Mine Water Footprint as a Primary Tool for Water Stewardship

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Strategies for Sustainable Water Management for Mining

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srk consulting

Historical Water Management Focus

Usually studied during the design phase, but left to operational staff to manage as best as they can after startup

Increasing focus on proactive water management as part of the mine water management plan

Maintaining water supply security

- Can we obtain the water needed by the mine
- Will water supply meet the needs of the mine in drought

Ensure compliance

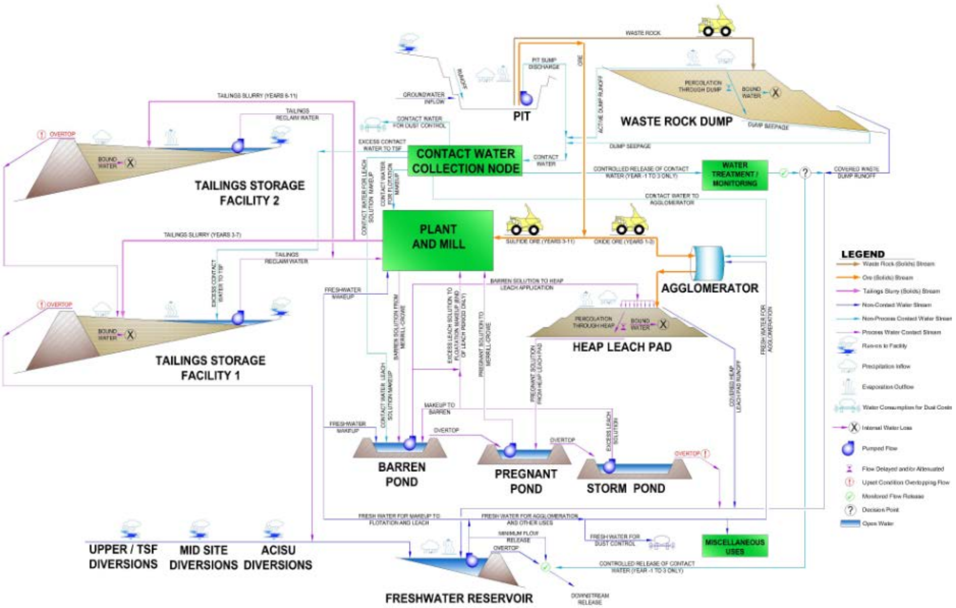
- Will we have to discharge excess water
- What quality will it be and what are the compliance issues

Development of a Mine Water Inventory

The Inventory should be a site visit to the operating mine, documenting all the routes by which water enters and moves through the mine

Physically walking the pipelines and ponds can reveal a great many things not obvious from the planning documents

A mine water inventory attempts to define all the inflows and outflows to a mine, as well as the inventory of water stored or consumed on site.



Water Inputs
- Surface Water
- groundwater flows
- Seawater
- Third Party

Water Outputs
- Surface Water
- Groundwater
- Seawater
- Third Party
- Other

Storage
- Ponds and Impoundments
- Transient Storage
- Recoverable Bound Water

Diversions
- Water actively managed by the site but not used for any task within the facility

Development of a Mine Water Inventory

Very useful in understanding the needs of the mine and the movement of water across the site, but:

- Has difficulty defining flows which cannot be measured (i.e. subsurface seepage)
- Cannot give a complete picture of all the flows at the site and how they interact
- Difficulties in projecting into the future if the project changes
- Difficulties in extrapolating the impact of extreme climate

Development of a Mine Water Balance

Should be calibrated to historical records using a limited number of inputs (i.e. climate, ore tonnages). Calibration allows definition of difficult to define flows

Operating rules allow calibrated model to make reliable projections of future behavior

The mine water balance takes the inventory and attempts to complete the picture and understand the interactions

- The inventory may be actual numbers in the case of an operating mine, or they may be based on what we know of the mine plan at this stage in the design process.
- Quantify unknown inflows or outflows based on known flows and understanding of the physical system
    - i.e. calculating groundwater seepage losses from a reservoir based on runoff, evaporation and measured transfer flows
- Develops operating rules to project current behavior into the future to predict system performance
    - i.e. establish rules for when treatment system is engaged to maintain desired levels in process ponds

Development of a Mine Water Balance (cont'd)

"No Mine plan survives contact with a miner"

Not only should the water balance model the changing nature of a mine, it should be able to update frequently as the mine updates the mine plan.

Exploring the uncertainties of the mine water management system is critical. We have no control over climatic inputs, which is the single biggest variable in the system.

