INTERNATIONAL JOURNAL OF RESEARCH AND SCIENTIFIC INNOVATION (IJRSI)
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue X October 2025

Conditions and Limitations to be Considered while Using the Total Station for Levelling Measurements

N. Malalarathne[1*], M.A.R.D. Gunathilaka[2], K.W.D. Sachinthana, D.R. Welikanna[3]

[1]National Aquatic Resources Research and Development Agency (NARA), Colombo 15, Sri Lanka

[2] Survey Department of Sri Lanka

[3]Faculty of Geomatics, Sabaragamuwa University of Sri Lanka

***Corresponding Author**

DOI: https://doi.org/10.51244/IJRSI.2025.1210000303

Received: 29 October 2025; Accepted: 05 November 2025; Published: 20 November 2025

ABSTRACT

Total station is a widely used instrument in the field of surveying for both distance and angle measurements. Indirect levelling is a function that total station can be used but the level of accuracy that can be achieved is uncertain. Therefore, it is expected to investigate conditions and limitations of using total station for leveling through this study. An 8km long level line was established for this purpose, covering various topographical features using into level. Selected segments of this level line were used for total station levelling. The result achieved from total station was compared with auto level heights. Error variation of total station readings in each segment was projected to graphs. According to results, the error was always negative when the level line slopes downwards and positive when rises upwards. Error generation was higher as longer the distance between instrument and target. Finally total station can be recommended for engineering surveys but not suitable for water supply and drainage projects where accuracy is critical.

Keywords – Total station, surveying, levelling, error variation

INTRODUCTION

Background of the Study

At present, total station has been widely spread and used in many survey sites, and sometimes total station is not fully used since users misunderstand the principles of this unit. One of them is the levelling, and in case use total station for levelling, the method is classified as the indirect levelling method, and the method that will yield acceptable misclosure and save time will be the best to be adopted for engineering works such as route surveying.

Levelling refers to height measurements for representing the relative difference in height between various points on the earth. Common levelling instruments include the spirit level, the dumpy level, the digital level, auto level and the laser level. In traditional method of levelling, where it is needed to be in touch on the ground. Therefore, basic equipment such as tripod, auto level, staff, bubble staff, and measuring tape are used.

For engineering activities like road construction, often vertical position is obtained from a combination of methods. Currently, level machine is used to establish vertical control. The method employs the use of auto level instrument and graduated staffs. Accurate results are obtained when all of the systematic errors are controlled and corrected. Short sight lengths and balanced sights are the most limiting restrictions. Generally, many instrument stations have to be established in a level line when it passes in hilly and mountainous regions. This increases the possibility of occurring instrumental errors and also extremely costly and time consuming.

Total Station is not exclusively used for levelling but it can be used for levelling under certain conditions and limitations. This research is carried out to investigate such conditions and limitations and they may include, topographic conditions, conditions in setting up instruments, weather conditions, distance between instrument and target, target height etc.

Problem Statement

When determining the height, number of instruments of different precisions and relatively different field procedures which ends with different precisions are available. The highest precision in levelling is obtained by the use of auto levelling. The use of total station levels saves computational and observation time. It is therefore expected to be less tedious than the conventional auto levelling. The question is conditions and limitations to be considered while using the total station for levelling measurements. It should be investigated whether it gives the same precision compared to conventional analogue auto levelling. These are the problems which are going to be discussed in the study.

Research Objectives

The objectives of the study are;

- Check the accuracy of total station for levelling and find whether misclosure is in acceptable range or not
- Find the suitability and usages of total station in water distribution and drainage

Scope and Limitations

The research would be helpful for users to select suitable instrument for a given task. The study is limited to an 8km long level line established using auto level and selected segments which cover a total distance of 5km for total station levelling. The selected level line covered a relatively flat area, an undulated area and a slope area.

Conceptual Method

Level network was designed along the section in Pambahinna-Rajawaka road and established bench marks in each kilometer. Study area was 8km in length. The study area was selected as it consist various topographies from plain terrain to hilly major terrain. The area found to be favorable for easy walking and there was good inter-visibility between consecutive points and also less traffic congestion existed.

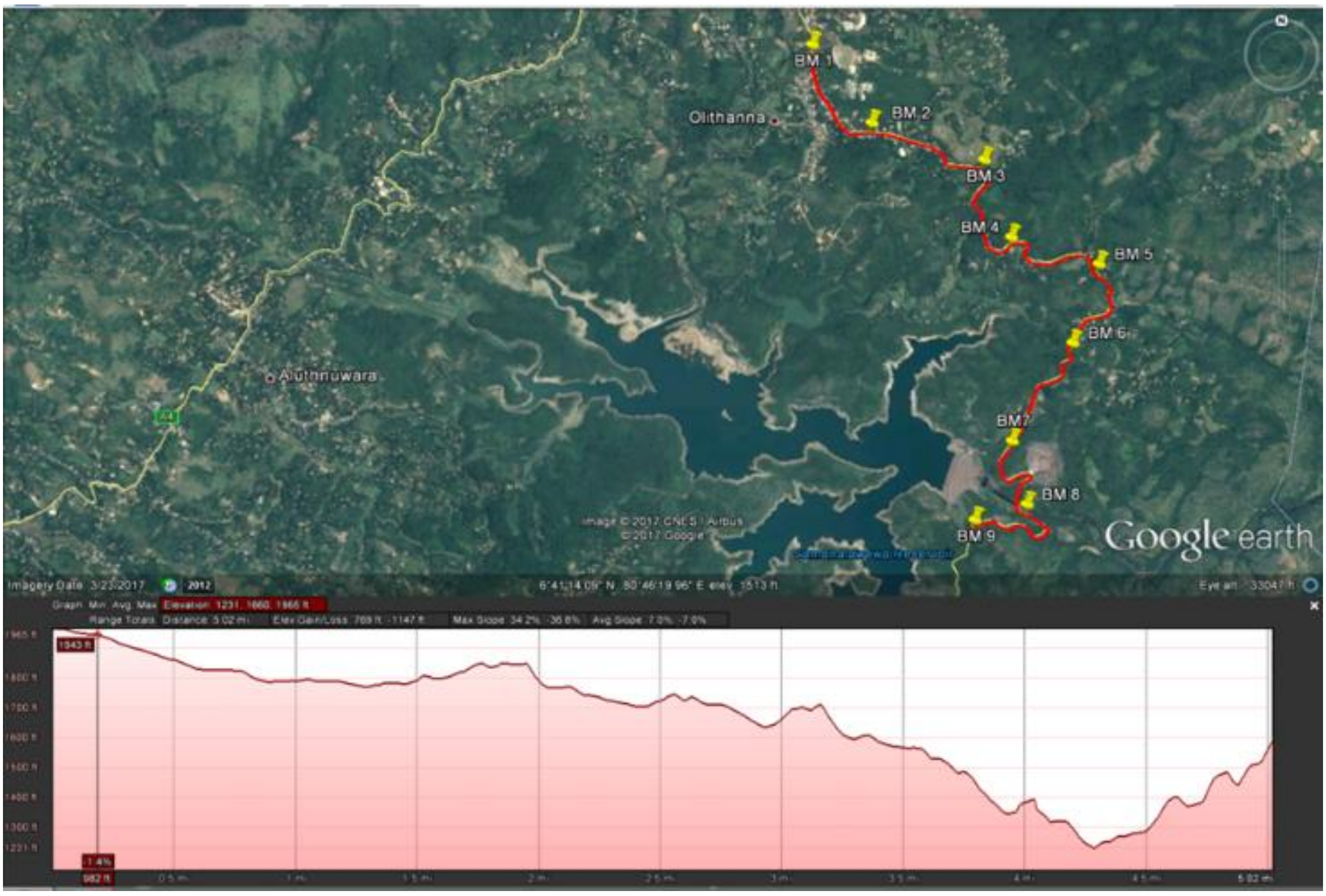


Figure **Error! No text of specified style in document.**.1 : Route for Level Network Establishment

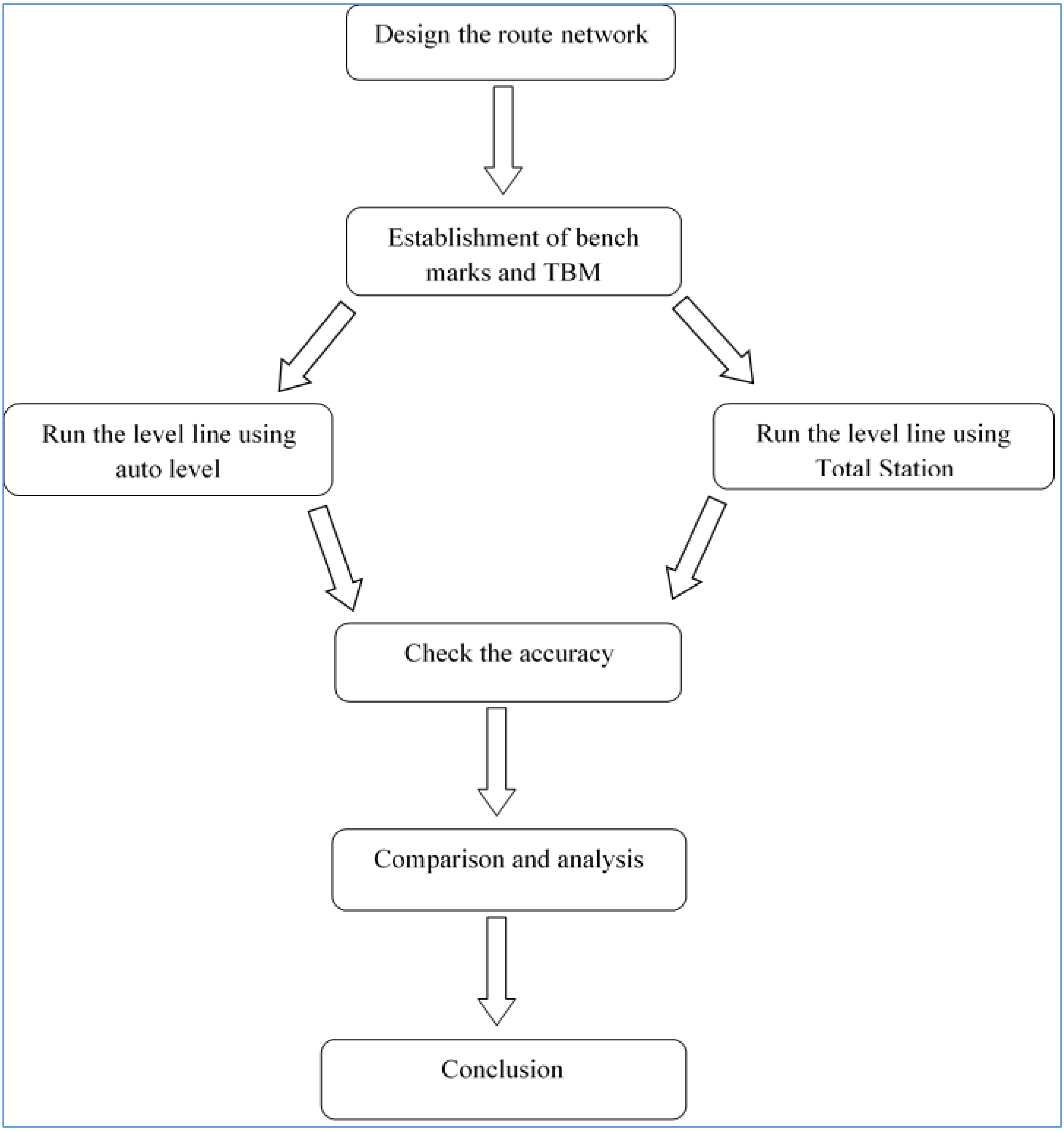


Figure **Error! No text of specified style in document.**.2 : Conceptual Framework

LITERATURE REVIEW

Levelling is a branch of surveying which is used to find elevation with respect to a given or assumed datum and to establish points with respect to a given or assumed datum. Therefore, levelling deals with measurements in vertical plane.

Level Surfaces, Plumb Lines and Height Systems

A level surface is an equipotential surface which is always perpendicular to the direction of gravity in any point on that surface. Plumb lines are imaginary lines which represent the direction of gravity. Plumb lines are defined as truly vertical lines (COMET, 2015).

