

Water Balance Study and Validation of Reservoir Releases for Merowe Dam

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Introduction:

- One of the studies proposed by MDEC
- On the main Nile near the 4th cataract,
- Largest storage capacity in Sudan 12.5 Bm³
- Largest installed power 1250 MW
- Accurate reservoir water balance is crucial for proper reservoir operation & water management



Objectives:

Accurately validate all components of the water balance of Merowe reservoir, specifically:

- Validation of reservoir inflows at Elgoro station
 - Discharge measurement equipment & procedure
 - Computation method (rating curves)
 - Flow time series (daily, 10-days, monthly and annual)
 - Upstream stations Barbar, (Tabya + downstream Girba dam);

Methodology:

- ✓ Collection of historical hydrological, reservoir/dam data
- ✓ Limited validation discharge measurements;
- ✓ Development of rating curves for all stations;
- ✓ Validation of inflow discharge data at Elgoro;
- ✓ Validation of reservoir releases at Elhesai;
- ✓ Validation of gates equations;
- ✓ Validation of reservoir's evaporation rates;
- ✓ Conduction of reservoir balance using the equation;
- ✓ Development of User Interface.

8	Computed daily discharges from automatic gauge at Elhesai	2015
Water levels		
9	Water levels at Barbar,	200
10	water level at Elgoro	200
11	water level at Elhesai	200
12	water level at Dongola	200
13	Upstream reservoir water levels	2009
14	Downstream reservoir water levels	2009
Reservoir Characteristics		
15	Gates specifications, dimensions, bottom level	pro
16	Low Level Sluice gates' equations and tables	pro
17	Bottom outlets equations and charts	pro
18	Overflow spillway equations /charts / tables	pro
19	Bathymetric survey results (Level/Volume, Level/surface area relationships)	pro
Operation		
20	Daily Spillway gates openings	201
21	Daily Bottom outlets openings	201
22	Daily Overflow spillway openings	201
23	Generated power (GWH)	201
24	Hourly power station data (Date& time, Stroke, Net head, Power generated, Discharge and Efficiency)	201
Evaporation		
25	Monthly average evaporation at Dongola	196
26	Monthly average evaporation at Karima	195
27	Monthly/daily Evaporation rates (mm/day)	pro
28	Monthly average evaporation from open water	pro
29	Evaporation losses (Mm ³ /day)	201
Climatic data		

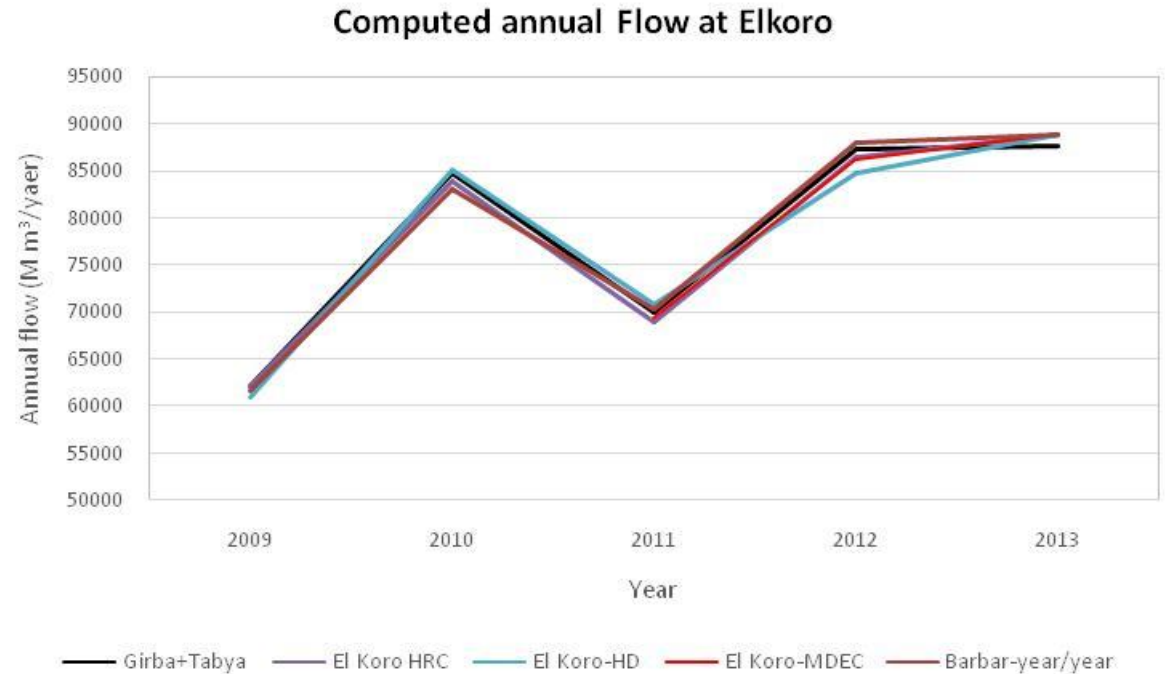
Results:

