Philosophy of Rivers

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Contents

1. **Philosophy of rivers**
2. **A 2000 years debate on wide or narrow river strategies for flood control in the lower Yellow River**
3. **River morphology-plastic or resilient**
4. **Conclusions**

1. Philosophy of Rivers

Philosophy of rivers is the epistemology about rivers through data analysis and abstractive thinking.

The responses of rivers to human disturbances are complex, many of them can not be understood or explained at science level. The philosophy of rivers lies in the probe into the issues that science has not yet studied or is unable to.

Rivers respond to a disturbance that cause variation of the river always in such a way that reduces and stops the variation.

River has its own way of thinking and may accept or refuse changes by humans.

Why Philosophy

Many river training problems can not be solved at science level:

Is damming bad or good for ecology? Impoundment of rivers impairs the pristine aquatic bio-community. On the other hand dams can also increase biodiversity.

To mitigate flood hazards should we make water flowing faster or slower (flood stage lower or higher) ?

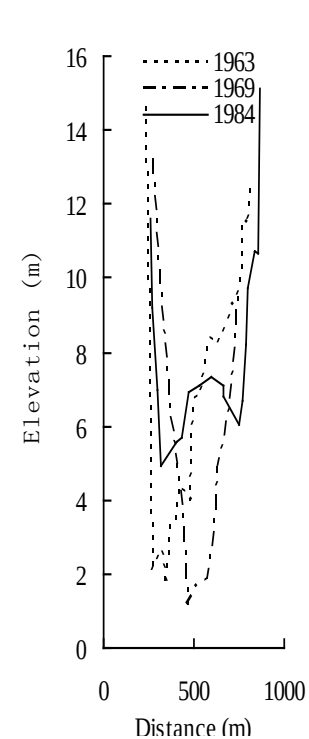
Is river morphology resilient or plastic? Or can river morphology be changed with no rebound?

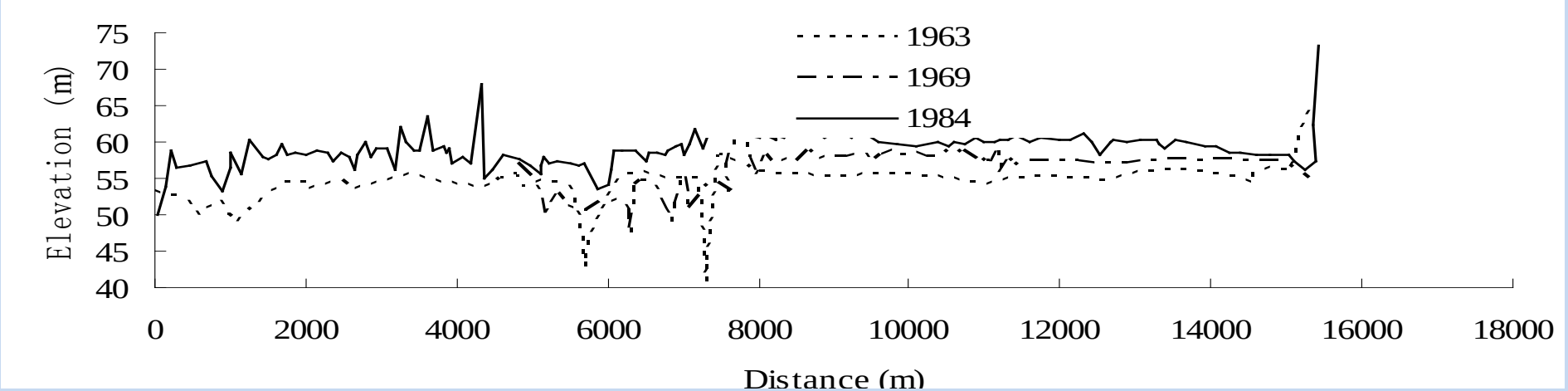
……..

A debate on “wide river” or “narrow river” for training the Yellow River has continued for 2000 years.

Wide river provides space for sediment to deposit and reduce sediment load. Narrow river maintains high flow velocity keeping sediment in suspension and transporting sediment into the ocean.

Both strategies have scientific evidences of effects on sedimentation reduction and levee breach control.





Lijin cross section (river width =0.6 km) and Mazhai cross section (16 km) of the Yellow River

Channelization increases or reduces flood hazard?

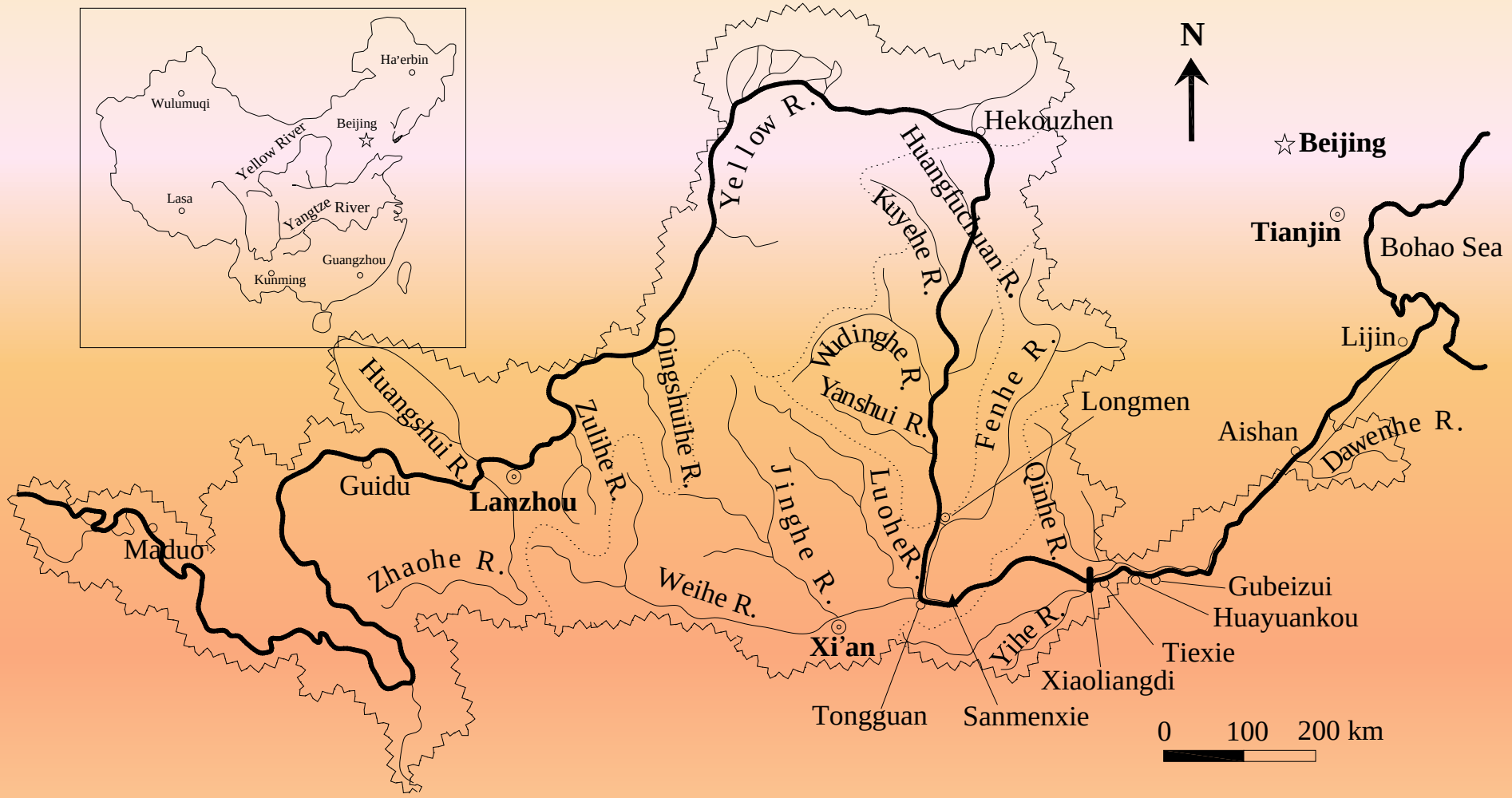
Channelization of streams reduces the resistance and flood stage.
But high flow velocity and high flow energy resulted in high scouring capacity and levee damages.
Low flood stage does not mean better security

- Channelization and smoothed banks resulted in high velocity and bank failures. Human had to change the idea and roughen the banks and increase the flow resistance for better flood security

Dam construction impairs ecology or improves ecology?

The Xinanjiang Dam impounded in 1960 created the thousand islands lake. The reservoir has become a habitat of birds. The fish species increased from 64 to 114 after the impoundment

2. **A 2000 years debate on wide or narrow river strategies for the Yellow River flood control**

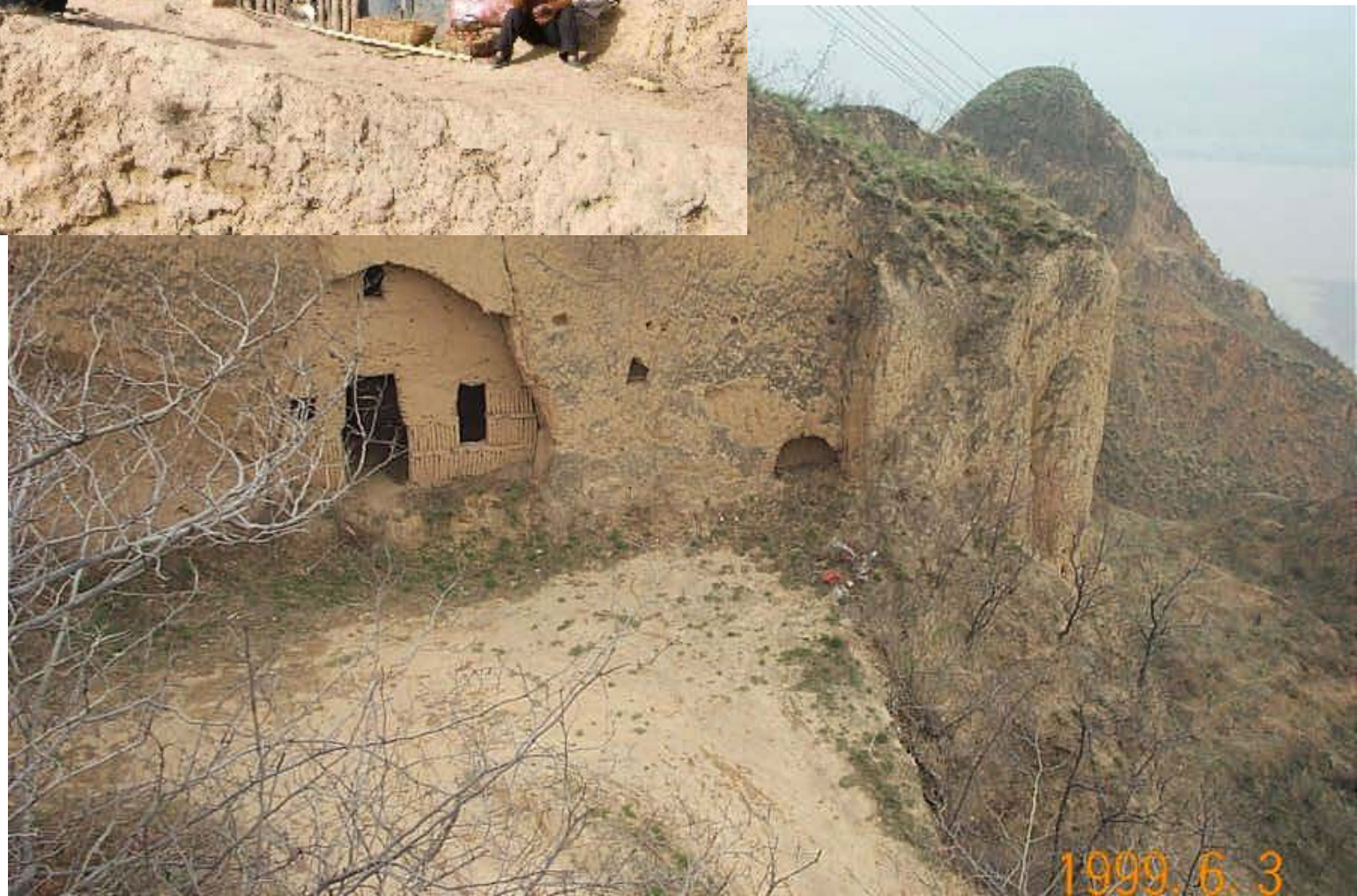


The Yellow River is 5464 km long and has a drainage area of 795,000 km^2 (second longest river in China)

Loess plateau- 640000 km^2. Soil erosion 10000 t/km^{2}yr

The thickness of loess is 200-400 m, which is very erodible. The rate of soil erosion was as high as 30000 t/km^{2}yr in the north part of the loess plateau and the erosion rate was 10000 t/km^{2}yr in the central of the plateau. Gully erosion is the main form of erosion.

