The Maps

The Maps in General

The coordinates of the maps used on this website are Universal Transverse Mercator (UTM) units. Some points on the maps are also designated in latitude and longitude coordinates. Both coordinate systems are referenced to the WGS 84 coordinate system, geoid and datum. The WGS 84 coordinate system is a three-dimensional Cartesian coordinate system centered at the center of mass of the earth. An understanding of these coordinate systems (except the WGS 84 coordinate system), the geoid and datum is important if the maps and data associated with the maps are used to locate points on French Hill Pond.

The Geoid

The earth bulges at the equator and is somewhat flat at the poles because it is spinning. Accurate measurements along the surface of the earth are not possible unless this flattening and bulging of the earth is taken into account. Unfortunately, the earth is also not smooth given the mountains, valleys and constantly changing level of bodies of water and magma beneath land areas because of tidal effects.

Geophysicists define a geoid as a surface of equal gravitational potential, that is, the force of gravity is essentially the same at every point on the geoid. This definition resolves the problems associated with mountains, valleys and bodies of water by providing a constant reference surface. However, it introduces a new problem in that gravitational potential may vary because of local buried material of high mass, like lead or gold deposits. (This characteristic permits geophysicists or geologists to locate potential deposits of heavy metals and even oil.) Therefore, the equal-potential geoid will not be smooth but will likely be smoother than the physical earth.

Space satellites orbit the earth under the influence of the earth’s gravitational potential. Their orbits will more or less mimic the shape of a geoid. Therefore, satellites orbiting the earth will be referenced to a geoid not the physical surface of the earth. At this point the reader might suspect that there is more than one geoid defined by geophysicists. In fact there are many geoids. Some geoids approximate the entire surface of the earth fairly well. Other geoids approximate a continent or region of the world better than any of the whole-earth geoids. The selection of a particular geoid will depend upon the region of the world to be surveyed, the accuracy desired and the satellite positioning system that is used if satellite positioning is used. Some geodetic systems are based on celestial observations.

Points on the maps used on this website were determined using the Global Positioning System (GPS), a space satellite system. The geoid used as a reference is the geoid associated with the World Geodetic System 84 (WGS 84), which is a whole-earth geoid adopted by geophysicists as of 1984. Most GPS devices default to the WGS 84 geoid because WGS 84 is the reference geoid for the GPS. However, GPS devices often have other geoids and datum available as options. Any GPS used to find positions on the maps on this website **must** be set to reference WGS 84 to ensure accurate positioning. The GPS used in the French Hill Pond surveys detected and used, that is, “locked onto” eight GPS satellites. A minimum of three GPS satellite locks are required for most GPS devices to plot two-dimensional maps.

The latitudes and longitudes on this website are also referenced to the WGS 84 geoid. If other maps, like United States Geological Survey (USGS) maps, are referenced; keep in mind that the coordinates will **not** be the same unless the map specifies that it conforms to WGS 84. Newer USGS maps may indicate their deviation from WGS 84, more about that later. Latitude and longitude is defined on a sphere. The latitudes and longitudes of the WGS 84 are projections of the spherical latitudes and longitudes onto the geoid or datum and vice versa.

The Datum

As mentioned earlier, there are many different geoids or gravitational equipotential surfaces. Geoids alone do not define a geodetic system. Physical features on the earth may be on, above or below the geoid. For example, the deepest point in French Hill Pond is about 25 meters from the WGS 84 geoid. Another surface that represents the physical rather than the gravitational features of the earth must be defined. This surface is a reference ellipsoid and associated topographical features called a “datum.”

Think of the geoid as being the surface that the satellites recognize and the datum as being the surface that people recognize. This concept is a simplification of reality but helps differentiate between the many geodetic systems. Geophysicists and mathematicians develop complex mathematical relationships between the geoid and the datum to locate points precisely. We need not bother ourselves with these complexities. If the reader wants detailed information about geodetic systems, the United States Department of Defense (DoD) National Imagery and Mapping Agency (NIMA) publishes technical reports that describe these systems in detail. Their detailed description of WGS 84 is found in NIMA technical report number 8350.2, *Department of Defense World Geodetic System 1984*, which is approved for release to the public and can be downloaded on the Internet.

In practice, the datum is of concern to users of a geodetic system, not the geoid even though the geoid is fundamental to the system. Currently, the WGS 84 ellipsoid for the datum is a flattened spheroid or ellipsoid with a radius at the equator of 6,378,137 meters. This radius is called the “transverse” or “major radius.” The distance from the center of the ellipsoid to one of the poles is 6,356,752.314 meters. This shorter radius is called the “conjugate” or “minor radius.” Note that the conjugate radius is precise to one millimeter. The current geoid for the WGS 84 is the 1996 Earth Gravitational Model (EGM96) last revised in 2004. The datum and geoid for WGS 84 is due for revision in 2010. When this revision takes place, the characteristics of both the geoid and datum may change. Keep in mind that the geoid is a reference for satellites but people are concerned with the datum.