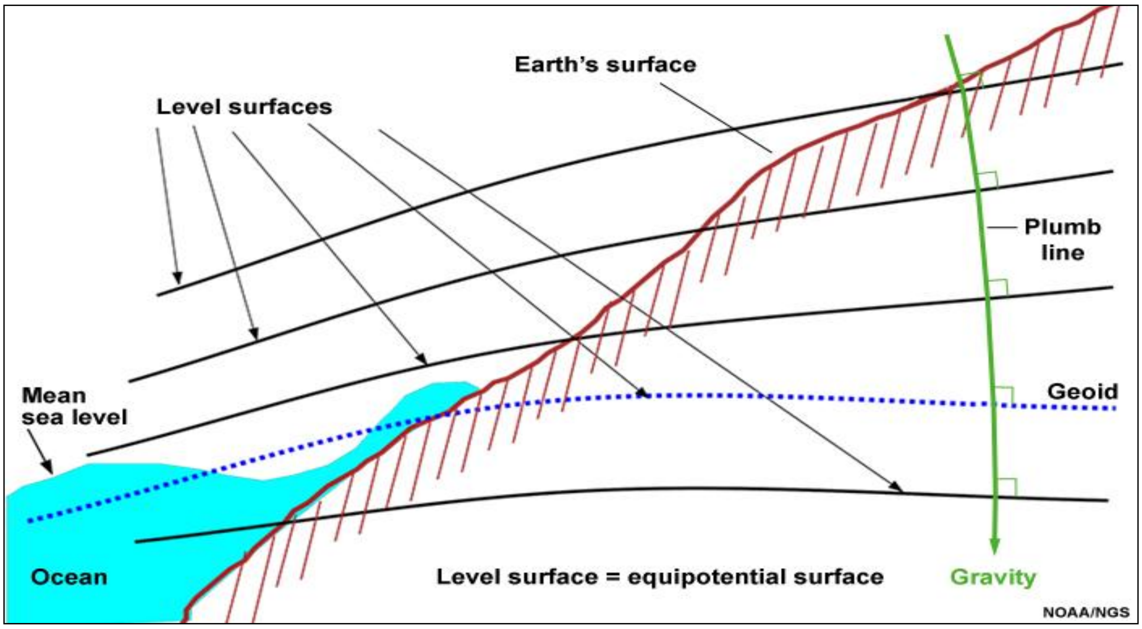


Figure **Error! No text of specified style in document.**.3 : Level Surface and Plumb Line (NOAA, 2016)

Height systems are defined in several ways as follows;

1. Ellipsoidal height: This is the distance along ellipsoid normal from ellipsoid to earth surface
2. Geoid height: This is the distance along ellipsoid normal between geoid and ellipsoid
3. Orthometric height: This is the height measured along the plumb line from geoid to earth surface

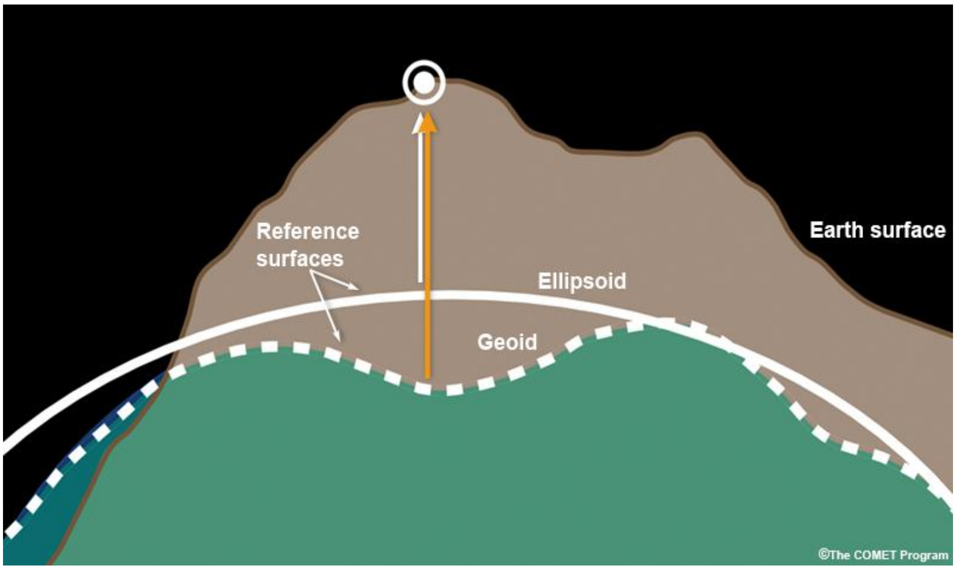


Figure **Error! No text of specified style in document.**.4 : Height Systems (COMET, 2015)

Usages of Levelling

- For building construction
- For bridge and tunnel construction
- To design water distribution and drainage systems
- For volume calculation
- To get cross sections and longitudinal sections along roads, railways, canals etc
- To identify topography and drainage

Methods of Levelling

There are three principal methods for determining differences in elevation, namely, barometric levelling, trigonometric levelling and spirit levelling (Tandon, 2013).

Barometric levelling

Barometric levelling makes use of the phenomenon that difference in elevation between two points is proportional to the difference in atmospheric pressures at those points. Therefore, a barometer may be used and the readings observed at different points would yield a measure of the relative elevation of those points. At a given point, the atmospheric pressure doesn't remain constant in the course of the day, even in the course of an hour. Therefore, this method is relatively inaccurate and is little used in surveying work except on reconnaissance or exploratory survey (Tandon, 2013).

Trigonometric Levelling (Indirect Levelling)

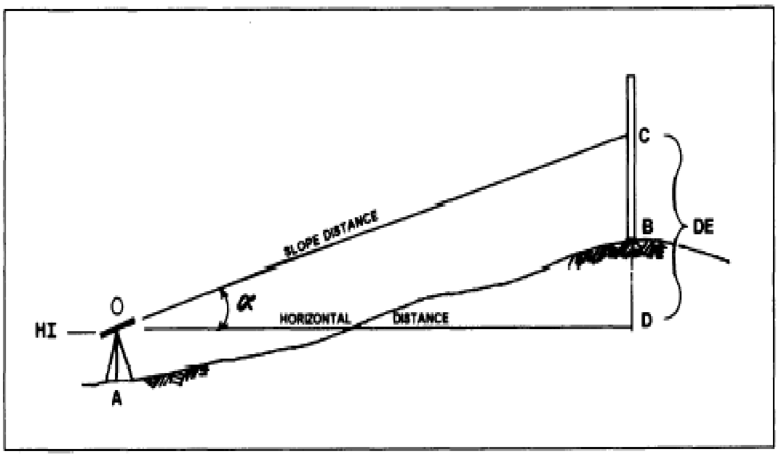


Figure **Error! No text of specified style in document.**.5 : Trigonometric Levelling (Punmia, 2015)

Trigonometric or indirect levelling is the process of levelling in which the elevations of points are computed from the vertical angles and horizontal distances measured in the field, just as the length of any side in any triangle can be computed from proper trigonometric relations. In a modified form called stadia levelling, commonly used in mapping, both the difference in elevation and the horizontal distance between the points are directly computed from the measured vertical angles and staff readings.

1.1.1 Spirit Levelling or Direct Levelling

It is that branch of levelling in which the vertical distances with respect to a horizontal line (perpendicular to the direction of gravity) may be used to determine the relative difference in elevation between two adjacent points. A horizontal plane of sight tangent to level surface at any point is readily established by means of a spirit level or a level vial. In spirit levelling, a spirit level and a sighting device (telescope) are combined and vertical distances are measured by observing on graduated rods placed on the points. The method is also known as direct levelling. It is the most precise method of determining elevations and the one most commonly used by engineers.

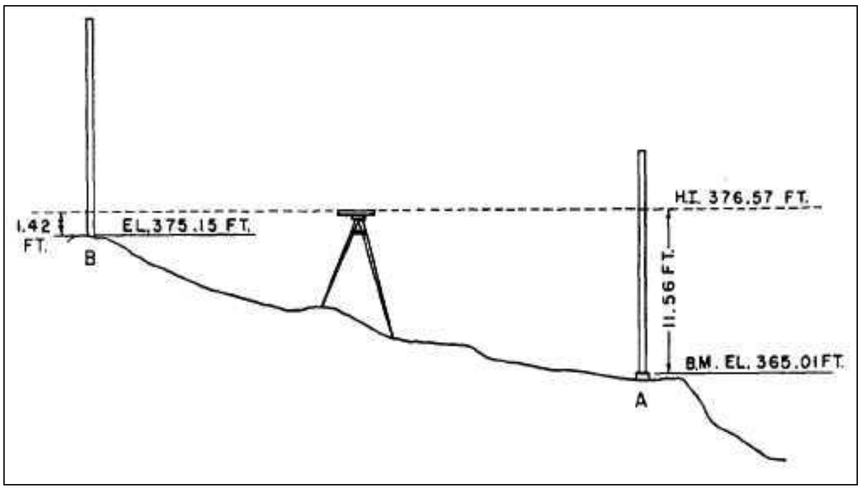


Figure **Error! No text of specified style in document.**.6 : Direct Levelling (Punmia, 2015)

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IX September 2025

Dumpy level, automatic level and digital level are the typical instruments that are used in direct levelling measurements (Tandon, 2013). Out of them, the automatic level is also termed as self-aligning level. It has a compensator which consists of an arrangement of three prisms. The two outer ones are attached to the barrel of the telescope. The middle prism is suspended by fine wiring and reacts to gravity. The instrument is first levelled approximately by the circular bubble, the compensator then deviates the line of sight by the amount that the telescope is out of sight (Tandon, 2013).

Important Terms in Levelling

Table **Error! No text of specified style in document.**.1 : Terms in Levelling (Mishra, 2017)

Level Line	A line lying in a level surface. It is, therefore, normal to the plumb line at all points.
Horizontal Plane	A plane tangential to the level surface at that point. It is, therefore, perpendicular to the plumb line through the point.
Horizontal Line	A straight line tangential to the level line at a point. It is also perpendicular to the plumb line.
Vertical Line	A line normal to the level line at a point. It is commonly considered to be the line defined by a plumb line.
Datum	Any surface to which elevation are referred. The mean sea level affords a convenient datum world over, and elevations are commonly given as so much above or below sea level. It is often more convenient, however, to assume some other datum, specially, if only the relative elevation of points are required.
Elevation or Reduced Level	The elevation of a point on or near the surface of the earth is its vertical distance above or below an arbitrarily assumed level surface or datum. The difference in elevation between two points is the vertical distance between the two-level surface in which the two points lie. This is often denoted as reduced level.
Vertical Angle	Angle between two intersecting lines in a vertical plane. Generally, one of these lines is horizontal.
Mean Sea Level	Average height of the sea for all stages of the tides. At any particular place it is derived by averaging the hourly tide heights over a long period of 19 years.
Bench Mark	A relatively permanent point of reference whose elevation with respect to some assumed datum is known. It is used either as a starting point for levelling or as a point upon which to close as a check.
Line of Collimation	A line joining the intersection of cross hairs of diaphragm to the optical centre of object glass and its continuation. It is known as line of sight.
Back Sight	A staff reading taken at a known elevation. It is the first staff reading taken after setup of instrument.
Fore Sight	Last staff reading taken denoting the shifting of the instrument.
Change Point or Turning Point	Point on which both fore sight and back sight are taken.
Intermediate Sight	Staff reading taken on a point where elevation is to be determined. All staff readings between back sight and fore sight are intermediate sights.

Benchmarks

Bench mark is a point of known elevation (Punmia, 2015). There are several types of bench marks such as; GTS (great trigonometrically surveyed bench mark), permanent bench mark, arbitrary bench mark, temporary bench mark etc. as classified according to the purpose served by them.

GTS Benchmark

The long form of GTS benchmark is Great Trigonometrical Survey benchmark. These benchmarks are established by national agency. In Sri Lanka, the Survey Department is involved with such works. GTS benchmarks are established all over the country with highest precision survey, the datum being mean sea level. A bronze plate provided on the top of a concrete pedestal with elevation engraved on it serves as benchmark. It is well protected with masonry structure built around it so that its position is not disturbed by animals or by any unauthorized person. The position of GTS benchmarks are shown in the topo sheets published (Punmia, 2015).

Permanent Benchmark

These are the benchmarks established by state government agencies like PWD. They are established with reference to GTS benchmarks. They are usually on the corner of plinth of public buildings.

Arbitrary Benchmark

In many engineering projects the difference in elevations of neighbouring points is more important than their reduced level with respect to mean sea level. In such cases a relatively permanent point, like plinth of a building or corner of a culvert, are taken as benchmarks, their level assumed arbitrarily such as 100m, 300m etc.

