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AREA USING ELECTRONIC TOTAL STATION**

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## **ABSTRACT**

A G.T.S. (Great Trigonometrical Survey) benchmark is a permanently fixed reference survey station (or point), having known elevation with respect to a standard datum (mean sea level). These are established all over India by Survey of India department with greater precision. A benchmark value is quite essential at any survey area, especially for reduction of observed sea level with respect to mean sea level or chart datum (CD). While carrying out bathymetric survey of a survey area, the datum referenced values thus obtained are used to compute the final depth contours of the survey area (with respect to CD). So, a benchmark, having known elevation is quite essential at the survey area, without which, preparation of a bathymetric chart is impossible. In some places, GTS benchmarks are available within a kilometer distance and can be easily transferred to the survey area by fly leveling using an automatic Level instrument and a graduated leveling staff. But in most of the cases, GTS benchmarks may be at far away distance from the area to be surveyed. In these cases, the most common traditional method of transferring the benchmark value using an automatic level instrument is a difficult task, consuming enormous amount of time and labour. To eliminate this process, a method is suggested in this technical report to transfer GTS benchmark from any far distance to the survey area. A latest Electronic Total Station (ETS) is the instrument that can be used for this purpose. The main advantage in applying this method is that considerable amount of time can be saved while maintaining the required accuracy.

## **INTRODUCTION**

A benchmark (B.M.) is defined as a fixed reference point of known elevation with respect to a standard datum. A datum (or plane) is any arbitrarily assumed surface level (or line) from which vertical distances are measured. G.T.S. benchmarks are the ones, which are established at spacial intervals all over the country, with very high precision by Survey of India (SOI) department. Their geographical position and elevation above the standard datum (mean sea level) are given in catalogues, as well as, on G.T.S. maps, published by SOI. While carrying out bathymetric surveys or observation of tides, these benchmarks are very much essential to refer the readings with respect to mean sea level or chart datum. If these G.T.S. benchmarks are available near the survey area, they can be easily used for this purpose. However, if these benchmarks are located beyond 5 kilometers away from the survey area, transferring this level to the survey area becomes very tedious, especially using a combination of an automatic level instrument (Fig: 1) and a graduated leveling staff (Fig: 2), which has been the traditional method so far. The traditional method being very tedious and time consuming, a better method is being suggested in this report.

## **ELECTRONIC TOTAL STATION**

In the improved method, to obtain the geographical positions of baseline points “A” and “B”, (Fig: 1), “Ceeducer” differential global positioning system (Fig: 4) can be used. This instrument computes geographical position of any point using the raw data collected from four satellites in the horizon. Also, it receives transit time error corrections from nearby land based marine beacons. After applying these corrections, the final position is obtained which has an accuracy within a meter. These positions can be entered in electronic total station to get the azimuth of the baseline “AB”. Electronic Total Station of “TOPCON” make and “GPT-3002N” model can be used for obtaining geographical co-ordinates and elevation of every point sighted with respect to G.T.S. benchmark “A”. Electronic Total Station uses both an invisible Pulse Laser Diode for distance measurement and a visible Red Laser Beam as a laser pointer to identify the measurement point at the center of the cross hair lines of the telescope. The instrument has a keyboard containing 24 keys, which makes it easier and quicker to key in codes and other alphanumeric characters. The output contains several displays based on

user's choice. The output contains measured field data display listing horizontal angle, vertical angle and laser measured slant distance, computed co-ordinate data display listing geographical location of the point surveyed (Easting, Northing) and elevation of the surveyed point with respect to the instrument station elevation and so on. A dual axis compensator sensor is included in this model, which automatically corrects the horizontal and vertical angle compensation for leveling error, thereby ensuring accurate and reliable reading.

The specifications of the instrument are as follows:

- 1) Maximum distance measurable using single prism: 3000 meters.
- 2) Accuracy in distance measurements:  $\pm (2 \text{ mm.} + 2 \text{ ppm.} \times D)$  where "D" denotes measured distance (mm)
- 3) Least Count in measurement: i) Fine measurement mode: 1mm.  
ii) Coarse measurement mode: 10mm.
- 4) Accuracy in angle measurements: 2" (2seconds).
- 5) Optical Plummet magnification: 3X
- 6) Weight of the instrument (including battery): 5.3 Kgs.
- 7) Operating temperature:  $-20^{\circ}$  to  $+50^{\circ}$
- 8) Maximum operating time including distance measurement: 4.2 hrs.  
(Rechargeable battery)
- 9) Battery charger recharging time: 1.8 hrs.
- 10) External battery: Input voltage: DC 7.0 to 9.8 V.
- 11) Display: Graphic LCD Display 160 X 64 Dots with backlight.
- 12) Internal memory: has a large internal memory to store upto 24,000 points for field data collection and layout works.

