Research on reservoir sedimentation of cascade hydro-projects

--Taking Dachaoshan Reservoir as an example
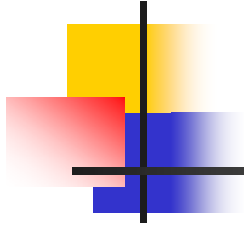
Case study II

Application of numerical simulation to Dachaoshan Reservoir

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Introduction

   Dachaoshan Reservoir is located in the lower reach of Lancang River. Its storage capacity is 0.74 billion m^3 at the operational water level of 899m and the total installed capacity is 1350MW.
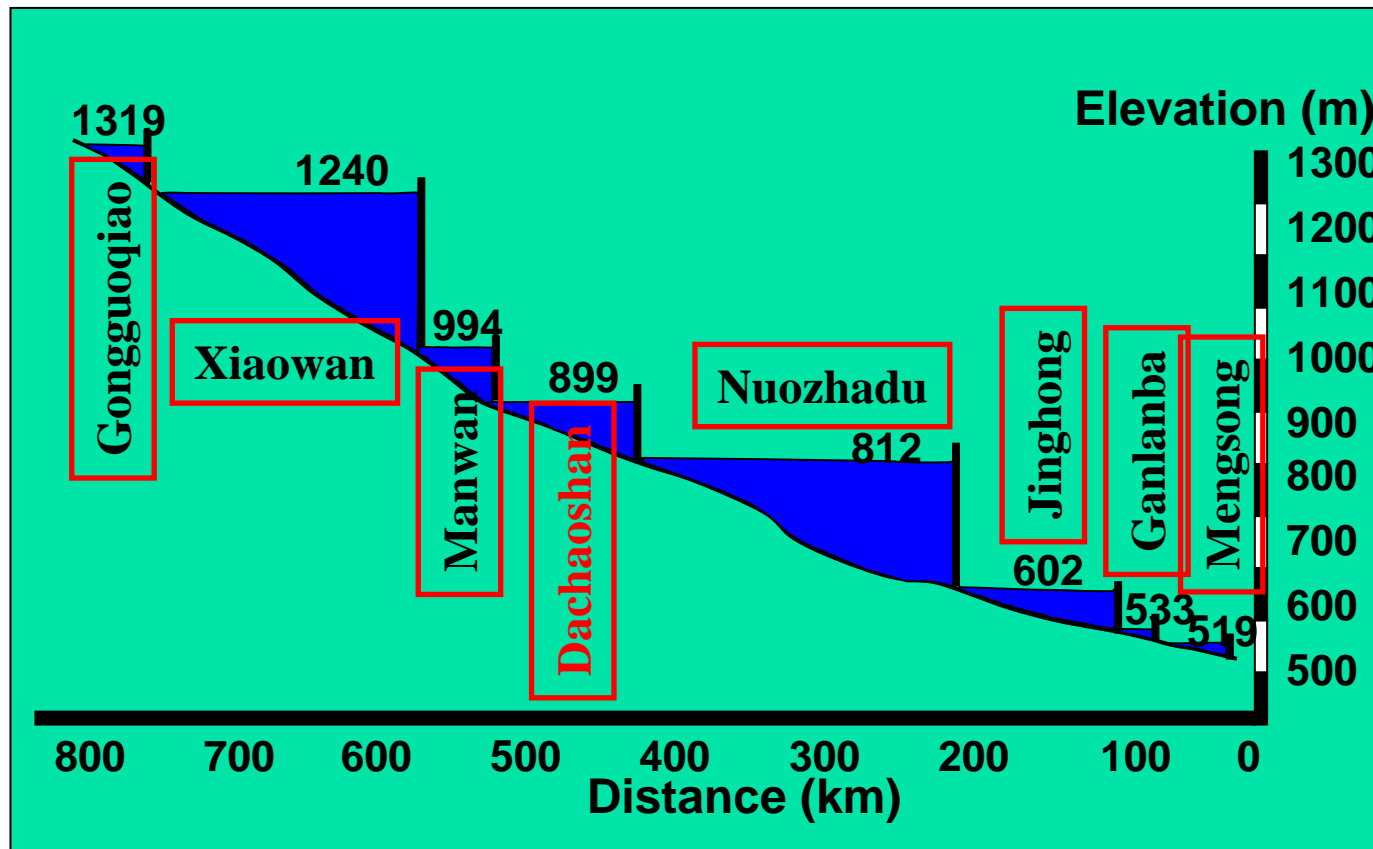
Introduction

Hydro-projects planning

The trunk of the Lancang River has enormous hydroelectric resources. According to the planning, 8 cascade hydro-projects were or will be constructed along the river reach of 800km in Yunnan Province with a total installation capacity of 25.66 million kw and annual electricity of 128.1 billion kw.h. The 8 cascade hydro-projects are Gongguoqiao, Xiaowan, Manwan, Dachaoshan, Nuozhadu, Jinghong, Ganlanba and Mengsong from the upper to the lower reach.

Introduction

Hydro-projects planning

Introduction

Hydro-projects planning

- Xiaowan reservoir, 2nd cascade project, will operate in 2010, storage capacity 14.9 billion m^3.
- Manwan reservoir, 3rd cascade project, was operated in 1993, storage capacity 0.92 billion m^3. .
- Dachaoshan reservoir, 4th cascade project, was operated in 2001, storage capacity 0.74 billion m^3.
- Sedimentation in Dachaoshan reservoir is affected not only by its operation, but also by the operation of the upper Xiaowan and Manwan hydro-projects.

Introduction

Objectives of the paper

- ➢ Taking Dachaoshan reservoir on Lancang River as an example, the influence of cascade hydro-projects on sedimentation is illustrated.
- ➢ Three calculation scenarios: (1) no reservoir in the upper reach of Dachaoshan project; (2) only Manwan project is considered; (3) both Xiaowan and Manwan projects are considered.
- ➢ Through the comparison of the three scenarios, the influence of cascade hydro-projects on the total sedimentation, deposition processes, sedimentation distribution, life span of Dachaoshan reservoir can be summarized.