Temporary Benchmark

This type of benchmark is established at the end of the day's work, so that the next day work may be continued from that point. Such point should be on a permanent object so that next day it is easily identified.

Total Station

A Total Station is modern, automated and much more complicated combination of theodolite integrated with an electronic distance meter (EDM), microprocessor with an internal data storage or external data collector. The total station is designed for measuring of slant distances, horizontal and vertical angles (earlier theodolite was used for this purpose) and elevations in topographic and geodetic works as well as for solution of application geodetic tasks. Like every optical and electro-mechanical instrument total station does have some source of error that need to be understand and instrument must be calibrated before the instrument move to field (Mishra, 2017).

Sources of Errors in Total Station Levelling (Mishra, 2017)

1. **Compensator index error:** Errors caused by not levelling a theodolite or total station carefully cannot be eliminated by taking face left and face right readings. If the total station is fitted with a compensator, it will measure residual tilts of the instrument and will apply corrections to the horizontal and vertical angles for these. However, all compensators will have a longitudinal error l and traverse error t known as zero-point errors. These are averaged using face left and face right readings but for single face readings must be determined by the calibration function of the total station.
2. **Horizontal collimation error:** Horizontal collimation error exists when the optical axis of the total station instrument is not exactly perpendicular to the telescope axis. To test for horizontal collimation error, point to a target in face one then point back to the same target in face two, the difference in horizontal circle readings should be 180 degrees. Horizontal collimation error can always be corrected for by meaning the face left and face right pointing of the instrument.
3. **Height of standards error:** In order for the telescope to plunge through a truly vertical plane the telescope axis must be perpendicular to the standing axis. As stated before, there is no such a thing as perfection in the physical world. All theodolites have a certain degree of error caused by imperfect positioning of the telescope axis. Generally, determination of this error should be accomplished by a qualified technician because horizontal collimation and height of standards errors interrelate and can magnify or offset one another. Horizontal collimation error is usually eliminated before checking for height of standards. Height of standards error is checked by pointing to a scale the same zenith angle above a 90-degree zenith in 'face-one' and 'face-two'. The scales should read the same in face one as in face two.
4. **Tilting axis error:** These axial errors occur when the titling axis of the total station is not perpendicular to its vertical axis. This has no effect on sightings taken when the telescope is horizontal, but introduces errors

into horizontal circle readings when the telescope is tilted, especially for steep sightings. As with horizontal collimation error, this error is eliminated by two face measurements, or the tilting axis error a is measured in a calibration procedure and a correction applied for this to all horizontal circle readings as before if a is too big, the instrument should be returned to the manufacturer.

5. **Vertical collimation error:** A vertical collimation error exists on a total station if the 0° to 180° line in the vertical circle does not coincide with its vertical axis. This zero-point error is present in all vertical circle readings and like the horizontal collimation error, it is eliminated by taking FL and FR readings or by determining.
6. **Pointing errors:** Pointing errors are due to both human ability to point the instrument and environmental conditions limiting clear vision of the observed target. The best way to minimize pointing errors is to repeat the observation several times and use the average as the results.
7. **Uneven heating of the instrument:** Direct sunlight can heat one side of the instrument enough to cause small errors. For the highest accuracy, utilize an umbrella or pick a shaded spot for the instrument.
8. **Vibrations:** Avoid instrument locations that vibrate. Vibrations can cause the compensator to be unstable.
9. **Atmospheric corrections:** Meteorological data corrections to observed EDM slope distances may be significant over longer distances. Usually for most topographic surveying over short distances, nominal (estimated) temperature and pressure data is acceptable for input into the data collector. Instruments used to measure atmospheric temperature and pressure must be periodically calibrated. This would include psychrometers and barometers.
10. **Optical plummet errors:** The optical plummet or tri-brachs must be periodically checked for misalignment. This would include total stations with laser plummets.
11. **Adjustment of prism poles:** When using prism poles, precautions should be taken to ensure accurate measurements. A common problem encountered when using prism poles is the adjustment of the leveling bubble. Bubbles can be examined by establishing a check station under a doorway in the office. First, mark a point on the top of the doorway. Using a plumb bob, establish a point under the point on the doorway. If possible, use a center punch to make a dent or hole in both the upper and lower marks. The prism pole can now be placed into the check station and easily adjusted.

Research in Total Station Levelling

There are several studies that had been carried out to investigate the use of total station for levelling. Some of them are described below.

The study done by Julius Geofrey, an undergraduate of Ardhi University in Tanzania, shows a comparison between digital levelling and total station levelling. The levelling route is 7km long and consists four segments; three 2km segments and a 1km segment. Benchmarks were established on the separation of each segment. In addition, minor benchmarks were established in between those segments. The forward and back levelling were run for each segment using both instruments and the loop misclosure was determined by subtracting the computed reduced level from the known reduced level of the benchmark. The root mean squares of the observed misclosure for each segment were in acceptable range both for the total station and digital level. However, they found that digital level is more precise as usual. The study recommends to carry out further research on different areas of interests with longer levelling routes in order to check the accumulation of errors in longer distances.

Another study has been done by Jongchool & Taeho, 2001, to investigate the application to levelling using total station. This study mainly focuses on the effect of EDM error. The distance measured by EDM is expressed by the formula;

$S = U + m\lambda/2$, where,

- U**:** phase shift of the reflected light wave
- λ**:** wavelength
- m**:** number of transmitted wavelengths

The device for measuring distance by light wave always should have the correction for the measured value. Here they have studied mainly the weather correction and zero correction. Weather correction consists variables such as refraction of atmosphere, height of sea level, refraction by projection method and difference of scale coefficient. Zero correction is influenced mainly by prism integer and error by incidence angle. The study area they had chosen was a 650m long asphalt paved road in Busan, Korea. Topcon's GTS-701 total station was used as the measurement device while Topcon's first-class levelling device was used for comparison. They have observed that the maximum distance they could discriminate the prism's central point from the telescope lens was 280m, and its error was 2.3mm that satisfies the second-class allowable error, 2.6mm. Therefore, it is judged that if the distance is applied that can discriminate the prism's central point, it can satisfy the second-class levelling.

Study Area and Methodology

Study Area

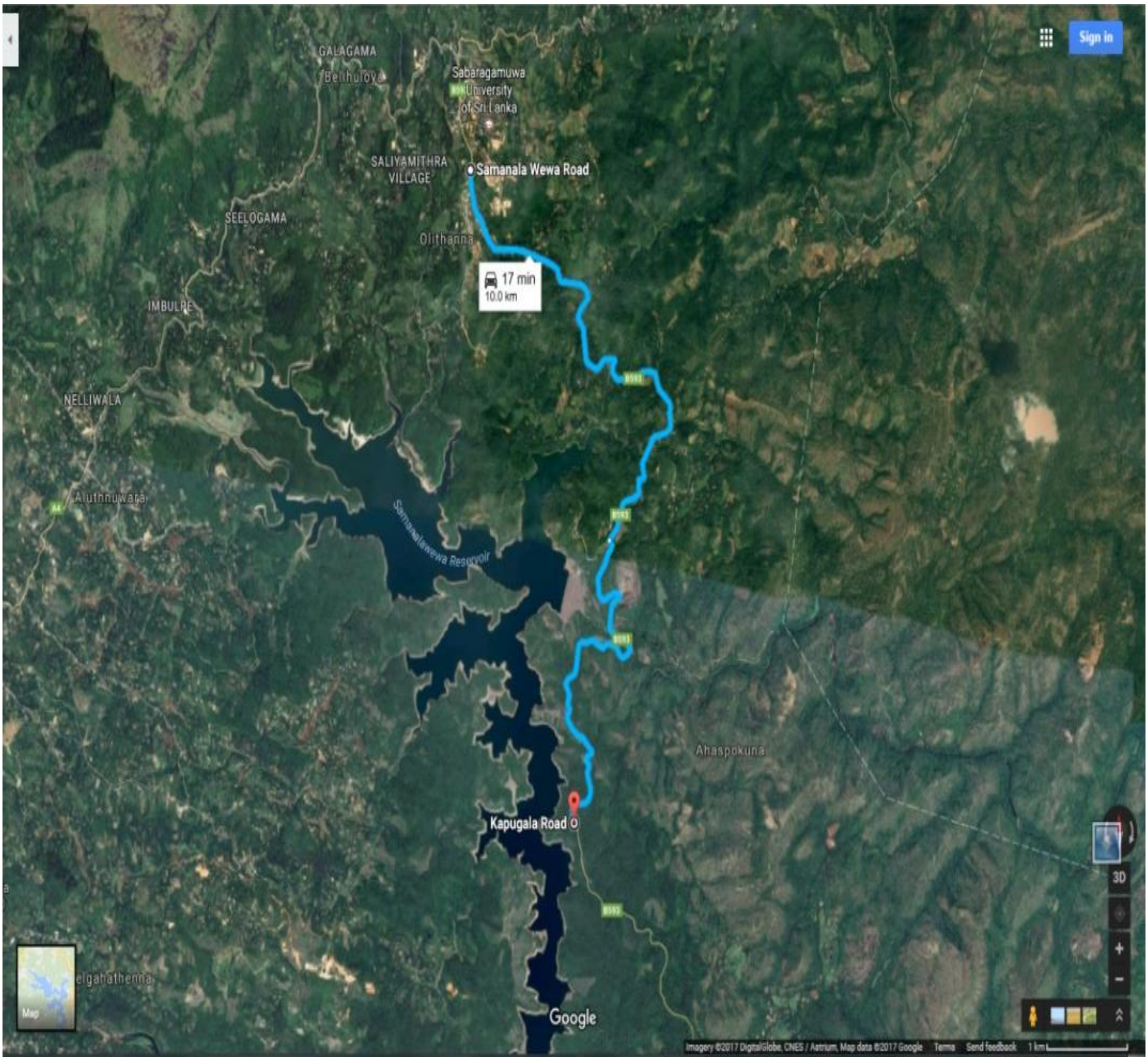


Figure **Error! No text of specified style in document.**.7 : Study Area

The study area was chosen along Pambahinna-Rajawaka road (B593). This road is situated within Imbulpe Divisional Secretariat, Ratnapura District, Sabaragamuwa Province. The road was exclusively designed for the Samanalawewa Reservoir project. For this study, the section between 1km post and 9km post of the road was selected. The beginning point is closer to university and the route is not congested by vehicular traffic except in the area adjacent to University and Pambahinna junction. This route consists of both relatively flat areas and undulated areas with many horizontal and vertical bends. Similar climatic conditions exists along the entire study area.

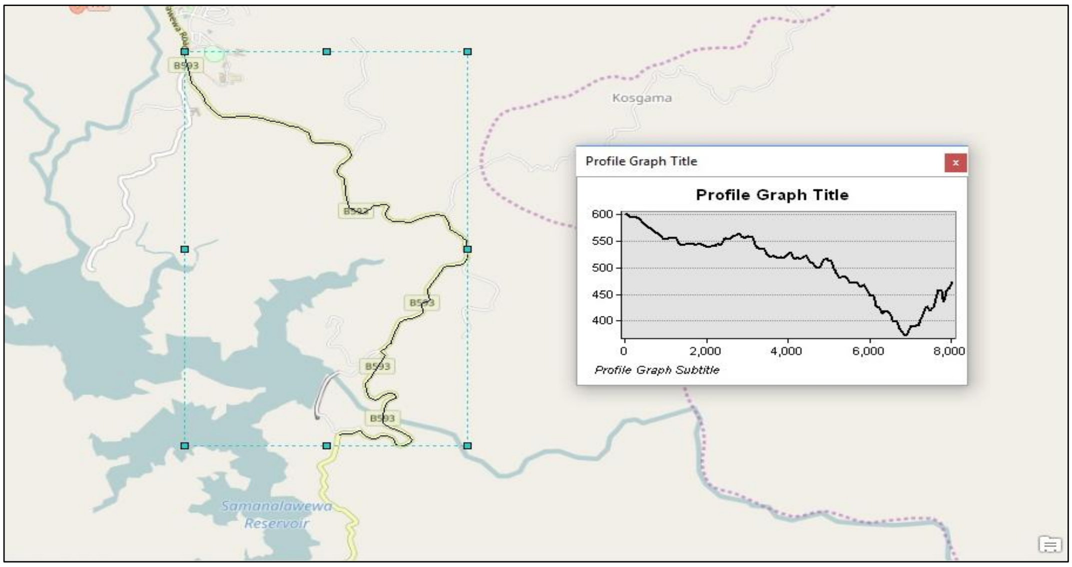


Figure **Error! No text of specified style in document.**.8 : Elevation Profile

In the first two kilometers of study route, the road is relatively flat and long straight sections can be found there. In the next three kilometers road becomes undulated with many horizontal and vertical bends. This area moderately slopes downwards. In the next two kilometers, road extremely slopes downwards and consists of sharp bends. The final kilometer climbs a hill with sharp bends again. There are huge gradients in the final three kilometers of the route.

