Boliden Aitik Mine Closure Planning: Overview of the Mine and the Overall Closure Planning Project

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The project has been developed mainly by:
Boliden Mineral AB, Boliden, Sweden
Enchemica LLC, Loveland, Colorado, US
Lorax Environmental Services Limited, Vancouver, BC, Canada
O´Kane Consultants Inc., Saskatoon, Canada
Sweco Environment AB, Sundsvall, Sweden

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● MINES
● SMELTERS
● HEADQUARTER

Aitik

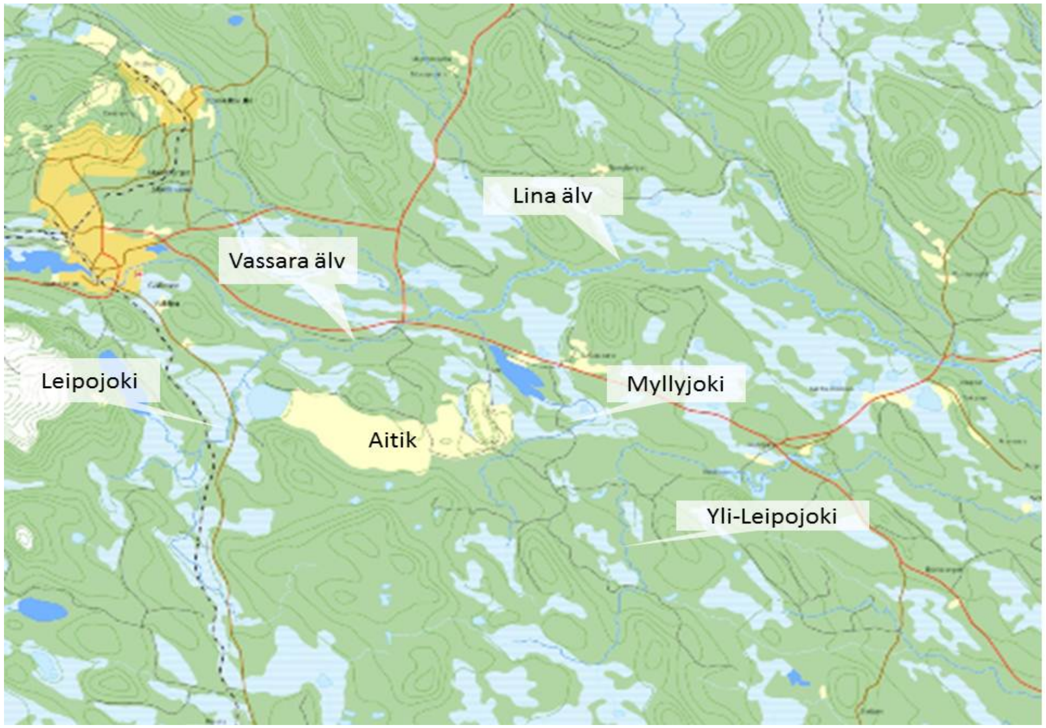
- One of the world's most productive open-pit copper mines
- Copper, gold and silver
- Large volumes and rational methods
- Milled tonnage 2017: 39 Mton
- Employees: 700