People lived in caves. Agriculture and fodder harvest exacerbated erosion



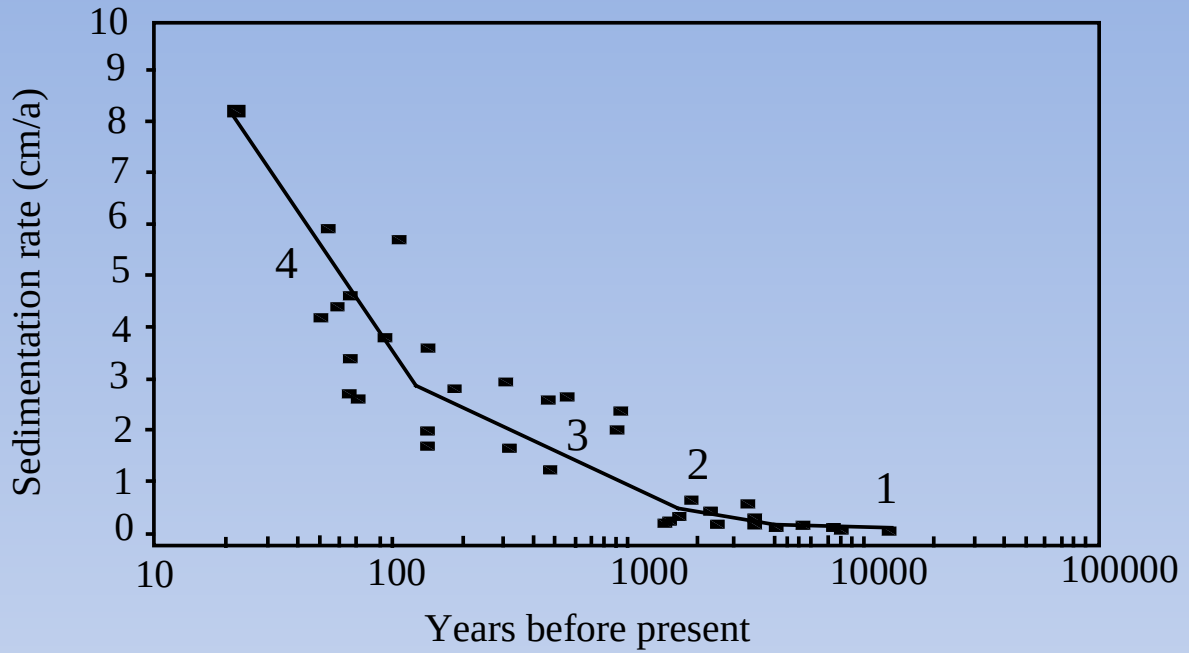
The sediment were transported into the rivers and resulted in hyper-concentrated floods.

The highest concentration in the Yellow River was 930 g/L and highest concentration in the tributaries was 1700 g/L

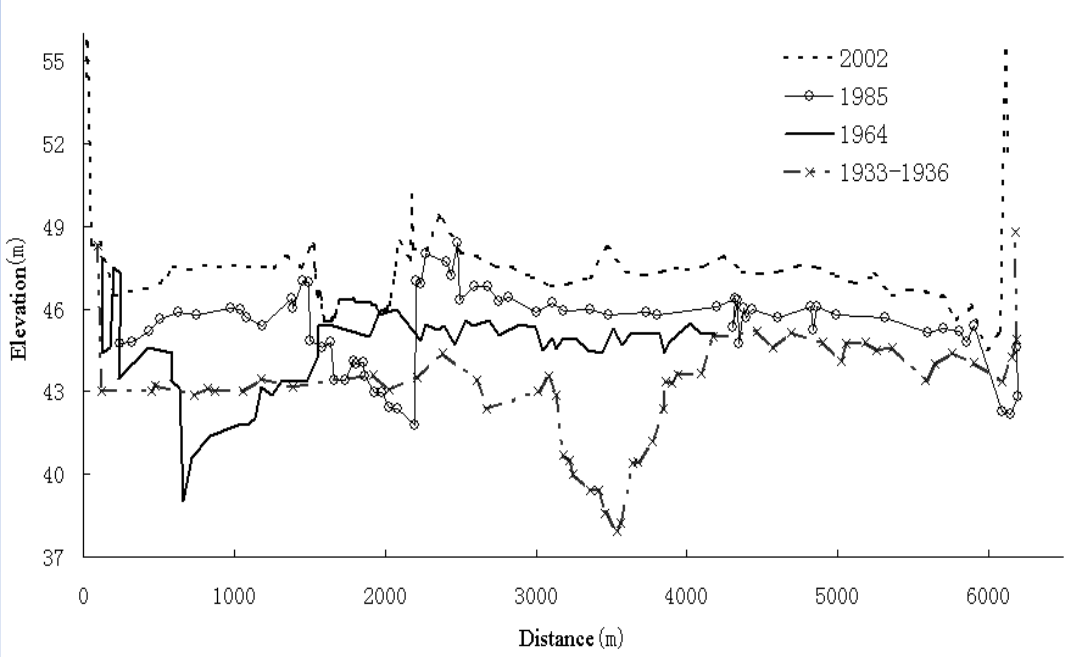
A huge amount of sediment was transported to the flat lower reaches. Sediment deposition caused continuous aggradation. The present riverbed is much higher than the surrounding land.

The river flows into the Bohai Sea and created land at the delta with its heavy sediment load at a rate of 25 km^2/yr (1855-1985)

Aggradation rate of the lower Yellow River bed during the past 10000 years.



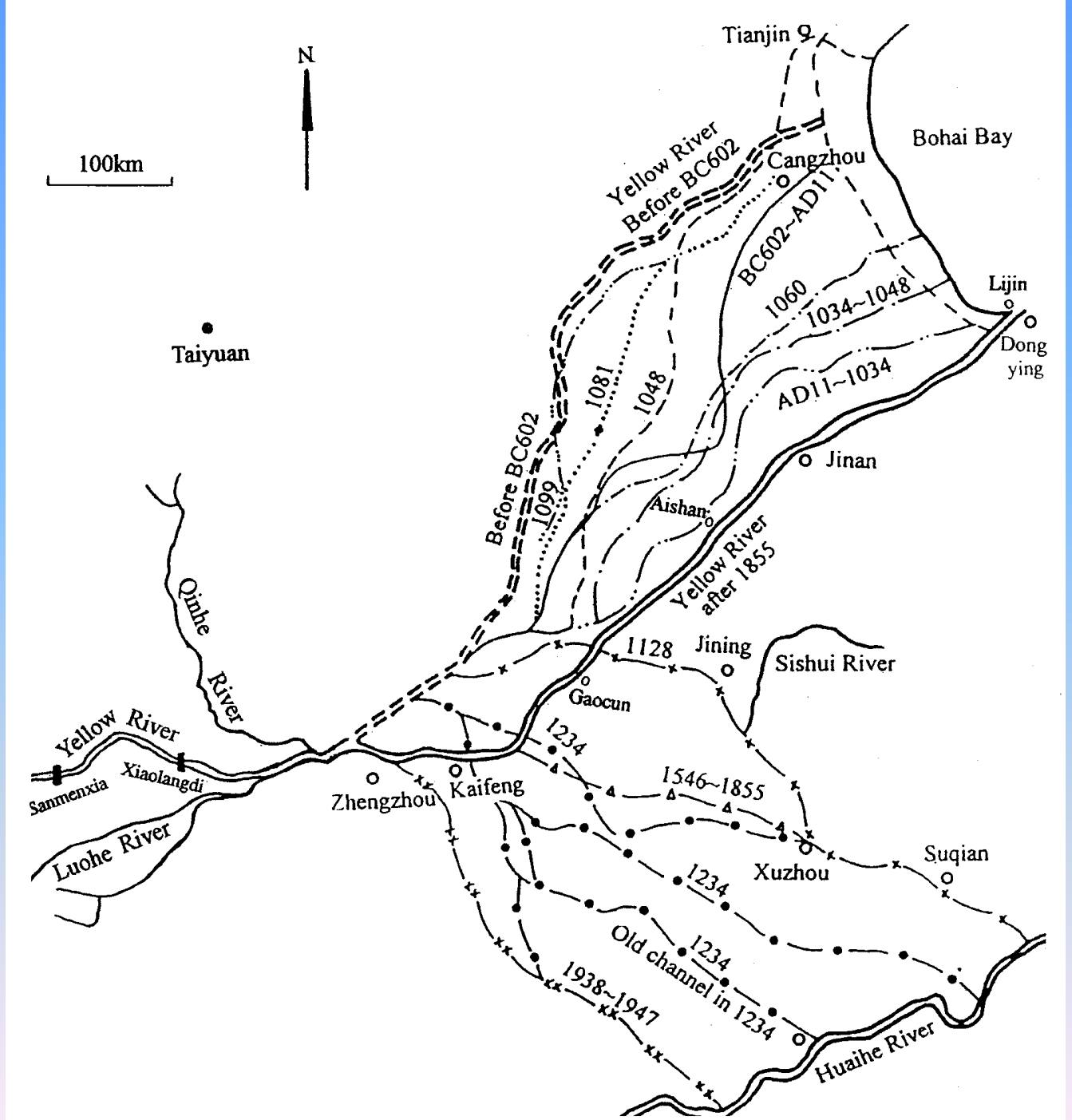
Sedimentation caused aggradation of the lower Yellow River. The Sunkou cross section is 440 km from the river mouth.