The relationship of the geoid to the datum is of concern only to geophysicists and mathematicians for our purposes.

The reason for this lengthy discussion is that when the geodetic system parameters change, maps are redrawn and GPS systems are updated. This information is important because after 2010, the coordinates listed on this website may not be valid with respect to updated GPS devices and updated maps. However, the relative positions should remain the same. That is, the distances between points will be the same but the GPS may place the points in slightly different positions on the new grid.

This problem exists currently with respect to United States Geological Survey (USGS) topographic maps. For example, the USGS topographic map used for this website was published in 1981. It uses the geodetic system (not space satellite referenced but celestially referenced) developed in 1927 called the North American Datum 1927 (NAD 27). In some of the scientific literature, NAD 27 is coded as NAS. This geoid and datum fits North America quite well. However, the NAD 27 was updated in 1983 to NAD 83 but the map could not be updated because the revised NAD had not been published. However, there is a note on the map saying, "To place on the predicted North American Datum 1983 move the projection lines 2 meters south and 46 meters west…" If one locates French Hill Pond on this map, the UTM coordinates will not match the coordinates found by the GPS because the GPS uses WGS 84, not NAD 27 or NAD 83. Realigning old map coordinates with the WGS 84 coordinates is usually a matter of adding or subtracting degrees or meters to/from the old coordinates but is not normally done for the type of surveys described on this website. Appendix A describes the conversion of latitude/longitude in the NAD 27 to WGS84 coordinates. Just be aware that the coordinates for the same point on different datums will usually not be the same.

The Meter

Before the French Hill Pond maps are discussed further, a few words about the meter measurement are necessary. The meter was originally defined in 1791 as 1/10,000,000 of the distance from the equator to the North Pole on a great circle passing through Paris France. The actual length of the meter has been redefined since but it remains an important unit of measure for cartographers. Theoretically, any point at 45degrees north latitude is 5,000,000 meters (5,000 kilometers) from the equator. However, the earth is not a perfect sphere. Therefore, the theory may not work perfectly in practice. Geodetic systems conform to reality rather than theory.

The Universal Transverse Mercator (UTM) System

If the only objective of a coordinate system is to locate a point on the earth, latitude and longitude coordinates are suitable. However, finding the distance between two points of latitude and longitude coordinates involves some tricky trigonometric computations. People interested in distances as well as location usually use a system like the UTM system.

The UTM system divides most of the earth into sixty sectors of longitude, numbered 1 through 60 in an easterly direction, with six degrees per sector. The Polar Regions, latitudes north of 84 degrees north and south of 80 degrees south, are excluded from this system of coordinates. (Polar Regions are mapped by the similar Universal Polar Stenographic System.) Sector 1 begins at 180 degrees longitude and extends to 174 degrees west longitude. Sector 2 is east of sector 1 (from 174 degrees west to 168 degrees west). Maine falls in sector 19 (72 degrees west to 66 degrees west). These sectors become narrower as they approach the Polar Regions. They are widest at the equator and narrower near the poles. At the equator, the regions are up to 833,000 meters wide allowing for equatorial bulge and the redefinition of the meter since 1791. The northern and southern parts of the sectors are only about 166,000 meters wide. This situation creates a reference line problem because if one of the boundaries of a sector is used as a reference and measurements end at the other boundary line, measurements of distance become awkward.

This problem is resolved by defining the center line of the sector to be the reference line having an artificial value of 500,000 meters from a theoretical edge of the sector on the equator. In reality, this theoretical edge will lie within the adjacent sector. In sector 19, this reference line is the meridian at 69 degrees west longitude. The east-west coordinate of a point in the sector west of the reference line is generated by subtracting the distance of the point from the reference line from 500,000. Thus, a point 100,000 meters west of the reference line would have the sector east-west coordinate 400,000. Similarly, the east-west coordinate of a point in the sector east of the reference line is computed by adding its distance from the reference line to 500,000. Thus, a point 50,000 meters east of the reference line would have a coordinate of 550,000. By convention, all east-west coordinates are termed “easting” regardless of the side of the reference line on which the point is located because the sectors are arranged in an easterly direction. On this website, the easting coordinate designation is often shortened to “east.”

