Enhanced risk management strategies for mitigating future droughts in Central Asia

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BACKGROUND

Relevance

Sedimentation reduces the storage capacity of reservoirs and thereby, the ability to conserve water for various intended purposes. Consequently, the frequency and magnitude of failures increases. Therefore, the effect of storage capacity losses on the water availability has to be considered within the management of available water resources, especially under water deficit conditions.

The focus of the study lies on the assessment of ongoing reservoir storage capacity losses of the Tuyamuyun Hydro-Complex (THC) and its effect on the compensation of water deficit volumes during exceptional drought events. The risk of reservoir storage capacity losses is a serious problem for the future water supply of the lower Amu Darya region, Central Asia. Especially the in-stream Channel Reservoir as the main reservoir of the THC, presents sedimentation processes strongly influenced by the seasonal variation of the Amu Darya inflow. The study assesses effects of past and developed reservoir operation strategies on siltation processes in the Channel Reservoir, to evaluate the risk of storage capacity losses and the effects on the water availability.

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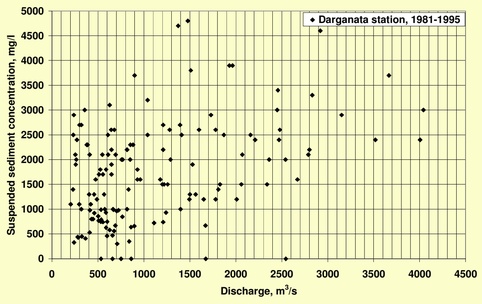
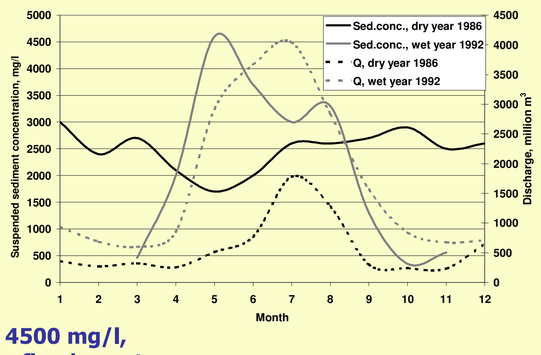
Suspended sediment in the lower Amu Darya River

Distribution of suspended sediment concentration (mg/l) on the Amu Darya river discharge, at the THC inflow reference station Darganata, 1981-1996



- **max. concentration, 4800 mg/l at a discharge of 1477 m³/s**
- **min. concentration, 300 mg/l at a discharge of 710 m³/s**

Monthly averaged suspended sediment concentration (mg/l) and monthly discharge (m³/s), for the wet year 1992 and dry year 1986



dry year 1986:

- **max. concentration: 3000 mg/l in January**
- **min. concentration: 1800 mg/l in May**

wet year 1992:

- **max. concentration: > 4500 mg/l, during the first summer flood events**
- **min. concentration: 500 mg/l, during the winter period**

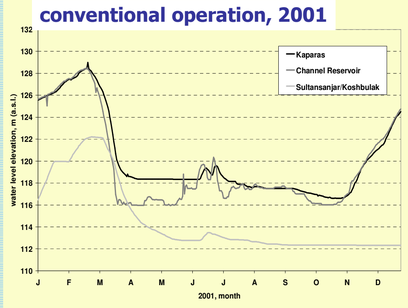
Enhanced reservoir operation for the THC

The existing reservoir system of the Tuyamuyun Hydro Complex (THC) offers highest capability for an adaptation of management strategies.

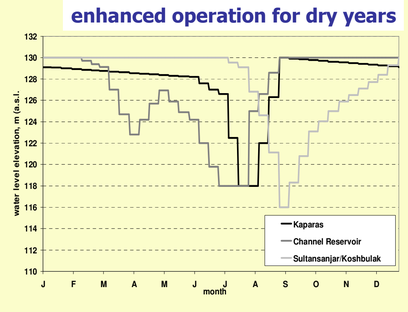
Applying the concept of enhanced reservoir operation it was planned to store mainly the low salinity summer flood in the drinking water reservoir Kaparas. The results have identified the most suitable combination of water level regimes for all reservoirs of the THC.