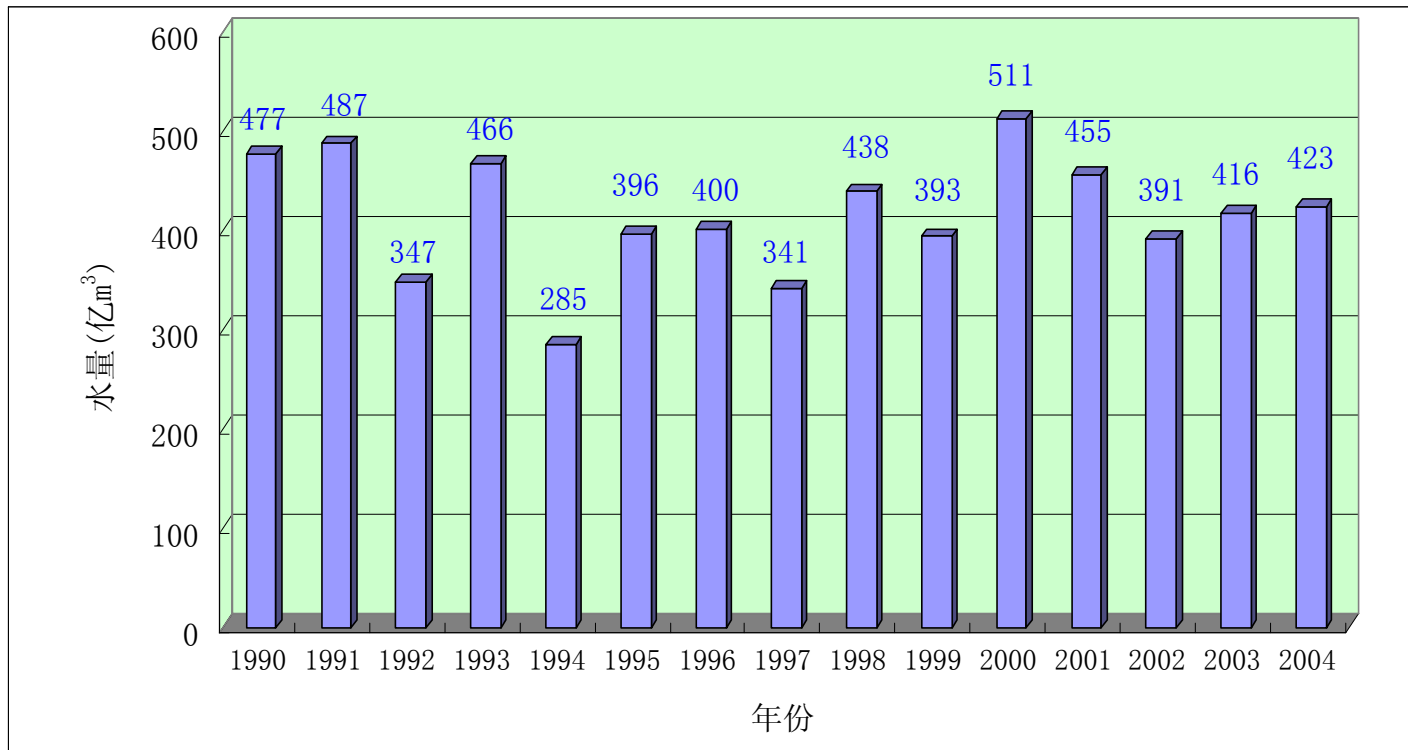# Introduction

Flow and sediment condition

Damsite: the annual runoff and sediment amount are 41.9 billion m^3 and 54.9 million t. The percentages of flow and sediment during flood season (Jun. to Oct.) are 77.8% and 95.8% respectively.

Inlet(Gajiu Hydr. Station): The annual runoff and sediment are 38.8 billion m^3 and 46.4 million t.

After the operation of Manwan Reservoir since 1993, the sediment into Dachaoshan was greatly reduced.
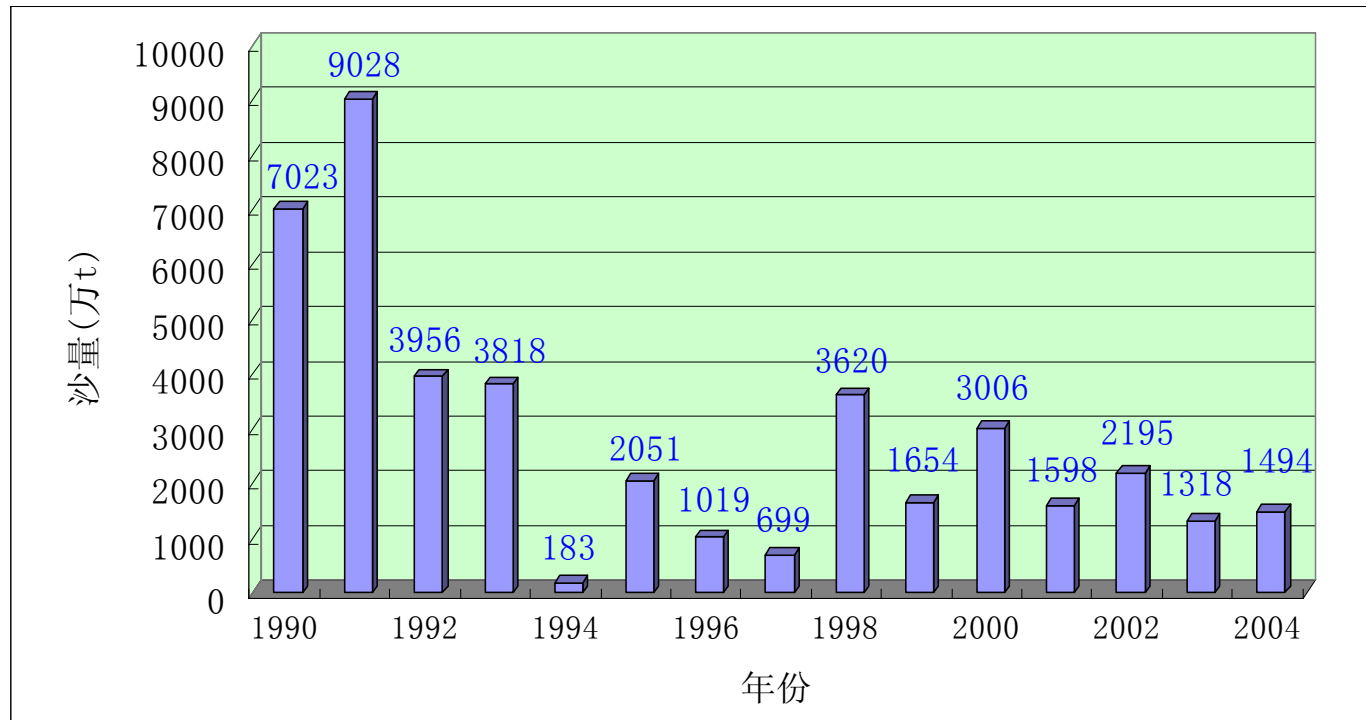
Introduction

