University of Southern Queensland

School of Surveying & Built Environment

Total Station Differential Levelling Procedure

V2.2 2023

University of Southern Queensland

Document History

Date	Version	Issue	Amendments	Author(s)
21/04/2023	1	0	Document Created	JAW/DLF
04/07/2023	2	0	Documented Redrafted	JAW/DLF
05/07/2023	2	1	Methodology Updated	JAW/DLF
15/09/2023	2	2	Introduction & calculations added	CMcA

Contents

1. Introduction

This document has been prepared to provide a practical explanation and example of differential levelling using a Total Station and a fixed height pole, as outlined in the Special Publication 1 v2.2 Guideline for Differential Levelling Section 3.2. The Guideline is available on the ICSM website here.

It was developed by two University of Southern Queensland Students, Jordan Williams and Damian Forknall, as part of their University studies, under the guidance of Department of Resources Geodetic Surveyor, Garry Cislowski, and UniSQ Professional Fellow (Surveying), Chris McAlister.

This document, along with additional resources, can be downloaded from the UniSQ Surveying github:

https://github.com/UniSQ-Surveying/Differential_Levelling

You can also access some short recordings outlining the general process here:

https://usq.au.panopto.com/Panopto/Pages/Sessions/List.aspx?folderID=fc3ac76a-fc84-4682-a7e6-b05b0047797e

Additional information will be added in time, however if you have feedback or comments, please contact Chris McAlister at chris.mcalister@usq.edu.au

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2. Equipment Specifications from SP1 Differential Levelling V2.1.

2.1. "1st Order" Equipment & Observation Requirements

The quality to be achieved is a maximum allowable misclose of $2mm \times \sqrt{k}\ (km)$

Where: k = distance in kilometres

2.1.1. Total Station Levelling Equipment List & Requirements

- Total Station Standard Deviation: Distance ±1mm +1ppm & Zenith Angle 1"
    - Daily calibration of vertical circle & level sensor
- Accuracy of level sensor or compensator: 0.5"
- Atmospherics measurement device accurate to: 1°C, Pressure 1mb, Relative Humidity 2%
- Tripod Type: Rigid
- Fixed height reflector rod with bipod support
    - Staff bubble attached and accurate to 10' verticality
    - Solid fixed height rod (e.g., Stainless Steel)
- Precision prism required
- Heavy duty change plates should be used where needed

2.1.2. Total Station Levelling Observation Requirements

- Pole height is fixed due to solid pole.
- Pole height in controller set to zero for entire process
- Survey specifics:
    - Two (2)-way levelling required for outcomes
    - If using two (2) poles, avoid fixed rod Index errors - Ensure the same rod is used for the first backsight & last foresight
- Atmospherics are recorded and applied at the start and at one (1)-hour intervals or pronounced changes in conditions
- Total station distance: approximately equal to backsight & foresight – measured to 1m
- Minimum number of rounds Face Left & Face Right is five (5)
- Height difference readings to nearest 0.1mm
- Maximum sight length 50m (100m total per setup)
- Minimum Ground Clearance for 1st order is 1m

2.2. "2nd Order" Equipment & Observation Requirements

The quality to be achieved is a maximum allowable misclose of $6mm \times \sqrt{k}\ (km)$

Where: k = distance in kilometres

2.2.1. Total Station Levelling Equipment List & Requirements

- Total Station Standard Deviation: Distance ±2mm +2ppm & Zenith Angle 3"
    - Daily calibration of vertical circle & level sensor
- Accuracy of level sensor or compensator: 1.5"
- Atmospherics measurement device accurate to: 1°C, Pressure 1mb, Relative Humidity 2%
- Tripod Type: Rigid
- Fixed height reflector rod with bipod support
    - Staff bubble attached and accurate to 10' verticality
    - Solid fixed height rod (e.g., Stainless Steel)
- Precision prism required
- Standard change plates should be used where needed

2.2.2. Total Station Levelling Observation Requirements

- Pole height is fixed due to solid pole.
- Pole height in controller set to 0.000m for entire process
- Survey specifics:
    - Two (2)-way levelling required for outcomes
    - If using two (2) poles, avoid fixed rod Index errors - Ensure the same rod is used for the first backsight & last foresight
- Atmospherics are recorded and applied at the start and at one (1)-hour intervals or pronounced changes in conditions
- Total station distance approximately equal to backsight & foresight
- Minimum number of rounds Face Left & Face Right is four (4)
- Height difference readings to nearest 0.5mm
- Maximum sight length 80m (160m total per setup)
- Minimum Ground Clearance for 2nd order is 0.5m