- **annual water demand: 20.2 km³/a**
- **annual inflow THC (dry year, 2001): 12.9 km³/a**

conventional operation, 2001



enhanced operation for dry years



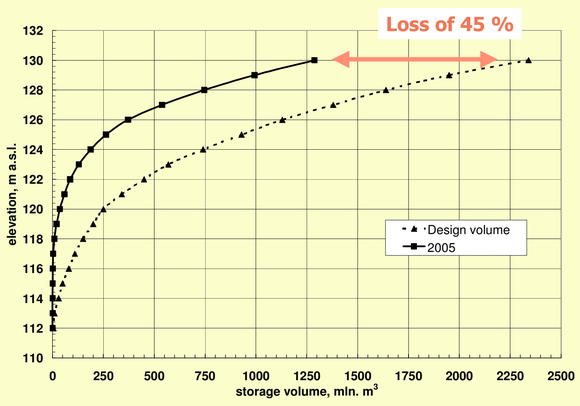
⇨ **an effective measure for a rapid and comprehensive improvement of the water quality in water crisis regions.**

⇨ **possibility to adapt the operation rules has been demonstrated the potential of the THC to supply the local population (of the lower Amu Darya region) with more potable water of higher quality even subject to a parallel reduction of water deficits**

RESERVOIR STORAGE CAPACITY ASSESSMENT

Storage capacity losses, Channel Reservoir

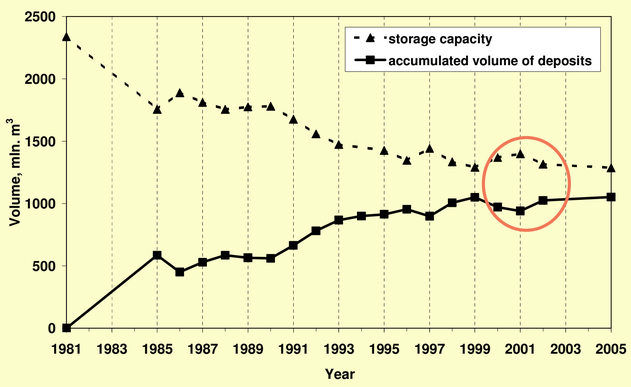
Actual Channel Reservoir bathymetric data (2005) for its comparison with the design capacities (1983).



⇨ **reduction of storage capacity: from 2 340 million m³ to 1 287 million m³ .**

⇨ **loss of 1 053 million m³ (= 45 %), an average of 48 million m³/a .**

Characterisation of Channel Reservoir siltation processes



- biggest volume of sediments with 222 million m³ accumulated in the high water years of 1991 - 1992 and with 108 million m³ in 1998
- removal of sediments
  maximum deposit volume of 135 million m³ during the low water year (THC inflow, 20.8 km³) in 1986, with 56 million m³ during 1997 (18.3 km³) and with 110 million m³ during the exceptional drought period 2000-2001 (18.7 and 13.6 km³)

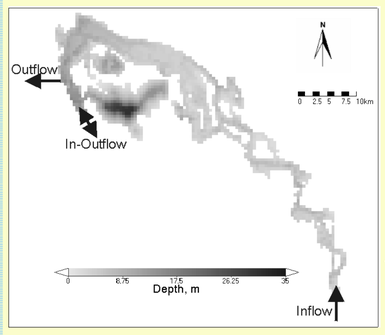
⇨ **dry years: flushing effects caused by past reservoir operation, with channelling the scarce water through the Channel Reservoir to the lower river without any storage.**

⇨ **wet years: increased risk of storage capacity losses, by conventional management**

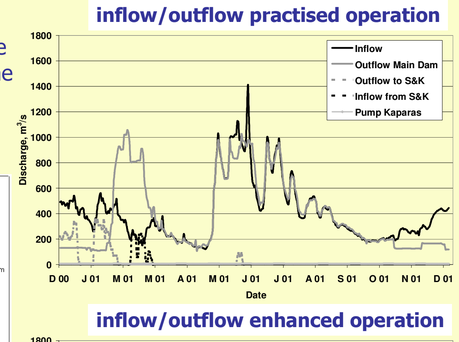
SIMULATION

Simulation of reservoir sedimentation processes, by MOHID

Boundary and initial conditions for the cohesive sediment simulation, with the 3D model MOHID Water



inflow/outflow practised operation



inflow/outflow enhanced operation

Developed average cohesive sediment inflow for dry years, as boundary condition

Past practised operation 2001 and Enhanced operation mode

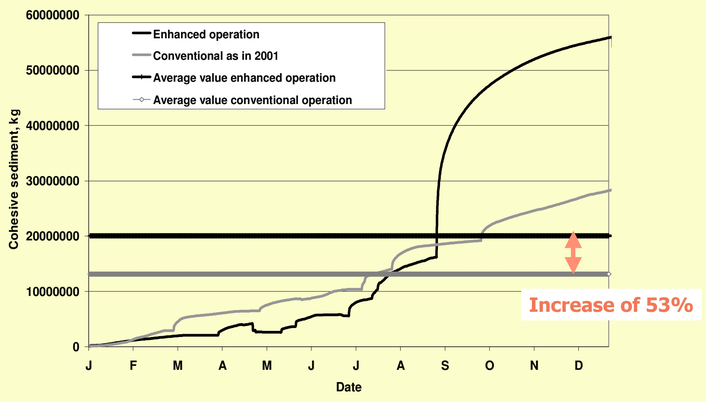
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cohesive sediment inflow mg/l	834	817	516	467	606	1640	910	665	490	302	344	495

RESERVOIR OPERATION ASSESSMENT

Simulation of conventional & enhanced operation

The aims of the following modelling exercises are the definition of the different reservoir operation effects on the sedimentation of cohesive sediment in the Channel Reservoir.