- Addresses the dynamic nature of the mine water management system and details how flows can be expected to change through time

    i.e. pit water inflows from dewatering may decrease as the regional aquifer is depleted, but rainfall capture reporting to the pit bottom will increase as the footprint grows

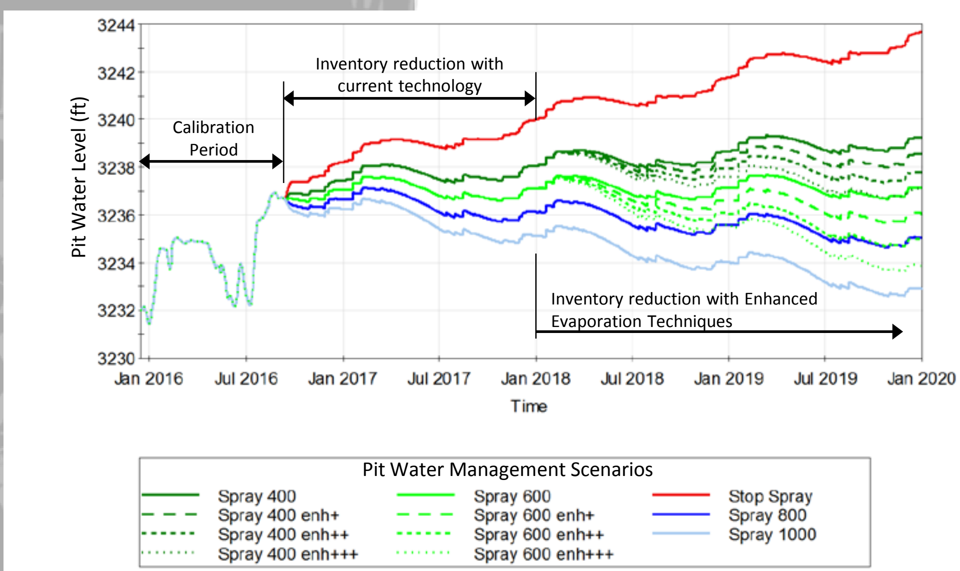
- Incorporates the uncertainties inherent in the understanding of the mine water system when making projections

    i.e. precipitation is highly variable and projecting into the future must account for wet and dry periods when planning water management infrastructure

Using an Mine Water Balance

Using water balance and inventory methodology to identify process improvements

- Identify leaks or miss-reported flows
- Water balance identifies open loops - reduce discharges and water take, increase reuse and recycle
- Evaluate impacts on water management from changes to mine plan or mining processes



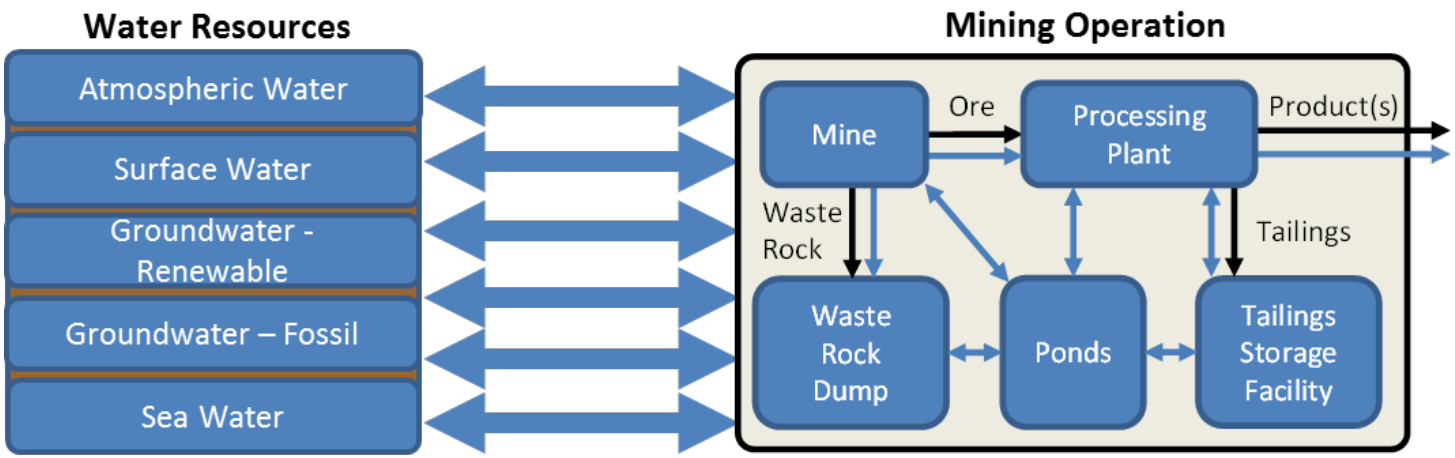
- Evaluate impacts of sourcing water from more reliable/less contentious sources
- Understand true cost of water
- Collects all the inflows, outflows and storage in one place for easy reporting

Mandatory and Voluntary Corporate Reporting Schemes

Corporate reporting schemes allow a company to demonstrate their commitment to sustainable water use

Many large mining firms proactively making their water use statistics publically available

