Guidelines for Mine Water Management

Management of Water Balance in Mining Areas

WaterSmart Seminar 28.8.2015

Report:
Guidelines for mine water management

Target groups:

- Mining companies in Finland to support design and decision-making processes throughout the mine life-cycle starting from early planning stages
- All other relevant parties involved such as consultants, environmental administration, technology providers, research institutes etc.

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Objectives

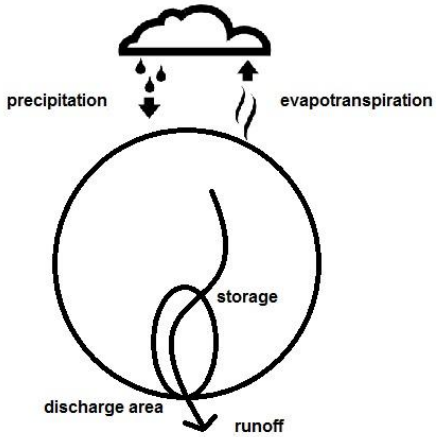
- Describe current status, needs, and challenges of management of mine water balance
- Identify expected future needs for water management solutions
- Introduce good practices for water balance management:
  - monitoring,
  - water balance modelling,
  - integration of monitoring, modelling and process control
- Present examples of good water management actions implemented in practice
- Describe water management procedures and decisions in different phases of mine life cycle

→ **Better implementation of the best practices in mine water management**

Background

- Water management is the most challenging stress factor at Finnish mines (Mine stress test report[1]):
  - Mining influences the quality and quantity of waters at mine areas and in the surroundings, and
  - changes hydrological and topographical circumstances of the area
    - Effects on the surface runoff, groundwater behaviour, soil moisture content and evapotranspiration

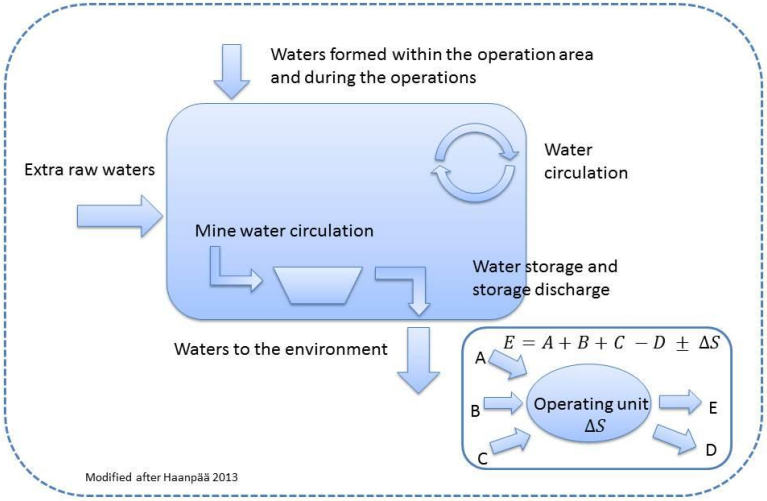
- Sites are unique – proper water management requires understanding of the site specific factors
- Water balance management and waste management are linked
- Minimum requirements on water balance monitoring and reporting set in legislation and permits



1 Välisalo et al.2013 Kaivosten stressitestit

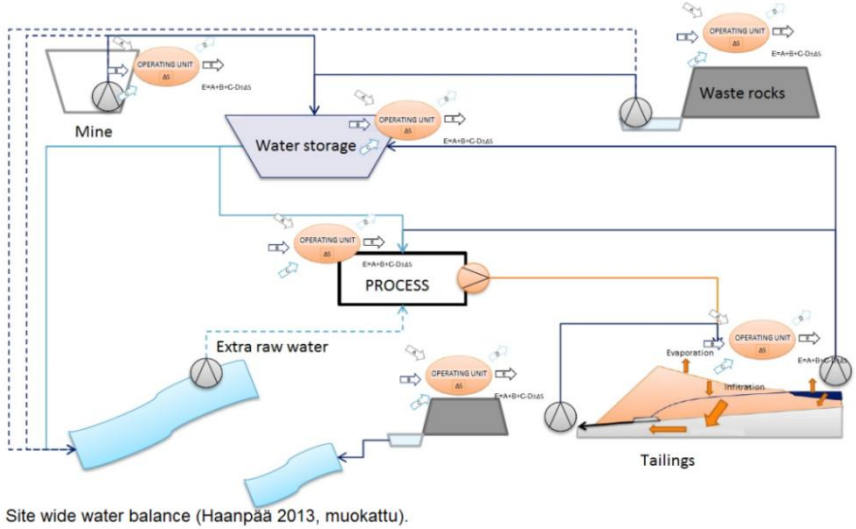
Proper water balance management is critical to the mine