Instruments Used

- Auto Level (L-48)
- Total Station (530R)

Permanent Bench Marks

Monuments were established near kilometre posts along the selected path under study to be used as permanent benchmarks of the level line. These were made up of concrete and provided by Faculty of Geomatics. They were established in places where stable ground conditions were available and far enough from road as they would be protected from vehicle movement.

Figure **Error! No text of specified style in document.**.9 : Permanent Bench Marks

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IX September 2025

Temporary Benchmarks

Temporary benchmarks were established within short durations where the job was of temporary in nature. The procedure involved establishment of temporary benchmarks which were made from wood. The nail in wood was used in each temporary bench mark.

Figure **Error! No text of specified style in document.**.10 : Temporary Benchmark

Field Procedure

First, permanent benchmarks were established in suitable places near kilometre posts. These benchmarks were monuments made up of concrete. They were provided by the Faculty of Geomatics. In the starting point, a benchmark established by Faculty of Geomatics was already available. Then a level line was started from that point to measure the heights of newly established benchmarks. Auto level was used for that along with other necessary equipment.

While running the level line, temporary benchmarks were established between permanent benchmarks in regular distances apart such as 500m, 250m and 100m.

Details of the Level Line

Table **Error! No text of specified style in document.**.2 : Details of the Level Line

Section	Description
1st kilometre	1 TBM; 500m distance apart
2nd kilometre	3 TBMs; 250m distance apart
3rd kilometre	9 TBMs; 100m distance apart
4th kilometre	1 TBM; 500m distance apart
5th kilometre	1 TBM; 500m distance apart
6th kilometre	1 TBM; 500m distance apart
7th kilometre	3 TBMs; 250m distance apart
8th kilometre	9 TBMs; 100m distance apart

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IX September 2025

Checking Collimation Error

Prior to establish the level line, an experiment was carried out to check the collimation error of the auto level which was to be used for the establishment of level line along the selected path.

First a suitable flat land was selected for the task. A 20m straight line was marked on the ground. Then the two corner points and the midpoint was marked clearly on that line. Two level plates were placed on the corner points. The level instrument was set on the midpoint and staffs were held on corner points and staff readings of corner points were taken.

Then a point is marked 4m distant towards one corner and instrument was shifted there. The staff readings were taken for that point. Again, the instrument was shifted towards the opposite side 4m from midpoint. The staff readings were taken for that point also.

The height differences were similar for the above three instances. Therefore, error of collimation was negligible in following tasks.

Table **Error! No text of specified style in document.**.3 : Collimation Error Measurements

	Mid-point	Move 4m towards back sight	Move 4m towards fore sight
Back sight	1.335	1.315	1.284
Fore sight	1.390	1.370	1.339
Difference	0.055	0.055	0.055

Automatic Levelling

The level line was started from BM 01 established by Faculty of Geomatics near 1km post using Auto Level. The arbitrary height was defined as 500m for BM1. Then the level line was continued until BM 09 near 9km post. On the way, TBMs were established between permanent benchmarks while recording heights of all BMs and TBMs. Three level plates were used while carrying out the level line.

After reaching BM 09, the flyback levelling was started there and continued towards BM 01. On the way, the heights were recorded for all the BMs and TBMs. The heights of the BMs and TBMs were set after the flyback of level line when it was assured that the error of misclosure is within allowable limit.

Checking Collimation Error for Total Station

This was conducted in the faculty premises. First a cross symbol was marked on a wall. Then the mark was observed in face left and the angle was recorded. Again, that mark was observed using face right. The both angles were nearly equal to 180 degrees. Therefore, collimation error was neglected for further activities.

Total Station Levelling

The starting point of level line was BM 01 established by Faculty of Geomatics. First the Total Station was setup on BM1 and it was oriented to arbitrary north. Then the horizontal coordinates were set as (1000,1000) and vertical coordinate as (500). Here, the instrument height was measured manually by tape and entered to Total Station. The target pole was kept on a cement picket (CP 01) on a nearby point. Bipods were used to keep target pole vertically. Target pole was a graduated one and height was set to 1.5m. The target height was entered in Total Station. Then an observation was taken and recorded.

Then the Total Station was taken to CP 01 and Target Pole was kept on BM1. Here the instrument height is not measured manually. Another observation was taken on target on BM 01 (back sight).

Then the vertical distance is displayed on the screen. This vertical distance was used in following formula to calculate Total Station instrument height. This was manually entered as the instrument height on CP 01.

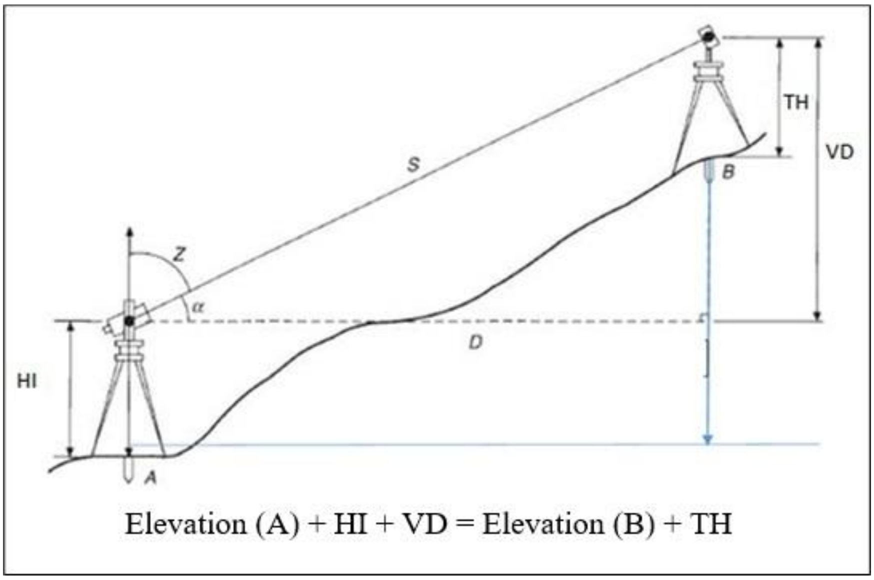


Figure **Error! No text of specified style in document.**.11 : Calculating the Instrument Height

Then CP 02 was established in a visible distance from CP 01. Target is kept over CP 02 and observation was taken and recorded. This procedure was continued until the level line came to BM 02. On the way, heights of temporary benchmarks were recorded.

Later, the same first kilometer was levelled again by changing the target height to 1.4m and 1.6m. For other 1km long sections, Total Station levelling was performed separately setting the target height as 1.5m. The Total Station levelling was carried out only for first three kilometers and final two kilometers. Because, those sections were sufficient to cover various topographical conditions that are considered in this study.

Data Processing

Using Microsoft Excel the difference in elevation was determined by the formula shown below.

Difference in Elevation (ΔH) = Foresight (FS) - Backsight (BS).

The difference in elevation was used to calculate the height of a point along the levelling route. The reduced level of the permanent benchmark and temporary benchmark was calculated and filled the table. It is shown in the next chapter.

The data from total station levelling was used to create various tables and graphs that indicate error and error variation using Microsoft word and Microsoft excel respectively for further analysis.

RESULTS, ANALYSIS AND DISCUSSION

Results and Analysis

First, the measurements from Auto Level were used to calculate the reduced levels of all the BMs and TBMs. They were recorded in tables using MS Excel.

Table **Error! No text of specified style in document.**.4 : Reduced Levels of BMs and TBMs

Station	Distance from starting point (Km)	Height(m)
BM 01	0	500
TBM 01	0.5	481.743
BM 02	1	452.987

TBM 02	1.25	449.168
TBM 03	1.5	438.535
TBM 04	1.75	437.26
BM 03	2	435.925
TBM 05	2.1	431.756
TBM 06	2.2	436.074
TBM 07	2.3	444.72
TBM 08	2.4	449.288
TBM 09	2.5	456.913
TBM 10	2.6	466.229
TBM 11	2.7	468.158
TBM 12	2.8	462.294
TBM 13	2.9	452.906
BM 04	3	449.266
TBM 14	3.5	423.335
BM 05	4	417.758
TBM 15	4.5	412.055
BM 06	5	405.038
TBM 16	5.5	370.251
BM 07	6	347.59
TBM 17	6.25	326.679
TBM 18	6.5	305.829
TBM 19	6.75	279.095
BM 08	7	278.22
TBM 20	7.1	286.348
TBM 21	7.2	293.956
TBM 22	7.3	302.925
TBM 23	7.4	310.005
TBM 24	7.5	317.017
TBM 25	7.6	323.796
TBM 26	7.7	332.615
TBM 27	7.8	343.59
TBM 28	7.9	356.559
BM 09	8	367.749

Table **Error! No text of specified style in document.**.5 : Summary of Misclosures for Selected Segments

Segment (With Flyback)	Length (km)	Allowable Misclosure (mm)	Observed Misclosure (mm)	Remarks
BM 01 – BM 02	2km	24	6	Observed misclosure is acceptable
BM 02 – BM 03	2km	24	1	Observed misclosure is Acceptable
BM 03 – BM 04	2km	24	9	Observed misclosure is Acceptable
BM 07 – BM 08	2km	24	16	Observed misclosure is Acceptable
BM 08 – BM 09	2km	24	4	Observed misclosure is Acceptable

Table **Error! No text of specified style in document.**.6 : Reduced Levels from Total Station

Station	Distance from starting point (km)	Height (m)			
		T.H 1.4	**T.H 1.5**	**T.H 1.5**	**T.H 1.6**
BM 01	0	500	500	500	500
TBM 01	0.5	480.759	480.748	480.756	480.766
BM 02	1	452.026	452.026	452.025	452.028
		TH = 1.5			
TBM 02	1.25	449.158			
TBM 03	1.5	438.528			
TBM 04	1.75	437.293			
BM 03	2	435.935			
TBM 05	2.1	431.761			
TBM 06	2.2	436.082			
TBM 07	2.3	444.734			
TBM 08	2.4	449.301			
TBM 09	2.5	456.925			
TBM 10	2.6	466.232			
TBM 11	2.7	468.146			
TBM 12	2.8	462.287			
TBM 13	2.9	452.896			
BM 04	3	449.262			
BM 07	6	347.59			

TBM 17	6.25	326.692
TBM 18	6.5	305.839
TBM 19	6.75	279.13
BM 08	7	278.277
TBM 20	7.1	286.344
TBM 21	7.2	293.947
TBM 22	7.3	302.915
TBM 23	7.4	310.007
TBM 24	7.5	317.011
TBM 25	7.6	323.778
TBM 26	7.7	332.591
TBM 27	7.8	343.576
TBM 28	7.9	356.541
BM 09	8	367.693

Table **Error! No text of specified style in document.**.7 : Summary of Misclosure for Total Station

Segment	Target height (m)	Length (km)	Allowable Misclosure (mm)	Observed Misclosure (mm)	Remarks
BM 01 – BM 02	1.4	1	24	961	Observed misclosure is not acceptable
	1.5 (Set 01)	1	24	961	Observed misclosure is not acceptable
	1.5 (Set 02)	1	24	962	Observed misclosure is not acceptable
	1.6	1	24	959	Observed misclosure is not acceptable
BM 02 – BM 03	1.5	1	24	10	Observed misclosure is acceptable
BM 03 – BM 04	1.5	1	24	4	Observed misclosure is acceptable
BM 07 – BM 08	1.5	1	24	57	Observed misclosure is not acceptable
BM 08 – BM 09	1.5	1	24	56	Observed misclosure is not acceptable

Following comparisons were made accordingly. Variation of error along with target height and distance of level line are also shown where appropriate;

