United Nations Educational, Scientific and Cultural Organization · International Sediment Initiative
United Nations Educational, Scientific and Cultural Organization · International Research and Training Center on Erosion and Sedimentation
IWHR
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Online Webinar

Online monitoring of suspended sediment concentration at the Zhicheng Gauging Station on the Yangtze River

Jingjiang Bureau of Hydrological and Water Resources Survey,

Bureau of Hydrology, Changjiang Water Resources Commission

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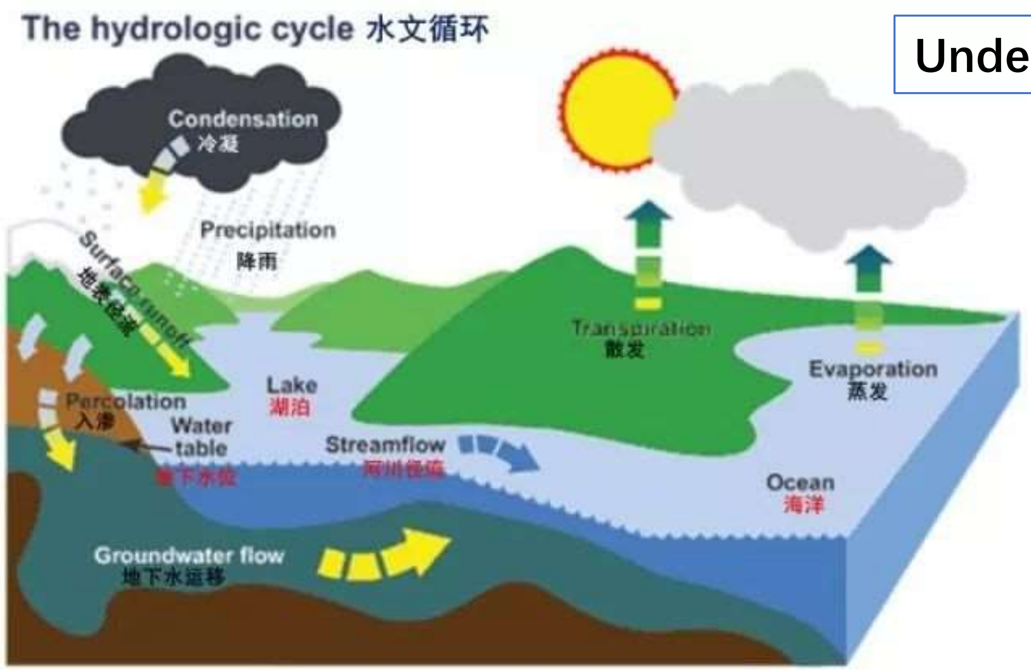
8:00-10:00 Coordinated Universal Time (UTC)
10:00-12:00 Central European Summer Time (CEST)
11:00-13:00 Eastern European Summer Time (EEST)
09:00-11:00 Western Africa Time (WAT)
10:00-12:00 Central Africa Time (CAT)
16:00-18:00 China Standard Time (CST)

UNESCO-ISI Online Training Workshop on Sediment Transport Measurement and Monitoring

Preface

Hydrologic monitoring



- Stage
- Discharge
- Water temperature
- Sediment
- Water quality
- Ice regime
- Precipitation
- Evaporation
- Storm surge
- Groundwater resources
- Soil moisture status
- Underwater topography
- ……

Online monitoring → Visualization, Automation, Intellectualization

Outline

- I. Basic techniques for suspended load measurement in rivers
- II. Innovative idea of monitoring method of suspended sediment
- III. On-line monitoring experiment at Zhicheng Gauging Station
- IV. Discussion on application problems
- V. Summary and outlook

Part 01

Basic techniques for suspended load measurement in rivers

Sediment measurement

Measurement of the form, quantity and evolution process of sediment movement in a river or water body, and the calculation of the scour and sedimentation volume in a certain section of a river or water body, including the suspended load discharge, bed load discharge, bed material measurement and sediment particle size analysis.

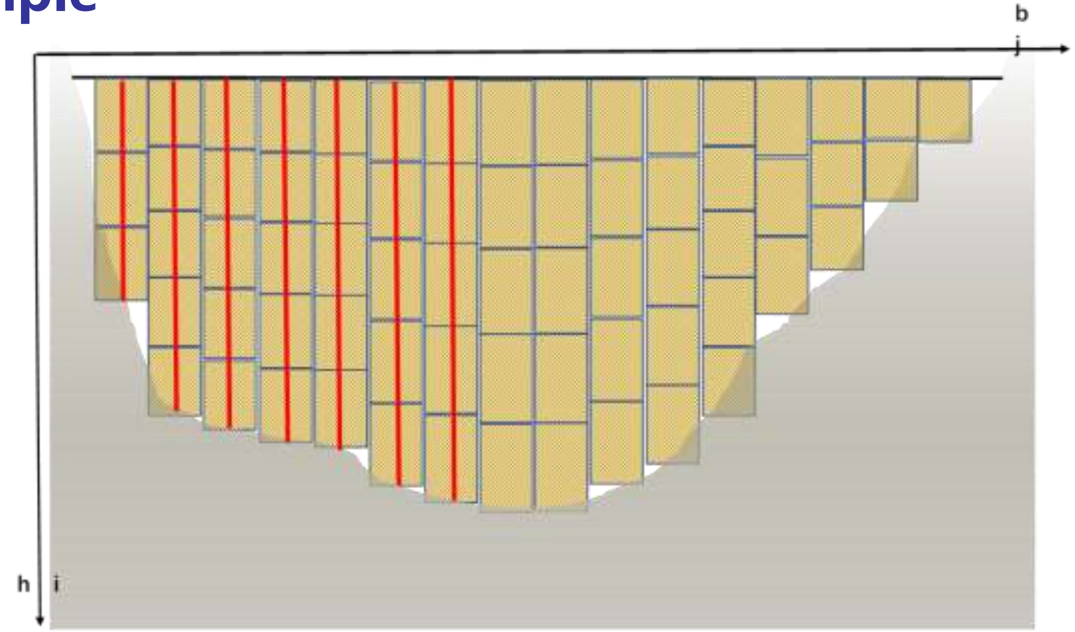
Suspended load

Sediment suspended in water and moved with the stream by the turbulent action of the current.

Suspended load discharge measurement

An operation to measure the quality of suspended sediment passing through a cross-section of a river or channel in unit time.

Suspended load discharge measurement principle



$$Q_s = \int_0^B \int_0^H C_s V \, dh \, db$$

$$Q_s = \sum_j^m \sum_{i=1}^n C_{s_{ij}} V_{ij} \Delta h_i \, \Delta b_j$$

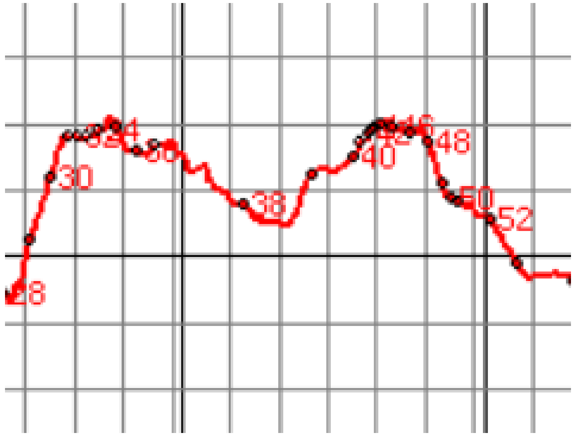
1.1 Measuring methods for suspended load in rivers

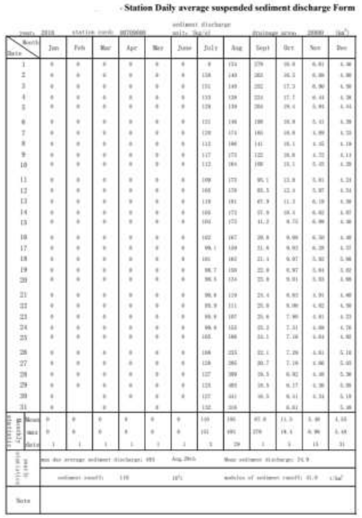
Single sediment measure

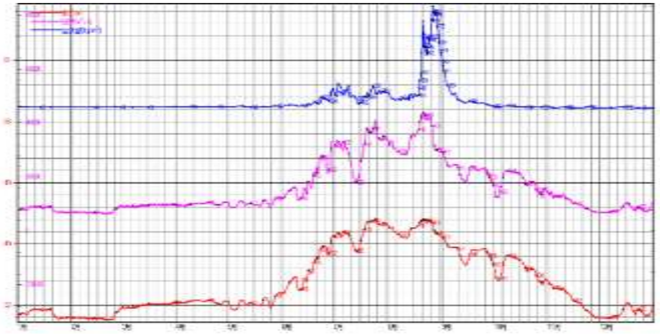
Sediment process control

Data Process


XXXX Station ADCP flow and sediment transport rate calculation table




Station Daily average suspended sediment discharge Form



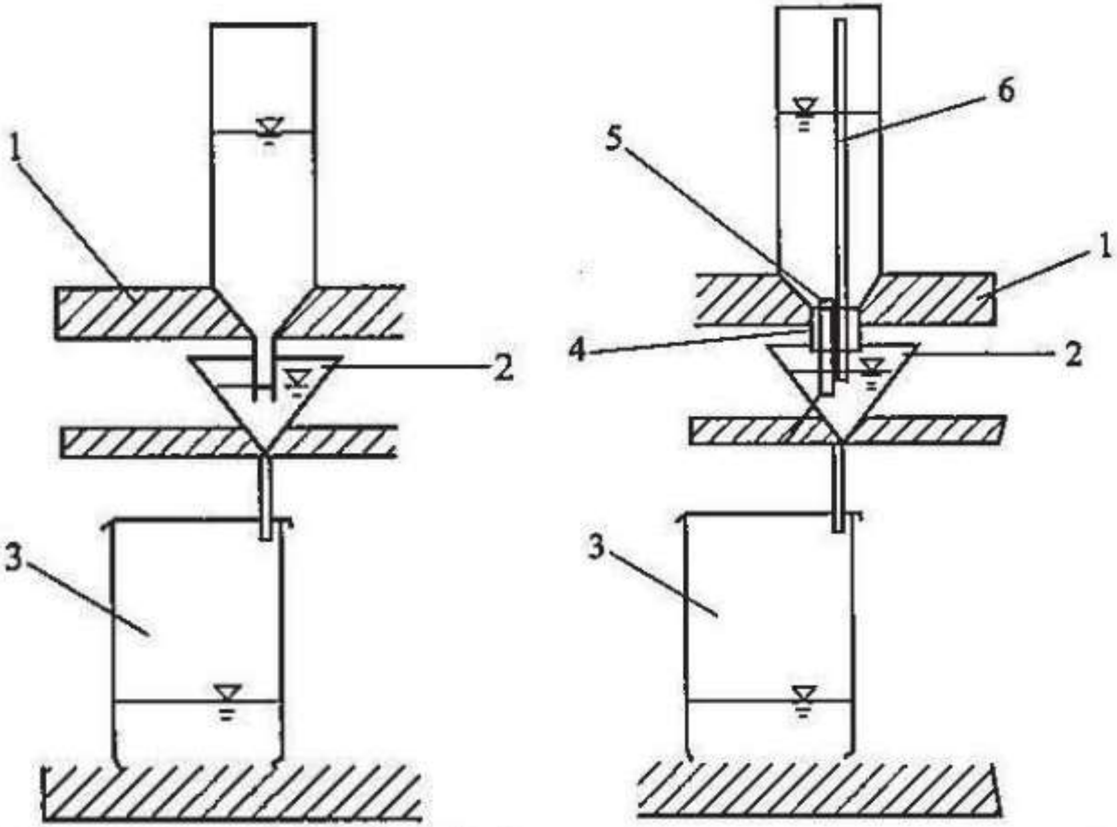
1.1.1 Single sediment measure






$$C_s = \frac{W_s}{V}$$

1.1.1 Single sediment measure



Filtration method

$$C_s = \frac{W_s}{V}$$

$$W_w = K(W_{ws} - W_w)$$

$$K = \frac{\rho_s}{\rho_s - \rho_w}$$

Displacement method

1.1.1 Single sediment measure

Suspended load discharge measurement method

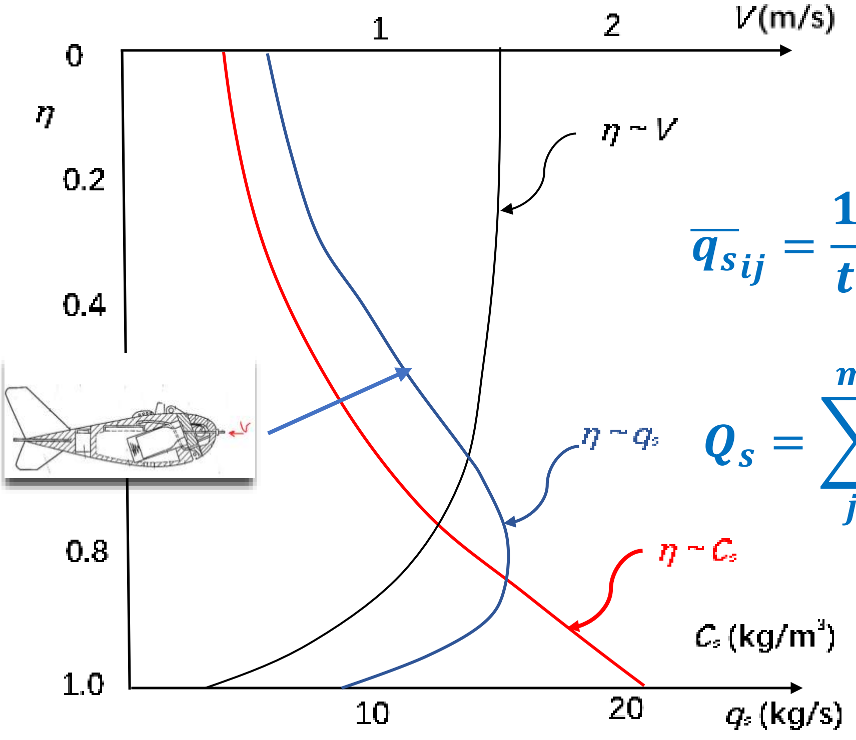
$$Q_s = \int_0^B \int_0^H C_s V \, dh \, db \Rightarrow Q_s = \sum_j^m \sum_{i=1}^n C_{s_{ij}} V_{ij} \Delta h_i \, \Delta b_j \Rightarrow Q_s = \sum_j^m \sum_{i=1}^n C_{s_{ij}} q_{ij}$$

The principle of segment discharge weighted method

Sectional sediment transport rate method	Cross-section mixing method	Asynchronous sediment measuring method
$\overline{C_s} = \frac{Q_s}{Q} = \frac{\sum_{i=1}^n q_{s_i}}{\sum_1^n q_i}$	$Q_s = \overline{C_s} Q$	Qs & Q measuring **NOT** the same time

Suspended sediment measurement principle

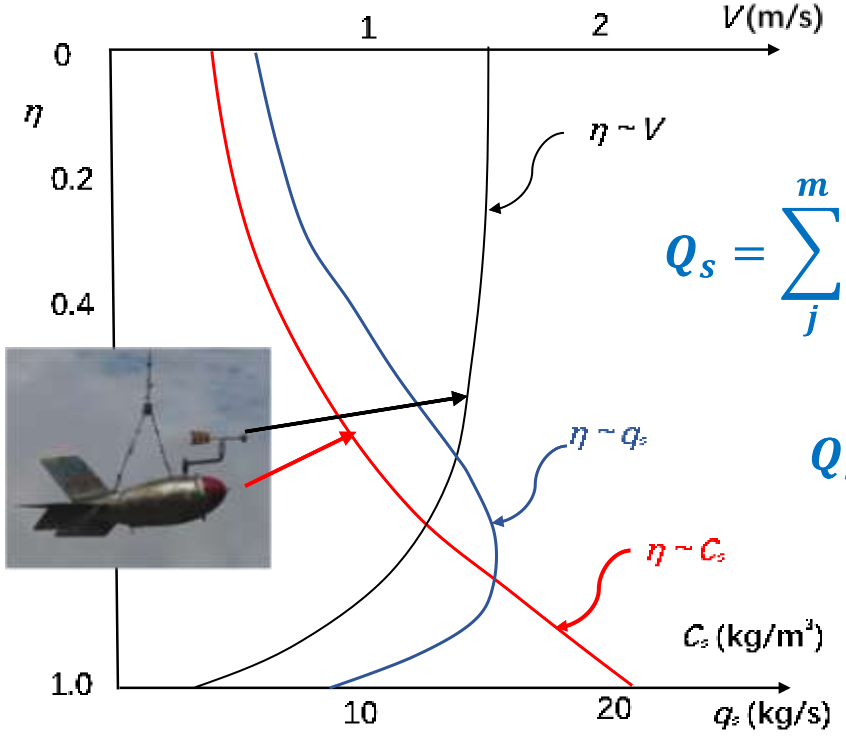
Direct measurement



$$\overline{q_{s_{ij}}} = \frac{1}{t}\int_0^t \alpha\, q_{s_{ij}} dt$$

$$Q_s = \sum_j^m \sum_{i=1}^n \overline{q_{s_{ij}}} \Delta h_i \Delta b_j$$

Indirect measurement

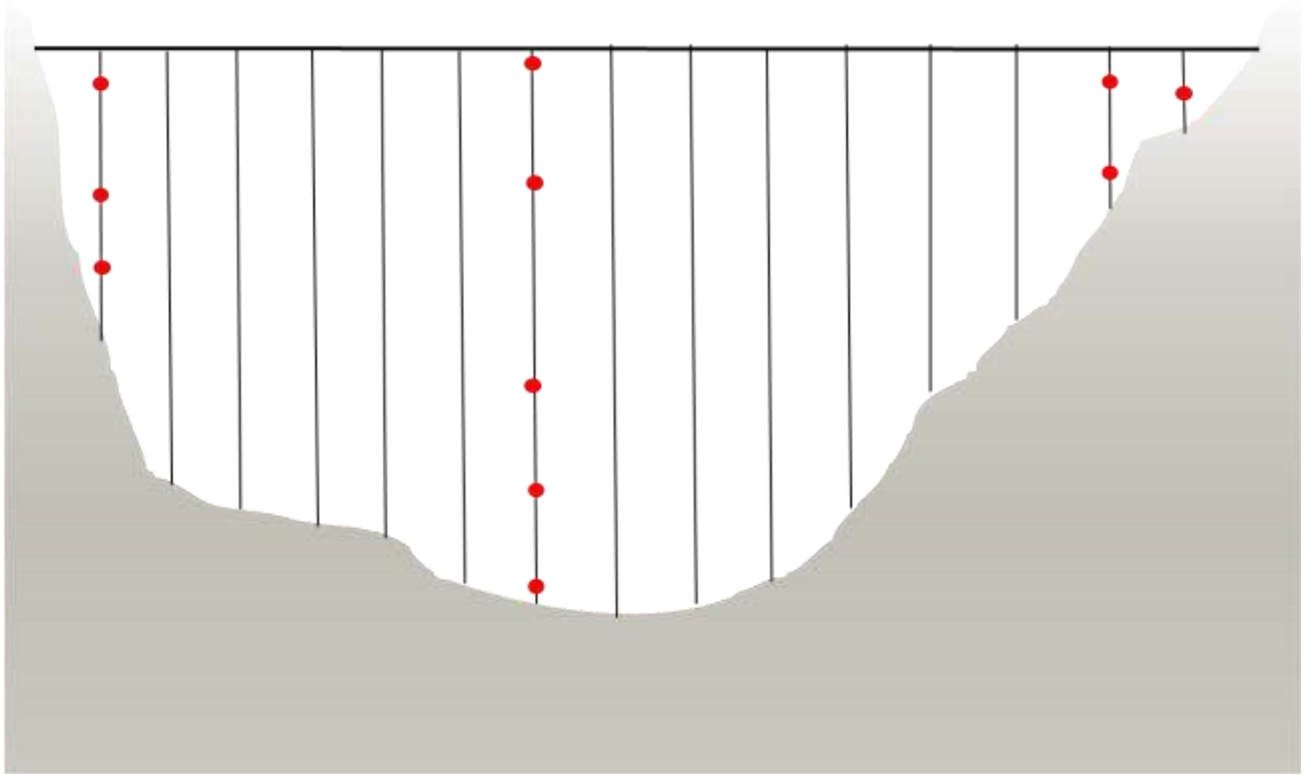


$$Q_s = \sum_j^m \sum_{i=1}^n \overline{C_{s_{ij}}}\,\overline{V}_{ij} \Delta h_i \Delta b_i$$

$$Q_s = \sum_{j=1}^m \overline{C_{s_j}} q_j$$

1.1.1 Single sediment measure

Mean sediment concentration at a vertical (MSCV)



$$C_{sm} = \frac{1}{10V_m}\begin{pmatrix} V_{0.0}C_{s0.0} + 3V_{0.2}C_{s0.2} + 3V_{0.6}C_{s0.6} \\ +2V_{0.8}C_{s0.8} + V_{1.0}C_{s1.0} \end{pmatrix}$$