The easting UTM coordinate is like longitude and can be converted to longitude. But, the UTM easting coordinate provides an easy means to find distances between points because the coordinate is a distance not an angle. The datum can be considered flat over relatively short distances and the Mercator map projection is designed to represent distances over the earth on a flat surface. Therefore, distances on a UTM map can be computed quite easily by using simple differences or the Pythagorean Theorem.

There are circumstances under which the coordinates of one sector may also become the coordinates of another sector after a positional adjustment (moving a point east or west) particularly near the Polar Regions or near the boundaries. However, ambiguities can be easily resolved by examining the coordinate’s position relative to the reference lines of each sector and choosing the coordinate representation that is closest to a reference line. In any case, distances are preserved and position is uniquely identified.

The UTM north-south coordinate or “northing coordinate” is easier to understand, at least for the northern hemisphere. It is simply the distance of the point from the equator in meters along the datum in the northern hemisphere. In the southern hemisphere, the equator is set to 10,000,000 meters (recall the definition of a meter) and a southern point's northing coordinate is its distance from the equator subtracted from 10,000,000. On this website, the designation "northing" is often shortened to "north."

It is necessary to designate whether the point is in the northern or southern hemisphere. There are two accepted ways of making this designation. The first is to indicate by the letters N or S that the point is in the northern or southern hemisphere respectively. This letter immediately follows the sector number. For example, the deepest point of French Hill Pond is in UTM sector 19 and 54,714 meters east of the sector 19 reference line (69 degrees west longitude) and 4,916,833 meters from the equator. The UTM coordinates are written as

19N 0554714 4916833

The first number is the sector number. That number is followed immediately by the hemisphere identifier. A space separates the hemisphere identifier from the easting coordinate. Another space separates the easting coordinate from the northing coordinate. This scheme confuses some people who expect the coordinate following the hemisphere coordinate to be the northing coordinate. Therefore, a second means of writing UTM coordinates has come into common use. This second scheme uses latitude banding.

Latitude Bands

Latitude bands are actually a part of the Military Grid Reference System (MGRS) but were introduced into the UTM system to be more specific concerning the location of points in the northerly direction.

The MGRS divides the non-polar regions of the earth into eight degree bands (except for the last band that has 12 degrees) beginning at the southern Polar Region and ending at the northern Polar Region. Each band is assigned a letter from the English alphabet beginning with C. The letters O and I are excluded because they resemble numbers. The letters N and S perhaps should have also been excluded because they conflict with the first UTM designation. The S-band of latitude is in the northern hemisphere, which might lead someone to believe that the point is in the southern hemisphere. Therefore, it is important to identify which designation is being used on a map or by a device. Most new GPS devices use the latitude band system and this system is becoming the standard. **All maps and descriptions on this website use the latitude band designation.**

Note in the table below that the last band has four extra degrees of latitude.

French Hill Pond is located in latitude band T. Therefore, the deepest point in French Hill Pond would have the UTM/latitude band coordinates:

19T 0554714 4916833

If maps from other sources are referenced or older GPS devices are used, the first designation may be used. Be careful not to confuse the two designations particularly if at some point in the future you are working in S-band regions.

Designator	Range
C	80 degrees south to 72 degrees south
D	72 degrees south to 64 degrees south
E	64degrees south to 56 degrees south
F	56 degrees south to 48 degrees south
G	48 degrees south to 40 degrees south
H	40 degrees south to 32 degrees south
J	32 degrees south to 24 degrees south
K	24 degrees south to 16 degrees south
L	16 degrees south to 8 degrees south
M	8 degrees south to 0 degrees south
N	0 degrees north to 8 degrees north
P	8 degrees north to 16 degrees north
Q	16 degrees north to 24 degrees north
R	24 degrees north to 32 degrees north
S	32degrees north to 40 degrees north
T	40 degrees north to 48 degrees north
U	48 degrees north to 56 degrees north
V	56 degrees north to 64 degrees north
W	64 degrees north to 72 degrees north
X	72 degrees north to 84 degrees north

Table Latitude Bands

The Global Positioning System Peculiarities

As already noted, the GPS is referenced to WGS 84. Maps or devices referencing other geodetic systems usually display coordinates that will differ from the GPS coordinates. In addition, the GPS can have an error as much as 100 meters because of the Selective Availability Program (SAP). However, the GPS has an error of less than 10 meters 95% of the time. In North America, this error is reduced to 3 meters 95% of the time by the Wide Area Augmentation System (WAAS). New GPS devices that use WAAS will have an error of about 3 meters or less most of the time. However, accuracy of about one meter can be expected.

The United States Department of Defense (DoD) developed and maintains the GPS. This system will locate points with great accuracy as required for military operations. Potential adversaries could use this system against the interests of the United States. Therefore, the DoD under certain circumstances introduces an artificial error in the system to help prevent nefarious use of the system. This error introduction is called the Selective Availability Program.