Segment 01 for Total Station

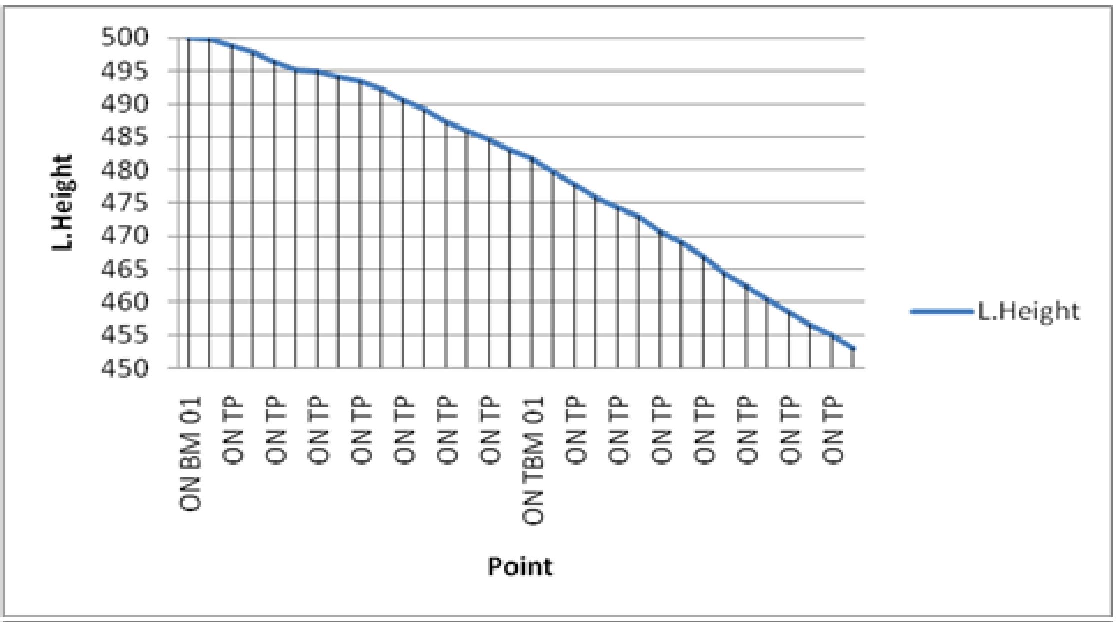
It has one temporary benchmark and two Permanent benchmarks named BM1 and BM2 with a separation distance of one kilometer.

Segment 01 – Set 01 – BM 01 to BM 02

- Instrument – Total station (530R) and auto level (L-48)
- Target height – 1.4m

Table **Error! No text of specified style in document.**.8 : Segment 01 – Set 01 – Reduced Level and Reduced Level Difference

Station	Height (m)		Difference (m)
	Auto Level	Total Station (T.H 1.4m)	
BM 01	500	500	0
TBM 01	481.743	480.759	0.984
BM 02	452.987	452.026	0.961



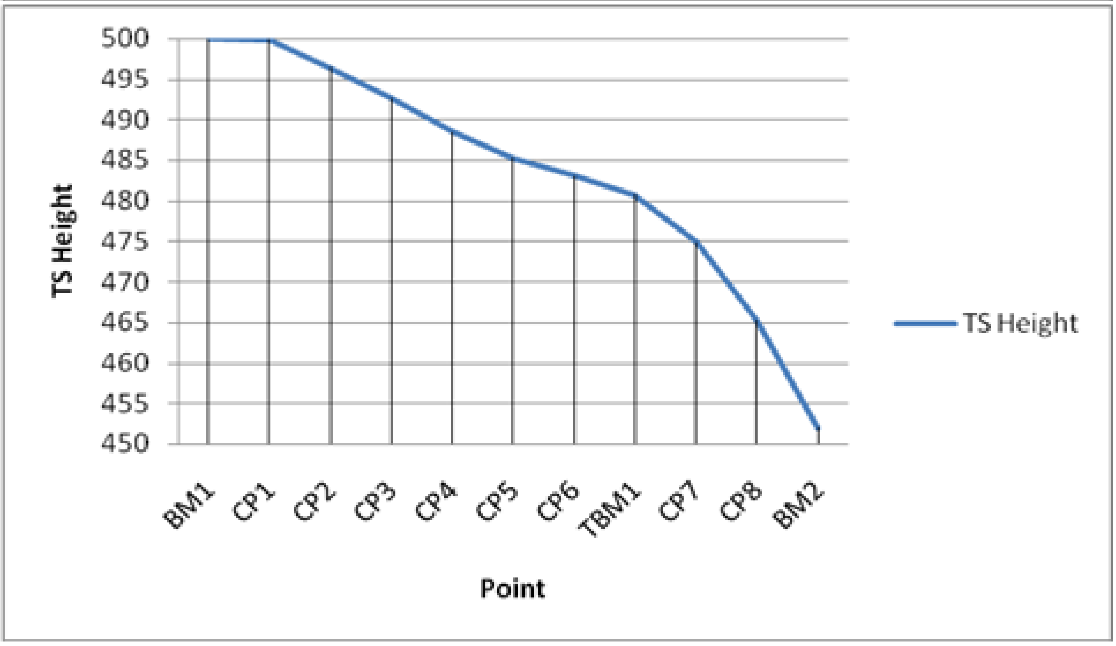


Figure **Error! No text of specified style in document.**.12 : Auto Level and TS Elevation Profile in Segment 1 – Set 1

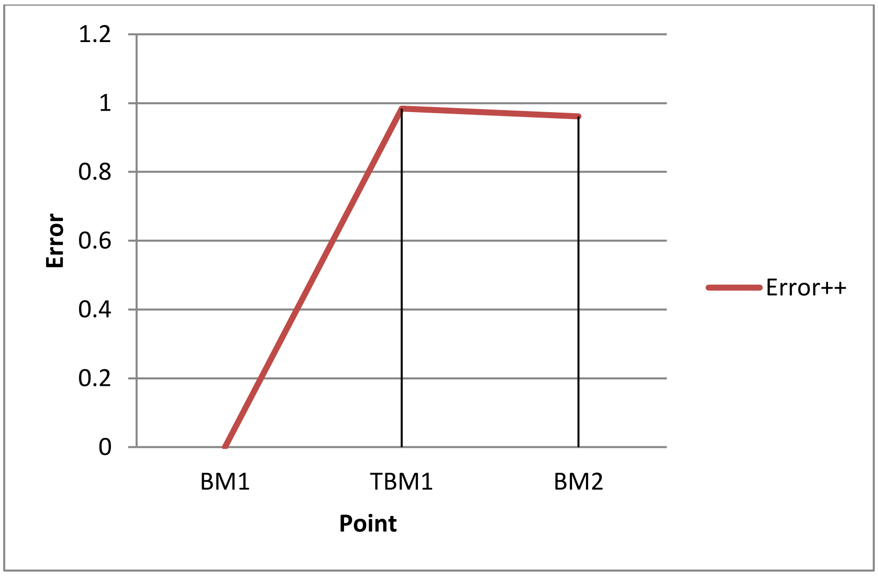


Figure **Error! No text of specified style in document.**.13 : Error Variation in Segment 1 - Set 1

Segment 01 – Set 02 – BM 01 to BM 02

- Instrument – Total station (530R) and auto level (L-48)
- Target height – 1.5m

Table **Error! No text of specified style in document.**.9 : Segment 01 – Set 02 – Reduced Level and Reduced Level Different

Station	Height (m)		Difference (m)
	Auto Level	Total Station (T.H 1.5m)	
BM 01	500	500	0
TBM 01	481.743	480.748	0.995
BM 02	452.987	452.026	0.961

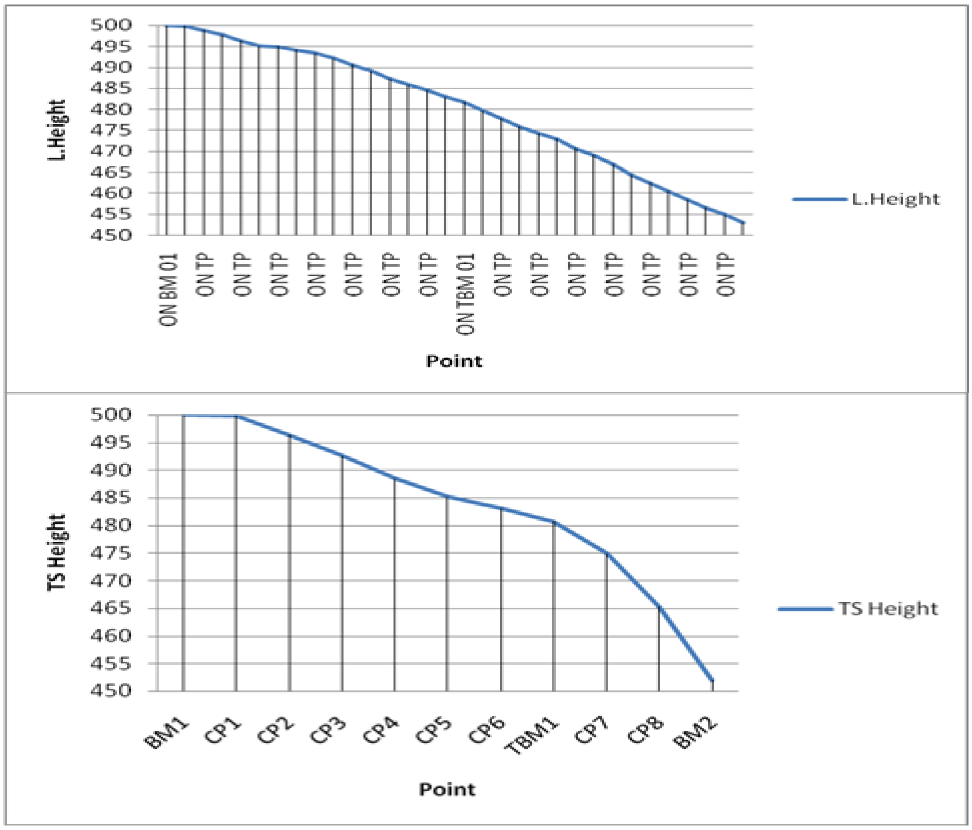


Figure **Error! No text of specified style in document.**.14 : Auto Level and TS Elevation Profile in Segment 1 - Set 2

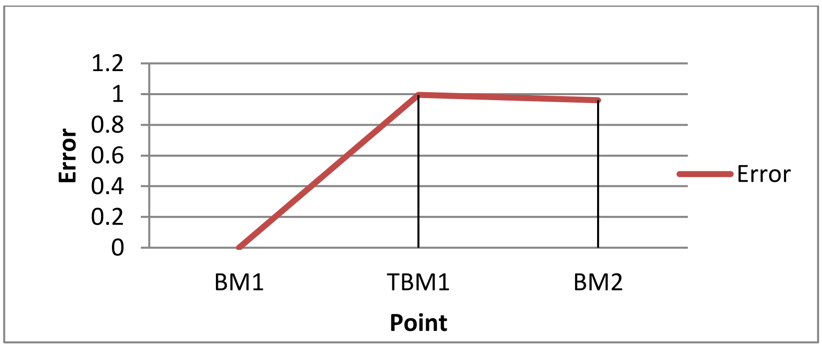


Figure **Error! No text of specified style in document.**.15 : Error Variation in Segment 1 - Set 2

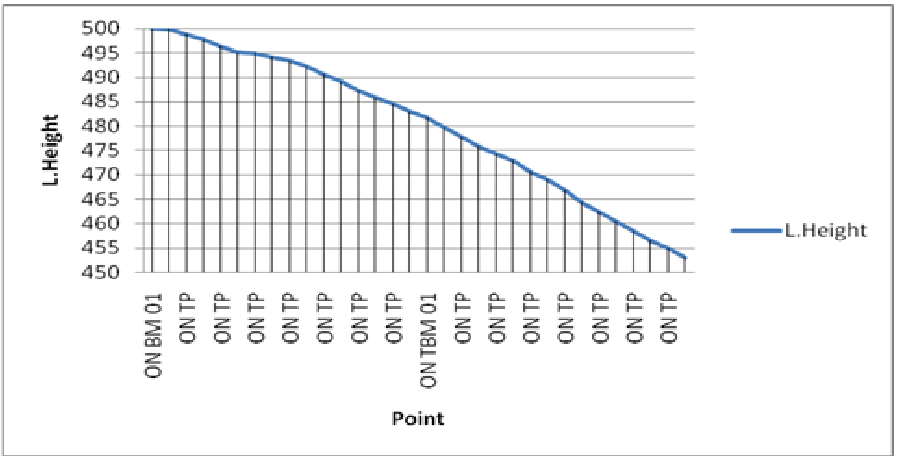
Segment 01 – Set 03 – BM 01 to BM 02

- Instrument – Total station (530R) and auto level (L-48)

- Target height – 1.5m

Table **Error! No text of specified style in document.**.10 : Segment 01 – Set 03 – Reduced Level and Reduced Level Difference

