Solutions for mine water management
Solutions for mine water management

Sound mine water planning, information and forecasting minimizes disruption & yields increased production.

DHI applies its knowledge of water using, physics based process models, and monitoring expertise to find cost effective solutions.
Mine Dewatering
Geological model using LEAPFROG Parameters zone and Faults Representation

Hydrogeological model FEFLOW:
Groundwater flow modeling, transport and density dependent flow, geochemistry,

Mine Hydrology using MIKE SHE:
Spatial and Dynamic water balance, distributed Recharge, ground and surface water interactions, stream flow, solutes and geochemistry,

Pore Pressures
Dewatering
TSF Seepage
Water Balance
FEFLOW - Full unstructured mesh including pinch out layers
Mine Inflow Forecasts & Uncertainty

- Parameter range instead single value
- Multiple samples from parameter range
- Explore range of predictions
- Reliable estimate of average expected inflow

![Mine Water Inflow Forecast](image)

Red: base case prediction, green: 90% likeliness range of prediction

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Data Worth Analysis

• Linear sensitivities represent the response of predictions to small parameter variations.
Data Worth Analysis
Integrating Water in Mine Planning & Operations
Conceptualisation of MIKE IPO Integration

Operational data

- Scada Historian (Assets)
- Groundwater, surface water, rainfall database(s)
- Borehole database
- Pump curves
- Other

Configuration tool

Import Script

Models (incl. inputs & outputs)

- Mine Development model
- Groundwater & Surface Water Models
- Hydraulic/ water infrastructure Model

External Tools

- Interpreted water surfaces
- Water Level & pit floor difference calculations

Operational plan;
- Mine plans (5yr, 2yr, 3mth)
- Planned vs actual water levels at key locations and spatially
- Planned vs. actual abstraction & quality
- Planned vs actual network pressures, flows, quality, etc
- Water use

Compliance;
- Plan, actual and trigger water levels at compliance monitoring locations

Asset performance;
- Pump availability, utilisation and productivity
- Pump health (referencing pump curve)

Custom views

- Real time forecast; flood levels
- Other

Expert user analysis

- Data analysis
  - Spatial; bore locations, pit floor & water surfaces, etc
- Measurements; head, discharge, TDS, pit level

Reconciliation

Model calibration;
- Planned vs obs heads
- Water balance at sub domain level

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Mine Water Reporting

Enhancing communication of business reporting via web enabled dashboards of forecasts and operations data
Risk Based Decision Making Framework
Using Uncertainty Analysis, data worth analysis

Traditional single model realization approach.
Calibrated model only provides base investment cost, no risk level
Risk Based Decision Making Framework
Using Uncertainty Analysis, data worth analysis

Multiple model realization approach. Suitable uncertainty analysis method (here: Monte-Carlo sampling) provides understanding of risk associated with different decisions.
Risk Based Decision Making Framework
Using Uncertainty Analysis, data worth analysis

Uncertainty analysis, data worth and risk based planning:
• Numerical uncertainty analysis
• provide data worth input to optimizing study programs; and
• informing risk based mine planning
Tailings Dam Seepage
TSF and Pit Inflow Seepage Analysis

- Groundwater – Surface Interaction Modelling
- Flow paths and travel times
- Quantitative assessment
- Evaluation of mitigation measure
Mine Planning For Floods

Ensham Mine Queensland - Australia
Mine planning for floods

Existing flooding

With flood protection
Mine planning for floods

Minor overtopping of levee

Major overtopping of levee
Mine Site Drainage

Assess Contact and Non Contact Water
2m Resolution
Forecasting for mine management

SCADA system for real-time rainfall and flows

Meteorological forecasts

Regional radar and satellite images

Dashboard

Local rainfall radar
Proactive flood management helps you:

- Minimize downtime due to flooding or potential flooding
  
  The Ensham Mine cost of downtime was over $1 million per day

- Improve safety and minimize damage during flooding
  
  The haul trucks are valued up to $3 million
  The drag-line recovery cost ~$100 million

- Reduce the risk of catastrophic mine closure
  
  Including lost production, the damage for the Ensham Mine flood disaster was in excess of $350 million

Ensham Mine Queensland - Australia
Sediments & Tailings
Tailings & Sediments

- Wet Tailings
- Dynamic morphological simulation.
- Beach Slope Development
- Prediction of distribution and grades.
- Spigot Optimization
Tailings & Sediments
Tailings Dam Breach Impact Assessment
Mine Hydrology
Reliable Water Balance Modelling
MIKESHE - Integrated Mine Hydrology
One Water — One System — One Model

- Precipitation and snowmelt
- Vegetation based evapotranspiration and infiltration
- Unsaturated groundwater flow
- Saturated groundwater flow
- Integrated water quality
- Demand driven water use
- Overland surface flow and flooding
- Channel flow
Surface Water Hydrology & Groundwater Recharge

What does Recharge really look like?

Recharge is;

- Spatially distributed
- Temporally distributed (dynamic),
- It cannot reliably be predefined
- Not a simple boundary condition.
Mine Catchment and principle mine affected areas

- Recently rehabilitated mine area
- Old, rehabilitated mining area
- On going mining, with concurrent rehabilitation
Spatial water balance

Topography

Surface water

Vegetation

Soils

Groundwater discharge to surface water

High groundwater recharge
Dynamic water balance

Response to stream flow peaks

Discharge delayed relative to rainfall
Mine Closure and Reclamation
Mine Closure

Understanding mine hydrology is the key to mine closure

- Recharge sources
- Pit/Groundwater rebound
- Decant locations/volumes
- Mitigation measures
- Treatment design
Mine Closure

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Case Study – Middleburg, South Africa

Mine Closure Plan – Water Treatment Plant
ARD treatment volumes were reduce by 50% compared to the estimates from simple models

- 50% lower expected decant volumes
- 30% lower capital costs for treatment plant
- 50% lower operational costs for 50+ years

Regulatory approvals had completely stalled
- Loss of confidence in Lumped Box Models (GOLDSIM)
- Physics based catchment modelling re-energized stakeholder engagement
- Reliability improved.
Phytoremediation

Conceptual model

Hydrologic model processes
Land cover changes to reduce infiltration

- Clay cap too expensive
- No easy source of clay
- Surface areas too large
- Reduce infiltration by increasing ET in the cover?