- Benefits of efficient water management and early planning:
  - Reduction of risks and environmental impacts
  - Cost savings, e.g. optimal storage capacity and diversion of different waters, optimal recycling
  - Social acceptance
- Preparation to extreme situations and changes of water balance during mine life-time
  - Assessment of water balances in mine planning stage
  - Forecasting of hydrological conditions
  - Sufficient monitoring of hydrological conditions, adaptation to potentially risky situations
  - Sufficient knowledge about the quality of water
  - Availability of data from longer periods
  - Dynamic development of monitoring program, water balance modelling and water management



Current needs

- Competence development and practical introduction of water management and modelling tools
- Improved (on-line) monitoring tools for data collection
  - Both water quantity and quality important for optimal collection, treatment and recycling of waters
- User-friendly water balance management tools
  - Quickly updatable, user-friendly interfaces
- Tools which enable integrating the water balances of different operations to one ***”site-wide-water-balance”***
  - How to overcome compabitility challenges
- Integration of water balance management to process control system of the mine



Site wide water balance (Haanpää 2013, muokattu).

Water balance modelling tools

- Spreadsheet, e.g. Excel based deterministic models quite commonly used but can act as dynamic models with a specialised add-in tool
  - Useful for easy projections, can be rapidly implemented and used to store, display, and check dynamic model inputs, or display and analyse dynamic modelling results
  - Drawbacks: Not transparent, not very well suited for complex modelling, complex models may be difficult to interpret or explain, add-ins needed for uncertainty assessment, errors
- Shift from deterministic methods towards dynamic models, that can be coupled to hydrologic, geochemical, economic, reactive transport and to chemical equilibrium models
- Dynamic modelling simulators: Extendable modelling platforms GoldSim, MATLAB Simulink; prepackaged modelling systems, STELLA, Vensim…
  - More versatile, suitable for complex modelling tasks and complex scenarios, more detailed evaluation

WSFS – Watershed simulation and forecasting system

- WSFS has mainly been used for flood forecasting, realtime monitoring, nutrient load simulation and climate change research

Other modelling tools

Hydrogeological and groundwater flow models

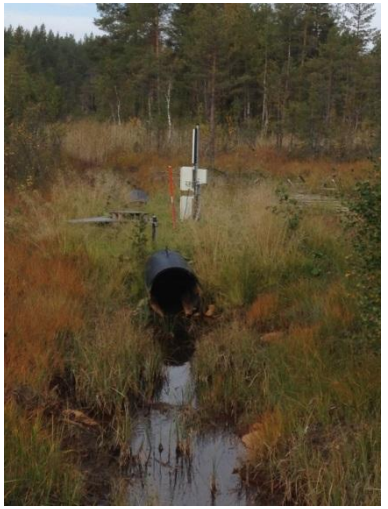
- MODFLOW, MT3DMS, FEFLOW, MODFLOW SURFACT, HydroGeoSphere (HGS), PHREEQC

Equilibrium and chemical models

- HSC Sim, PHAST; PHREEQC, TOUGHREACT, HYDRUS 2D/3D, ChemSheet, OLI

Monitoring

- The water monitoring program depends on the mine characteristics, surrounding grounds and waters, *etc.*
  - *Parameters, such as temperature, pH, EC, Eh, O_2, alkalinity, anions, metals, N, P, etc.*
  - *Groundwater monitoring –physico-chemical quality and groundwater level, in parallel with local climate measurements*
  - *Monitoring of surface water and other natural waters – flow measurements, physico-chemical analysis*
  - *Monitoring of tailings, dams, etc.*
  - *Weather data – own weather station if possible*
- Monitoring tools: on-line, on-site/field and laboratory
  - On-line: flow, water level, pH, T, EC, turbidity, NO_3-N, NH_4-N
  - Field methods: pH, T, EC, turbidity



Fotos: Henna Punkkinen

Monitoring, recommendations

- The monitoring program should progress and develop
  - *Starting from the measurement of baseline water conditions and gathering of meteorological information*
  - *Development on the basis of critical assessment of results from longer periods*
- Continuous monitoring of water flow and water level in basins are recommend as good practices
  - Regular basin inspections are important to confirm the operation of monitoring equipment and water level in basin
- Regular monitoring of surface and groundwaters and water level combined with weather data are important for forecasting of hydrological conditions, to prevent unexpected water situations
- Monitoring results should be available in a database with easy access
- Integration of data from on-line monitoring tools to water management program would be ideal