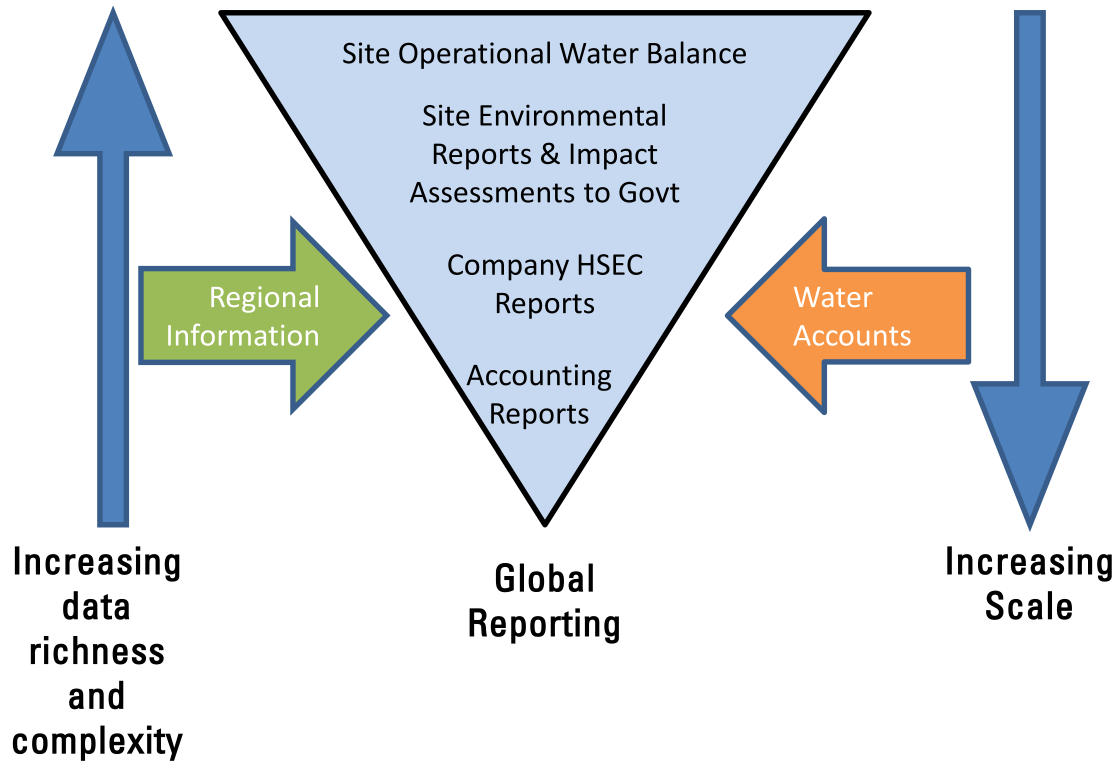
- Global Reporting Initiative
- CDP Water
- MCA Water Accounting Framework
- Life Cycle Assessment



Northey et al., 2014. Minerals Engineering, 69: 65-80.
Northey et al., 2016. J. of Cleaner Production, 135: 1098-1116.

Water Accounting

Water accounting takes the highly detailed data from the water balance and reduces it to a few results that represent the mine at a large scale



Water Accounts bridge the Site Water Balance Reporting to the arena outside the mine

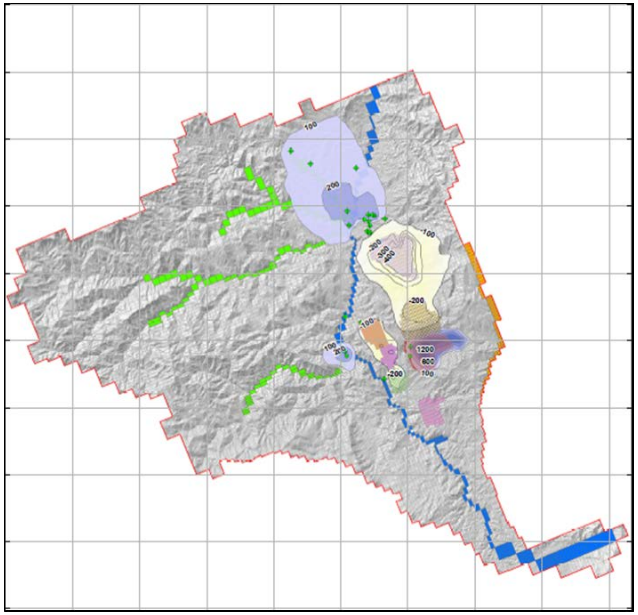
Adapted from Water Accounting Framework for the Minerals Industry, Minerals Council of Australia, April 2012

