International Training Workshop on Integrated Sediment Management in River Basin
November 5-10, 2018
Beijing, China

Sedimentation and mitigation measures in Sudan

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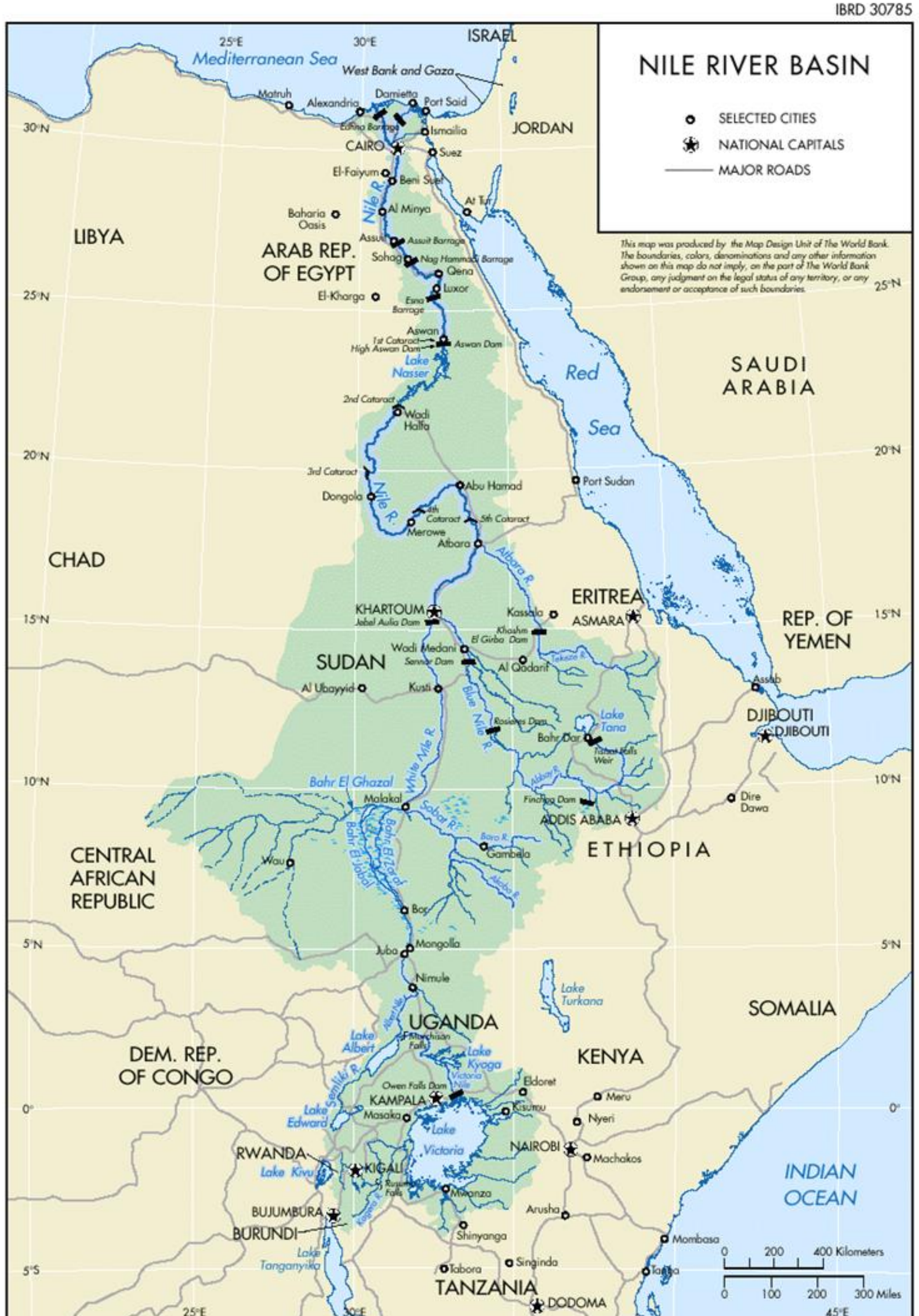
Nile River Basin



Water Resources in Sudan

Water Resources	Quantity (bcm)	Constraints
Sudan present share from the Nile Waters Agreement	20.5	Seasonal pattern coupled with limited storage vessels. Expected to be shared with riparian.
Wadis Waters	5 to 7	Highly variable, short duration flows which are difficult to monitor or harvest. Some are shared with neighbors
Renewable Groundwaters	4.0	Deep water entailing high cost of pumping. Remote areas of weak infrastructure
Present Total	30.0	
Expected from reclamation of swamps	6.0	Capital investment need with considerable social and environmental cost.
Total	35.5 to 37	

Sudan water Demand

The water demand projection as given by the MIWR within the Long Term Agricultural Strategy (2002-2027)

Water demands (BCM)

Year	Agriculture	Water Supply	Animals & Others	Total
2010	27.1	1.1	3.9	32.1
2020	32.6	1.9	5.1	39.6
2025	40.3	2.5	5.3	48.1
2027	42.5	2.8	7.3	52.6

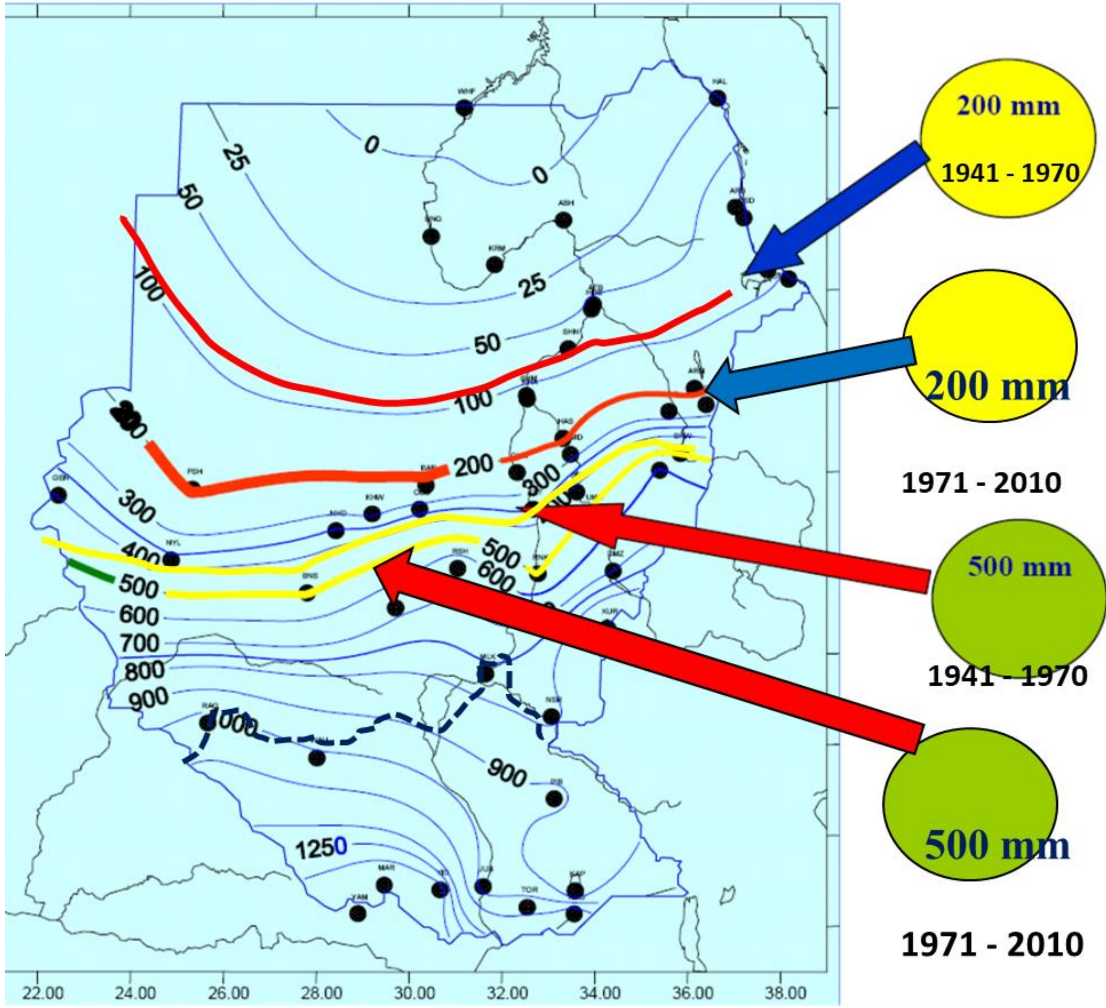
water demand will exceeds the available water resources

Stresses on Water Resources

- *Population growth (More Certain!)*
- *Climate Impact (Uncertain!)*

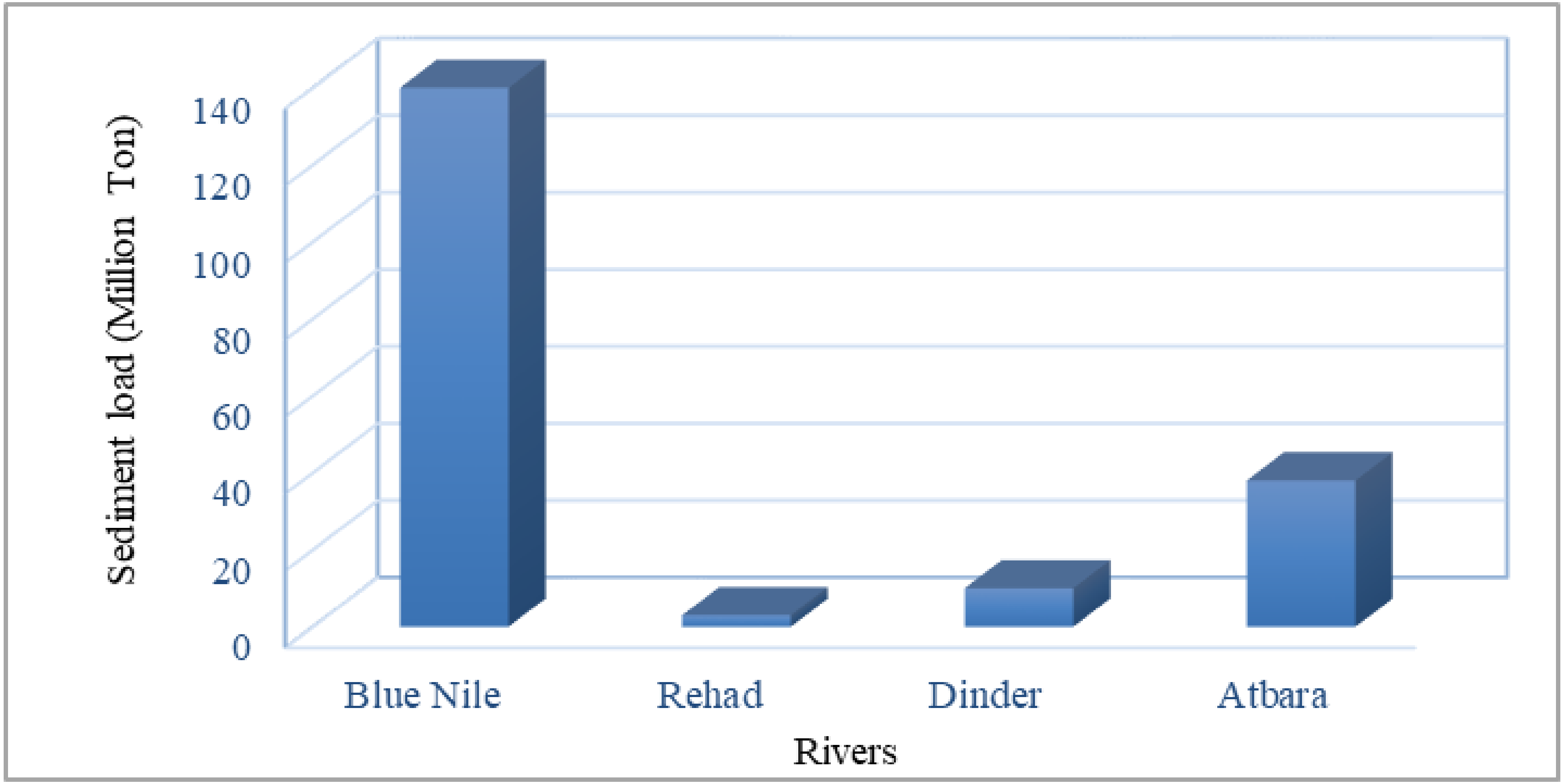
Challenges

- **Reliable Water Supply**
  more storage is needed
  Preserve Reservoir Storage
- **Increases water use efficiency**
- **sustainable development of water resources**