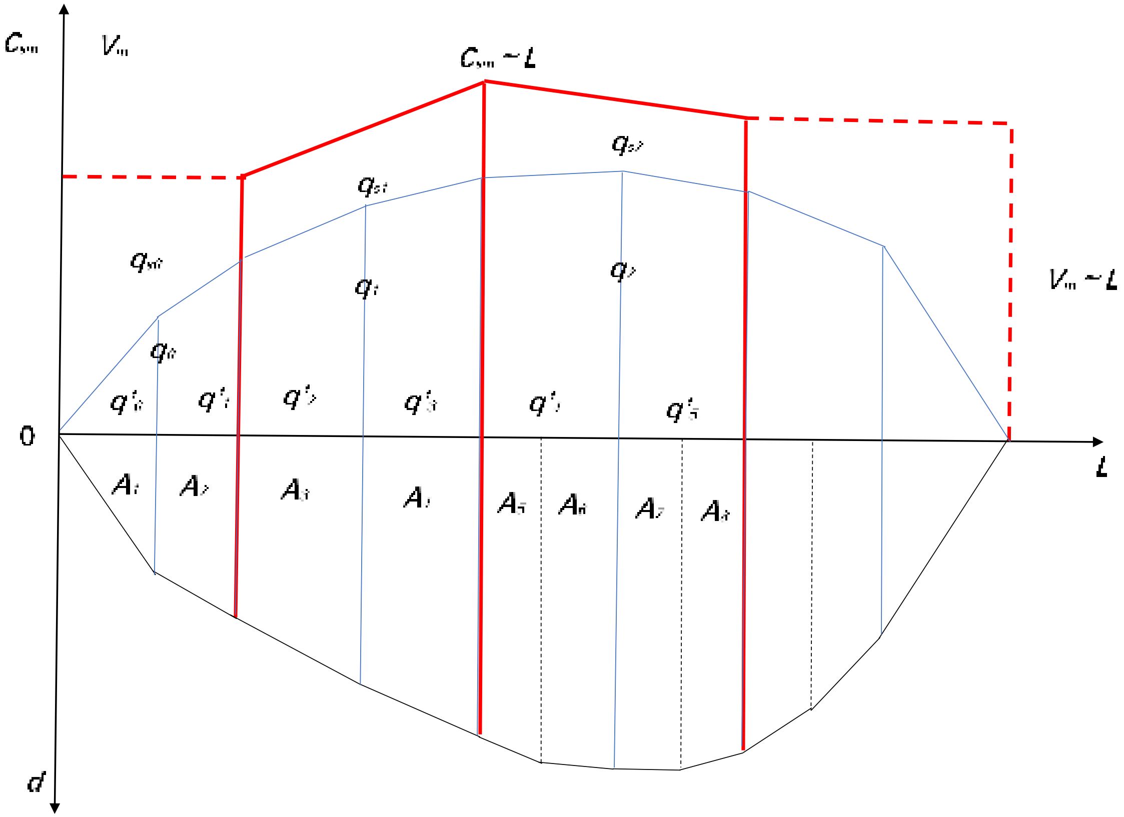
$$C_{sm} = \frac{V_{0.2}C_{s0.2} + V_{0.6}C_{s0.6} + V_{0.8}C_{s0.8}}{V_{0.2} + V_{0.6} + V_{0.8}}$$

$$C_{sm} = \frac{V_{0.2}C_{s0.2} + V_{0.8}C_{s0.8}}{V_{0.2} + V_{0.8}} \quad \text{or} \quad C_{sm} = \frac{C_{s0.2} + C_{s0.8}}{2}$$

$$C_{sm} = \eta_1 C_{s0.6}$$

1.1.1 Single sediment measure

Mean sediment concentration at a cross-section (MSCC)



$$Q_s = C_{sm1}q_0 + \frac{C_{sm1} + C_{sm2}}{2}q_1 + \frac{C_{sm2} + C_{sm3}}{2}q_2 + \dots + \frac{C_{smn-1} + C_{smn}}{2}q_{n-1} + C_{smn}q_n$$

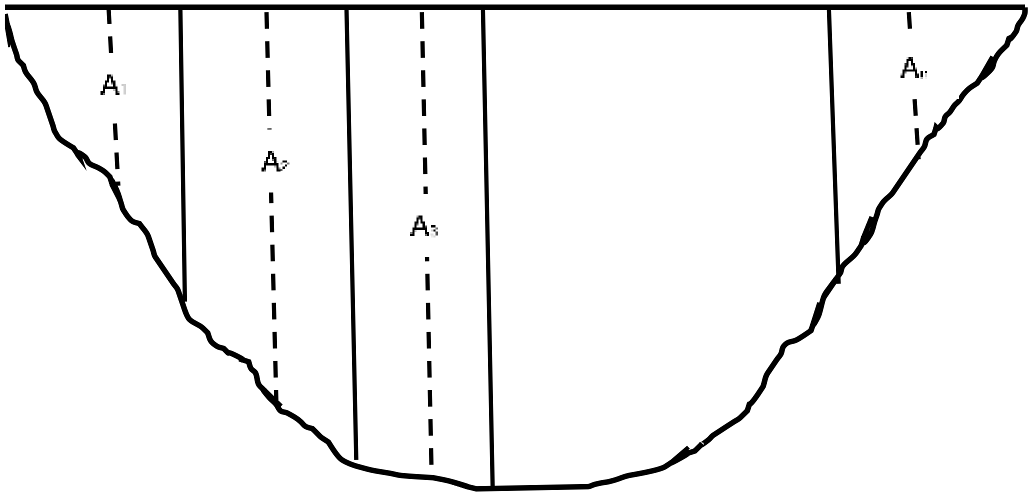
$$\overline{C_s} = \frac{Q_s}{Q}$$


XXXX Station ADCP flow and sediment transport rate calculation table

1.1.1 Single sediment measure

Cross-section mixing method

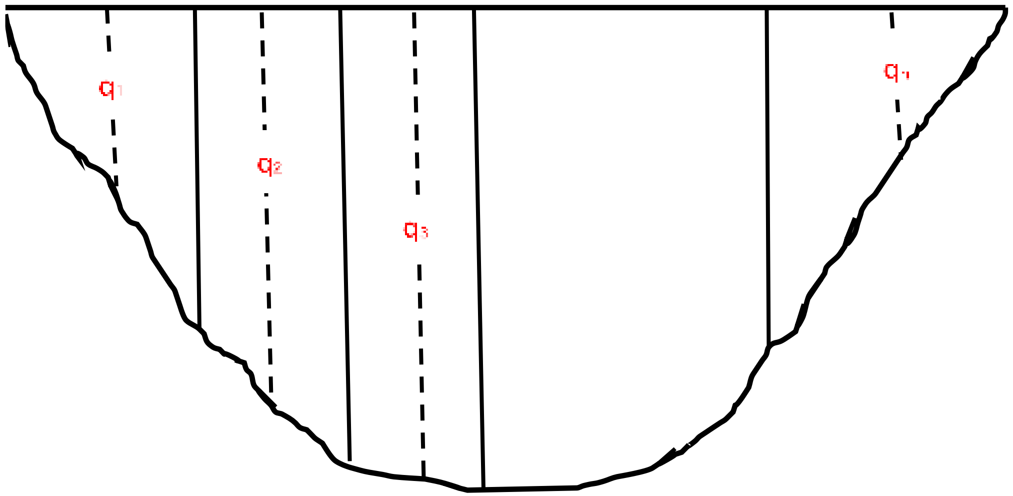
Equal-segment-area cross-section mixing method



$$A_1 = A_2 = A_3 = \cdots = A_n$$

$$T_1 = T_2 = T_3 = \cdots = T_n$$

Equal-part-discharge cross-section mixing method

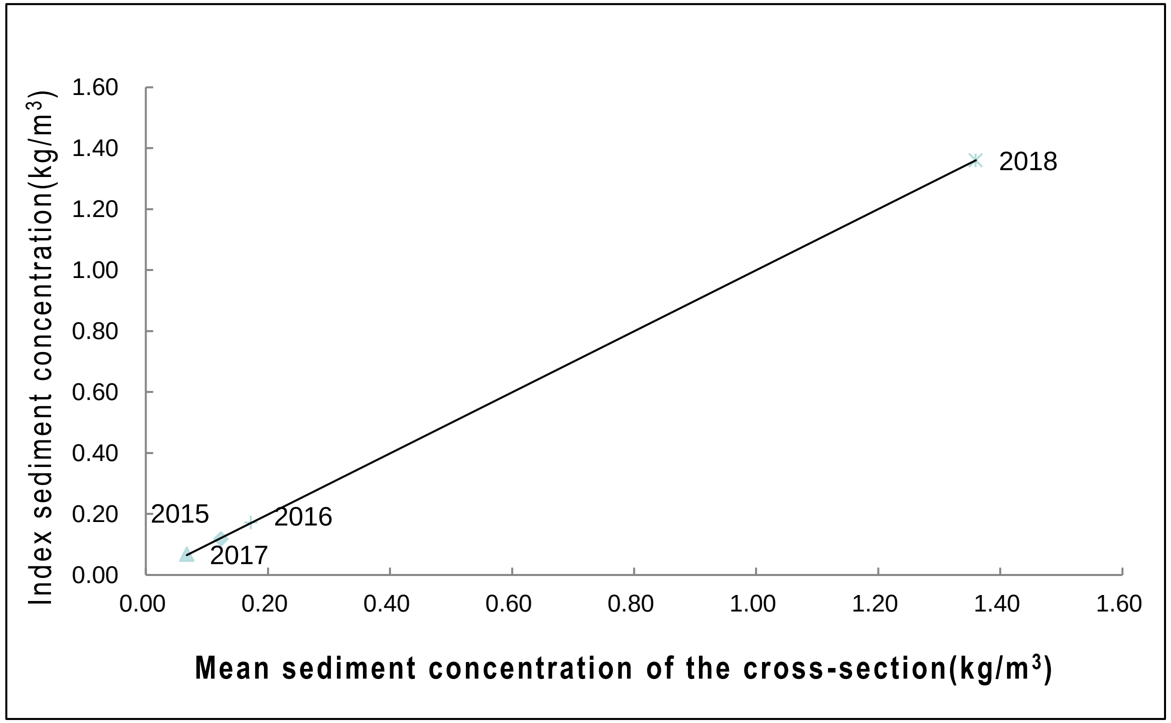


$$q_1 = q_2 = q_3 = \cdots = q$$

$$V_1 = V_2 = V_3 = \cdots = V_n$$

1.1.1 Single sediment measure

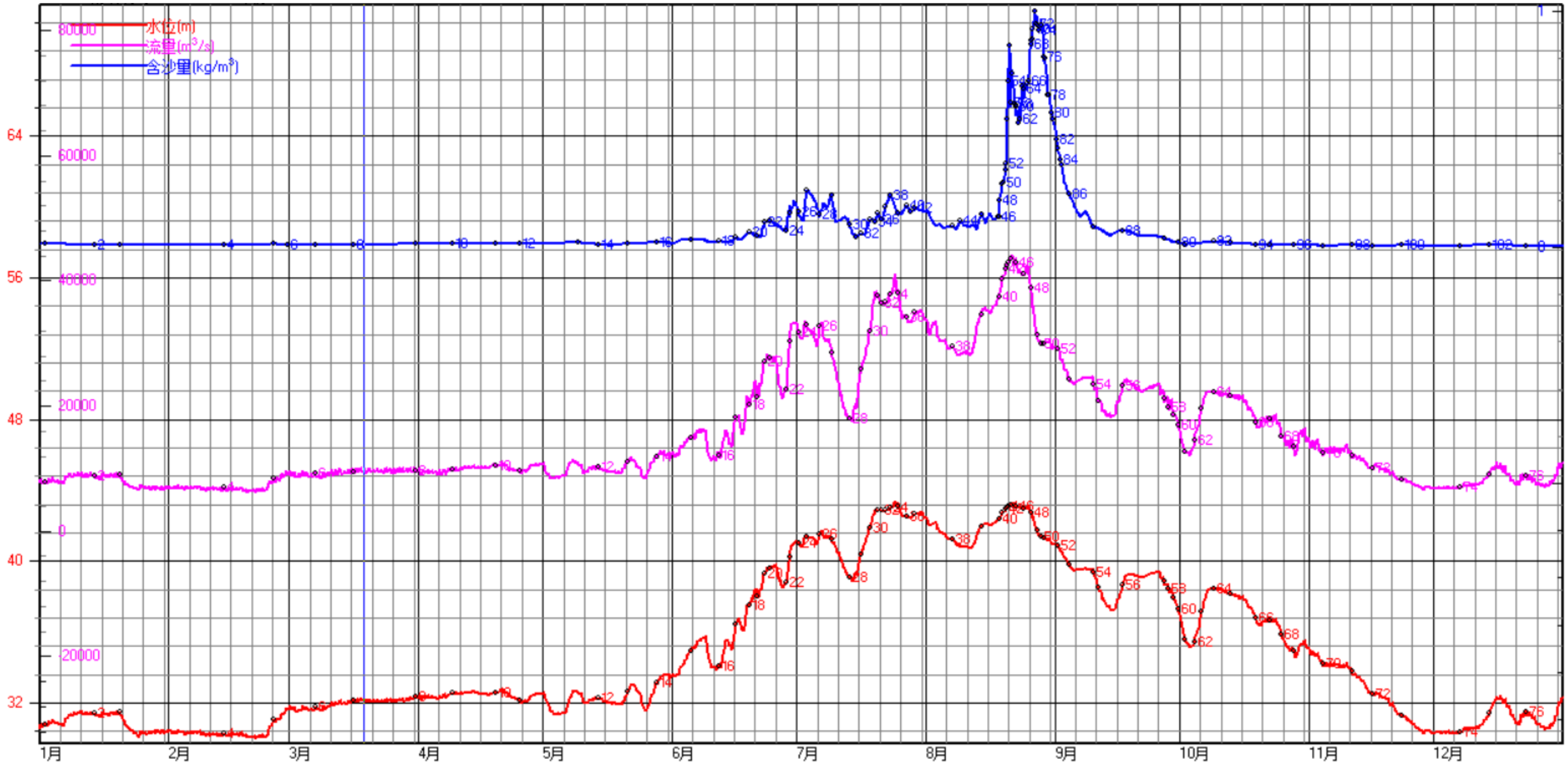
The index sediment concentration measure methods



$$\overline{C_s} = f(C_{s_I})$$

- Representative line method
- Equal discharge multi-line method
- Mainstream multi-line method
- Cross line method

1.1.2 Measuring frequency control



1.1.2 Measuring frequency control

- When the cross-section mean sediment concentration hydrograph method is used for data processing, measurement times should be able to control the whole process of sediment concentration change.
- In the case of index and cross-section average sediment concentration relation curve method, index sediment concentration measurement should control the change process of sediment concentration, the cross-section average sediment concentration and the equivalent index sediment concentration measurement should meet the requirements of relation curve determination and control the turning point of the relation curve changing.

1.1.2 Measuring frequency control

- When using the hydrograph method of index and cross-section average sediment concentration ratio to process data, the measurement times should be evenly distributed and the turning points of the proportional coefficient changing should be controlled, and should distribute measurement times at the main turning points of flow discharge and sediment concentration.
- When the flow discharge and sediment discharge relation curve method is used to process the data, the measurement times distribution should be able to control the changing process of the main flood peak, a small number of measurements should be distributed in the normal-flow and low-flow period, and the measurement numbers distribution of sediment transport rate should meet the requirements of data process and relation curve determination.

1.1.3 Data Process

$$Q_s = \frac{1}{48}\sum_{i=1}^{n}\left[\left(q_i c_{si} + q_{i+1} c_{s(i+1)}\right)\Delta t_i\right]$$

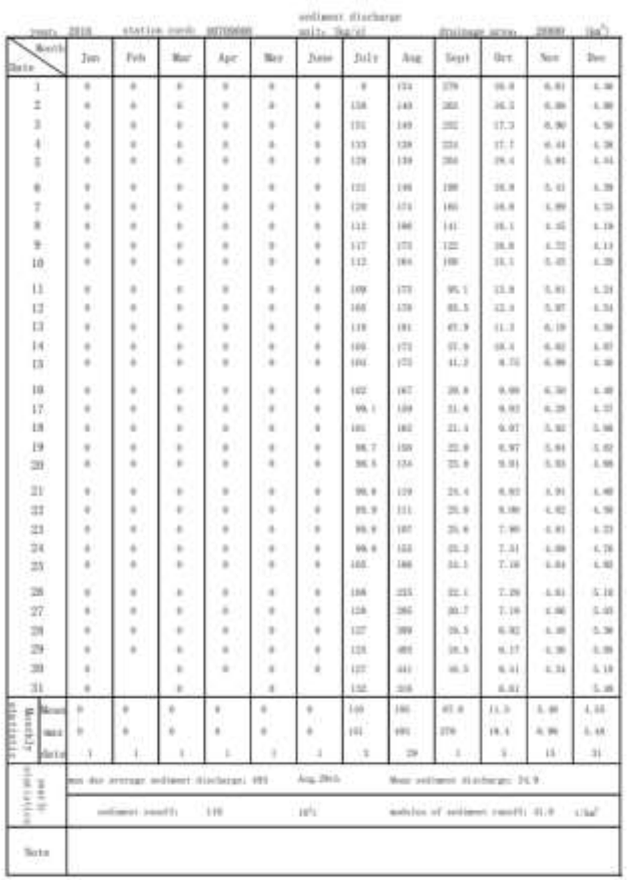
$$Q_s = \frac{1}{96}\sum_{i=1}^{n}\left[\left(q_i + q_{i+1}\right)\left(c_{si} + c_{s(i+1)}\right)\Delta t_i\right]$$

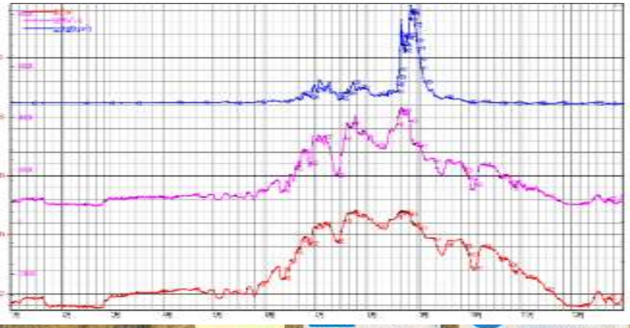
$$Q_s = \frac{1}{72}\sum_{i=1}^{n}\left[\left(q_i c_{si} + q_{i+1} c_{s(i+1)}\right)\Delta t_i\right] + \frac{1}{144}\sum_{i=1}^{n}\left[\left(q_i c_{s(i+1)} + q_{i+1} c_{si}\right)\Delta t_i\right]$$

$$W_s = Q_s T(t)$$

$$M_s = \frac{W_s}{F} \qquad y_s = \frac{V_c}{F} = \frac{W_s/\gamma_s'}{F} = \frac{M_s}{\gamma_s'}$$

Station Daily average suspended sediment discharge Form





1.1.3 Data Process

Classical methods for the suspended sediment data processing

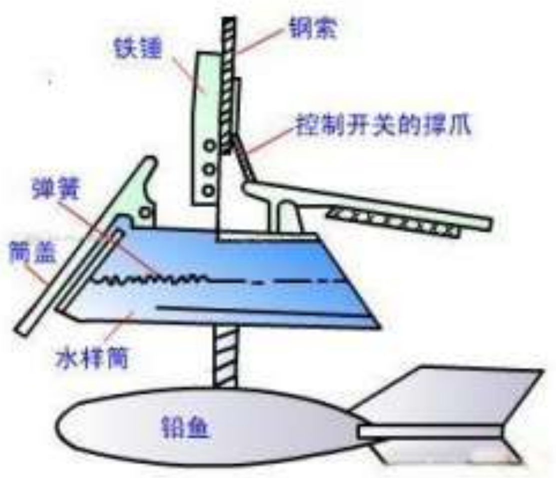
- Cross-section mean sediment concentration hydrograph method
- Index and cross-section mean sediment concentration relation curve method
- Index and cross-section mean sediment concentration ratio hydrograph method
- Discharge and sediment discharge relation curve method
- Nearby station’ s index sediment correlation relation curve method
- Water-sediment ratio coefficient correlation method

1.2 An overview of suspended sediment measuring instruments

Time-integrated sampler

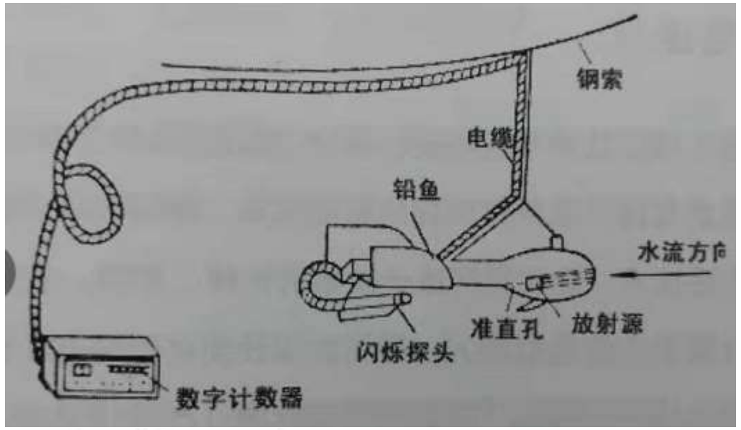
1.2 An overview of suspended sediment measuring instruments

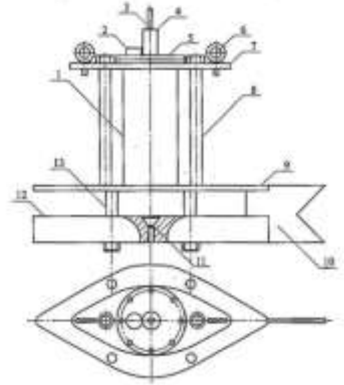
Instantaneous sampler



1.2 An overview of suspended sediment measuring instruments

Sediment concentration meter



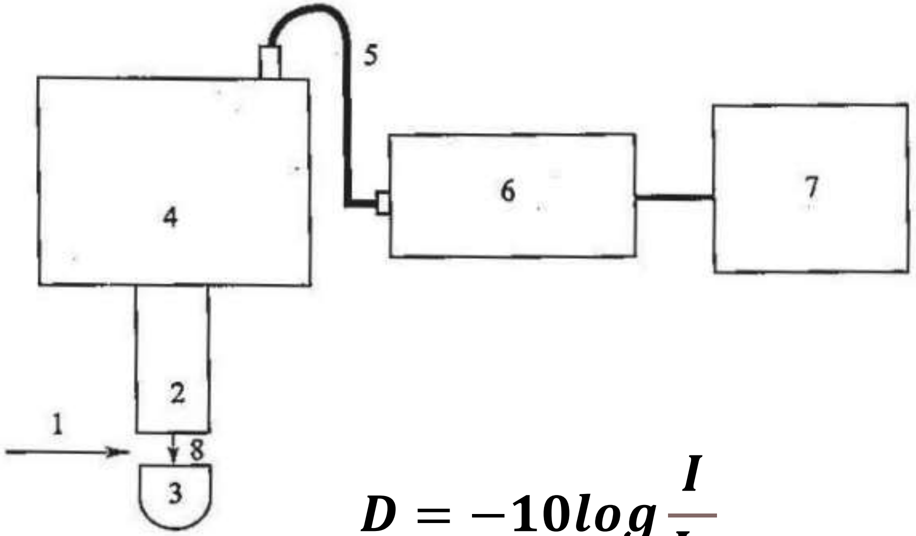


Nuclear sediment meter

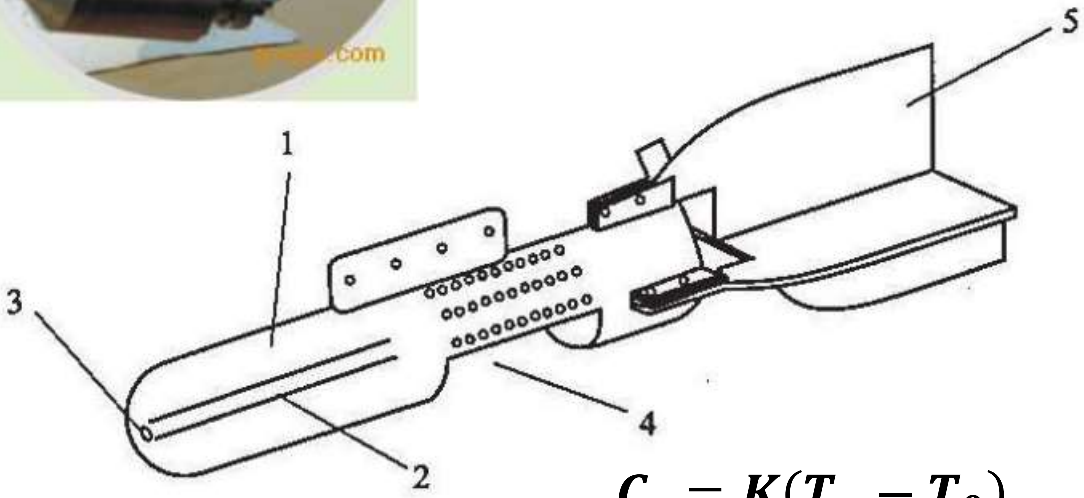
Turbidimeter

1.2 An overview of suspended sediment measuring instruments

Sediment concentration meter



$$D = -10log\frac{I}{I_0}$$



$$C_s = K(T_n - T_0)$$

Acoustic sediment concentration meter

Vibrational sediment concentration meter

1.3 Overview of online monitoring technology

Part 02

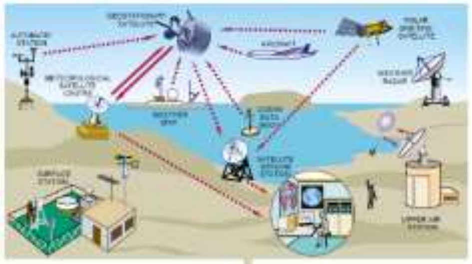
Innovative idea of monitoring method of suspended sediment