There are a large number of civilian applications for the GPS and millions of people have become somewhat dependent on GPS devices for navigation, directions, hiking, surveying and other activities requiring location information. Therefore, the DoD has refined the GPS to provide better accuracy in North America in spite of the SAP. This refinement is the Wide Area Augmentation System. It consists of monitoring stations in North America that collect atmospheric and other data that affect the error of the GPS and transmit corrections to the GPS satellites on a regular basis. The satellites in turn transmit these corrections to GPS devices with WAAS capabilities increasing the accuracy of readings.

If you purchase a GPS device, ensure that it has WAAS processing capabilities. When using a GPS device, try to take all the related readings you need in one session. Establish a reference point like a pole, rock etc. that you can recheck during a GPS session to ensure that your readings remain accurate.

It is possible to obtain very accurate data using a GPS device but the techniques required to do so are beyond the scope of this website and are unnecessary for the objectives of the surveys described on this website. For example, the origin of the WGS 84 coordinate systems are thought to be within two centimeters of the center of mass of the earth and, as indicated above, the poles of the earth are located within one thousandth of a meter (one millimeter) indicating that one may be able to locate points within millimeters of their true location on the earth. No survey of French Hill Pond would require such accuracy. Very precise equipment is also very expensive. Inexpensive GPS devices and rough procedures should not be used for highly critical applications.

Converting from One Datum to Another

It is possible to convert from one datum to another. GPS devices often come with computer programs that make these conversions. For example, the MapSource program that is included with Garmin® GPS devices will convert WGS 84 coordinates to NAD 27 or other datums and vice versa. Appendix A illustrates the mathematics involved. One can access converters on the Internet for this purpose. The APSalin ® Company, a radio and television engineering-services company, has a website with excellent online converters. The website is www.apsalin.com. Click on the tab “Online Tools/Reference” to access these converters.

Summary of Map and GPS Cautions

All maps and GPS devices reference some geodetic system. It is important to ensure data from maps and GPS devices reference the same geodetic system if the data is used to compare or find locations. The UTM grid system is good for finding distances in meters as well as location. However, be sure to identify the UTM hemisphere identification scheme used by the map or device. If in doubt, assume WGS 84 and latitude banding.

The importance of the consistency of geodetic references cannot be over emphasized. Consider the following point on French Hill Pond referenced to WGS 84:

19T 0554707 4916657

The same point referenced to the NAD 27 is:

19T 0554657 4916446

The NAD 27 reference locates this point 50 meters west and 211 meters south of the WGS 84 location. When these NAD 27 coordinates are located on the USGS topographic map that is referenced to NAD 27, the position is consistent with the WGS 84 maps in this website. One datum is generally not better than another for the purposes described on this website but they cannot be mixed.

When using a GPS device, plan to complete a survey in one session. Establish a reference point that you can use to check that you are getting the greatest accuracy possible from your GPS device and not being “SAPed.” Even if the positioning is off, the relative locations of waypoints may still be good. Checking position and distance against a known reference point helps build confidence in the survey results.

Website Maps Computer Properties

All the maps on the website are drawn with north at the top and east to the right in compliance with convention. The computer object used to generate the maps is a bitmap graphics file. This object consists of picture elements (pixels) in a rectangular closed region 500 pixels wide and 700 pixels high. The pixel in the upper left-hand corner has the computer coordinate (0, 0). This point has the UTM map coordinate (0554550, 4916950). The lower right hand corner of the bit-map has the computer coordinates (500, 700) and UTM map coordinates (0554800, 4916600). Keep in mind that the ordinate axis on a computer bit-map is opposite to the mathematical convention. All the points of French Hill Pond lie within this region.

The distance between any two horizontal or vertical adjacent pixels represents ½ meter. This arrangement allows a precise positioning of any UTM coordinate on the bitmap object. The transformation equations to convert UTM coordinates to pixel coordinates are:

$$X = 2(\text{UTM easting} - 554550) \text{ and } Y = 2(4916950 - \text{UTM northing})$$

Where (X, Y) are computer bitmap coordinates.

The Pond Outline Map

The pond outline map is the basis for all other maps of French Hill Pond. The outline was determined using a Garmin® eTrex Venture HC GPS receiver and aerial photographs.

Waypoints were established at approximately 10 meter intervals, more or less, depending upon the shape of the shore. The criteria for determining the edge of the pond was that the depth of the water was six inches or greater at the time of the survey. The edge of the pond is unambiguous for most of the shore. There are no beaches and the water at the edge is frequently very deep. It was necessary to walk through stands of emerging plants, mostly cattails, to reach water's edge. Marshy areas around the pond were wet but the water was less than six inches deep. Therefore, these wet areas were not considered part of the pond.