Flow and sediment condition

Annual runoff at Gajiu Station

Introduction

Flow and sediment condition

Annual sediment amount at Gajiu Station

Mathematical Model

Governing equations of the model

Flow,
$$\frac{\partial H}{\partial x} + \frac{1}{2g}\frac{\partial}{\partial x}\left(\frac{Q}{A}\right)^2 + \frac{1}{g}\frac{Q}{A^2}q_x + \frac{n^2 Q|Q|}{A^2 R^{4/3}} = 0$$

Sediment,
$$\frac{\partial hUS}{\partial x} = -\alpha\omega\left(S - S^*\right)$$

Bed Deformatio n,
$$\rho'\frac{\partial Z_b}{\partial t} = \alpha\omega\left(S - S^*\right)$$

H=Water level; Q=flow discharge; q_x=lateral flow discharge; A=flow area; U=Velocity; S=Sediment concentration; S^*=Sediment-carrying capacity; ω=settling velocity; R=Hydraulic radius; C=Chezy coef.; ρ'=dry density; h = Flow depth; and Z_b= Channel bed elevation.

Mathematical Model

Verification of the model

Domain: the simulated reach is about 89km, from cross section D54 to D01. 54 CS in total are used with a average distance about 1.66km.
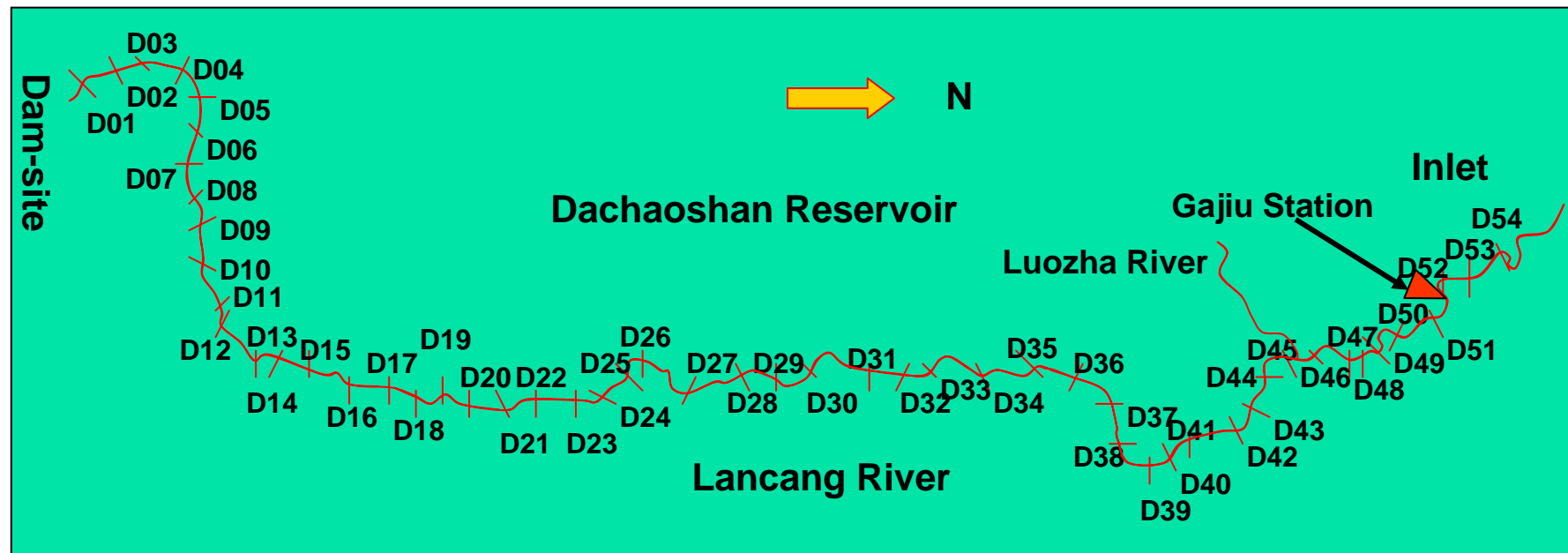
Mathematical Model

Verification of the model

Duration: from May 2000 to April 2003

Time interval: time step in flood season is one day and in non-flood season is 5~7days.

Boundary condition: at the inlet, Q, S, P should be given; at the dam, operational water level and discharge should be given.

Initial condition: 54 CS measured in May 2000 are used, the initial bed size gradation is also given.
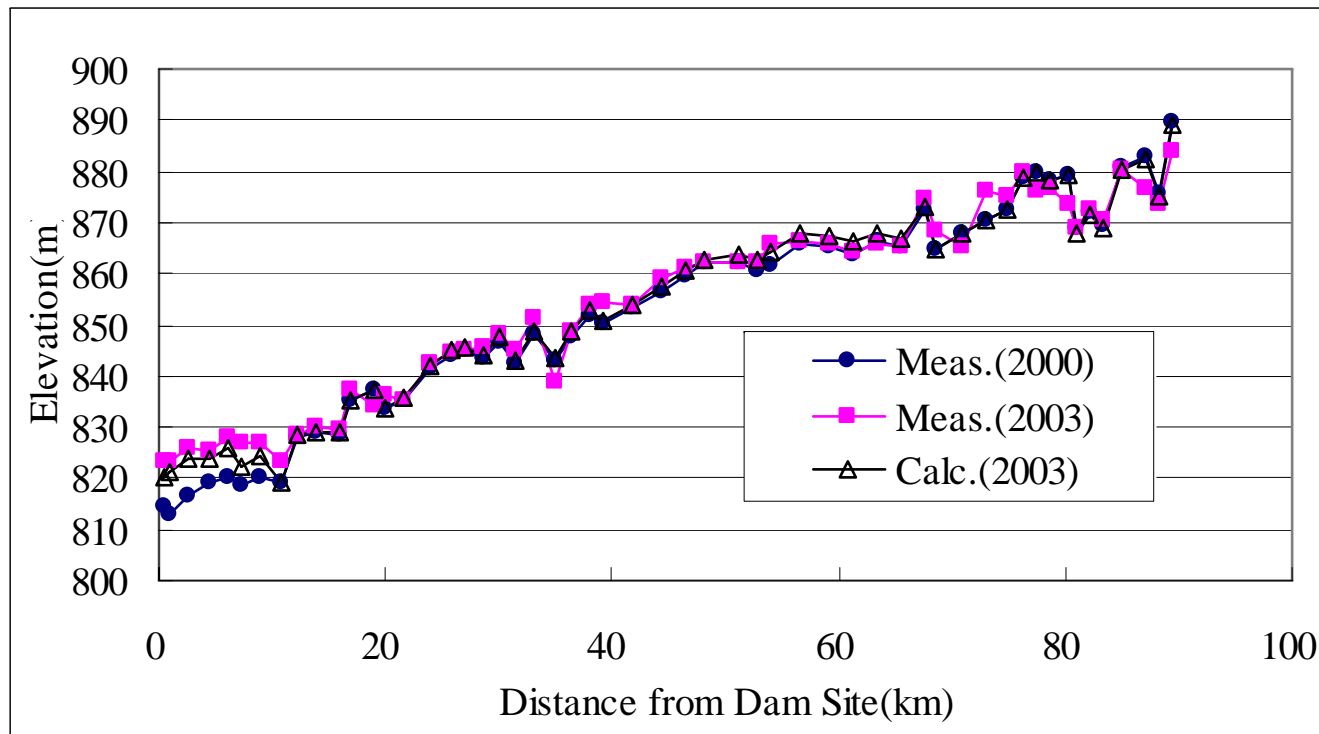
Mathematical Model