- Discharge measurements conducted at:
 - ✓ Elgoro station (inflow)
 - ✓ Barbar station
 - ✓ Ehesai (Release)
- No significant difference in measured discharges (<5%)



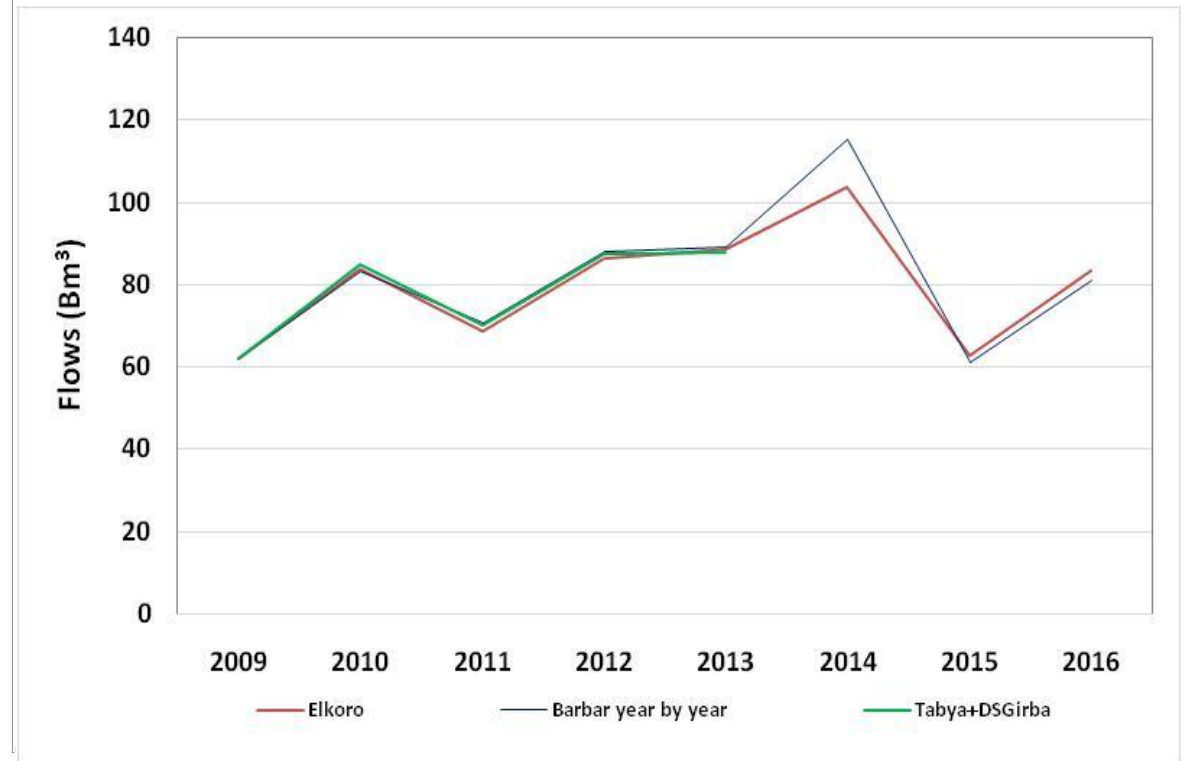
Inflows at Elgoro station:

- Discharge measurements no significant diff.
- Rating curves of MDEC & HRC are identical;
- No diff. in computed daily, 10-days, monthly and annual discharges (MDEC, HRC & HD);