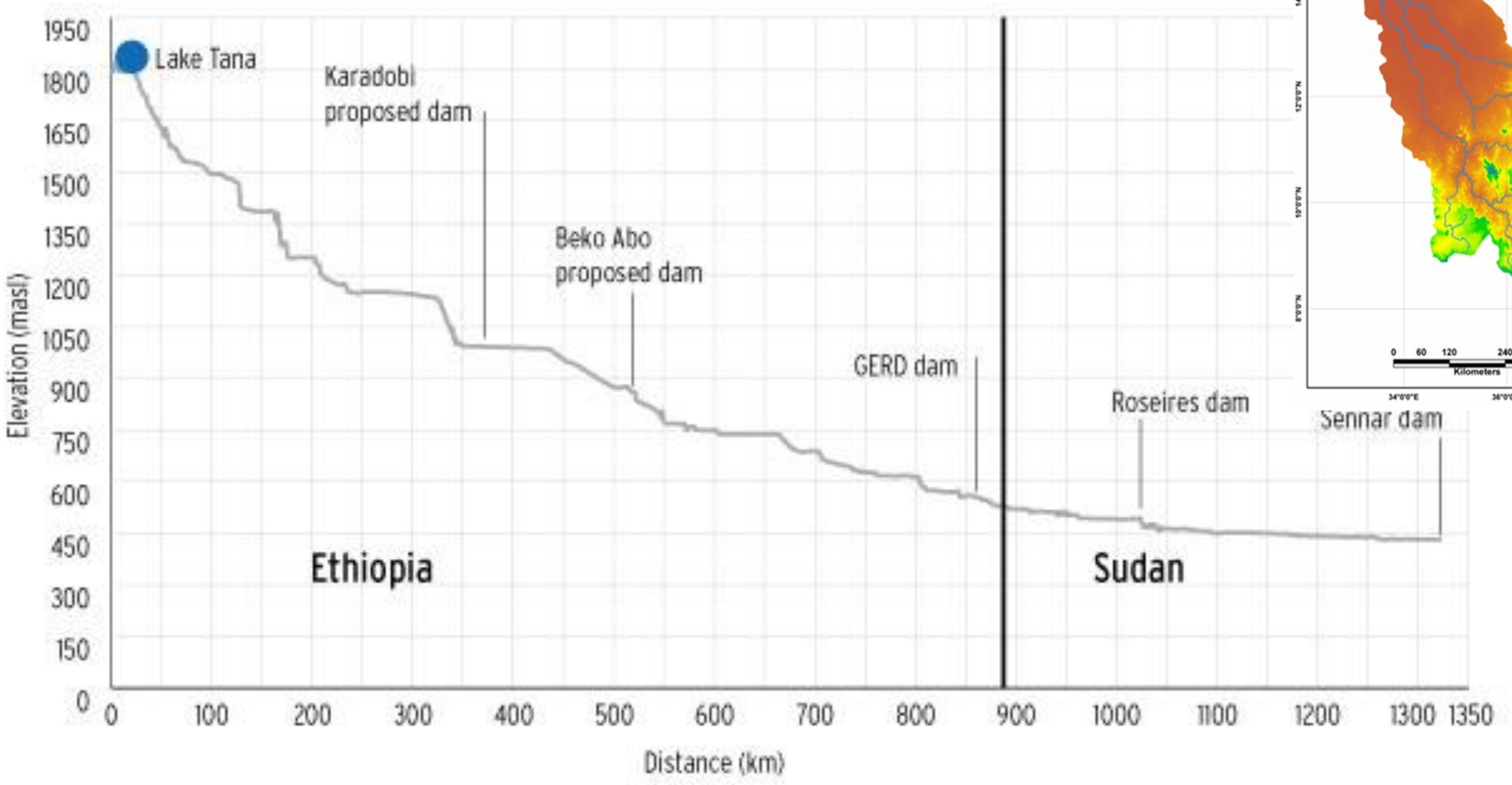


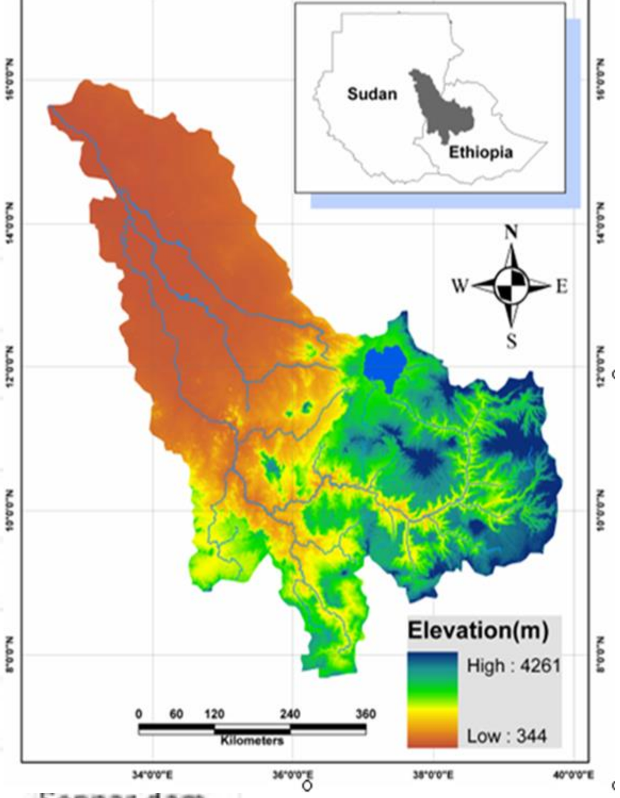
Sediment management is playing a key role in achieving ‘water security’

Total annual sediment load (million tons) for different rivers

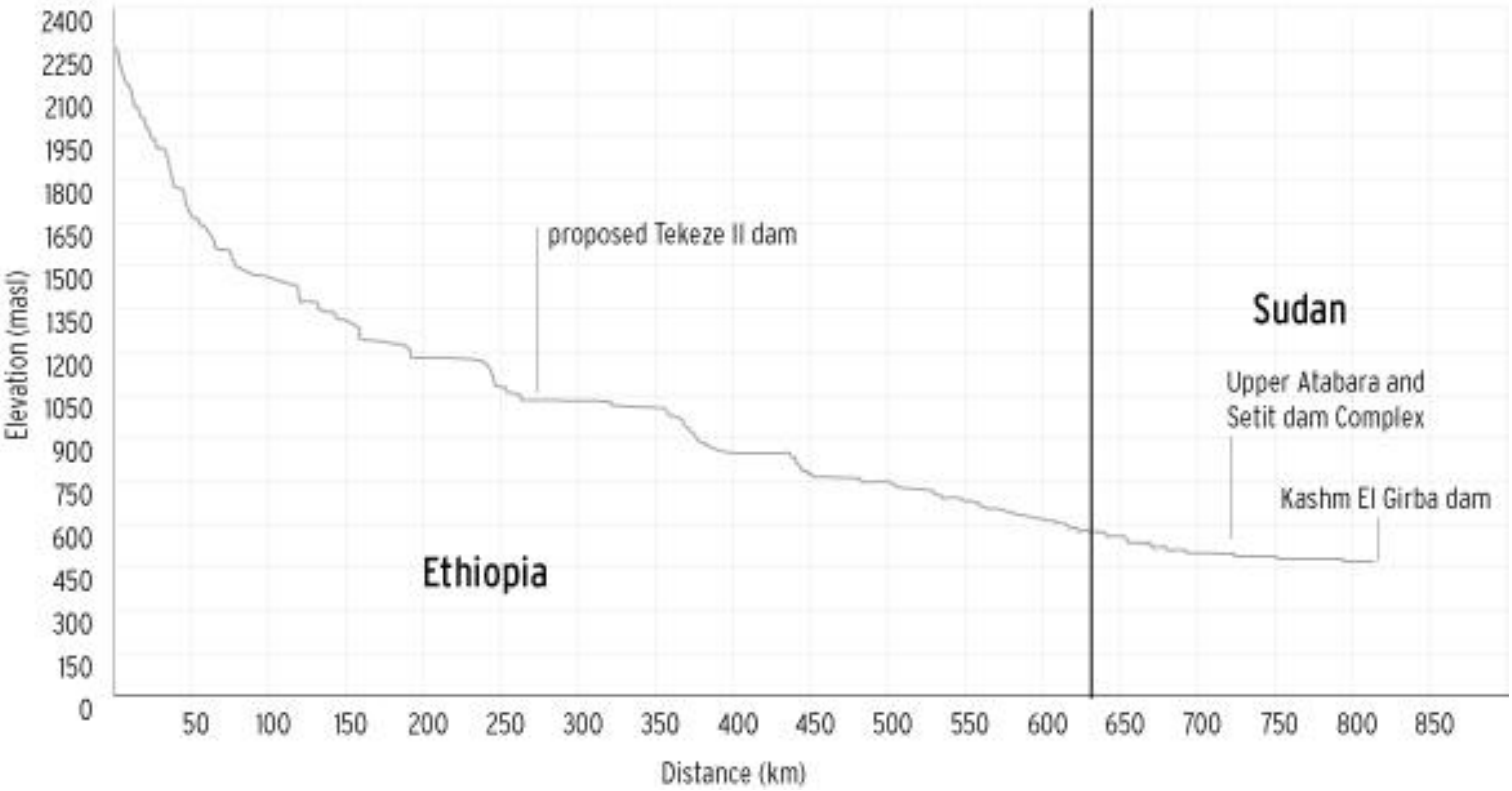


Blue Nile River Longitudinal Profile

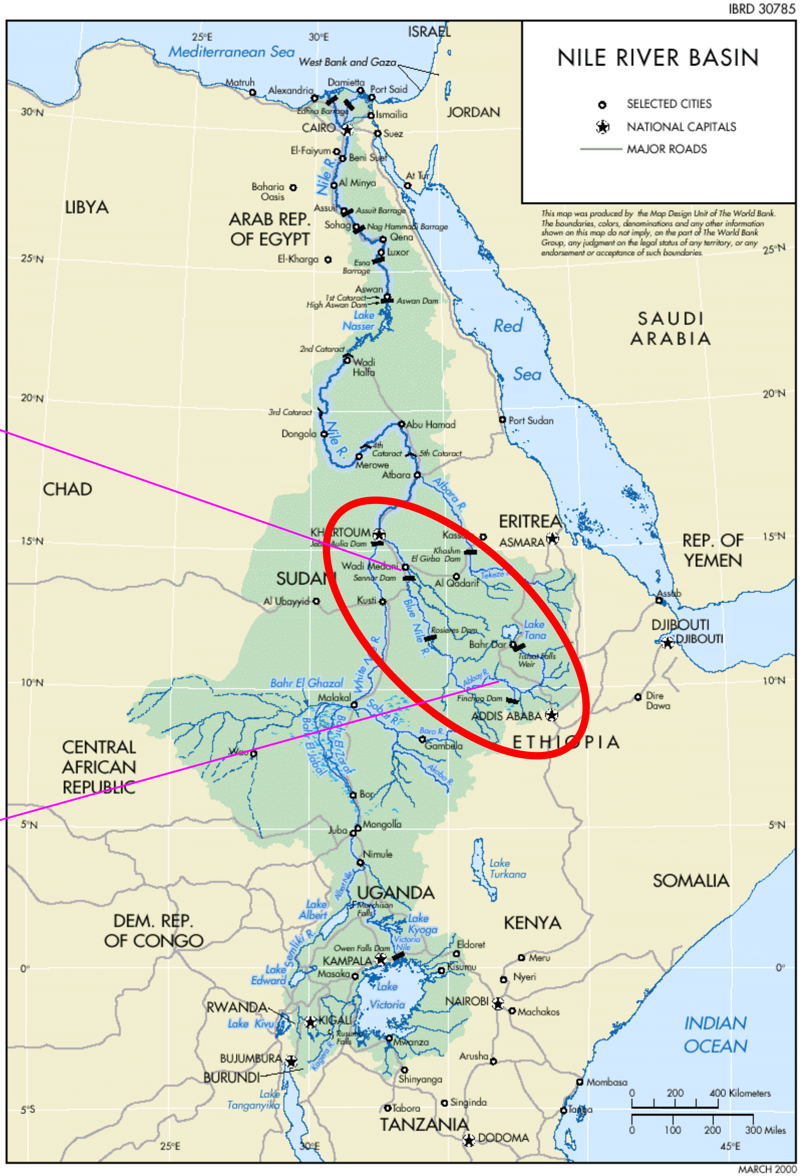




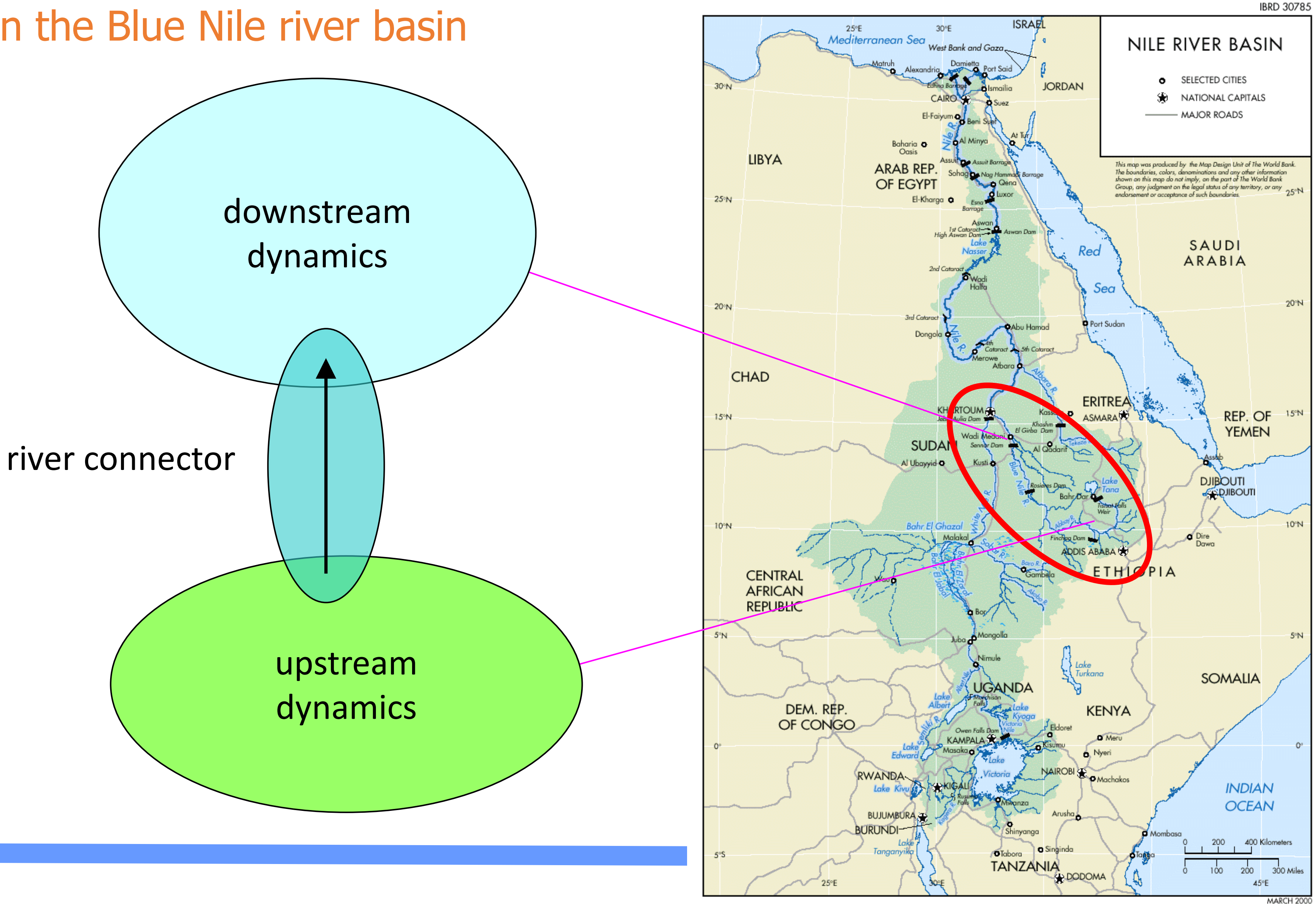
Tekeze-Atbara River Longitudinal Profile



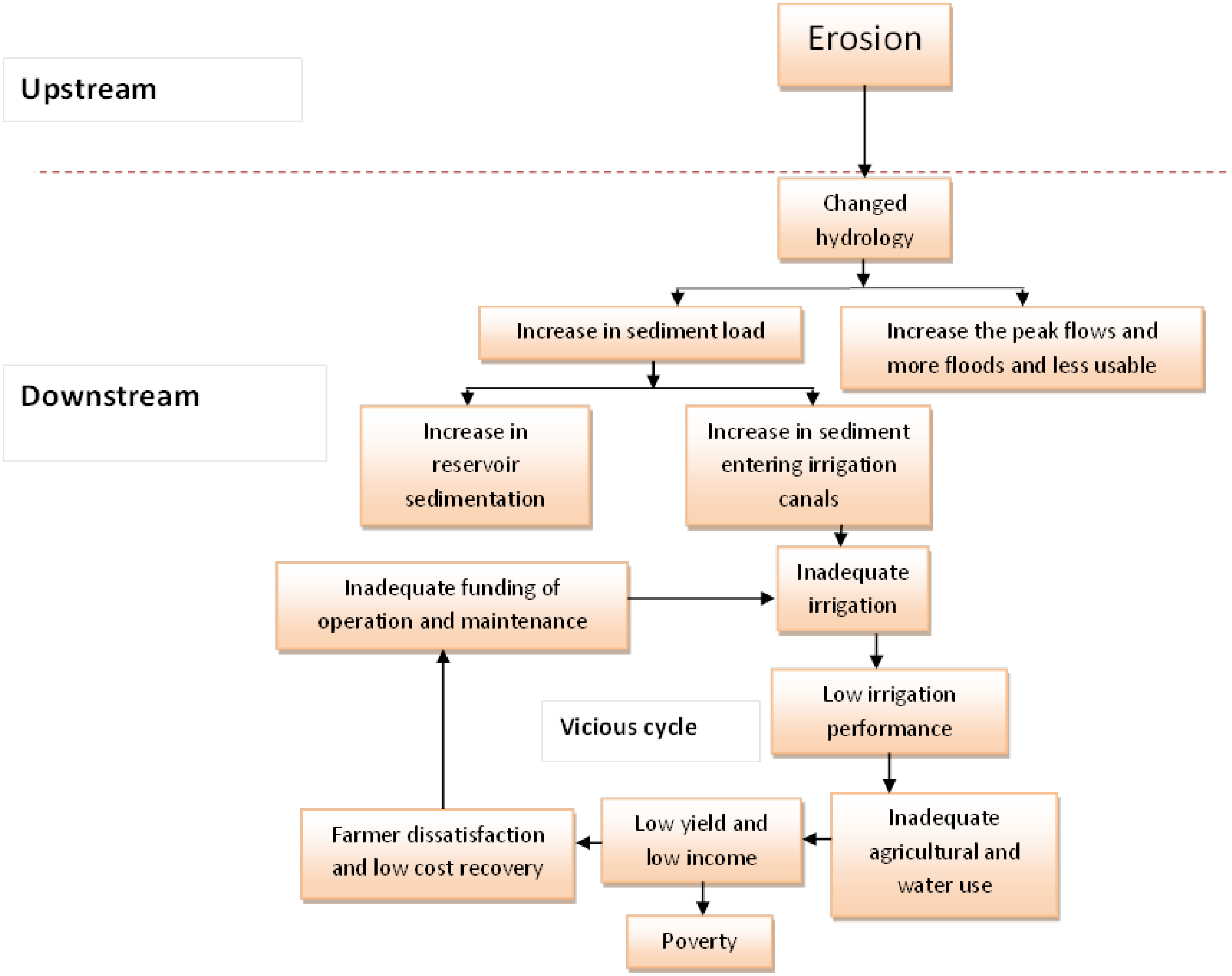
Sedimentation of the Blue Nile river basin



In search of sustainable catchments and basin-wide solidarities in the Blue Nile river basin



The effect of the sedimentation downstream the Blue Nile Basin



Characteristics of the Blue Nile sediment

- Fine sediment distribution (clay, silt and fine sand)
- Suspended Sediment yield estimates of the Blue Nile catchment area is 480 (t/km^2 /year)
- Total annual sediment inflow at El Deim about 140 Million tons
- The peak of sediment concentration 20,000-25,000 ppm during the flood season.