Verification of the model
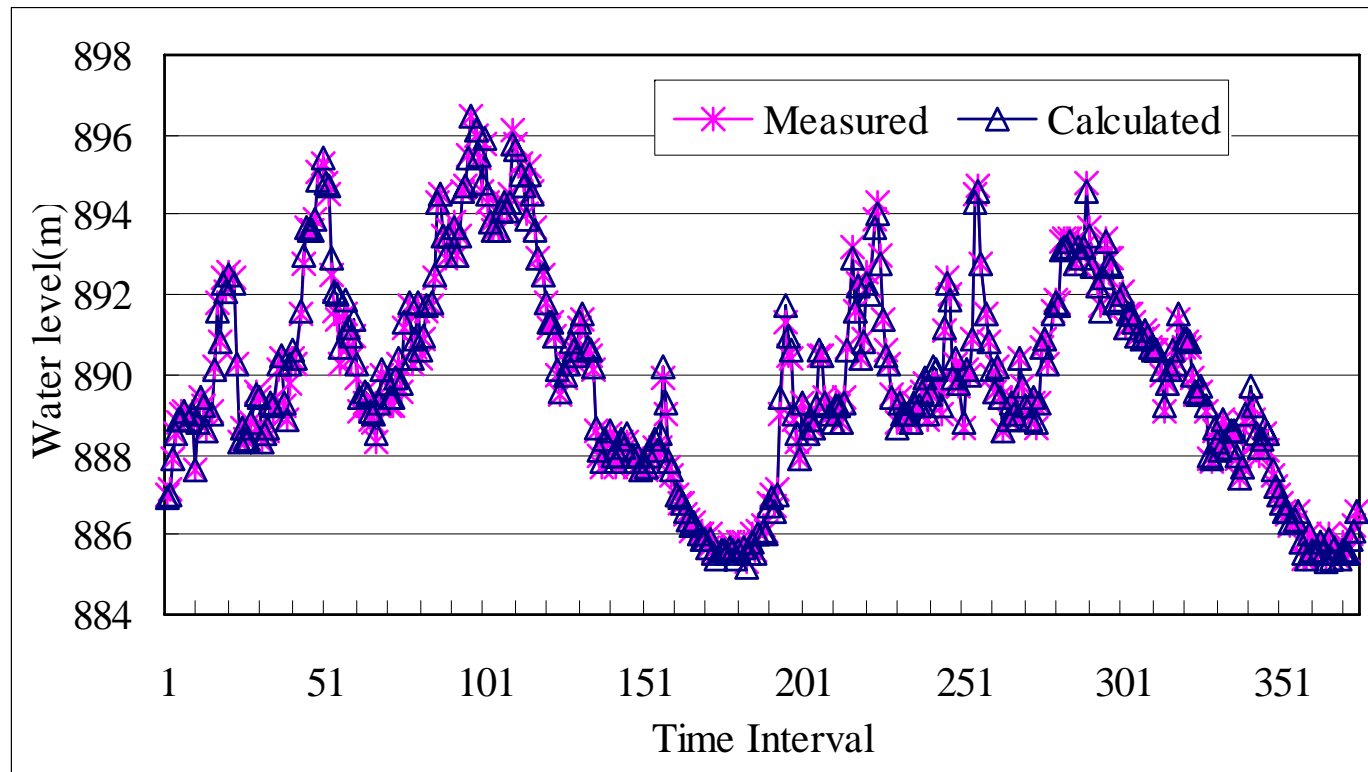
Water level at Gajiu station

Mathematical Model

Verification of the model

Longitudinal sedimentation profile

Effect of cascade dams on Dachaoshan reservoir

Three scenarios

To estimate the effect of Manwan and Xiaowan on the sedimentation in Dachaoshan reservoir in the future 50 years, three scenarios are considered.

➢ Scenario 1 (SC1): no cascade hydro-projects upstream and the natural flow-sediment is used as inlet boundary;

➢ Scenario 2 (SC2): only Manwan reservoir and the flow-sediment released from Manwan is used as inlet boundary;

➢ Scenario 3 (SC3): both Manwan and Xiaowan are operated, and the flow-sediment into the Dachaoshan is that released from Manwan with consideration of Xiaowan .