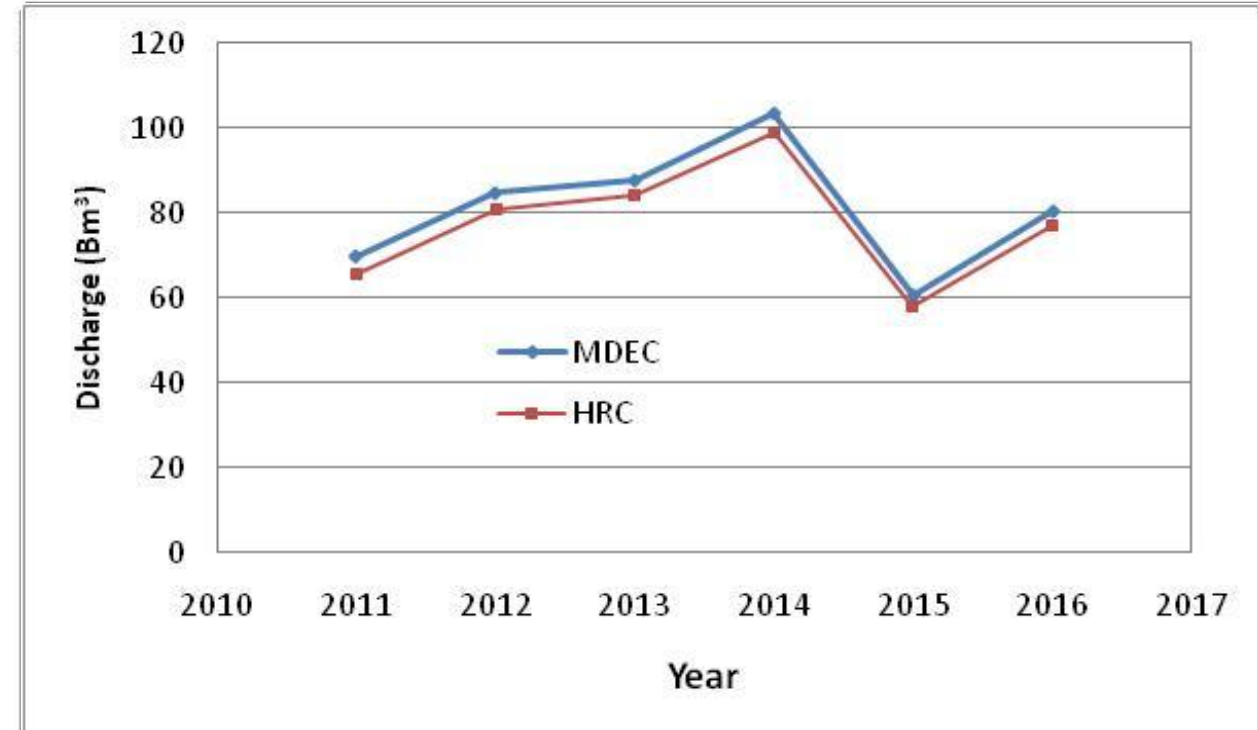
Barbar station:

- Scatter in rating curve at high discharges
- No differences in daily flows bet. HRC & T+DSG
- Some differences at high flows daily, and monthly bet. HD & T+DSG
- Flows at Barbar less than (DS El-Girba + Tabya) computed HD
- No difference when flows at Barbar computed year/year