Dams within the Nile basin

Reduction in Storage Capacity in dam reservoirs due to Sedimentation

Name of dam	location	Year of commission	Design Capacity (10^9 m^3)	Present capacity (10^9 m^3)	% reduction
Sennar	Blue Nile	1925	0.93	0.36	60
Jebel Awlia	White Nile	1937	3.0	3.0	0
ElGirba	Atbara River	1964	1.3	0.6	54
Roseries	Blue Nile	1966	3.2 (before heightening)	1.9 (before heightening)	40

Sennar Dam

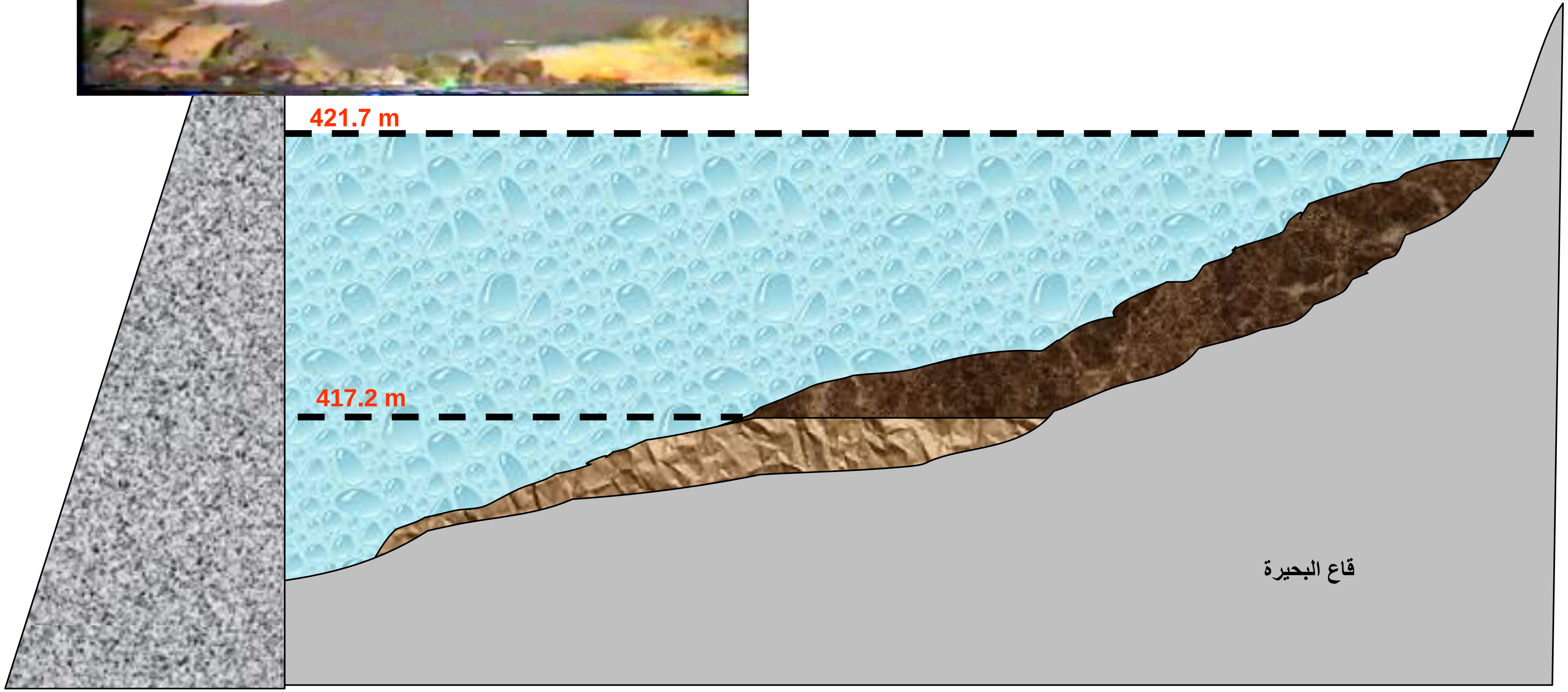
Sennar Dam

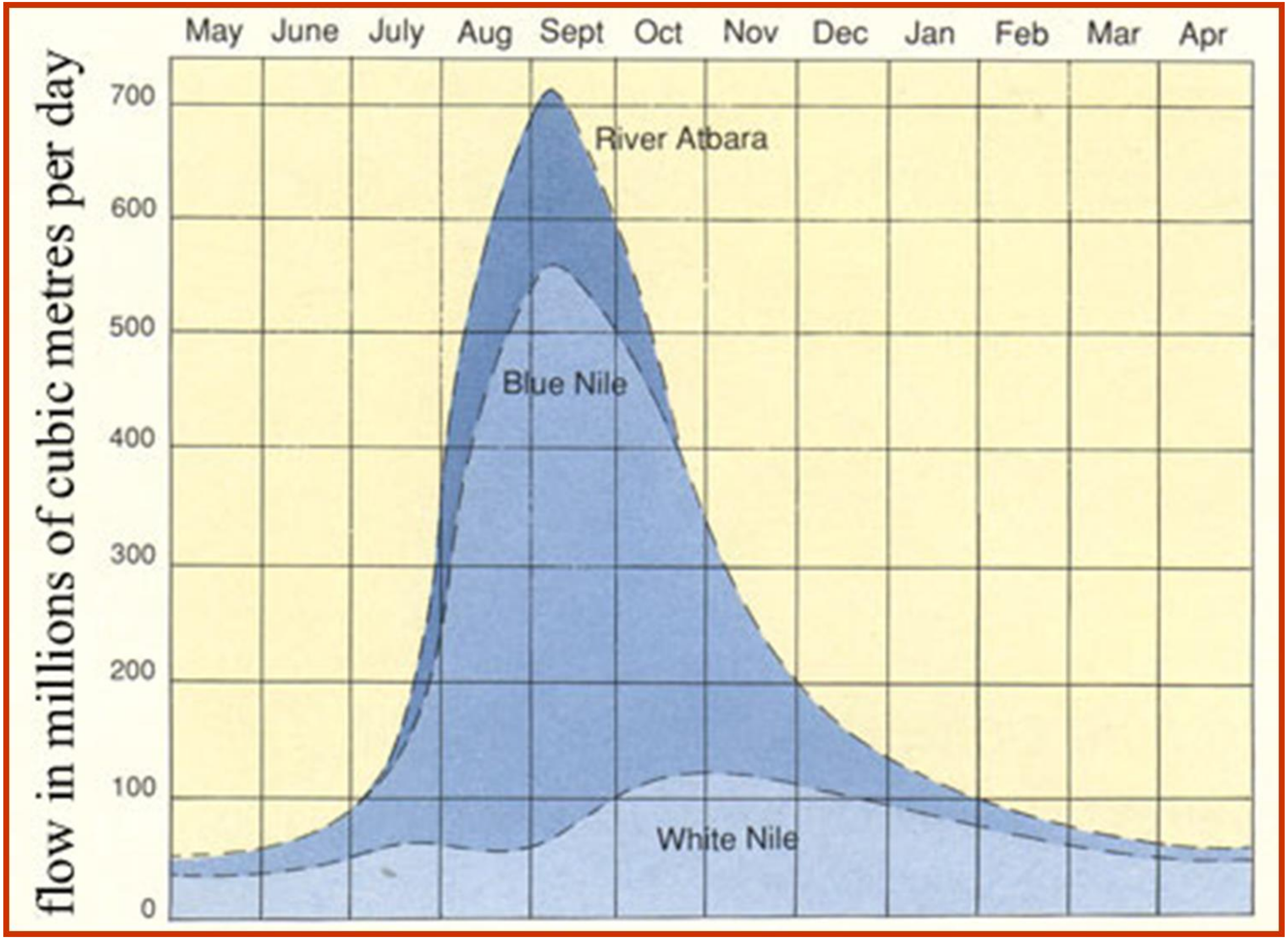
- located on the Blue Nile, about 300 km upstream of Khartoum
- The main purpose is to store water for irrigation schemes, with hydropower as a supplementary purpose.
- 80 low-level sluice gates sluiced the annual volume of sediment.
- 112 spillway gates to pass the peaks of extreme floods.
- Two turbines of 7.5 MW each installed in 1962 for hydropower generation.

Sennar Dam

Initial storage capacity= 980 Mm^3

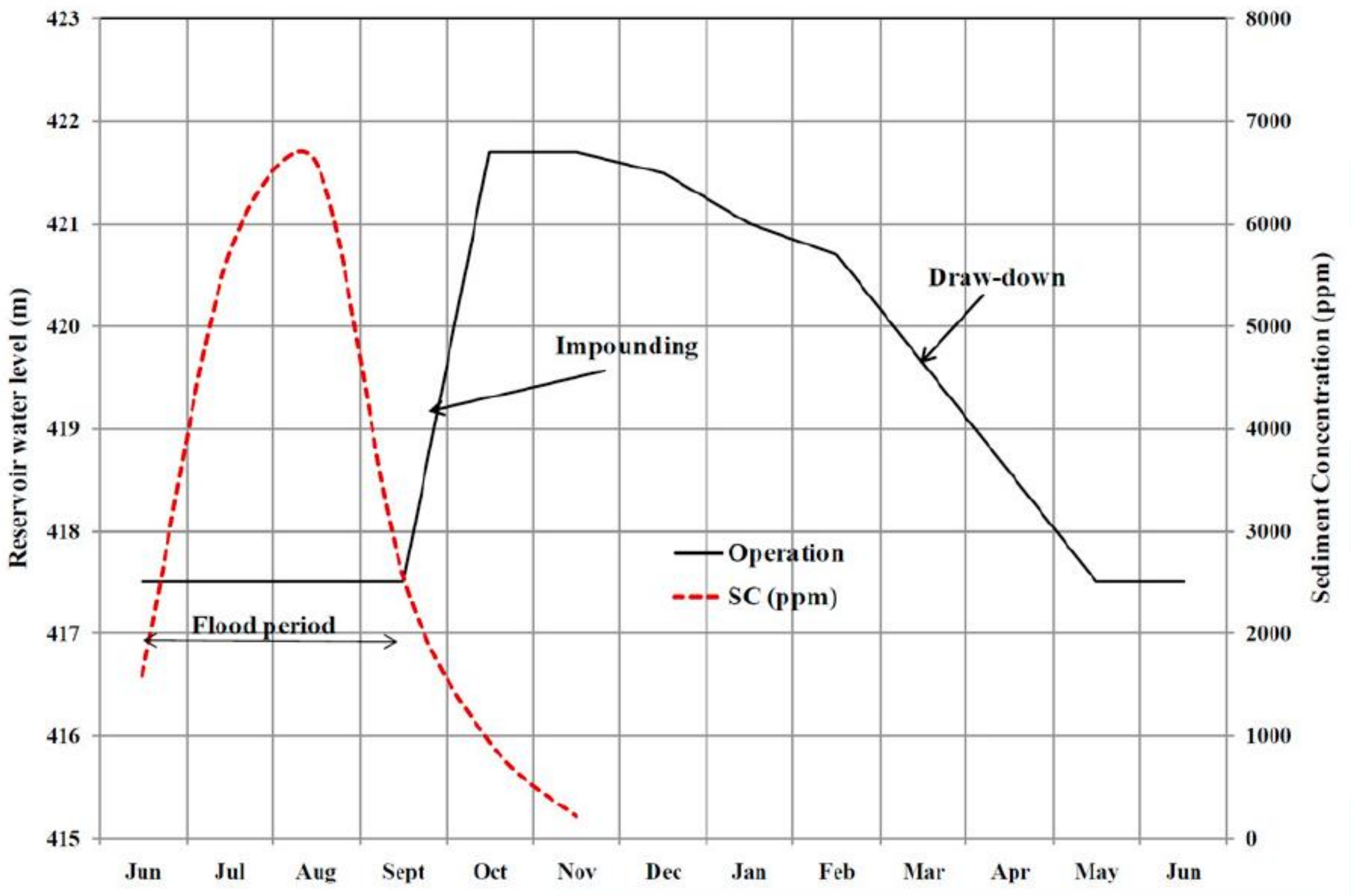
Current storage capacity = 360 M m^3





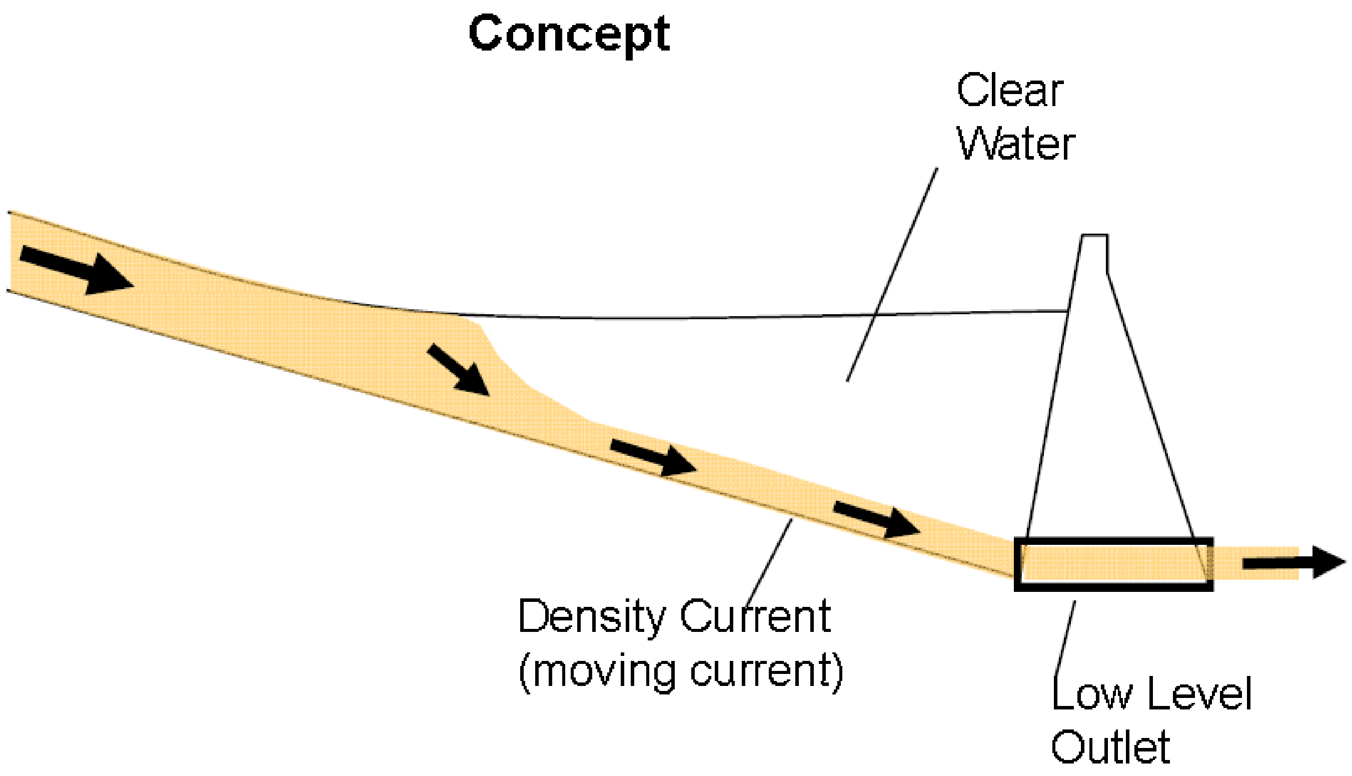
May
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
flow in millions of cubic metres per day
700
600
500
400
300
200
100
0
River Atbara
Blue Nile
White Nile