The pond outline survey was accomplished on July 31, 2009. The outline of the island was established on August 7, 2009. This outline of the island contains dense communities of emerging plants that seemed to have a water depth of less than six inches. The island may be smaller than depicted on the map if these communities have deeper water than was apparent.

The areas of the pond and island were determined by the Garmin® computer program *MapSource* that computed the areas within the waypoints determined by the GPS receiver. The area of the pond outline was computed as 163,761 square feet that equates to 3.76 acres. The area of the island was computed as 1,792 square feet or 0.04 acres. Therefore, the surface area of French Hill Pond at the end of July and beginning of August 2009 was about 3.72 acres.

As other waypoints were established on and around the pond, these waypoints were used to verify the outline of the pond and island. These waypoints, taken during August at various times, validated the outline of the pond.

Aerial photographs from Microsoft Bing® (circa 2000, United States Geological Survey photograph), Google Earth® (imagery dated: September 13, 2003 and July 25, 2007, United States Department of Agriculture photographs, and United States Geological Survey photographs dated July 24, 1991 and May 24, 1996) and the Town of Bar Harbor (dated: May 5, 1989) also validates the outline and size of the pond. A sample of the GPS waypoints was superimposed on the Google Earth imagery using software supplied by Google and showed excellent congruence considering the earlier years were drier than 2009. See Appendix B for a description of these analyses.

Most of these aerial photographs were taken several years ago before two beaver lodges were constructed on the pond. These lodges were counted as a part of the shoreline not the pond because they are built adjacent to the shore. No attempt was made to determine the extent of the pond water under these lodges even though beaver lodges normally have an opening into relatively deep water under the lodges.

The Depth Map

The author could not locate a depth map of French Hill Pond. Before the surveys could begin, soundings of the pond were necessary. Of particular concern was finding the deepest point of the pond. This task was arduous and lengthy.

Soundings were taken with a NorCross®, Hawk-eye F33P sonar depth sounder (fish finder) and verified with a Secchi disk. The sonar device was suspended from a float and used to find the depths of the pond in a rough manner. This device was not useful in waters less than about two feet deep. The Garmin® GPS was used to locate positions in conjunction with the depth finder. When positions on the pond were determine that were representative of the depth of the pond in that general area, accurate depth readings were taken.

The boat was anchored by two mushroom anchors before accurate depth readings were taken. The GPS device was used to ensure that the boat was well anchored. The depth sounder active element dangling in the water was allowed to settle and hang straight before the depth in feet was recorded. The Secchi disk was then used to find the depth to the nearest centimeter. Care was taken to ensure the Secchi disk was hanging straight and touching the bottom. Later, the Secchi disk reading was converted to feet and compared to the depth meter readings. The Secchi disk reading was always 6 inches to about a foot greater than the depth meter. This difference was due to the fact that the depth meter active element hung at least six inches below the float and often more. It was necessary to adjust this length periodically because as the depth meter active element was towed behind the boat, the distance between the depth meter active element and the float would increase or decrease as the active element or float acquired weeds.

The depth meter provided other information about the pond besides the depth. It indicated that the deeper parts of the pond are quite rocky. There are few plants in the deeper areas. On occasion, the depth meter indicated the presence of fish or other aquatic animals.

The Plant Survey Map

A plant survey of French Hill Pond was undertaken at various times during the months of August and September 2009. The Garmin GPS device was used to locate plant community boundaries on the map. High definition photographs of the plants were time-stamped and correlated with the times of the GPS readings to ensure the communities were properly identified and located on the map.

The Water Sources and Output Map

The French Hill Pond Water Sources and Output map is the depth map with water sources and other physical characteristics of the pond added. All the items on this map were located using the Garmin GPS device.

Other Maps

Other maps on this website were extracted from USGS products.

Summary

All the maps produced for this website were generated using a Garmin® eTrex Venture HC Global Positioning System receiver and verified using aerial photographs of French Hill Pond taken for the United States Geological Survey, United States Department of Agriculture and Town of Bar Harbor. The depths of the pond were roughly determined with a NorCross® depth/fish finder and verified with a Secchi disk.

The maps reference the WGS 84 datum and use the Universal Transverse Mercator coordinate system. The deepest point on the maps is also located by latitude and longitude referenced to WGS 84. The reader is cautioned to ensure that all uses or verification of the information on the maps use WGS 84 as a reference datum or that the data obtained for verification or use be converted to WGS 84 before conclusions are drawn.