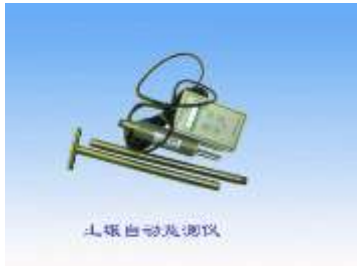
Hydrometry





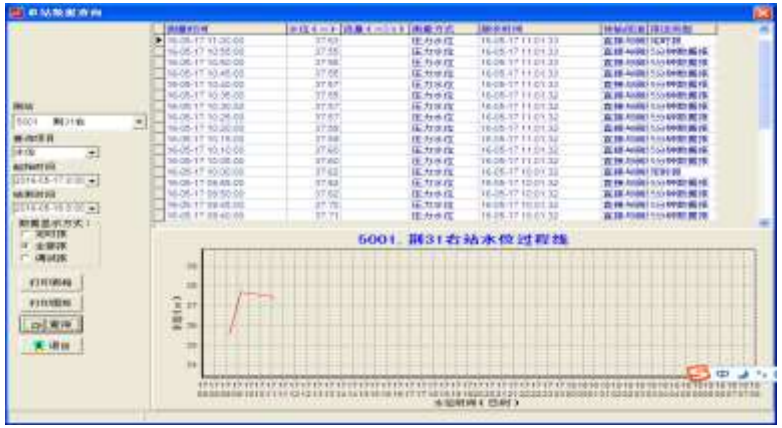

- Hydrometry 4.0
  - 1.0 Li Bing and Son, Dujiangyan stone man
  - 2.0 Stage and rainfall observation record (paper), semi-automatic cableway
  - 3.0 Flood Control Command System, automatic collection, transmission and storage
  - 4.0 Automation, intelligence, intensification, multi-dimensional (space, sky and earth integration), Internet +

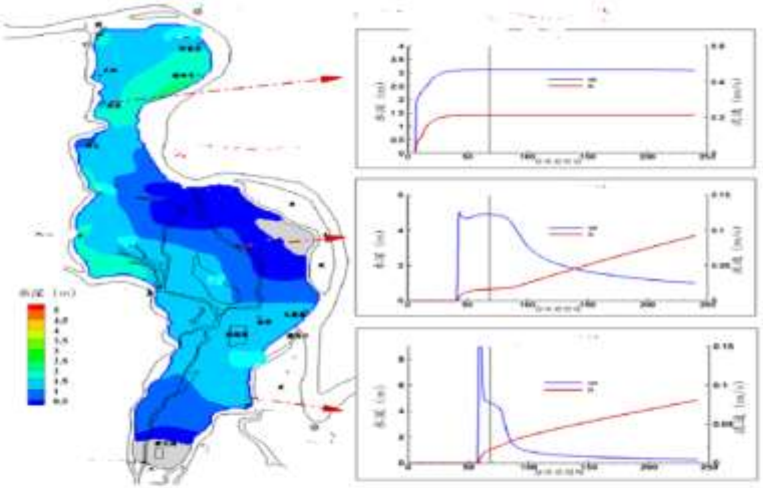




Hydrometry

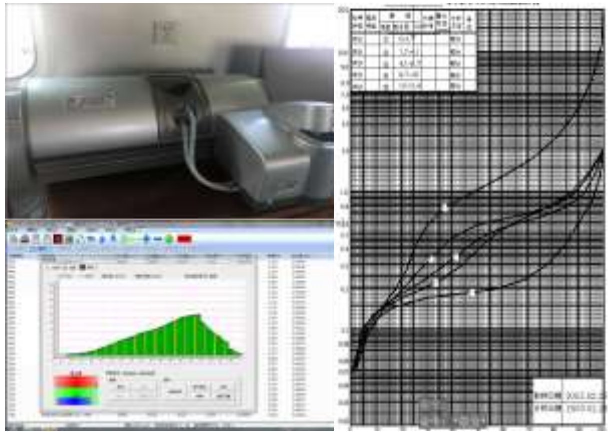
Hydrologic monitoring for emergency response





Sediment Measurement

Online monitoring 



Elements	Mainstream method	Procedure of main method	Field fast measurement method using	Online monitoring method using	Measuring, reporting and processing integrated method
Suspended load concentration	Sampler class method	Sampling, volume measuring, settling, concentrating, oven drying, weighing, calculating	Sediment concentration meters are used in a part of stations	Seldom	Rarely
Suspended grain-size distribution	Sampler class method Laser particle size meter	Sampling, volume measuring, settling, concentrating, sieve analysis or water analysis or laser method analysis, calculating	Laser class meter are using in a part of stations	Rarely	Did not see
Soil bed load	Sampler class method	Sampling, water weighting, sieve analysis or water analysis, calculating	Some using for bulky grain Rarely for others	Experiments are carrying out on few scientific research project	Did not see
Pebble bed load	Sampler class method	Sampling, measuring size, weighting, drying, sieve analysis, calculating	Field measuring sizes Rarely for others	Experiments are carrying out on few stations	Did not see
Bed material	Sampler class method	Sampling, drying, measuring size, sieve analysis, calculating	Some using for bulky grain Rarely for others	Required frequency not high Did not see	Did not see

2.1 Problems facing

- Development bottleneck of sediment measurement monitoring technology
- Affected by the engineering project
- Higher service requirements

2.1 Problems facing

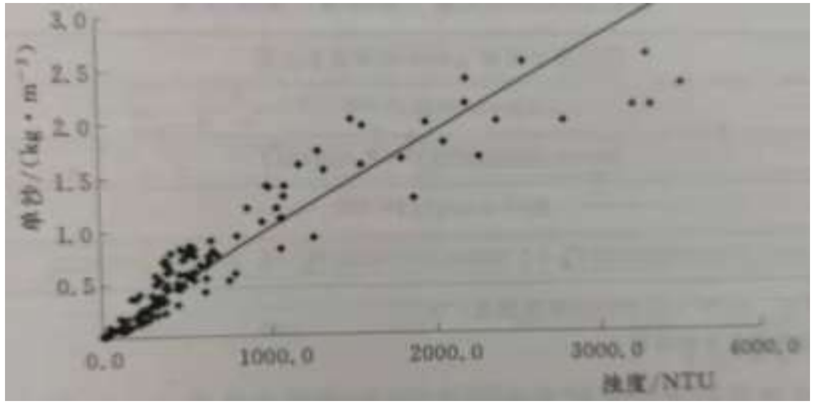
Main innovation by Changjiang Hydrology in present century

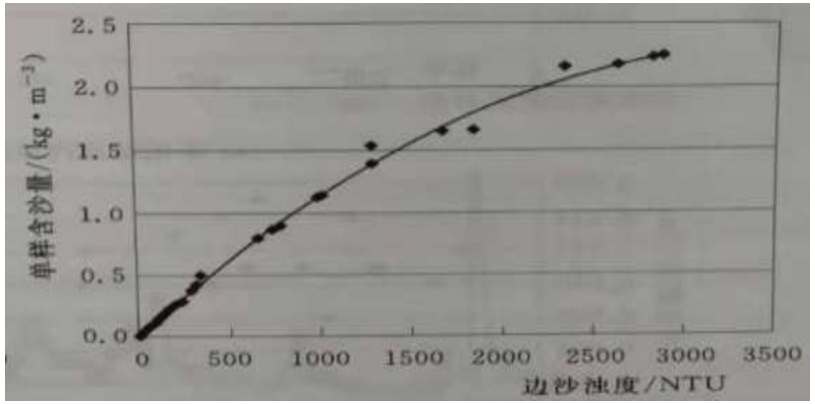
Requirements for hydrologic service system investigation	Hydrometric management system study
Discharge measurement method innovation	Sediment measurement method innovation
Hydrologic monitoring for emergency response and practical technology	Hydrometric accuracy control technology
New hydrological data processing technology	Adaptability of hydrometric standard

2.1 Problems facing

Sediment measurement method experiment and research

$$K = NTU_{standard}/NTU_{measure}$$



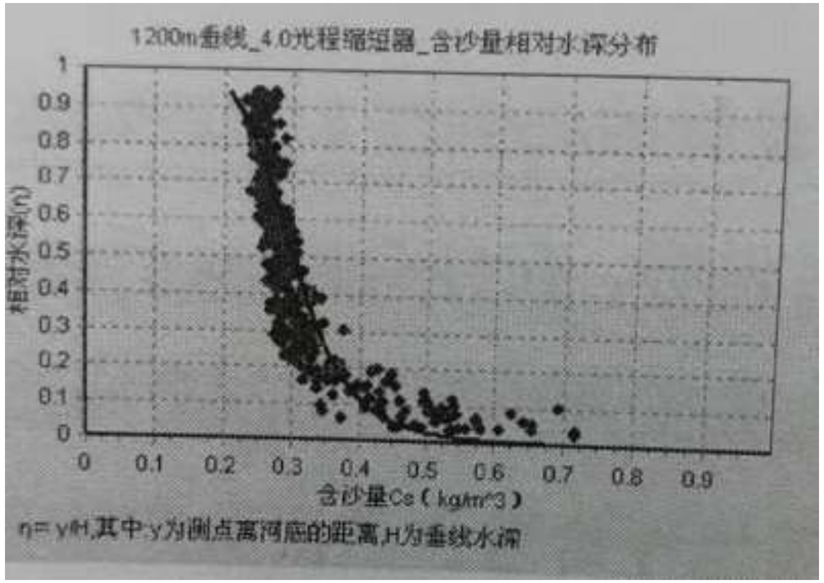


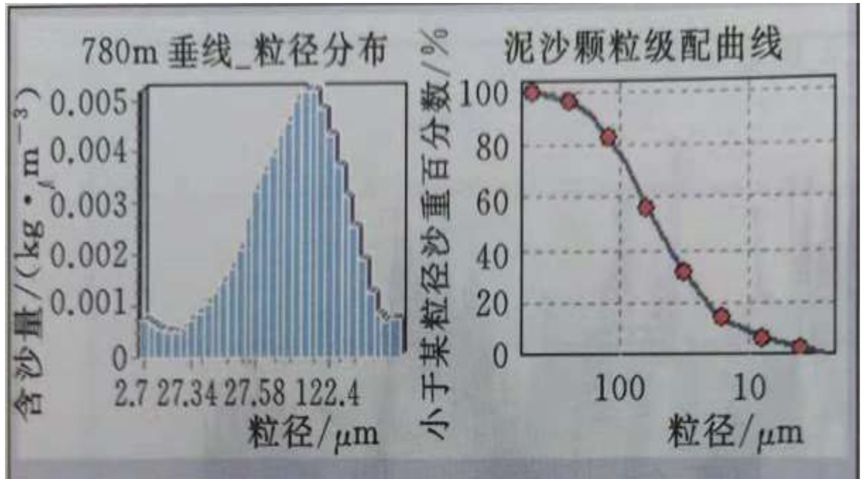
2.1 Problems facing

Sediment measurement method experiment and research

2.1 Problems facing

Sediment measurement method experiment and research

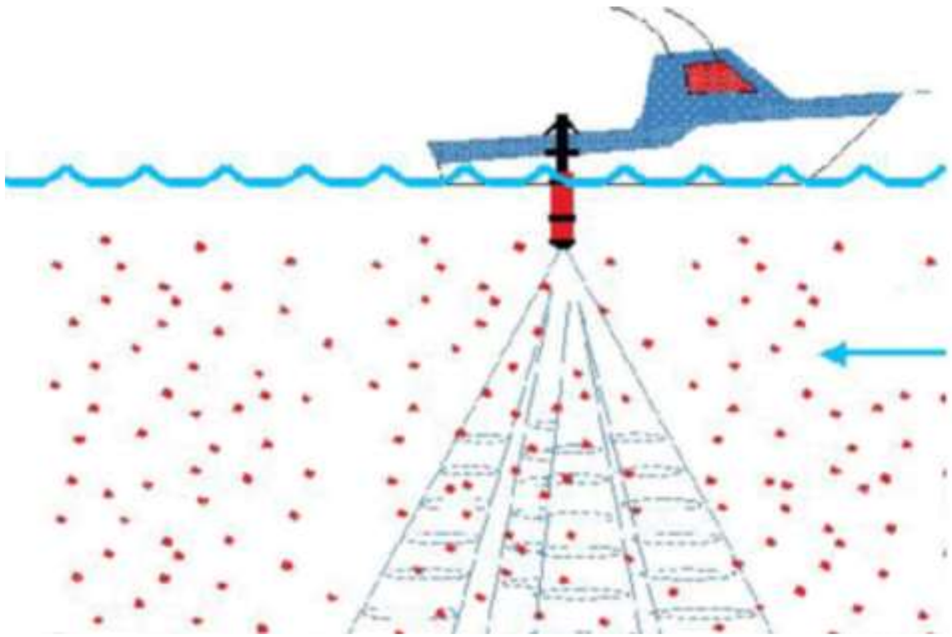




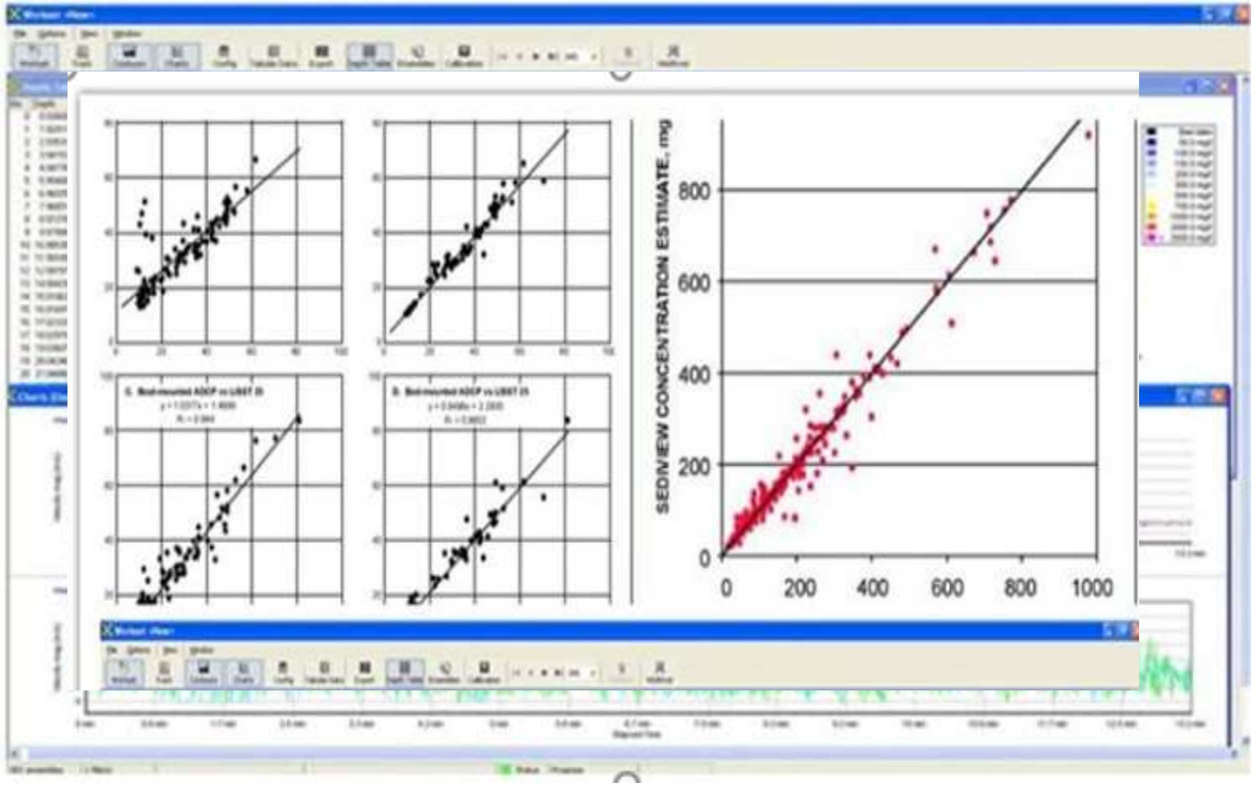
粒径/μm	4	8	16	32	62	125	250	500
百分数/%	3.1	6.7	14.5	31.6	56.3	82.9	96.5	100.0

2.1 Problems facing

Sediment measurement method experiment and research

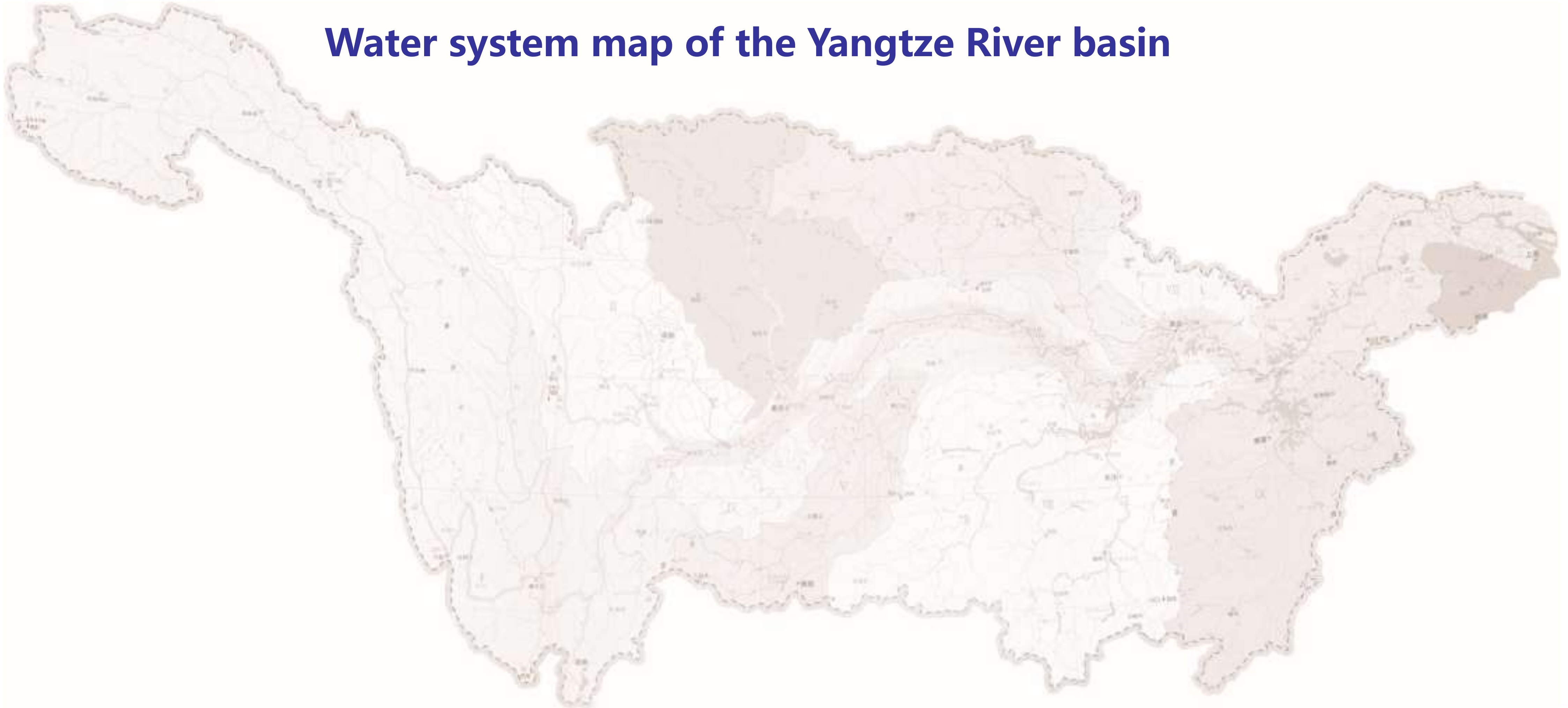


$$SSC_{estimated} = 10^{(A+B*RB)}$$



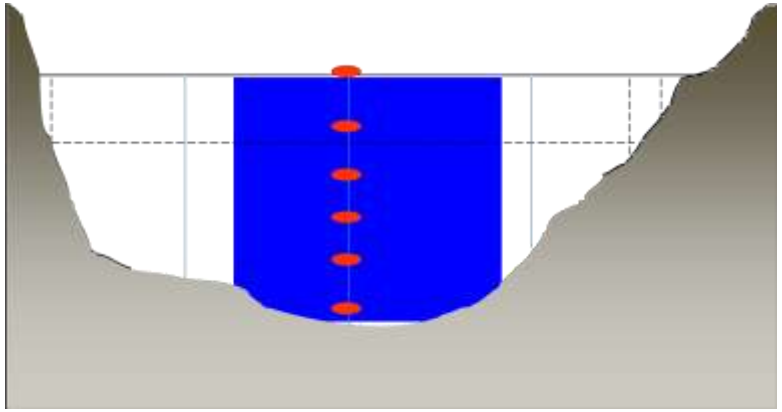
2.1 Problems facing

Water system map of the Yangtze River basin



2.2 Ideas to solve problems

Improve and optimize classical measure methods



Assuming that the water depth is 40m, six layers of water samples are taken, and the length of the sampler to travel is about:

