Differential Leveling

Importance of Vertical Positions

- A vertical position is the height of a point relative to some reference surface, such as mean sea level, a geoid, or an ellipsoid.
- The roughly 600,000 vertical control points in the U.S. National Spatial Reference System (NSRS) are referenced to the North American Vertical Datum of 1988 (NAVD 88).

Differential Leveling

The Level

- A level consists of a high-powered telescope
- The level is attached to a spirit or bubble level that keeps the line of sight of the telescope horizontal

Differential Leveling

Importance of Vertical Positions

- Surveyors created the National Geodetic Vertical Datum of 1929 (NGVD 29, the predecessor to NAVD 88), by calculating the average height of the sea at all stages of the tide at 26 tidal stations over 19 years
- Surveyors extended the control network inland using a surveying technique called leveling.

Differential Leveling

Importance of Leveling

- The determination of elevations is called leveling
- Measuring relative elevations changes is a comparatively simple process
- Precise and accurate control of relative elevations are critical to most construction projects

Differential Leveling

Level Instrument

- Red numbers indicate foot intervals
Differential Leveling

**Definitions**

- **Bench mark (BM)** - relatively permanent point of known elevation
- **Backsight (BS)** - a sight taken to the level rod held at a point of known elevation (either a BM or TP)
- **Height of instrument (HI)** - the elevation of the line of sight of the telescope
- **Foresight (FS)** - a sight taken on any point to determine its elevation

Starting point (elevation 100.00 ft)

Point A

Point B

Elevation = 103.22 ft
Differential Leveling

Computation of Elevations – Find Elevation of BM₂

<table>
<thead>
<tr>
<th>Point</th>
<th>BS</th>
<th>HI</th>
<th>FS</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM₁</td>
<td>12.64</td>
<td>112.64</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>TP₁</td>
<td>10.88</td>
<td>120.41</td>
<td>3.11</td>
<td>109.53</td>
</tr>
<tr>
<td>TP₂</td>
<td>9.72</td>
<td>127.57</td>
<td>2.56</td>
<td>117.85</td>
</tr>
<tr>
<td>BM₂</td>
<td>3.10</td>
<td>124.47</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HI = BS + Elevation

Computation of Elevations – Find Elevation of BM₂

<table>
<thead>
<tr>
<th>Point</th>
<th>BS</th>
<th>HI</th>
<th>FS</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM₁</td>
<td>12.64</td>
<td>112.64</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>TP₁</td>
<td>10.88</td>
<td>120.41</td>
<td>3.11</td>
<td>109.53</td>
</tr>
<tr>
<td>TP₂</td>
<td>9.72</td>
<td>127.57</td>
<td>2.56</td>
<td>117.85</td>
</tr>
<tr>
<td>BM₂</td>
<td>3.10</td>
<td>124.47</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BS = 10.88

BS = 9.72

FS = 2.56

FS = 3.10
Differential Leveling

Computation of Elevations – Find Elevation of BM2

- Check the summation of the backsight and the foresight with the change in elevation

<table>
<thead>
<tr>
<th>Point</th>
<th>BS</th>
<th>HI</th>
<th>FS</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM1</td>
<td>12.64</td>
<td>112.64</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>TP1</td>
<td>10.88</td>
<td>120.41</td>
<td>3.11</td>
<td>109.53</td>
</tr>
<tr>
<td>TP2</td>
<td>9.72</td>
<td>127.57</td>
<td>2.56</td>
<td>117.85</td>
</tr>
<tr>
<td>BM2</td>
<td>3.10</td>
<td>124.47</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Change in elevation = \(33.24 - 8.77 = 24.47\)

Differential Leveling

Computation of Elevations - Group Problem 1

- Prepare a set of level notes for the survey illustrated below. What are the elevations of points TP1 and TP2?

<table>
<thead>
<tr>
<th>Point</th>
<th>BS</th>
<th>HI</th>
<th>FS</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM1</td>
<td>12.27</td>
<td>112.27</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>TP1</td>
<td>4.85</td>
<td>-1.01</td>
<td>2.33</td>
<td>117.85</td>
</tr>
<tr>
<td>TP2</td>
<td>4.11</td>
<td>6.11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Differential Leveling

- The initial backsight (BS) is taken to a point of known elevation
- The backsight reading is added to the elevation of the known point to compute the height of the instrument (HI)
- The level may be moved to a temporary point called a turning point (TP)
- The elevation of a point is the height of the instrument (HI) minus the foresight (FS)
Differential Leveling

Computation of Elevations - Group Problem 2

- Prepare a set of level notes for the survey illustrated below. What are the elevations of points TP1 and TP2?

<table>
<thead>
<tr>
<th>Point</th>
<th>BS</th>
<th>Hi</th>
<th>FS</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM1</td>
<td>6.46</td>
<td></td>
<td>3.11</td>
<td></td>
</tr>
<tr>
<td>TP1</td>
<td>8.78</td>
<td>3.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP2</td>
<td>1.02</td>
<td>5.67</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Differential Leveling

Common Mistakes

- Misreading the rod - reading 3.54 instead of 3.45
- Moving the turning point - use a well-defined TP
- Field note mistakes - work within your group to check your records
- Mistakes with extended rod - make sure the leveling rod is fully extended

Differential Leveling

Suggestions for Good Leveling

- Anchor tripod legs firmly
- Check the bubble level before and after each reading
- Take as little time as possible between BS and FS
- Try to keep the distance to the BS and the FS equal
- Provide the rodperson with a level for the rod

Any Questions?