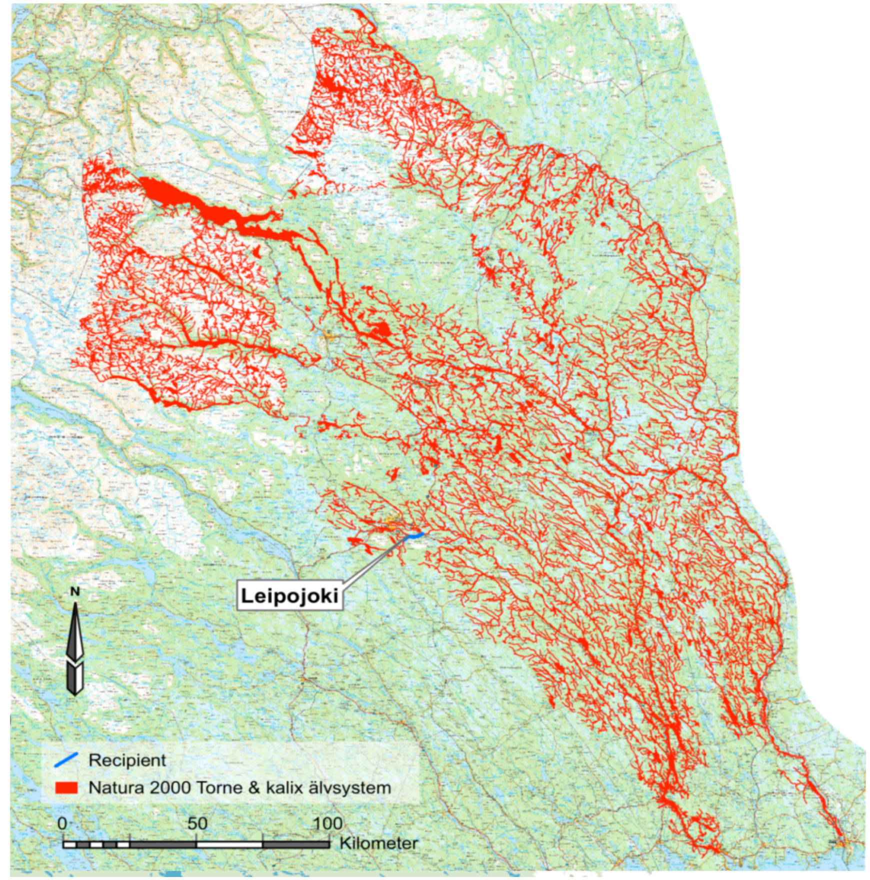
Aitik

The main closure components include:

- 700 ha of waste-rock storage facilities of which 400 ha contain PAG waste-rock while 300 ha contain NAG waste-rock
- 1700 ha tailings facility
- 3 km long, 1 km wide and 525 m deep Aitik open pit
- Salmijärvi pit which is 1 km long, 0.7 km wide and 270 m deep.

Setting





After closure water will ultimately flow from the site to the Lina River, which forms part of the N2000 Kalix & Torne river system

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Complex system

Complex system to analyse at any given time – even more so when predicting future behaviour and results of planned closure measures – with e.g.:

- •Multiple sources
- •Multiple recipients/discharge points
- •Numerous operational and closure alternatives
- •Evolution over time

We need:

- •Systematic approach
- •Solid conceptual models
- •Performance based closure objectives

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Performance based closure objectives

In performance-based design:

- closure measures that make up the closure scenario are selected based on predictions of impact to the recipient environment.
- the relationship between closure measures and predicted impacts to the environment can be quantified by numerical analysis.

This provides an opportunity to develop site-specific performance-based design criteria based on quantification of the acceptable loadings to the recipient environment.

How good is good enough?

- Mine closure has many objectives
- Mines with potential ARD problems: often recipient water quality issues are in focus – the case in Aitik
- The overall closure objectives will be set by what is considered as acceptable recipient water quality

Climate scenario

- Legal requirements
- Recipient flow and quality

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Acceptable discharge flow and quality

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- Site layout and properties
- Material characteristics
- Management options
- Closure options and performance

Recipient water quality objectives

- The European WFD and N2000 implemented into Swedish legislation

- N2000 – extreme burden of proof in order to obtain environmental permits ”beyond reasonable scientific doubt”