Continuous siltation caused flood stage rising and levee breaches. In the past 26 centuries 1593 levee breaches and flood disasters occurred. Among them 26 levee breaches resulted in large avulsions (change of the river course in the lower reaches). Millions people were killed by floods

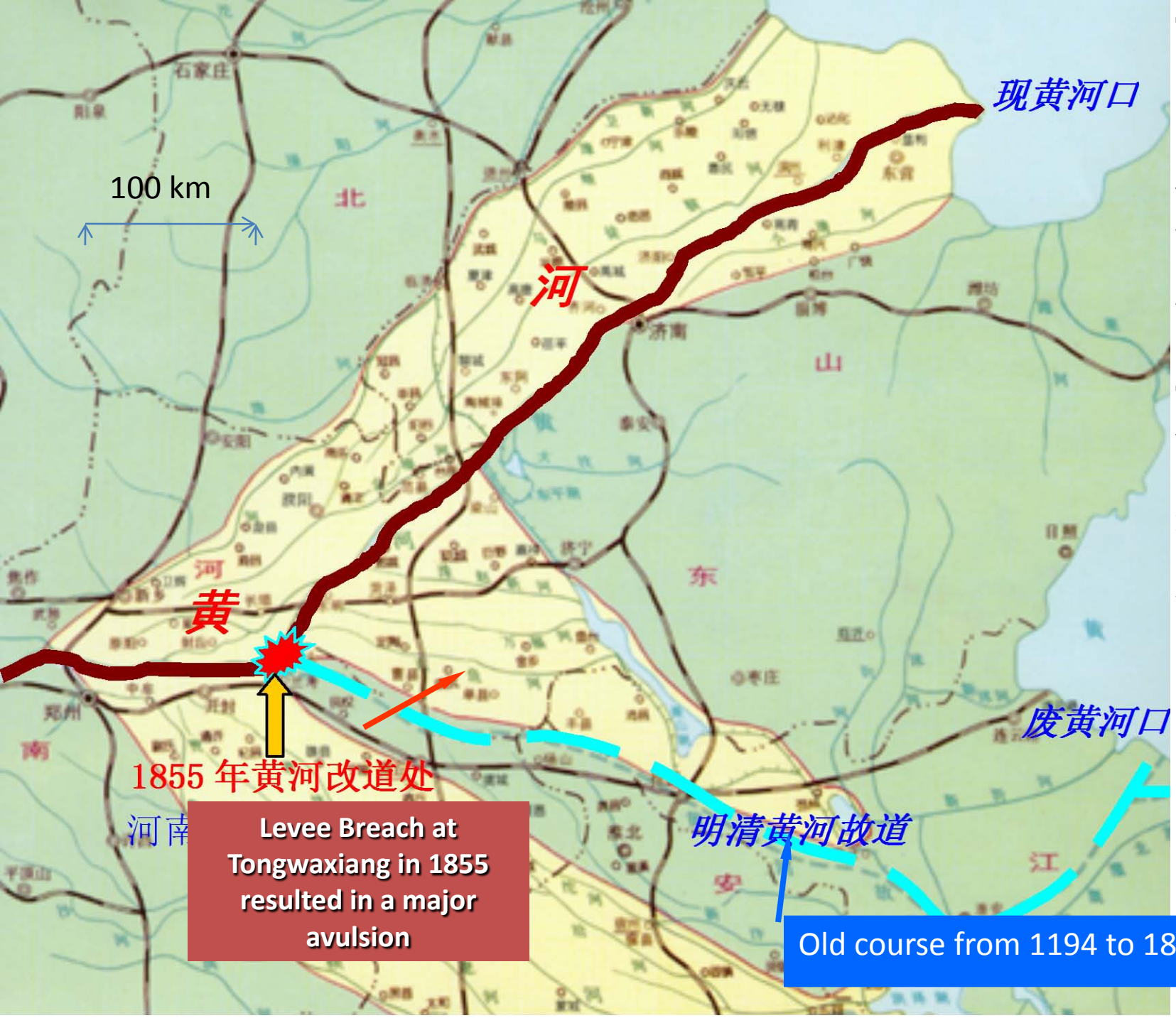
Levee breaches and flood disasters in the Past 900 Years

year	Discharge m3/s	Flooded counties	Lives claimed
1117			1,000,000
1642		Kaifeng	300,000
1761.8	32000	24	50,000
1843.8	36000	27	30,000
1855.8	27000	53	200,000
1933.8	22000	67	18,293
1938.6.9		44	890,000
1958.8	22300	1700 villages	No data



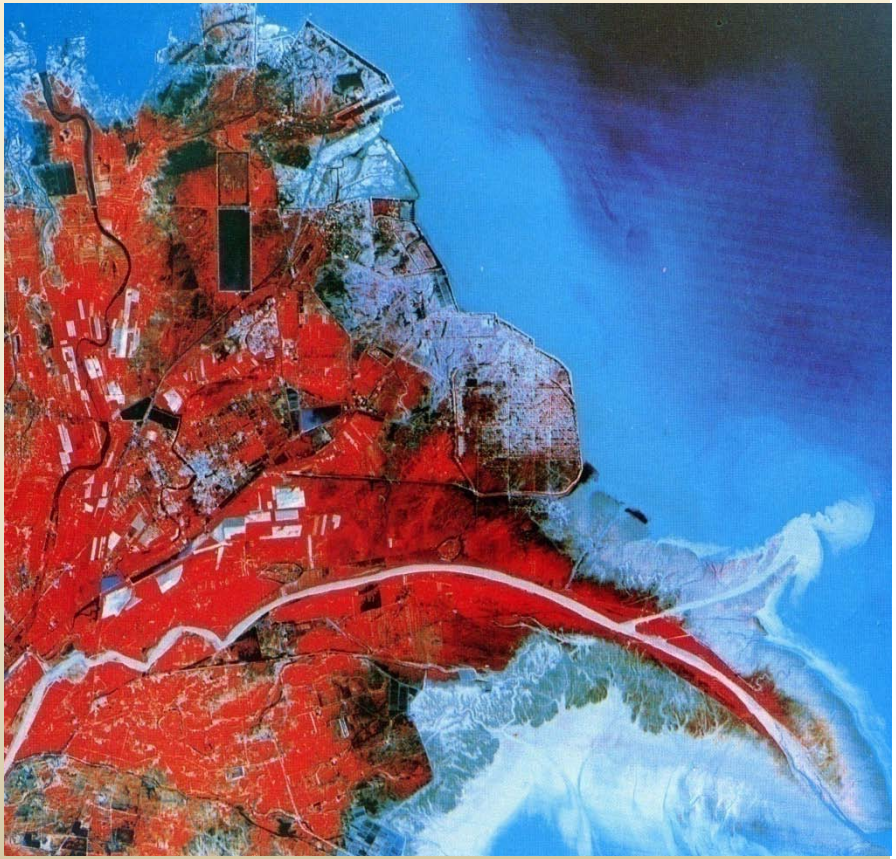
Large avulsions and abandoned channels of the Yellow river (26 large avulsions in 2600 years)

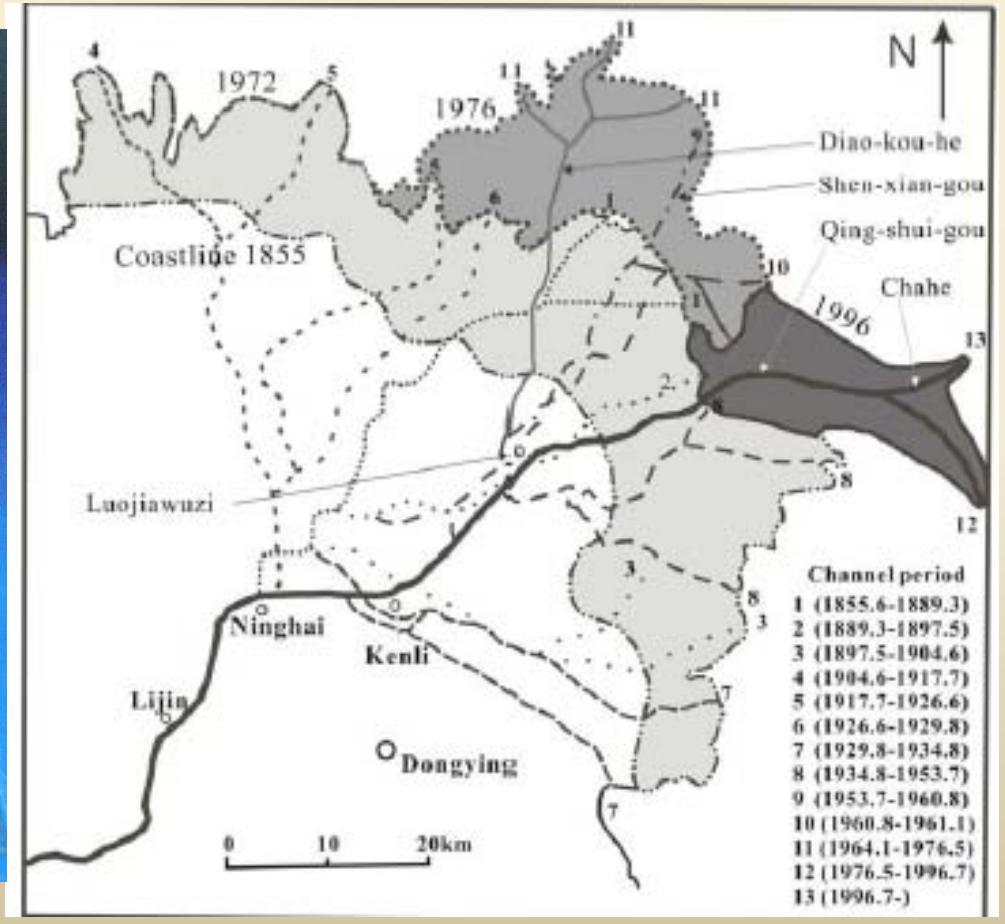
- The levee was breached by flood and an avulsion occurred at Tongwaxiang in Aug. 1855, which killed more than 200000 people and resulted in 7 million refugees.
- The Yellow River changed its course and flows into the Bohai Sea since then.
- The river captured the Daqing River course， which was too small to allocate the Yellow River water. Therefore, the river flooded the nearby areas every year until 1890.



The river captured the Daqing River course, which was too small to allocate the Yellow River water. Therefore, the river flooded the nearby areas every year until 1890.

After the large avulsion at Tongwaxiang in 1855, the Yellow River shifted to the present cause and pour into the Bohai Sea. In the past 150 years (except for 1938-1947) 12 small avulsions occurred and created 4500 km^2 of land, on which the second largest oil field of China was found.





Two training strategies and four great masters of Yellow River trainning

Two strategies and four great river trainers

Zhang Rong (AD 0004) described the Yellow River "Bucket of water, sediment six", which means 60% of the Yellow River flood water is sediment. The key point for Yellow River training is the sediment management, for which there were two strategies.

1 Depositing sediment in wide river and diverting flood (Wang Jing)

2 Scouring sediment with converging flow in narrow channel (Pan Jixun) - Confine the flow within a narrow channel, close all branch channels, enhance the flow velocity to carry sediment into the sea.