## **METHOD OF SURVEY**

The nearest GTS benchmark may be assumed as point "A". It can be on the basement of a light house or near any port office. The location and values of all the G.T.S. benchmarks are given in GTS booklets and maps published by Survey of India, Dehra Dun. A baseline point "B" can be selected about 100 meters away from point "A" for azimuth purpose (Fig: 5). The geographical positions of both "A" and "B" should be obtained accurately in WGS-1984 UTM co-ordinates using Ceeducer DGPS instrument. Electronic Total Station should be set up over Point "A" and all initial settings such as

leveling, etc. should be done very accurately. The U.T.M. (Universal Transverse Mercator) co-ordinates and elevations of both “A” and “B” should be entered through the keyboard of the Total station. The telescope should be aimed towards a point “C” on top of a building or any huge structure, which may be about 1500 to 2000 meters away from instrument station “A”, towards the survey area. A reflector prism should be exactly placed over that point (“C”), holding as vertical as possible by a helper. By aiming the point “C” accurately and releasing the laser pulse, both geographical position as well as the elevation value are computed by the instrument and recorded into the memory. The elevation of Point “C” is now known with respect to the GTS benchmark point “A”. The point “C”, where the reflector prism was placed should be marked accurately. The instrument can be now shifted to point “C”. From point “C” another baseline point (“D”) can be selected at a distance of about 100 to 500 meters long, towards the survey area direction. Point “D” can be selected preferably on top of any huge building or structure (where the instrument can be set up next). Keeping “C” and “D” as the base line points, the above method of surveying can be repeated, simultaneously proceeding towards the survey area. Before shifting the instrument to every successive station, the prism may be placed at every temporary benchmark (Fig: 6) selected on the way (established by the survey party, who has done as per the traditional method) for comparing the elevation obtained from both the methods. Finally the prism should be kept exactly near the survey area at TBM: 10 (transferred benchmark). The final main point on the survey area (TBM: 10) should be selected in such a way that good line of sight is available throughout the stretch of the area to be surveyed. The geographical position and elevation of point TBM: 10 should be recorded. The elevation thus obtained over TBM: 10 will be with respect to mean sea level. This whole process of transferring G.T.S. benchmark to the survey area should get completed within 3 setups of Total Station (“A”, “C” and “D”), provided the distance between the GTS benchmark and the survey area is within 6 kilometers. The whole process may take roughly about 3 hours for completion. In comparison, by using the traditional method of transferring the benchmark, it may take at least 12 hours for completion using automatic level instrument (2 days of tedious job). Finally, the electronic total station can be set up over point TBM: 10 (in the survey area) and further surveys like delineation of low tide line, high tide line and even inter-tidal zone surveys can be carried out as per the survey principles. (Ganesan, 2003.).

## **PERMISSIBLE ERROR LIMITS**

In the old traditional method, while carrying out transfer of benchmark from one place to another using Automatic level and a graduated staff (the traditional old method), closing error tends to occur. The magnitude of the permissible limit of closing error depends on the purpose for which the leveling is required. It wholly depends on the order of the accuracy demanded or the precision of leveling. In general, the permissible closing error in traditional method of surveying is expressed as

$$E = C\sqrt{K} \quad \text{where}$$

**E** = the error in millimeters.

**C** = the Constant and

**K** = the distance in kilometers.

The value of “C” depends upon four criteria namely:

- 1) Quality of the instrument
- 2) Observer’s care and skill
- 3) The character of the site and
- 4) The atmospheric conditions.

The closing error “E” and the value of “C” for different types of leveling are given in Table: 1 (Kanetkar, 2006).

## **PRECAUTIONS TO BE TAKEN**

Survey of India established G.T.S. benchmarks with great precision and come under the category of “Precise Leveling”. To come closer to the accuracy standard maintained by Survey of India, the following precautions should be taken while surveying using Electronic Total Station:

- 1) Electronic Total Station instrument should be set up very accurately over the reference points and leveled precisely.
- 2) While taking observations to every point, the telescope should be sighted exactly at the center of the reflecting prism, which is fixed on a graduated rod. Accurate distance between the foot of the prism rod and the optical center of the prism should be measured for input. Sufficient care should be taken by the prism rod holder to keep the prism as vertical as possible.

