4th SADC GROUNDWATER CONFERENCE
10th -12th of November 2021
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# Evaluating large-scale MAR in Botswana based on water supply security, cost-effectiveness, and sustainability

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# Botswana

- Low rainfall (200-400 mm/yr)
- High rates of potential evapotranspiration (>2 500 mm/yr)
- Limited natural groundwater recharge
- Water stressed environment
- Increase in water demand
- Need for:
  - IWRM
  - Water losses measures
  - Water saving technologies
  - Water re-use and recycling


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# Feasibility study for MAR at Palla Road Wellfield

Project main objective:

Broadly appraise the feasibility of MAR for the NSC-system using borehole injection focusing on the confined Palla Road aquifers to improve the sustainability of the groundwater resource in the area and also as an act to balance groundwater storage systems to allow for both sustainable and additional yields through borehole injections

Comprehensive study including:

- Hydrochemical assessment including geochemical modelling
- Drilling of new boreholes
- Borehole injection tests
- Numerical groundwater modelling
- NSC-system modelling
- Preliminary and schematic design

# Feasibility study for MAR at Palla Road Wellfield

Tasks related to evaluating MAR from a system as well as local hydrogeological perspective:

- Develop and apply a comprehensive and dynamic water balance model (water supply security model, WSSM)
- Simulate and show the predicted water shortage over time
- Combine the water balance model with numerical groundwater model (SPRING)
- Evaluate the sustainability of MAR scenarios using Multi-Criteria Analysis (MCA), incl. economic, environmental, social, technical and reliability (risk) performance

Collaboration

- Botswana Department of Water and Sanitation
- Sweco International
- Chalmers University of Technology
- WCS (Botswana), GEOSS (RSA)
- Botswana Water Utilities Corporation