Four great masters of Yellow River training in the past 2000 years: Wang Jing, Pan Jixun, Jin Fu and Wang Huayun

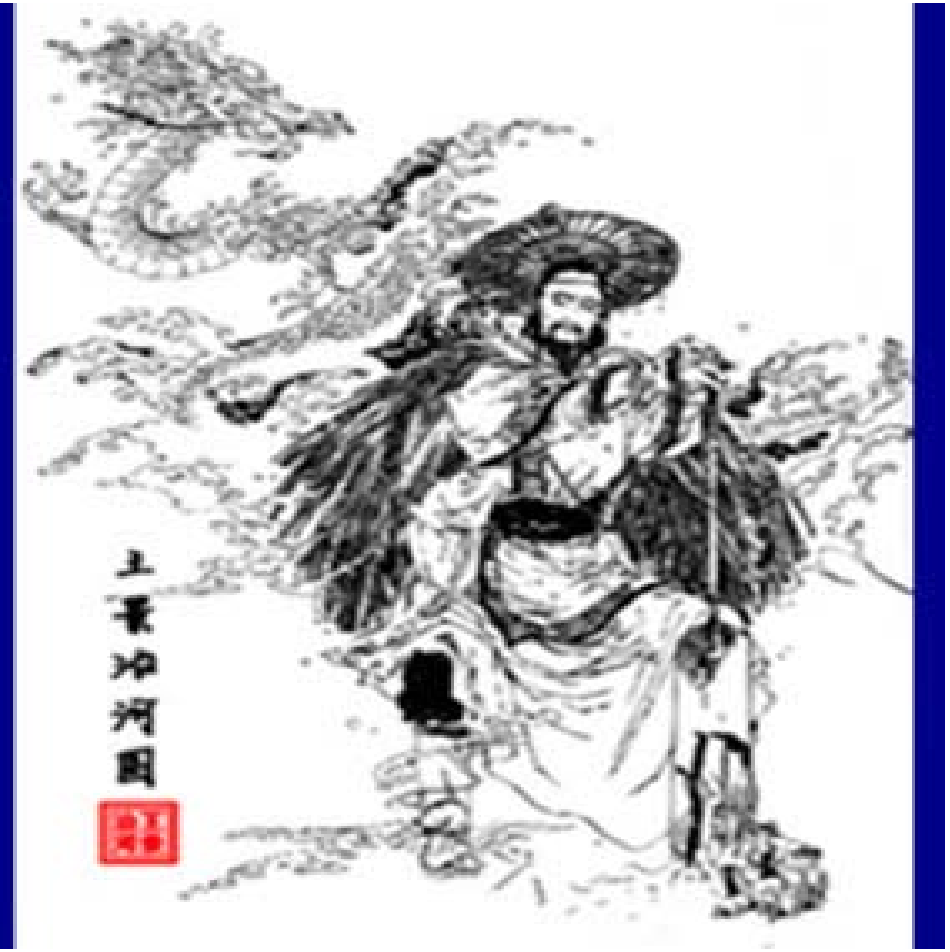
Wide river and depositing sediment

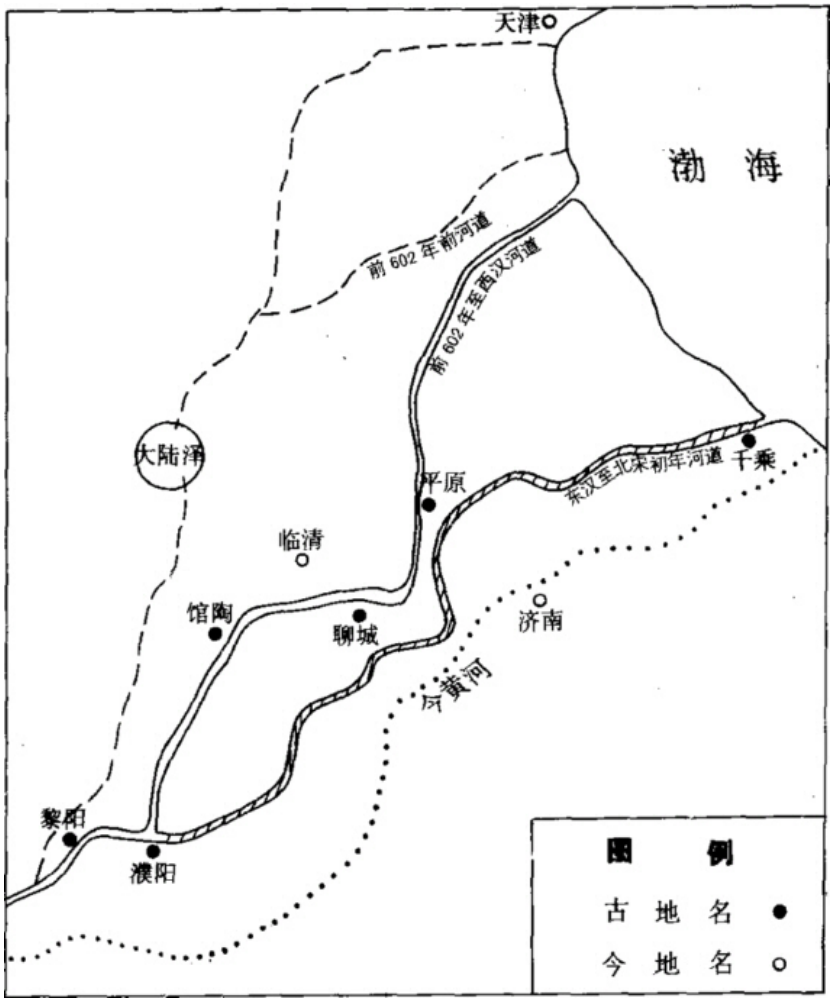
- Wang Jing （AD30-85）proposed and practiced the wide river and depositing sediment strategy from AD69.
- He completed and enhanced levees, built many diversion channels and constructed water gates per 5 km.
- The width between the levees was very wide. The flow velocity was low and sediment deposited within the grand levees.
- In the following 800 years after Wang Jing the Yellow river was calmed and very few flood disasters occurred. (王景治河八百年安流）

Wang Jing (AD30-85）

The technology of Wang Jing from historical records was only Water gates per 5 km and wide river channel.

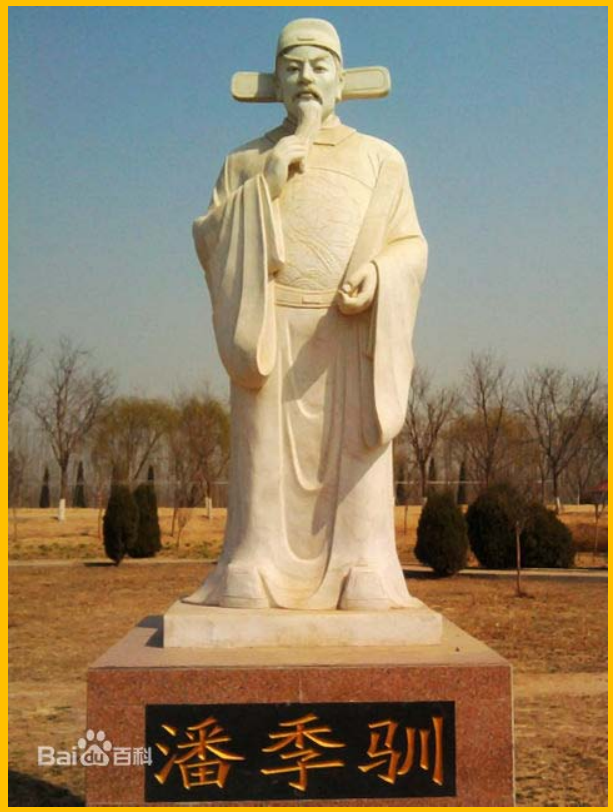
Water gate=Spillway weir for flood water diversion



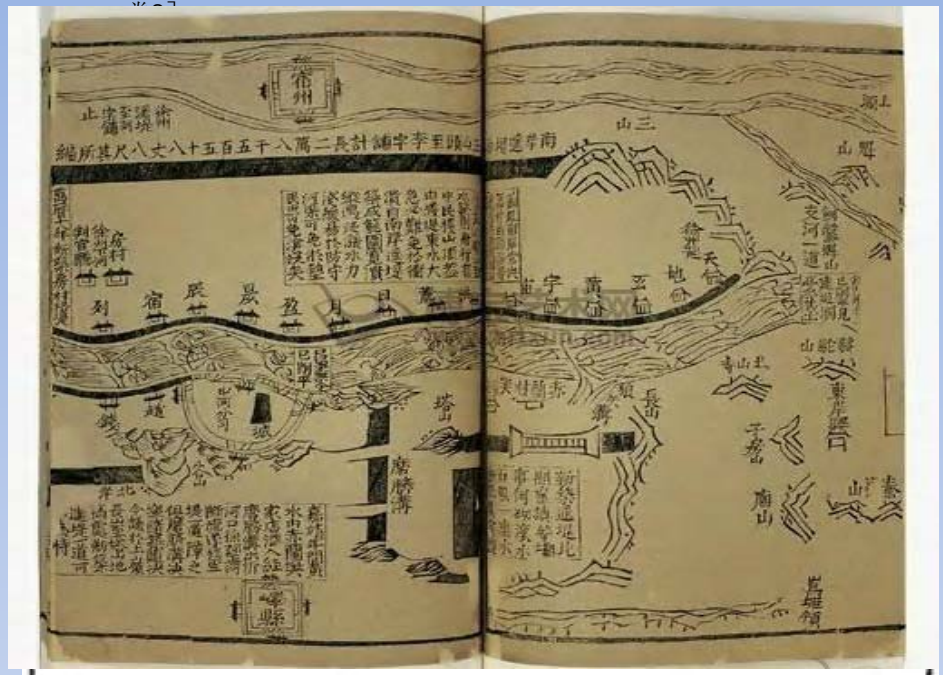


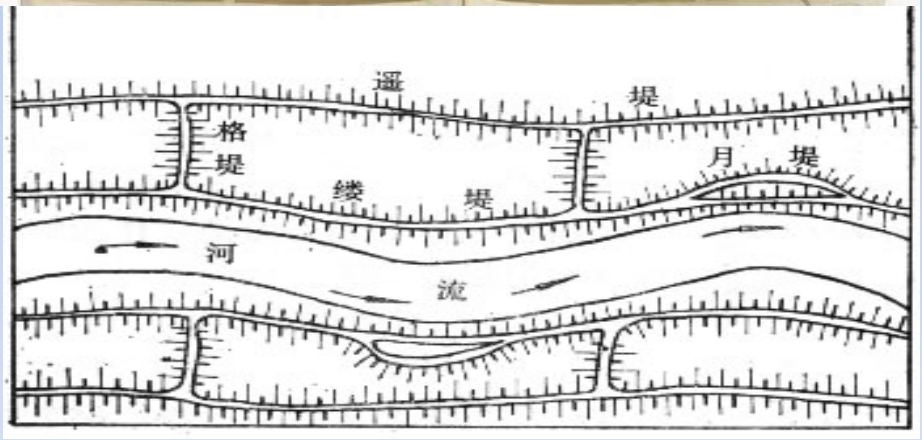
Narrow channel and scouring sediment

Pan Jixun （1521-1595）proposed the strategy of scouring sediment with converging flows by narrowing the channel. He regulated the levee system, blocked many branches of the river and made the river flowing in a single channel in the period 1565-1592.



Pan Jixun1521-1595 Minister of construction and industry





Pan published a book “Overview of Yellow River flood defence” and explained the mechanism of Scouring sediment with converging flows in narrow channel for sedimentation and levee breach control

Narrow river strategy practitioner

Jin Fu （1633～1692 Minister of military）and Chen Huang in Qing Dynasty were the third great Yellow River trainer.

The Yellow River breached the levees and caused great catastrophes after death of Pan. Jin and Chen applied Pan's theory and practiced "converging flow with narrow channel and scouring sediment with high flow velocity.

Jin and Chen were measuring the water level and discharge shown in a movie of their story. Jin invented the method for measurement of flow discharge.