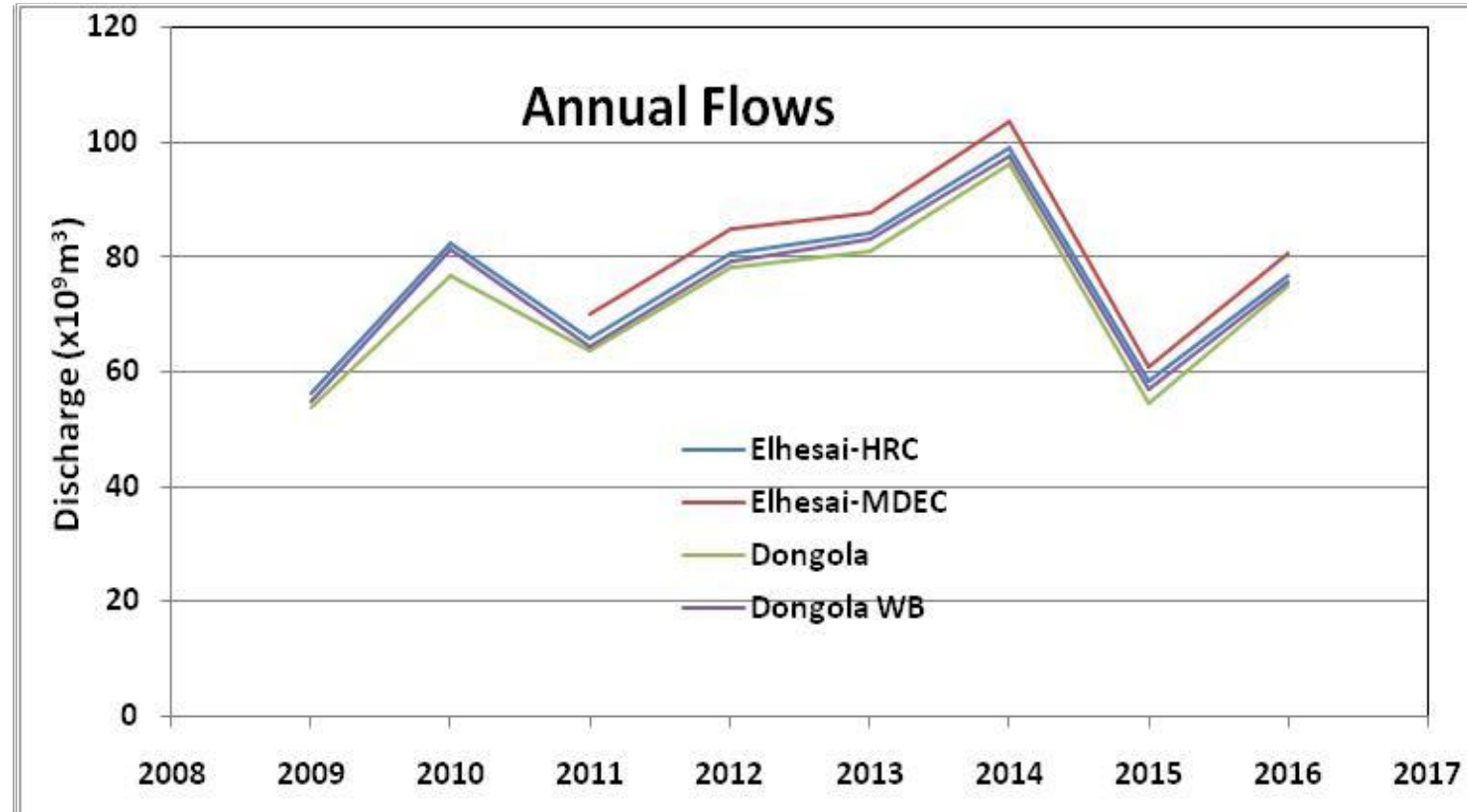
Releases at Elhesai station:

- Discharge measurements ADCP good
- Procedure for deriving rating curve is good
- Scatter in rating curve high flows;
- Degrading measuring section
- diff. in computed daily, 10-days, monthly and annual discharges (HRC & MDEC);