Current cover: grass
Annually harvested for animal feed
Thin, shallow rooted
Deeper rooted, denser vegetation?
Construction changes to reduce infiltration

- Backfill compaction during emplacement?
  - Lower conductivity, lower porosity

- Slope modifications?
  - Enhanced runoff
Pit Lakes and Groundwater Rebound
Pit Rebound
Remote Sensing in Mining
Screening for surface minerals

Airborne hyperspectral mapping:
- detailed mapping of surface materials
- Vegetation proxy mapping for surface minerals.

Copper Mineralisation
Water quality mapping

- Suspended Sediments
- Biological
Planning – topographic mapping

Topographic mapping in remote locations.

Accuracy of +/- 1 meter.

Comparison of aerial LiDAR derived DEM with satellite derived.
Solutions for mine water management

Physics based solutions

- Reliable forecasts.
- More efficient planning
- Reduced downtime
- Higher regulatory confidence
- Improved compliance

Cost effective solutions

- Mine Dewatering
- Mine Flooding
- Water Surplus and Scarcity
- Stream Diversions
- Acid Mine Drainage
- Water Balance Forecasting
- Climate Change Impacts
- Wetland & Stream Restoration
- Mine Closure
- Compliance Monitoring
- Mine Closure
Thank you
Additional information
Integrating Water in Mine Planning & Operations
Framework for Integrating Water in Mine Planning and Operations

DHI Solutions for planning optimization and risk management
• Uncertainty analysis, data worth and risk based planning
• Regional integrated watershed modelling
• Mine site water balance
• Dewatering and water supply system design
• Fluvial morphology
• Surface water and groundwater impact assessment
• Dam break analysis
• etc

DHI Solutions for planning & operations & reconciliation
• MIKE IPO
• real time reconciliation of planning and operational data enabling targeted and timely response to emerging risks and opportunities
• Improving efficiency and QA for data integration in multi-function planning process
Framework for Reconciliation of Water Budgets

- Data sources integrated into single platform
- Enabling efficient and quality assured reconciliation of planning and operations data
- Identify causal factors of impending interactions between mine advancement and watertable
- Focused early response.

Operations Reconciliation:
- Abstraction volumes
- Pump mechanical availability
- Pump utilization
- Pump productivity (well column, rates)

Operations

Mine Plan

Mine Pit Elevation Reconciliation: Mine Plan vs Survey

Surveyed pit elevation
Planned pit elevation

Plan
Outcome

Mine plan Water level

Mine Plan

Dewatering plan

Dewatering Forecast Reconciliation: forecast vs hind cast modelling

Hindcast forecast
Platform for Mine Water Management - MIKE IPO

MIKE IPO: Component UI (Scientific View/Configurator View)

Maps (GIS)

Time series

Data base

Open architecture (API)

Spreadsheets

Add User tools
Conceptualisation of MIKE IPO Integration

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Example workflow

**Import Operational Data**
- Active connection to data sources such as Envirosys, Aquire, SCADA Historian, pit survey
- Import interpreted datasets (ie. WL contours)
- Data stored in related Time series, worksheets and spatial formats

**Import Mine Plan File**
- Import and store mine plan files (csv.)
- Create time series spatial features (rasters)
- Create timeseries for selected points

**Compare current WL with mine plan**
- Compare spatial data sets
- Compare timeseries data

**Define dewatering asset array**
- Examine asset capacity; availability, productivity
- Define additional assets

**Generate Forecast WL**
- Automatic connection or embedded dewatering simulator
- Run dewatering simulator and auto post process results
- Compare spatial and timeseries outputs with mine plan data

**Publish plan**
- Publish plans as forecasts and targets via dashboards
- Link operational data to dashboards for live updates

**Reconcile plans and asset performance**
- Visual reconciliation of forecasts with operational data (ie. abstraction rates, WL’s, asset performance)
- Automate reconciliation of forecasting tool with operational data
- Reconcile mine plan with survey elevation

**Decision making**
- Make rapid and informed decisions to align mine planning, dewatering planning and operations
- Informed status for subsequent planning cycle
Mine Water Reconciliation

Enhancing planning, operations and reconciliation through integration of datasets and data forms (time series, spreadsheet and spatial)
Enhancing communication of business reporting via web enabled dashboards of forecasts and operations data
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Optimum?
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Mine Planning For Floods
Forecasting for mine management

Provide Flood Warnings

<table>
<thead>
<tr>
<th>Flood Categories</th>
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<tbody>
<tr>
<td>Major Flood Stage:</td>
<td>22</td>
</tr>
<tr>
<td>Moderate Flood Stage:</td>
<td>20</td>
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<tr>
<td>Flood Stage:</td>
<td>16</td>
</tr>
<tr>
<td>Action Stage:</td>
<td>14</td>
</tr>
</tbody>
</table>

Operate flood structures

Dashboard

Forecast flows and levels

Time of forecast

48 hr forecast

48 hr hindcast

Publish Flood Maps