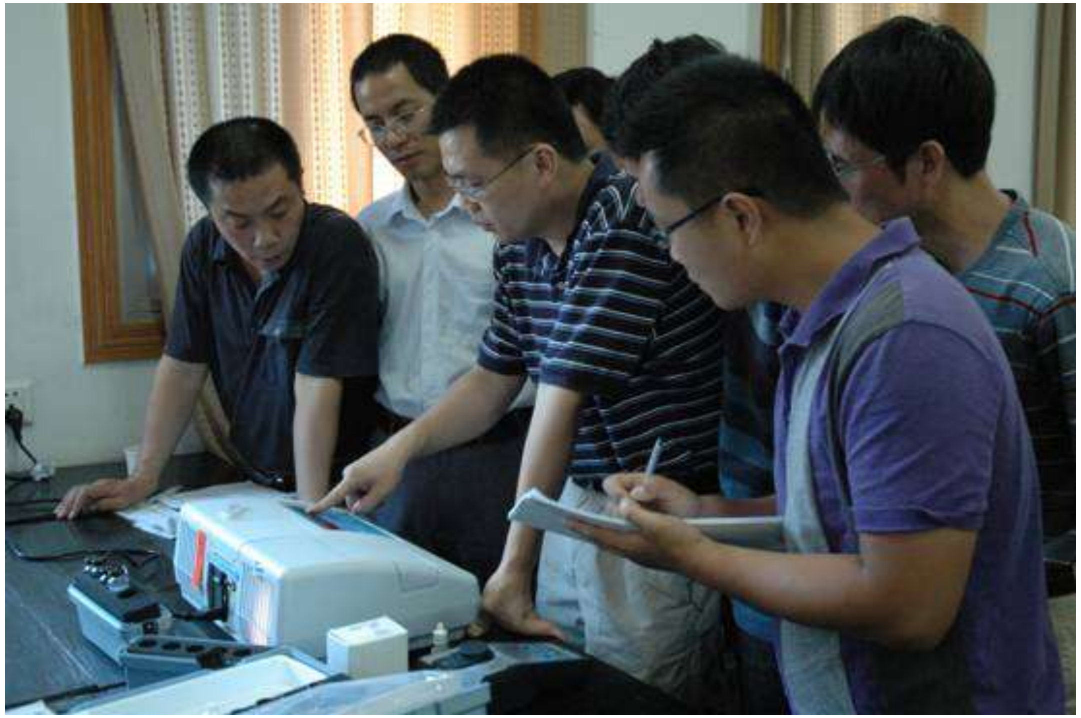
39.5*2+40*0.8*2+40*0.6*2+40*0.4*2+40*0.2*2+2*0.5=**240m**

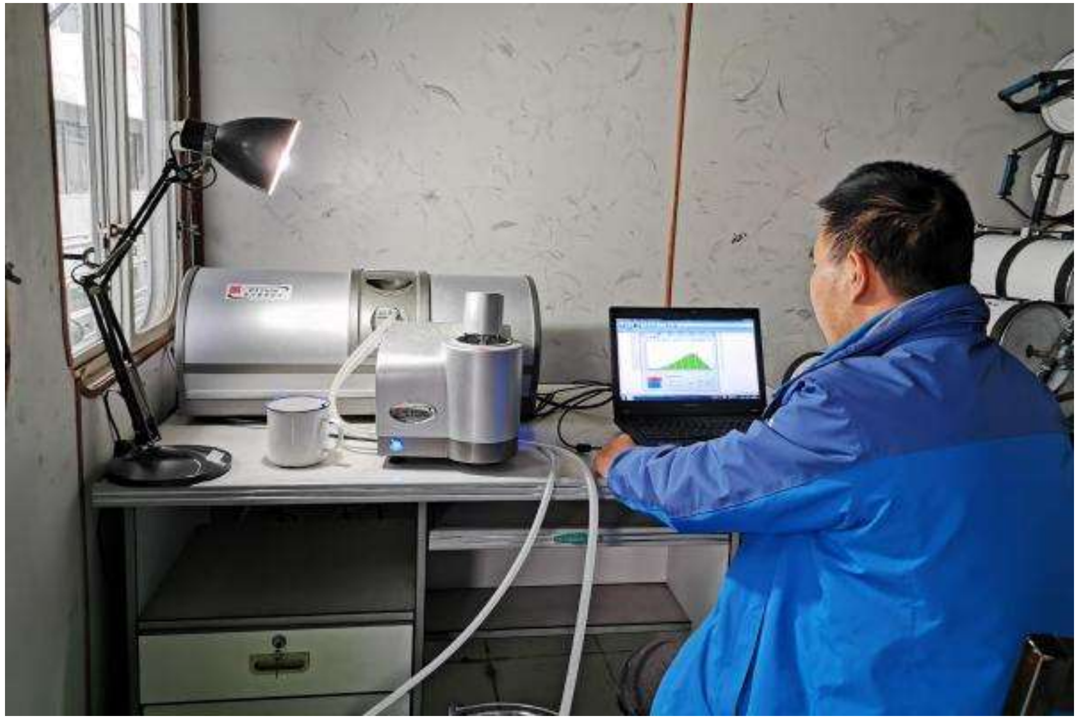
Now if we use the multi-cabins instantaneous sampler, the length of the sampler to travel is about: 39.5*2=79m

We can save about 2/3 of the time!

2.2 Ideas to solve problems

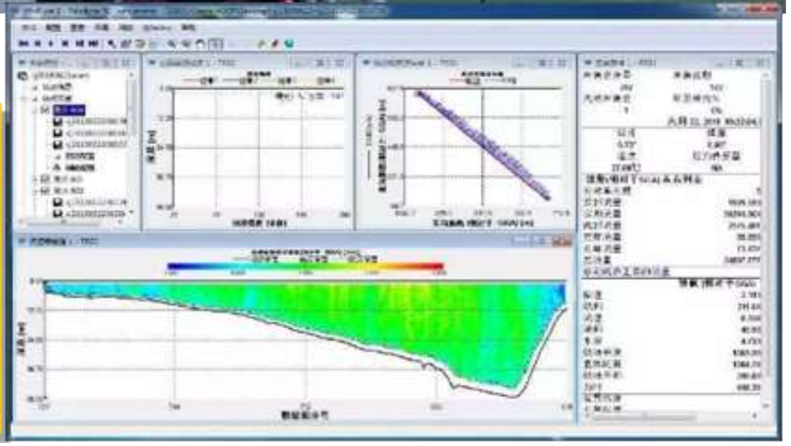
Use the field sediment measuring instrument to quickly measure on site

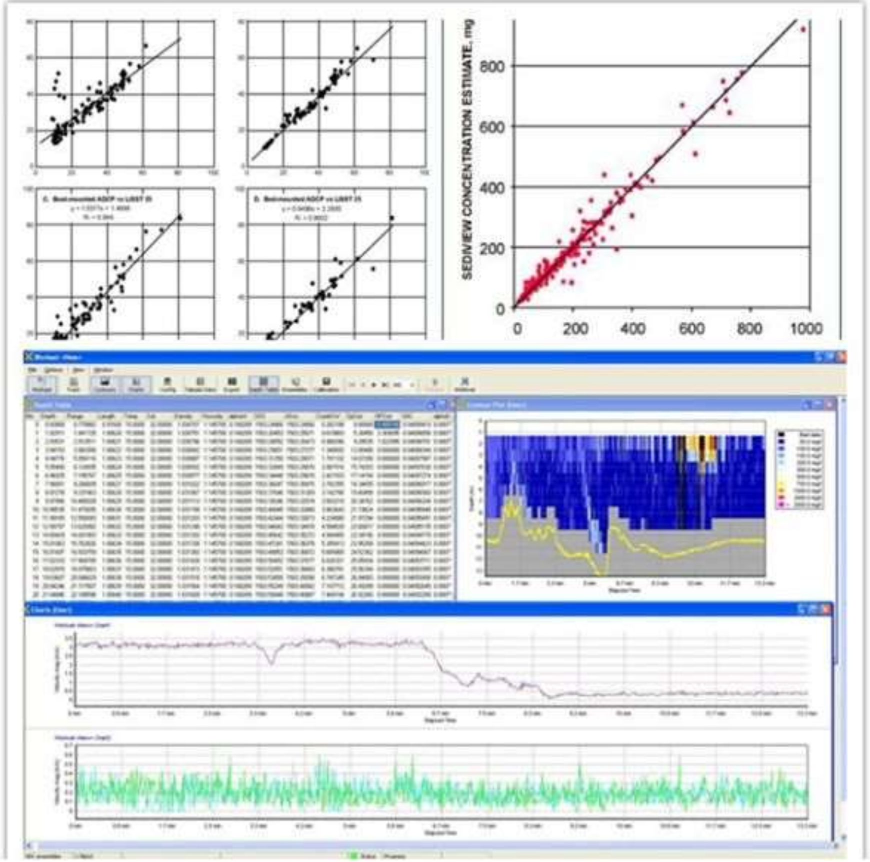




2.2 Ideas to solve problems

Scan and perceive cross-section sediment concentration directly

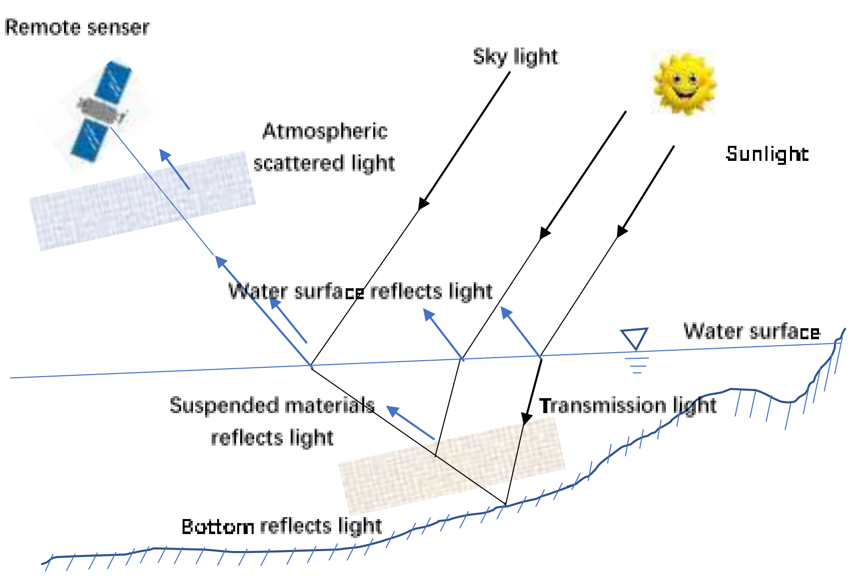


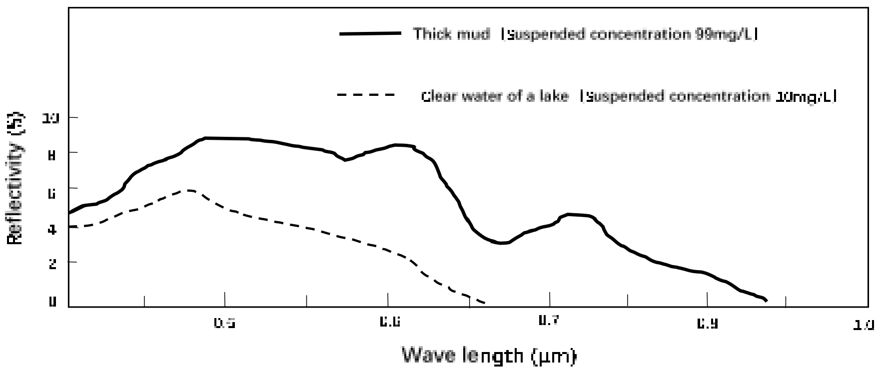


2.2 Ideas to solve problems

Measure sediment by remote-sensing technology

The incident light (including direct light of the sun and sky light) reaches the water surface, except the light directly reflected by the water, the remaining light enter into the water by refraction and transmission, most of them will be absorbed and scattered by water molecules, and will form the reflected light in water by such as scattering and reflection by the suspended material, the intensity is associated with the turbidity of the water.





Other physical or chemical methods

Part 03

On-line monitoring experiment at Zhicheng Gauging Station

3.1 Brief introduction of Zhicheng Gauging Station

Basic information of the station

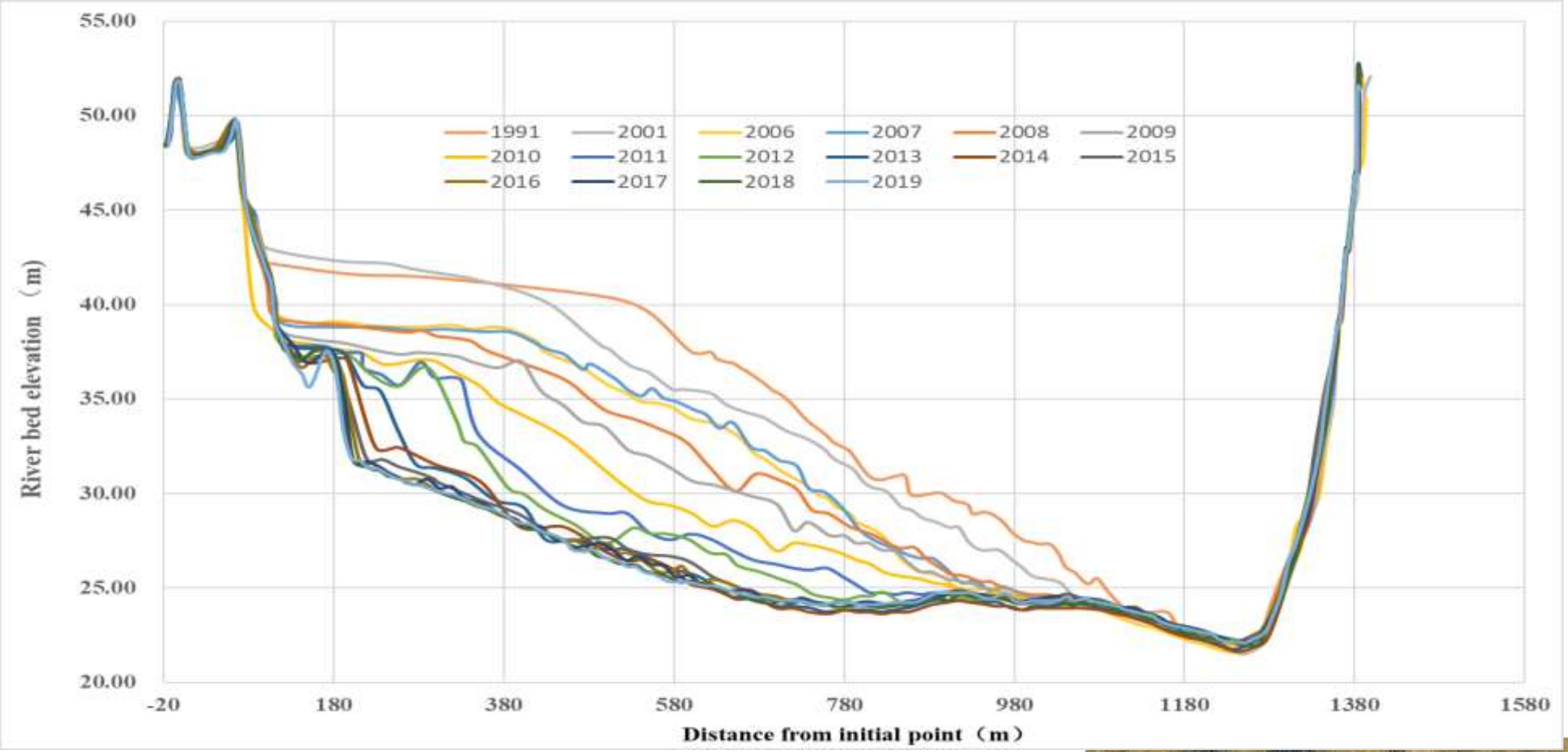
3.1 Brief introduction of Zhicheng Gauging Station

Background

- Basic production task is too heavy.
- Should report sediment information for the Three Gorges operation once a day in flood season.
- The bottleneck of automatic sediment monitoring needs to be broken through.

3.1 Brief introduction of Zhicheng Gauging Station

The characteristics of river reach and hydrometric cross-section



3.1 Brief introduction of Zhicheng Gauging Station

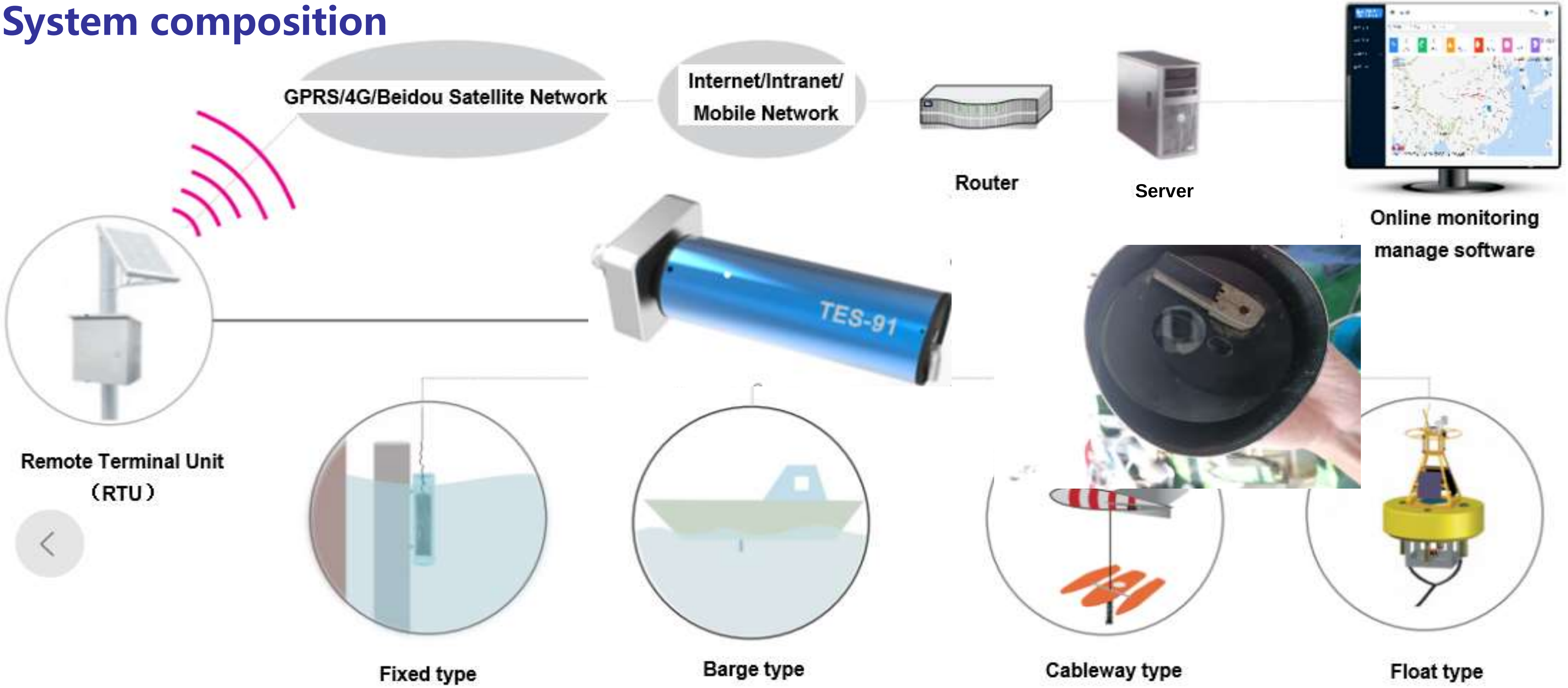
Sediment properties

0.002-1.16 kg/m^3

< 0.300 kg/m^3

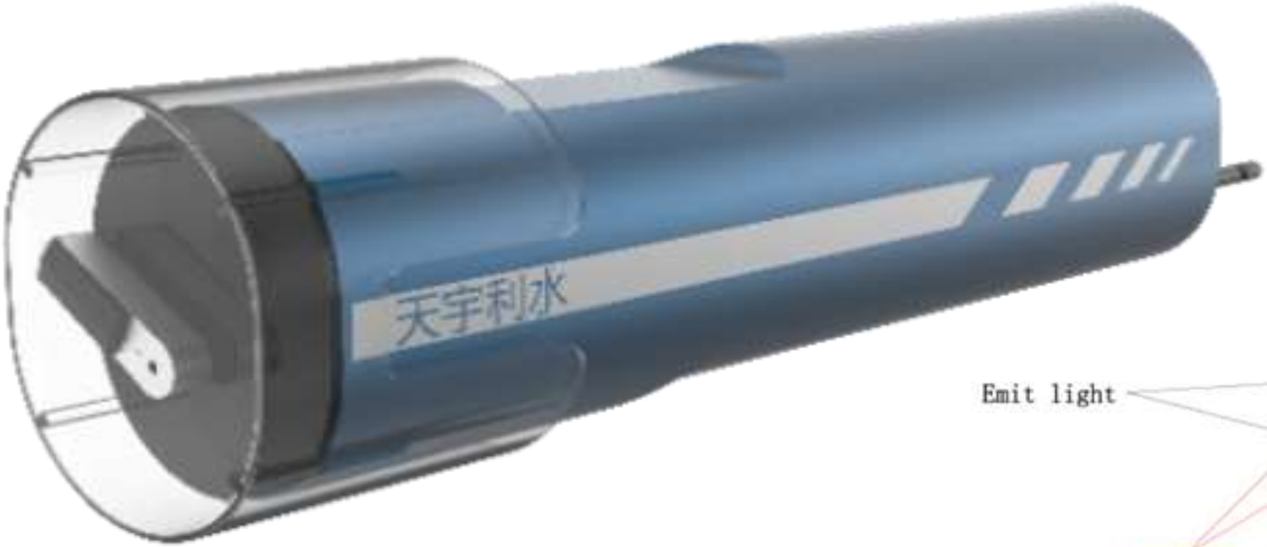
3.2 TES-91 online sediment concentration monitoring system

