

Integrated Dynamic Mine Water Balance Modelling with EcoBalance Model Libraries

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Abstract

Integrated water balance modelling is a tool that assists in the critical mining industry task of water management planning. The process starts with conceptualisation, which includes identification and description of all relevant site water management structures and usually involves the introduction of simple water balance modelling spreadsheets. Irrespective of their complexity, these models are usually analytical and utilise a deterministic approach. For more flexible modelling and a better understanding of the water management scenarios, dynamic water balance models are applied. This paper presents how the Ecolego[®] software tool is used for integrated dynamic mine water balance modelling.

Keywords: Water Balance Modelling, Water Management, Dynamic Modelling, Ecobalance, Ecolego

Introduction

The diversity of mining projects has increased substantially over the past three decades. At the same time, there has been an emphasis on environmental issues, decontamination of former industrial sites, a recognition of global warming issues, and a focus on the ability of project developers to initiate, operate, and close transient projects without compromising the land and water resource values that underpin existing and future land uses (Hancock & Wolkersdorfer 2012). For mine sites, water balance modelling is the primary tool for water management planning. Water management challenges vary depending on mine geographical location, local environs, and mine operations. Notwithstanding, mine water management can be considered as a global challenge for the industry.

The probabilistic site water balance modelling approach has become increasingly common during the past fifteen years.

Dynamic and probabilistic modelling approaches were introduced by Nalecki & Gowan in 2008. Today, the probabilistic site water balance modelling approach is generally accepted in the mining industry. The use of a solely probabilistic approach has, however, been disputed (Swanson *et al.* 2018) due to risk of over-engineering and a hybrid deterministic water balance modelling approach has been introduced.

Despite the modelling approach, a model is always an appendage of an expert on the field. As stated by Swanson *et al.* (2018), the modeller must understand the model's dynamics, including when and where the project is most vulnerable to extreme events, and why the vulnerability exists. To provide an advanced tool for deterministic, hybrid deterministic, or solely probabilistic site water balance modelling, this paper describes how the Ecolego[®] software tool could work as an appendage of a site water management modelling professional.

Ecolego® Software Tool

Ecolego® (<https://www.ecolego.se/>) is a powerful and flexible software tool for creating dynamic and complex process models and performing deterministic or probabilistic simulations. Ecolego® has primarily been used for conducting risk assessments of complex dynamic systems evolving over time, with specialised databases and other add-ons designed for the field of radiological risk assessment. However, Ecolego® is easily adapted to various other applications, e.g., transport of chemicals and elements from emission to biota uptake, water balance simulation in mining industry (EcoBalance), or contaminated land simulation, using its compartmental modelling approach. Ecolego® is designed with re-usability and quality assurance as a primary focus, which leads to better models and less work for the user. Libraries of model components are easily created and modified. Ecolego® includes a parameter database with an integrated system for data tracking and quality assurance. Ecolego Player allows a reviewer to browse the model, inspect equations, and re-run simulations.

Ecolego® interface is comprised of an interaction matrix view that makes complex models easier to organize and view, a model graph view that presents the model conceptually, and a relationship graph view where interactions between objects can

be established and manipulated. Ecolego® possesses all requirements for advanced probabilistic analysis, including probability density functions, Monte Carlo and Latin Hypercube sampling, and parameter correlation settings. In addition, Ecolego® features a powerful and simple-to-use library of models where specific model components can be stored and later inserted into other analyses.

The EcoBalance Model

Introduction

The objective of the integrated dynamic mine water balance systems model is to inform the planning, design and management of mine water and mass load throughout the mining life cycle. Of specific importance is to identify the water demand in the different sections of the mine, as well as the containment reservoir requirements for contaminated mine water storage and re-use. The integrated system approach allows for environmental value engineering by means of risk-cost-benefit optimisation.

EcoBalance

EcoBalance is a dynamic and integrated mine water balance system-level model within Ecolego® that is used to analyse mine water systems for the purposes of mine planning, design, optimization and value engineering throughout the mining life cycle. Some