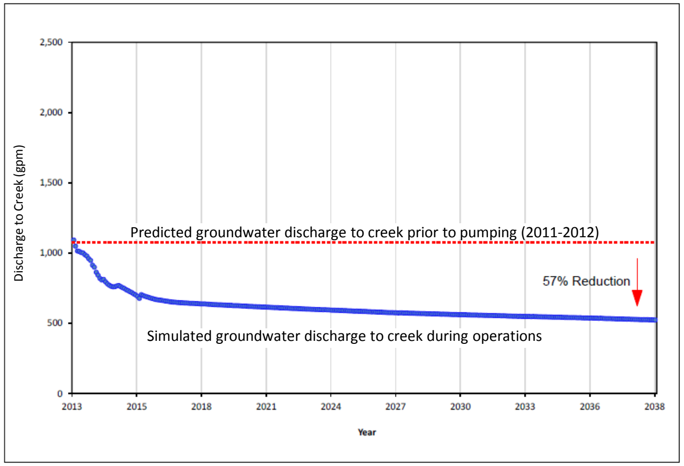
Use Water Resource Evaluations to Understand Regional Impacts

Hydrologic, hydrogeologic and geochemical characterization and modeling studies are used to define the source of water supply and region characteristics

Important to understand these components to secure the mine water supply and understand the system before it is impacted

- Water supply studies
- Mine dewatering impacts
- Pre-development water quality vs discharge water quality





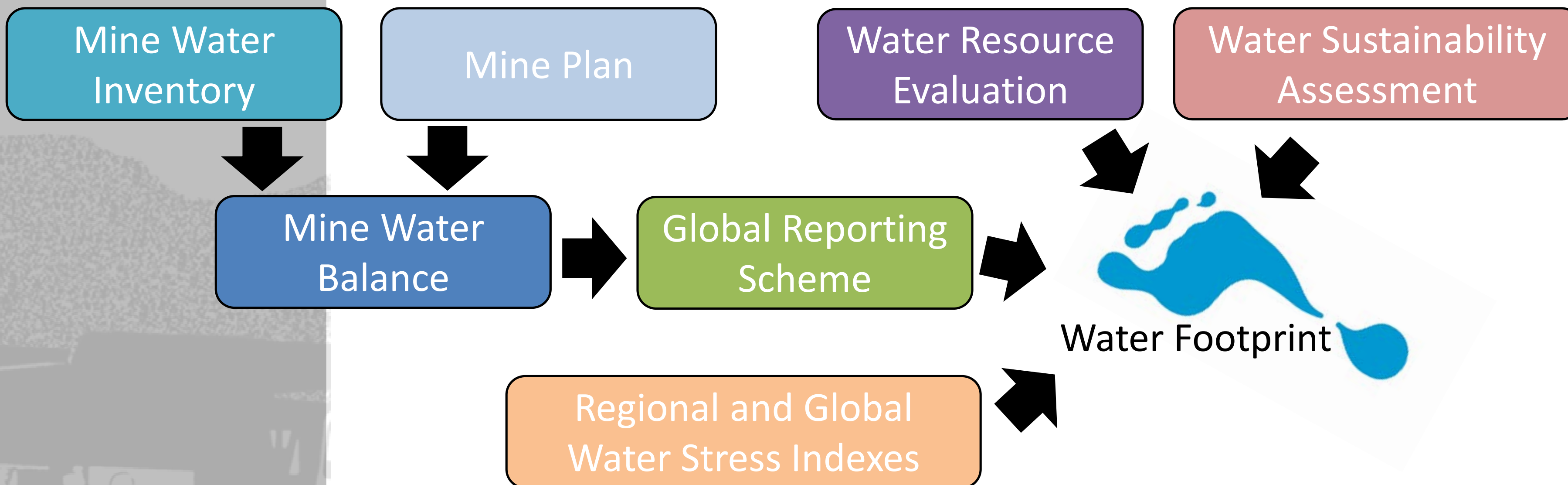
Improve Recognition of the Impacts That Occur Due to Mining

Several recent mine projects where solid science and engineering designs were able to obtain regulatory approval, yet failed to gain the social license needed to open the mine

What can conventional studies miss?

- Increasing trend to develop large scale mines (>100,00 tpd) with low grades in arid regions -
  - Opening up potential for conflict
  - Creates vulnerable to activist campaign
  - Increased scale of impacts
- Increasingly stricter regulatory environment
- Social media expands influence of NGOs
  - Radical transparency expected
  - Need to be proactive with Human, Environmental, Social, and Community issues
- Issues can be real and perceived
- Increasing importance of water in social license issues
- Communicating water use and impacts has become necessary to maintain positive community relations