Average operation curve for Sennar dam since 1962 to facilitate sluicing - except for the period 1981 to 1986



Sediment Management in Sennar Dam

Density Current Venting



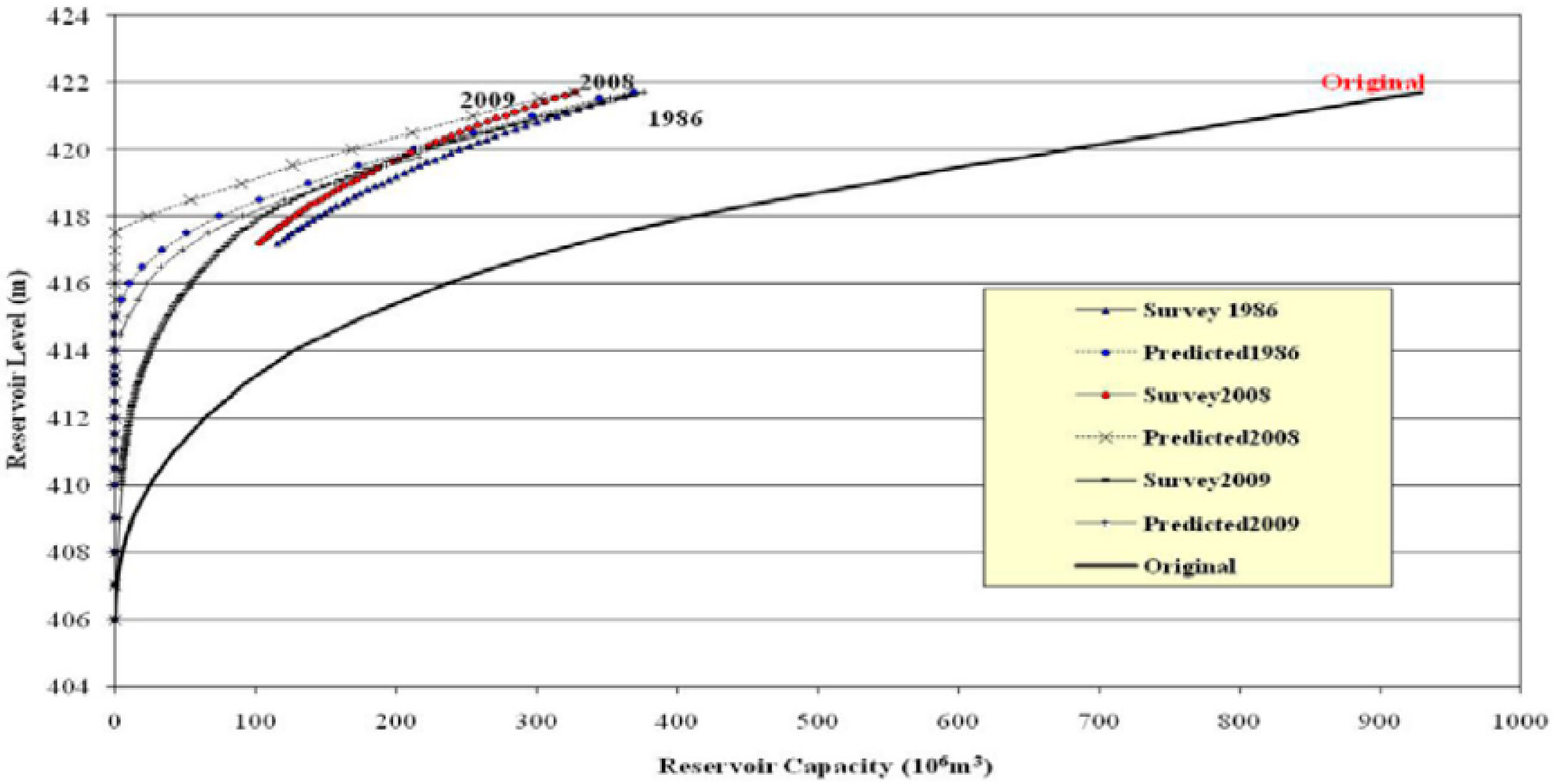
Effects of changing the operation policy of Sennar Dam (1981 and 1986)

- loss of storage from 1925 to 1981 (56 years) about 4.6 Mm^3 / year (0.5 % per year represent 28%)

- loss of storage from 1981 to 1986 (5 years) about 54 Mm^3 / year (5.8 % per year represent 29 %).

- The changed of operating policy between 1981 and 1986 increase the deposition tenfold.

Reduction of reservoir storage capacity over years



Roseries Dam

Roseries Dam

Location: Roseires dam first stage, commissioned in 1966, is on the Blue Nile at Roseires town some 500 km south of Khartoum.

Purpose: Irrigation, hydropower

The Reservoir:

Design capacity at R.L. 480 m a.m.s.l.	3200 Mm^3
Surface area	290 km^2
Design capacity R.L. 490 m a.m.s.l. (after heightening)	7200 Mm^3
Minimum retention level	467 m a.m.s.l.
Normal range of annual regulated water level	13 m

Hydrology:

	Blue Nile catchment area	254,230 km2
	Average peak flood discharge	6,300 m^3/s
	Maximum recorded flood	10,800 m^3/s
	Average low river flow	100 m^3/s
	Total average annual flow at Roseires	50,000 Mm3

Design Capacity to mean annual inflow ratio = 0.06

Sediment Inflow:

Reasonable measured data for sediment transport are available. The measurements are mainly for suspended sediment transport during the rainy season. Rating curve for suspended sediment transport was developed from these measurements which indicated a peak transport rate of about 3 million metric tons per day

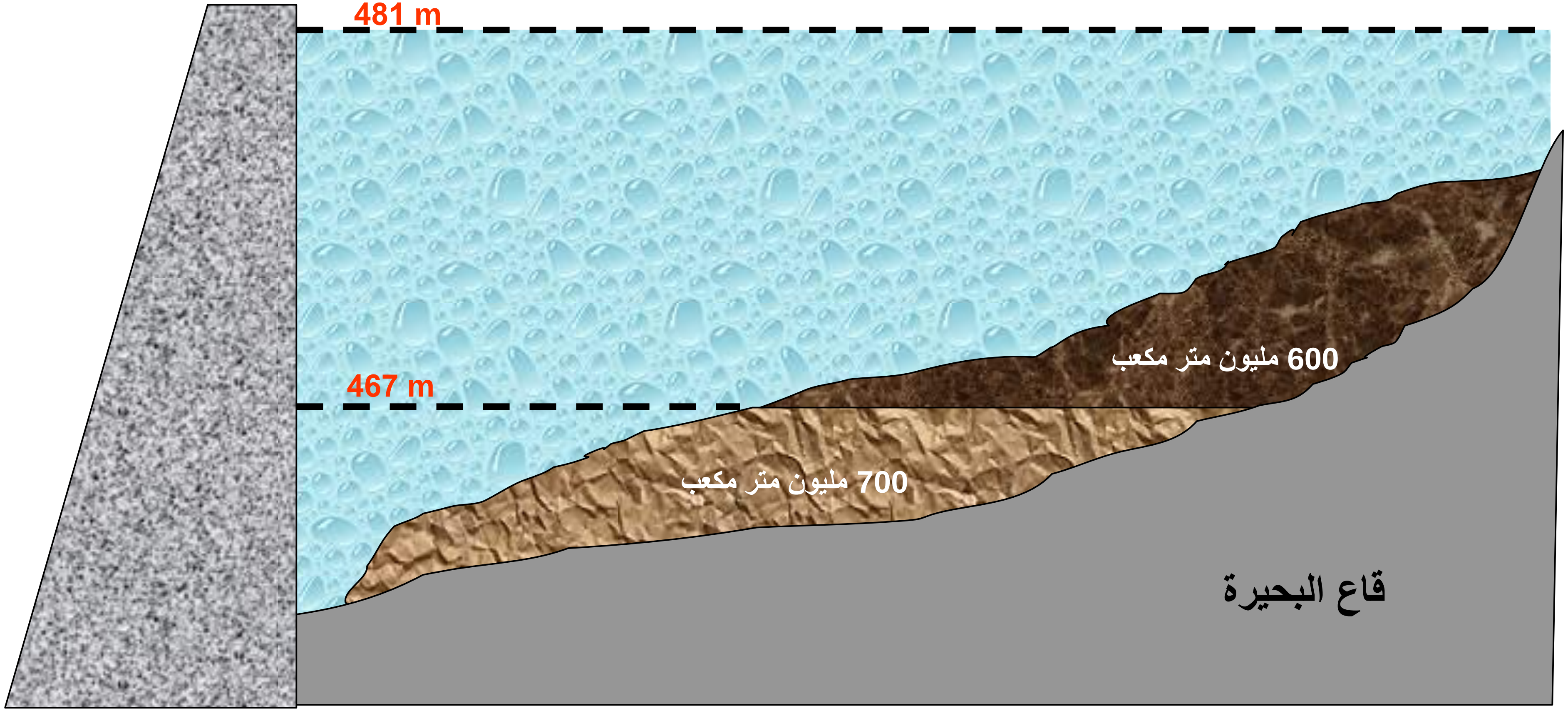
Reservoir Resurveys: Made in 1976,1981, 1985, 1992, 2005, 2013, 2016 and one satellite imagery in 1995