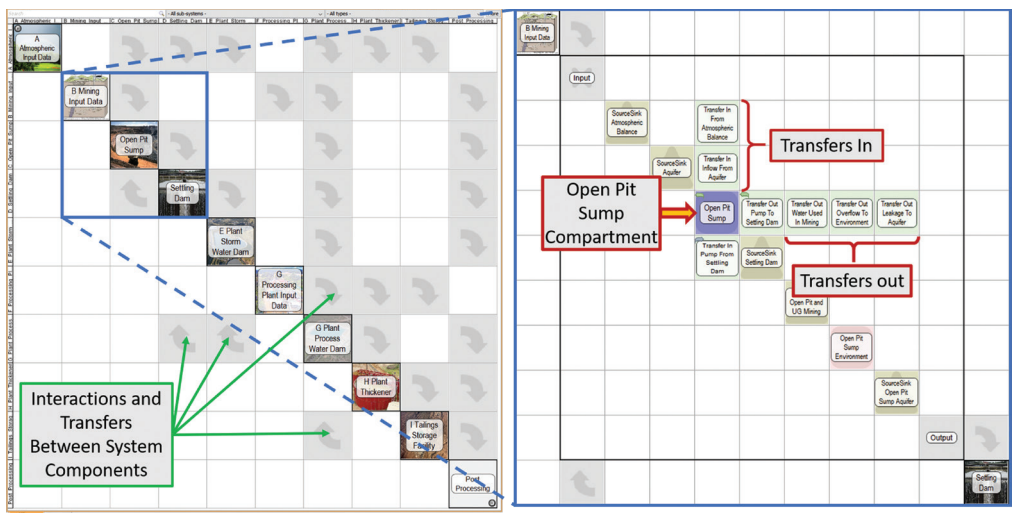


Figure 1 EcoBalance Compartmental Systems Modelling Approach.

of the inherent Ecolego® features makes it particularly attractive for integrated dynamic mine water balance modelling. EcoBalance adopted the interaction matrix together with the compartmental systems modelling approach embedded in Ecolego® to represent the transient transfer of water through the natural and mining environment, as well as within each compartment (fig. 1).

The possibility to develop and incorporate predefined libraries of typical mining components that are easily adaptable for the water fluxes and balances for the mining environment, is of particular advantage. As illustrated below, this means that typical mining components (e.g., open pit, settling dam, storm water dam, or tailings storage facility) can be defined as an available Block in the Library Folder. Each of these Blocks contain typical features and parameter values that can be altered to the project specific conditions (fig. 2).

By combining these predefined and validated libraries, it is possible to create integrated mine water balance models that can be used for performing deterministic and probabilistic simulations. The optimisation routine embedded to Ecolego® can be used to optimise the design of system features and operational conditions (e.g., pumping rates). A specific advantage of EcoBalance is that the component libraries automatically link inputs and outputs and check the component and total system balances. Using the library collection, EcoBalance allows for easy construction of a site-specific and integrated dynamic mine water balance. This feature allows for a considerable time-, and subsequently, cost-saving factor while managing balance errors in complex systems.

The user interface visualisation utilises an interaction matrix approach that makes complicated models with many interconnections easier to view and manage