2.3. "3rd Order" Equipment & Observation Requirements

The quality to be achieved is a maximum allowable misclose of $12mm \times \sqrt{k}\ (km)$

Where: k = distance in kilometres

2.3.1. Total Station Levelling Equipment List & Requirements

- Total Station Standard Deviation: Distance ±3mm +2ppm & Zenith Angle 5"
    - Daily calibration of vertical circle & level sensor
- Accuracy of level sensor or compensator: 2.5"
- Atmospherics are not taken into consideration in 3rd order specification
- Tripod Type: Telescopic
- Fixed height reflector rod with bipod support
    - Staff bubble attached and accurate to 10' verticality
    - Fixed height ensured with flat base foot
- General prism required
- Standard change plates should be used where needed

2.3.2. Total Station Levelling Observation Requirements

- Pole Height in field set to consistent height
    - 1.5m was used for the example using Trimble included at the end of this document
- Pole height in controller set to 0.000m for entire process
- Survey specifics:
    - Two (2)-way levelling required for outcomes
    - If using two (2) poles, avoid rod Index errors - Ensure the same rod is used for the first backsight & last foresight
- Atmospherics are not taken into consideration in 3rd order specification
- Total station distance approximately equal to backsight & foresight
- Minimum number of rounds Face Left & Face Right is three (3)
- Height difference readings to nearest 1mm
- Maximum sight length 120m (240m total per setup)
- Minimum Ground Clearance for 3rd order is 0.5m

3. Methodology

These general methodologies are provided as a guide – how each process works for specific brand of equipment, that is the process in which you need to capture data in the controller, will vary. As they are developed, the specifics of each brand will be included as addendums to this document.

3.1. 1st Order Methodology

1. Set up Total Station to ensure a maximum backsight & foresight of 50m, within 1m of each other. Use of a rope with a marker at 50m can assist where it might be impractical to use a long tape.
    a. Height of instrument is not required
    b. Ensure ground clearance is 1m minimum
2. Set height of instrument in controller as zero (0) metres
3. Attach fixed height pole with compliant flat base foot to bipod
4. Set pole height in controller to zero (0) metres
5. Occupy backsight station with pole and bipod - ensure pole is secure & level within the bipod
6. Observe five (5) rounds of Face Left & Face Right to the backsight station
7. Move pole & bipod to the foresight station - ensure pole is secure & level within the bipod
8. Observe five (5) rounds of Face Left & Face Right to the foresight station
9. Move instrument to next set up
10. Repeat steps 1 to 9 until forward run is complete
11. To commence reverse run, do an independent set up of the Total Station and repeat the process for the entire run, until returned to the original benchmark.
12. Reduce observations using an appropriate method, such as:
    a. Traditional Backsight minus Foresight calculation, inverting the solution
    b. A Foresight – Backsight calculation
    c. A spreadsheet or similar established for the specific data format from your instrument

An example set up and observation requirements are shown in Figure 3.1.1.

