Error Sources in Digital Leveling

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For **digital levels** we're ignoring:

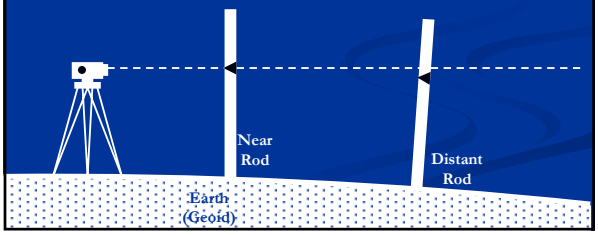
- Booking and math errors
- Parallax and rod reading errors

For **low order** work we're ignoring:

- Shading the instrument
- Invar staffs
- Orthometric correction

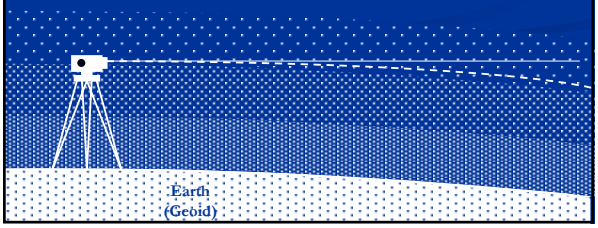
Earth Curvature Error

- The earth appears to "fall away" with distance
- Rod reading is too high
- Error increases exponentially with distance



Refraction Error

- Air below is denser than air above
- Line-of-sight is bent downward
- Negates earth curvature error by 14%



Curvature + Refraction Error

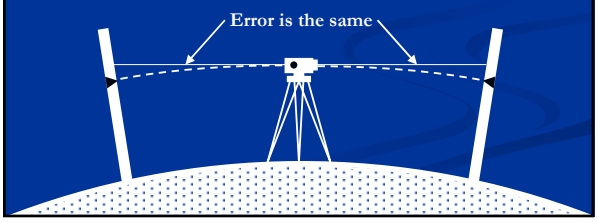
- Error (ft) = $0.0206 \times D^2$ (D = thousands of ft)

- So... 160 ft shot = **.00053 ft error**
  220 ft shot = **.001 ft error**
  1000 ft shot = **.021 ft error**
  1 mile shot = **.574 ft error**

The Correction

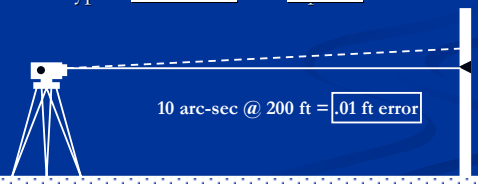
- Apply formula to measurements, OR

- Balance backsight and foresight for each setup



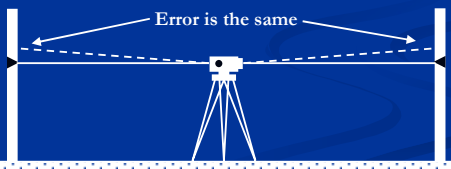
Collimation Error

- Line-of-sight not perfectly horizontal
- Two types: Electronic and Optical



The Correction

- Calibrate with two-peg test
- Balance foresights & backsights



Settling Error

- Tripod or rod settles between measurements
- Can cause systematic error

Correction

- Quick measurements between rods
- Avoid muddy or thawing ground
- Avoid hot asphalt
- Don't exert pressure on turning point

Rod not Plumb

- Rod reading too high
- More error near top of rod
- 0.3 ft out of plumb ...
  0.004 ft vertical error

Correction

- Check and calibrate rods regularly
- Brace rod firmly; Use head/body

Heat Shimmer

- Ground heating causes chaotic refraction of light
- Worst at high noon

Correction

- Shorten the length of shots
- Keep measurement 2-3 ft above ground
- Avoid leveling during noon hours

Vibration

- Wind
- Heavy vehicles
- Vibratory rollers
- Bridges

Correction

- Place one hand on tripod
- Wait for vibrations to stop
- Use mean/median mode

- Set rod on bridge, not the instrument

Mismatched rods

- Rods are not identical
- Difference can be compounded
- Proper methods will eliminate

Correction

- "Leap frog" the two rods

- Designate one rod for turning points only

Turning points

- When turning the rod between shots, the rod must be returned to exactly the same elevation

Correction

- Set nails and hubs with a prominent point

- Clean the bottom of the rod
- Clearly mark the point

Summary: At the Instrument

- Balance backsights/foresights
- Calibrate for collimation error (two peg test)
- Keep earth curvature correction on
- Setup on stable ground
- Measure 2-3 ft above ground when HOT
- Shorten the distance to rod when HOT
- Use mean/median mode for VIBRATION
- Hold tripod to dampen VIBRATION
- Avoid bridges; place rod on bridge instead

Summary: At the rod

- Check & calibrate bubble level
- Brace rod firmly
- "Leap frog" two rods
- Designate one rod for turning points only
- Clean the bottom of the rod
- Choose a solid, prominent turning point
- Clearly mark the turning point