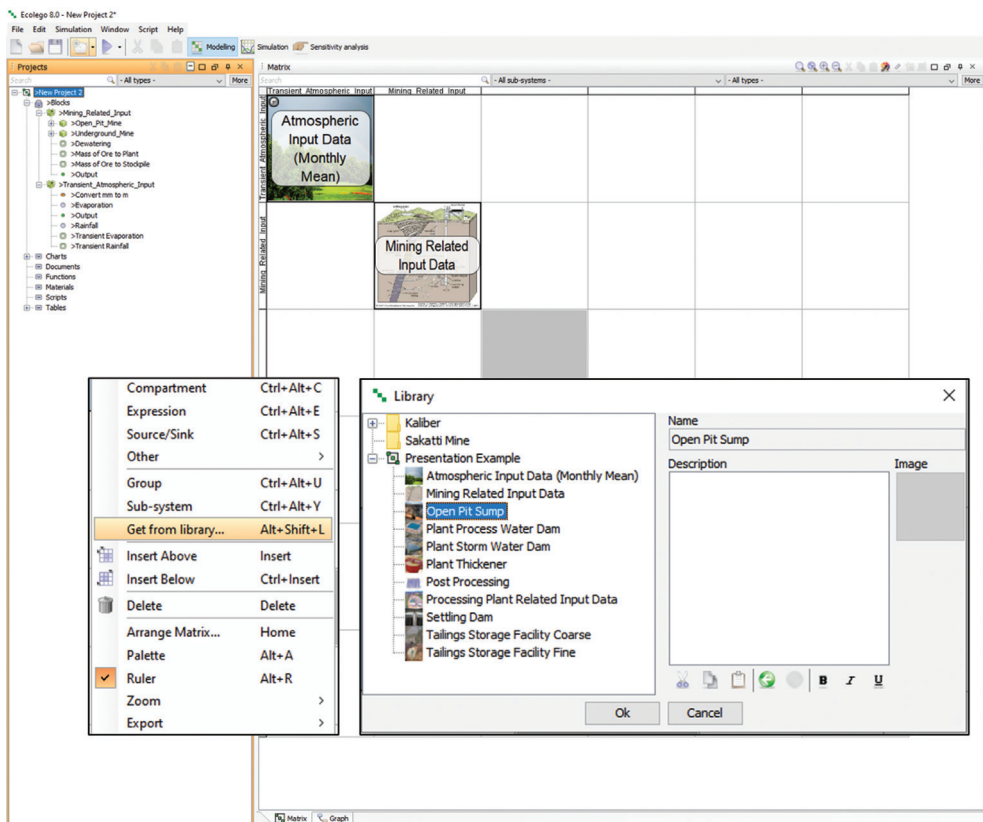


Figure 2 Predefined Blocks of Typical Mining Features Can Be Imported into a New Project from the Library Folder.

(fig. 3). Combined with hierarchical sub-systems, the user interface facilitates the ease of construction and documentation of large complex models. A model graph option as an alternative to the interaction matrix presents the system in a conceptually intuitive way. Salt and chemical constituent mass load and transport modelling are also allowed as an integrated and dynamic linked option.

EcoBalance Implementation to A Real-Life Mining Environment

EcoBalance has been applied to diverse mining environments, including the Keliber mine (Keliber Technology Oy) in Finland for a site wide water and loading balance modelling. As a further example, below is visual representation of the mine water balance flow main components and interactions diagram for a mine in Southern Africa where EcoBalance was implemented and applied for site wide

water balance modelling (fig. 4). The model could be applied to an integrated open pit and underground linked project. The modelling scenarios were used to inform storm water design criteria and quantify surplus water volumes and the life of mine water quality as chemical constituent concentrations. Based on both flow and mass modelling, mine water containment reservoirs and transfer pumping capacities could be informed to identify value engineering opportunities as potentials of capital expenditure reduction and postponement.

For illustrative purposes, examples of important life of mine dynamic modelling outcomes produced from EcoBalance, amongst many other informative transient analyses, include e.g. mine external make-up water demand curve (fig. 5) and overflows to the environment as timing of events and volumes (fig. 6).

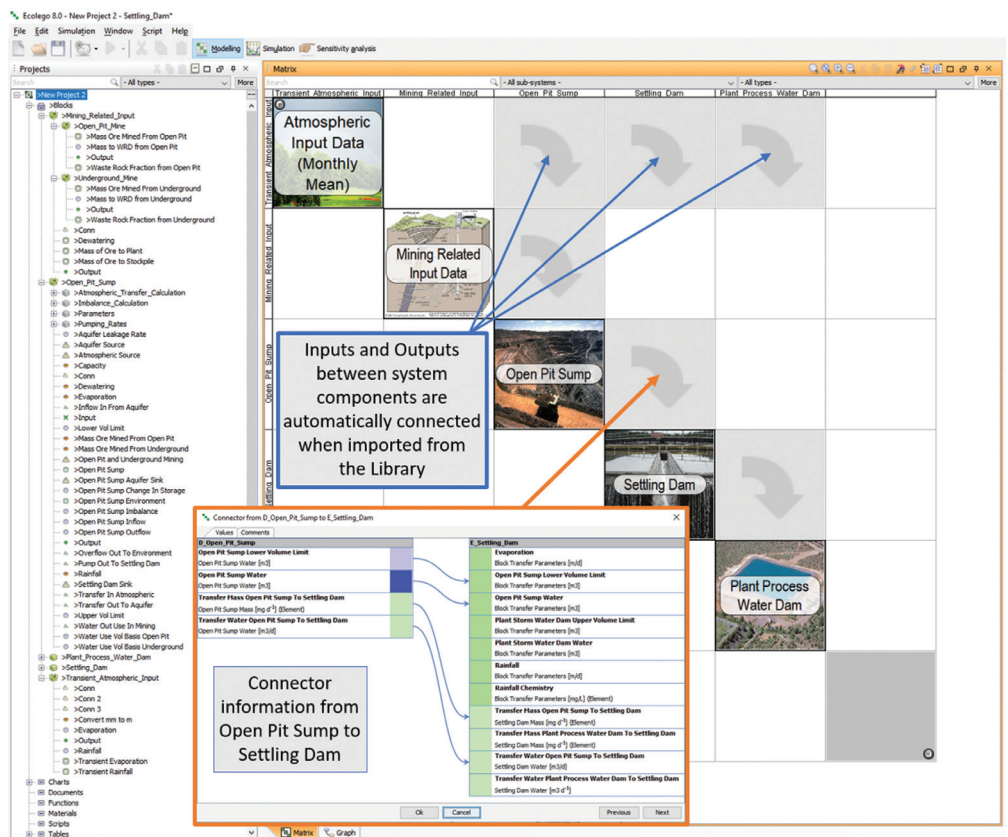


Figure 3 EcoBalance Visualization of an Interaction Matrix.