Effect of cascade dams on Dachaoshan reservoir

Operation mode of Dachaoshan reservoir

➢ Nov. to Apr., operation water level 899m;

➢ May, slowly down to 883m before Xiaowan or 887m after Xiaowan;

➢ Jun. to Oct., Q<4000m³/s, water level lower than 891m; 4000<Q<7010m³/s, 886 to 891m before Xiaowan or 890 to 891m after Xiaowan; Q>7010m³/s, 886m before Xiaowan or 890m after Xiaowan;

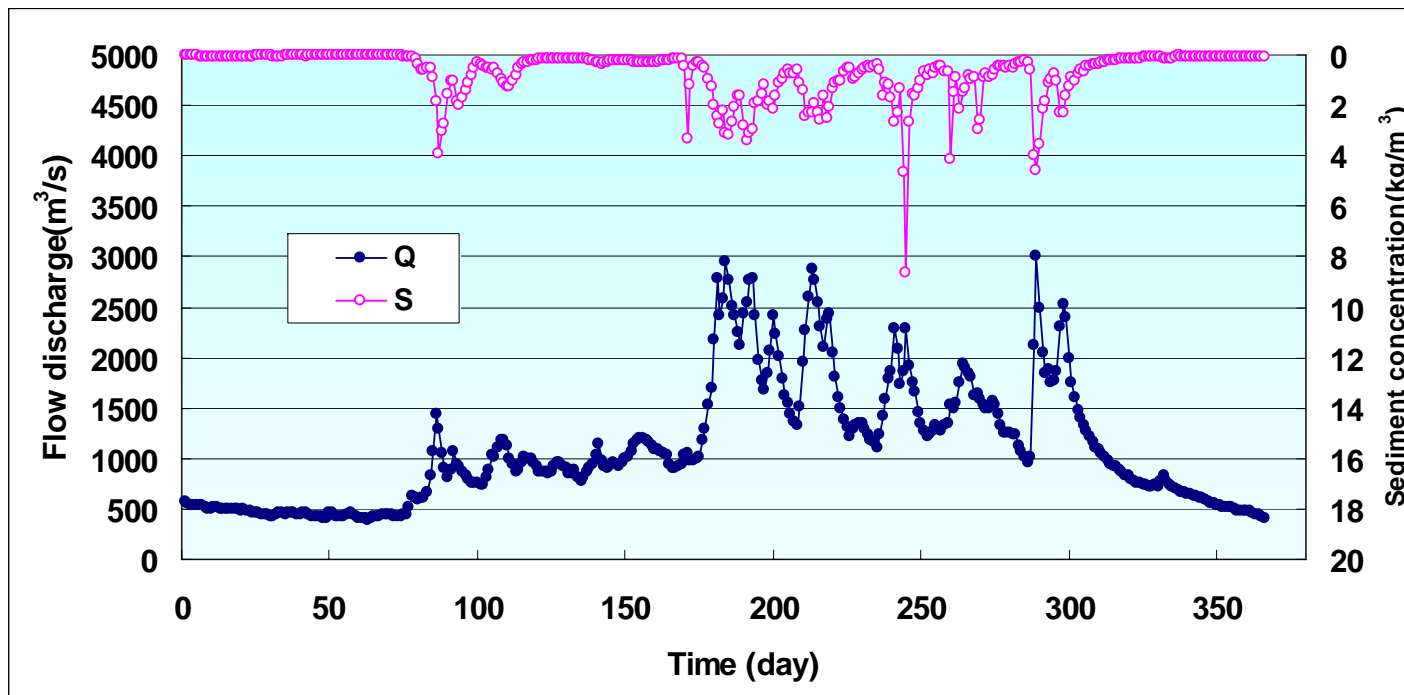# Effect of cascade dams on Dachaoshan reservoir

Calculation conditions

- ➢ **Typical year: according to annual runoff and sediment amount, the measured flow and sediment series in 1992 are selected as the typical year.**
- ➢ **Initial CS: the measured CS in April 2003 are used as the initial channel bed condition.**
- ➢ **Initial channel bed material size: given by the verification results.**
- ➢ **Calculation duration: the future 50 years from 2003.**

Effect of cascade dams on Dachaoshan reservoir
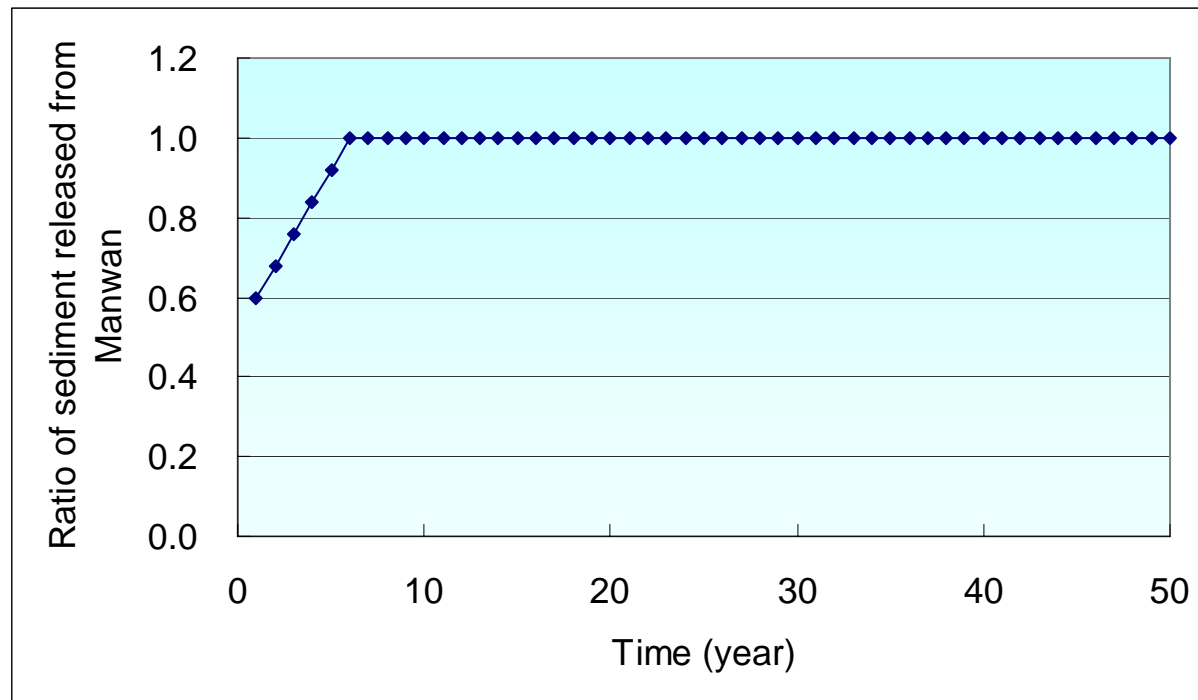
Calculation conditions

➢ **SC1: the measured flow and sediment in 1992 is used as the flow and sediment condition at the inlet.**