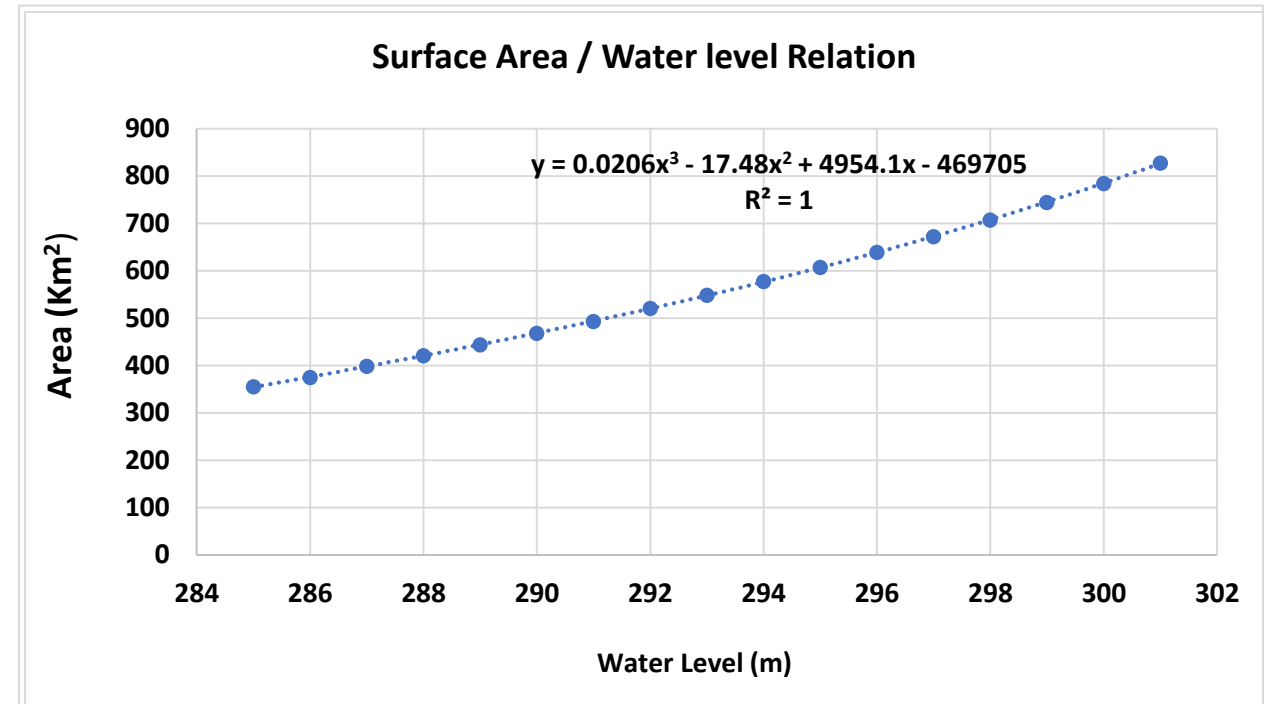
Dongola station:

- Dongola rating curve is good
- Stable measuring section
- Elhesai-HRC > Dongola (0.7 - 5.7%)
- Elhesai-MDEC > Dongola (5.6-9.2%)



Reservoir volume/area-level relationships

- A bathymetric survey conducted in 2014
- Based on 2003 Bathymetric survey
- Operation level between 285m – 301m



Reservoir Volume:

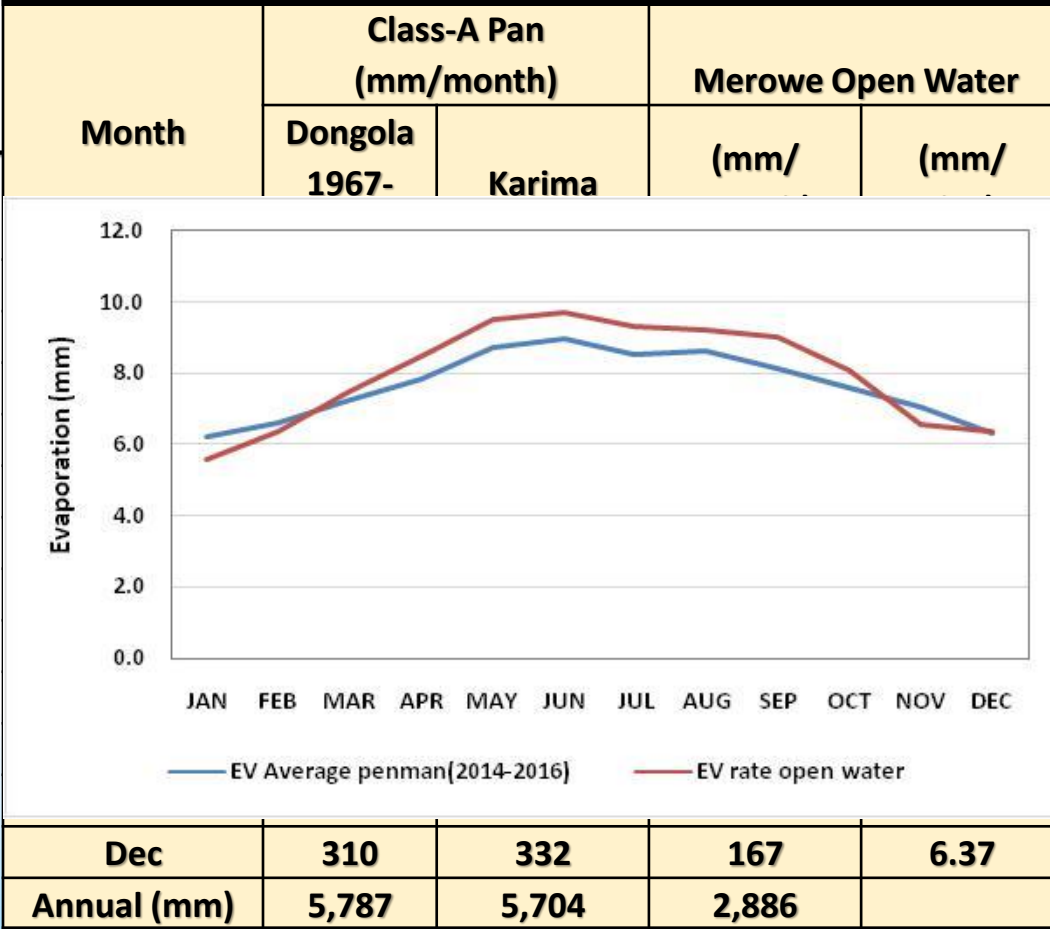
$$V(\text{Mm}^3) = 0.216x^3 - 176.2x^2 + 47947x - 4E+06, R^2=1$$