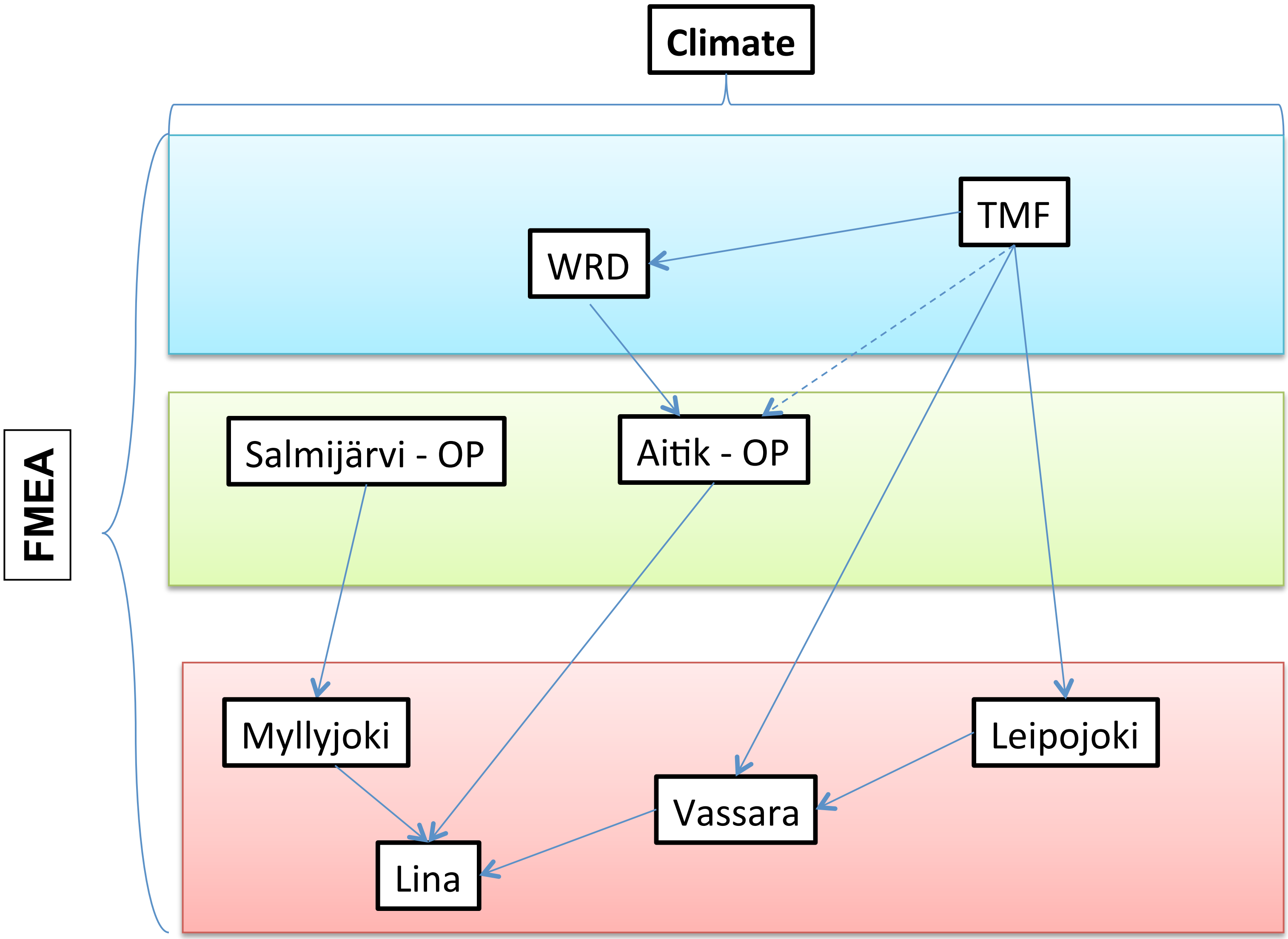
- EQS for water bodies set by HVMFS 2013:19, up-dated 2015-05-01

Substance	Annual average concentration (µg/l)	Maximum concentration (µg/l)
Cd	≤ 0,08 (class 1)	≤ 0,45 (class 1)
	0,08 (class 2)	0,45 (class 2)
	0,09 (class 3)	0,6 (class 3)
	0,15 (class 4)	0,9 (class 4)
	0,25 (class 5)	1,5 (class 5)
Ni	4 bioavailable concentration	34 bioavailable concentration
Pb	1,2 bioavailable concentration	14
As*	0,5	7,9
Cu	0,5 bioavailable concentration	
Cr	3,4 total concentration Cr^{VI}	
U*	0,17	8,6
Zn*	5,5 bioavailable concentration	
*above background		

Used evaluation methodology

- Development of conceptual and quantitative models for each risk object.
- Site investigations and supporting studies to obtain good input data to the models.
- Development of common 200 year climate scenario for all models which affects performance and recipient conditions.
- Evaluation of cover performance for waste-rock facilities (WRF) and tailings management facility (TMF) under selected climate scenario and design.
- Geochemical modelling of leachate water quality and flow over time for the WRF and TMF as a function of waste characteristics and cover performance under selected climate scenario.
- Modelling of Open Pit (OP) filling, pit geochemistry, discharge water quality and flow under selected climate scenario and planned closure measures.
- Modelling of resulting recipient water quality and flow under selected climate scenario and the modelled load from the closed Aitik site over time.
- Modelling of bio-available concentrations and evaluation of results against EQS.
- Failure Modes and Effects Analysis (FMEA)