Evolution of Water Impact Assessment



Water footprint quantifying impacts to environment

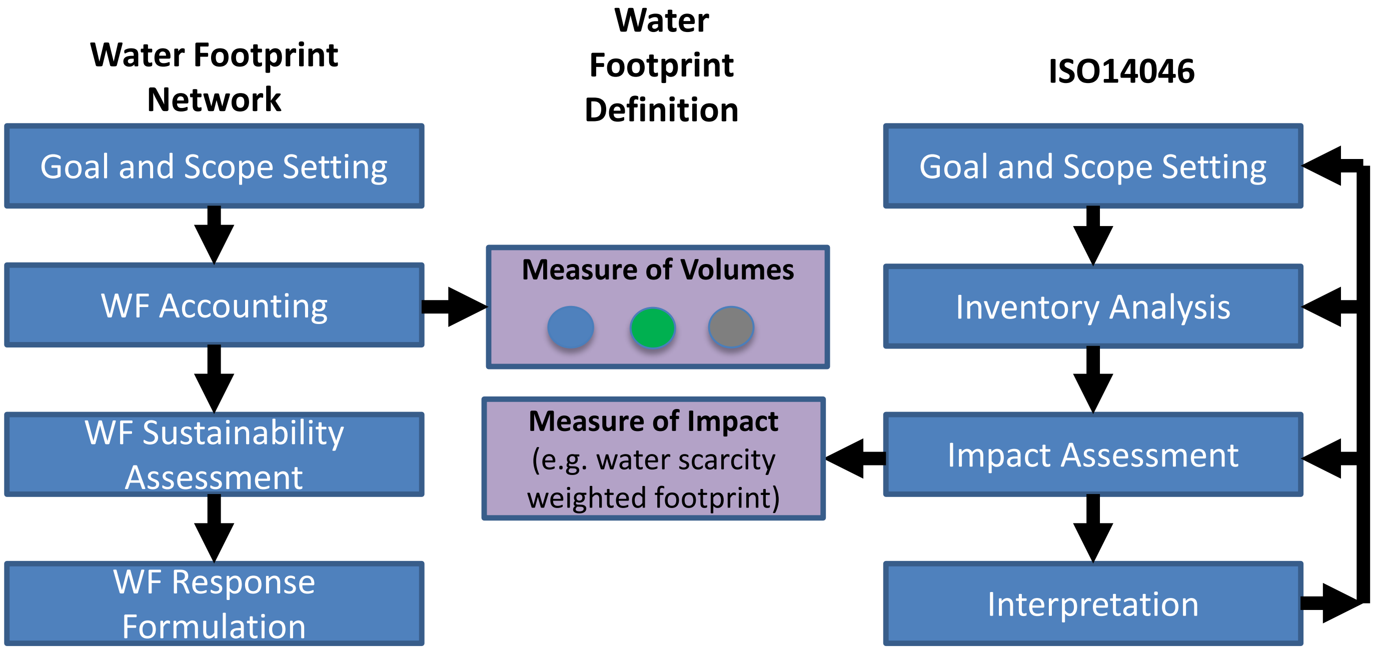
- Measures freshwater appropriation
- Spatial and temporal dimension
- Actual, locally specific values
- Always referring to full supply-chain
- Focus on reducing own water footprint (water use units are not interchangeable)

Water Footprint Methods

The ISO method defines the process by which the water footprint is developed, but there are several methods by which the Water Footprint can be developed

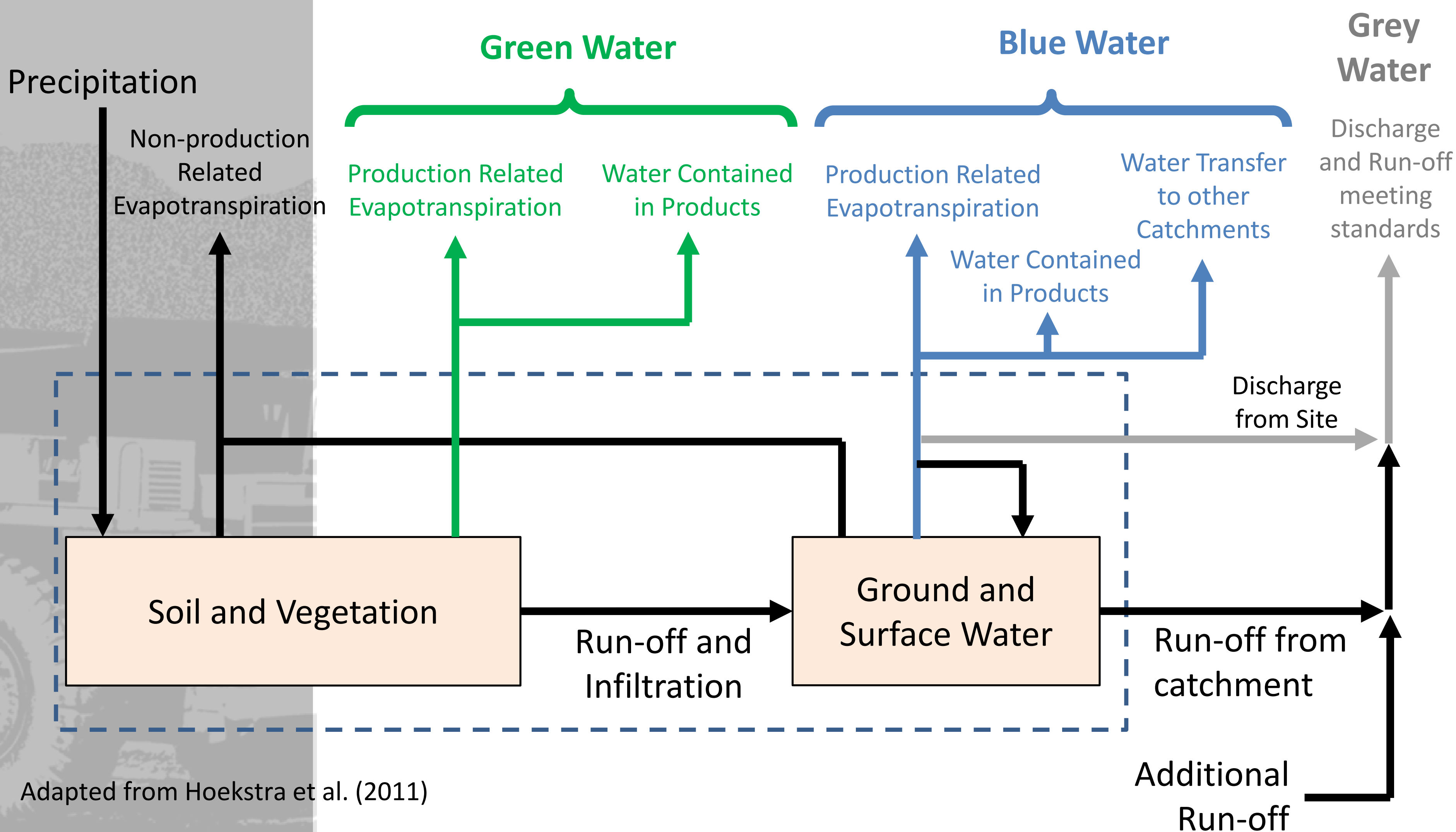
The method by Hoekstra et al. (2009, 2011) considers water in 3 categories: blue, green, and grey