Station	Height (m)		Difference (m)
	Auto Level	Total Station (T.H 1.5m)	
BM 01	500	500	0
TBM 01	481.743	480.756	0.987
BM 02	452.987	452.025	0.962



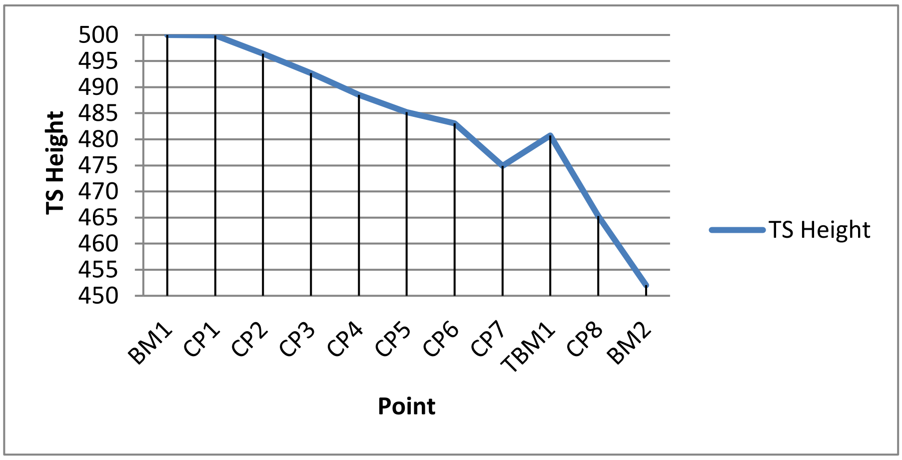


Figure **Error! No text of specified style in document.**.16 : Auto Level and TS Elevation Profile in Segment 1 – Set 3

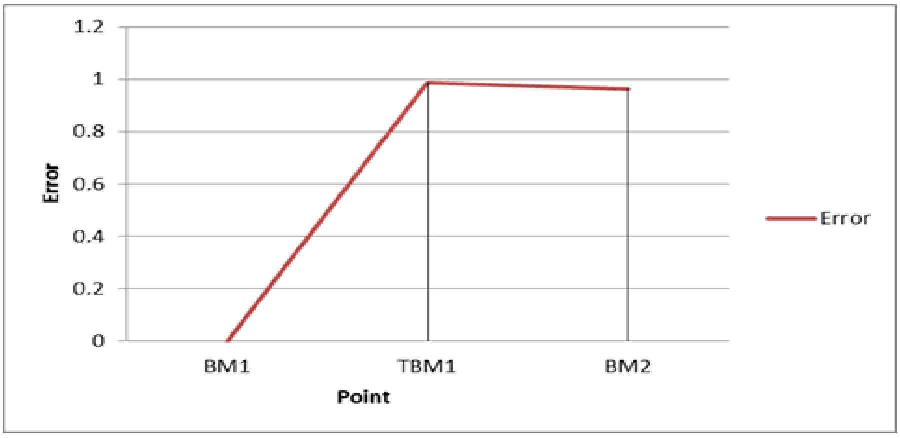


Figure **Error! No text of specified style in document.**.17 : Error Variation in Segment 1 - Set 3

Segment 01 – Set 04 – BM 01 to BM 02

- Instrument – Total station (530R) and auto level (L-48)
- Target height – 1.6m

Table **Error! No text of specified style in document.**.11 : Segment 01 – Set 04 – Reduced Level and Reduced Level Difference

Station	Height (m)		Difference (m)
	Auto level	Total station (T.H 1.6m)	
BM 01	500	500	0
TBM 01	481.743	480.766	0.977
BM 02	452.987	452.028	0.959

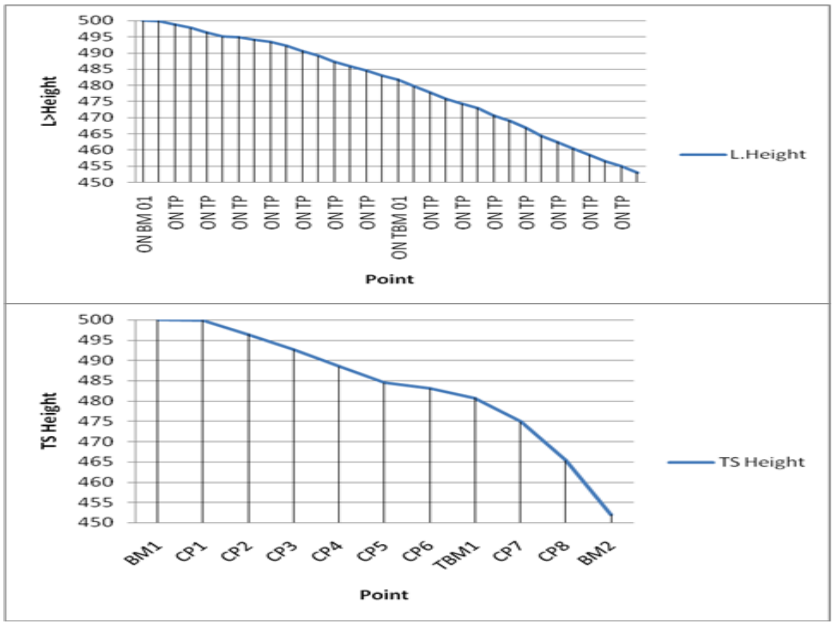


Figure **Error! No text of specified style in document.**.18 : Auto Level and TS Elevation Profile in Segment 1 – Set 4

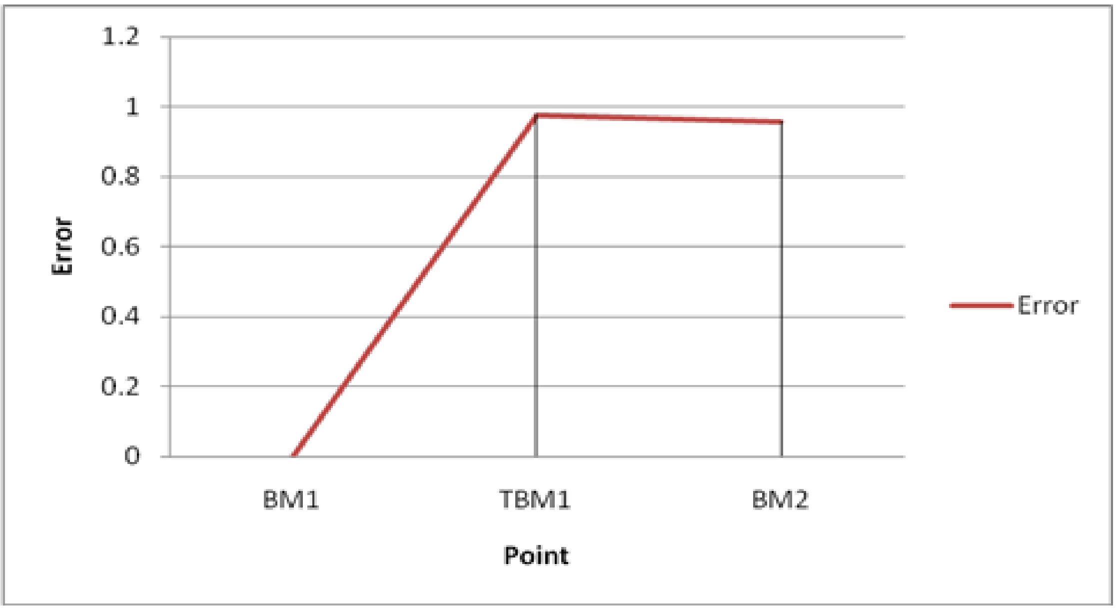


Figure **Error! No text of specified style in document.**.19 : Error Variation in Segment 1 - Set 4

In the first segment, direction and gradient of the slope is relatively uniform. Total Station levelling was conducted twice for this segment using same target height; one in morning and the other one in evening (Tables 4.6 and 4.7). The results were similar for both tasks.

First segment was levelled using Total Station three times for different target heights; 1.4m, 1.5m and 1.6m. The results were similar for all these target heights as shown in tables above (Table 4.5, 4.6, 4.7 and 4.8).

Only one TBM was set in the midpoint of the segment at 500m distance from starting point. Very large horizontal distances were set between instrument and target while levelling this segment using Total Station as good inter-visibility was available for such long distances. And it was helpful to carry out the task rapidly. Some distances were longer than 100m. The error of Total Station levelling was very much larger than the acceptable error (Table 4.2).

1.1.2 Segment 02 for Total Station

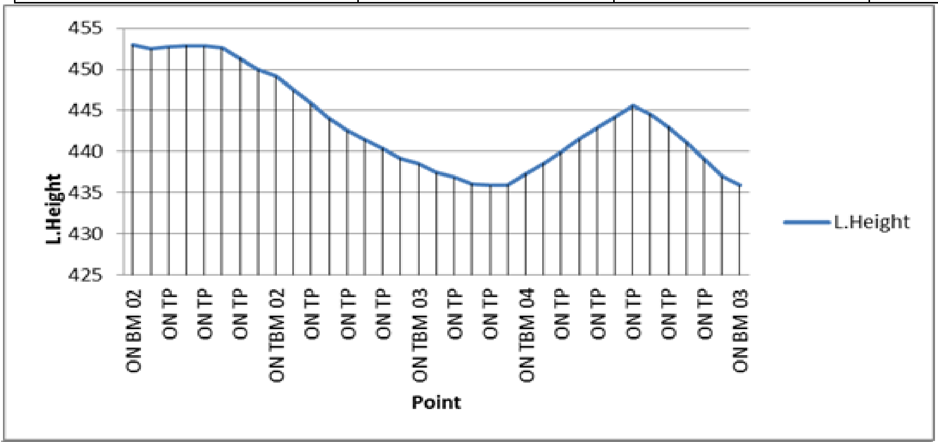
It has three temporary benchmark and two Permanent benchmarks named BM 02 and BM 03 with a separation distance of one kilometer.

Segment 02 – BM 02 to BM 03

- Instrument – Total station (530R) and auto level (L-48)
- Target height – 1.5m

Table **Error! No text of specified style in document.**.12 : Segment 02 – Reduced Level and Reduced Level Difference

Station	Height (m)		Difference (m)
	Auto Level	Total Station	
BM 02	452.987	452.987	0
TBM 02	449.168	449.158	0.01
TBM 03	438.535	438.528	0.007
TBM 04	437.26	437.293	-0.033
BM 03	435.925	435.935	-0.01



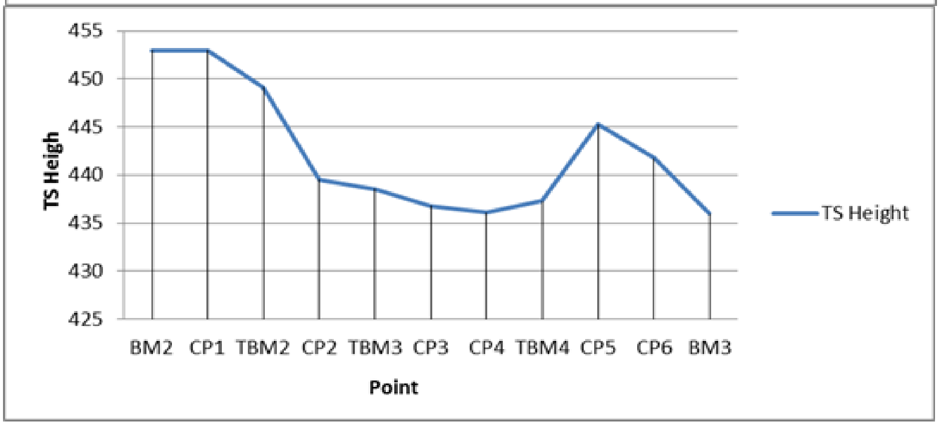


Figure **Error! No text of specified style in document.**.20 : Auto Level and TS Elevation Profile in Segment 2