3) To maintain high standard of accuracy, the successive station points chosen in such a way, that horizontal angle of cut should always lie between  $30^\circ$  and  $100^\circ$ .

4) In spite of leveling the instrument accurately, during the course of survey, the vertical axis may not be perpendicular to the horizontal axis of the instrument due to slight deflection of level bubble in the instrument. This will result in erroneously measured horizontal angles. The extent of this error depends upon the amount of the tilt of axis, the elevation of the target and the horizontal angle between the direction of the tilt of the vertical axis and the target. To correct this error, the tilt sensors should be activated (enabled), by which, automatic correction of vertical and horizontal angle for mislevelment will be displayed. In general, if at all, any tilt is found within safe limits (after leveling very accurately at the beginning) during the course of survey, the corrections are applied to the measured angles automatically. But if the tilt range is more than the safe limits, the instrument displays "Tilt Over" and the instrument has to be leveled again manually to start fresh from that setup. Care has to be taken to keep the tilt sensors turned on, to ensure very precise angle measurements.

To maintain very high accuracy standards, atmospheric corrections should be entered in the instrument, while starting the survey. The ambient temperature and atmospheric pressure may be entered as an input. Electronic Total Station is capable of measuring distance, taking into account correction for refraction and Earth's curvature. So, this particular part also is taken into consideration, as far as accuracy of field data measurements are concerned.

## **RESULTS AND CONCLUSIONS**

On experimental basis, the suggested method was attempted at a remote location. The results were compared with the accuracy table shown in Table:1. It was observed that the closing error over every temporary benchmark using the suggested method falls between ordinary and accurate leveling category, when compared with the traditional method of surveying results. It has been found that Electronic Total Station ("TOPCON" make) GPT 3002N model is quite ideal for this type of work, satisfying the accuracy limits required for coastal surveys. The traditional method of transferring GTS benchmark using automatic level took about 12 hours (2 days of survey), while the method suggested in this report, using Electronic Total Station took roughly about 3



hours. In the proposed method, a hired vehicle should be used for shifting the instrument and to move between successive survey points.

The suggested method is quite useful for setting up and transferring the mean sea level (or Chart Datum) on tide poles (for tidal observations) wherever it needs to be installed. As it is quite easier to transfer known mean sea level elevation from anywhere to the survey area, bathymetric surveys along inter-tidal zones at remote areas can be performed with great ease. In this method, the geographical positions of the two base line points (including the light house point) can be observed using Ceeducer DGPS instrument. As Electronic Total Station is a land based survey instrument requiring only two known geographical locations and one elevation above mean sea level, the same instrument can be used for delineating high tide line, low tide line and inter-tidal zone surveys (Fig:7). As hiring of boat is not essential for performing this job, the expenditure can be reduced to bare minimum. If ultimate care is taken at every setup, while handling and operating the instrument, better results can be obtained.

The suggested method is very useful and is the first stage of any survey to be carried out before performing the following land and hydrographic surveys:

- i) Bathymetric surveys along inter-tidal zone areas, where boat cannot reach due to less or no water.
- ii) Delineation of Low tide line surveys. Basically, low tide line is the zero meter contour line of the survey area with respect to chart datum. After transferring the benchmark to the main point (TBM: 10) on the survey area, low tide line survey can be started immediately from the same point, by setting up Electronic Total Station over point TBM: 10. As the final output of the survey is based on land based control points, the accuracy of the final output will be much more stable, when compared to doing the same survey using a boat. Tidal observations at periodical intervals are useful for several hydrographic applications. But after observations, all the tidal values have to be reduced to mean sea level or chart datum. The suggested method is very useful for fixing mean sea level as well as chart datum over installed tide poles, at any remote locations.
- iii) As the instrument displays and records into the internal memory every surveyed (target) point's geographical location and elevation, there is no need to note down the readings manually, thereby eliminating manual error in copying. But in the old traditional method of surveying using automatic level instrument, every surveyed point has to be carefully noted in a register manually and the computations have to be performed manually to get the final elevations. The closing error after computation of field data

(comparing both methods) is given in Table: 2. The value of Chart datum with respect to mean sea level is given in Indian Tide Tables and in hydrographic charts for most of the places. If needed, all benchmarks can be reduced with respect to chart datum.

