Keeping Health Life of Yellow River:

Integrated Water and Sediment Management of Yellow River

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Outline:

I. Yellow River Characteristic and Strategy of Integrated Water and Sediment Management of Yellow River

II. Implementation of Yellow River Water and Sediment Regulating

III. Main Technical Approaches and Innovation

IV. Success and Effectiveness Analysis
I. Yellow River Characteristic and Strategy of Integrated Water and Sediment Management of Yellow River

Yellow River Characteristics

- Less water with more sediment, disharmony of sediment and water
- Annual water inflow: 58 billion m³; Annual sediment transportation: 1.6 billion t; Sediment contents: 35kg/m³
Annual water inflow of YR is 6% of Yangtze, however, annual sediment transportation of YR is 3.7 times of Yangtze. If the sediment of YR was built in a mound 1 meter high and 1 meter wide, it could circle the equator of the earth 27 times!
Yellow River in History

YR is known for its large amount of sediment, suspended river, tendency to silt, to break, to move, and frequent flood disaster;

During the past 2540 years before 1938, YR is breached averagely twice every three years and changes its course once every hundred years.

The lower YR bed was silting up 10 cm/a. The embankment of lower YR has been raised up for 4 times since 1950, with a total input of 20 billion RMB.

“the Sorrow of Chinese Nation”
Yellow River in Nowadays

- Carrying capacity of flood and sediment decreased; Plain runoff reduced from 6000m³/s to 1800m³/s; Main channel silted and shrank severely.

- Large-scale overflow with only small flood; 1.8 million inhabitants suffering from the floods.

- “Secondary silting” is serious; High risk of dike breaching.

- Flood level with current 7600m³/s is 29 cm higher than 22300m³/s in 1958 (Huayuankou Station)

Situations of Yellow River safety is getting severe.
The Diagram of Cross-section in Yangxiaozhai of Yellow River lower region

Distance of Jumping-off (m)

-1000 0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000

Height

Flood Plain
River Channel

Yellow River Dike

1958-10-25
1982-10-24
2002-7-22
Key Problems of Yellow River Management

- Restrict the tendency of downstream silting and shrinking, resume the plain runoff, avoid "large-scale overflow with small flood", decrease the risk of disaster in the lower Yellow River.

- To achieve high efficiency of sediment transportation with limited water resources, improve the carrying capacity of sediment and flood, control the trend of "secondary silting", make sure the safe of Yellow River.

- To accomplish sediment flushing in both reservoir and river channel, extend the operating life of reservoir, extend the running time of lower river course, make sure Yellow River keep good training and safety in a long term.
Water and sediment regulating is one of the main approaches to harmonize the water and sediment of the YR.

**Approaches**

- **Increase water**
  - Save water
  - Trans-boundary water division
- **Decrease sediment**
  - Water and soil conservancy
  - Silt tracking by main projects
  - Check dam
  - Joint regulating of reservoir groups
- **Water and sediment regulating**
  - River channel

Build a harmony relationship between water and sediment.
Strategy of Integrated Water and Sediment Management of Yellow River

Based on long term theory study, model experiment, practical experience;

Make reasonable scheme for water and sediment regulating;

Use reservoir group in main stream and tributary as regulation method;

Build a relative harmonious relationship between water and sediment;

Rehabilitate and maintain the carrying capacity of sediment and flood in main channel, expand plain runoff, to reduce silting in both water course and reservoir, to mitigate the harsh situation of flood control in lower Yellow River;

Explore the trend of water and sediment movement in Yellow River.
To rehabilitate the carrying capacity of flood and sediment in lower river channel, to increase the plain runoff, to mitigate the situation of “large overflow when small flood”

To explore the technology index system to harmonize water and sediment in YR, and the operation methods of water and sediment regulating with reservoir groups.

Control the developing trend of “secondary silting”, make sure the YR is safe every year.

To explore the movement rules of YR water and sediment in river course and reservoirs, to build a technological foundation and accumulate experiences for the water and sediment regulating in the whole River.