Main Problems: Loss in capacity, interruption in hydropower generation

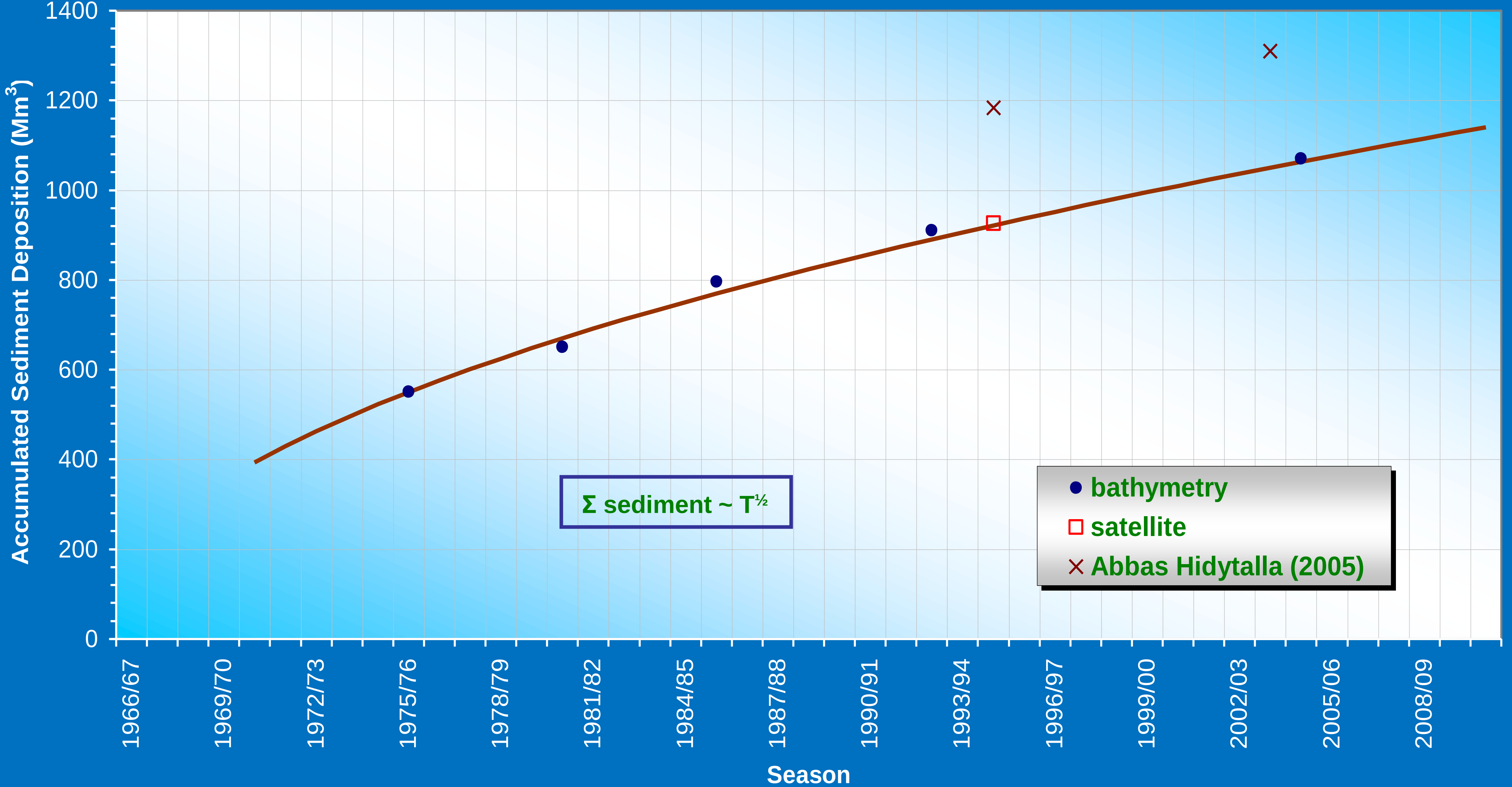
Roseries Dam

Initial storage capacity=3200 Mm^3

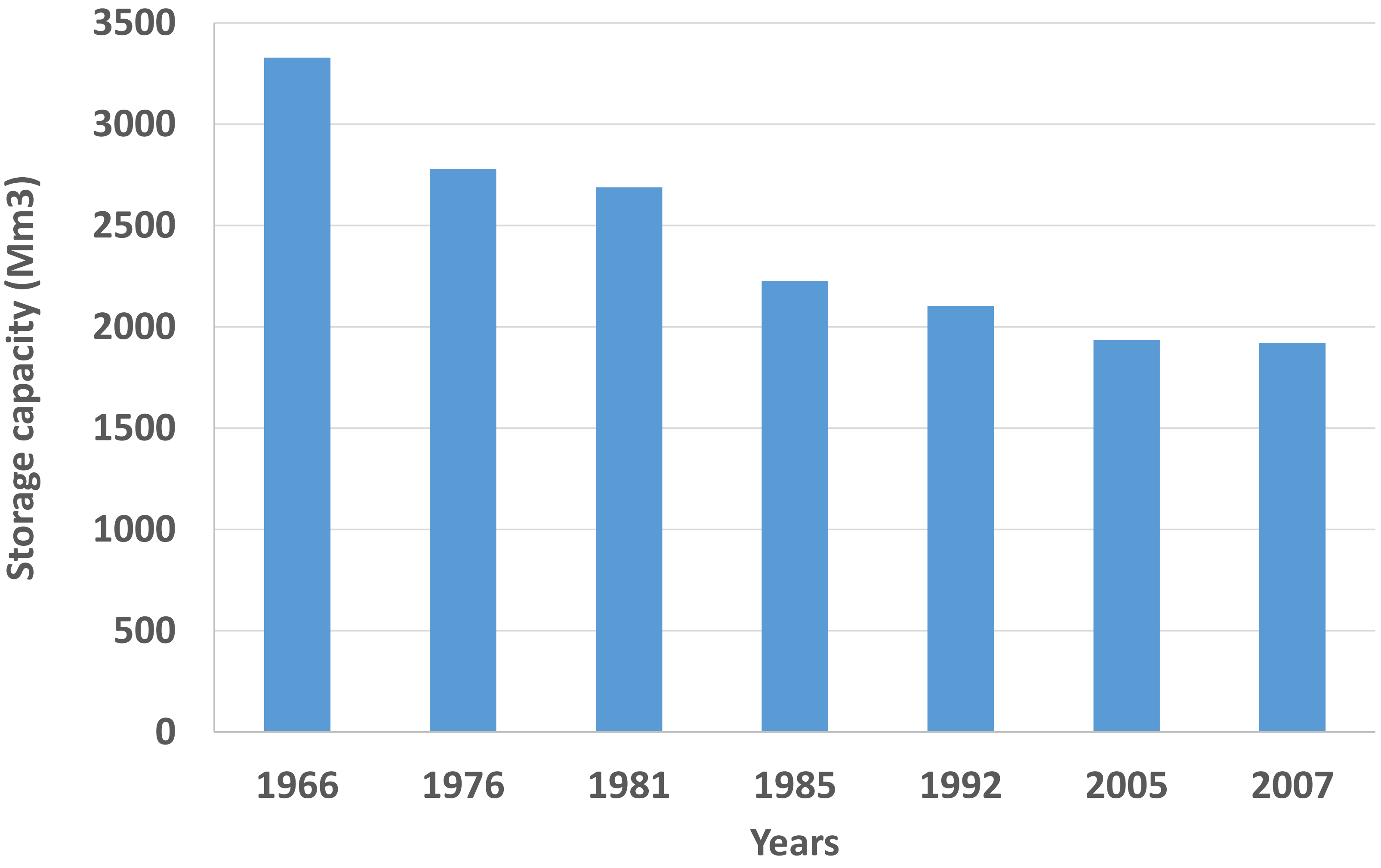
Current storage capacity = 1900 Mm^3



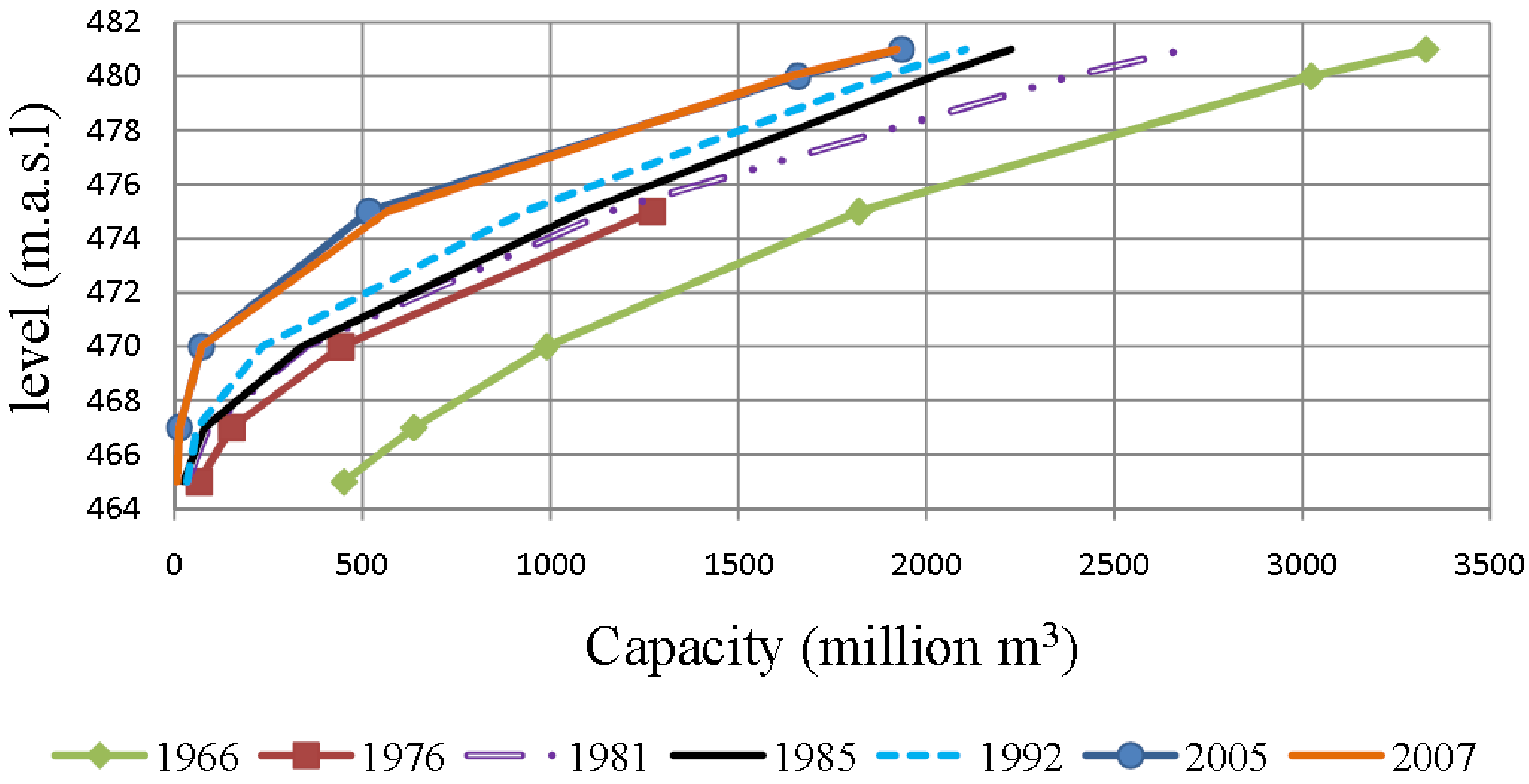
Accumulated sediment deposits with time in Roseires reservoir



Reduction in storage capacity of Roseries Reservoir over years



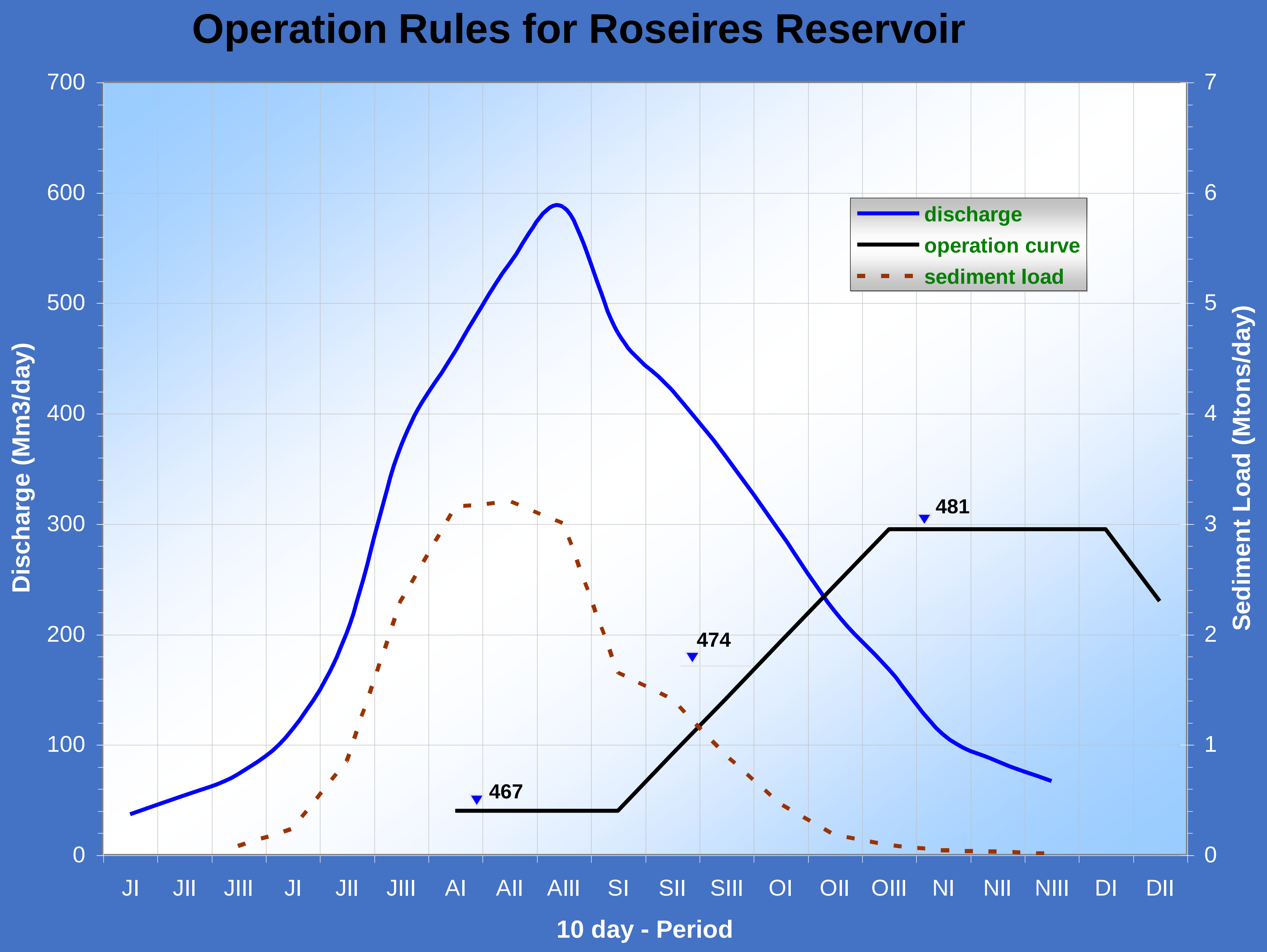
The Roseires Reservoir capacity reduction with time



Roseires Reservoir capacity reduction with time in selected upper levels of the reservoir
(Source: Abd Alla and Elnoor, 2007).

Control measures

1. Sediment Sluicing



Operation of Roseries Dam

From Jun- mid Sept During Flood:

- It is the minimum level for operating the power station to increase the velocity of the river flow to reduce the effect of silt.
- the deep sluice gates are used to pass the flow (five sluiceways controlled by five radial gates their size are 10.5m height and 6 m wide.)
- the spillway gates are used to pass the excess flow (even radial gates their size are 13m height and 10m wide)

From mid Sept. to Nov

When the silt content in the water is reduced, impounding commences, taking about 60 days to raise the level of the reservoir from 468 to R.L 490 m

The filling Programme

a) On 22 August if by that date the flow at Eddeim either has never risen above 450 Million m^3 per day or, having previously risen above that rate, has by then fallen below it, Or

b) On the date later than 10^{th} of September immediately following the day when the flow at Eldeim has fallen to 450 Million m^3 per day, Or

c) On 26^{th} of September at latest, even if the flow at Eddeim then is still greater than 450 Million m^3 per day.

2. Sediment Dredging

- A dredging process is executed every year in front of the power intake by dredging the sediment and dumping it in front of the deep sluice gates between 100,000-200,000 m^3.

- The sediment removal flushed during the flood season when all the dam gates are opened. The process is generally carried out before the flood season.

- The average annual reduction in power generation in Roseires during August is 3.27 MWh which costs about 0.35 million US$, (ENTRO, 2007)