Appendix A

Multiple Regression Equations (MREs)
For Converting North American Datum 1927 (NAD 27) to WGS 84

This appendix illustrates the mathematics required to transform NAD 27 coordinates to WGS 84 coordinates. These transformation equations apply only to the continental United States and are used to convert NAD 27 latitude and longitude coordinates to WGS 84 latitude and longitude coordinates. The accuracy of the transformations is ±2 meters (about one second of arc). The source of this information is NIMA TR8350.2, *Department of Defense World Geodetic System 1984*, third edition, 3 January 2000, page D-11, where NAD 27 is coded as NAS.

Let ϕ be the latitude coordinate in the NAD 27 datum and λ be the longitude coordinate in the NAD 27 datum. Let Φ be the latitude coordinate in the WGS 84 datum and Λ be the coordinate for longitude in the WGS 84 datum. The basic transformation equations are:

$$\Phi = \phi + \Delta\phi'' \text{ and } \Lambda = \lambda + \Delta\lambda''$$

where $\Delta\phi''$ and $\Delta\lambda''$ are changes or "shifts" in the NAD 27 latitude and longitude values in **seconds of arc**.

First, one must find the values of the two variables, U and V, in the multiple regression equations from the following expressions:

$$U = 0.05235988\,(\phi - 37.0) \text{ and } V = 0.05235988\,(\lambda + 95.0)$$

where ϕ is the latitude in the NAD 27 datum expressed as decimal degrees from 0 to 90. The minutes and seconds of the coordinate must be converted to decimal degrees e.g. 32^o 30' would become 32.5^o. Likewise, λ is the longitude in the NAD 27 datum expressed as decimal degrees from 0 to -180 because the continental United States is in the Western Hemisphere. The shifts are computed from the following multiple regression equations:

$$\begin{aligned}\Delta\phi'' = {} & 0.16984 - 0.76173\,U + 0.09585\,V + 1.09919\,U^2 - 4.57801\,U^3 - 1.13239\,U^2V \\ & + 0.49831\,V^3 - 0.98399\,U^3V + 0.12415\,UV^3 + 0.11450\,V^4 + 27.05396\,U^5 \\ & + 2.03449\,U^4V + 0.73357\,U^2V^3 - 0.37548\,V^5 - 0.14197\,V^6 - 59.96555\,U^7 \\ & + 0.07439\,V^7 - 4.76082\,U^8 + 0.03385\,V^8 + 49.04320\,U^9 - 1.30575\,U^6V^3 \\ & - 0.07653\,U^3V^9 + 0.08646\,U^4V^9\end{aligned}$$

$$\begin{aligned}\Delta\lambda'' = {} & 0.88437 + 2.05061\,V + 0.26361\,U^2 - 0.76804\,UV + 0.13374\,V^2 - 1.31974\,U^3 \\ & - 0.52162\,U^2V - 1.05853\,UV^2 - 0.49211\,U^2V^2 + 2.17204\,UV^3 - 0.06004\,V^4 \\ & + 0.30139\,U^4V + 1.88585\,UV^4 - 0.81162\,UV^5 - 0.05183\,V^6 - 0.96723\,UV^6 \\ & - 0.12948\,U^3V^5 + 3.41827\,U^9 - 0.44507\,U^8V + 0.18882\,UV^8 - 0.01444\,V^9 \\ & + 0.04794\,UV^9 - 0.59013\,U^9V^3\end{aligned}$$

Clearly, one would want to program a computer to perform these computations. GPS devices and related computer software will usually be programmed to make these computations.

Appendix B

French Hill Pond Outline Verification

The outline of French Hill Pond was verified using aerial photographs. The earliest photograph was taken for the Planning Department of the Town of Bar Harbor May 5, 1989. Although this photograph shows the outline of the pond quite well, it has no grid coordinates. However, it was useful by showing that the general size and shape of the pond has not changed in twenty years.

Another aerial photograph was taken for the United States Geological Survey (USGS) about the year 2000 and is available on the Microsoft® Corporation map and directions website. This photograph does not have a useful grid but did provide a means of estimating the surface area of the pond, which agrees with the Garmin® data.

The Google Earth® website provides two aerial photographs taken for the United States Department of Agriculture (USDA) on September 13, 2003 and July 25, 2007 and two aerial photographs taken for the USGS on Jul 24, 1991 and May 14, 1996. Google® also provides grid and location tools that enable the user to superimpose coordinates from another source on the aerial photograph. The precision of these tools is to one centimeter, but the author doubts that the photographs are that accurate. Waypoints generated by the Garmin® Global Positioning System (GPS) were selected and input to the Google Earth® system. Even numbered waypoints were used to avoid clutter.

