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Surveying and Mapping Devil's Kitchen Lake, Williamson County, Illinois

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WILLIAMSON COUNTY, ILLINOIS

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Currently, the formal techniques used in the construction of hydrographic maps are undergoing radical changes in the way data is collected, stored, transferred, and graphically represented. Global Positioning Systems, (GPS) are revolutionizing the industry with the ability to locate and set control to within sub-meter accuracy. Likewise, the surveying profession is adjusting to meet the demands of this new technology.

Today, the methods selected for the final quality of a product depends on the accuracy and the density of the observations. For instance, a general reference hydrographic map's measurement requirements are considerably less than an oil company's oceanic exploratory study whose purpose is to pinpoint gas and oil fields, or a crash investigation of downed military/commercial vessels where sophisticated thermal equipment records depth and position every second.

The execution of hydrographic surveys share common elements of planning that may be divided into four components: 1. preliminary office preparations, 2. preliminary field work, 3. sounding operations, and 4. data preparation.

It is imperative to construct all possible information on the survey area such as, descriptions and positions of horizontal control, prior surveys, aerial photography, topographic maps, and meteorological characteristics.

Survey requirements must be thoroughly examined and understood. The area to be surveyed has to be clearly defined, particularly the inshore limits, therefore, it is beneficial to obtain a relatively large-scale map depicting the entire survey area and mark off the limits where the project is to be conducted.

For reference purposes, the methods used on the Summer, 1999 Devil's Kitchen Hydrographic Survey will be examined against additional surveying techniques. Geographic Information Systems (GIS) were eliminated from consideration because the data generated by GIS are unsuitable for legal records.

Prior to beginning sounding operations, shore side reference points must be established, and a water-level monitoring device recovered or installed. If the survey area is non tidal, water-level monitoring is necessary only during sounding operations.

In the matter of the Summer, 1999 Devils Kitchen survey, under the direct supervision of an Illinois licensed Land Surveyor, a traverse was run around the area to be surveyed. Horizontal control points were established and details or features of the shoreline pinpointed. A cross-reference grid was also established whereupon horizontal angle and distance are recorded in conjunction with displayed depth, which, in turn, generates contours of the lake bottom.

Among the various boat-positioning methods, radiation and angle intersection are frequently selected if total station instruments or theodolites are used. Radiation is particularly efficient, especially if a total station instrument is used, because only one person on shore is needed to track the boat. After setting up on one control station and backsighting another, an angle and a distance are measured to locate each boat position.

The water depth measurements are made as the vessel transits range lines while the depth sounder continuously records bottom profiles. At regular intervals, fixes are taken by measuring angles to the boat from shore stations designated by the sounding plan. The simplest sounding plan consists of a set of discrete observation points combined with positioning parameters for each. The sounding vessel proceeds from point to point, recording at each the time, measured depth, and position.

The position of the sounding vessel is determined by measurements made from or to reference points (RPs) of known location. Such measurements define lines of position (LOPs) along which the vessel is located. The point of intersection of two or more simultaneously determined LOPs defines the vessel's location.
Measurement of distance to an RP or the angle between two RPs defines a circular LOP. Measurement of bearing to, or azimuth from, an RP or observations of two RPs on range

yield straight LOPs. Measurement of the difference between ranges to two RPs produces hyperbolic LOPs. The above-mentioned methods satisfied all technical requirements concerning the degree of accuracy for a second-order hydrographic survey.

Other methods used in the construction of hydrographic surveys are, and as mentioned earlier, dependent on the requirements and parameters of the project.
In the matter of delineating water depths alongside vessel mooring facilities, such as piers, wharfs, and bulkheads, Tagline positioning is utilized where location is accomplished by projecting a line of position (LOP), corresponding with a sounding line, into the survey area. A sounding vessel then proceeds along the line measuring depths at predetermined distances from the reference point (RP). This method requires establishing a base line along a structure adjacent to the survey area.

Another accurate and reliable method currently in use is the Three-Point Sextant Fix. One attractive feature of this method is that it requires a minimum investment in equipment, and is most useful in waters within visual range (approximately 5 km) of the shoreline.

A circular LOP is defined by measuring the angle between two Rps from a vessel, using a sextant in the horizontal position. Simultaneous observations of two such angles, sharing a common center RP, yield two LOPs whose intersection defines the vessels position. This positioning method requires a large number of RPs ashore to provide good-fix geometry throughout a survey area. The three-point sextant fix is a counterpart to resection in horizontal control surveying. As such, vessel position can be computed analytically, however, control of the vessel track is difficult with this method. Additionally, the high manpower requirement and vulnerability to human error must be factored into account.