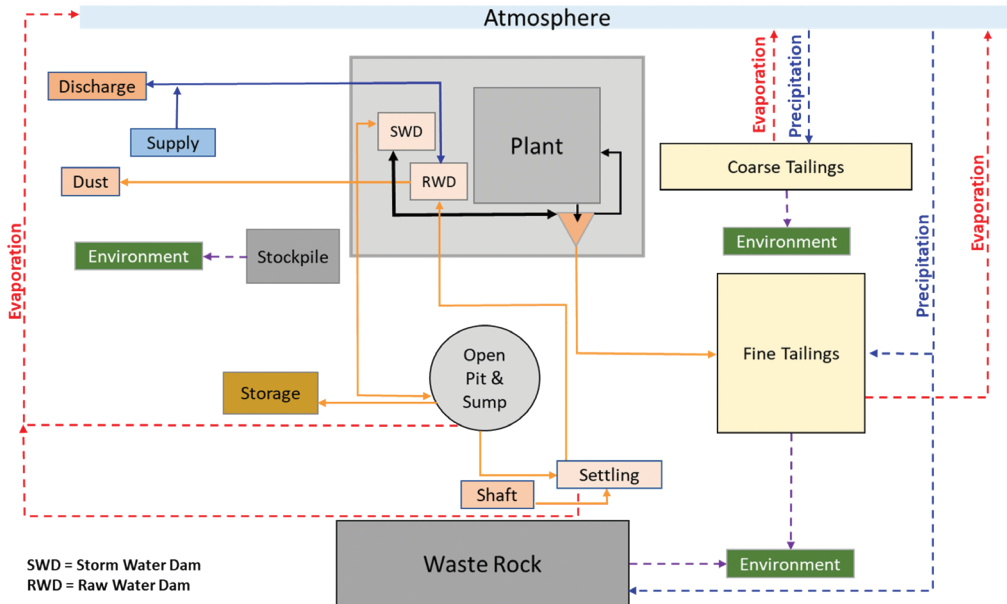


Figure 4 EcoBalance Case Example Water Flow Main Components.

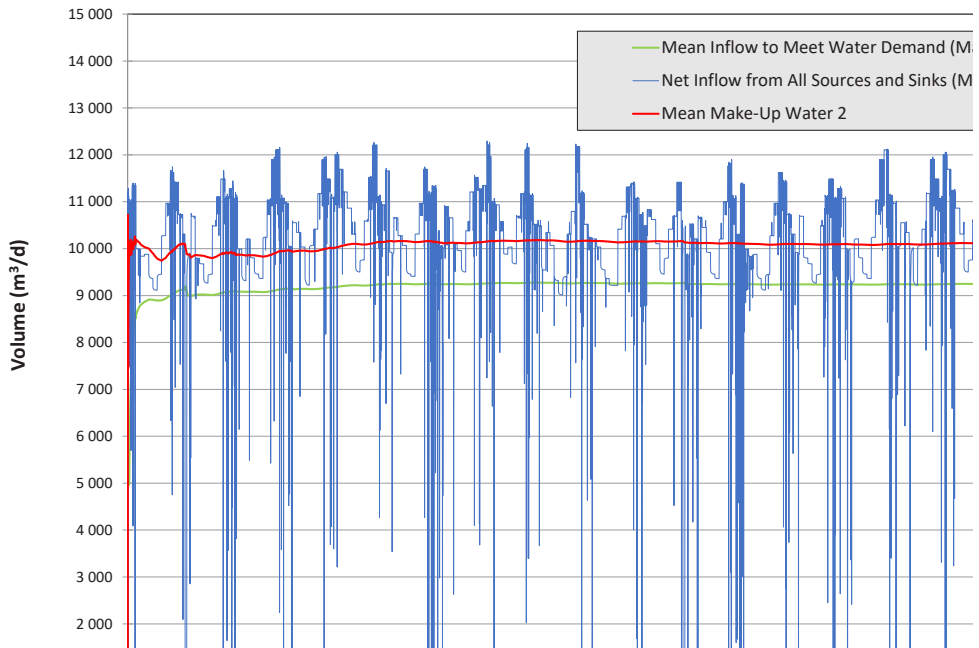


Figure 5 EcoBalance Example: Mine External Make-Up Water Demand Curve.