The tips of the pushpin symbols generated by the Google Earth® system when the Garmin® GPS data was input to the Google® program show the location of the Garmin® waypoints superimposed on the USDA photograph of July 25, 2007. The points are virtually exactly on the shoreline when consideration is given to the fact that the water level of the pond was lower when the USDA photograph was taken. This conclusion is more apparent when the photograph is viewed on a computer screen where subtleties of color are clearer. The waypoint data is available in Appendix C. The reader is invited to use the Google Earth® website to verify these results and see the correlations clearly. Google Earth® is free to non-commercial, individual users.

The aerial photographs indicate that the maps on this website fairly represent the shape and location of French Hill Pond and its physical characteristics. However, the reader should carefully adhere to the instructions for the use of a GPS system when locating points on the pond.

The three other maps available on Google Earth® were also examined with the GPS coordinates superimposed. The shape and extent of the pond has changed with time. These changes are best viewed by accessing the Google Earth® maps and superimposing the waypoints on a computer screen.

These photographs show that the shape and extent of French Hill Pond have not changed very much over an 18-year period. Some parts of the shoreline have receded but in other sections the land has extended further into the pond. The activities of beavers have contributed to these changes. However, some of the changes appear to be a result of people using all-terrain vehicles and snowmobiles on the shore of the pond.

Given the relatively quick drop-off of depths at the shoreline, the author speculates that the shape and size of the pond will not change significantly over the next twenty years barring human intervention.