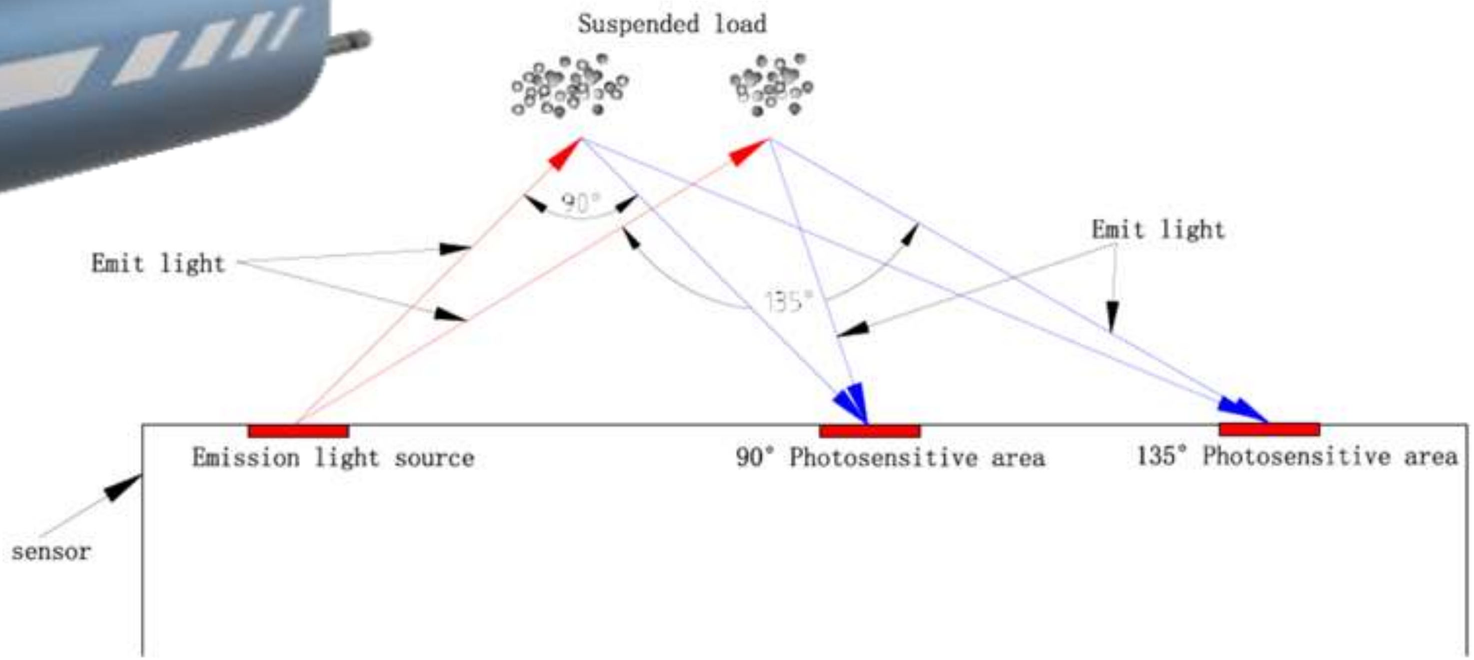
System composition



3.2 TES-91 online sediment concentration monitoring system

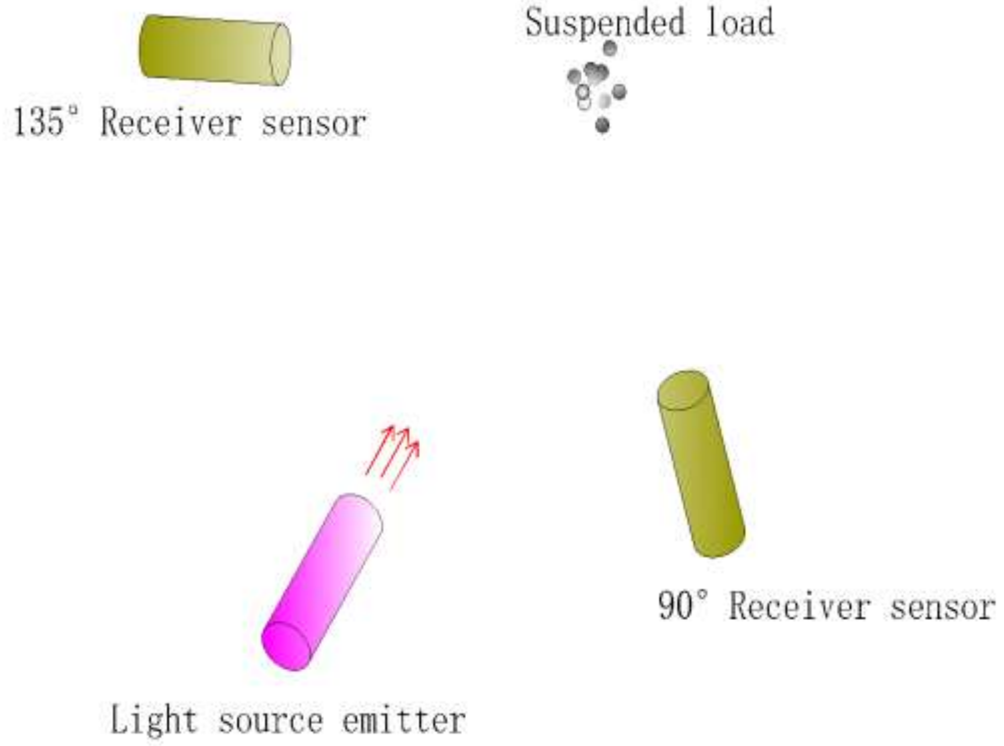
Operating principle of the system

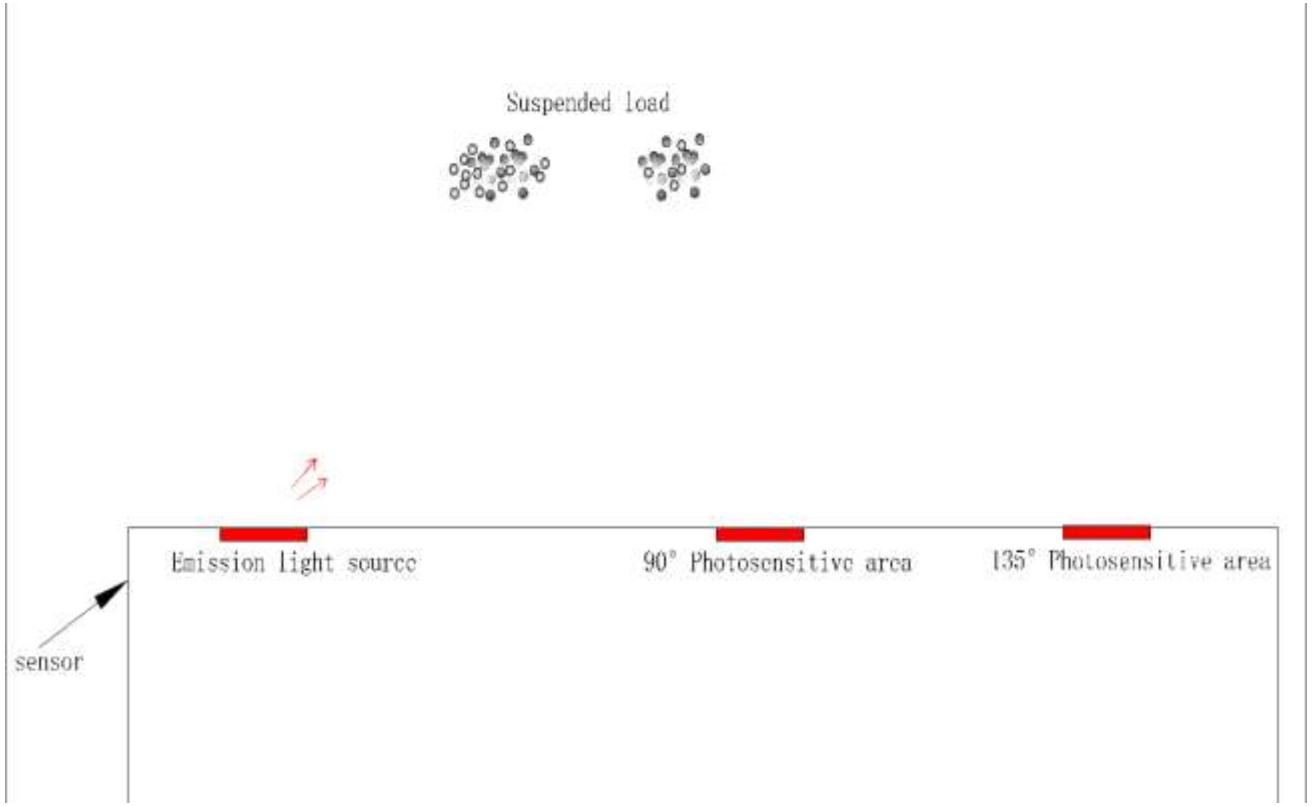




3.2 TES-91 online sediment concentration monitoring system

Operating principle of the system





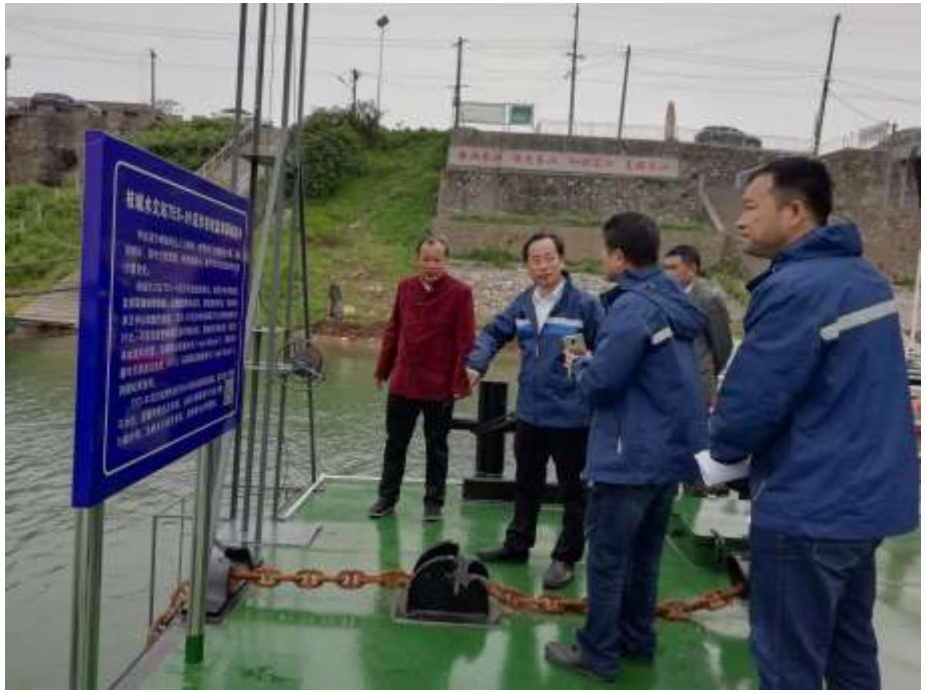
3.2 TES-91 online sediment concentration monitoring system

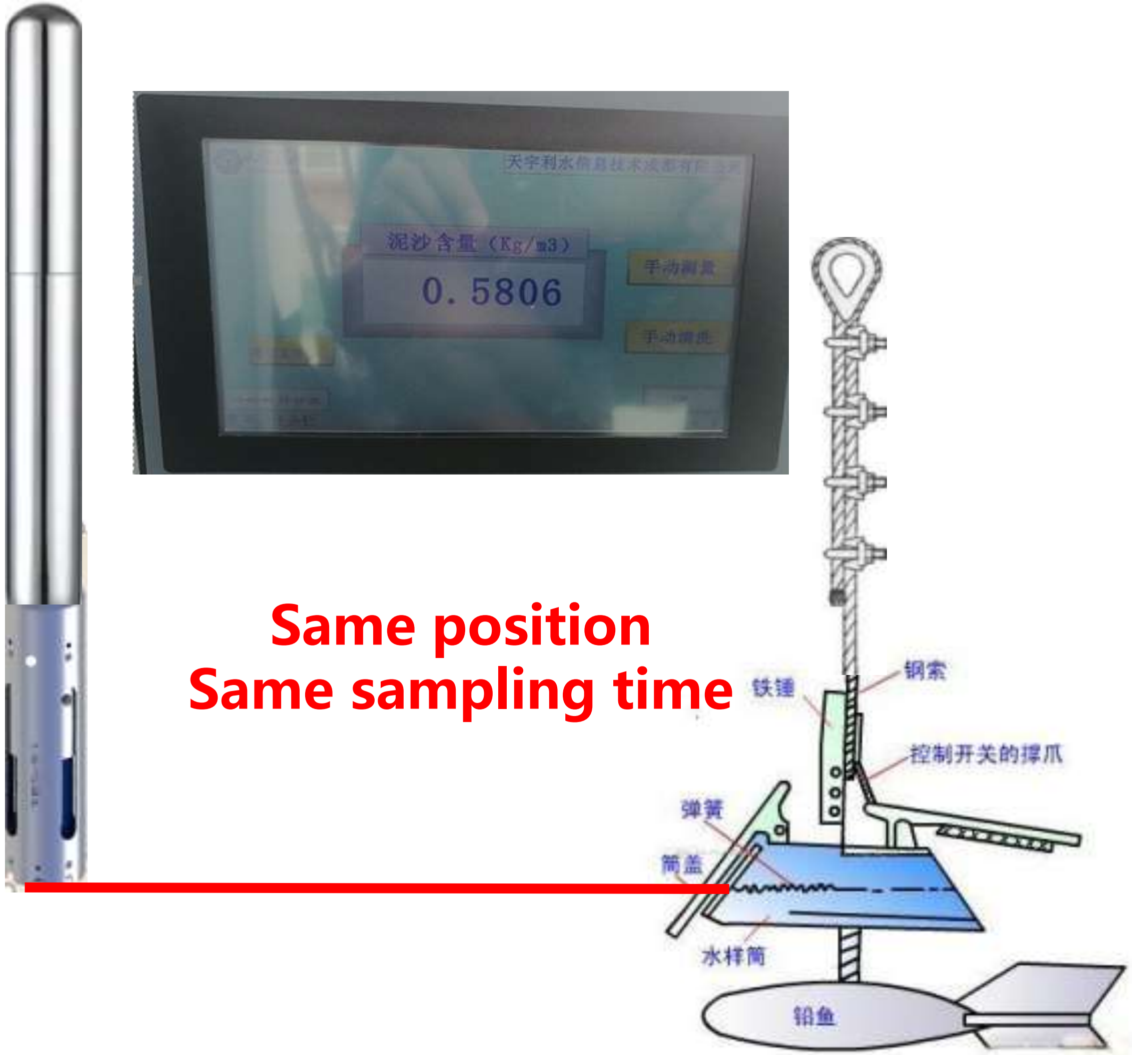
Operating principle of the system

Measuring range	0.001-120 kg/m^3
Accuracy of measurement	5% of the reading
The flow velocity	Less than 6.0 m/s or 19.8 ft/s
Measure ambient temperature	0 to 55 ℃
Main materials of sensor	Titanium alloy, sapphire, PVC, fluorine rubber and so on
Calibrate	Multi-point calibration is performed according to sediment homogeneity
Protection grade	IP68/NEMA6P

3.3 Adaptability test

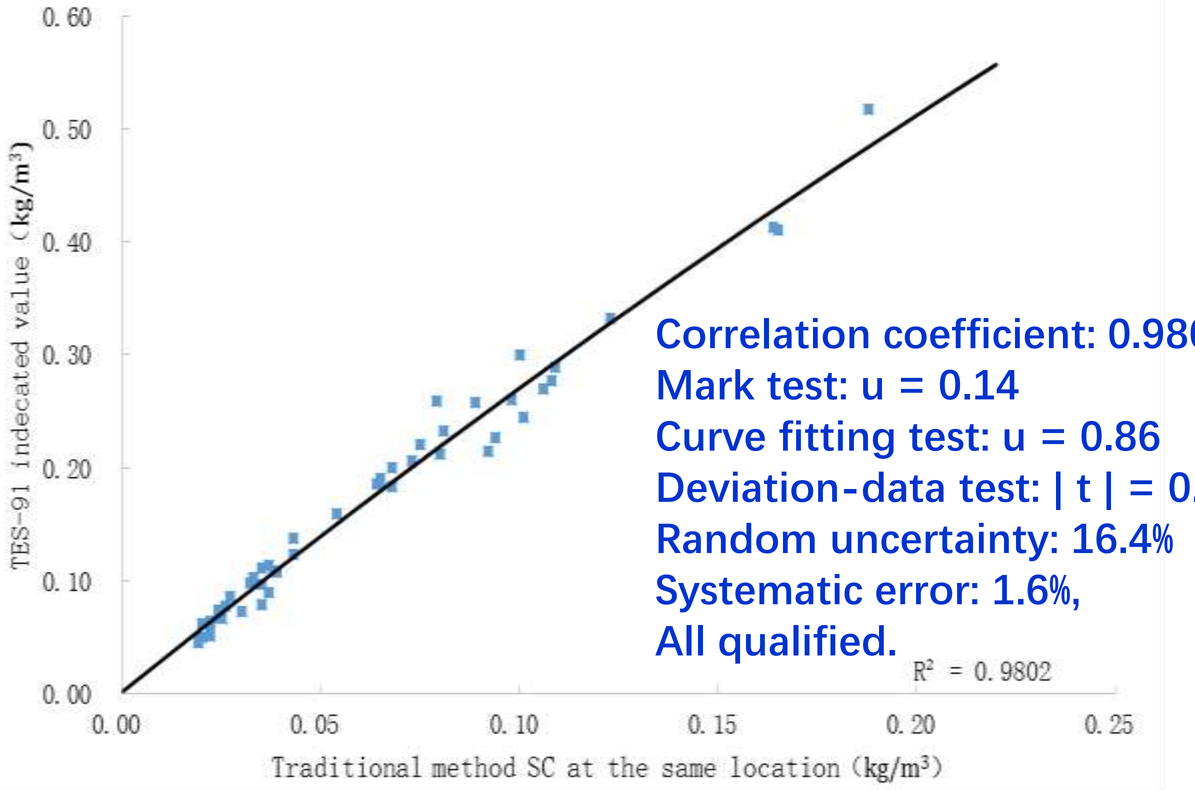
Test method





3.3 Adaptability test

Test results



Correlation coefficient: 0.9802
Mark test: u = 0.14
Curve fitting test: u = 0.86
Deviation-data test: | t | = 0.97
Random uncertainty: 16.4%
Systematic error: 1.6%,
All qualified.

$$u = \frac{|k-np|-0.5*}{\sqrt{npq}} = \frac{|k-0.5n|-0.5}{0.5\sqrt{n}}$$

$$u = \frac{(n-1)p-k-0.5}{\sqrt{(n-1)pq}} = \frac{0.5(n-1)-k-0.5}{0.5\sqrt{n-1}}$$

$$t = \frac{\bar{p}}{s_{\bar{p}}} \qquad s_{\bar{p}} = \frac{s}{\sqrt{n}} = \sqrt{\sum\left(p_i-\bar{p}\right)^2/\left(n(n-1)\right)}$$

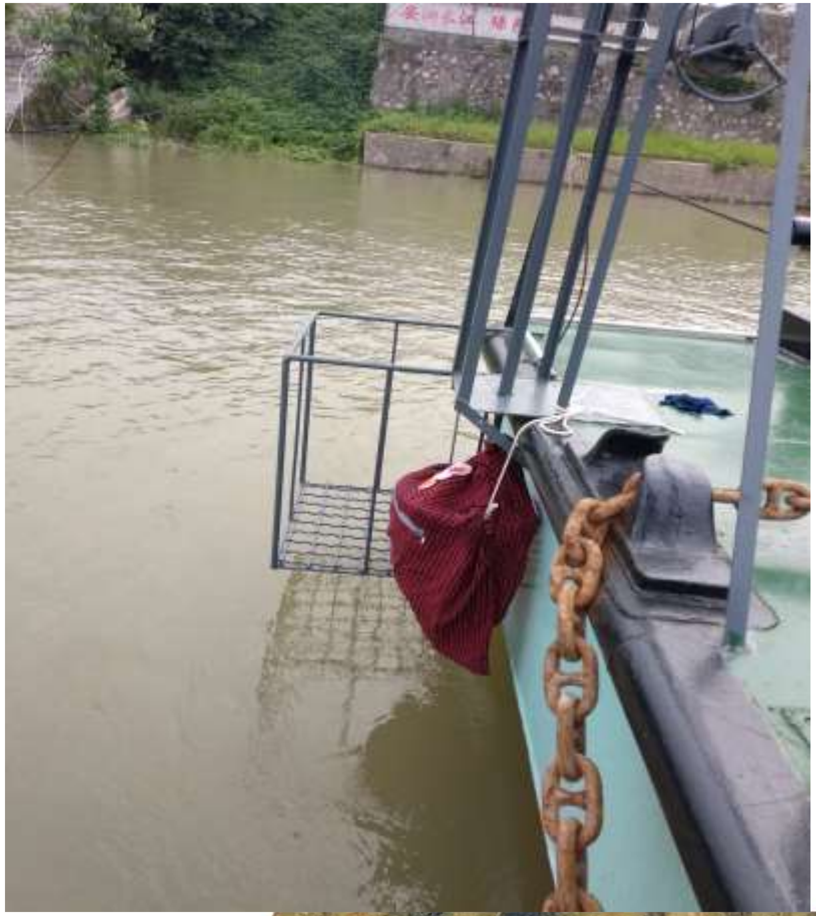
$$S_e = \left[\frac{1}{n-2}\sum\left(lnC_{s_i} - lnC_{s_{ci}}\right)^2\right]^{\frac{1}{2}} \times 100\%$$

$$S_e = \left[\frac{1}{n-2}\sum\left(\frac{C_{s_i} - C_{s_{ci}}}{C_{s_{ci}}}\right)^2\right]^{\frac{1}{2}} \times 100\% \qquad X'_{C_s} = 2S_e$$

$$\delta_{C_{s_i}} = \frac{C_{s_i} - C_{s_{ci}}}{C_{s_{ci}}} \times 100\% \qquad \overline{\delta}_{C_s} = \frac{1}{n}\sum \delta_{C_{s_i}}$$

3.3 Adaptability test

Some situation



3.3 Adaptability test

Some situation

Using lens brush to clean automatically before each measurement can effectively improve the measurement quality.

3.3 Adaptability test

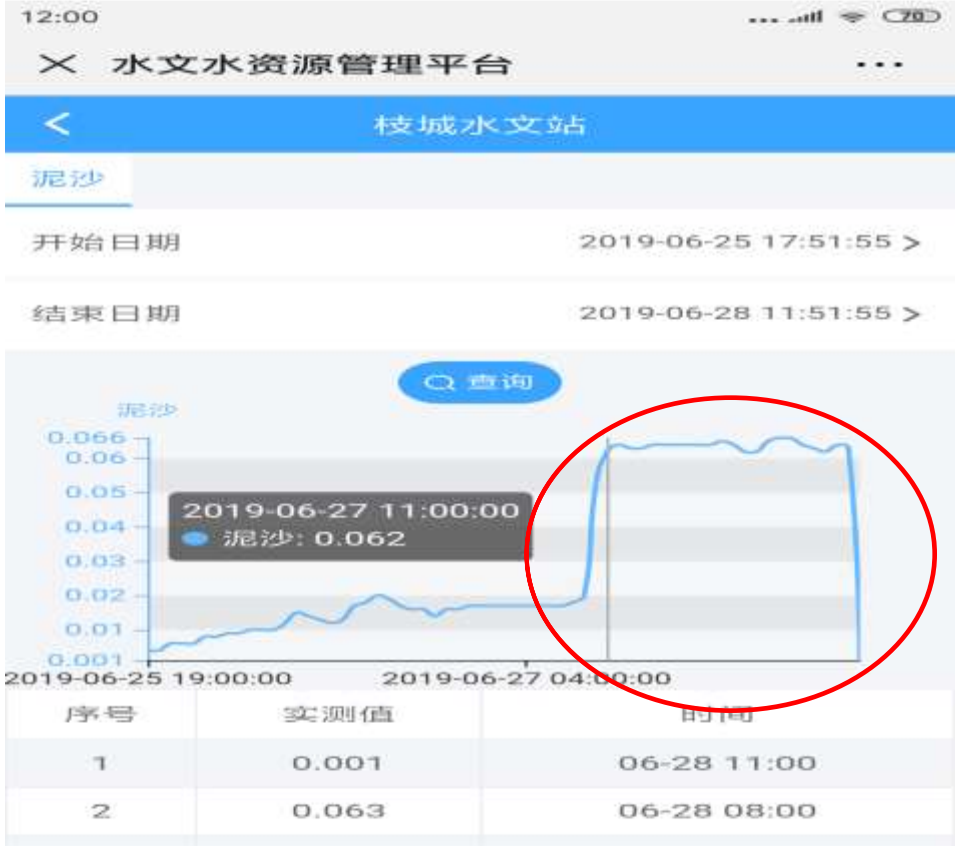
Some situation

Floating matter affects measurement results.