Methodology

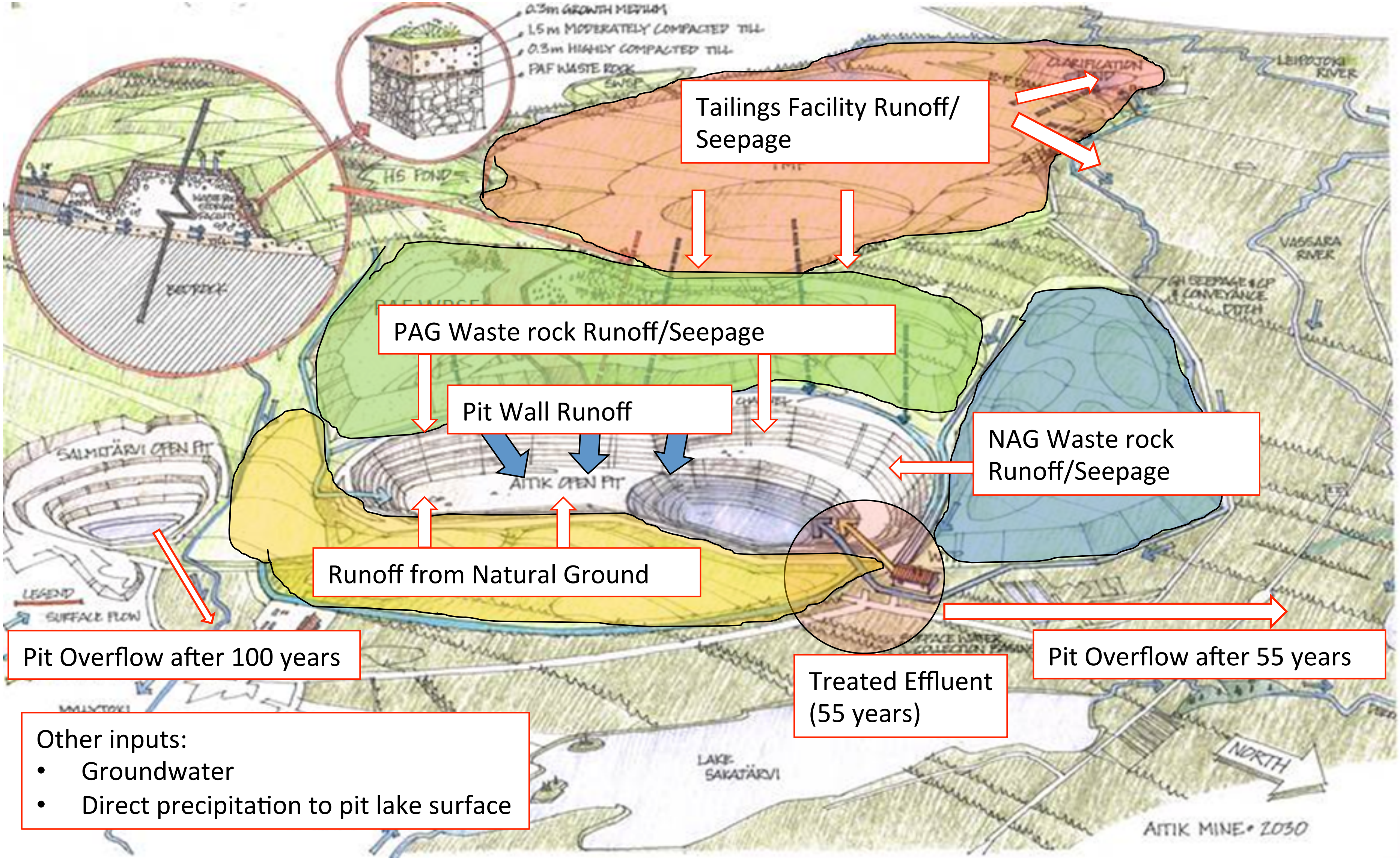


- Site investigations
- Hydrogeology
- Cover performance
- O2-transport
- H2O-transport
- Geochemistry
- Leachate Q & C

- Pit filling period
- Overflow discharge rate
- Physical evolution of water column
- WQ predictions of water column