Simulation results for the cohesive sediments at the reservoir bottom, in total and average for the conventional and enhanced reservoir operation.

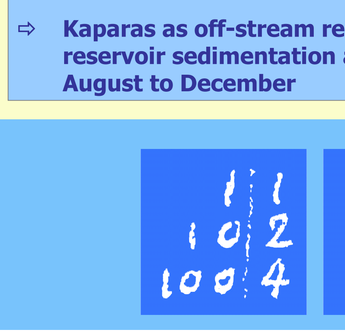


⇨ **conventional operation, as in 2001: continious sedimentation increase up to the max. of 28 200 000 kg, with an annual average of 13 000 000 kg/a**

⇨ **enhanced operation for dry years: continious sedimentation increase up to 16 200 000 kg in August, followed by a sharp rise to the max of 55 900 000 kg, with an annual average of 20 000 000 kg/a**

Simulation analysis

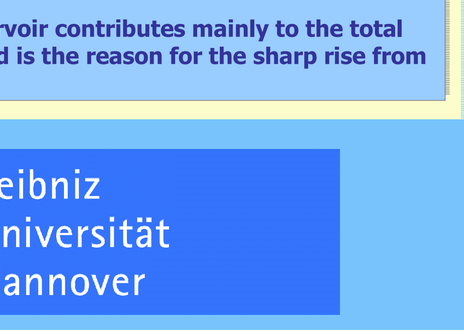
Cohesive sediments at the reservoir bottom, for predefined reservoir sections, Box 1-4.



Channel Reservoir, Box 1-3:
- **conventional operation: total max. 26 300 000 kg**
- **enhanced operation: total max. 33 100 000 kg**

Kaparas reservoir, Box 4:
- **conventional operation: max. 1 930 000 kg**
- **enhanced operation: max. 22 700 000 kg**

conventional operation



enhanced operation

⇨ **impact of the enhanced operation on variation of water levels, with the refill of the Channel Reservoir and Kaparas in August/September to provide water of low salinity, flow velocities fell and sedimentation rise to its maximum**

⇨ **Kaparas as off-stream reservoir contributes mainly to the total reservoir sedimentation and is the reason for the sharp rise from August to December**

CONCLUSION

The THC significantly influences the sediment regime of the lower Amu Darya as a sediment trap. The results illustrate that a huge amount of sediments is stored at the THC reservoirs. Initially, THC had a total storage capacity of 7.8 km³ but due to siltation, by 2001 the total storage was reduced to 6.9 km³. Since the initiation of impoundment of the Amu Darya in 1983, at the normal pool level of 130 m (a.s.l.), Channel Reservoirs storage capacity has been reduced by 45%. This is an average of slightly over 2% to 3% per year. In consideration of the results for the potential reservoir capacity losses it can be assumed, that Channel Reservoir with a currently available total storage volume of 1 287 million m³, will be able to operate without silt removal for at least another 25 years.

However, already the total design capacity, 7.8 km³, of the THC reservoirs provide not enough storage volume for keeping a strategic reserve for covering water deficits and irrigation demands of 20.2 km³ for the lower Amu Darya region, during dry years as 2001 (with an average discharge of 12.8 km³). Furthermore, the assessment results for the risk of storage capacity losses and therefore the opportunity to compensate water deficits by drought events indicate currently an increased risk of failure for the THC storage volume.

The assessment of the reservoir operation strategies has identified an increase in annual sedimentation of 13% for the Channel Reservoir and of 53% for the system Channel Reservoir-Kaparas by enhanced operation during dry years. However, Kaparas provides a sufficient volume for sedimentation, because of the big dead storage volume of 320 mln. m³. The loss in Channel Reservoir storage capacity can be assumed as a comparably minor effect if simultaneously a reduction of water deficit from 21.5% (conventional operation) to 9.9% can be achieved by applying the enhanced reservoir operation during dry years.

The results shows the need for sustainable sediment management for the reservoir in order to avoid further capacity losses. It should be proofed which sediment management is applicable for the special characteristics of the Channel Reservoir and how it can be implemented in an enhanced reservoir operation method. The sediment management method of flushing and sluicing could be appropriate, by application in high or normal water years.

The study has emphasized that a more precise understanding of reservoir sedimentation processes and resulting storage capacity losses provides necessary background information for assessing management options during drought events and the impact of climate change on water availability during the next 50 years.

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