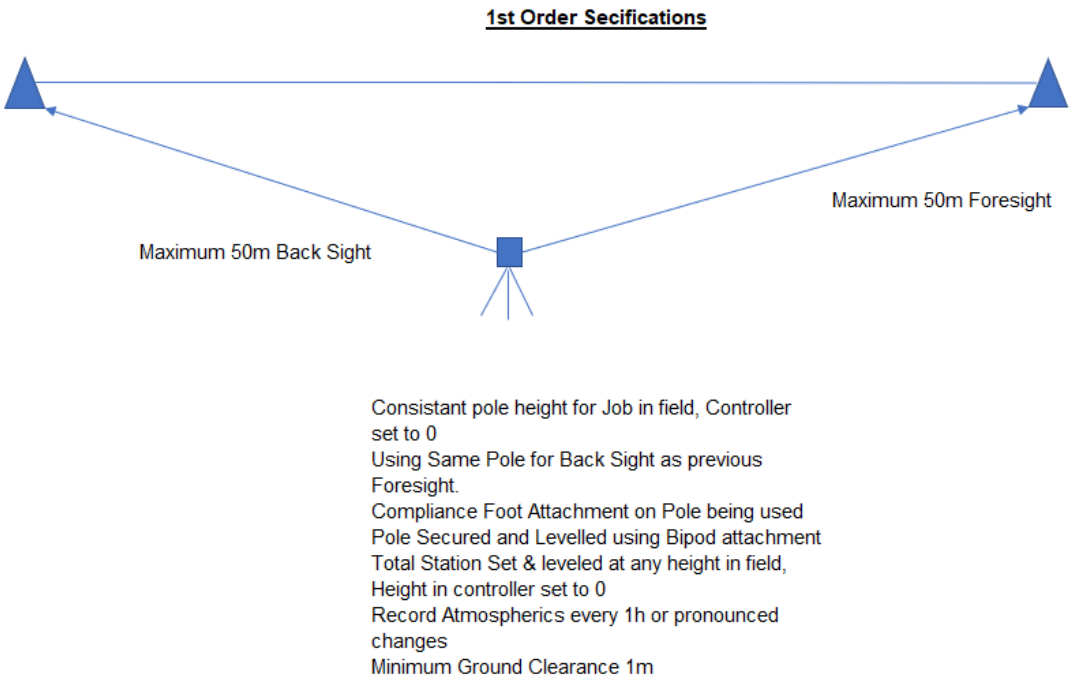


Figure 3.1.1: 1st order levelling observation requirements

3.2. 2nd Order Methodology

1. Set up Total Station to ensure a maximum backsight & foresight of 80m, with the backsight and foresight being approximately equal. Use of a rope with a marker at 80m can assist where it might be impractical to use a long tape.
    a. Height of instrument is not required
    b. Ensure ground clearance is 0.5m minimum
2. Set height of instrument in controller as zero (0) metres
3. Attach fixed height pole with compliant flat base foot to bipod
4. Set pole height in controller to zero (0) metres
5. Occupy backsight station with pole and bipod - ensure pole is secure & level within the bipod
6. Observe four (4) rounds of Face Left & Face Right to the backsight station
7. Move pole & bipod to the foresight station - ensure pole is secure & level within the bipod
8. Observe four (4) rounds of Face Left & Face Right to the foresight station
9. Move instrument to next set up
10. Repeat steps 1 to 9 until forward run is complete
11. To commence reverse run, do an independent set up of the Total Station and repeat the process for the entire run, until returned to the original benchmark.
12. Reduce observations using an appropriate method, such as:
    a. Traditional Backsight minus Foresight calculation, inverting the solution
    b. A Foresight – Backsight calculation
    c. A spreadsheet or similar established for the specific data format from your instrument

An example set up and observation requirements are shown in Figure 3.2.1.