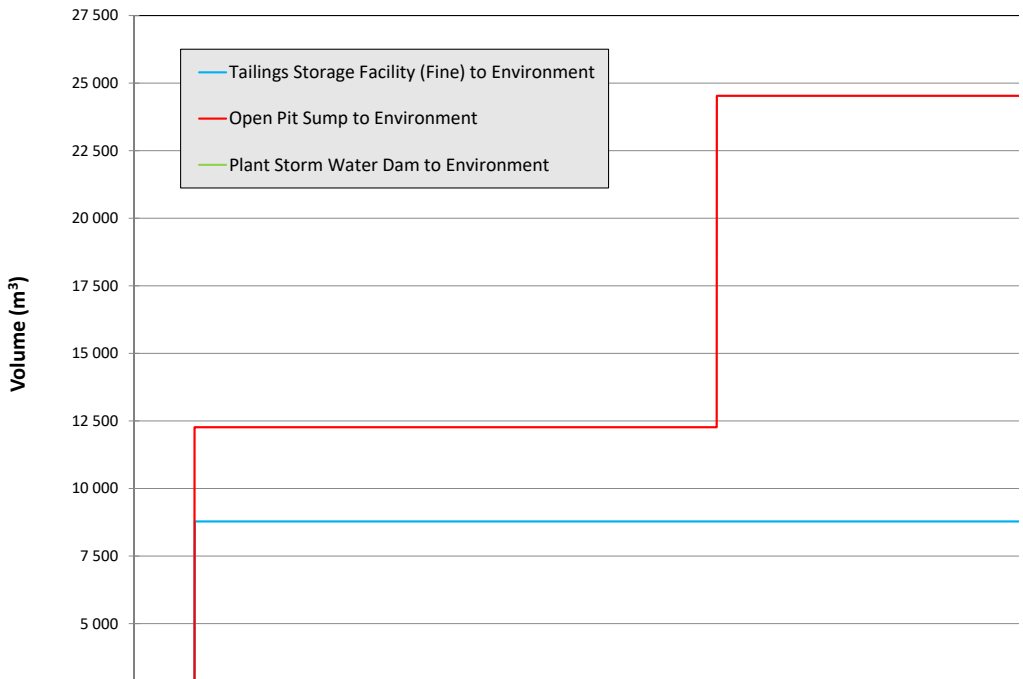


Figure 6 EcoBalance Example: Overflows to the Environment, Timing of Events and Volumes.

Conclusions

Integrated water balance modelling is a tool that assists in the critical mining industry task of water management planning. EcoBalance is a dynamic and integrated mine water balance system-level model within Ecolego® that is used to analyse mine water systems for the purposes of mine planning, design, optimisation and value engineering throughout the mining life cycle. Some of the inherent Ecolego® features makes it particularly attractive for integrated dynamic mine water balance modelling. Using the library collection, EcoBalance allows for easy construction of a site-specific and integrated dynamic mine water balance. This feature allows for considerable time-saving, and subsequently, cost-saving factor while managing balance errors in complex systems. A specific advantage is that the component libraries automatically link inputs and outputs and check the component and total system balances. Salt and metal transport modelling are also allowed as an integrated possibility. The user interface visualisation utilises an interaction matrix that makes complicated models with many interconnections easier to

view and manage, whereas the model graph presents the system in a conceptually intuitive way. Combined with hierarchical sub-systems, the user interface and large library of models facilitates the ease of construction and documentation of large complex model systems.

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References

- Hancock S, Wolkersdorfer C (2012) Renewed Demands for Mine Water Management. In: Mine Water and the Environment, June 2012, DOI: 10.1007/s10230-012-0176-6
- Nalecki P, Gowan M (2008) Mine Water Management – Dynamic, Probabilistic Modelling Approach. In: Rapatnova N, Hrkal Z, 2008 Mine Water and the Environment, Ostrava (VSB – Technical University of Ostrava), p 469-472
- Swanson S, Breckenridge L, Leduc M (2018) Mine Water Balances – A New Proposed Approach. In: Drebenstedt C, Paul M, IMWA 2016 – Mining Meets Water – Conflicts and Solutions, Freiberg/Germany (TU Bergakademie Freiberg), p 528 – 534