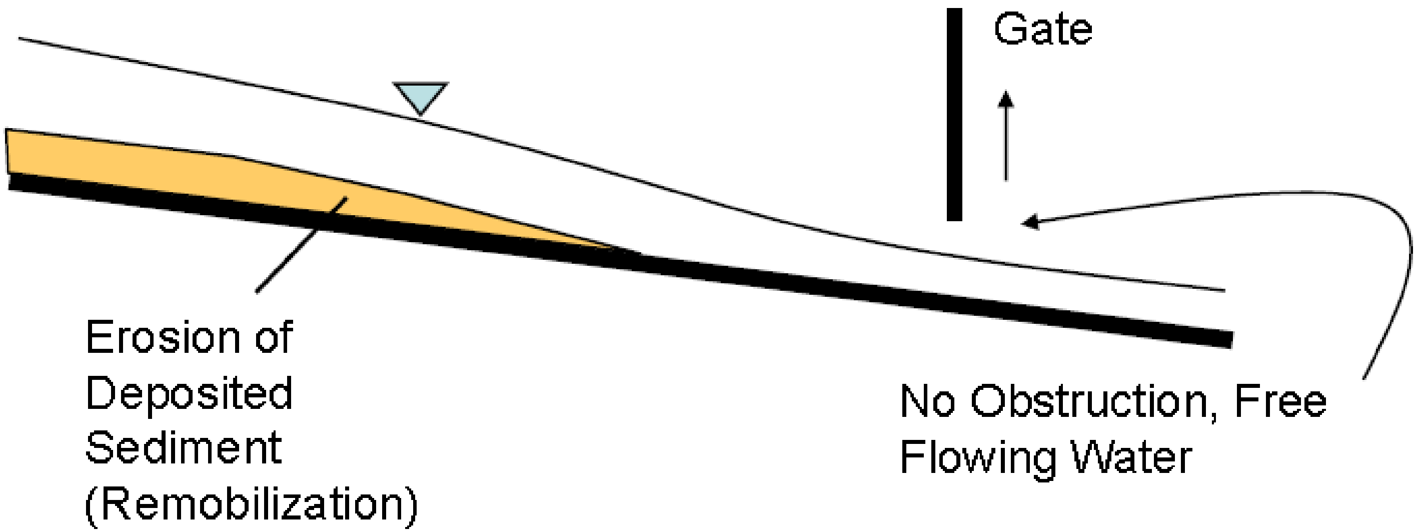
Khashim ElGirba Dam

Initial storage capacity= 1300 Mm^3

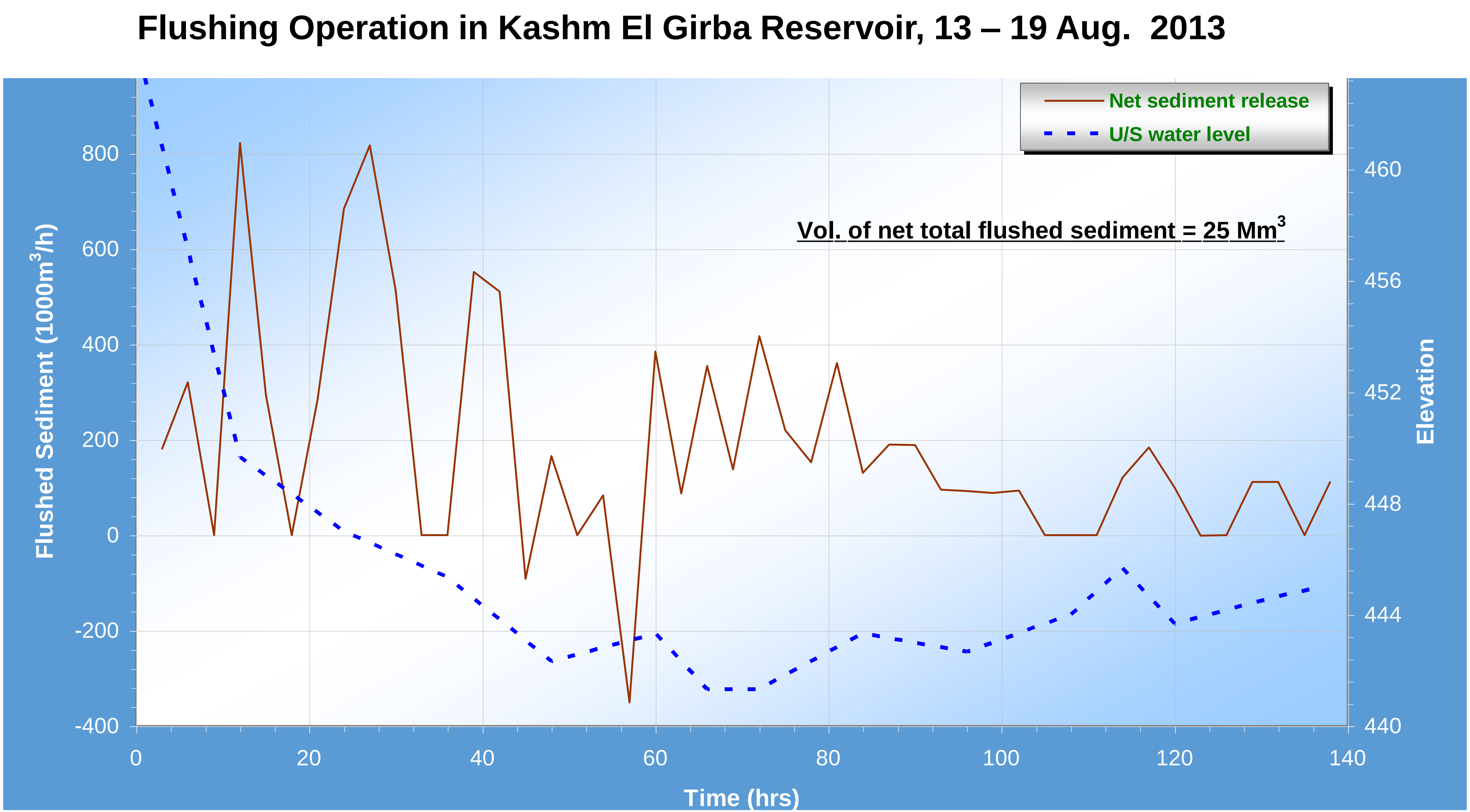
Current storage capacity = 600 Mm^3

Drawdown Flushing

Concept

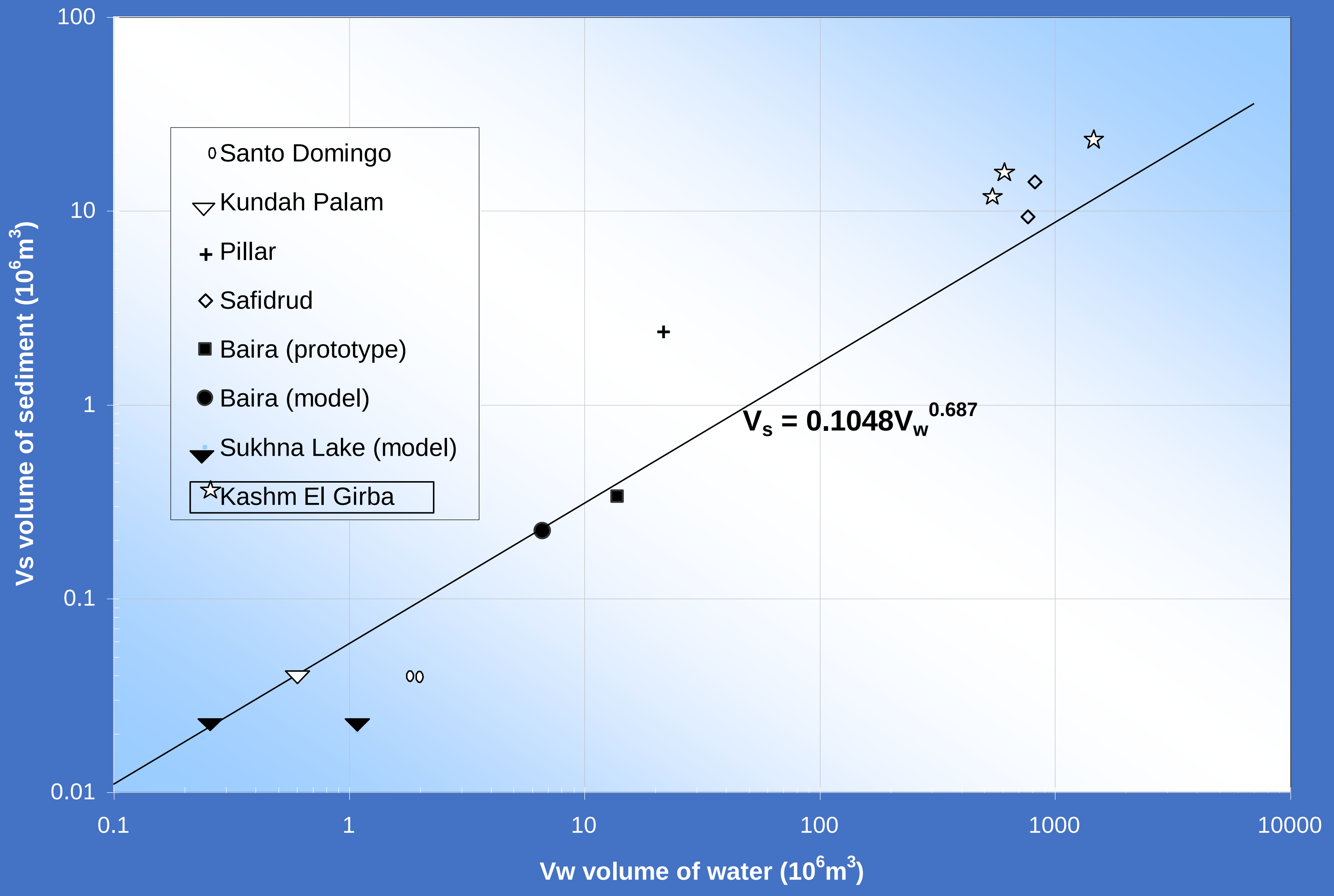


"Sediment flushing is a technique in which the flow velocities in a reservoir are increased to such an extent that **deposited sediments are remobilized and transported through bottom outlets**." (Page 47 of ICOLD Bulletin 115)


Flushing Operation in Kashm El Girba Reservoir, 13 – 19 Aug. 2013
Net sediment release
U/S water level
Vol. of net total flushed sediment = 25 Mm^3
Flushed Sediment (1000m^3/h)
800
600
400
200
0
-200
-400
Elevation
460
456
452
448
444
440
0
20
40
60
80
100
120
140
Time (hrs)

Khashm El Girba Reservoir after Flushing

Variation of sediment flushed with water used (after Paul & Dhillon 1988)



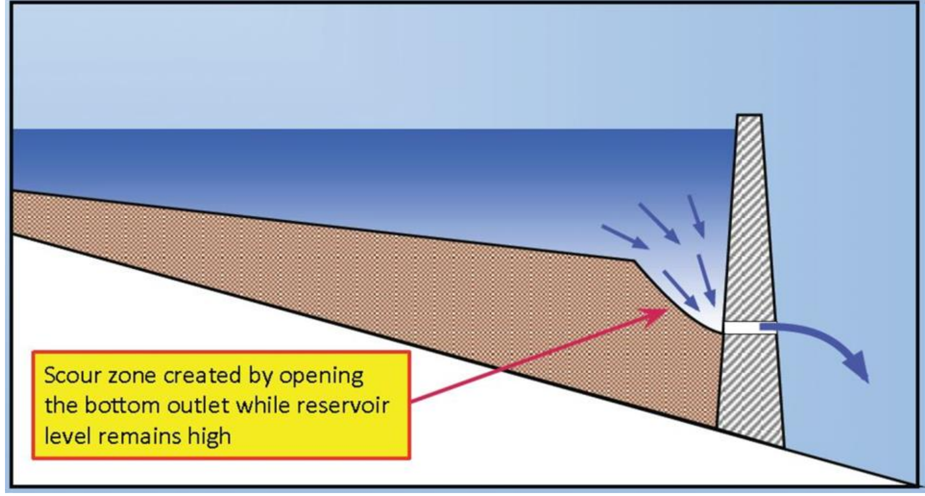
Effects of sediment in Khashem Elgirba Dam

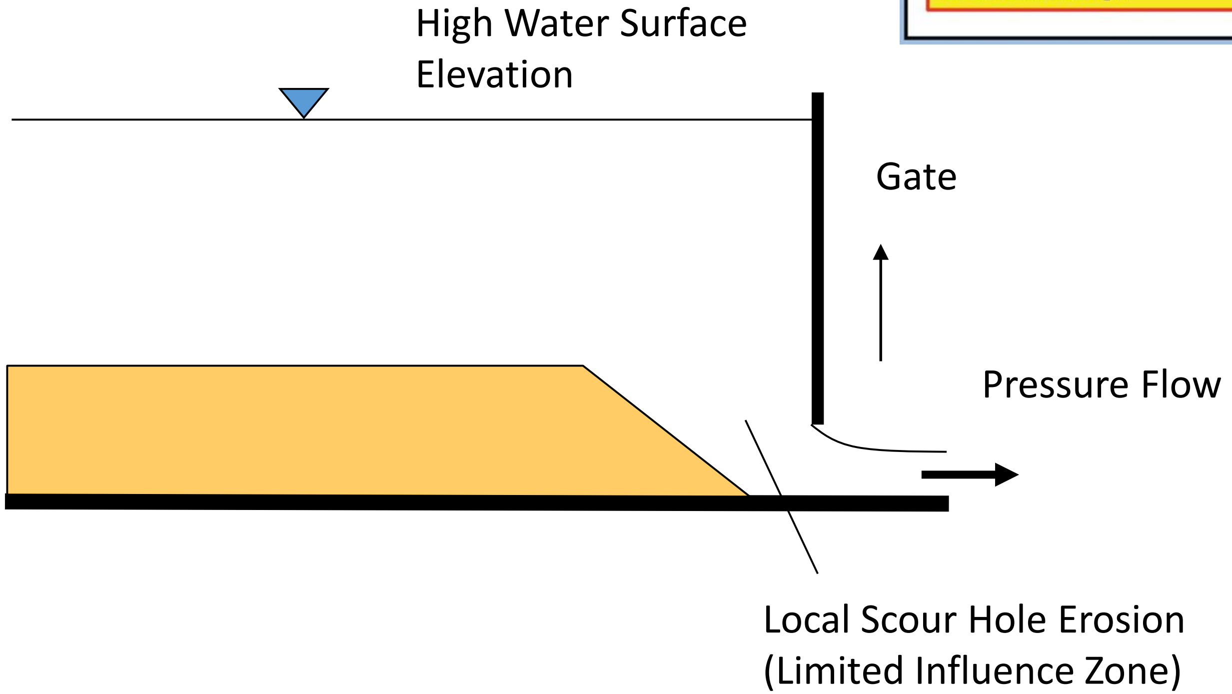
- The annual deposit sediment 20-50 Mm^3
- Reduction in irrigated area in Halfa Irrigation Scheme from 330,000 fed to 180,000 fed (50%) and hydropower generated due to loss of storage.
- The cost of hydroelectricity production forgone due to loss of storage is estimated as 0.1 million US$/year.
- An area of 5850 Feddans of irrigated land in Halfa is lost every year due to sedimentation in Khashm ElGirba (ENTRO, 2007).

Marowe Dam

- Start operation 2009
- capacity 12.5 Billion m^3
- Installed capacity of hydropower plant 1,250 MW (10 units at 125 MW each).

