## SHORT NOTE

# Comparison of three surveying techniques applied to hydrogeological studies: level, barometer, and GPS

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**RESUMEN**

El error obtenido de una nivelación de un circuito de cuatro kilómetros realizado dentro del campus de la Universidad Nacional Autónoma de México fue calculado utilizando tres técnicas diferentes, nivel, barómetro de mano y GPS de mano para determinar su exactitud y costo-beneficio para estudios hidrogeológicos. El polígono fue nivelado una vez utilizando el nivel y el barómetro, y dos veces con el GPS. Los errores en la vertical utilizando estas técnicas fueron de 17mm, 13 metros y 114 metros, para el nivel, barámetro y GPS, respectivamente. De las tres técnicas empleadas, la primera continúa siendo la más cara. Sin embargo, de acuerdo con el margen de errores, continúa siendo el método más exacto, por lo cual es el método sugerido, a pesar de su alto costo (de las tres técnicas comparadas).

**PALABRAS CLAVE:** Control topográfico, nivel, barómetro, GPS, geohidrología.

**ABSTRACT**

The error from three different surveying techniques- level, hand-held barometer, and hand-held GPS-were compared in terms of accuracy and cost effectiveness for hydrogeological studies by surveying a four-kilometer circuit within the campus of the Universidad Nacional Autonoma de Mexico.The polygon was surveyed once with the level and the barometer, and twice with GPS. Vertical errors were 17 mm, 13 meters and 114 meters, for the level, barometer and GPS, respectively. Of the three options, the first is by far the most expensive. Thus, the preferred method for height determinations continues to be the level, even if it is the more expensive option.

**KEYWORDS:** Surveying, level, barometer, GPS, hydrogeology.

## INTRODUCTION

In order to construct water-table maps, it is necessary to be able to determine with accuracy the elevation of the objects of interest whether they are wells, cenotes (sink holes), springs, etc. Typically, this is accomplished using some surveying technique (Freeze and Cherry, 1979). Once the sites have been surveyed, they are referenced either to a local or regional datum, such as mean sea level. This allows one to determine the ground water flow directions, recharge/discharge areas, etc. The accuracy required for each study is project-oriented. For example, hydrogeological research in Yucatán can only accept an error on the order of millimeters, since the regional hydraulic gradient is on the order of 7-10mm/km (Marín, 1990; Steinich and Marin, 1996,1997). However, the error may be relaxed in an environment with abrupt topography, such as Mexico City or Puebla.

In hydrogeological investigations, the vertical elevation is typically obtained through surveying, using either a level or a theodolite. In areas where sparse topographic data is available, other methods have had to be employed. Until recently, barometers were the only alternative. Hand-held GPS units are currently being favored for georeferencing. Since these instruments also give an elevation, they are widely used to determine the elevation of sites of interest. A common hand-held unit, the Garmin 50 model, has a horizontal error of 15 meters (according to the manufacturer), however, no mention is made of the error in the vertical direction.

Ignoring the error bars associated with these surveying techniques has resulted in erroneous hydrogeologic interpretations. Thus, the Instituto Mexicano del Agua (IMTA) discovered that a reported ‘drawdown’ of 60m was an artifact introduced by the surveying technique- the use of a hand-held barometer that was calibrated once every 24 hours. Barometers measure atmospheric pressure; however: (1) they must be used under stable weather conditions, and (2) it is necessary to establish a time-drift curve, by taking repeated measurements at a base station. If the drift is linear, and the time is recorded when the altimeter readings are taken, this drift value may then be subtracted (Brinker, 1982). Consultants in Mexico are now warming up to the use of hand-held GPS units, and it is of concern that these instruments may be used improperly. The objective of this technical note is to evaluate three methods and to establish error bars for each one. We chose a four-kilometer circuit within the campus of the Universidad Nacional Autónoma de México to conduct this study.

## METHODOLOGY

The following instruments were used: a Carl Zeiss Jena NJ-020A level, a Lietz Air hand-held barometer model Air-HB-1L, and a Garmin-50 hand-held GPS. The survey was conducted in February, 1995. For the barometer and the GPS survey, the time of day was recorded. The survey using a level took four hours; the survey with the barometer took one hour, and each of the two GPS surveys took half an hour. The GPS lectures were obtained within up to five minutes, but often in two minutes. For the barometer, the readings had to be stable before they were recorded. In all cases, the circuit was closed. The number of stations were 40, 10, and 10, respectively.

## RESULTS AND DISCUSSION

The closure error with the level was 17 mm. The maximum error allowed for a second order survey is 42 mm. Thus, the error obtained was within acceptable limits (Ballesteros, 1984). The closure error with the barometer was 12.3 meters. As the circuit was short, it was not deemed necessary to keep coming back to the base station in order to establish a time vs. atmospheric change drift curve. Thus, even when working under ideal conditions, the elevations may be off by several orders of magnitude. The limited results from this study suggest that a barometer should be employed with care, and only when absolutely necessary (i.e. when there are no benchmarks nearby).

The closure errors for the hand-held GPS were 86 and 141 meters, respectively, giving an average of 114 m. The second survey was conducted because of the large closure error obtained in the first survey (86m); the second survey yielded an even larger closure error (141m). The results suggest that the GPS technique is inappropiate to obtain elevation data because the error introduced may be in the range of two orders of magnitude.

In terms of cost, clearly the most expensive surveying technique is using the level. The current commercial cost in Mexico is on the order of 1,000 pesos (approximately 100 USD) per kilometer surveyed. The two other methods are significantly less expensive; however, in many cases the results are of questionable value. Our recommendation is to use a level whenever possible to obtain elevation data. Use the barometer with a time-drift curve for areas where sparse topographic data is available, and use the GPS for orientation but not to obtain elevations of points of interest.

## CONCLUSIONS

Three different techniques to obtain elevations were evaluated: level, barometer, and hand-held GPS. The range in errors for a four kilometer polygon is 17 mm, 13 m, and 114 m, respectively. Although surveying with a level is by far the most expensive technique of the three presented here, it is still the best in terms of accuracy. We suggest that whenever possible, this is the technique of choice. Barometers may also be used if a time-drift curve is established. We do not reccommend the use of hand-held GPS to obtain elevation data.

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