Increasing the depth of the sensor can reduce the influence of floating objects.

3.3 Adaptability test

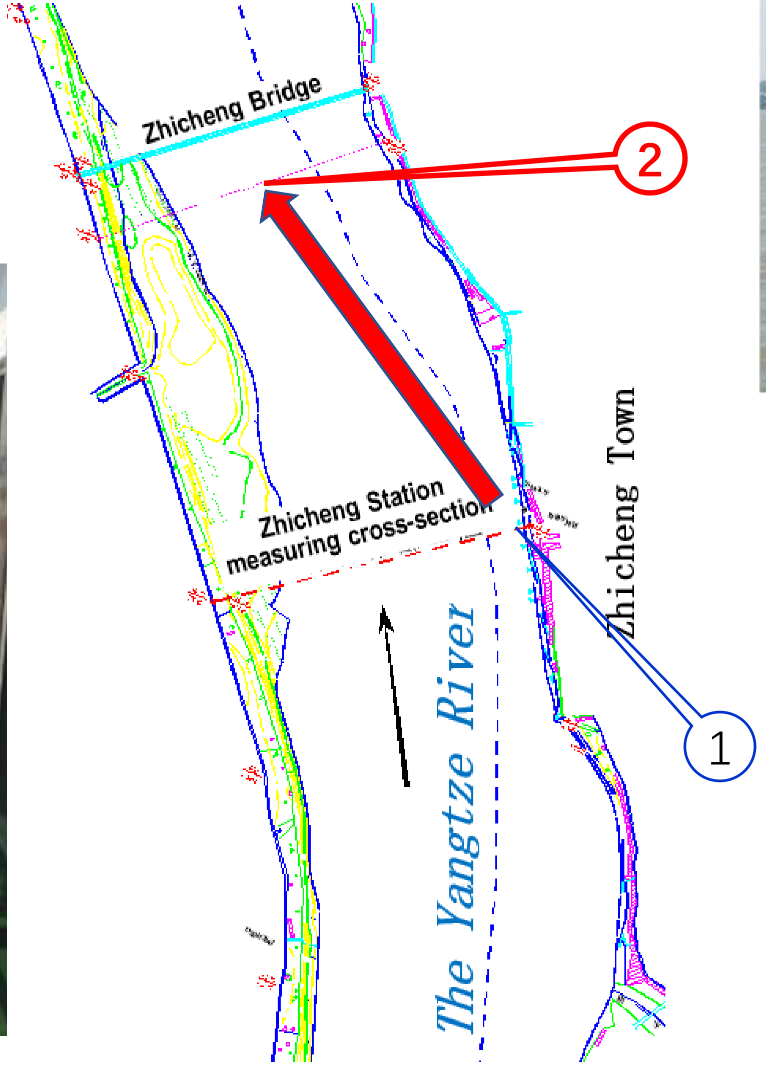
Some situation



Heavy rainfall affects the sediment concentration in coastal waters, and instrument measurement results lose representativeness. The solution is to install the instrument in the mainstream away from the shore.

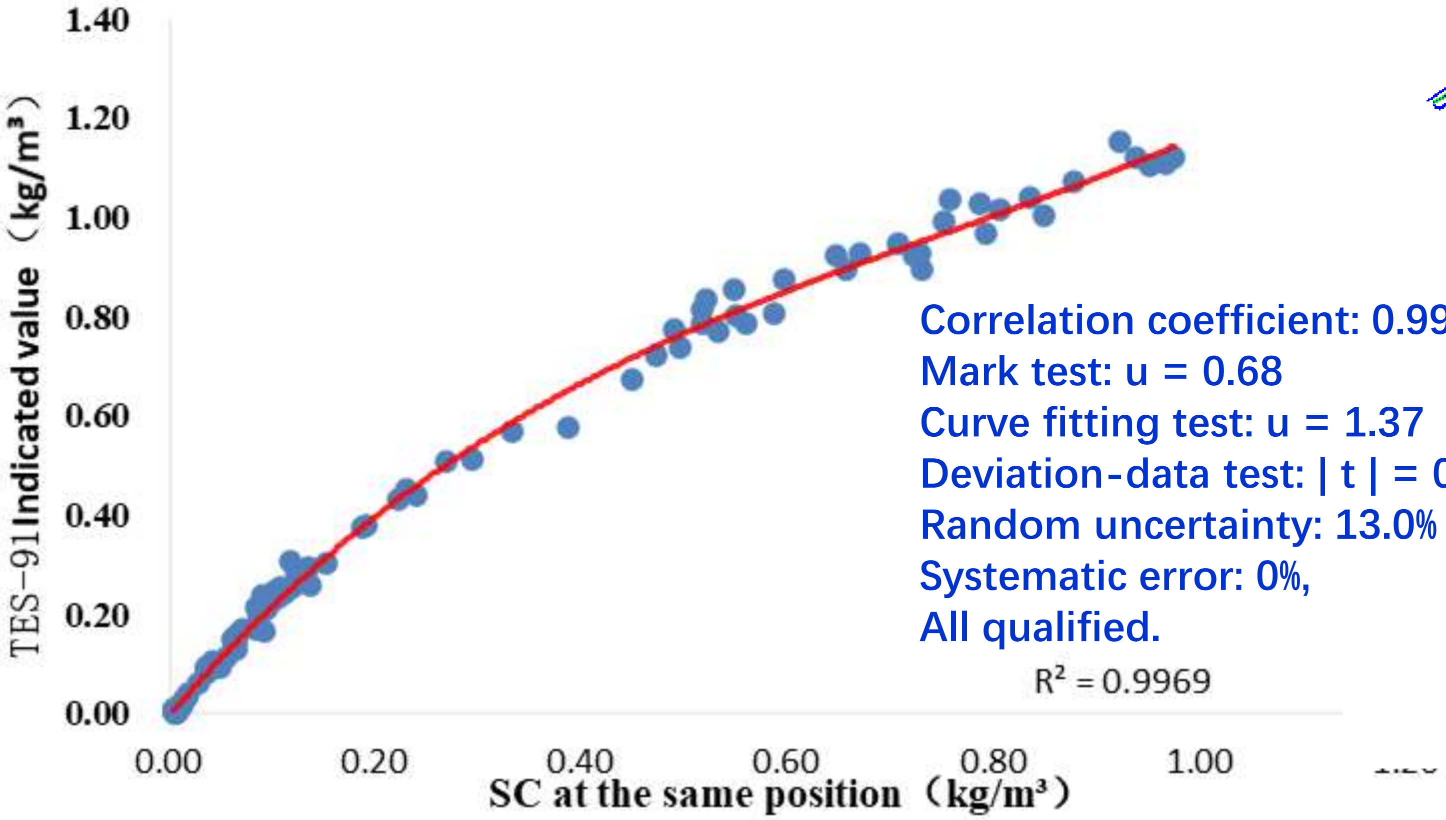
3.4 Formal experiment

Instrument installation

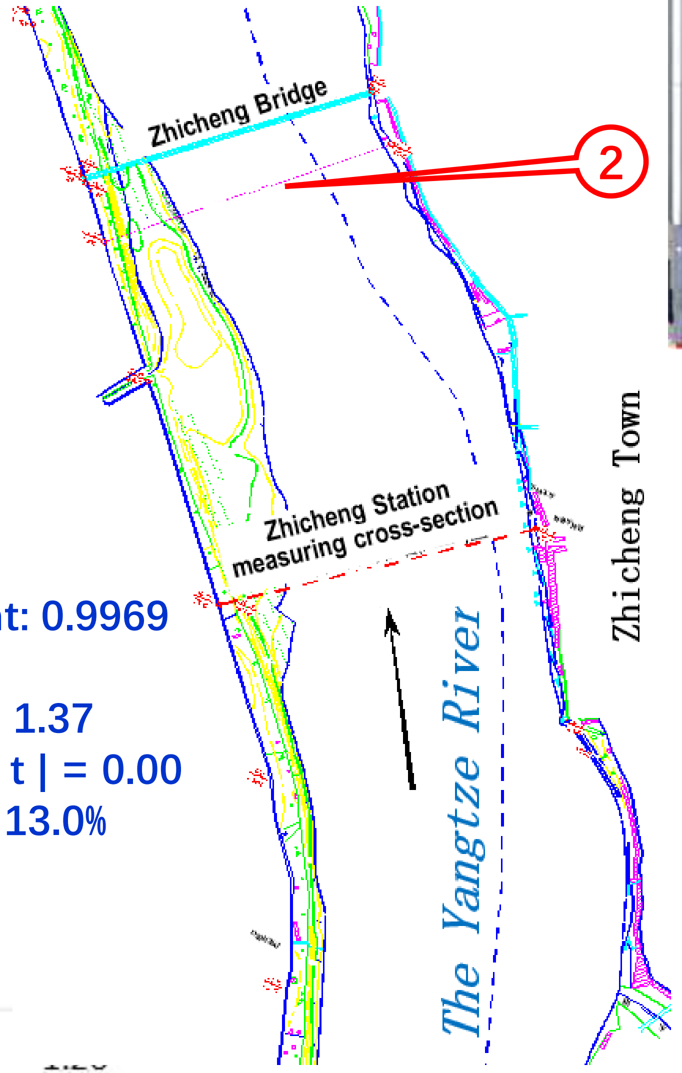


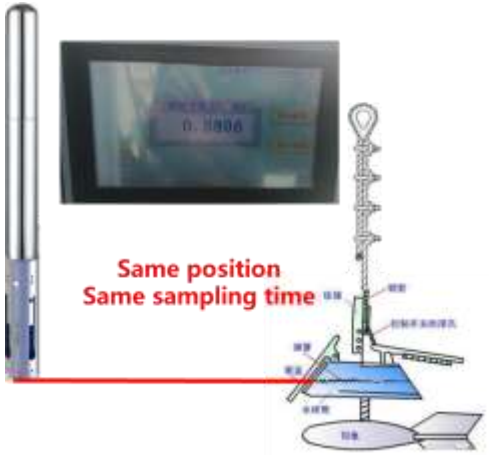
3.4 Formal experiment

Test methods and results



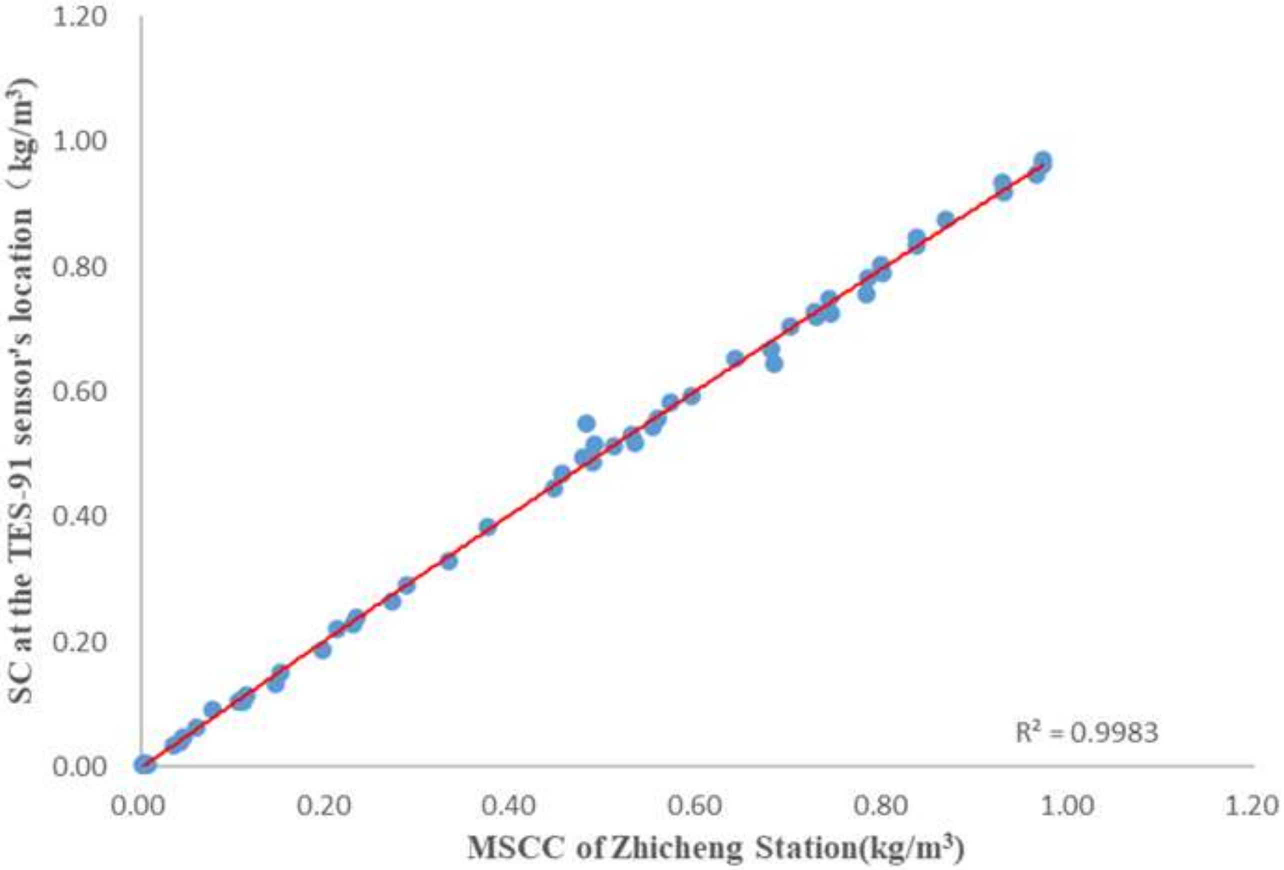
Correlation coefficient: 0.9969
Mark test: u = 0.68
Curve fitting test: u = 1.37
Deviation-data test: | t | = 0.00
Random uncertainty: 13.0%
Systematic error: 0%,
All qualified.

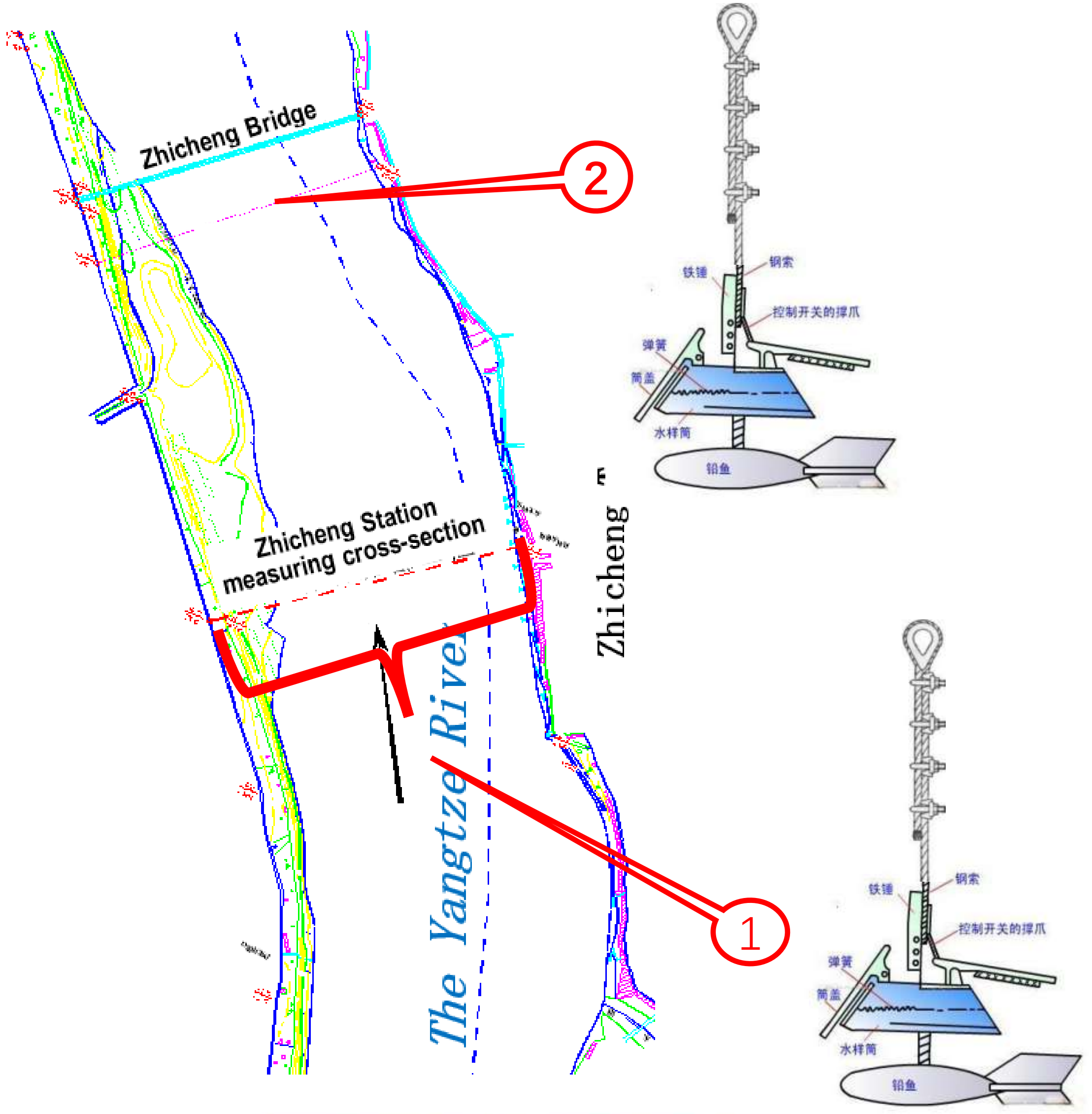




3.4 Formal experiment

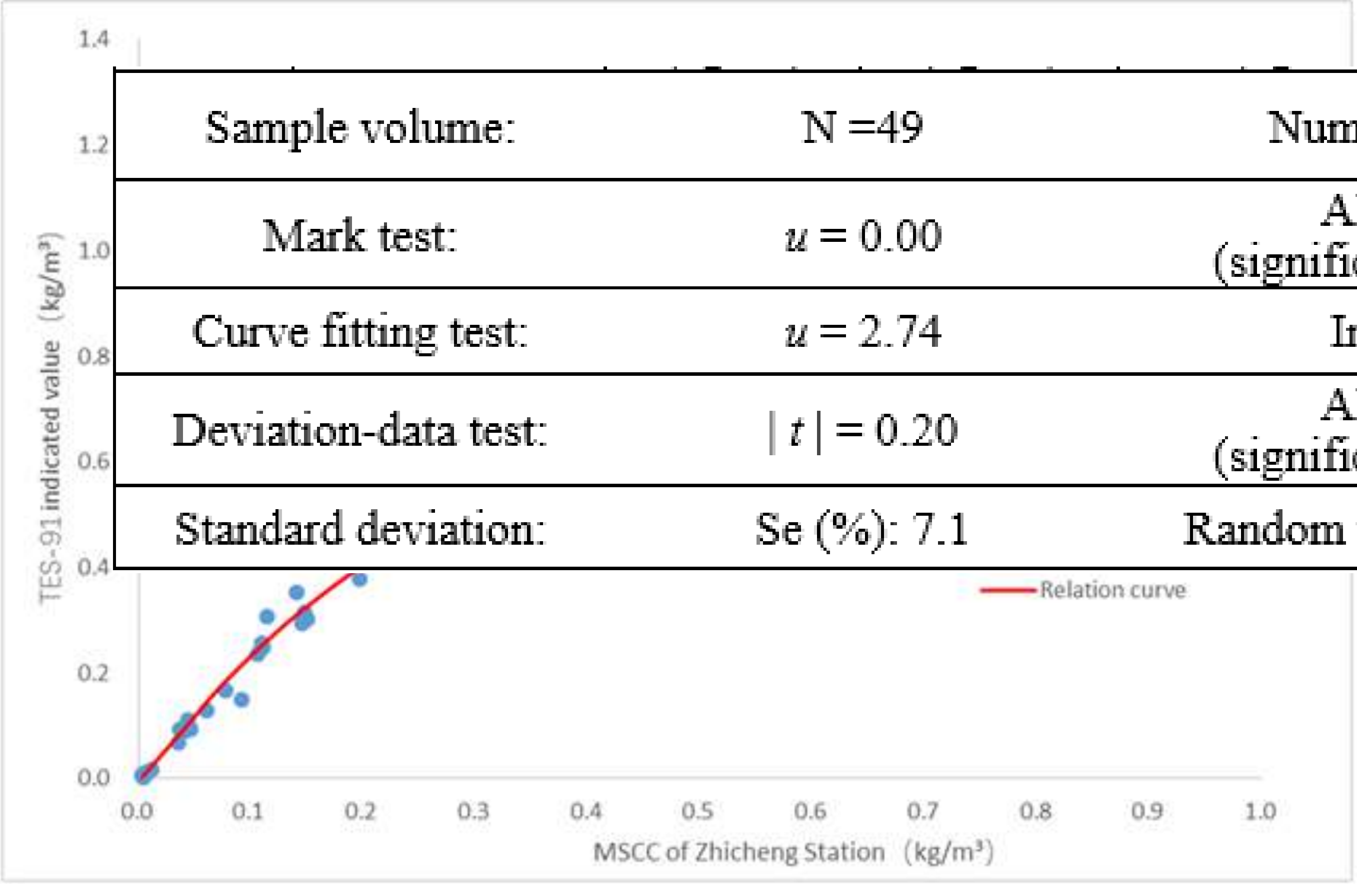
Test methods and results

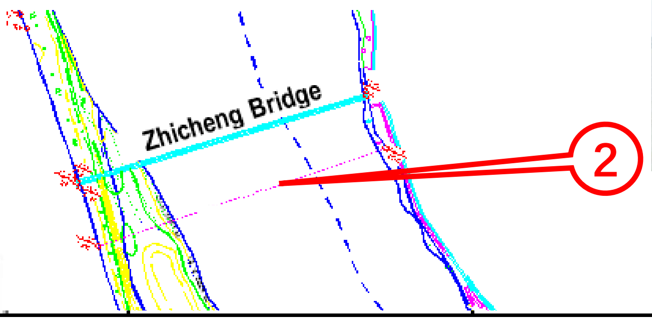




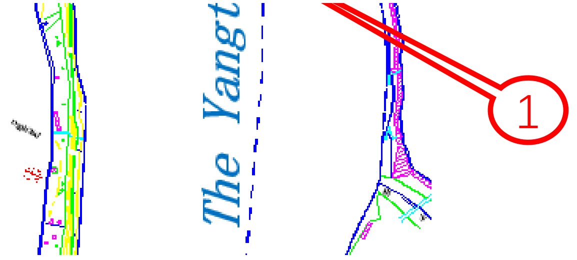
3.4 Formal experiment

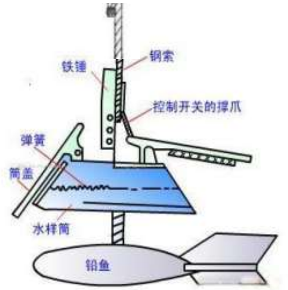
Test methods and results





Sample volume:	N =49	Number of pluses: 24	Number of symbol exchanges: 33
Mark test:	u = 0.00	Allowable: 1.15 (significance level a =0.25)	qualified
Curve fitting test:	u = 2.74	Inspection-free	
Deviation-data test:	$\vert t \vert$ = 0.20	Allowable: 1.05 (significance level a =0.10)	qualified
Standard deviation:	Se (%): 7.1	Random uncertainty (%): 14.2	Systematic error (%): 0.2