Reservoir Surface Area:

$$A(\text{km}^2) = 0.020x^3 - 17.48x^2 + 4954.x - 46970, R^2=1$$

Reservoir evaporation

- Monthly evaporation rates were provided by MDEC
- Monthly /daily evaporation rates from reservoir- Class-A pan records of Dongola, and Karima → open water
- Validated Penman Method (1948).
- Daily reservoir evaporation is the product of the daily evaporation rate and the surface area of the reservoir



Reservoir Water Balance:

$$Q_{in} + R = Q_{out} + Abs + E + Seep + \Delta s$$

Q_{in} = Inflow at Elgoro,

R= Direct rainfall on the reservoir (≈ 0),

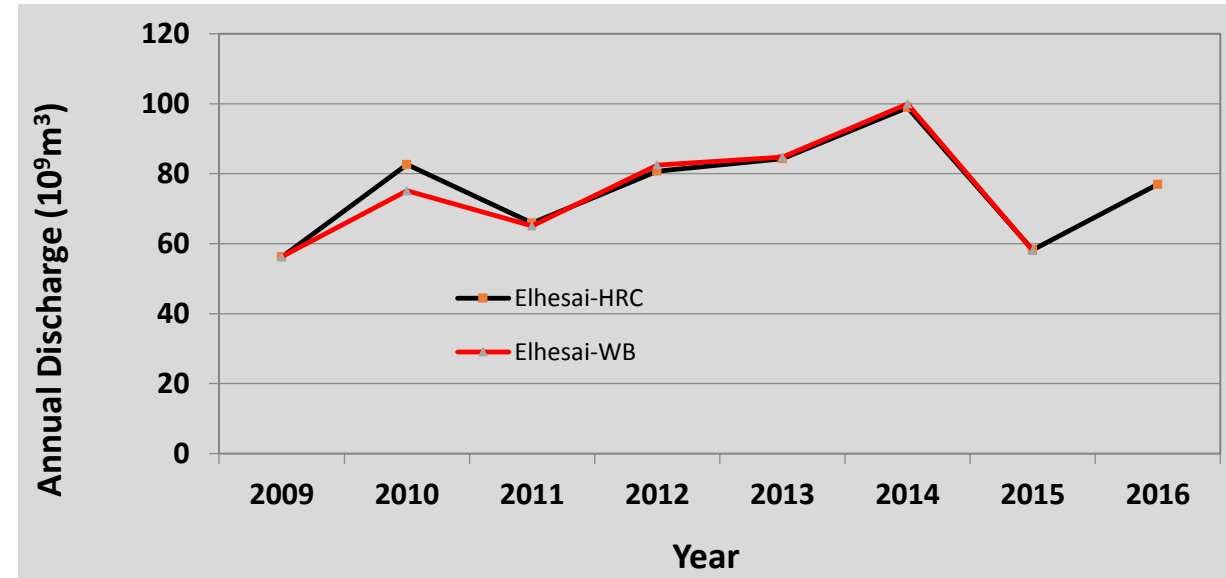
Q_{out} = Release at Ehesai,

E= Evaporation losses,

Abs =Abstraction by irrigation schemes upstream reservoir, **Annual Reservoir Water Balance**