- ISO 14046 Water Footprint
- Water Footprint Network Categories
  - Green water: meteoric water
  - Blue: Freshwater
  - Grey: Dilute discharges to meet standards



Adapted from Hoekstra et al. (2011)

Water Footprint Methods



Adapted from Hoekstra et al. (2011)

Water Footprint Methods
(Ridoutt and Pfister, 2013)

The Water Footprint CUI and DUI takes the Water Footprint and Normalizes it to a Global Scale

Comparing a WF number from mines in different climates is now feasible

Consumptive Water Use Index

- Reduction in water volume available in a store or catchment
- Water Stress Index (WSI) – measure of water availability
- Adjusted for site by Regional WSI/Global WSI

Degradative Water Use Index

- Impacts from changes in water quality
- Water Quality Index – ReCiPe impact assessment method
- Adjusted for site by Regional WQI/Global WQI

Water Footprint Methods (cont'd)

(Ridoutt and Pfister, 2013)

Single-indicator water footprint

- Consumptive Water Use Index - Degradative Water Use Index
- Adjusts water footprint to lessen footprint in areas of low water stress or areas with poor quality background water
- Useful to inform corporate structures of how to compare different sites
- Understand the regional context of their operations
- Can be communicated to internal and external stakeholders to provide a comparative number on water impacts

Water Footprint

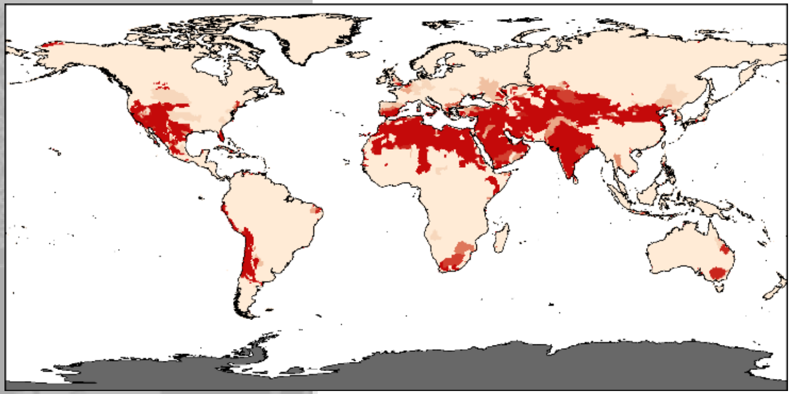
Without regional adjustment, it can be very difficult to compare water footprints between two regions with different climates or water availability

Factors affecting the water footprint

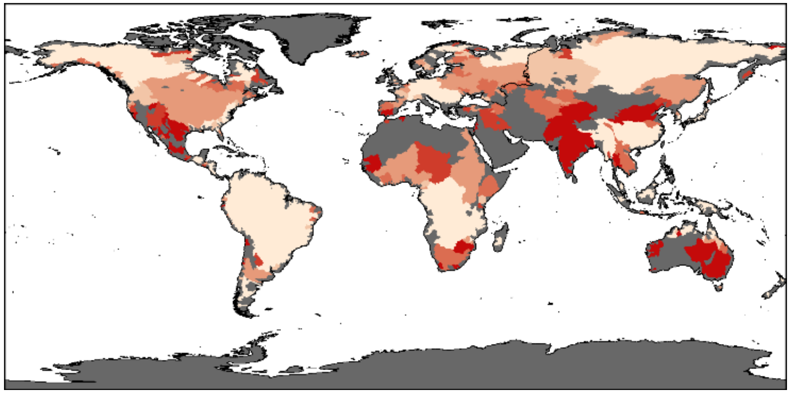
- Climatic conditions - i.e. higher or seasonal rainfall or greater evaporation potential
- Site conditions (ability to divert watersheds, high groundwater table,
- Access to water sources
- Ore mineralogy, geochemistry, processing method
- Mine water management strategies
- Waste disposal method (i.e. tailings vs dry stack)
- Background water quality
- Regional availability of water