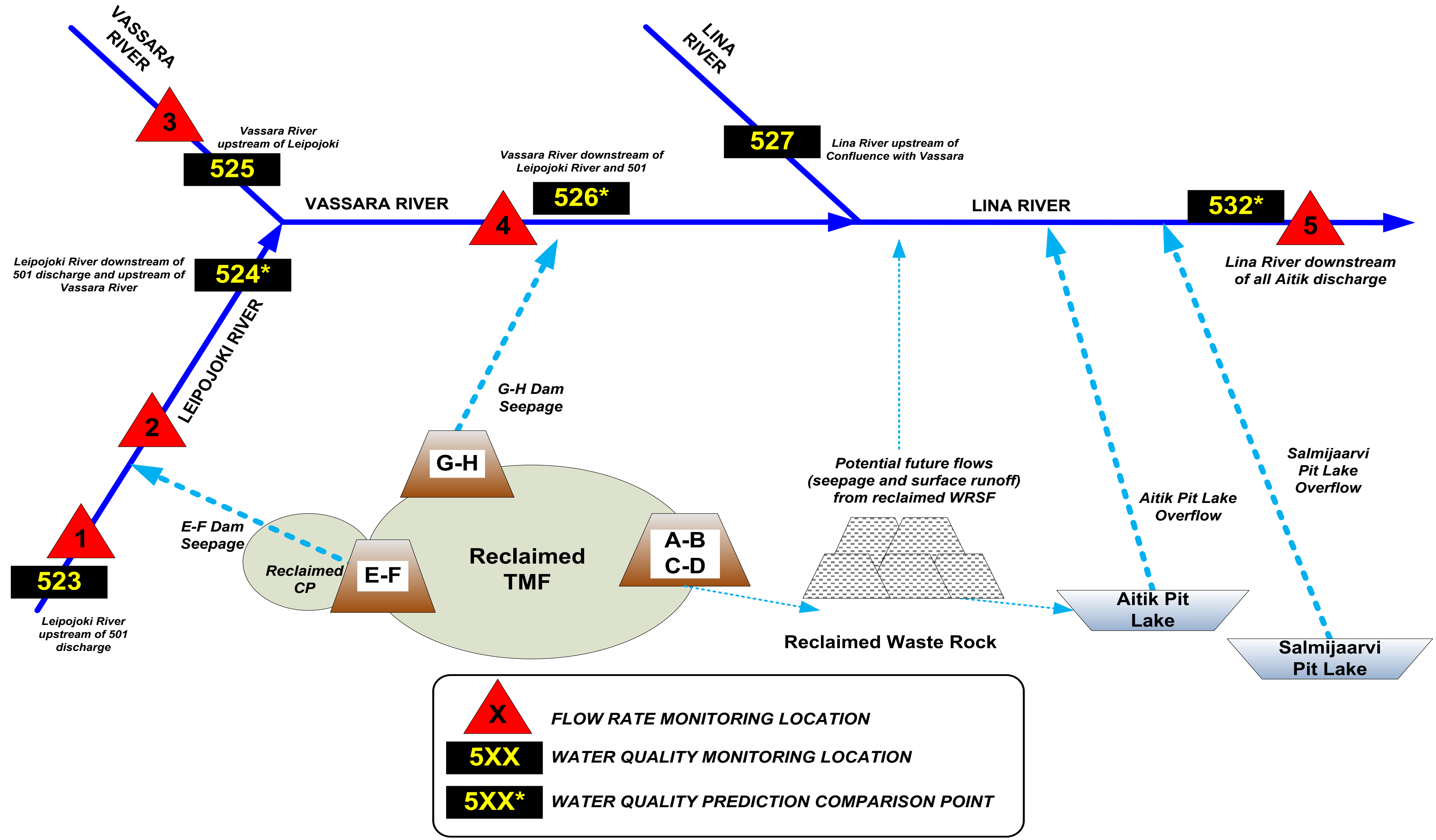
- Resulting recipient flow and quality
- Recipient impact
- Compliance to objectives (EQS)

Base case



Tailings Facility Runoff/ Seepage
PAG Waste rock Runoff/Seepage
Pit Wall Runoff
NAG Waste rock Runoff/Seepage
Runoff from Natural Ground
Pit Overflow after 100 years
Pit Overflow after 55 years
Treated Effluent (55 years)
Other inputs:
• Groundwater
• Direct precipitation to pit lake surface
0.3m GROWTH MEDIUM
1.5m MODERATELY COMPACTED TILL
0.3m HIGHLY COMPACTED TILL
PAF WASTE ROCK
HS POND
BEDROCK
SALMIJÄRVI OPEN PIT
AITIK OPEN PIT
LEGEND
SURFACE FLOW
LEIPOJOKI RIVER
VASSARA RIVER
LAKE SAKATÄRVI
NORTH
AITIK MINE • 2030

Conceptual Model for Flows and Chemical Loads for Closure Conditions in Aitik



Conclusions

- Regulatory environmental quality standards (EQS) for water bodies are available to use as overall performance-based closure objectives in Sweden.
- These EQS provide the opportunity to evaluate the overall requirements for the integrated closure of the Aitik mine.
- An iterative and systematic approach was developed to evaluate the integrated effect of different closure options and to develop a base-case closure scenario that fulfils water quality objectives in the recipient.
- FMEA performed in order to identify risks and to further guide & improve closure planning

Thank you!