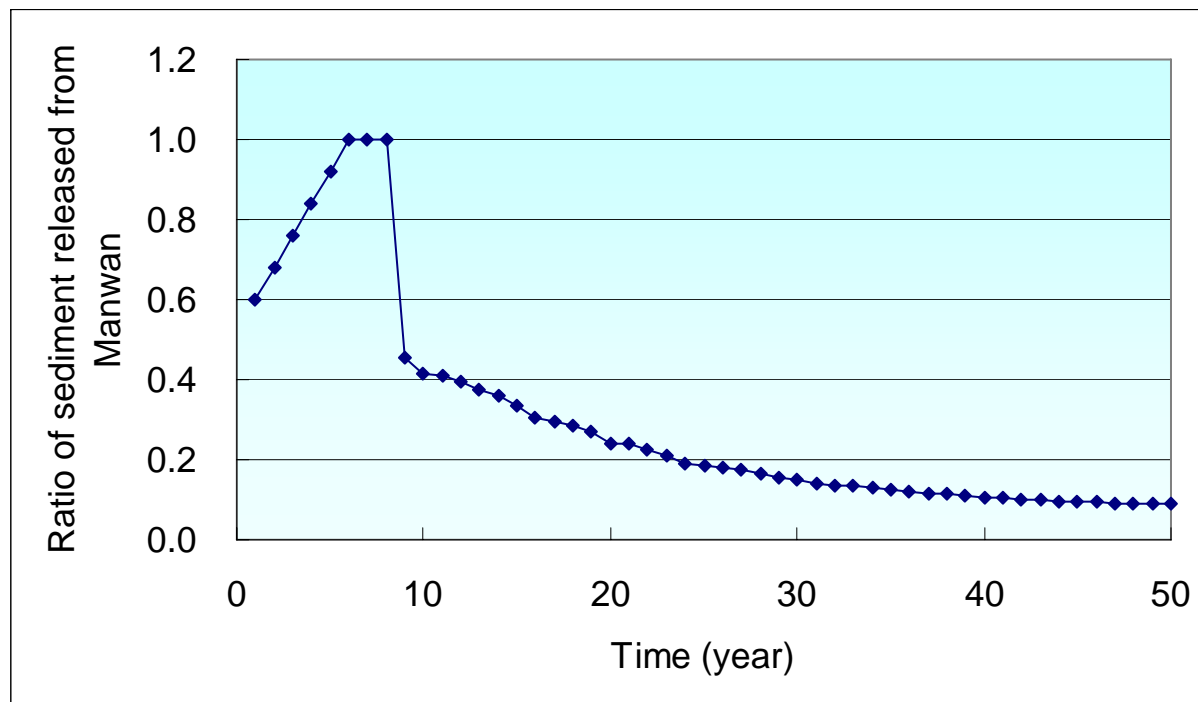# Effect of cascade dams on Dachaoshan reservoir

Calculation conditions

➢ **SC2: the incoming flow condition is same as SC1, but the effect of Manwan Reservoir on sediment should be considered based on the ratio of sediment released from Manwan Reservoir.**
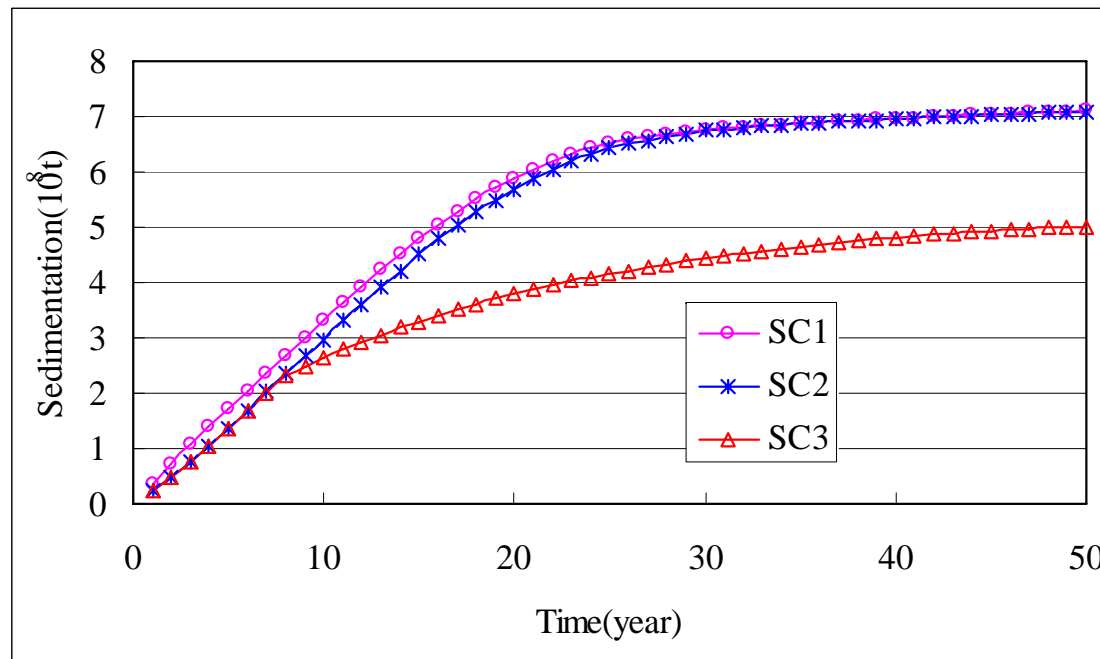
Effect of cascade dams on Dachaoshan reservoir

Calculation conditions

➢ **SC3: the incoming flow condition is same as SC1, but the incoming sediment condition should consider the effect of Manwan and Xiaowan Reservoirs.**