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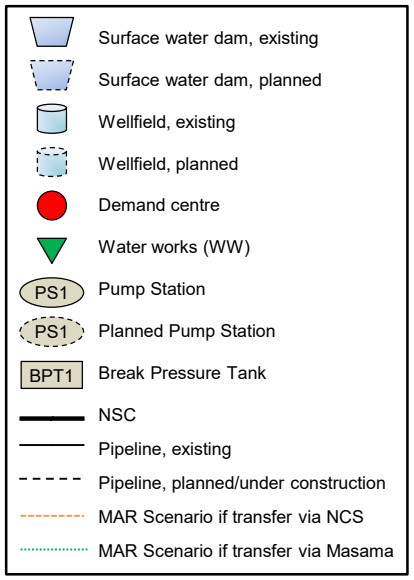
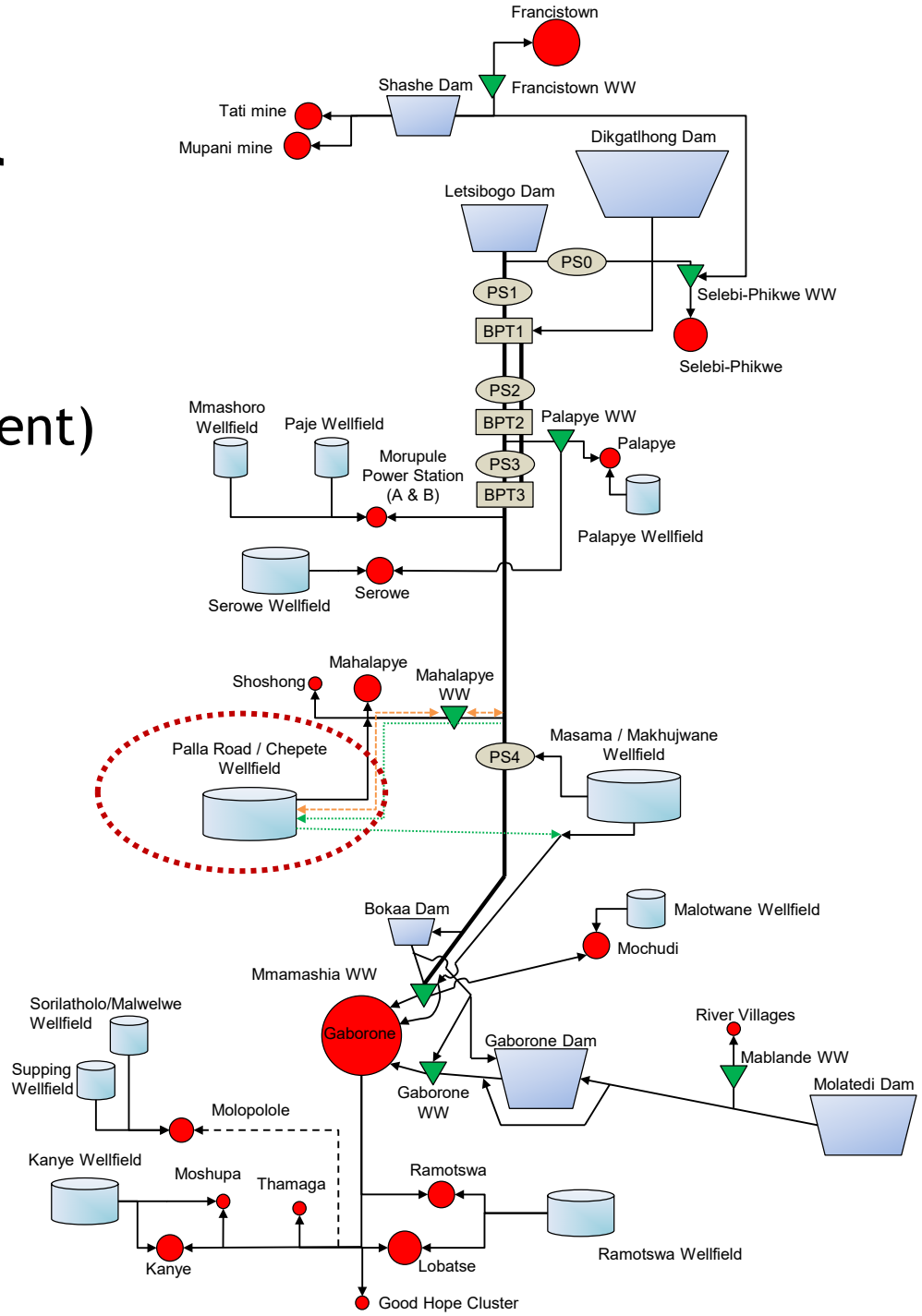
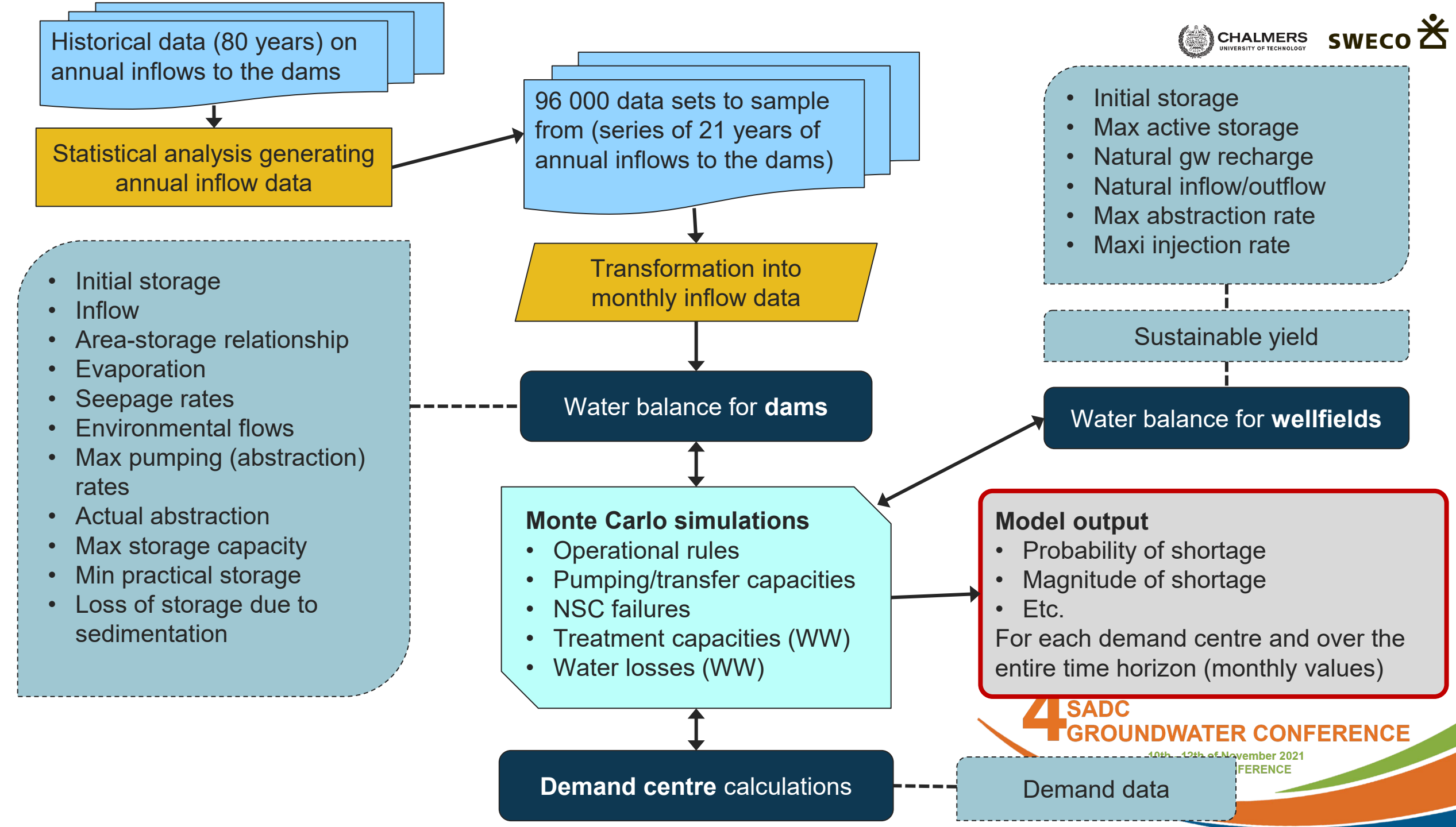
# Water Supply Security Model (WSSM)