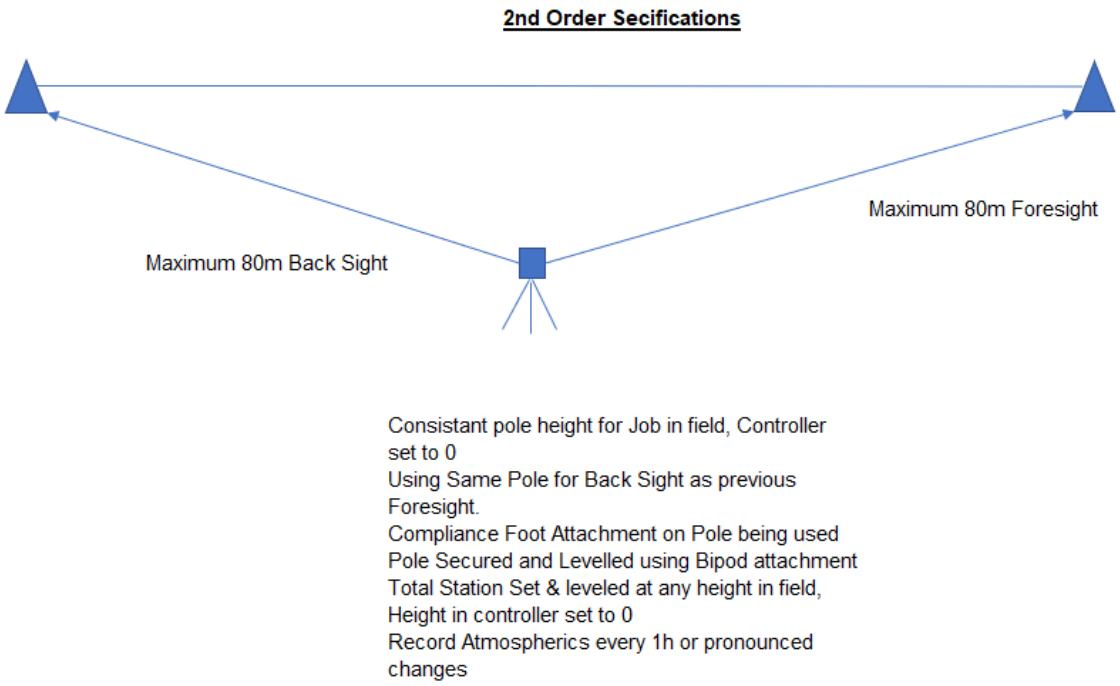


Figure 3.2.1: 2nd order levelling observation requirements

3.3. 3rd Order Methodology

1. Set up Total Station to ensure a maximum backsight & foresight of 120m, with the backsight and foresight being approximately equal. Use of a rope with a marker at 120m can assist where it might be impractical to use a long tape.
    a. Height of instrument is not required
    b. Ensure ground clearance is 0.5m minimum
2. Set height of instrument in controller as zero (0) metres
3. Set the height of the pole to a fixed height, ensuring to use the pin mechanism where available. This height will be maintained for the entire level traverse. A height of 1.5m is common.
4. Ensure pole has a compliant flat base foot attached
5. Attach pole to bipod
6. Set pole height in controller to zero (0) metres
7. Occupy backsight station with pole and bipod - ensure pole is secure & level within the bipod
8. Observe three (3) rounds of Face Left & Face Right to the backsight station
9. Move pole & bipod to the foresight station - ensure pole is secure & level within the bipod
10. Observe three (3) rounds of Face Left & Face Right to the foresight station
11. Move instrument to next set up
12. Repeat steps 1 to 10 until forward run is complete
13. To commence reverse run, do an independent set up of the Total Station and repeat the process for the entire run, until returned to the original benchmark.
14. Reduce observations using an appropriate method, such as:
    a. Traditional Backsight minus Foresight calculation, inverting the solution
    b. A Foresight – Backsight calculation
    c. A spreadsheet or similar established for the specific data format from your instrument

An example set up and observation requirements are shown in Figure 3.3.1.

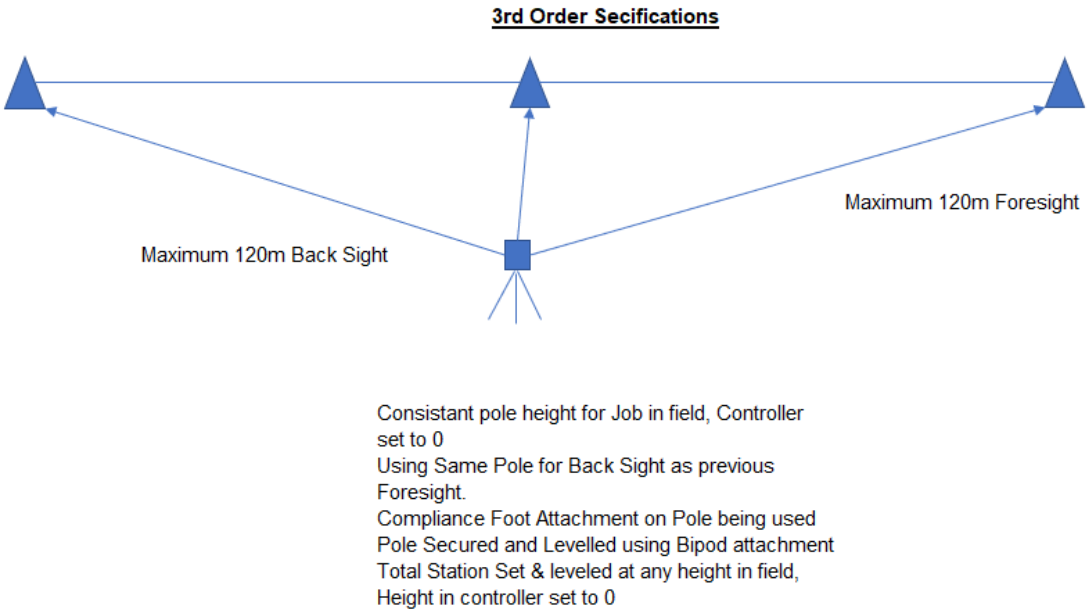
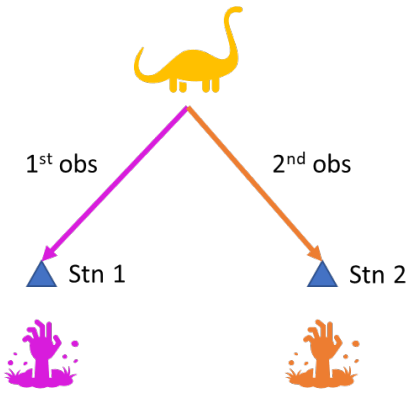


Figure 3.3.1: 3rd order levelling observation requirements

3.4. Methodology notes on using two poles

Each Order method is able to also be completed using two poles, in a leap frogging style method. An example of the first set up with a total station, observing two (2) poles is shown in Figure 3.4.1.



