 94085

**Boundary Research & Map and Compass:**

Working With Your Woodland, Mollie Beatie, Charles Thompson, Lynn Levine, 1993, University Press, Hanover, NH.

Legal Aspects of Owning and Managing Woodlands, Thomas J. McEvoy 1998, Island Press. Washington, D.C., Covelo, CA.

**GIS, Topo, and Mapping:**

Umass Earth Sciences: [www.umass.edu/tei/esio](http://www.umass.edu/tei/esio)

Terraserver: <http://terraserver.microsoft.com>  
<http://mac.usgs.gov/mac/isb/pubs/booklets/symbols/index.html>

Geographic Information Systems, United States Geological Survey—<http://www.usgs.gov/research/gis/title.html>

To measure distances between monuments, set off on the left or right foot and count every two steps as 1 pace. Pace varies with slope (shorter uphill and on steep downhills, longer on mild downhills) and conditions (e.g., shorter in snow). With practice, it is possible to adjust for changes in terrain by occasionally adding a full or half pace. Note also that map distances are measured horizontally from one monument to another, and don't take into account the undulations in between. On hilly sites, paced distances will be greater than the map distances.

Where more accurate measurements are required, such as laying out an unmonumented building envelope, a hip chain may be used. A hip chain is a belt-mounted device that contains a spool of biodegradable thread tied to a counter calibrated to measure in feet, meters or other distance units. One end of the thread is tied to an object at the starting point, and the distance traveled is displayed as the thread pays out. A 100' tape measure can also be used, depending on distances, topography and vegetative cover.

Many older maps and metes and bounds descriptions use rods, chains and links. A rod is 16.5 feet, a chain is 66 feet, and link is 7.92 inches (1/100 of a chain). There are 4 rods to a chain. The chain is a useful unit of measurement as 80 chains equal one mile (5,280 feet), and 10 square chains equal an acre (43,560 square feet). For ease of use in the field, these measurements should be restated in feet or paces.

**Topographical Maps and Aerial Photographs:** Topographical maps and aerial photographs with the property boundaries outlined by hand or using GIS can be very helpful for boundary location. A topographical map may reveal that a corner or marker is near a prominent feature such as an outcrop or a stream. Aerial photographs show variations in vegetation that can be used to locate corners or bounds in the field (e.g., a corner near a small stand of white pines).