- Probabilistic (stochastic) and dynamic (time-dependent)
- Incl. all major components of the supply system
- Periods (time step 1 month)
  - Pre-feasibility study 2013-2035
  - Feasibility study 2020-2040
- North-South Carrier (NSC) System
  - A bulk water supply system
  - 360 km pipeline
  - 6 surface water dams
  - 9 wellfields
  - 7 water works
  - 18 demand centres




Historical data (80 years) on annual inflows to the dams
Statistical analysis generating annual inflow data
96 000 data sets to sample from (series of 21 years of annual inflows to the dams)
Transformation into monthly inflow data
Initial storage
Inflow
Area-storage relationship
Evaporation
Seepage rates
Environmental flows
Max pumping (abstraction) rates
Actual abstraction
Max storage capacity
Min practical storage
Loss of storage due to sedimentation
Water balance for dams
Monte Carlo simulations
Operational rules
Pumping/transfer capacities
NSC failures
Treatment capacities (WW)
Water losses (WW)
Demand centre calculations
Initial storage
Max active storage
Natural gw recharge
Natural inflow/outflow
Max abstraction rate
Maxi injection rate
Sustainable yield
Water balance for wellfields
Model output
Probability of shortage
Magnitude of shortage
Etc.
For each demand centre and over the entire time horizon (monthly values)
Demand data
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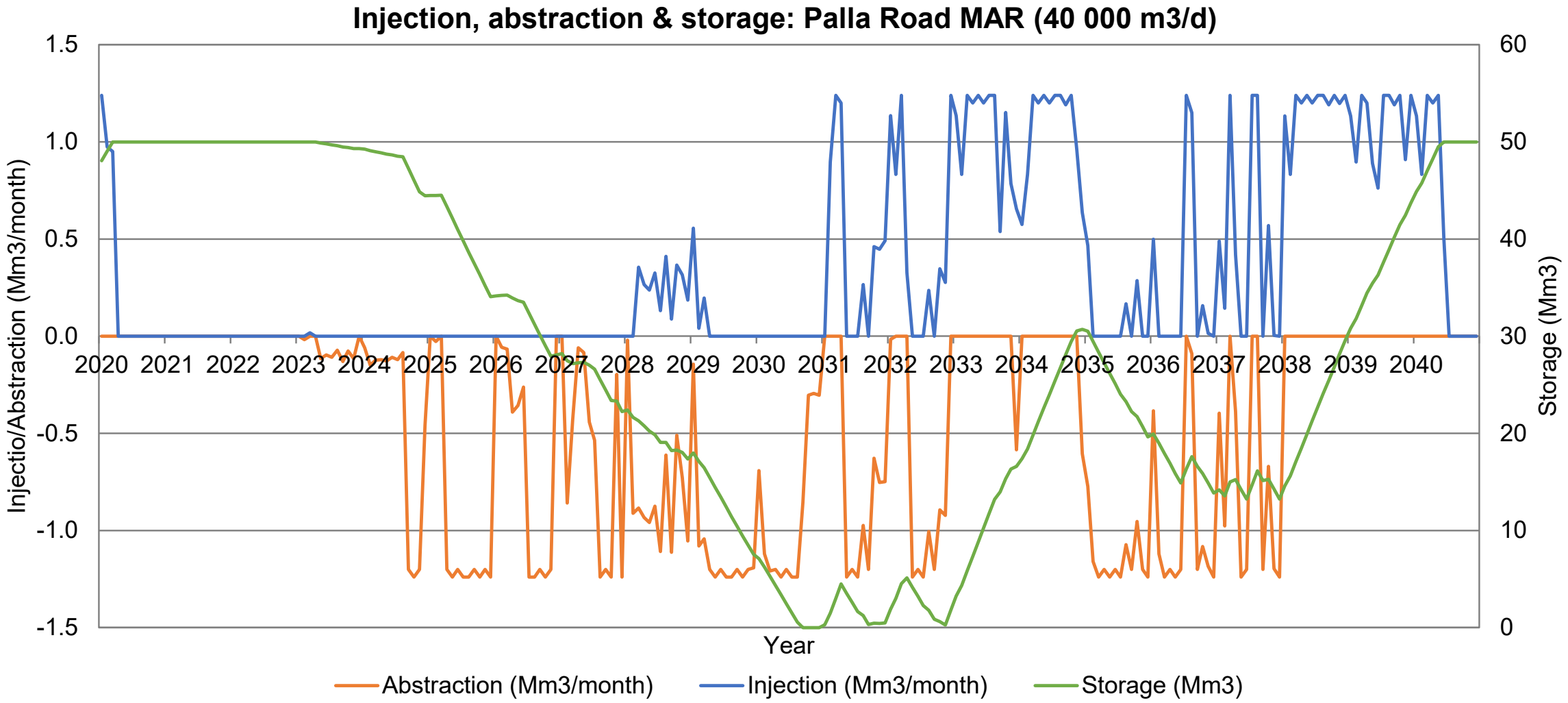
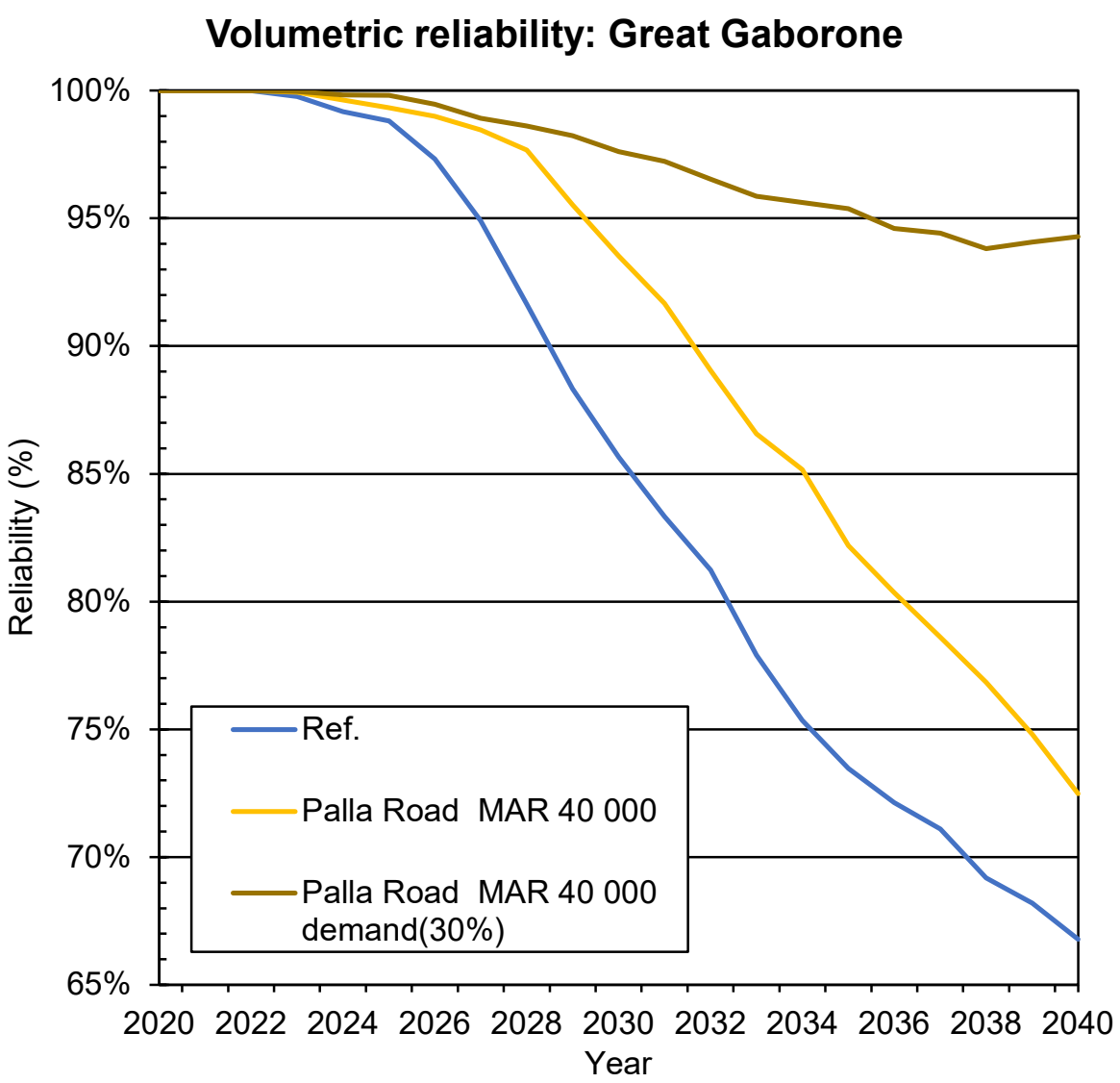
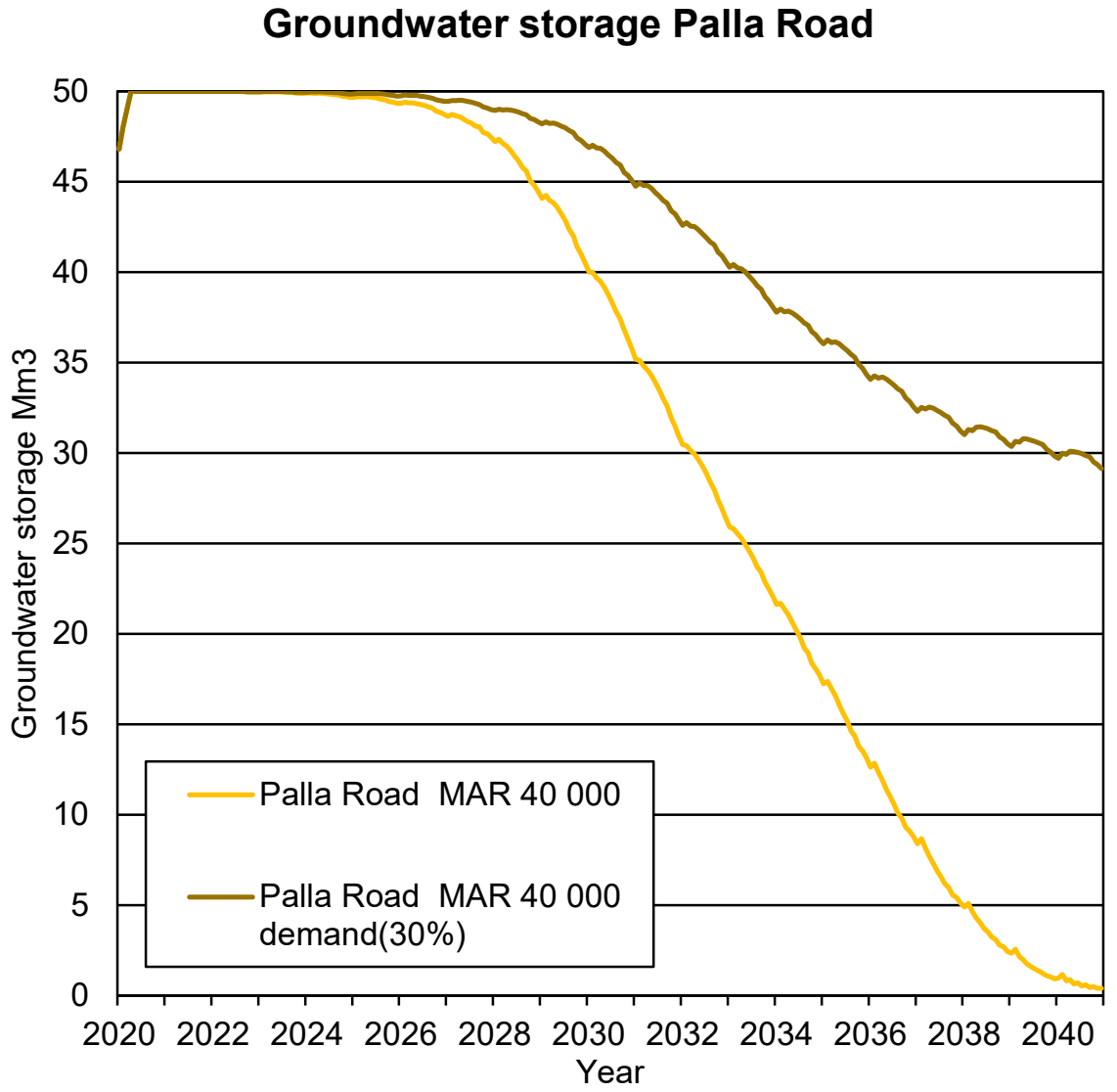
# Stochastic time series analysis