- Sources: Välisalo, et al. 2014 + several other literature sources

Good practices

- Pro-active approach aiming to solving out the causes behind problems beforehand instead of addressing symptoms
- Water balance management is started from the early planning stages and continues throughout the life-cycle of the mine
  - Needs to be developed and updated along different phases and within phases
    - Development of knowledge, changes of water balance and operations
- The report includes general guidance tables summarising:
  - which topics should be considered in different phases of the mine life-cycle
  - which kind of results and data should be produced, and
  - the most important permits
- Applied case specifically, e.g. different phases may be parallel

Water management in different mine phases

Mine phase	Contents/ Requirements	Results and information for the regulatory units	Permits
Prospecting	• Gathering information from other regional mining operations • Performing environmental baseline study • Water availability	• Baseline studies of environment, vegetation, fish, etc. including meteorological data, hydraulic properties to be performed at least 2 yrs before any changes to the environment to help in developing monitoring program	• Reservation notification • Prospecting work
Prefeasibility	• Planning the use of water on a monthly basis implemented in the water model • Planning water treatment using the baseline study data • Preliminary mine closure plan	• Site-specific water supply implementation to project requirements • Preliminary water treatment plan for water user and discharge • What-if scenario from model • Information for Environmental Impact Assessment • Mine closure evaluations	• Natura Assessment
Exploration	• Sampling of site for mineral analysis without alterations to environment	• Mineral profile data	• Ore prospecting permit • Notification of pilot activities
Conceptual design	• Planning water monitoring program • Water management model setup • Catchment descriptions and management plans	• Mine risk class • Knowledge of water sufficiency for the mine life cycle • Knowledge on project mine water requirements • Water treatment discussions • Compilation of the regulatory processes	• Comply with Nature Protection Act • Disposal Permits related to Conservation Act

Mine phase	Contents/ Requirements	Results and information for the regulatory units	Permits
Feasibility	• Mine feasibility evaluations and impact assessment from baseline data • Daily water management program that includes water quality and quantity monitoring • Water sources and demands for mine • Discharge quantity and quality as well as costs	• Mine water management program implementing model and monitoring data • Mine water plan including water sources, requirements of the mine, water treatment for use and discharge, etc.	• Nature Assessment • Environmental Impact Assessment • Waste management plan • Redemption permit for the mining site • Dam Safety
Investment decision and mine site plan	• Updating plans and models: mine water plan, water management plan, monitoring plan, water treatment plan, etc. • Water infrastructure plan and design	• Water use permits • Water infrastructure construction • Water supply and dam safety approvals	• Land Use & Building Act • Water permit • Environmental permit • Disposal permit • Mining permit
Construction and commissioning	• Water infrastructure in detail • Water monitoring and reporting • Revisions of models and programs	• Water infrastructure (treatment plants, etc.) fulfilled according to permits • Reporting of water qualities and quantities according to permits	• Mining safety permit
Operation	• Water quality and quantity data collection/monitoring and assessment for revision purposes • Water management model revisions according to collected water monitoring data • Revisions according to operational needs • Update of closure plans	• Reporting and monitoring of water quality and quantity according to the permits • EIA revisions approval	• Permit revisions and updates
Closure, post-closure and after-care	• Water management plans for closure • Implementation of water quality and quantity monitoring during closure phases	• Water monitoring and reporting during closure in compliance with permits • Rehabilitation plan	• Permit revisions and updates

Estimated development of water balance management

	Present (*state of the art*) 2014	Intermediate 2020	VISION 2030
Technology	• Software available, few appl. to mines & if applied, only during operation stage • Monitoring of env. waters not connected to software (dynamic)	• Dynamic software for environmental waters • Implementation of chemical equilibrium modules	Dynamic water management including online quantity & quantity monitoring and chemical equilibrium/reaction modules
Products	• Software: GoldSim, Stella… • Online monitoring sensors for flow, level, temp only • Onsite measurements of pH, EC. etc • Lab. measurement for ions, BOD, COD, etc	• Fast lab measurements • Larger array of online sensors	• Water management software for mine-specific adaption with userfriendly interface showing water quantity & quality for process, tailings, environment, groundwaters • Online water quality sensors
Drivers	• Legislation • Public opinion • Environmental accidents • Water shortage/surplus	• Risk minimization • Increased water recycling	• Safety for the environment • Public approval
Bottlenecks	• Premine operation data not available • Online monitoring, e.g. sensor lifetime • Groundwater management • Information sources required for establishing a site wide water balance is scattered to different stakeholders	• Online measurements for fast reacting to perturbations	Sensor lifetime/maintenance costs


Thank you!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