3.5 Effect of online monitoring solution

Technical effect

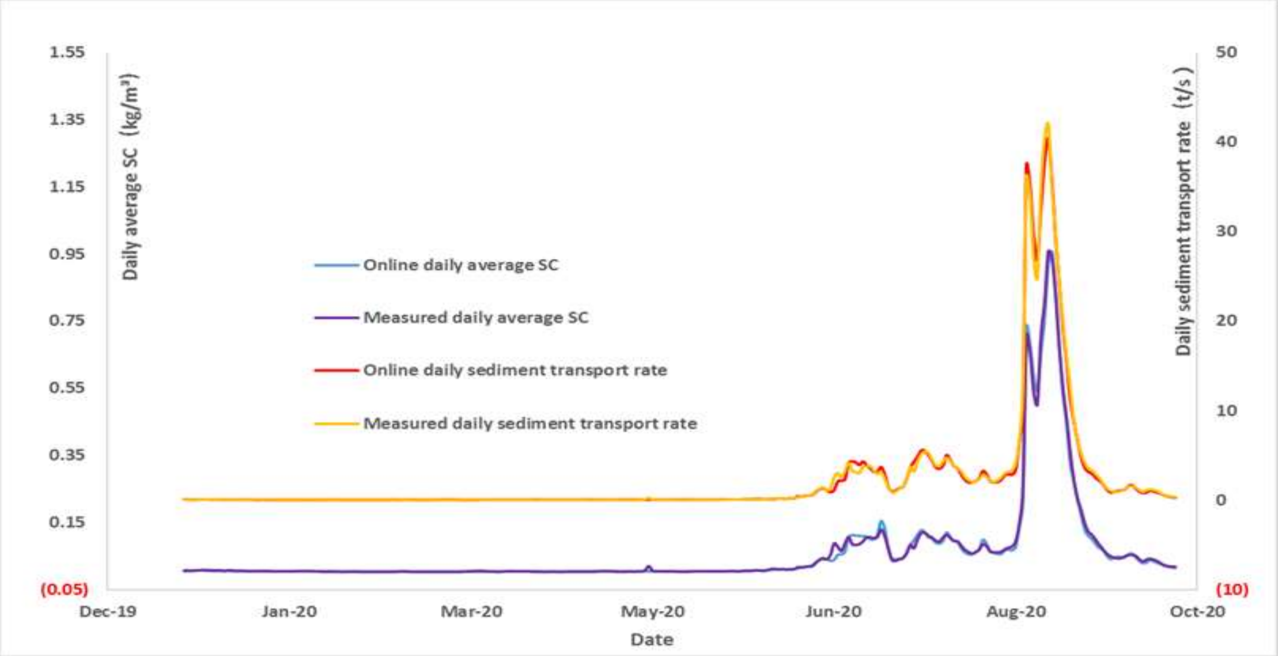
Better stability and timeliness

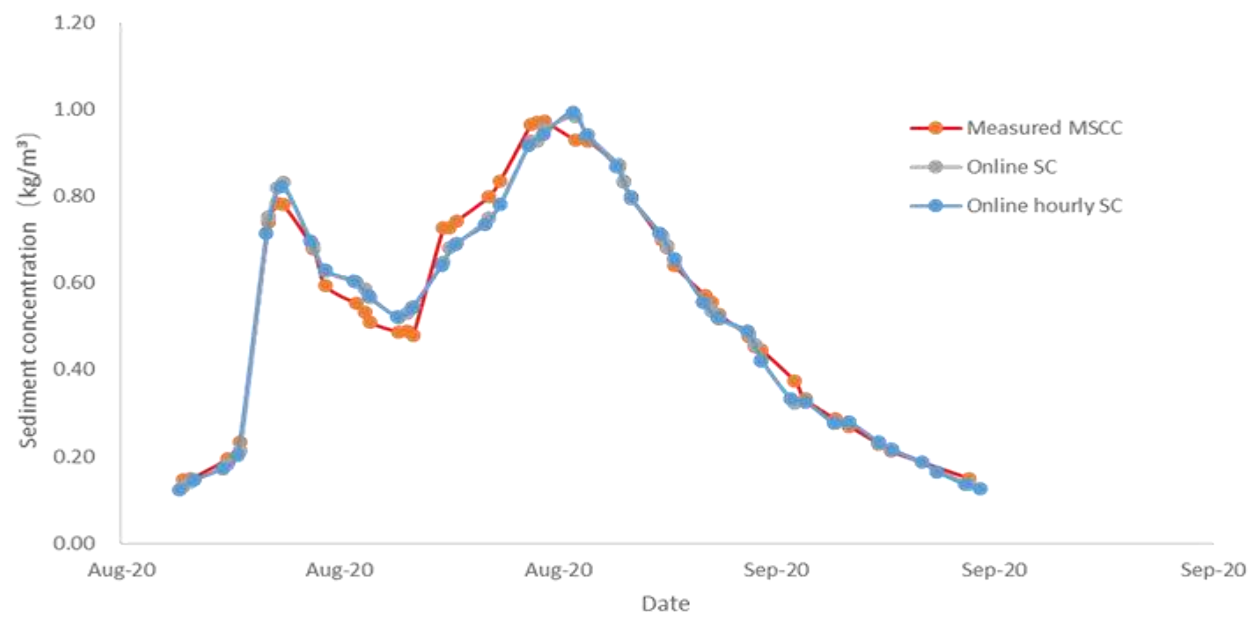
Higher quality of measuring frequency control

More convenient on data processing

Station classification	The random uncertainty of middle and high sediment concentration	The random uncertainty of low sediment concentration
1 class station	**20.0**	**24.0**
2 class station	**22.0**	**27.0**
3 class station	**30.0**	**32.0**
The allowable error can be increased by 2% if the data are compiled by other methods other than the relationship of discharge and sediment transport rate or the relationship of index SC and MSCC.		

E_{online}= *f* (*Instrument perception error*, *model representativeness error*, *process control error*, *data processing error*)

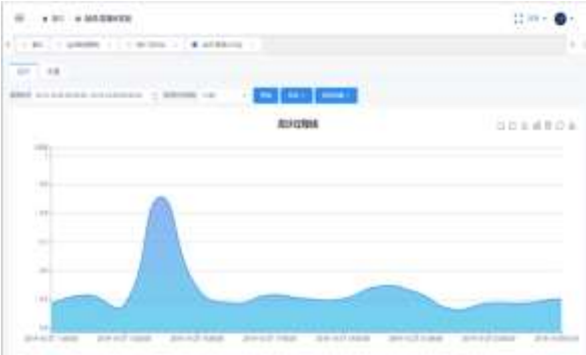




The processing method	Subject	Jan to May	June to September	Annual (January - September) sediment load
Measured sediment concentration	Sediment load ($\times 10^4$t)	51.54	5383	5440×10^4t
	Proportion %	0.9%	99.0%	
Online sediment concentration	Sediment load ($\times 10^4$t)	50.86	5327	5380×10^4t
	Proportion %	0.9%	99.0%	
Relative error of sediment load %		- 1.3%	- 1.0%	1.1%

3.5 Effect of online monitoring solution

Greatly emancipate manpower, improve efficiency and save cost



Measurement times comparision between covention method and online system

Method	Year	2015	2016	2017	2018	2019	2020	Average
Covention	Index SC	220	229	244	297	255	258	250.5
	MSCC	40	39	45	72	45	79	50.3
Online	Parallel year							15-30
	Test gauging year							3-5

Can carrying out sediment forecasting

Part 04

Discussion on application problems

4.1 Applicability of Zhicheng Station

About the reliability of the scheme

- Inflow and sediment source conditions stabilization
- Small sediment concentration
- Fine sediment particle
- Suspended sediment evenly distributed
- Parallel operation for 1 year
- Test gauging every year
- Extend the working curve or model in time
- Conventional measure when special occur

About environmental adaptability

- Sunshine intensity had no significant influence
- Storm and heavy rain may affect representativeness
- Sailing vessels affects the safety of the platform
- Floating objects and suspended plants will lead to data distortion, and affect the safety of the probe
- Microorganisms, algae, snail shells may reduce the data quality

4.2 Generalizability

Matching of sediment characteristics

Nominal diameter

$$d = \left(\frac{6V}{\pi}\right)^{\frac{1}{3}}$$

Triaxial mean particle diameter

$$d = \frac{1}{3}(a + b + c)$$

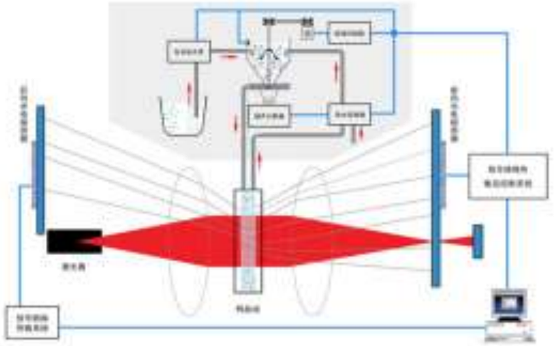
Geometric mean particle diameter

$$d = \sqrt[3]{abc}$$

Sieve diameter

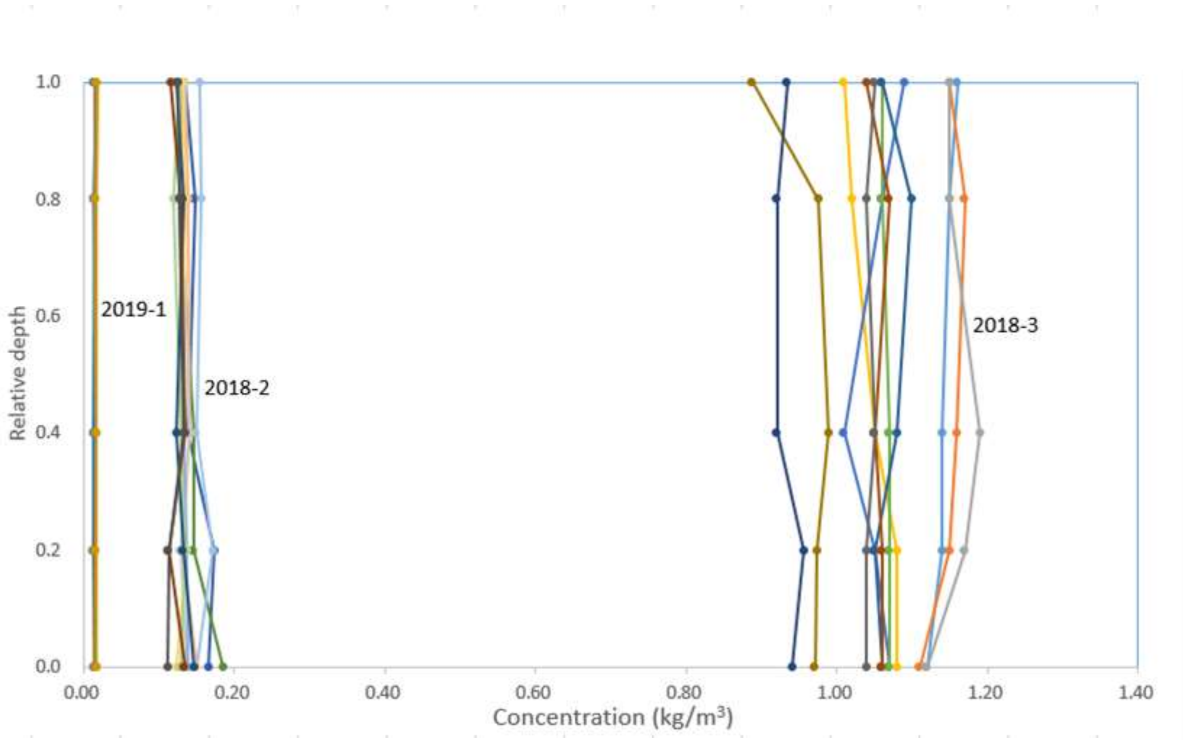
Settling diameter

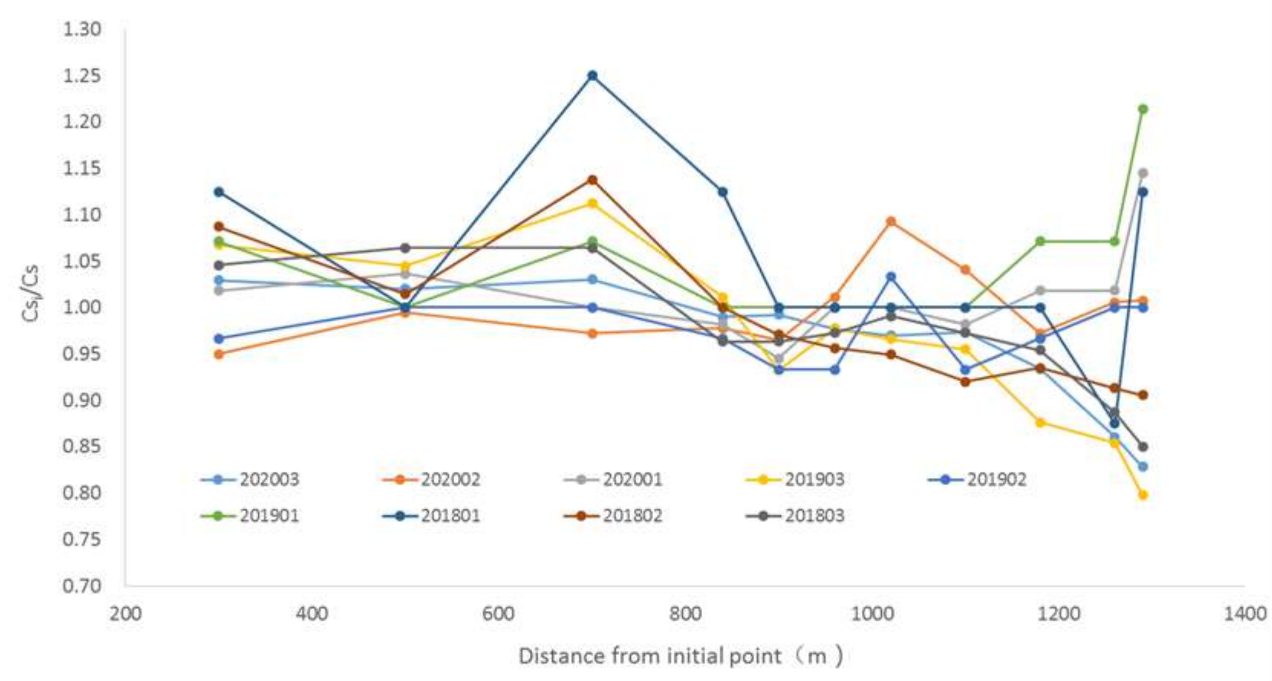
Projected diameter



4.2 Generalizability

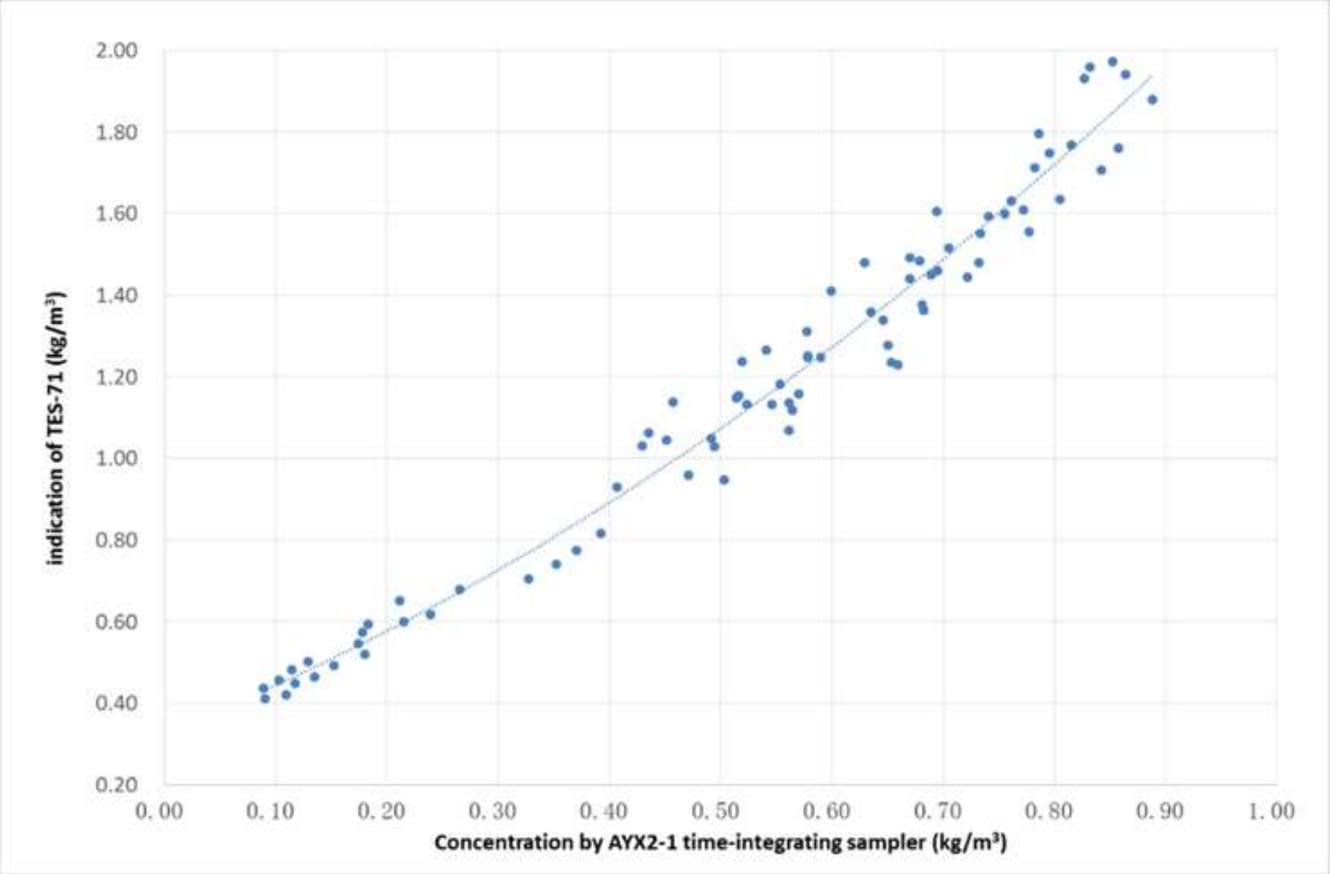
The uneven distribution of sediment





4.2 Generalizability

Circumstances of no monitoring platform building



4.2 Generalizability

One station, one strategy!

Other circumstances

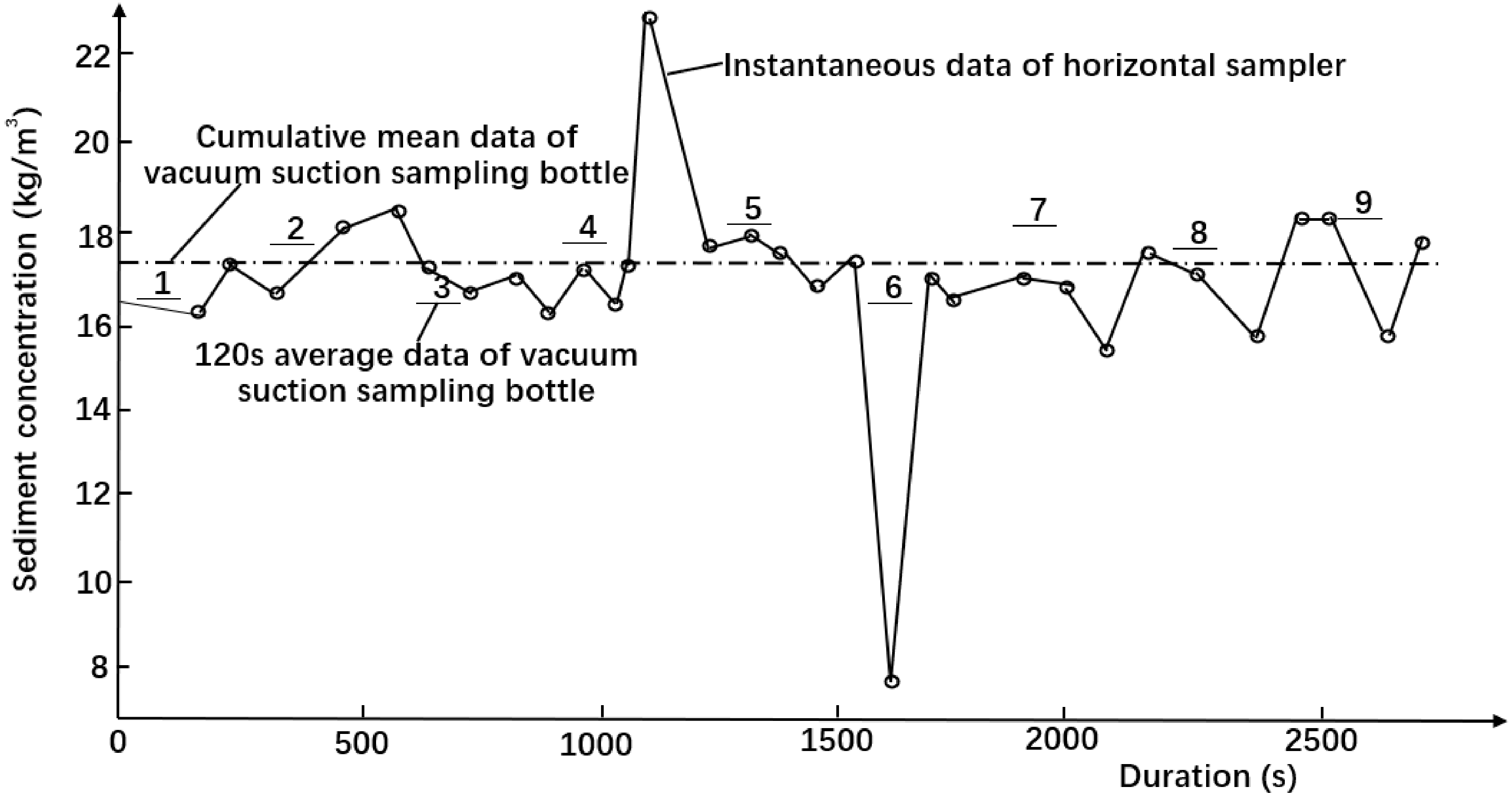
If needs the sediment concentration distributed data along the cross-section or along the vertical line, may adopt the rapid or online monitoring mode according to the river conditions and data using requirements. The rapid monitoring method is also suitable for tour gauging or mobile non-station work, which can reduce sampling, handling, water sample treatment, sediment concentration calculation and other parts. For new hydrometric stations, rapid monitoring tests can be used first, and then on-line monitoring can be decided according to the conditions.