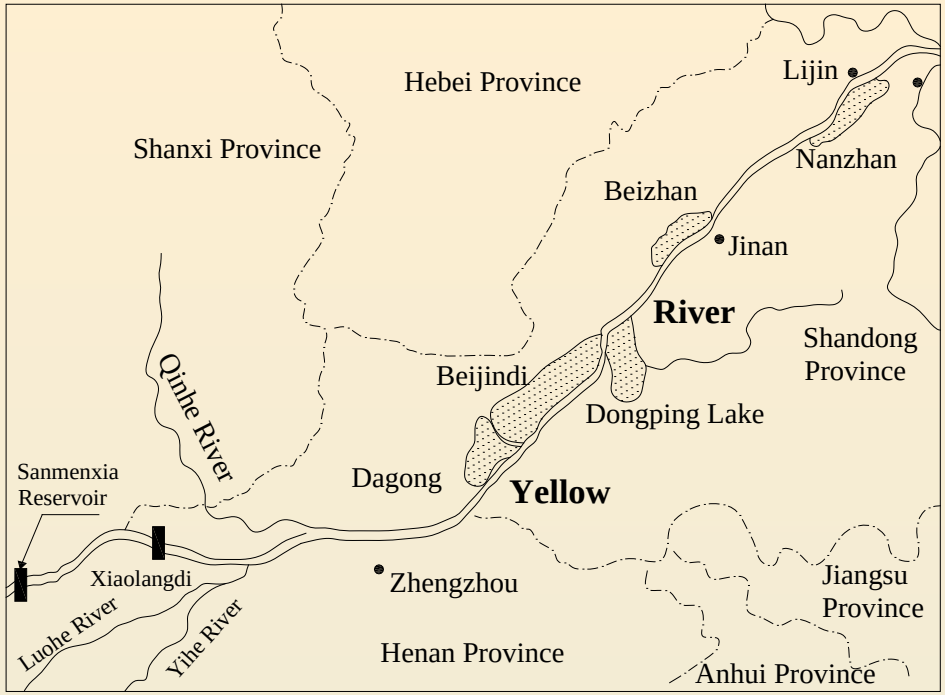
Wide river strategy practitioner

Wang Huayun（1908-1992）was the fourth great river trainer. He was vice minister of water resources of China and director of the Yellow River commission.

Wang Huayun was in charge of the Yellow River training from 1950 to 1990. He applied the wide river and depositing sediment strategy. Wang proposed 16 words for river training
“宽河固堤，蓄水拦沙，上拦下排、两岸分滞”
Widen river and enhance levees, store water and trap sediment, deposit sediment upstream and discharge sediment downstream, divert sediment and water to detention basins

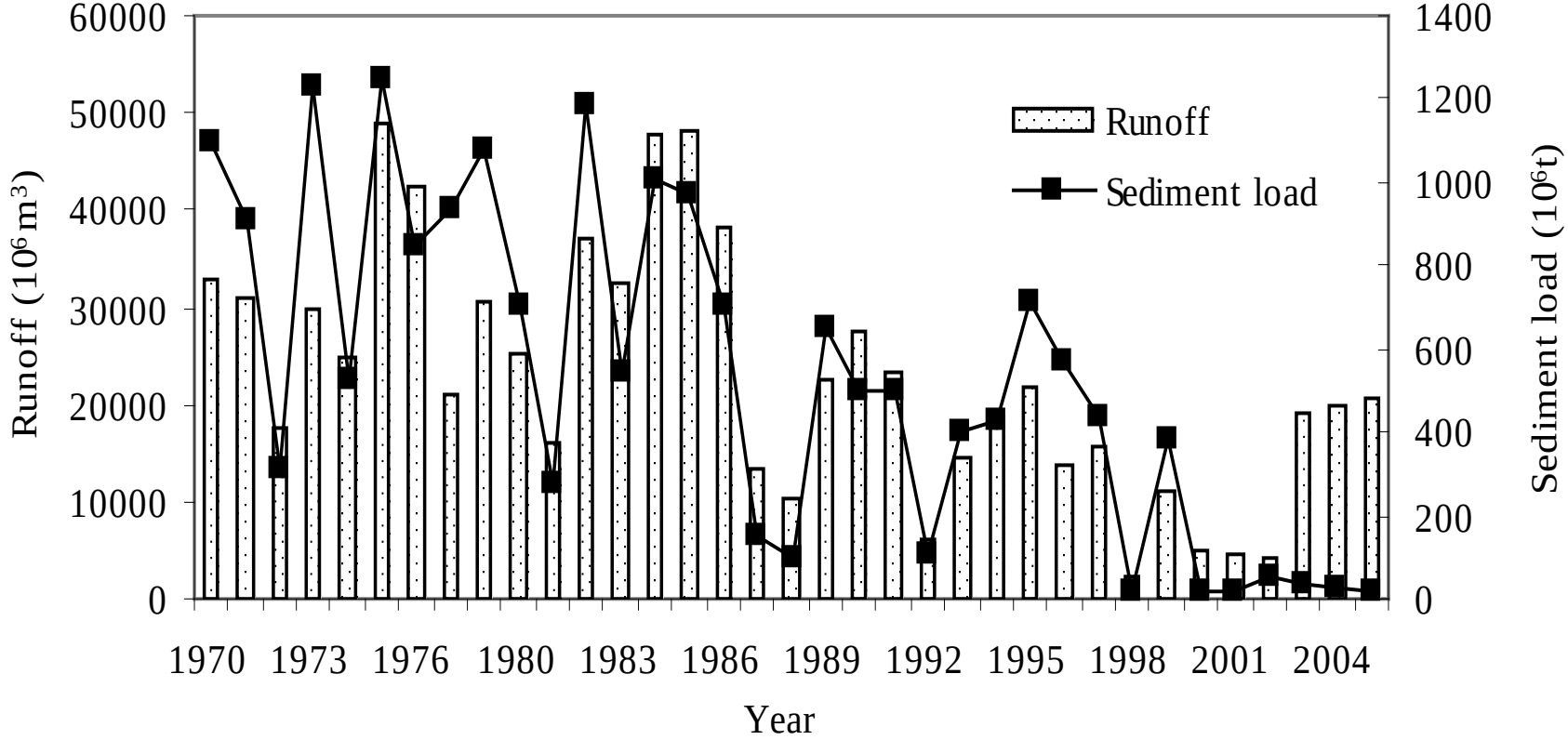
Wide river in the lower reaches providing space for sediment deposition

Trap sediment with reservoirs and check dams in the upper reaches



Divert water and sediment to the basins on the lee side of the levees, allowing sediment deposition making the levee wider and higher.

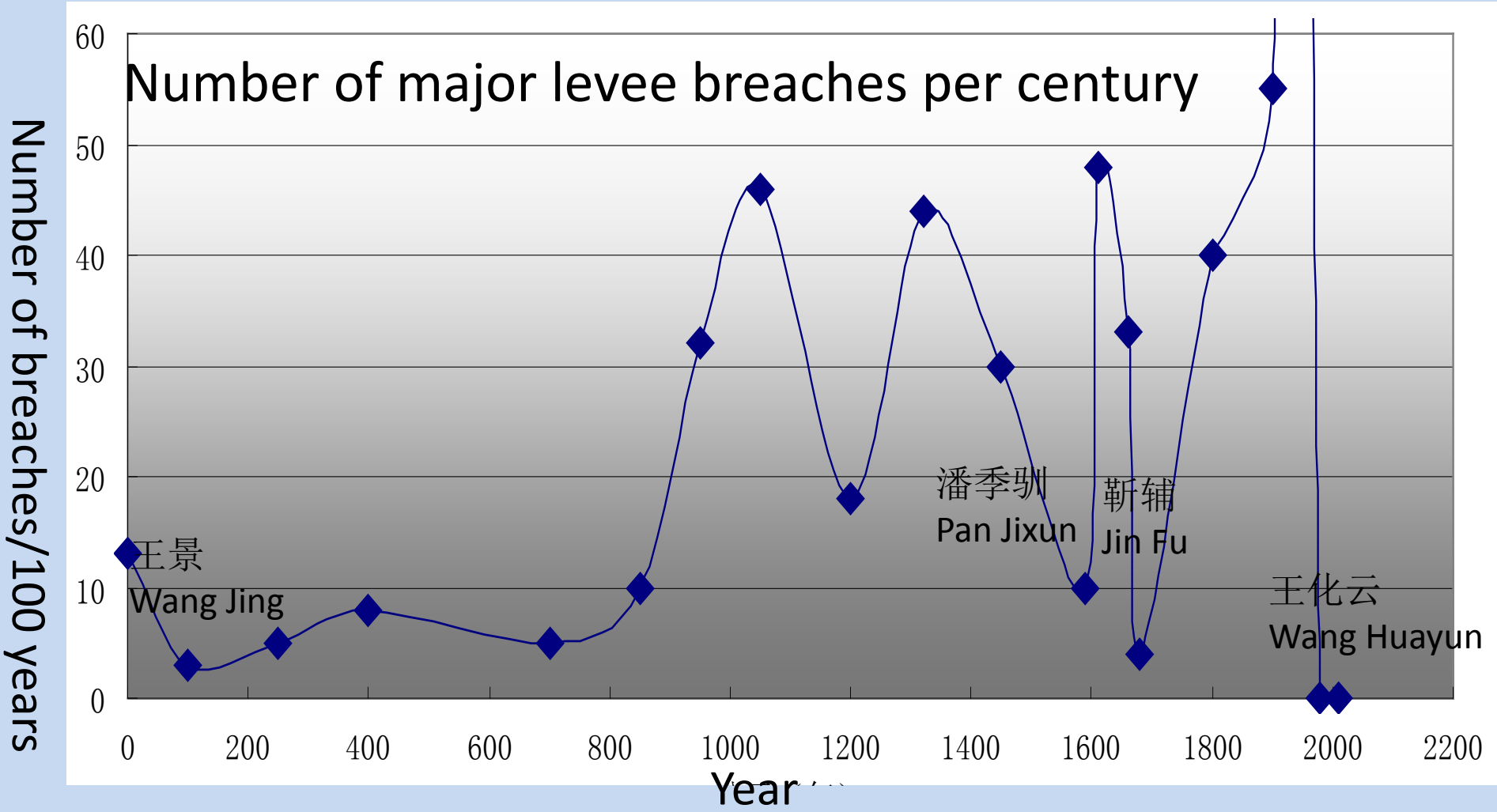
Construct 5 flood detention basins: Dagong, Beijindi, Dongping, Beizhan, and Nanzhan for flood detention and sediment deposition



- Sediment load transported to the ocean by the Yellow River has been reduced by 90% in the past 30 years due to erosion control, sediment trapping by reservoirs on the river and check dams on the loess plateau, sediment deposition on the flood plain and flood diversion.

Debate on the two strategies

- The narrow channel and scouring sediment strategy was spoken highly (less land and looks more sophisticated). Pan Jixun and Jin Fu enjoyed high reputation. Qing dynasty agreed and local people built temple for Jin.
- Nevertheless, the result of the strategy was not good. Levee breaches continuously happened.
- The debate on wide or narrow river strategies became international as Freeman proposed to further narrow the river as he visited China in 1917
- Engles conducted physical model experiments in 1931-1934. The result indicated that wide river is better.
- Franzius conducted another experiment and support narrow river theory. Ben Yen indicated Franzius' results was not so reliable as Engles's.