To explore methods to extend the operating time of lower river course, to achieve YR’s long term safety.
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II. Implementation of Yellow River Water and Sediment Regulating

1. Preparation

1. Since 1960’s to the operation of Xiaolangdi Reservoir in 1999, several generations of people work hard consistently to explore methods to harmonize the relationship between water and sediment of YR.

2. Since 1990’s to 2001, many researches on various index and approaches of YR water and sediment regulating, finally formed the schemes of YR water and sediment regulating.
2. Experiments

2002~2004, three experiments of Yellow River water and sediment regulating were conducted. The range of experiment includes the reservoirs in the mainstream and tributaries of Middle Yellow River like Xiaolangdi, Sanmenxia, Wanjiazhai, Luhun, Guxian, and also the 2000km river course from Wanjiazhai reservoirs to the River estuary. To ensure the success of the experiments, dozens of schemes and experimental process have been made.
On 4-15 July 2002, the first experiment of YR water and sediment regulating was conducted mainly using the storing water of Xiaolangdi Reservoir, combined with the inflow above Sanmenxia Reservoir.
First time YR water and sediment regulating

Experiment start

**am 9:00**

4 July

Discharge: **2740 m³/s**
Water discharged: **2.61 billion m³**
Average Sediment content when release from the reservoir: **12.2 kg/m³**

**Totally 11 days**

**am 9:00**

15 July

Return to normal discharge
3. Regular Operations

Up to the present from 2005, five times operations of Yellow River water and sediment regulating have been undertaken.
More than hundreds thousands people has involved in the experiments and operations of YR water and sediment regulating, and acquired over 10 millions sets of scientific data about hydrology and sediment.
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1. ✓ First time to successfully implement large-scale, systematic, well-planned experiments of water and sediment regulating;
   ✓ Acquired lots of scientific data and huge outputs;
   ✓ Makes significant benefits for flood control in the lower YR;
   ✓ A magnificent innovation in the world history of river management.
2. Put forward the index system of water and sediment regulating, including the critical flow of initial sediment trapping in Xiaolangdi reservoir;

Through joint regulating of water and sediment by reservoir groups, realized the artificial density flow, and developed the approaches on reservoir sediment discharge.
Index system of water and sediment regulating in lower Yellow River under current condition.

Unit: Sediment content: kg/m³  Runoff: m³/s

<table>
<thead>
<tr>
<th>Sediment content in Huayuankou</th>
<th>Runoff in Huayuankou</th>
<th>Runoff in Aishan</th>
<th>Flood Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>S ≤20</td>
<td>Q ≥ 2600</td>
<td>Q ≥ 2300</td>
<td>T ≥ 9 days</td>
</tr>
<tr>
<td>S ≤30</td>
<td>Q ≥ 2700</td>
<td>Q ≥ 2500</td>
<td>T ≥ 12 days</td>
</tr>
<tr>
<td>S ≤40</td>
<td>Q ≥ 3000</td>
<td>Q ≥ 2700</td>
<td>T ≥ 8 days</td>
</tr>
</tbody>
</table>

Note: Amount of fine sediment with d<0.025mm take account more than 90%
3. Three application models of Yellow River water and sediment regulating in the initial stage of Xiaolangdi Reservoir operation has been put forward as:

- Priority on single reservoir regulating of Xiaolangdi Reservoir,
- Connection of water and sediment in spatial scale,
- Joint regulating of reservoir groups in the main stream.
4. Made scientific scheme of water and sediment regulating based on river monitoring, modeling and digital stimulating; Achieved effective control on the process of water and sediment through the systematic innovation and integration on hydrology weather forecast, coupling of forecast and regulating, remote monitoring of water regulating, etc.
5. ✔ Developed vibratory suspending sandiness measuring system, muddy water interface detector; introduced advanced equipments suitable for muddy river measuring, such as laser particle size analyzer, etc.