Pressure Flushing





Retaining long term storage

Reservoir Sedimentation Management Options

Manage amount of sediment generated by the catchment

Upstream Management

- Check Dams
- Re-Forestation
- Contour Farming

Allow sediment inflows to pass through or around the reservoir

Sediment Routing

- Sluicing
- Density Current Venting
- Bypass

Remove sediment which accumulates in the reservoir

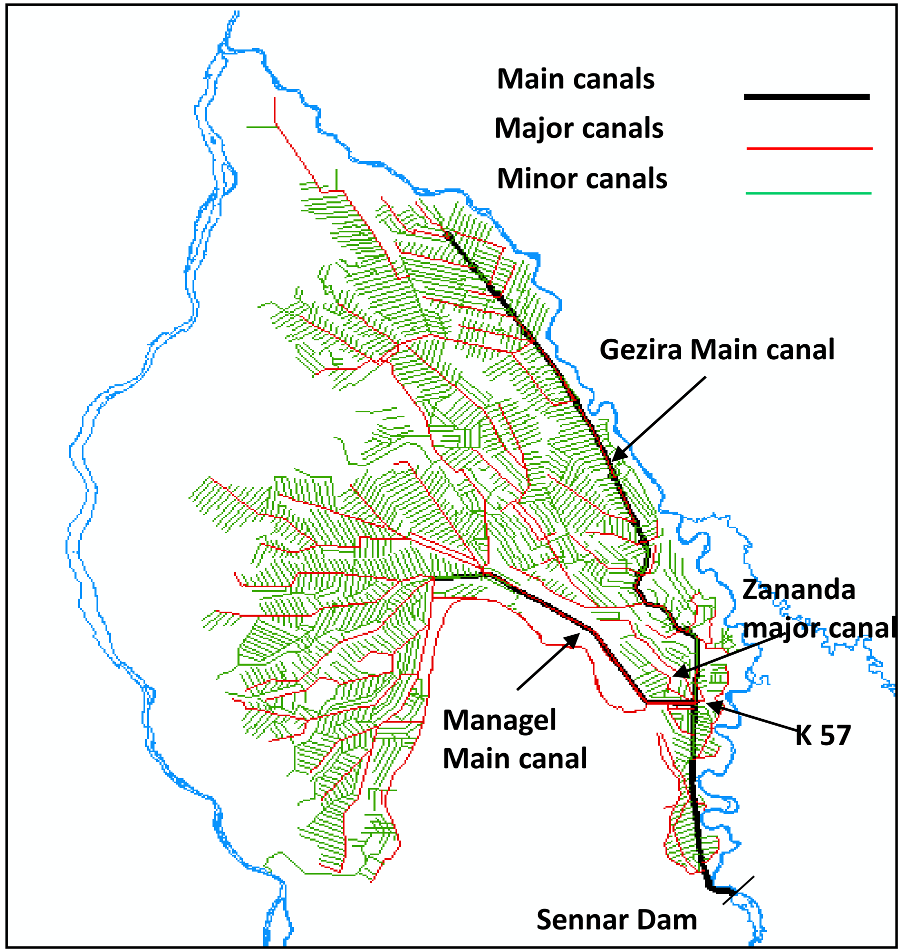
Sediment Removal

- Dredging
- Excavation
- Hydro-suction
- Pressure Flushing
- Drawdown Flushing

Sedimentation in irrigation canals

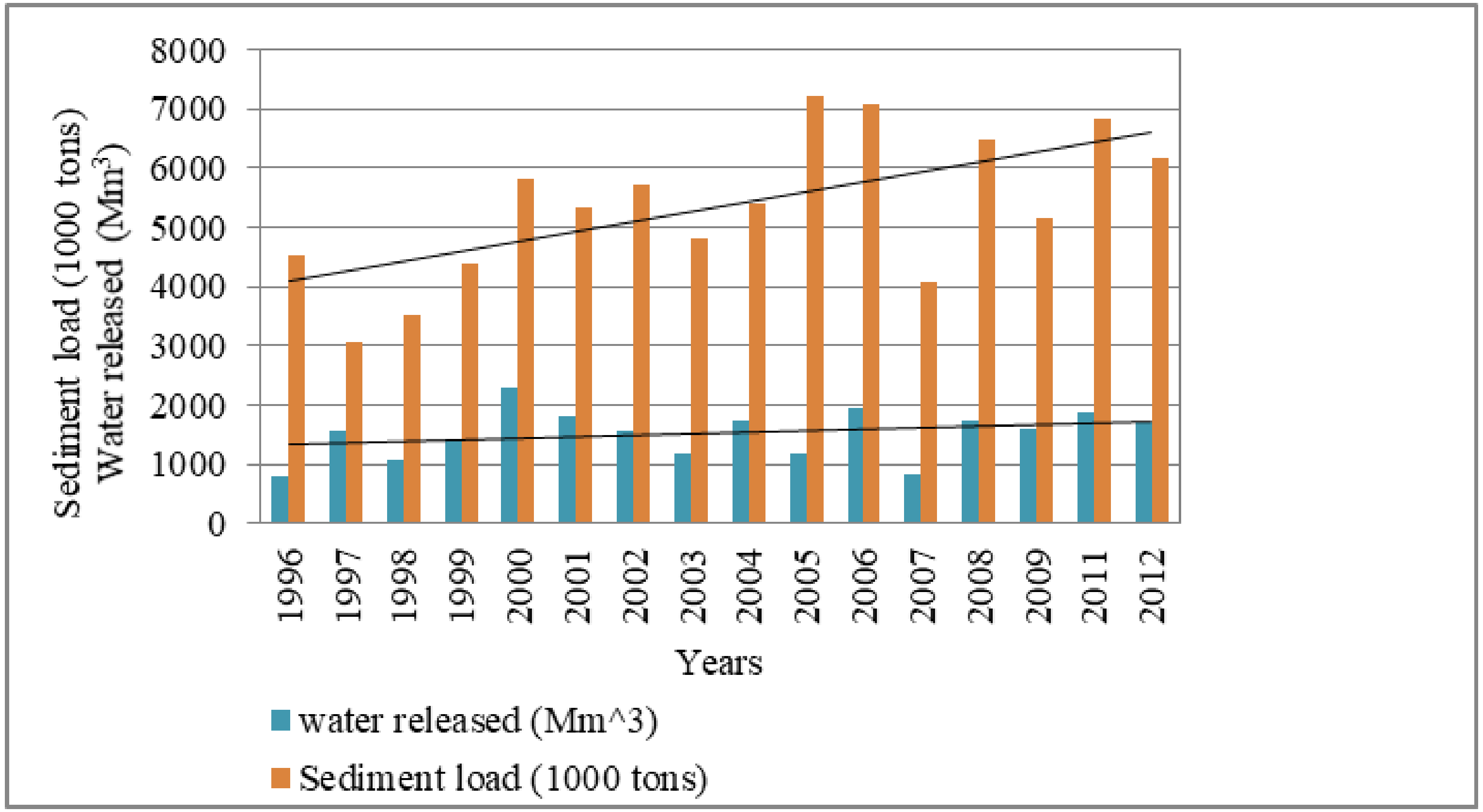
Gezira Irrigation Scheme

- Total area 880,000 ha.
- Total water delivered 6-7 BCM per year
- Total sediment load 10 Million ton
- The sediment concentration reached 15000 mg/l



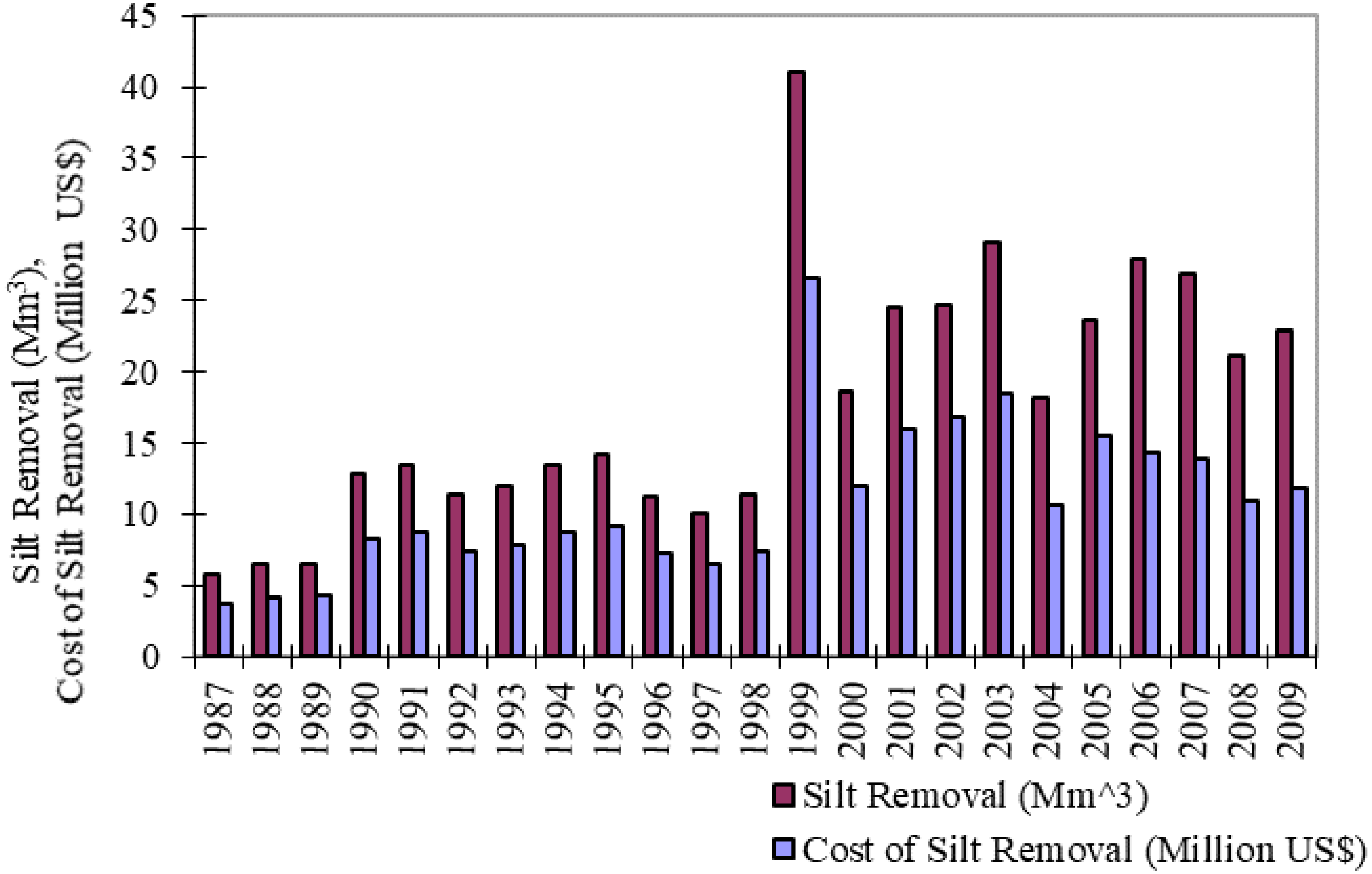
Sedimentation problems in irrigation canals

Sediment load and water release in Gezira Main Canal

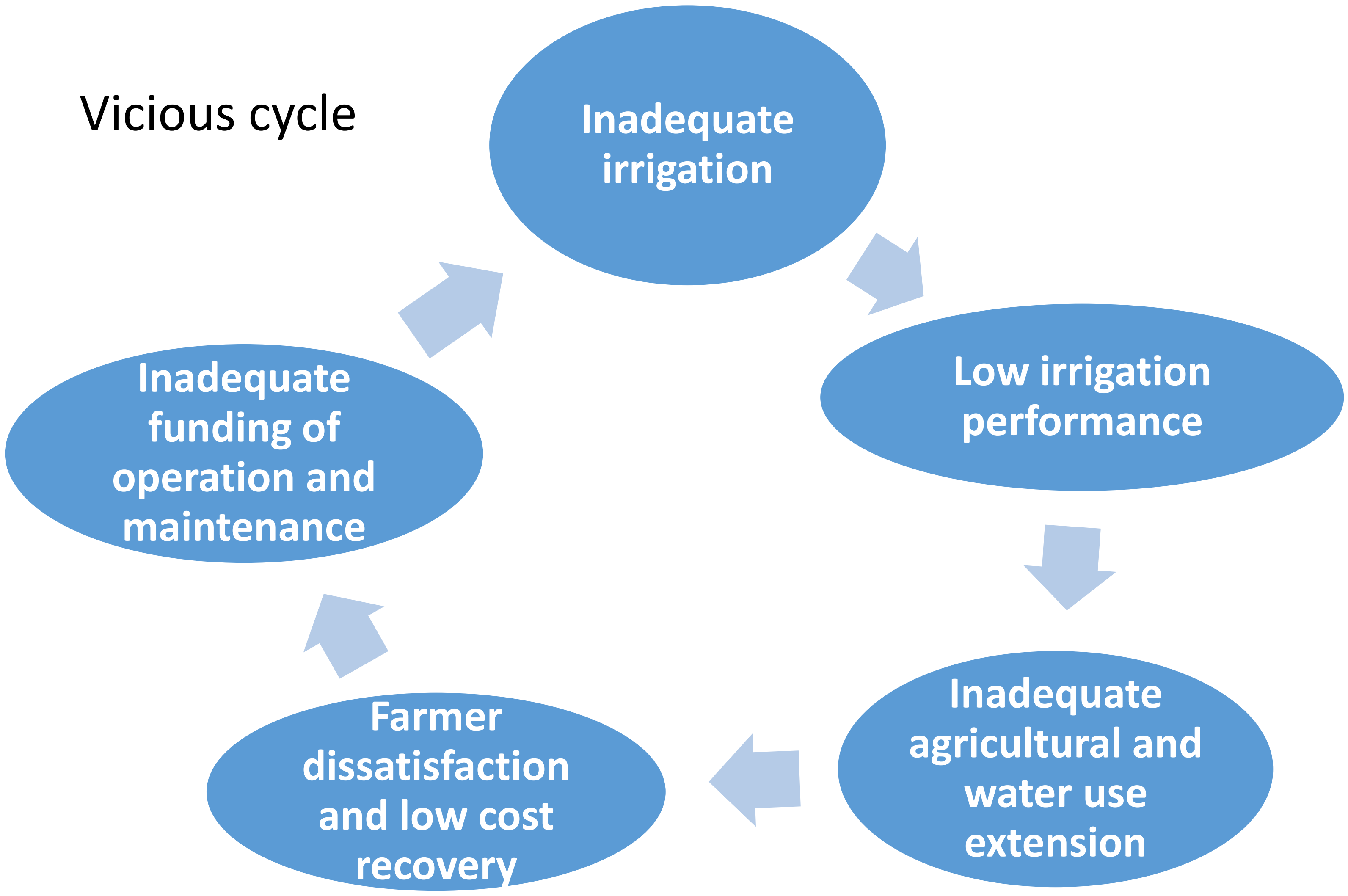


Sediment load and water release at the off-take of Gezira Main Canal at Sennar between July and October for the last 16 years

Amount of sediment removal and cost of the removal



Vicious cycle

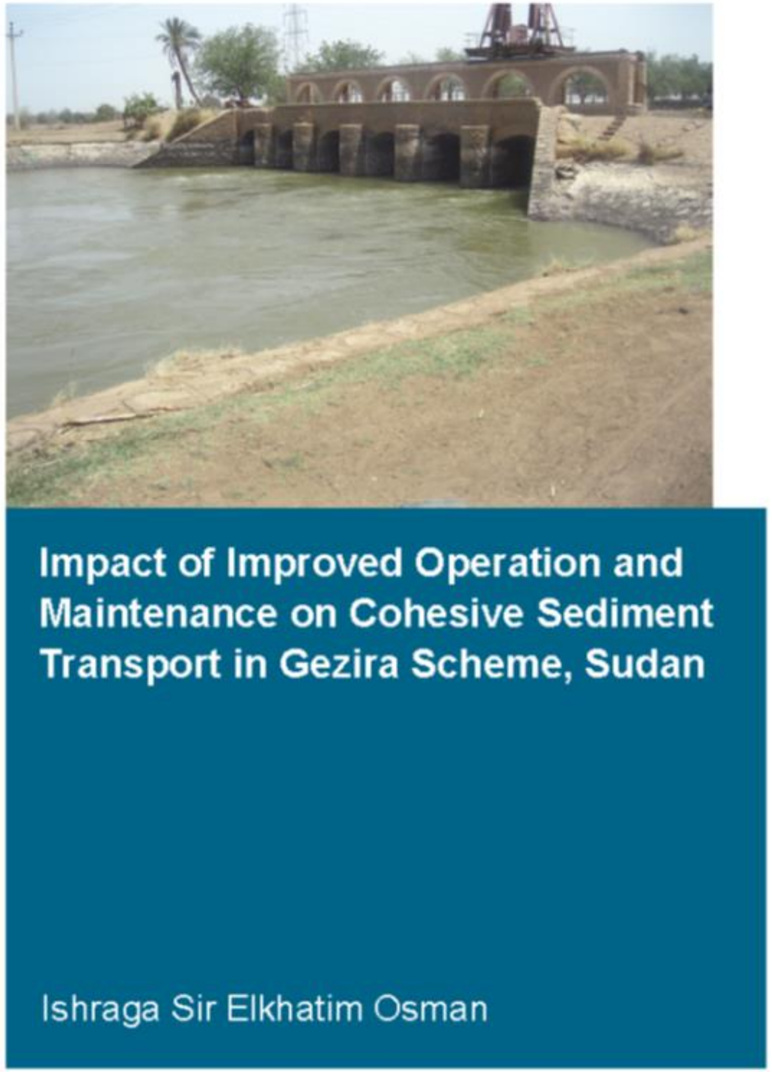


Sediment management in irrigation canals

- To reduce the impacts of sediment deposition in irrigation canals by improving operation and maintenance procedures

- To develop a numerical model to simulate suspended sediment transport in irrigation canals

- To improve the reliability of irrigation water delivery in Gezira Scheme considering the sedimentation problem