Appendix C

French Hill Pond Outline Date	Time	Latitude Integer Degrees	Latitude Minutes	Longitude Integer Degrees	Longitude Minutes	Latitude Decimal Degrees	Longitude Decimal Degrees	UTM 19 Meters East	UTM 19 Meters North	Bit Map X	Bit Map Y	Way Point
7/31/2009	13:53:00	44	24.181	-68	18.768	44.403017	-68.312800	554721	4916867	342	166	4
7/31/2009	13:55:00	44	24.178	-68	18.766	44.402967	-68.312767	554725	4916860	350	180	5
7/31/2009	13:56:00	44	24.175	-68	18.763	44.402917	-68.312717	554728	4916854	356	192	6
7/31/2009	13:57:00	44	24.171	-68	18.762	44.402850	-68.312700	554729	4916847	358	206	7
7/31/2009	13:59:00	44	24.166	-68	18.761	44.402767	-68.312683	554731	4916839	362	222	8
7/31/2009	14:00:40	44	24.163	-68	18.756	44.402717	-68.312600	554737	4916832	374	236	9
7/31/2009	14:01:46	44	24.159	-68	18.754	44.402650	-68.312567	554740	4916825	380	250	10
7/31/2009	14:02:50	44	24.156	-68	18.751	44.402600	-68.312517	554744	4916820	388	260	11
7/31/2009	14:04:11	44	24.151	-68	18.750	44.402517	-68.312500	554746	4916812	392	276	12
7/31/2009	14:05:22	44	24.147	-68	18.747	44.402450	-68.312450	554750	4916804	400	292	13
7/31/2009	14:06:19	44	24.145	-68	18.745	44.402417	-68.312417	554752	4916800	404	300	14
7/31/2009	14:07:28	44	24.142	-68	18.744	44.402367	-68.312400	554754	4916794	408	312	15
7/31/2009	14:08:38	44	24.139	-68	18.743	44.402317	-68.312383	554755	4916789	410	322	16
7/31/2009	14:10:22	44	24.134	-68	18.746	44.402233	-68.312433	554751	4916779	402	342	17
7/31/2009	14:11:37	44	24.133	-68	18.749	44.402217	-68.312483	554748	4916778	396	344	18
7/31/2009	14:12:43	44	24.132	-68	18.752	44.402200	-68.312533	554743	4916776	386	348	19
7/31/2009	14:13:59	44	24.130	-68	18.757	44.402167	-68.312617	554737	4916771	374	358	20
7/31/2009	14:15:09	44	24.126	-68	18.760	44.402100	-68.312667	554733	4916764	366	372	21
7/31/2009	14:16:19	44	24.123	-68	18.761	44.402050	-68.312683	554732	4916758	364	384	22
7/31/2009	14:17:18	44	24.119	-68	18.760	44.401983	-68.312667	554733	4916751	366	398	23
7/31/2009	14:18:07	44	24.115	-68	18.758	44.401917	-68.312633	554736	4916745	372	410	24
7/31/2009	14:19:02	44	24.112	-68	18.757	44.401867	-68.312617	554737	4916738	374	424	25
7/31/2009	14:20:11	44	24.106	-68	18.756	44.401767	-68.312600	554739	4916728	378	444	26
7/31/2009	14:21:03	44	24.103	-68	18.756	44.401717	-68.312600	554739	4916722	378	456	27
7/31/2009	14:22:00	44	24.099	-68	18.754	44.401650	-68.312567	554741	4916714	382	472	28
7/31/2009	14:23:48	44	24.095	-68	18.752	44.401583	-68.312533	554743	4916707	386	486	29
7/31/2009	14:24:51	44	24.091	-68	18.753	44.401517	-68.312550	554742	4916700	384	500	30
7/31/2009	14:25:55	44	24.087	-68	18.754	44.401450	-68.312567	554741	4916693	382	514	31
7/31/2009	14:27:04	44	24.084	-68	18.755	44.401400	-68.312583	554741	4916686	382	528	32
7/31/2009	14:28:22	44	24.081	-68	18.755	44.401350	-68.312583	554740	4916681	380	538	33
7/31/2009	14:29:36	44	24.076	-68	18.756	44.401267	-68.312600	554739	4916672	378	556	34
7/31/2009	14:30:54	44	24.072	-68	18.756	44.401200	-68.312600	554739	4916665	378	570	35
7/31/2009	14:32:27	44	24.068	-68	18.758	44.401133	-68.312633	554736	4916656	372	588	36
7/31/2009	14:33:42	44	24.064	-68	18.760	44.401067	-68.312667	554734	4916649	368	602	37
7/31/2009	14:34:37	44	24.062	-68	18.762	44.401033	-68.312700	554731	4916645	362	610	38
7/31/2009	14:35:39	44	24.060	-68	18.763	44.401000	-68.312717	554729	4916642	358	616	39
7/31/2009	14:37:54	44	24.056	-68	18.760	44.400933	-68.312667	554734	4916636	368	628	40
7/31/2009	14:40:03	44	24.053	-68	18.760	44.400883	-68.312667	554734	4916630	368	640	41
7/31/2009	14:41:24	44	24.052	-68	18.760	44.400867	-68.312667	554734	4916628	368	644	42
7/31/2009	14:43:50	44	24.047	-68	18.762	44.400783	-68.312700	554732	4916619	364	662	43
7/31/2009	14:45:50	44	24.045	-68	18.767	44.400750	-68.312783	554725	4916614	350	672	44
7/31/2009	14:47:08	44	24.044	-68	18.768	44.400733	-68.312800	554724	4916613	348	674	45
7/31/2009	14:48:41	44	24.042	-68	18.775	44.400700	-68.312917	554714	4916608	328	684	46
7/31/2009	14:50:25	44	24.040	-68	18.783	44.400667	-68.313050	554703	4916606	306	688	47
7/31/2009	14:53:11	44	24.042	-68	18.790	44.400700	-68.313167	554694	4916608	288	684	48
7/31/2009	14:55:45	44	24.051	-68	18.787	44.400850	-68.313117	554698	4916626	296	648	49
7/31/2009	14:57:12	44	24.057	-68	18.789	44.400950	-68.313150	554696	4916636	292	628	50
7/31/2009	14:59:05	44	24.065	-68	18.797	44.401083	-68.313283	554685	4916652	270	596	51
7/31/2009	15:02:18	44	24.072	-68	18.807	44.401200	-68.313450	554671	4916664	242	572	52
7/31/2009	15:04:34	44	24.078	-68	18.805	44.401300	-68.313417	554674	4916675	248	550	53
7/31/2009	15:07:02	44	24.085	-68	18.804	44.401417	-68.313400	554675	4916688	250	524	54
7/31/2009	15:07:55	44	24.089	-68	18.803	44.401483	-68.313383	554677	4916696	254	508	55
7/31/2009	15:08:26	44	24.096	-68	18.802	44.401600	-68.313367	554678	4916708	256	484	56
7/31/2009	15:08:56	44	24.101	-68	18.802	44.401683	-68.313367	554678	4916718	256	464	57
7/31/2009	15:09:26	44	24.108	-68	18.802	44.401800	-68.313367	554677	4916730	254	440	58
7/31/2009	15:09:52	44	24.114	-68	18.802	44.401900	-68.313367	554677	4916742	254	416	59
7/31/2009	15:10:18	44	24.120	-68	18.802	44.402000	-68.313367	554678	4916752	256	396	60
7/31/2009	15:11:07	44	24.125	-68	18.802	44.402083	-68.313367	554678	4916762	256	376	61
7/31/2009	15:11:47	44	24.131	-68	18.799	44.402183	-68.313317	554680	4916773	260	354	62
7/31/2009	15:12:32	44	24.136	-68	18.801	44.402267	-68.313350	554679	4916783	258	334	63