Effect of cascade dams on Dachaoshan reservoir

Effect on total sedimentation amount

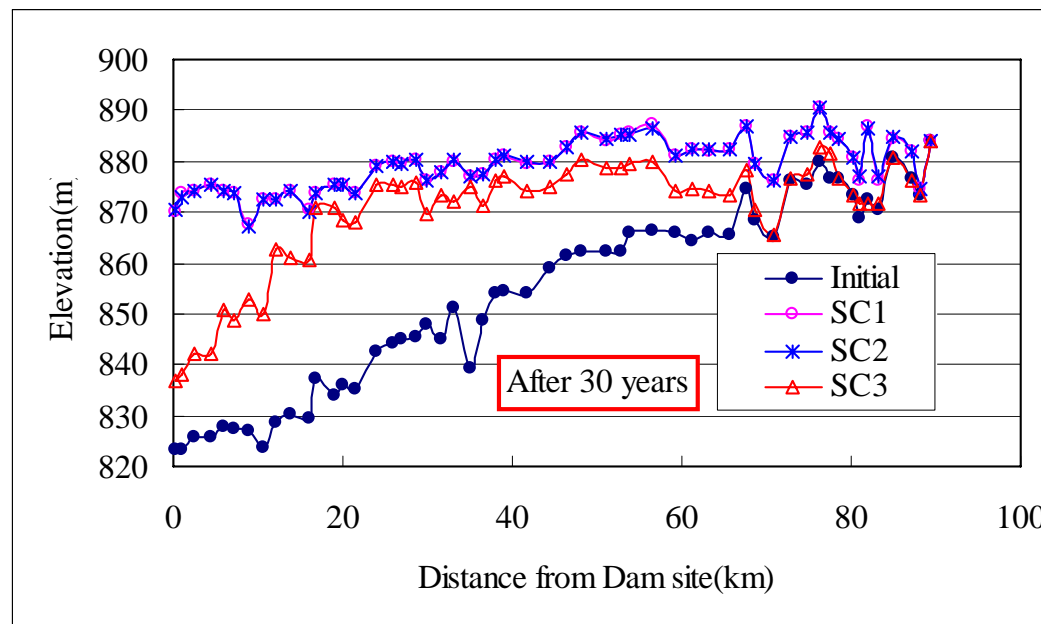

Total sedimentation in 50 years (billion tons)
SC1: 0.710
SC2: 0.709
SC3: 0.50

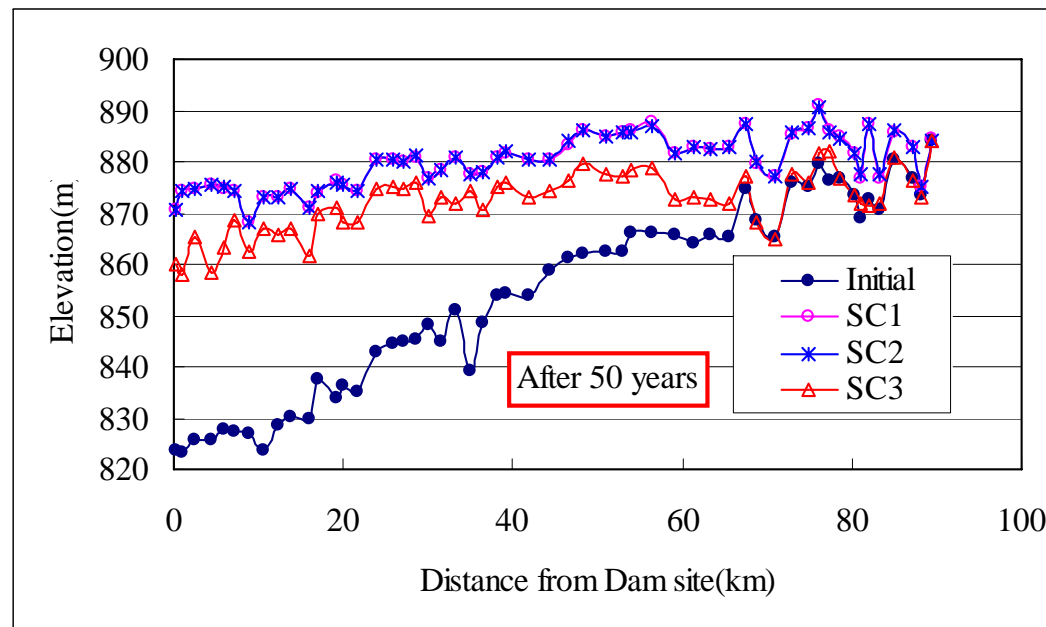# Effect of cascade dams on Dachaoshan reservoir

Effect on longitudinal profiles

Longitudinal profile in 30th year of SC3 is much lower than SC1 and SC2, which means SC3 has more effective storage capacity and longer life span.

Effect of cascade dams on Dachaoshan reservoir
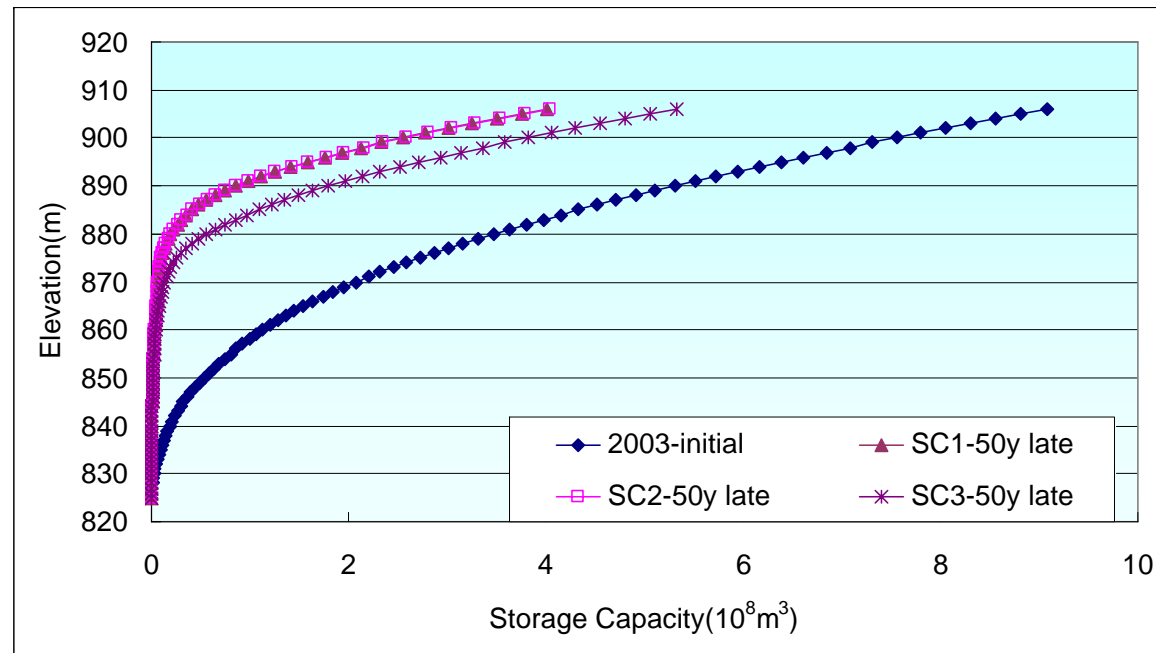
Effect on longitudinal profiles

Longitudinal profile in 50th year of SC3 is still lower than SC1 and SC2. Sedimentation is still on the way to equilibrium.