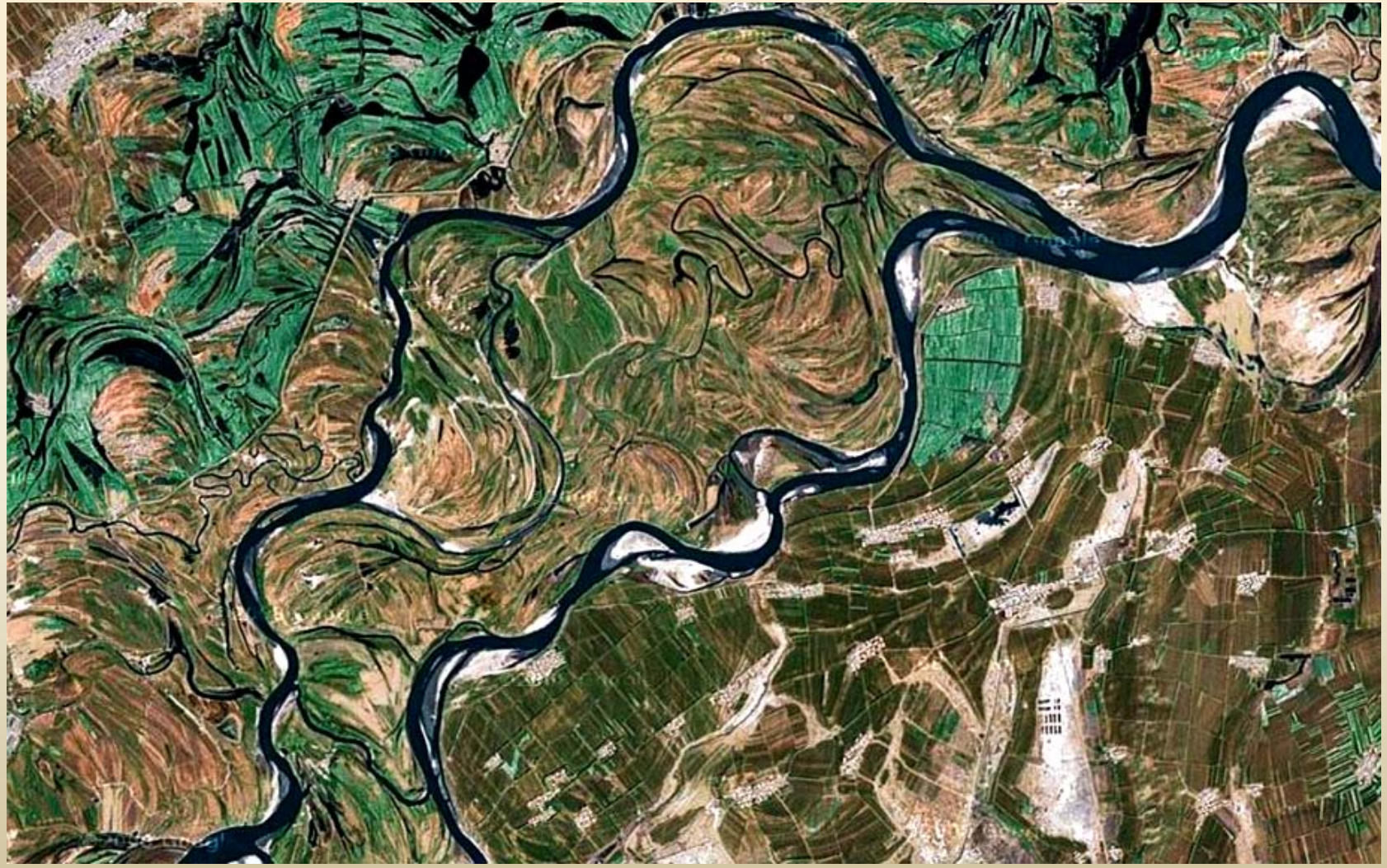
Results of the two strategies for levee breach and flood control in the past 2000 years

- The narrow channel and scouring sediment strategy is difficult to manage. Pan and Jin were very skillful and very carefully managed the high velocity flow. Thus, they maintained short periods of low breaches.
- After Pan and Jin, the levee breaches became more than before because high sediment concentration is very unstable and the successor of them could not control the flow in the narrow channel.
- Suffer from levee breaches and floods people remembered the relatively safer time during Pan and Jin and therefore regarded them as gods.

- The wide channel and depositing sediment strategy resulted in long term flood safety. Wang Jing applied this strategy and resulted in 800 years low frequency of breaches. Wang Huayun used the strategy and no levee breach occurred in the past 60 years, which is a only period of zero levee breaches in the Yellow River history.
- Wang Jing and Wang Huayun were not so well known as Pan and Jin although their training projects resulted much better effects for flood control.
- This can be understood as “Good general has no brilliant achievements in wars” (Sun Tzu's The Art of War) because he has defeated the enemy before the war.

3. Is river morphology plastic or resilient?

Humans change river morphology by constructing dams, cutting off meanders, and channelizing streams. If the river morphology is plastic, the changed river morphology may remain stable. If it is resilient the changed river morphology will rebound.



Viewpoint 1: Meandering feature of rivers is resilient

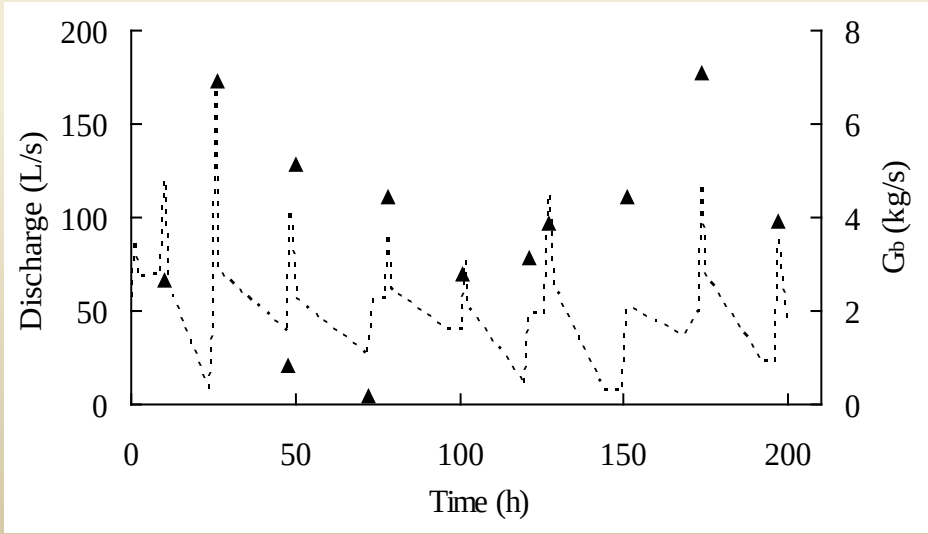
Given slope, sediment, vegetation and varying range of flow rate the stream channel become meandering with a certain sinuosity.

Sinuosity = length of channel/length of the river valley

Changing meandering channel into straight will rebound.

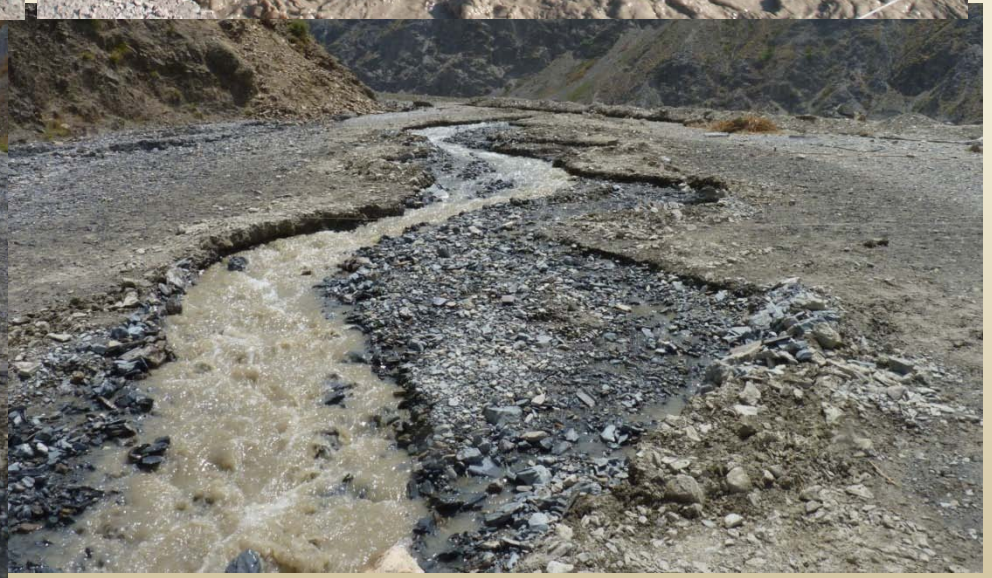
Experiment on resilience of meandering channel Jiangjia valley in upper Yangtze river watershed

The experiments was done with initial sinuosity of 1.0, 1.15 and 1.71. The flow process simulated the natural floods.



Discharge process simulating seasonal variation

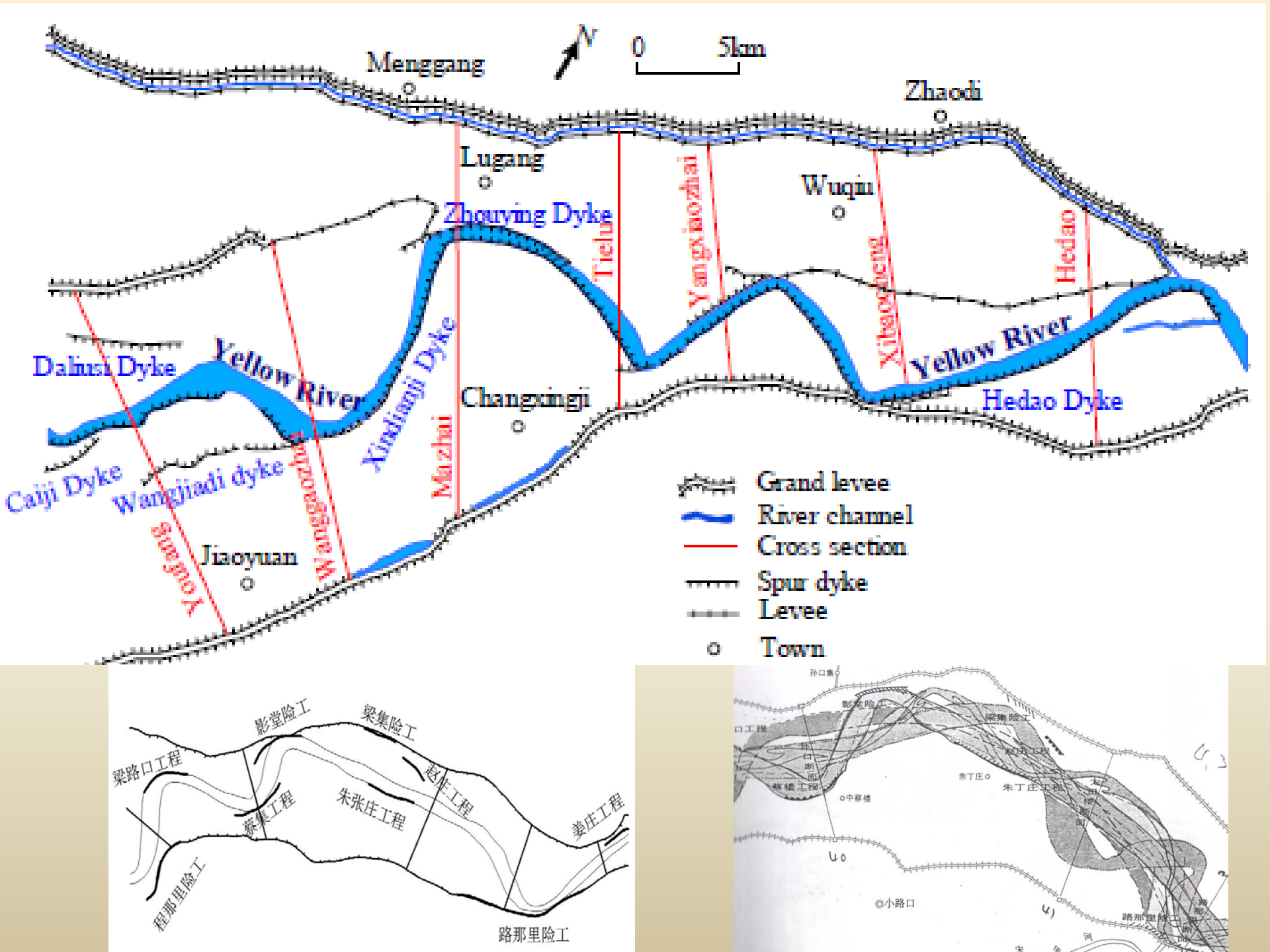
Straight channel developed meanders and high sinuosity channel deformed. Finally all initial channels developed into meandering channel with the same sinuosity about 1.4.