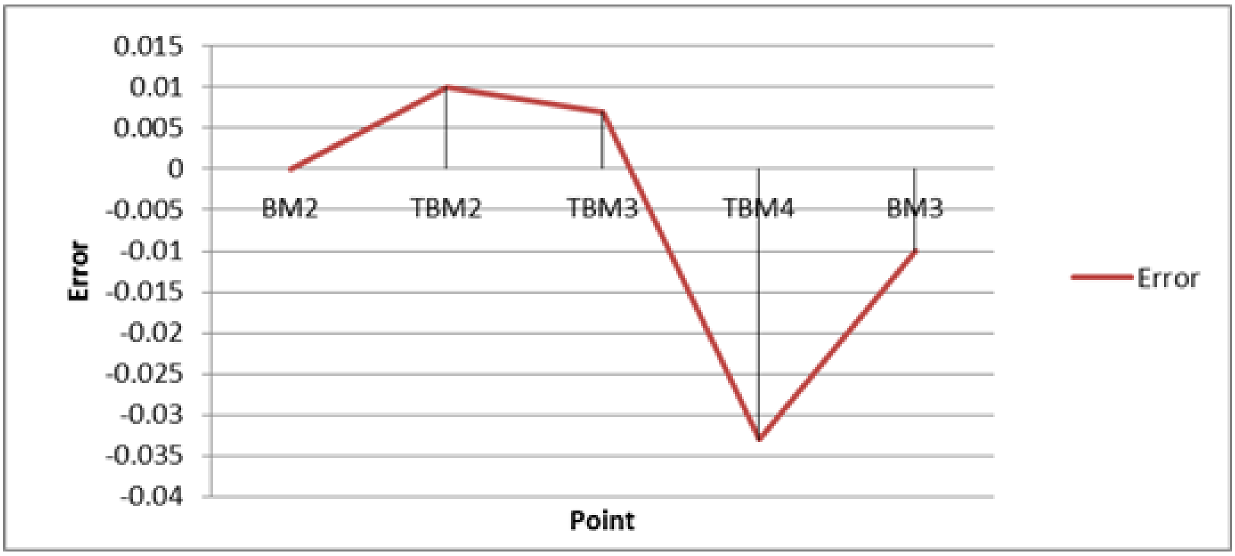


Figure **Error! No text of specified style in document.**.21 : Error Variation in Segment 2

The slope of this segment was varying in a wider range compared with segment one as shown in Figure 4.9. TBMs were set in 250m distances apart in this segment. Though the error was within acceptable range for the entire segment, error was not acceptable for TBM 04 and it was larger than the acceptable error for entire segment (Table 4.9). TBM 04 was located at the bottom of a slope and the elevation is increasing towards BM 04 from that point.

Segment 03 for Total Station

Segment 03 – BM 03 to BM 04

- Instrument – Total station (530R) and auto level (L-48)
- Target height – 1.5m

Table **Error! No text of specified style in document.**.13 : Segment 03 – Reduced Level and Reduced Level Difference

Station	Height (m)		Difference (m)
	Auto Level	Total Station	
BM 03	435.925	435.925	0
TBM 05	431.756	431.761	-0.005
TBM 06	436.074	436.082	-0.008
TBM 07	444.72	444.734	-0.014
TBM 08	449.288	449.301	-0.013
TBM 09	456.913	456.925	-0.012
TBM 10	466.229	466.232	-0.003
TBM 11	468.158	468.146	0.012
TBM 12	462.294	462.287	0.007
TBM 13	452.906	452.896	0.01
BM 04	449.266	449.262	0.004

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XII Issue IX September 2025

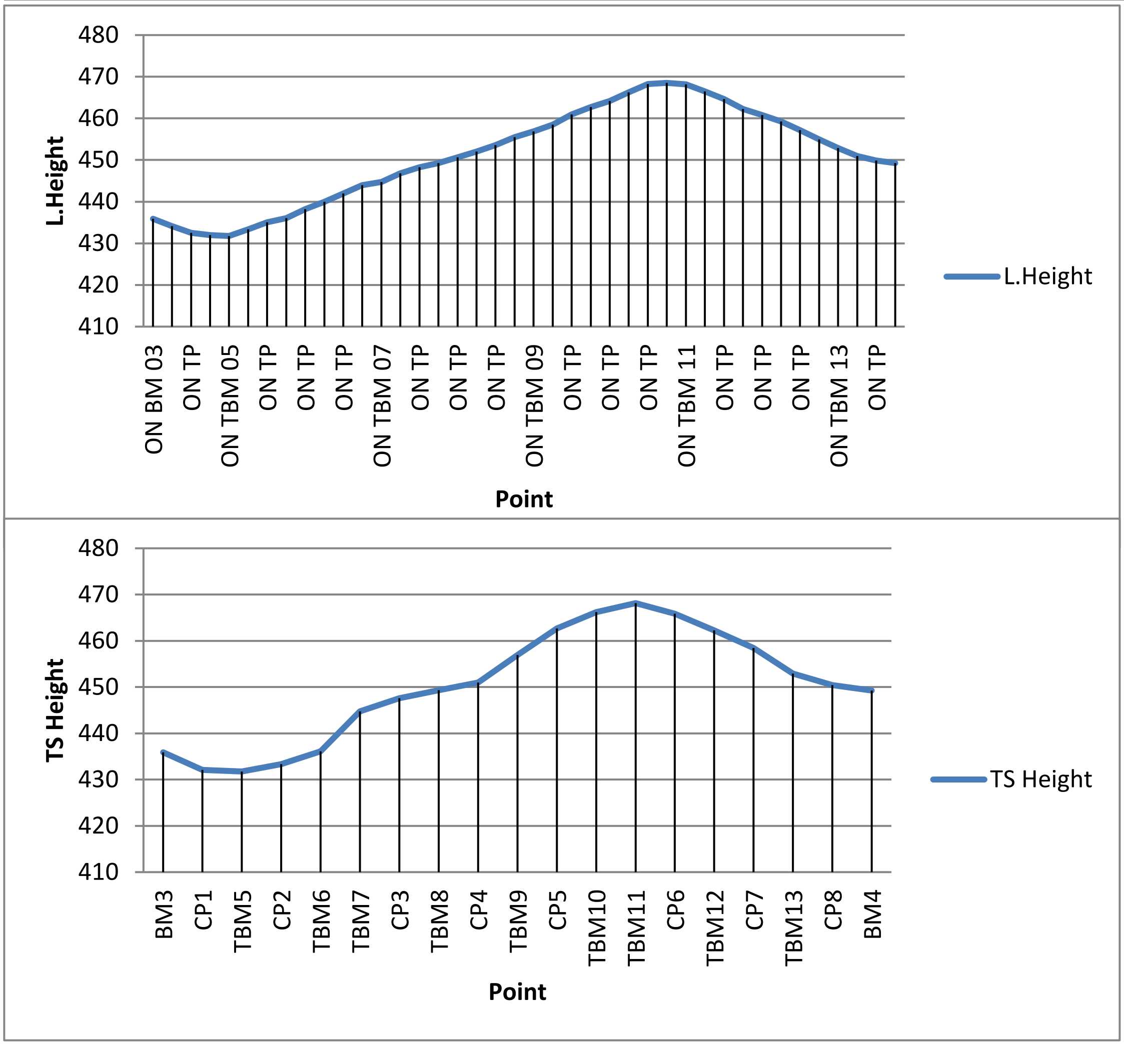


Figure **Error! No text of specified style in document.**.22 : Auto Level and TS Elevation Profile in Segment 3

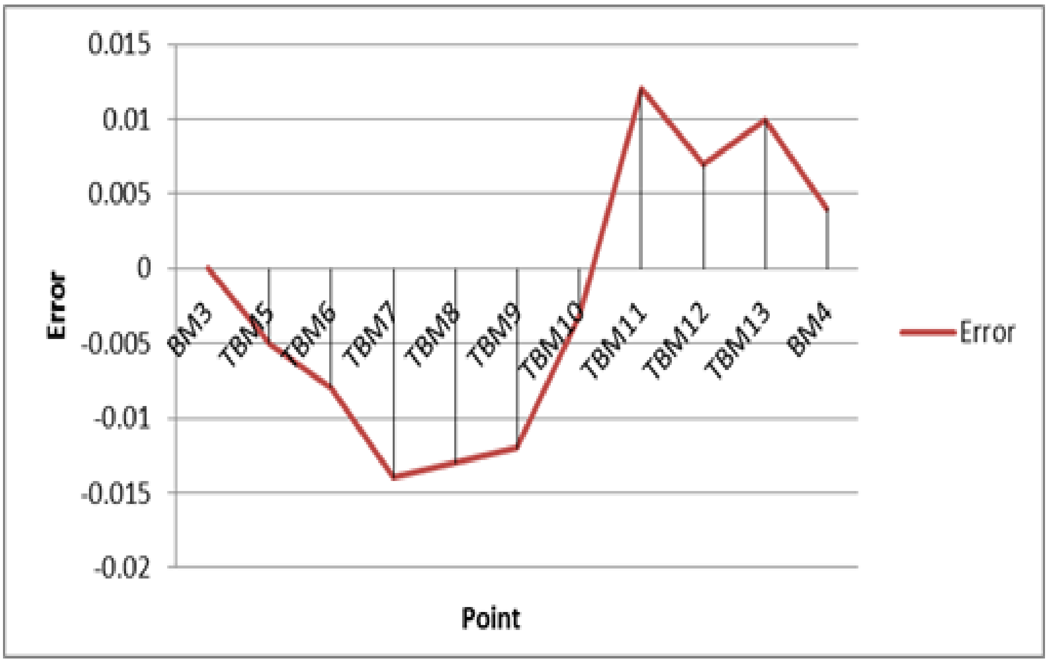


Figure **Error! No text of specified style in document.**.23 : Error Variation in Segment 3

TBMs were set in 100m distances apart in this segment. Therefore, distance between instrument and target was less than 100m in every instance. This segment consists a hill with slope rising and falling in a fairly constant gradient.

Error is acceptable for entire segment and for every TBM except for certain TBMs (Table 4.10). Error variation is different by place to place as indicated in Figure 4.12.

1.1.3 Segment 04 for Total Station

It has three temporary benchmark and two Permanent benchmarks named BM7 and BM8 with a separation distance of one kilometer.

Segment 04 – BM 07 to BM 08

- Instrument – Total station (530R) and auto level (L-48)
- Target height – 1.5m

Table **Error! No text of specified style in document.**.14 : Segment 04 – Reduced Level and Reduced Level Different

Station	Height (m)		Difference
	Auto Level	Total Station	(m)
BM 07	347.59	347.59	0
TBM 17	326.679	326.692	-0.013
TBM 18	305.829	305.839	-0.01
TBM 19	279.095	279.13	-0.035
BM 08	278.22	278.277	-0.057

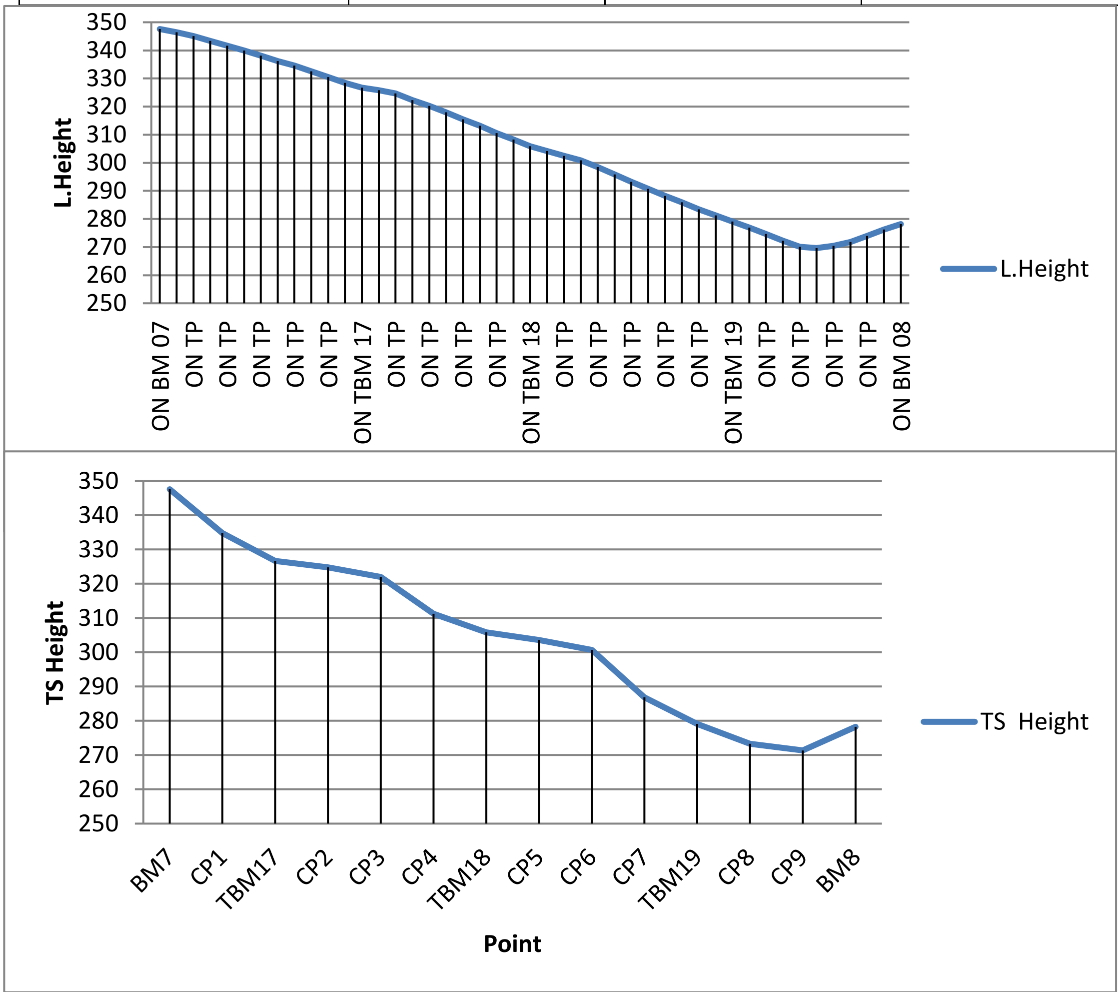


Figure **Error! No text of specified style in document.**.24 : Auto Level and TS Elevation Profile in Segment 4