Properly executed, the three-point sextant fix method is capable of producing positions with an accuracy of approximately 1m per km of range from the RPs.

The Range/Azimuth method is widely used on projects that are within visible range of the shoreline and particularly useful in complex areas, where sight distances are limited and full electronic positioning net deployment is impractical. It is also frequently used in those areas along the base line of range/range systems, where their accuracy is degraded.

Since the RP is occupied, this method requires additional logistical support to move equipment and personnel to the site. Changes from one RP to another involve relocation. Since one observation is made on the vessel (range) and the other (azimuth) ashore, reliable communications are mandatory. The entire survey area must be visible from at least one RP, and each RP must be intervisible with a minimum of one other.

Plotting positions can be accomplished by preplotting range rings around the RP and intersecting them with azimuths. Interpolation of range is made using a metric scale. Among the strengths of this method are excellent track control and consistently good intersection geometry.

One element that all methods share is depth measurement. Measurements of depth at known positions provide data points from which topography is inferred by construction of depth contours. They are made either directly by a sounding pole or leadline or indirectly by an acoustic echo sounder.

In use, the graduated sounding pole is lowered vertically into the water until it touches bottom, then read at surface level. Though rudimentary, the sounding pole is an inexpensive tool for measuring shallow areas not to exceed the recommended depth of 4m.

Indirect depth measurement using an acoustic echo sounder is produced by transmitting an acoustic pulse vertically into the water column through a single beam or phased-array transducer, and measuring the elapsed time until reception of the returning echo reflected off the bottom. The elapsed time is converted to depth, based on the speed of the sound in the water. On the Devils Kitchen project, both the acoustic echo or depth sounder, and range rod were employed, along with angle intersection, generating the desired data.

Most hydrographic methods are contingent on water-level monitoring systems, more commonly known as the water surface elevation, however, water level is not a stable reference datum and must be corrected accordingly. In order to accurately represent the bottom shape from discrete measurements of depth, surveyed depths must be relative to a common and stable reference surface or vertical datum.

With the introduction of satellite positioning systems, (GPS) traditional methods of data collection, including the location of relative position, are undergoing massive changes. It is important to note that GPS procedures for determining precise point positions consist fundamentally in measuring distances from points of unknown location to satellites whose positions are known at the instant the distances are measured. Conceptually, this is identical to performing conventional resection using distances measured by taping or EDM instruments from a station of unknown position to several control stations. The basic difference is that in GPS, the control stations are satellites.

Using new technology introduces new origins for error. In GPS, errors may occur in the satellite's position or clock, receiver and ephemeris errors or mulitpath (bounced signal) errors, including Upper and Lower atmosphere errors. Finally, for GPS receivers without the differential beacon receiver, signal degradation is deliberately introduced by Selective Availability, further eroding the accuracy of locating positions.
Although tree "canopy's" interfere with transmission of signals, precipitation can act much like an umbrella and degrade the broadcast signal. With the introduction of correcting technology or computations to eliminate the source for error, and utilizing x y & z state plane coordinates in conjunction with DOS based windowing software, GPS is a welcomed tool for aiding the professional land surveyor.

In today's competitive market, costs associated with equipment, manpower and the dimensions of the project are taken into consideration. Established firms with experienced licensed surveyors may offer the most competitive bids over smaller companies or individuals. Equipment rental costs are prohibitive considering that daily rentals of a single frequency depth sounder may run as much as $190 per day, or a complete system as much as $2650 per week or $7900 per month.

Factor in the total station and associated equipment, computer plotters and hardware, vessel and manpower associated with the successful completion of the project, serious consideration must be given to the established land surveyor.

Although conventional ground survey methods remain indispensable in the effort to locate reference points ashore, aerotriangulation and satellite positioning systems are regularly applied to support hydrographic surveying. The total station concept has been applied to short-range positioning afloat (range/azimuth) and refined to the extent that autotracking, autoreading, autotransmitting devices are available. Electronic positioning systems provide multiple LOPs and least squares fitting. The avant of global positioning systems promises to revolutionize positioning afloat, even at survey accuracies.

Acoustic echo sounders vary from high frequency, narrow beam to multiple/selectable frequency to beam forming swath sounding systems. Airborn sounding systems using a laser light medium have been developed, and an electromagnetic devise tested.

Regardless of the current technology, the basic measurements remain the same; depth and position.