# WSSM results



| Key criteria | Sub-criteria | Description |
|---|---|---|
| **Technical** | Water supply security | Water supply security in NSC |
| | Long-term operation reliability | Long-term operational reliability |
| **Economic** | Costs for infrastructure and wells | The expected investment costs |
| | Operation and maintenance | The expected operation and maintenance costs |
| | Societal economic benefits due to change in water supply security | The expected total economic effects in society, such as production in goods and services |
| **Environmental** | Impact on aquatic systems | Effects on aquatic ecosystem viability due to reduced baseflow to Limpopo |
| | Impact on terrestrial systems | Effects on terrestrial ecosystem viability due to e.g. land use changes |
| | Energy use at construction | Total energy use at construction |
| | Energy use during operation | Total energy use at production and distribution of drinking water |
| | Materials for construction | Use of non-renewable materials for construction |
| | Use of chemicals | Effects on total chemical use in water production |
| **Social** | Consumer's trust | Effects on consumers' trust in the water providers |
| | Equity | Effects on equity regarding if some consumers and/or municipalities are made worse off by the scenario |
| | Health | Effects on human health due to access to secure drinking water |
| | Access and participation | Effects with regard to public access and participation in water supply, including local job opportunities |
| **Risks** | Competing industrial use | Potential of competing industrial use/demand of water, e.g. from mines |
| | Competing agricultural use | Potential of competing agricultural use/demand of water |
| | Contamination risks during construction | Risk for contamination during construction by e.g. hydrocarbons |
| | Contamination risik during operation | Risk for contamination during operation from e.g. agriculture or transports of hazardous goods |

# Conclusions

- The Water Supply Security Model
  - Provides decision support for more efficient and sustainable use of water resources
  - A practical tool for evaluating a wide variety of scenarios and measures
- Connecting MAR wellfields improves water supply security
- MAR provides a more long-term sustainable use of the Palla Road aquifer, due to less depletion of storage over time
- The increased demand for water reduces the potential of MAR being effective, since time for injection is limited
- Sustainability analysis of MAR-alternatives (scenarios) at Palla Road
  - MCA provides a structured comparison of MAR relative to non-MAR operation
  - MAR provides a more sustainable operation due to e.g. improved water supply security, resource utilization and consumer wellbeing