LEGEND
Dinosaur = Total Station
Pink Zombie hand = Pole 1
Orange Zombie hand = Pole 2

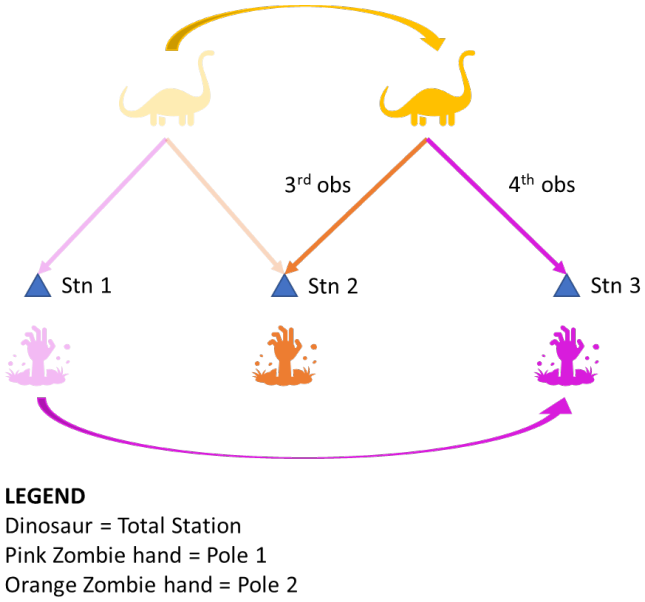
Figure 3.4.1: Initial set up using two poles

The main consideration when using two (2) poles is that of Index error of the poles, and ensuring this error is managed consistently and appropriately in the traverse.

To manage the Index errors of the poles, the following method should be adhered to:

1. Both poles must be observed in each set up I.e., Pole 1 and Pole 2 must both be observed from each total station set up. This ensures the poles form a paired "error set" – where the combined Index error of both poles remains consistent for each set up in the traverse.
2. The same pole must be used on the same mark, in both the forward and reverse runs
3. An even number of set ups are required - The pole that is on the initial station (first backsight) MUST be used on the final station (last foresight) in the last leg of the run.

An example of how to complete a level traverse using two poles is shown in Figure 3.4.2.



LEGEND
Dinosaur = Total Station
Pink Zombie hand = Pole 1
Orange Zombie hand = Pole 2

Figure 3.4.2: The leap frogging process needed when using two (2) poles

3.4.1. For an odd number of marks

When there are an ODD number of marks to be observed, and additional temporary mark (e.g. using a change plate) will be required to ensure an even number of set ups with the Total Station.

4. Example calculations

The raw data below in Table 3.4.1 is from a four (4) station level traverse using a single pole, collected at the UniSQ Springfield campus. It is provided as an example of how to reduce the collected data. No adjustment has been made.

FORWARD RUN				**Date**	15/09/23	**Project**	UniSQ SF
B.S.	Int.	F.S.	Δ Ht (FS-BS)	Rise	Fall	R.L	Remarks
-0.469						100.000	SF3041
0.044		0.483	0.952	0.952		100.952	SF3040
0.371		0.004	-0.040		-0.040	100.912	4000 OIP
		0.120	-0.251		-0.251	100.661	F108
Σ=-0.054		Σ=0.607		0.952	-0.291		
ΣFS-ΣBS=	0.661		ΣRISE-ΣFALL=	0.661	ΔRL=	-0.661	
REVERSE RUN				**Date**	15/09/23	**Project**	UniSQ SF
B.S.	Int.	F.S.	Δ Ht (FS-BS)	Rise	Fall	R.L	Remarks
0.113						100.661	F108
-0.010		0.363	0.250	0.250		100.911	4000 OIP
0.455		0.032	0.042	0.042		100.953	SF3040
		-0.498	-0.953		-0.953	100.000	SF3041
Σ=0.558		Σ=-0.103		0.292	-0.953		
ΣFS-ΣBS=	-0.661		ΣRISE-ΣFALL=	-0.661	ΔRL=	0.661	

Table 3.4.1: Example data using a single pole for a level traverse of four (4) marks

END OF DOCUMENT