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## LIST OF TABLES AND FIGURES

**TABLE: 1**

The Table below shows the closing error “E” for different types of leveling:

Sl. No.	Leveling Type	Closing Error “E” (mm)
1.	Rough Leveling	$E = \pm 96 \sqrt{K}$
2.	Ordinary Leveling	$E = \pm 24 \sqrt{K}$
3.	Accurate Leveling	$E = \pm 12 \sqrt{K}$
4.	Precise Leveling	$E = \pm 6 \sqrt{K}$

Where **E** = Error (mm)

**C** = Constant and

**K** = Distance (km)

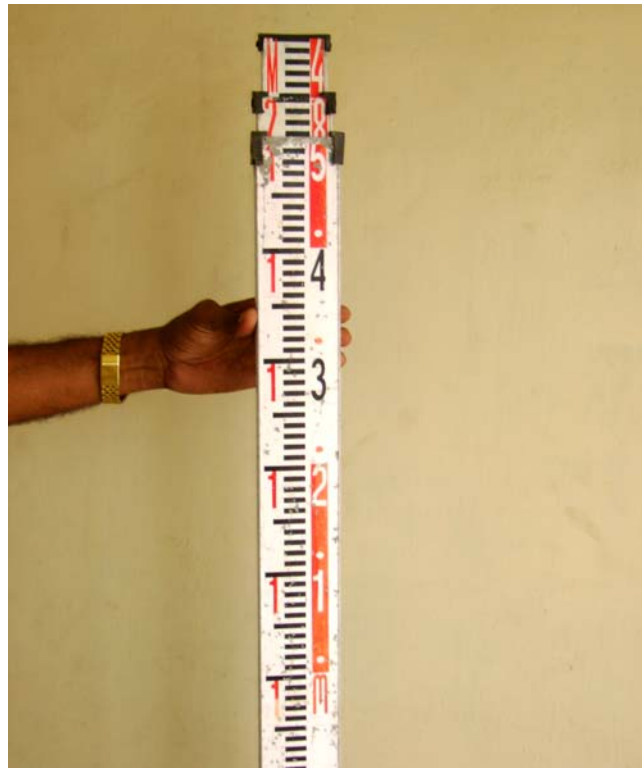
**TABLE: 2**

The closing error at all temporary benchmarks after the survey is given below:

S.No.	Temp. BM No.	Using traditional method from M.S.L. (m.)	Using the suggested method from M.S.L. (m.)	Closing error (mm)	Remarks.
1.	Over GTS BM	+ 4.625	+ 4.625	-----	Start survey from this point.
2.	TBM: 5	+ 4.095	+ 4.128	33	Temporary benchmark
3.	TBM: 6	+ 3.925	+ 3.960	35	Temporary benchmark
4.	TBM: 7	+ 3.285	+ 3.639	35.4	Temporary benchmark
5.	TBM: 8	+ 4.025	+ 4.057	32	Temporary benchmark
6.	TBM:9	+ 4.960	+ 4.993	33	Temporary benchmark
7.	Over TBM: 10 near survey area.	+ 3.260	+ 3.292	32	Final value after completing transfer to the survey area



**Fig:1.** An Automatic Level instrument used for transferring benchmark, by the traditional method.



**Fig:2.** A graduated leveling staff of 4 meters high, used along with Automatic Level instrument, for transferring benchmark.



**Fig: 3.** Latest Electronic Total Station GPT-3002N model instrument, that can be used for transferring G.T.S. benchmark value to survey area using the suggested method.



**Fig:4.** “Ceeducer” Differential Global Positioning System, which can be used for obtaining accurate geographical and UTM co-ordinates of base stations “A” and “B”.