Meandering is the inherent characteristic of streams. Human changed a meandering channel straight with concrete walls. The stream struggles to meander and want break the constraints.

Constrain meandering with spur dykes in the Lower YR

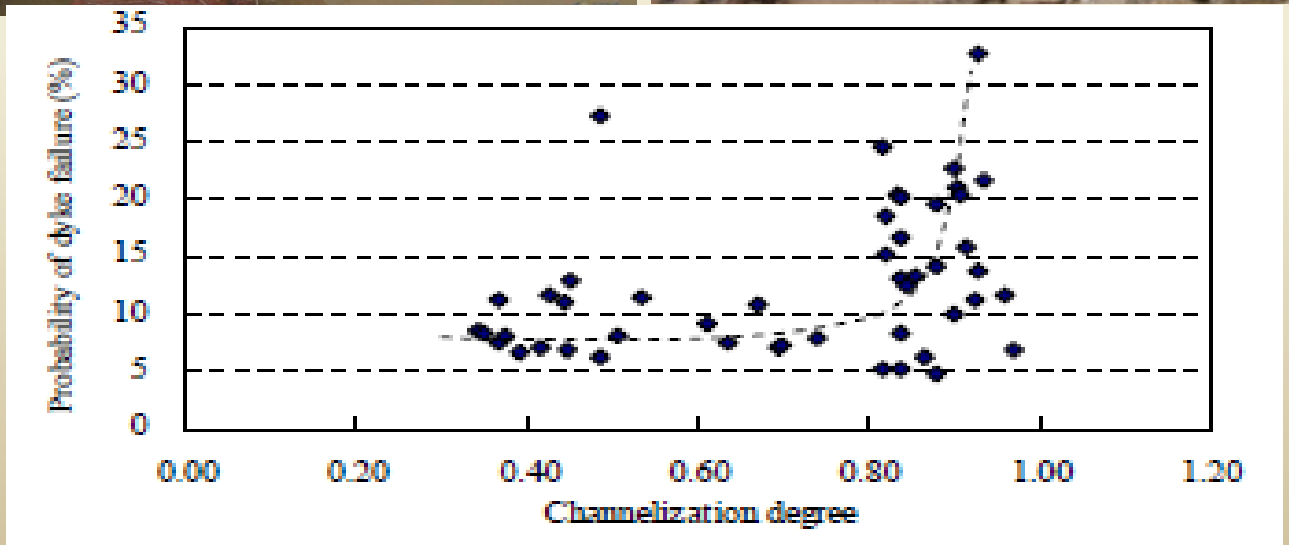
The present lower Yellow River has very wide valley defined by the grand levees. There are 2 million people living in the river within the grand levees. To have more land for agriculture and other land uses, people built many spur dykes to control development of meanders.


N
0
5km
Menggang
Zhaodi
Lugang
Wuqiu
Zhouying Dyke
Tielu
Yangxiaozhai
Xiaogucheng
Hedao
Yellow River
Dalinzi Dyke
Yellow River
Xindianji Dyke
Changxingji
Hedao Dyke
Caiji Dyke
Wangjiadi dyke
Wanggangzhuang
Majhai
Yongfang
Jiaoyuan
Grand levee
River channel
Cross section
Spur dyke
Levee
Town

影堂险工
梁集险工
梁路口工程
蔡集工程
朱张庄工程
赵庄工程
姜庄工程
程那里险工
路那里险工

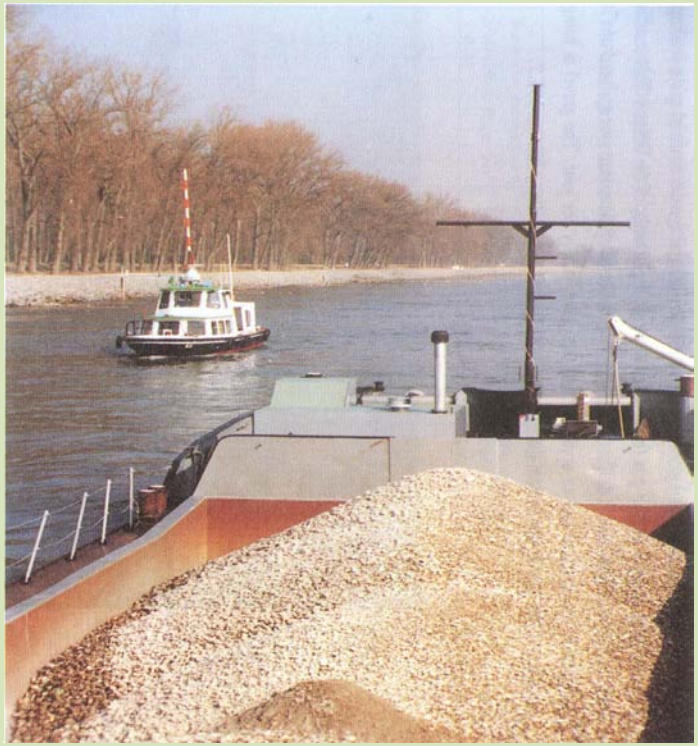
孙口集
影堂险工
梁集险工
口工程
朱丁庄
朱丁庄工程
蔡楼工程
中蔡楼
小路口
路那里险工

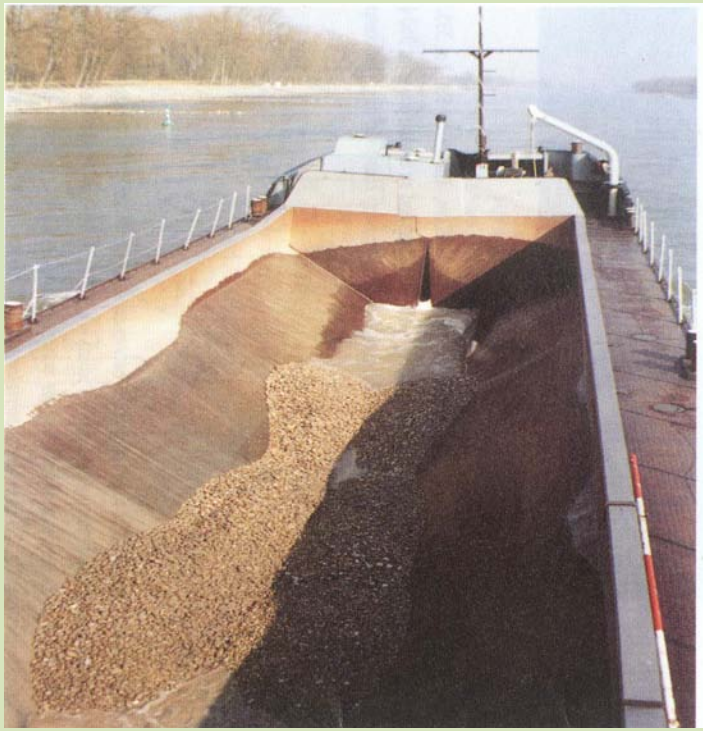
The river breaks the spur dykes for developing meanders. The probability of dyke failure increased with increasing channelization degree and reached 30% as the channelization degree was over 0.8 (the total length of the spur dykes on the two sides of the river was 0.8 time of the channel).



The Rhine River was meandering with beautiful meanders. Tula (1850s) cut off the meanders and made the river straight for navigation and land use.

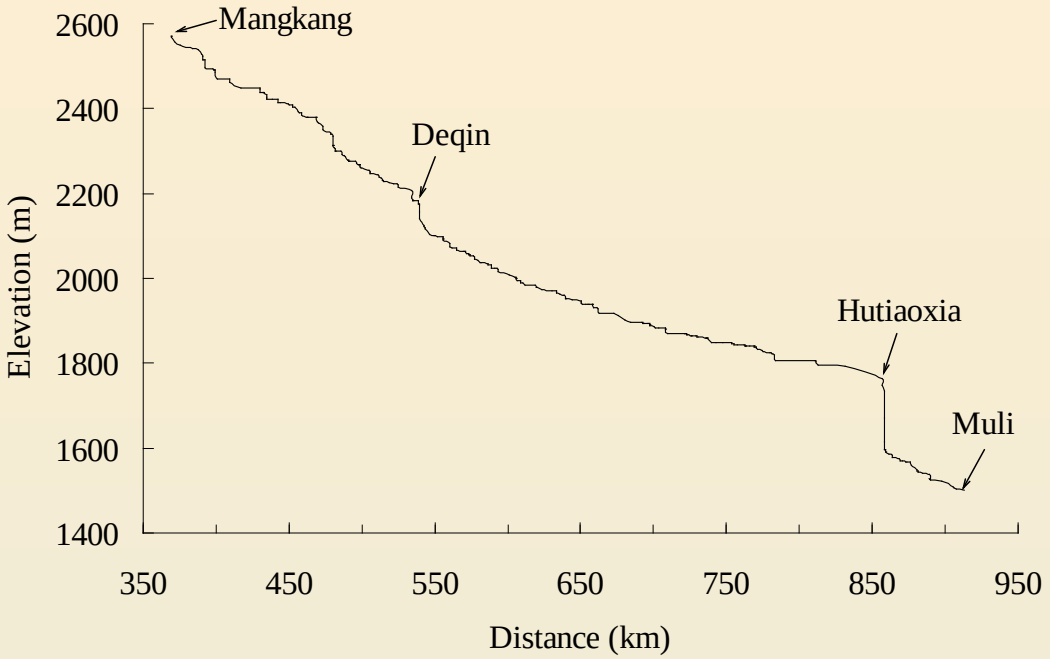
Nevertheless, the flow in the straight channel scoured the riverbed 2 m down and caused many problems. German engineers have to dump sand-gravel mixture on to the river bed to mitigate the incision.