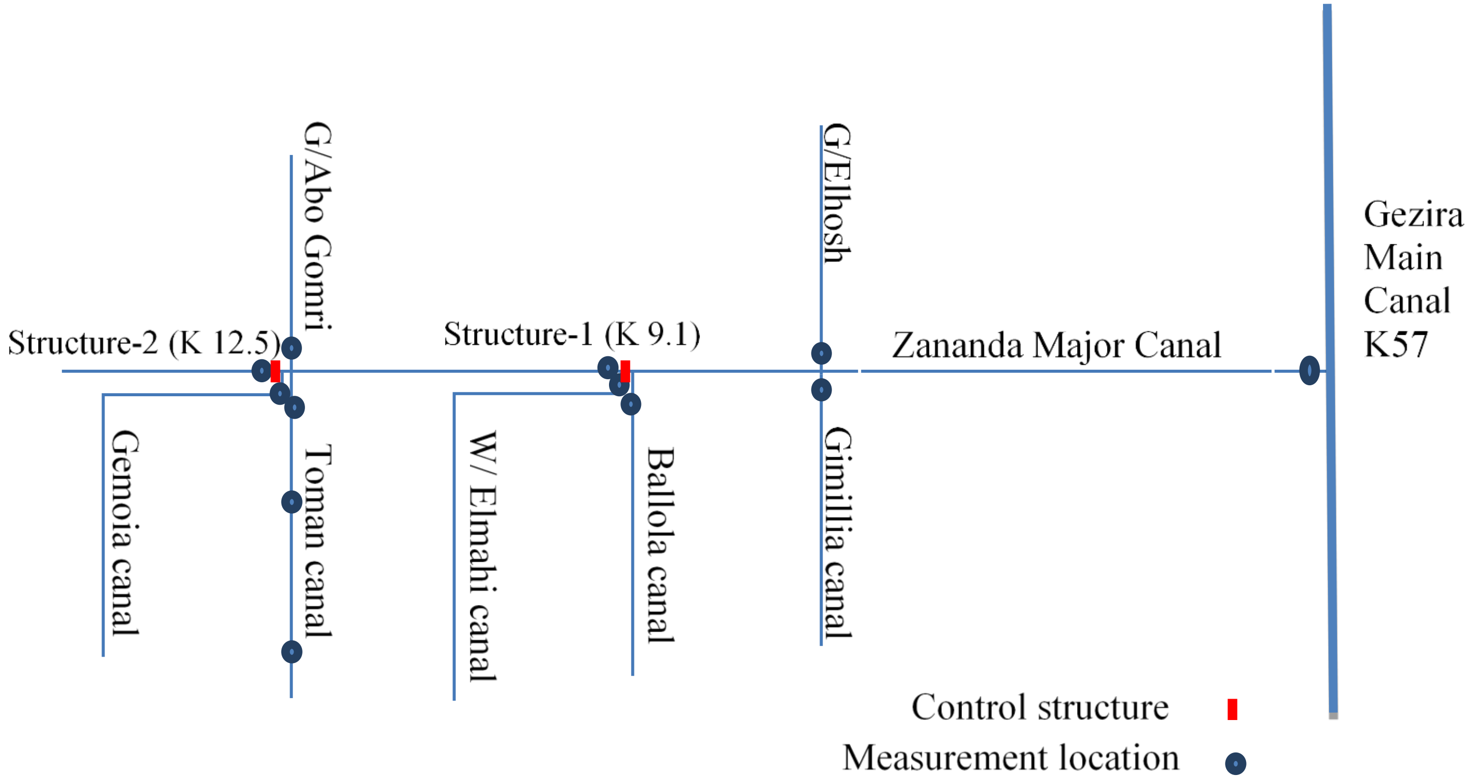
Field measurement and data collection

Field measurement between July and October in 2011 and 2012.

Data collected:

- water level measurement
- flow velocity
- sediment data
- bathymetric survey
- cropped area, sowing dates
- maintenance activities

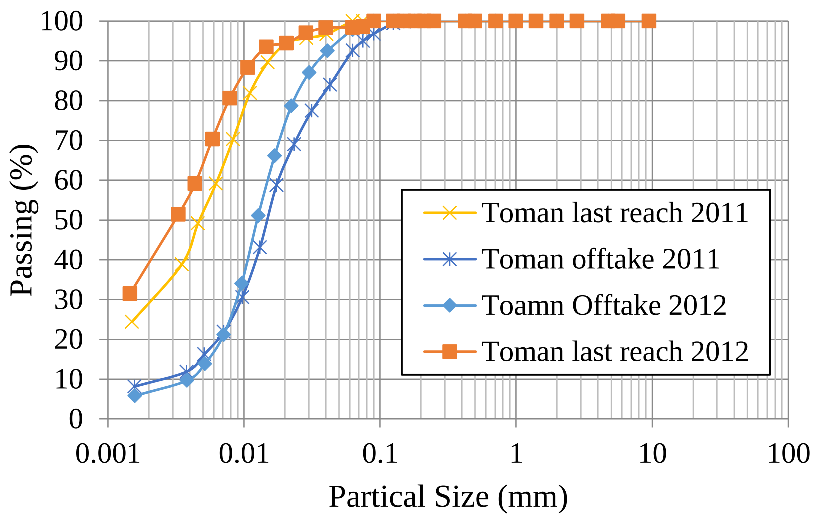
Measurement locations



- 1080 water levels readings per year
- 1290 sediment samples were analysed

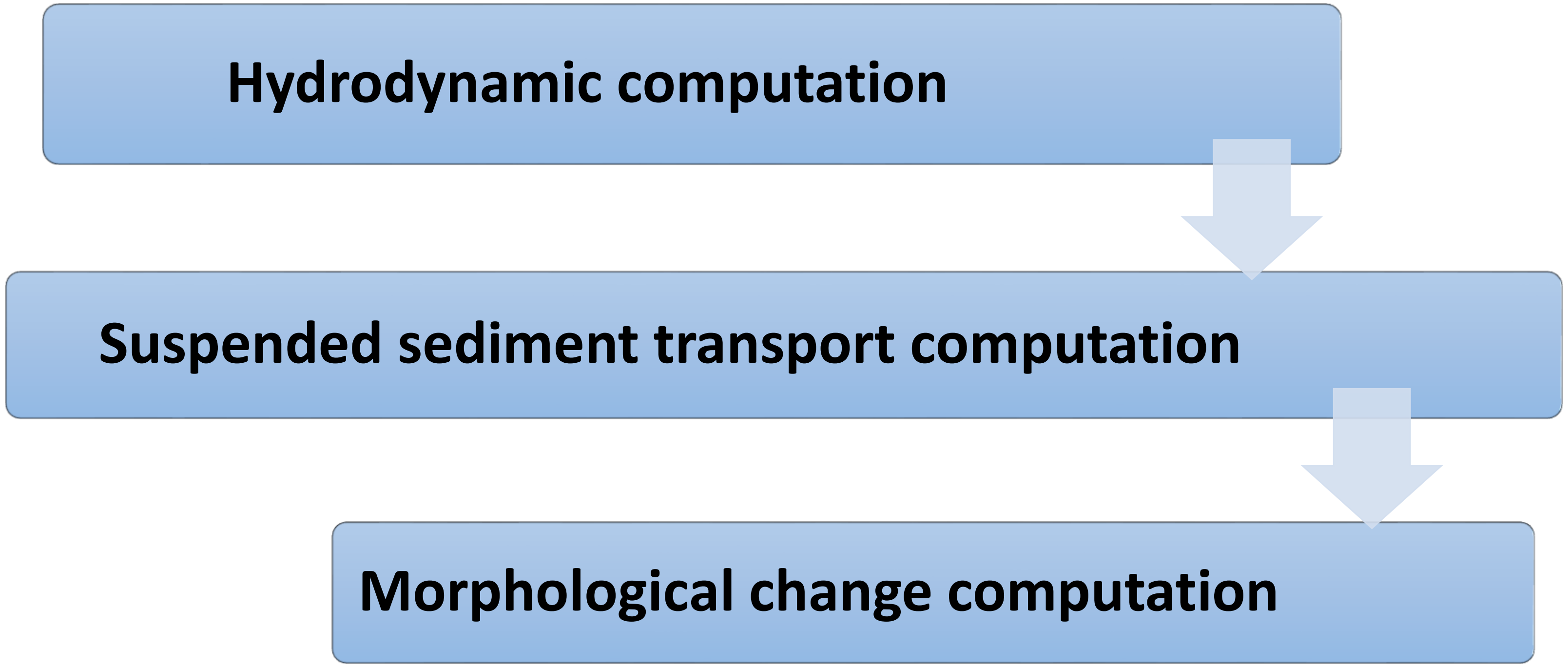
Scheme analysis

- Stability of the water level
- Effect of change in geometry and structures settings on the water level
- Calibration of measuring structures
- Mass balance studies
- Laboratory analyses

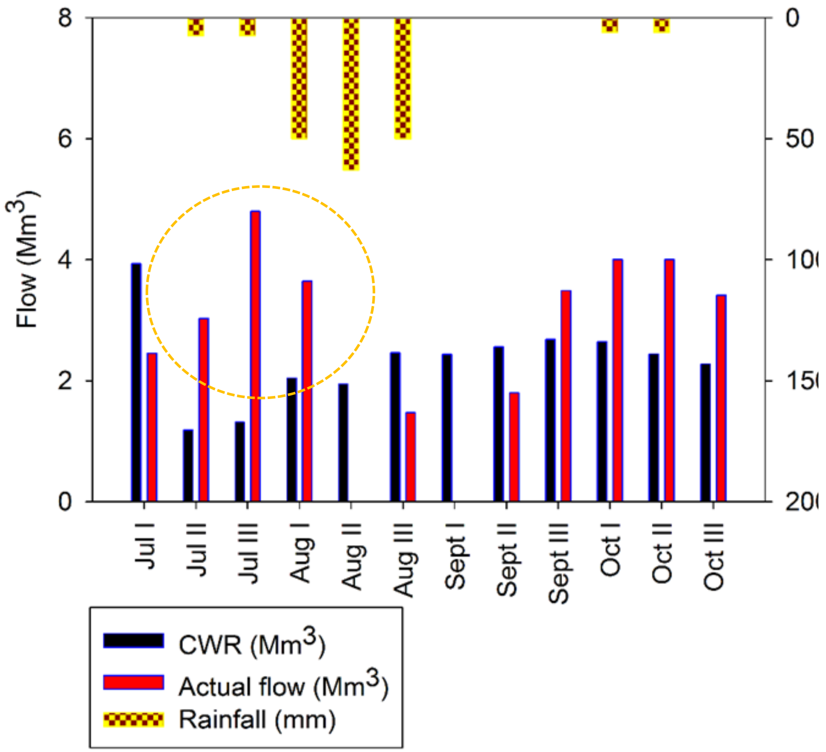


Process of deposition with time

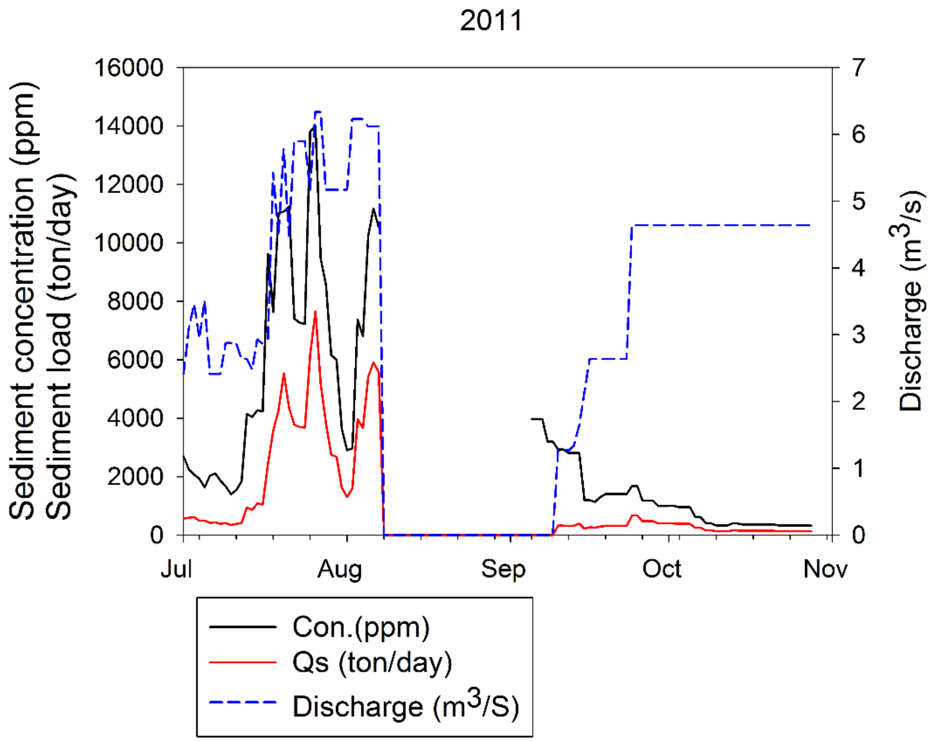
Numerical Model development (FSEDT)



Water released and crop water requirement



. Crop water requirement and release to
Zananda Major Canal in 2011



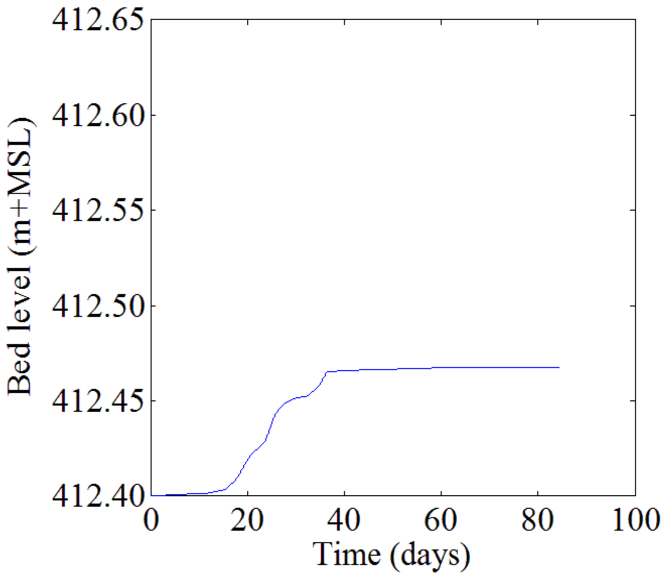
Water released at offtake
Zananda Major Canal

Options of operation for the major canals

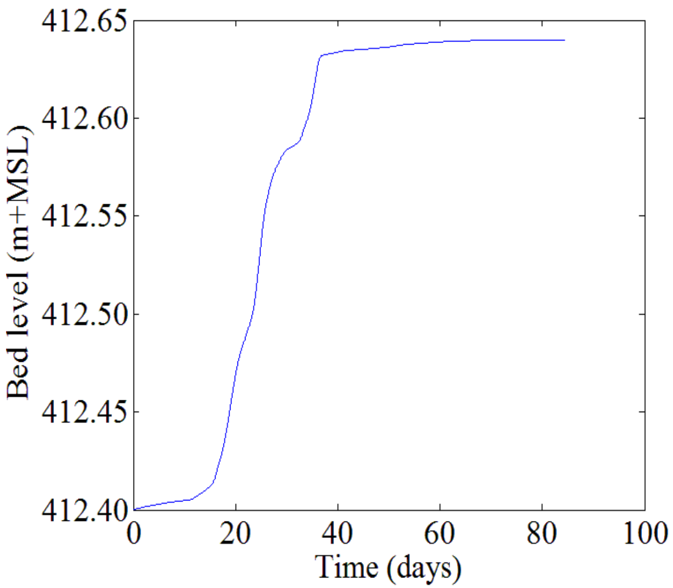
Reduction in deposition for different scenarios compared to actual situation in 2011

Operation scenarios	Reduction in deposition %	
	1st reach	2nd reach
Based on crop water requirement	51	55
Future scenario, 50% reduction in concentration	74	81

Operation under future conditions



(a) Reduction by 50%



(b) Actual situation

Accumulation of sediment at offtake of major canal based on reduction of concentration by 50% and in actual situation

Conclusions and the way forward

- Adjust supply to satisfy the crop water demand in irrigation canals with full capacity of the field outlet pipes is the way for better sediment and water management
- In Search of Sustainable Catchments and Basin-wide Solidarities; Integrated sediment and Water Management of the Blue Nile River Basin is highly needed
- Regional and international cooperation soil conservation of catchments, should be given the highest priority
- Sediment management is highly needed to increase the live time of dams and reduce the cost of dredging as well as construct of sediment control measures.
- Upgrading the monitoring system and the development of a new techniques is needed.


Thank you