Need further research and technical standards

Online monitoring is a new technology. Compared with traditional methods, changes have taken place in the aspects of information perception, single sediment concentration calculation, measurement frequency control, data processing, etc. Online monitoring has tended to be integrated in the workflow, so it is necessary to summarize technical guidelines and formulate technical standards in time. Among them, when determining the allowable error index, factors such as the importance of data, the demand of data users, the possible accuracy level under realistic conditions, economy and so on should be comprehensively considered.

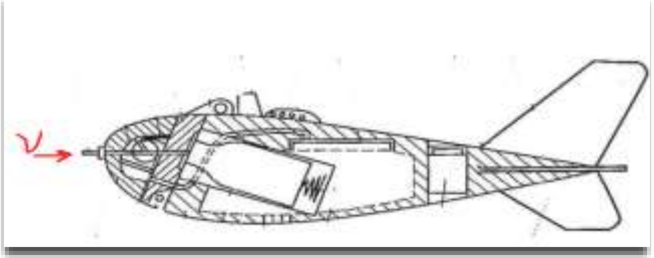
4.2 Generalizability

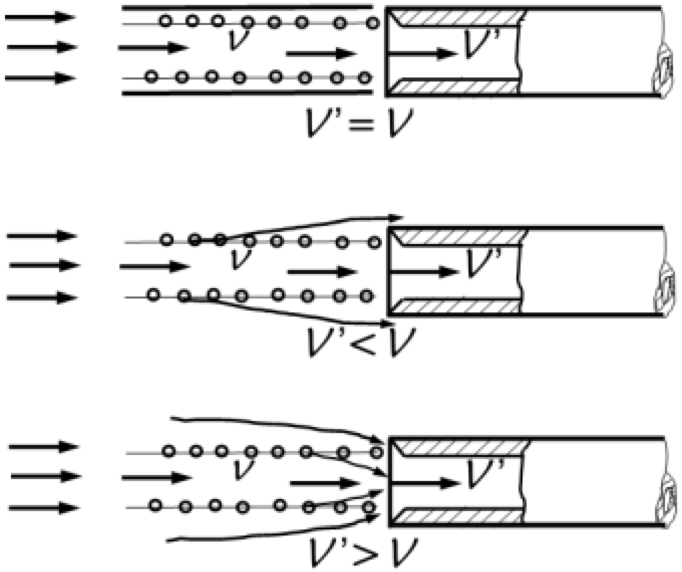
About sediment pulsation

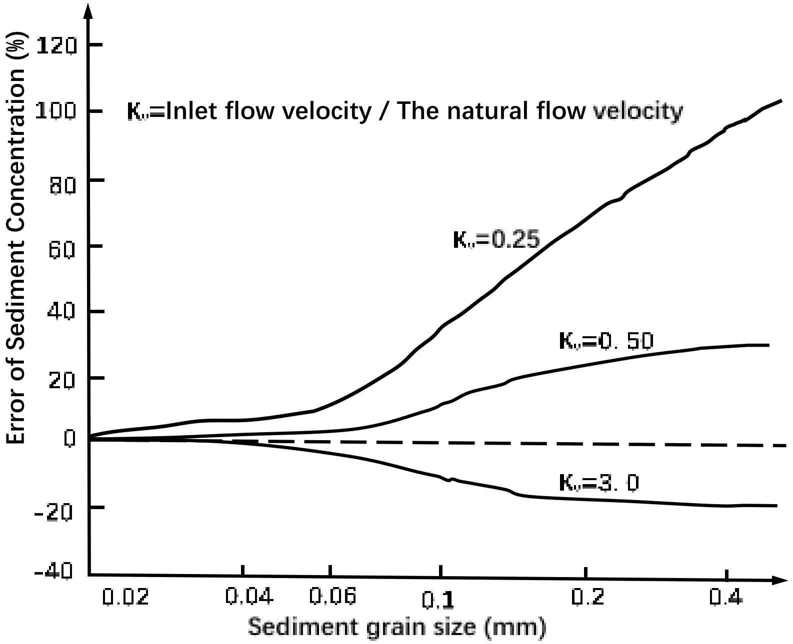


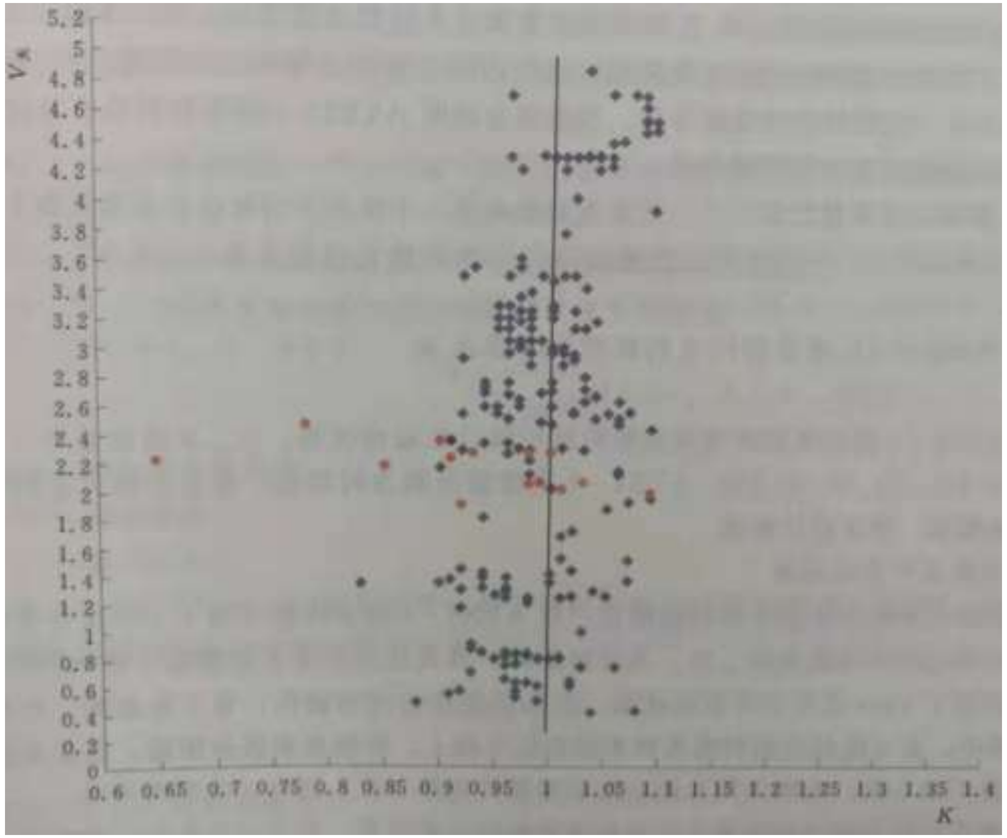
4.2 Generalizability

About the influence of intake flow velocity



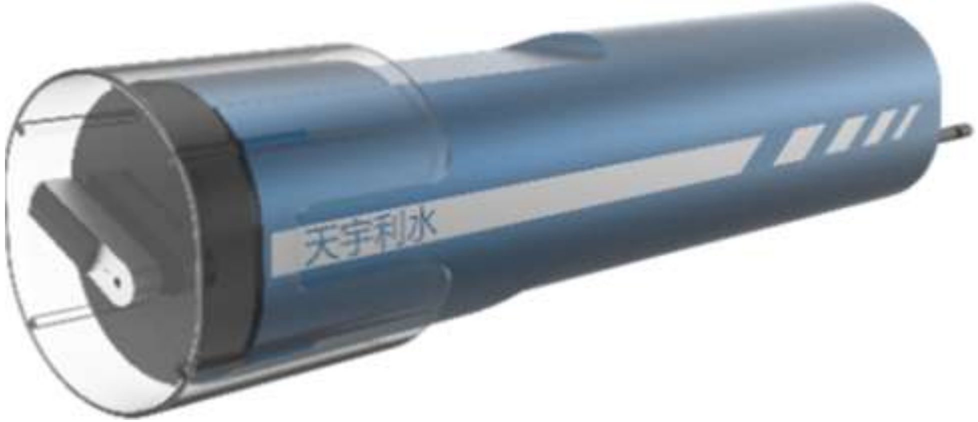






4.2 Generalizability

Other application cases of TES-91



Part 05

Summary and outlook

5.1 How to carry out an on-line monitoring experiment?

Select suitable instruments according to the sediment characteristics and monitoring setting of hydrometry of the river reach or cross-section, test to calibrate instrument working curve.

↓

Select representative points (lines or areas) according to the characteristics of sediment distribution, and follow the basic technical principles of hydrometry.

↓

Select monitoring platform scheme according to the flow conditions, comprehensive water environment, riverbed conditions and sailing conditions.

→

Select the communication scheme according to the data transmission requirements and communication conditions.

↑

Implement **comparative gauging** with the traditional method, develop online monitoring model and inspect the model through measurement.

↑

Preparation of **production** plan, and **optimize** and **expand** the model and plan during the operation.

↑

Develop technical standards

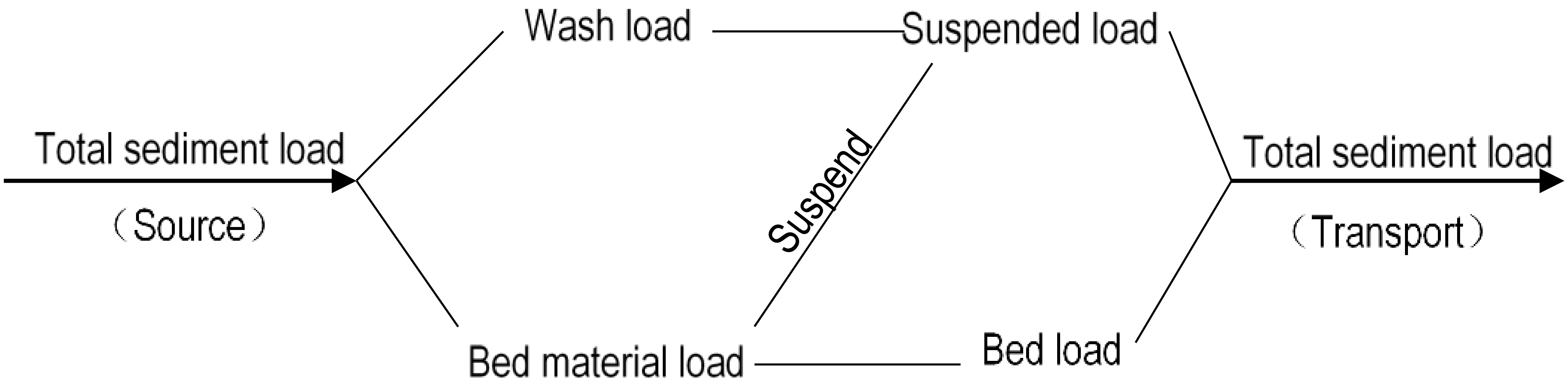
5.2 Discussions on the conditions of an on-line monitoring system

- The instrument can accurately perceive the sediment concentration and its changing process. Its stability, reliability and accuracy can meet the specification requirements and production needs, and its endurance capacity can meet the requirements of long-term online work.
- The system equipment can adapt to the work environment, effectively deal with the bad weather such as scorching sun, rainstorm, wind and waves, and can adapt to different sediment concentration, different water depth, flow velocity, water temperature, water quality and aquatic biological environment.
- The representative points (representative lines, representative areas) can be found in the measure river reach/cross-section. The measure parameters and measure frequency are controllable, and the representativeness, reliability and consistency of the data can meet the production needs.

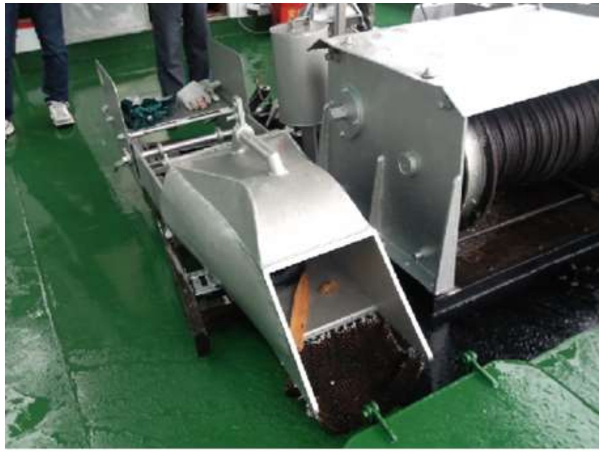
5.2 Discussions on the conditions of an on-line monitoring system

- The timeliness, reliability and security of information transmission can meet certain requirements, and the shoreline station can obtain the sediment concentration data information and equipment running status information in time.
- The precision of measuring and processing can meet the requirements of relevant specifications and data using needs.
- It is helpful to improve efficiency and improve the level of science and technology. It is simple to construct, convenient and easy to use, and the economic cost is acceptable.

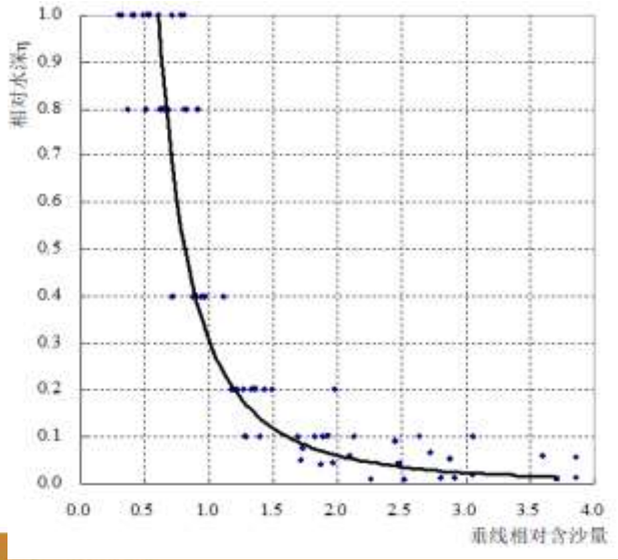
5.3 Looking forward

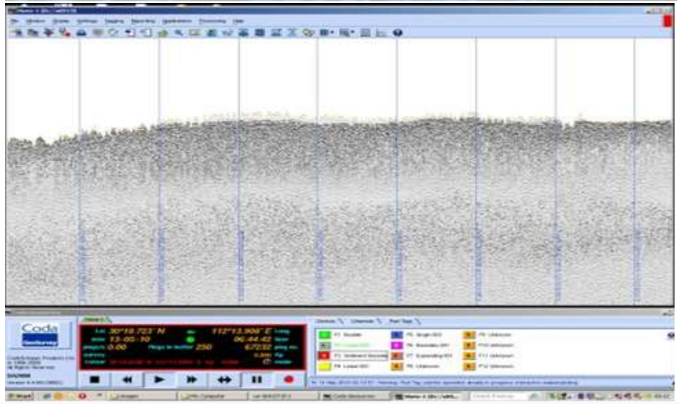


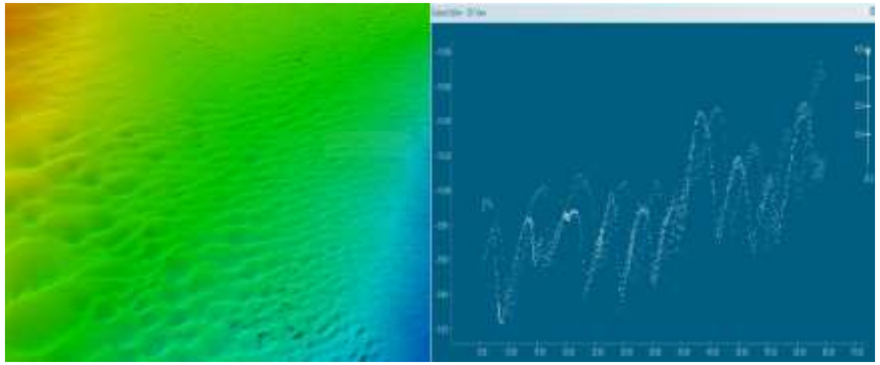
5.3 Looking forward



5.3 Looking forward







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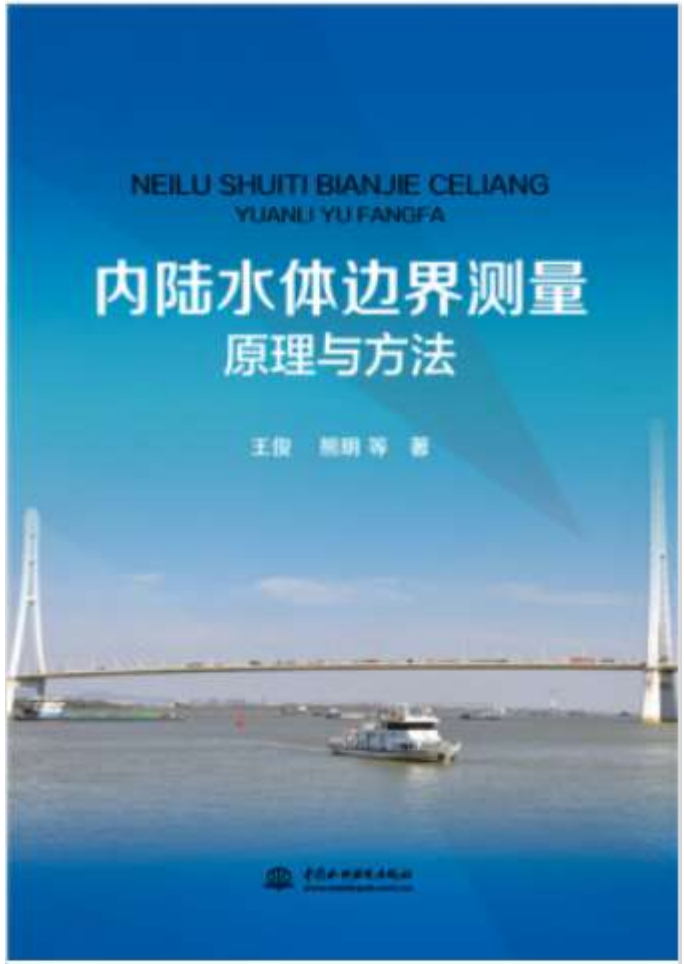

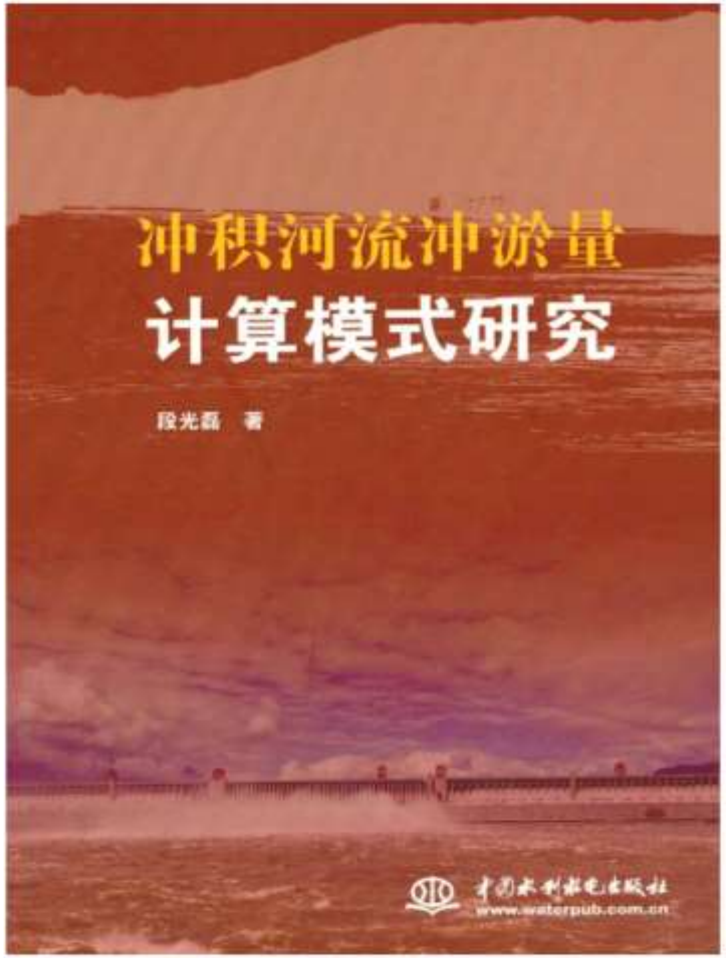

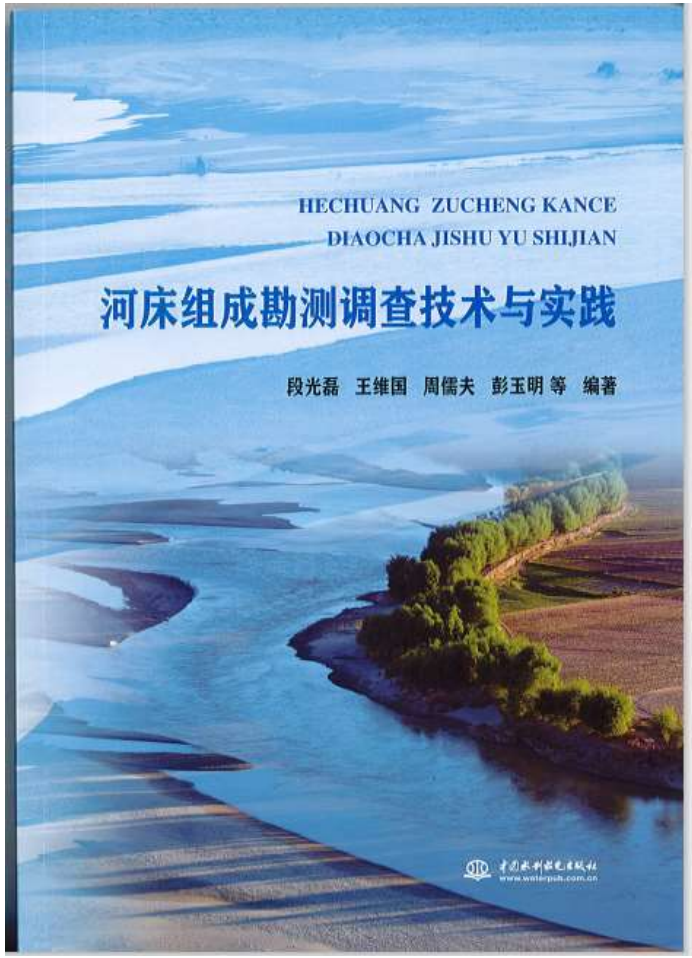

Thanks!

Dibing Xu, Email: jjxudb@cjh.com.cn