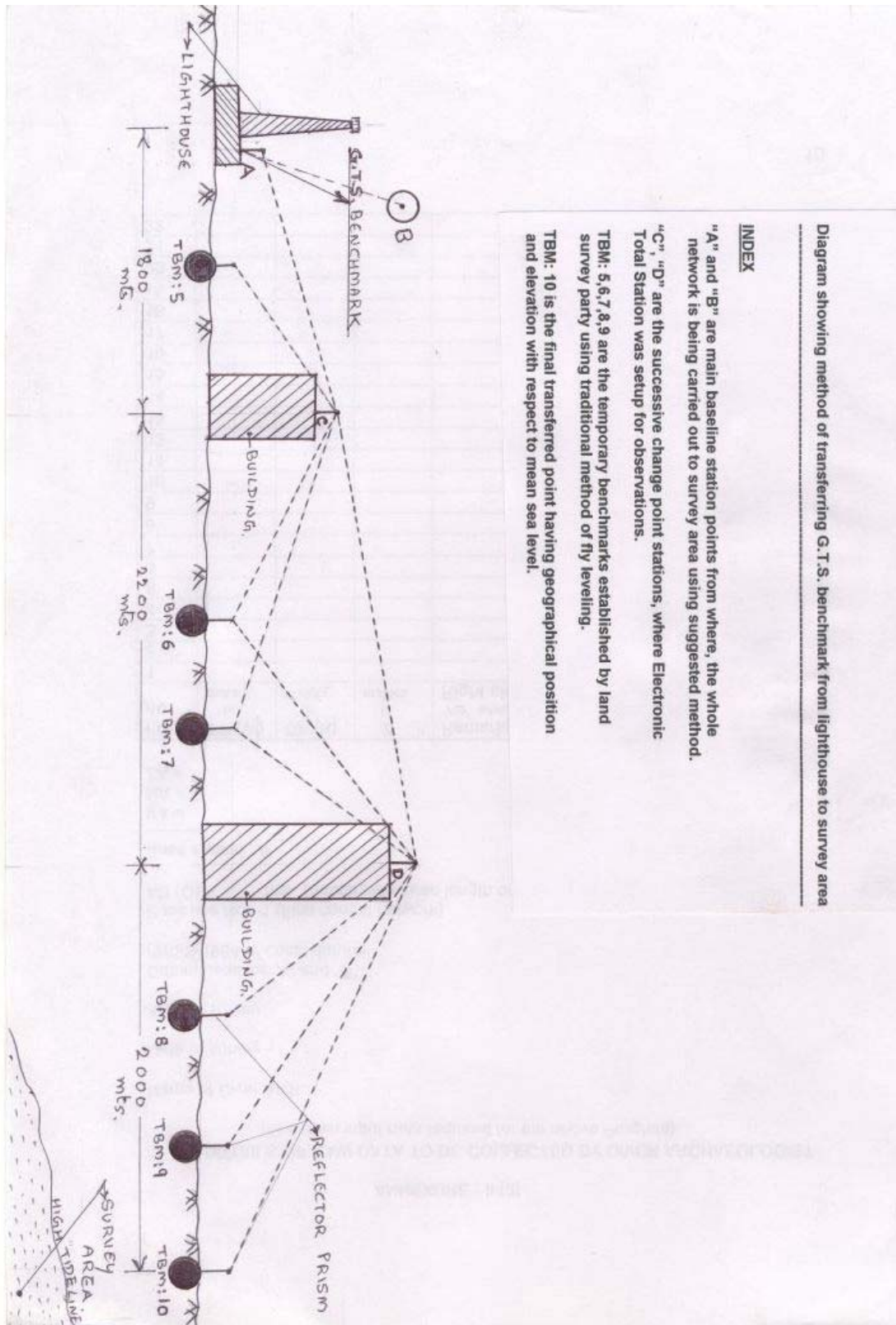


Fig: 5. The method adopted for transferring G.T.S. benchmark from a lighthouse (Point "A") to survey area (over point TBM:10).





**Fig: 6.** One of the temporarily transferred benchmarks established above a road-side culvert, by a survey party. Same benchmarks were used for counter checking the elevation using Electronic Total Station.



**Fig: 7.** A survey party carrying out delineation of high tide line and low tide line surveys from newly established bench mark station in a survey area (TBM:10), using Electronic Total Station instrument.

## **LIST OF ACRONYMS**

<b>GTS</b>	<b>Great Trigonometrical Survey</b>
<b>CD</b>	<b>Chart Datum</b>
<b>ETS</b>	<b>Electronic Total Station</b>
<b>SOI</b>	<b>Survey of India</b>
<b>UTM</b>	<b>Universal Transverse Mercator</b>
<b>BM</b>	<b>Benchmark</b>
<b>TBM</b>	<b>Temporarily transferred benchmark</b>
<b>MSL</b>	<b>Mean Sea Level</b>
<b>HTL</b>	<b>High Tide Line</b>
<b>LTL</b>	<b>Low Tide Line</b>
<b>DGPS</b>	<b>Differential Global Positioning System</b>