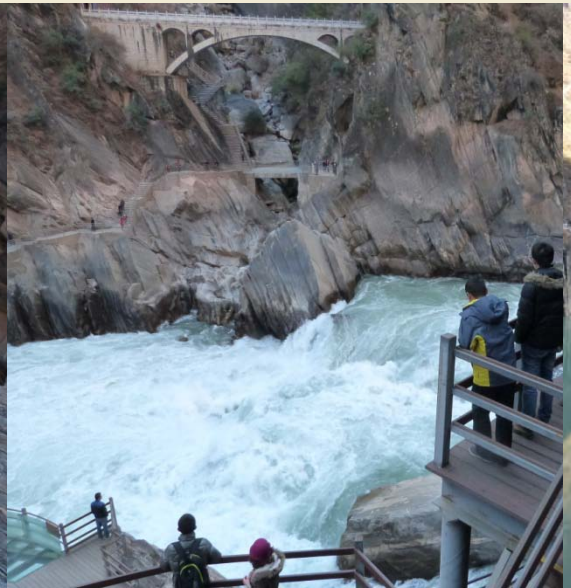




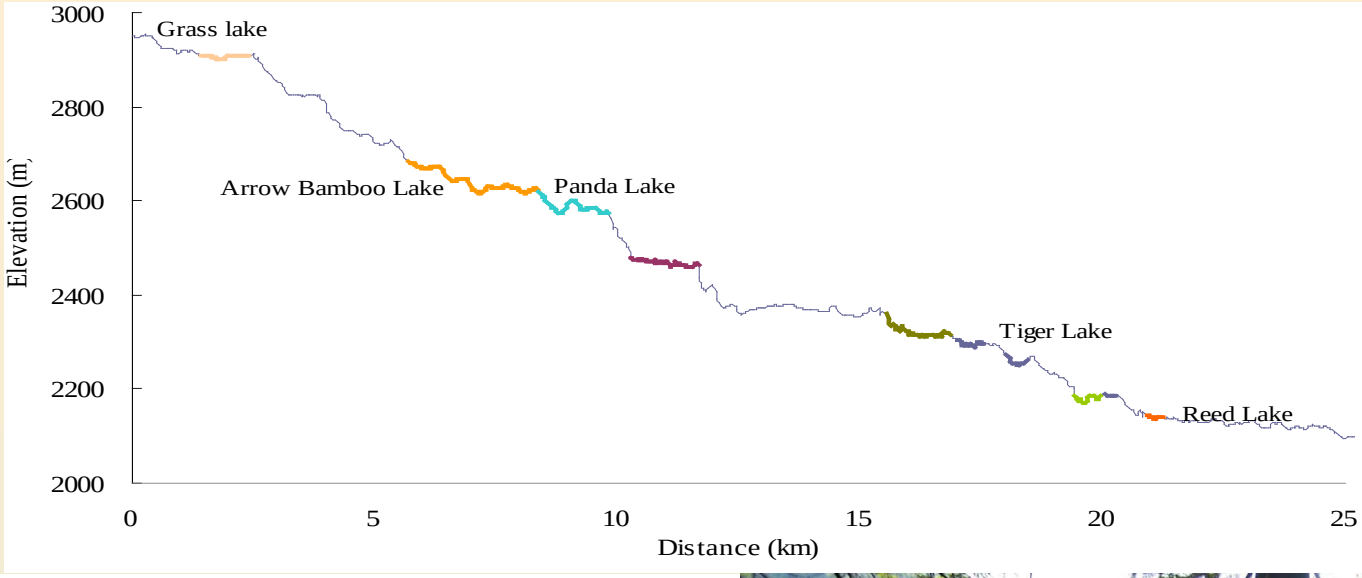
Viewpoint 2: Longitudinal profile of riverbed is plastic

Bed profile of the Jinsha River has been changed by several landslide dams, which formed knickpoints. The landslide dam at tiger leaping gorge is 213 m high and has existed for more than 500 years.

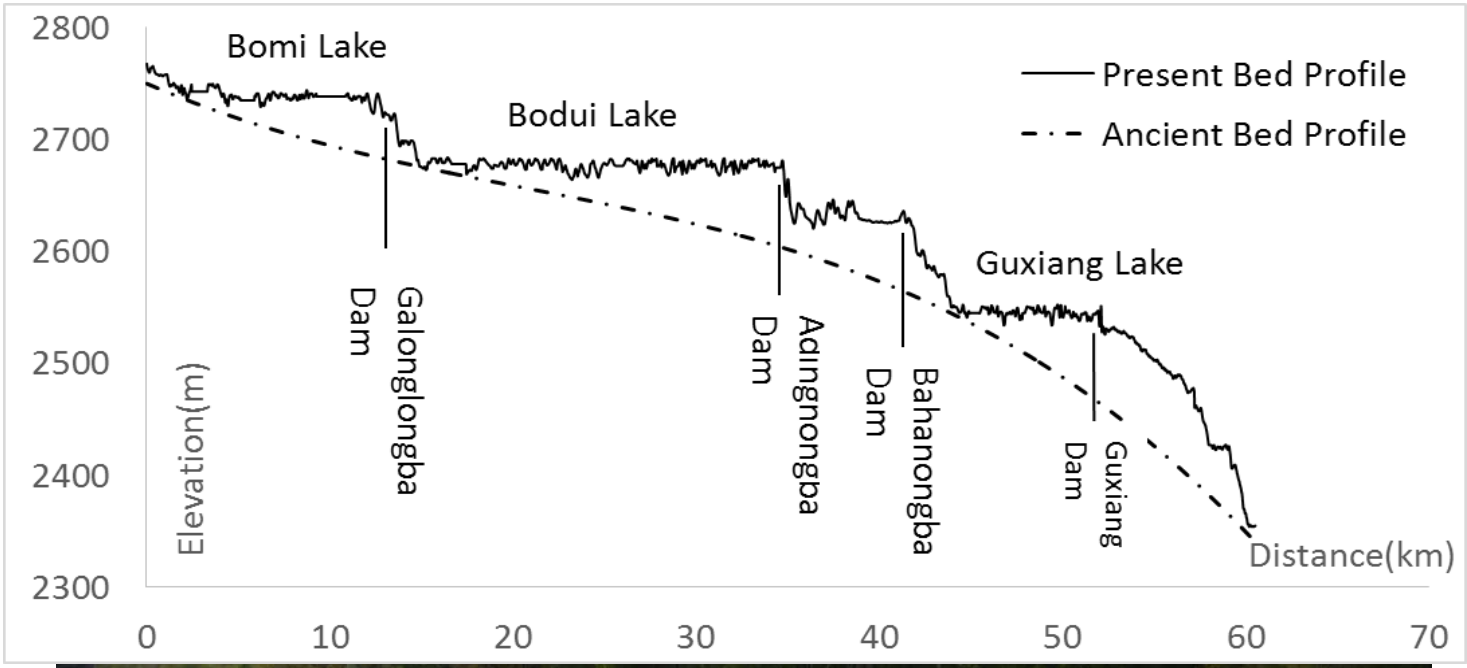




More than 100 landslide dams changed the bed profile of Jiuzhaigou Creek about 20000 years ago

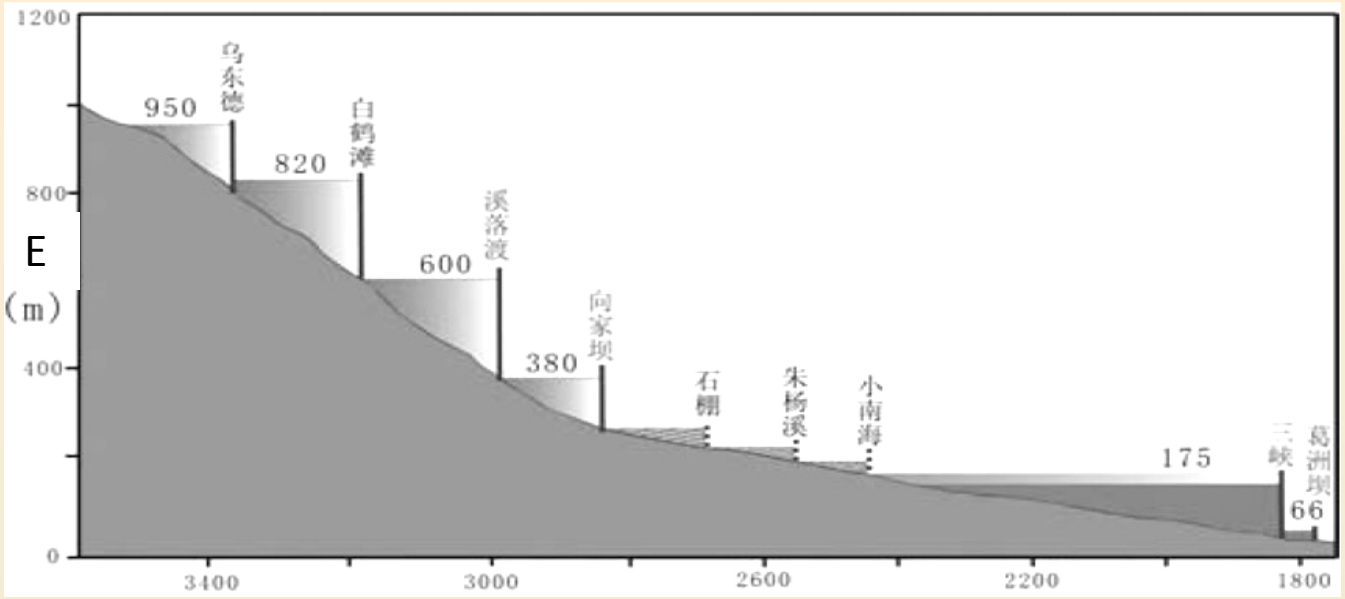


A debris flow from Guxiang Gully dammed the Parlong Tsangpo in 1953, which resulted in a knickpoint and changed the bed profile of the river.

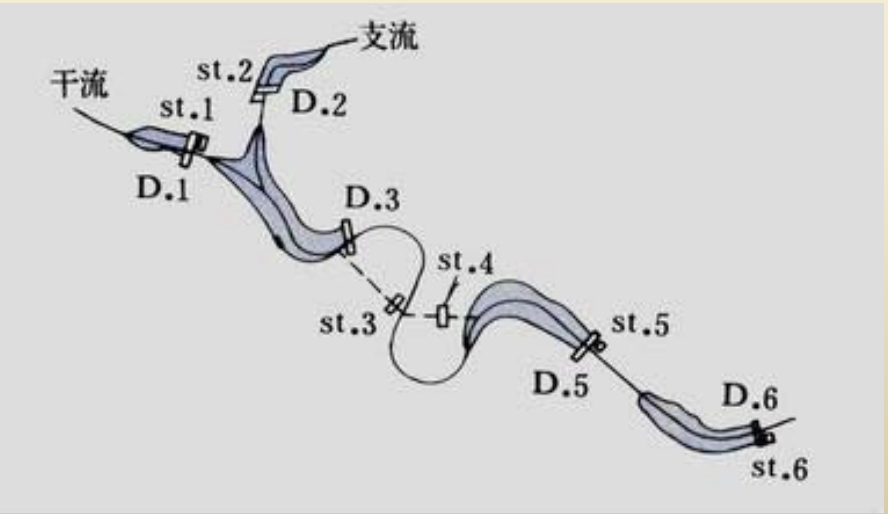


The longitudinal bed profile is plastic, thus dams constructed on rivers changed the profile of rivers and may remain stable. In other words the river may accept the morphological change by dams. The effort of humans changing rivers into steps with cascade hydropower dams will not cause setbacks.

Constructed and planned dams on the Yangtze River



Distance to the river mouth (km)



Cascade hydro-power development can permanently change the longitudinal riverbed profile

Conclusions

- The responses of rivers to human disturbances are complex, many of them can not be understood or explained at science level. The philosophy of rivers studies the issues that science has not yet studied or is unable to.
- The debate on wide and narrow river strategies for sediment management and flood control of the Yellow River has continued for 2000 years. It is proved that the narrow river theory is not good and has only short term effect. The strategy of depositing sediment with wide river channel mitigates flood hazard for long period of time.
- The meandering feature of rivers is resilient. Cutoff of meanders and any efforts to make river straight will be rebounded. The longitudinal bed profile is plastic. Therefore, dam construction on rivers can permanently change the river bed profile without setback.

Thank you

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Wang Z, Lee J. and Melching S., 2015. River Dynamics and Integrated River Management, Springer Verlag and Tsinghua Press, Berlin and Beijing