MEASUREMENT OF WATER IN UNDERGROUND MINES

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The Plan

First ask the questions:

• What is mine water management and why do we care?

Then take a look at:

• The need for data
• Types of inflow to an underground mine
• Challenges to measuring inflow
• Methods – application notes, pros and cons
• Trends in the industry
Mine Water Management

• Management in this context means:
  o Collecting and conveying inflow
  o Controlling inflow and discharge from sumps
  o Pumping to the surface

• Pumping can be a high overhead cost and varies by:
  o Lift
  o Horsepower
  o Staged interim storage
  o Pipe run lengths

• Discharge requirements often driven by permits
Need for Comprehensive Data Collection

Measurement of flow and pressure is needed for:

- Operational efficiency and cost management
- Water balance
- Rock engineering
- Treatment and discharge requirements
Components of a Water Balance

Water Balance Summary

Inflow: 3095
Outflow: 4793
Difference: -1698

Legend:
- Flume
- Pipe Meter
- Sump
- Difference where outflow > inflow
- Difference where inflow > outflow
- Uncontrolled overflow

9W New
- Inflow: 2153
- Outflow: 3310
- Difference: -1157

9W Old
- Inflow: 65
- Outflow: 15

15E
- Inflow: 1336
- Outflow: 1183
- Difference: 153

15E Tunnel
- Inflow: 588
- Difference: 545

16W
- Inflow: 95
- Outflow: 748

14W
- Inflow: 1163
- Outflow: 1193
- Difference: 153

P15E-P15E8E
- Flume: 362
- Pipe Meter: 362

P15E
- Flume: 821
- Pipe Meter: 821

P9E
- Flume: 1418
- Pipe Meter: 1418

F8E-2
- Flume: 41
- Pipe Meter: 41

F8E
- Flume: 1418
- Pipe Meter: 1418

P11E
- Flume: 417
- Pipe Meter: 417

F13E
- Flume: 32
- Pipe Meter: 32

F14E
- Flume: 343
- Pipe Meter: 343

PGDW1
- Flume: 748
- Pipe Meter: 748

P14W
- Flume: 653
- Pipe Meter: 653

F7W
- Flume: 357
- Pipe Meter: 357
Flume Data 12-Hour Avg.
Information Content

Pipe Flow Meter - P15E

Flow Rate, GPM

Date

Gridlines Indicate Midnight of Each Day

Daily Avg.
7-Day Avg.
Data Analysis

Drill hole flow & recovery test data

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Data Analysis

Drill hole flow test Theis recovery analysis

Corehole Flow Test Recovery Analysis

\[ T = \frac{264Q}{s} \]

where:
- \( T \) = transmissivity (gpd/ft)
- \( Q \) = avg. flow rate (gpm)
- \( s \) = recovery over one log cycle (ft)

\[ T_2 = \frac{(264)(5.40)}{116} = 12.3 \text{ gpd/ft} \]
Mine Water Inflow

Sheet flow on rib
Mine Water Inflow

Diffuse Inflow – Slow dripping or seeping
Mine Water Inflow

Flowing drill holes
Mine Water Inflow

Karst and large voids
Mine Water Inflow

Seepage through seals or bulkheads
Measurement Challenges

Pipe flow discharges underground
Measurement Challenges

Precipitate and debris in ditch
Measurement Challenges

Full, flat gradient ditch
Measurement Challenges

Sediment in shut-in apparatus
Measurement Challenges

Destruction from flood
Methods of Measurement

Ad Hoc bag dam to collect diffuse flow.
Accumulation measured with sharp-crested weir.
Methods of Measurement

Weir in ditch to collect “casual” flows. In this case, drainage through railroad ballast.
Methods of Measurement

Parshall flume in ditch

Application Note:
Stepped base, narrow throat
Methods of Measurement

Palmer-Bowlus flume in ditch

Application Note:
Round base, large range, wide throat
Methods of Measurement

H-Flume at surface to measure seepage into a block cave subsidence zone

Application Note:
Requires free outfall, large range
Methods of Measurement

Ultrasonic Dual Transit Time Flow Meter

Application Note:
Non-invasive, any pipe material, any size
Methods of Measurement