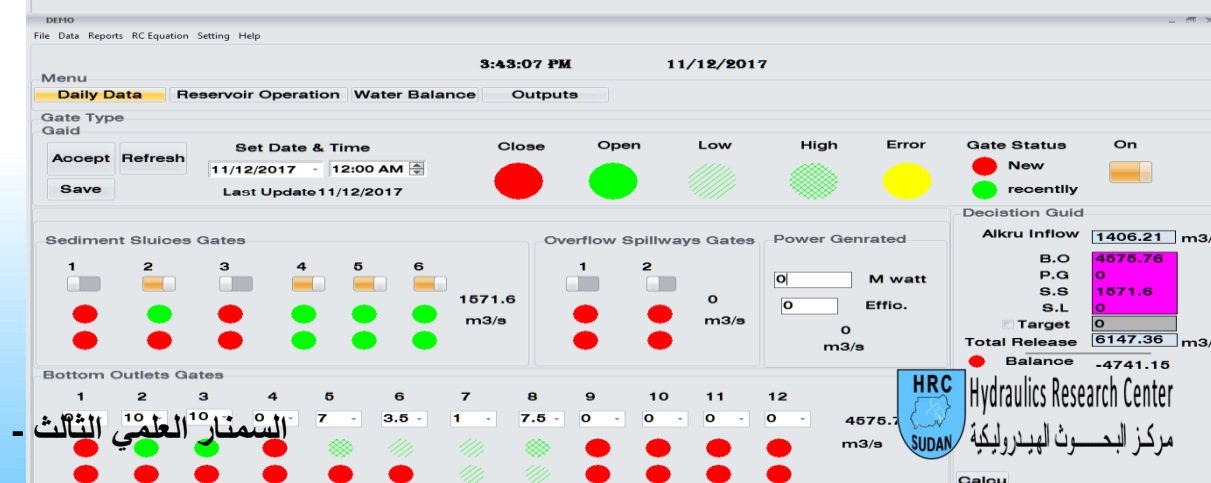
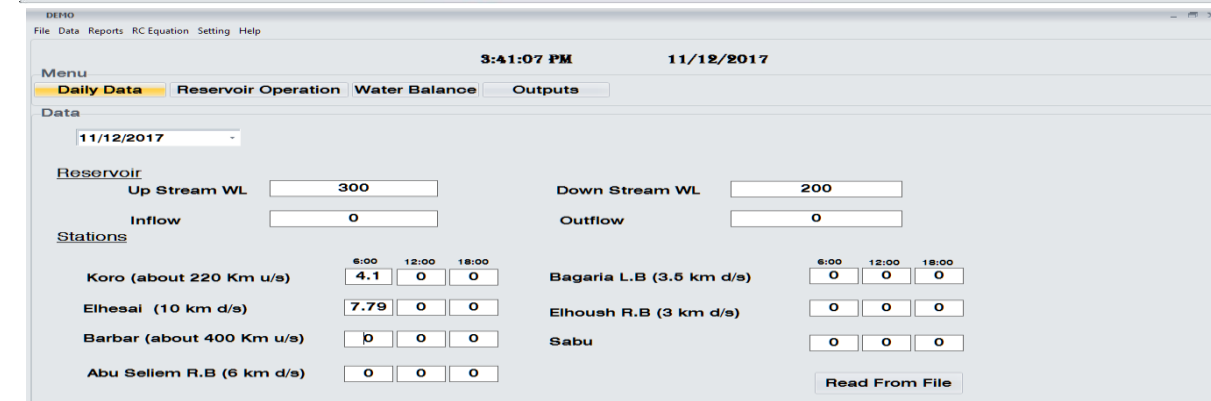
Seep= Seepage losses,

Δs = change in storage content of the reservoir.



Graphical User Interface

- Developed for Merowe dam operation.
- Can be modified for other dams
- Main components are:
 - Daily operation data entry
 - Reservoir operation
 - Water balance
 - Output screen
 - Bulletin
 - Time series management
 - Graph
 - Histograms



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Conclusions

1. Elgoro station

- Discharge measurements at Elgoro agreed with HRC
- MDEC method of deriving rating curves at Elgoro is compatible with HRC method.
- Elgoro measuring section is stable
- No sig. diff. in computed discharges by MDEC & HRC for Elgoro
- MDEC discharge series for Elgoro is reliable