Water Stress Index

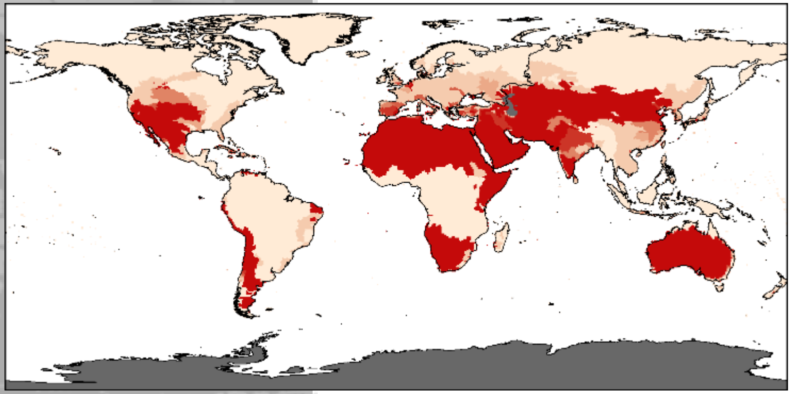
Water Footprint can be corrected by the relative abundance or scarcity of water in the region compared to the global average



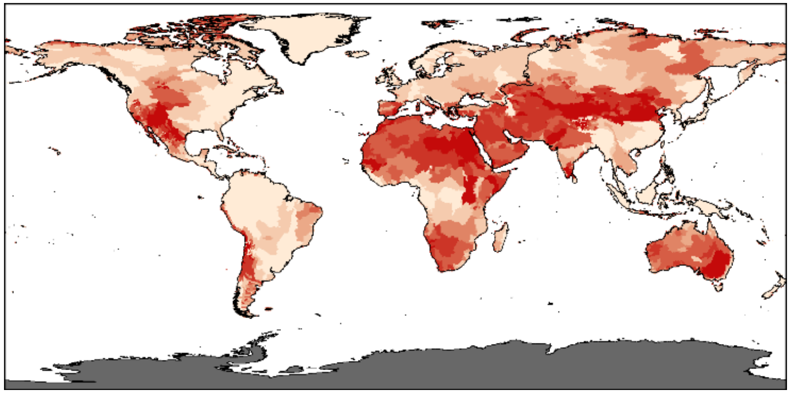
Water Stress Index (Pfister et al., 2009)



Blue Water Scarcity (Hoekstra et al., 2012)

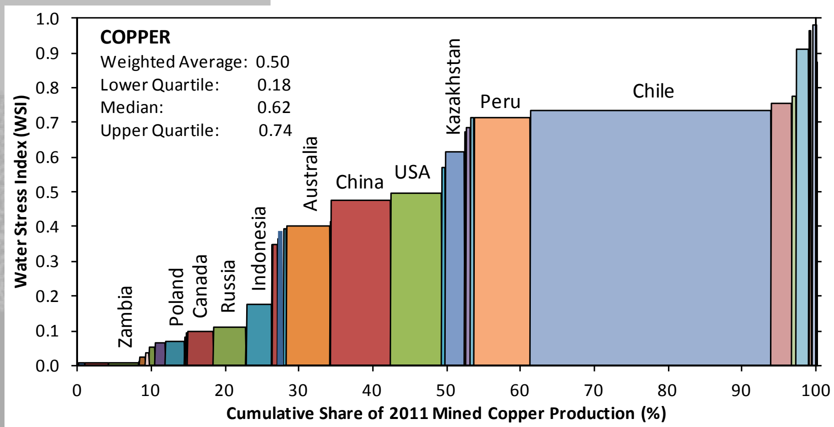


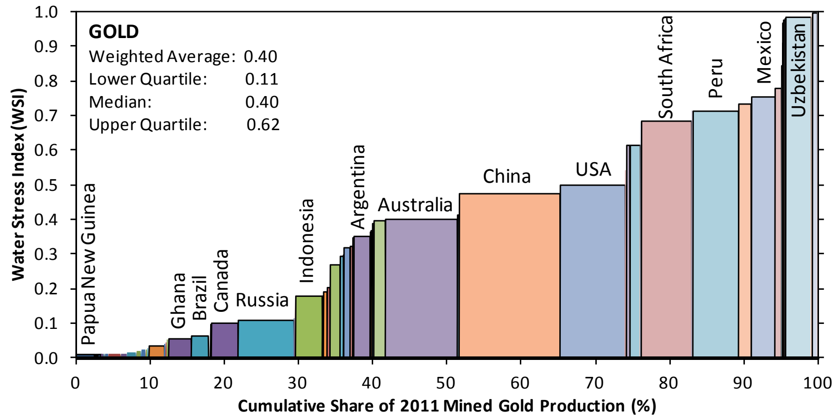
Water Depletion Index (Pfister et al., 2009)