Sump Level Measurement

Sonic meter

Pressure datalogger
Methods of Measurement

Rock hydrostatic pressure measurement

Application Note:
Flow/shut-in tests provides estimate of K,
Cost effective compared to packer testing from surface
<table>
<thead>
<tr>
<th><strong>Ditch Flow</strong></th>
<th><strong>Applications</strong></th>
<th><strong>Cost</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Weir</td>
<td>Still water (Pool)</td>
<td>Low ($1,500 - $3,000)</td>
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<tr>
<td></td>
<td>Requires freeboard</td>
<td></td>
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<tr>
<td></td>
<td>No debris, no precipitation</td>
<td></td>
</tr>
<tr>
<td>Flume</td>
<td>Moving flow</td>
<td>Higher cost ($2,000 - $5,000)</td>
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<tr>
<td></td>
<td>Minimal raise in head</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Self cleaning (handles debris)</td>
<td></td>
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<tr>
<td></td>
<td>Some types handle submerged flow</td>
<td></td>
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<tr>
<td><strong>Pipe Flow</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>Non-invasive to pipe</td>
<td>High cost ($2,500 - $4,000)</td>
</tr>
<tr>
<td></td>
<td>Doppler vs. Dual transit time</td>
<td></td>
</tr>
<tr>
<td>Magnetic</td>
<td>Invasive</td>
<td>Most costly ($3,500 - $5,000)</td>
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<tr>
<td></td>
<td>No moving parts</td>
<td></td>
</tr>
<tr>
<td>Propeller</td>
<td>No debris, no precipitation</td>
<td>Lowest cost ($500 – $1,500)</td>
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<tr>
<td></td>
<td>Invasive to different degrees</td>
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<tr>
<td><strong>Sump Level</strong></td>
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<tr>
<td>Float Wheel</td>
<td>Still water, minimal air movement</td>
<td>Low cost ($750 – $2,000)</td>
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<td></td>
<td>Low cost ($750 - $2,000)</td>
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<tr>
<td>Pressure Transducer</td>
<td>Direct readings of depth of water</td>
<td>Low cost ($500 - $1,500)</td>
</tr>
<tr>
<td></td>
<td>Low cost ($500 - $1,500)</td>
<td></td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>Does not contact water</td>
<td>High cost ($2,000 - $4,000)</td>
</tr>
<tr>
<td>Method</td>
<td>Advantages</td>
<td>Disadvantages</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------------------------------</td>
<td>----------------------------------------------------</td>
</tr>
<tr>
<td><strong>Ditch Flow</strong></td>
<td></td>
<td></td>
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<tr>
<td>Weir</td>
<td>Simple</td>
<td>Vulnerable measurement point</td>
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<tr>
<td></td>
<td>Many installation options</td>
<td>Not self cleaning</td>
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<tr>
<td></td>
<td></td>
<td>Requires still pool - raises head</td>
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<tr>
<td>Flume</td>
<td>Self cleaning</td>
<td>More involved installation</td>
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<tr>
<td></td>
<td>No large raise in head - good for ditches</td>
<td>More expensive than weirs</td>
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<td>New designs allow submerged conditions</td>
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<tr>
<td></td>
<td>Tend to be more accurate than weirs</td>
<td></td>
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<tr>
<td></td>
<td>Good option for unattended operation</td>
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<tr>
<td><strong>Pipe Flow</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>Non-invasive to pipe</td>
<td>Cost</td>
</tr>
<tr>
<td></td>
<td>No moving parts, accuracy not degraded with time</td>
<td>Complex meter programming</td>
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<tr>
<td>Magnetic Induction</td>
<td>No moving parts</td>
<td>Invasive installation (flanged insert)</td>
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<td></td>
<td>Long track record of use</td>
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<tr>
<td>Propeller/paddle wheel</td>
<td>Low cost</td>
<td>Moving parts, accuracy degrades with time</td>
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<tr>
<td></td>
<td>Long track record of use</td>
<td>Affected by debris, encrustation, cavitation</td>
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<tr>
<td></td>
<td>Invasive to pipe, but often simpler than magnetic</td>
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<tr>
<td>Sump Level</td>
<td></td>
<td></td>
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<tr>
<td>Float Wheel</td>
<td>Dependable, long track record of use</td>
<td>Moving parts</td>
</tr>
<tr>
<td></td>
<td>Low cost</td>
<td>Not set up for electronic datalogging</td>
</tr>
<tr>
<td>Pressure Transducer</td>
<td>Direct readings of depth of water</td>
<td>Can be affected by water chemistry</td>
</tr>
<tr>
<td></td>
<td>Low cost</td>
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<td>Ultrasonic</td>
<td>Does not contact water</td>
<td>Cost</td>
</tr>
<tr>
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<td>Can be affected by changes in air density</td>
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Trends in Mine Water Management

Mine water management will increase in importance if (when) commodity prices fall.

- Pumping, storing, and conveying water is often a high overhead cost.
- Environmental controls are becoming a more important driver at mine sites outside of the US.

Technology is an important driver

- Automated data collection continues to improve and drop in price.
- More mines are adopting SCADA controls and many operators expect a seamless integration into a comprehensive mine monitoring system.
- Pipe flows and sump levels are measured in most mines. Many still not automated, but most are moving that way.
The Take Away

• All inflow and conveyance conditions can be measured. Some collection may be needed.

• A water balance model is only as good as its data.

• Measurement devices should be carefully selected for the conditions to take advantage of the strengths of each.

• Minimize maintenance, maximize data content.
Thank You

Questions.........?