✔ Achieved the fast online monitoring of sediment, which ensured the real time water and sediment regulating.
Main technical methods of water and sediment regulating

Technology of water and sediment regulating

- Index of balanced water and sediment relationship
- Forecast and control of sediment content flowing out of reservoir
- Artificial sediment disturbing
- Water and sediment connection
- Flowing capacity forecast of lower main channel
- Overall flow process control
- Reservoir silting reduction
- Hydrology monitoring and forecasting

Validated and developed through experiments and practical operations

Good technological foundation for future operation of YR water and sediment regulating
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1. • Lower YR main channel has accomplished all line flushing;  
   • Capacity of flood and sediment transportation is highly improved;  
   • Plain runoff increased from 1800m3/s to 3800m3/s, and  
   • Form of river channel has been modified.
2. Achievements of YR Water and Sediment Regulating

Eight times YR water and sediment regulating (2002-2008):

Water entering the downstream: 29.4 Billion m³

Sediment flushing to the sea: 0.540 Billion T

Sediment reduced from the lower channel: 0.322 Billion T

Average Scouring of the lower channel elevation: 1.70 m
Effectiveness Analysis of Eight Times Water and Sediment Regulating in the Middle and Lower Yellow River

<table>
<thead>
<tr>
<th>Year</th>
<th>Mode</th>
<th>Regulated runoff (m³/s)</th>
<th>Regulated sediment content (kg/m³)</th>
<th>Sediment flushing to the Sea (million ton)</th>
<th>Flushing from river course (million ton)</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Priority on single reservoir regulating of Xiaolangdi</td>
<td>2600</td>
<td>20</td>
<td>66.4</td>
<td>36.2</td>
<td>Experiment 1</td>
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<td>2003</td>
<td>Connection of water and sediment in spatial scale</td>
<td>2400</td>
<td>30</td>
<td>120.7</td>
<td>45.6</td>
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<td>2004</td>
<td>Joint regulating of main stream reservoir group</td>
<td>2700</td>
<td>40</td>
<td>69.7</td>
<td>66.5</td>
<td>Experiment 3</td>
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<td>2005</td>
<td>Joint regulating of Wanjiazhai, Sanmenxia and Xiaolangdi reservoirs</td>
<td>3000 ~ 3300</td>
<td>40</td>
<td>61.26</td>
<td>64.67</td>
<td>Operation</td>
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<tr>
<td>2006</td>
<td>Joint regulating of, Sanmenxia and Xiaolangdi reservoirs</td>
<td>3500 ~ 3700</td>
<td>40</td>
<td>64.83</td>
<td>60.11</td>
<td>Operation</td>
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<td>2007 Pre-flood season</td>
<td>Joint regulating of Wanjiazhai, Sanmenxia and Xiaolangdi reservoirs</td>
<td>2600 ~ 4000</td>
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<td>52.40</td>
<td>28.80</td>
<td>Operation</td>
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<td>2007 Flood season</td>
<td>Connection of water and sediment in spatial scale</td>
<td>3600</td>
<td>40</td>
<td>44.93</td>
<td>00.03</td>
<td>Operation</td>
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<td>2008</td>
<td>Joint regulating of Wanjiazhai, Sanmenxia and Xiaolangdi reservoirs</td>
<td>2600 ~ 4000</td>
<td>40</td>
<td>59.82</td>
<td>20.07</td>
<td>Operation</td>
</tr>
<tr>
<td>Total</td>
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<td>540 322</td>
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</table>
3. **Notable integrated social benefits**

- Flow passing ability of main channel is improved, the plain runoff is increased;
- The situation of continuous shrinking of main channel is in primarily controlled;
- The situation of “secondary silting” is mitigated;
- Water for YR sediment transportation is regulated;
- Deepened the common understanding of “harmony life of human and river”;
- The ecological environment in the estuary region has improved.
Conclusion Remarks:
Through the YR water and sediment regulating:

- Pressure of flood control in the lower reach is released on certain degree;
- Social stability of the floodplain is protected;
- Promoted the development of relevant subjects;
- Significant impacts on the social, economy and ecological development.
Thanks for you attention!