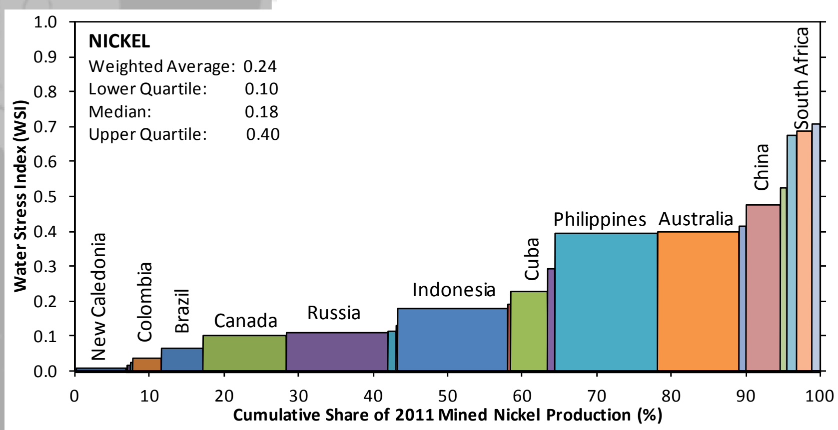


Available Water Remaining (WULCA, 2015)

Water Stress Index where Metals are Mined







A large percentage of the worlds Copper is mined in areas with high Water Stress Indices, while Nickel is largely mined in areas with low Water Stress Indices

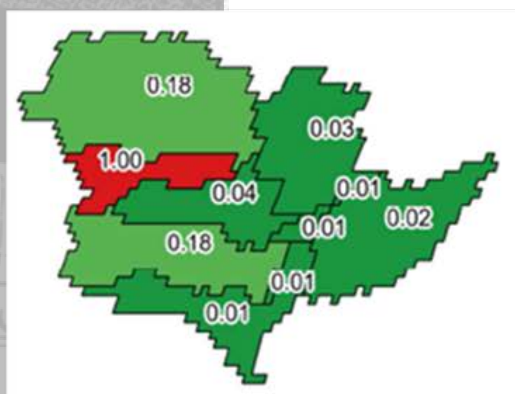
Northey et al., 2014. Minerals Engineering, 69: 65-80.

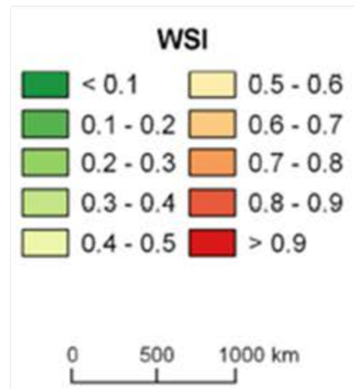
Regional Water Stress Index

When appropriate, the WSI can be developed on a regional scale, providing refined Water Footprints

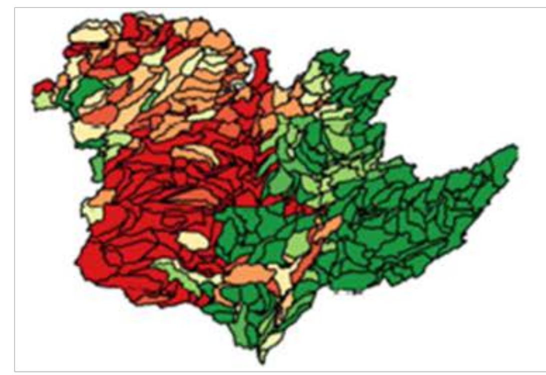
Mississippi Basin

Global model





Sub-watershed model



Pfister et al. 2009. Env. Sci. & Tech. 43.

Scherer et al. 2015. Env. Sci. & Tech. 49.

Take Away

Demonstrate corporate social responsibility: gain trust of key groups

- Corporate image
- Shorter development time
- Lower development cost
- Better relationship with community
- Better relationship with regulators

Company wide understanding of where water risks exist

- Allocate resources to sites at greatest risk
- Identify where to best invest in water saving technology or processes
- Understand sustainability of water use

Improve water security

- Plan for expansions
- Plan for climate change
- Proactively communicate water needs

Take Away (cont'd)

Develop plan to address water management

- Use, reuse, recycling, discharge management
- Emergency plans for drought, flood and shutdown

Indicator of impact the mine might have on the surrounding environment and communities

- Prioritizes actions
- Highlights areas of mutual benefaction with communities
- Manage risks