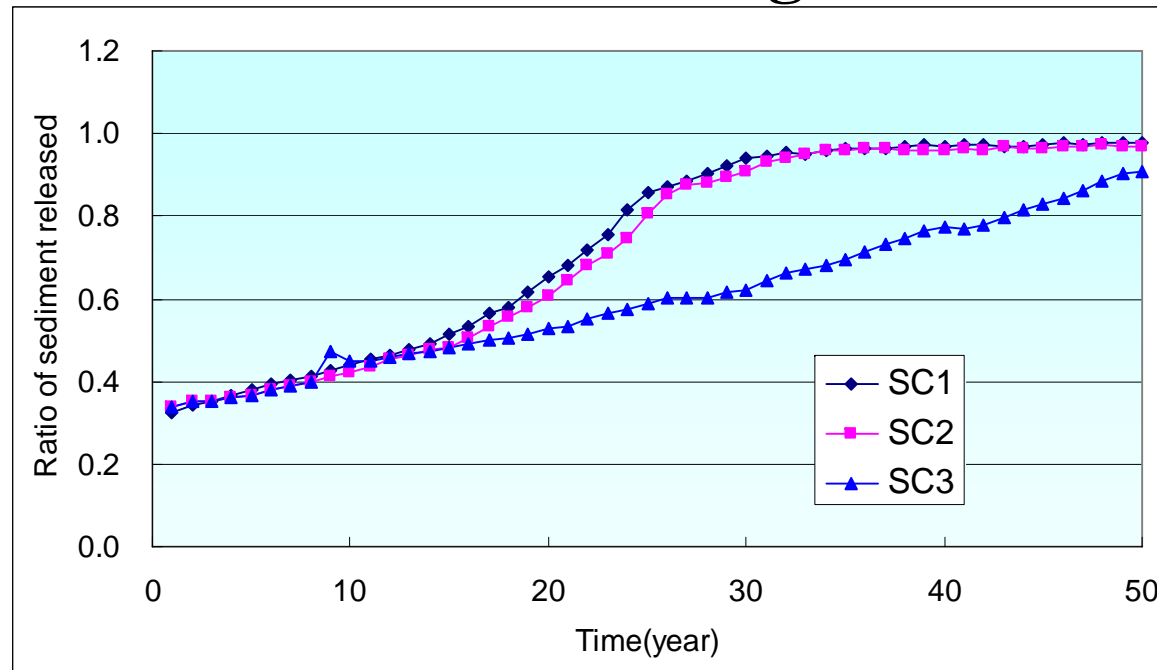# Effect of cascade dams on Dachaoshan reservoir

Storage capacity remained

Storage capacities at water level 899m remained after 50 years for SC1, SC2, and SC3 are 0.233, 0.235 and 0.36 billion m³ respectively.

Effect of cascade dams on Dachaoshan reservoir

Sediment releasing ratio

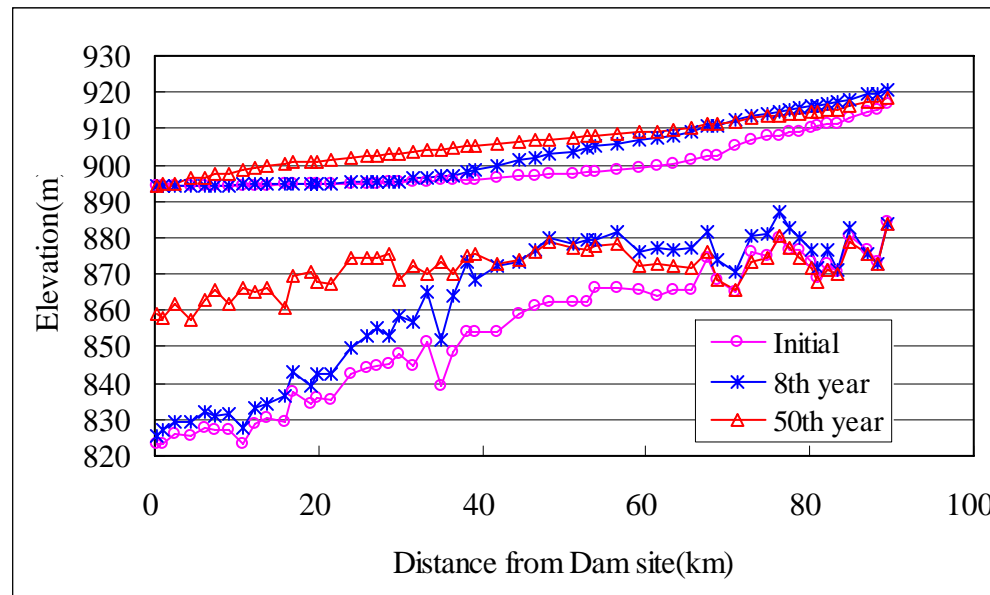SC1 is close to SC2, but SC3 is largely smaller than those of SC1 and SC2.

SC1 and SC2: the ratio at 30th year is over 0.9, equilibrium

SC3: ratio at 30th year is only 0.6, far from equilibrium,
     ratio at 50th year is about 0.9, equilibrium

Effect of cascade dams on Dachaoshan reservoir

Effect on flood level

Water level profiles of the flood with frequency 100 years

- Tail water level in 8th year at inlet (before Xiaowan) is 3.95m higher than that in initial time.
- Water level in 50th year is 1.99m lower than that in 8th year, but higher than that in initial time by 1.97m
- Lowering of water level in tail reach could benefit a lot to the power generation of Manwan hydro-project. .
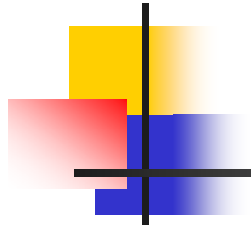
Conclusions

➢ **If there is no cascade hydro-project upstream, the sedimentation process in Dachaoshan reservoir would be very fast and a new equilibrium condition would appear after 30 years.**

➢**The operation of Xiaowan reservoir greatly reduces the sediment entering Dachaoshan reservoir, remarkably alleviates the sedimentation progress, and obviously prolongs the life span of Dachaoshan hydro-project.**

Conclusions

➢ **The operation of Xiaowan reservoir effectively improves the longitudinal sedimentation distribution, prevents the water level at the tail reach from rising, and increases the power generation of Manwan hydro-project.**

Thanks