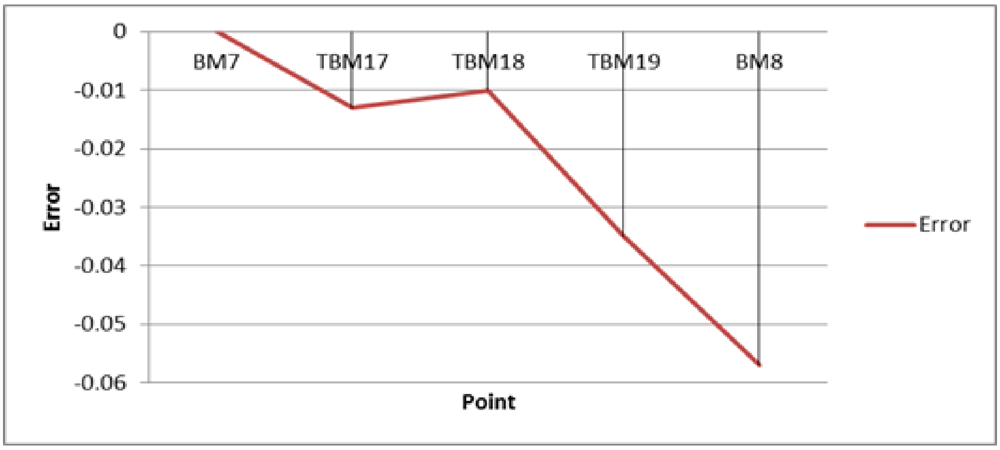


Figure **Error! No text of specified style in document.**.25 : Error Variation in Segment 4

TBMs were set in 250m distances. This segment consists a slope downwards with a huge gradient except in final part and several sharp bends. Error was not acceptable for the whole segment (Table 4.11). All errors were in minus side (Figure 4.14).

Segment 05 for Total station

It has nine temporary benchmark and two permanent benchmarks named BM8 and BM9 with a separation distance of one kilometer.

Segment 05 – BM 08 to BM 09

- Instrument – Total station (530R) and auto level (L-48)
- Target height – 1.5m

Table **Error! No text of specified style in document.**.15 : Segment 05 – Reduced Level and Reduced Level Difference

Station	Height (m)		Difference (m)
	Auto Level	Total Station	
BM 08	278.22	278.22	0
TBM 20	286.348	286.344	0.004
TBM 21	293.956	293.947	0.009
TBM 22	302.925	302.915	0.01
TBM 23	310.005	310.007	-0.002
TBM 24	317.017	317.011	0.006
TBM 25	323.796	323.778	0.018
TBM 26	332.615	332.591	0.024
TBM 27	343.59	343.576	0.014
TBM 28	356.559	356.541	0.018
BM 09	367.749	367.693	0.056

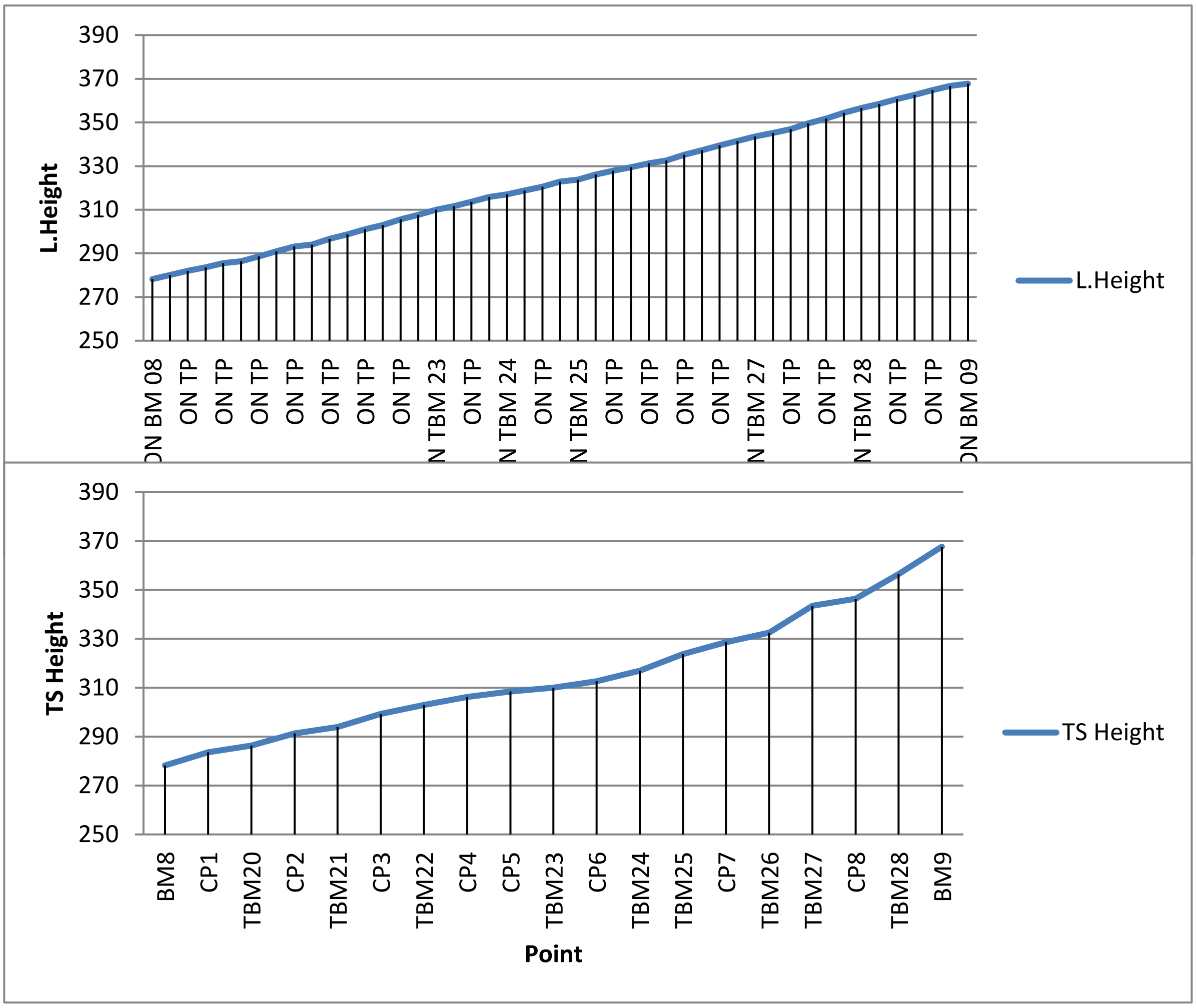


Figure **Error! No text of specified style in document.**.26 : Auto Level and TS Elevation Profile in Segment 5

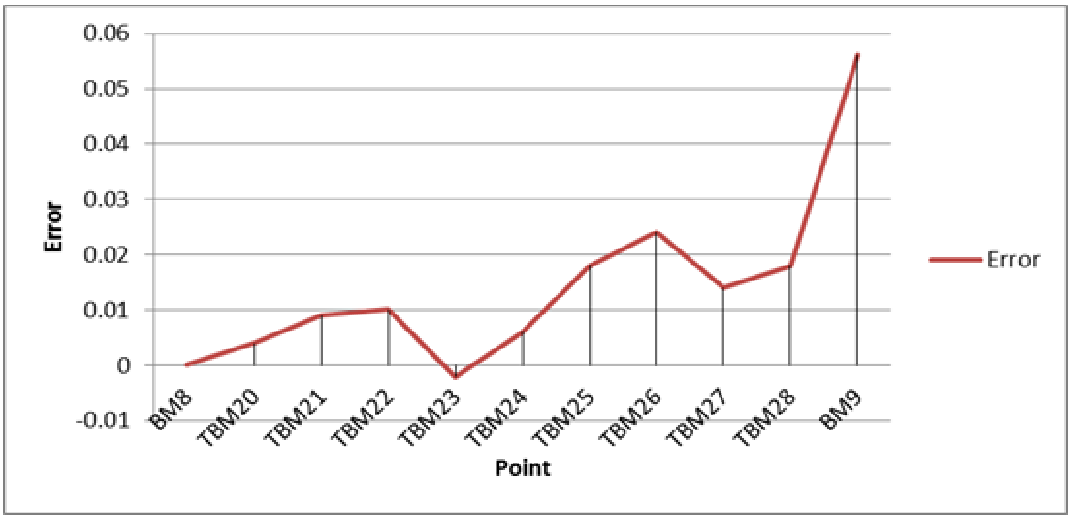


Figure **Error! No text of specified style in document.**.27 : Error Variation in Segment 5

TBMs were set in 100m distances apart and the segment rises upwards towards BM 09. The gradient of slope was very high (Figure 4.15). This segment also consists of sharp bends. Therefore, distance between instrument and target was always less than 100m. Error exceeds acceptable limit in this segment also (Table 4.12) and all are in plus side (Figure 4.16).

CONCLUSION AND RECOMMENDATIONS

Conclusion

There were no much considerable effects to the error from weather in this study as total station levelling was conducted twice in different parts of the day for same target height and same segment and similar results were obtained. The effect of climate is uncertain in this study as this was carried out along a level line that passes areas with similar climatic conditions.

Also, the readings were similar for three different target heights for same segment. Therefore, it can be assumed that target height does not do much effect to error in total station levelling. It is remarkable that error generation is high when the distance between instrument and target is longer. The first segment is an example for that.

According to the results in 4th and 5th segments, error generation is high when the slope is high. Therefore, it can be assumed that error in total station levelling has some relation with slope. Error was almost positive when the elevation rises along a hill and negative when elevation decreases along a slope. Error of misclosure was acceptable in segments where the gradient of slope is low and shorter distances were set between instrument and targets.

Recommendations

A good analysis can be done regarding error variation when the number of TBMs is high. Therefore, the density of TBMs should be increased in order to find a better relation of error with relevant error factors in total station levelling. Total station levelling cannot be recommended for water supply and drainage projects where high accuracy and precision is required because error variation is different from place to place.

LIST OF REFERENCES

1. COMET. (2015, March 31). *Online Course - Understanding Heights and Vertical Datums*. Retrieved from Comet - MetEd Education and Training: https://learn.meted.ucar.edu/#/online-course-player/981233d9-353e-4709-9bbf-93f2bc7e0e8e
2. Geofrey, J. (n.d.). *Comparison Between Digital Levelling and Total Station Levelling.* Academia.edu.
3. Lee, J., & Rho, T. (2001). Application to Leveling Using Total Station. In New Technology for a New Century International Conference FIG Working Week 2001. : . *New Technology for a New Century International Conference FIG Working Week 2001.* Seoul, Korea: FIG Conference Proceedings.
4. Mishra, G. (2017). *Error Sources in Total Station in Surveying.* Retrieved from The Constructor: https://theconstructor.org/surveying/error-sources-in-total-station/6052/
5. NOAA. (2016). Retrieved from National Geodetic Survey: https://www.ngs.noaa.gov/datums/
6. Punmia, B. (2015, August). *Levelling.* Retrieved from Civil Blog: https://www.civilblog.com/levelling/
7. Tandon, G. H. (2013, October 6). Levelling. Slideshare.