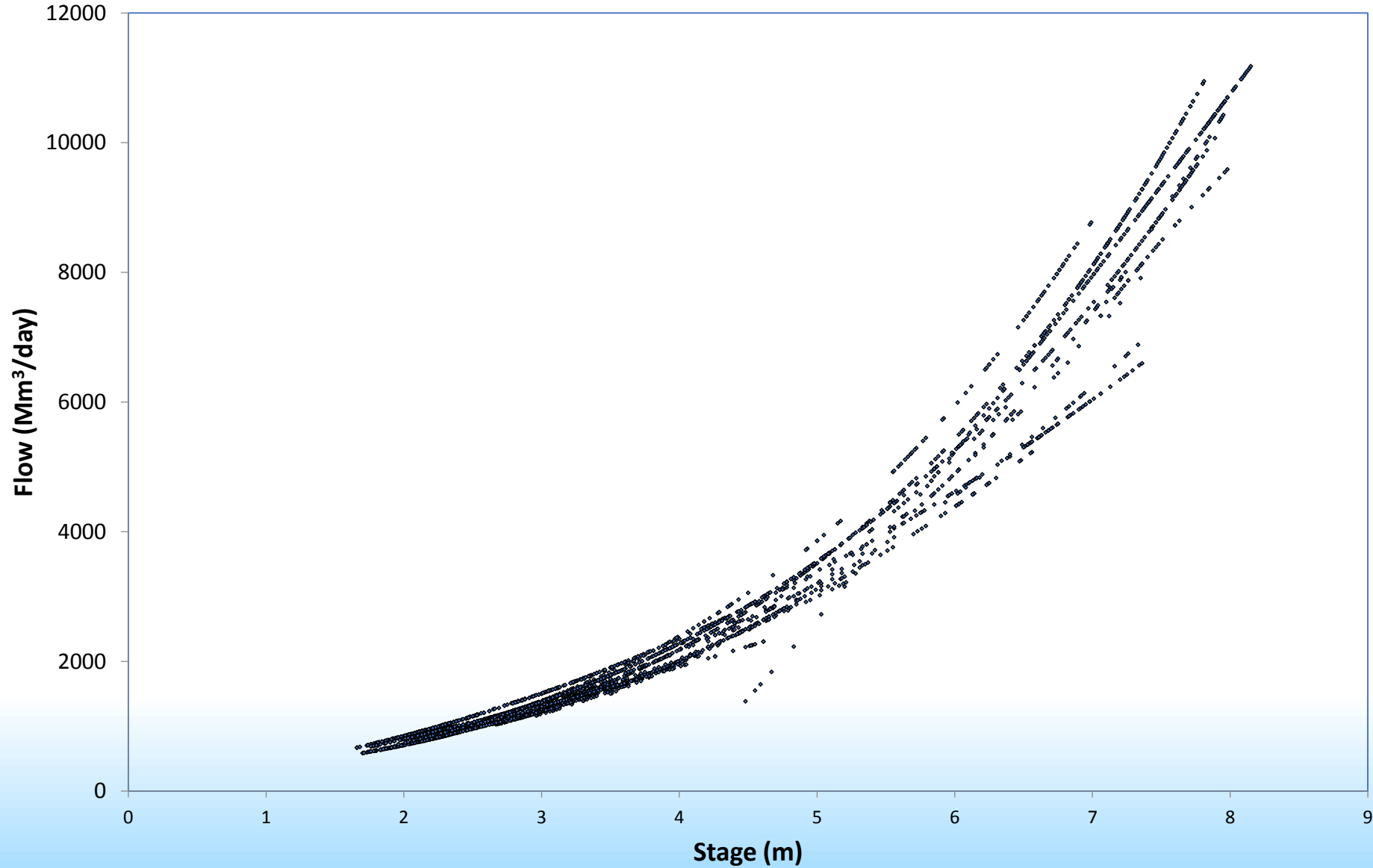
2. Elhesai station

- Discharge measurements at Elhesai agreed with HRC
- MDEC method of deriving rating curves at Elhesai is compatible with HRC method.
- Elhesai measuring section is degrading
- No sig. diff. in computed discharges by MDEC & HRC for Elhesai
- MDEC discharge series for Elhesai is affected by measuring section degradation
- Annual water balance for the reservoir is good

3. Developed UI will enhance the daily operation of the dam

Thank you

Rating curve for computed flow vs stage at Barbar by HD (2007-2017)



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