

Structural Safety Assessment with Multi-Criteria on Anqing Dikes

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- ⌘ 6 Some conclusions

Coming up next.....



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This is a Challenging Topic

- ⌘ According to the existing code of dike design, the designing method of dike is safety margin method based on limit equilibrium analysis, which can't offer reliability index/failure of probability for the practical engineering.
- ⌘ But for the probabilistic method, the stochastic character of the geometric and strength parameters can be taken into account, so various designing indexes are adopted according to the importance of different components of dike in order to decrease engineering cost.

Conventional → Rational Means

This is a Challenging Topic



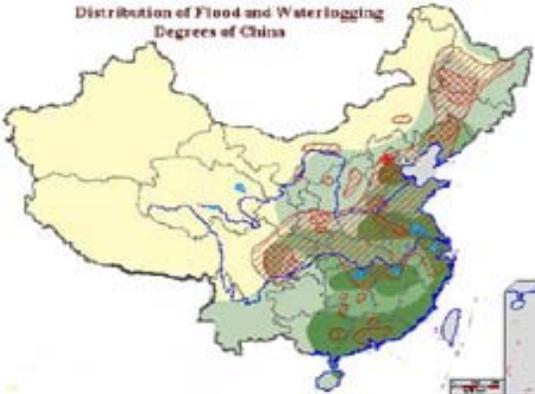
- ☒ Recent years, drastic floods have occurred in some large river basins. After flood, dikes must be heightened and widened. Therefore, it is important to study the influence of the variation of Geometry and Geotechnical parameters of flood defense on structural safety or reliability index for design, construction and safety management of dikes.
- ☒ In the Netherlands/Australia/USA/Canada, some methods of probabilistic design and safety assessment of embankment and revetment engineering have been discussed by some design guides and handbooks. But in China, further study should be carried out.

The conventional method is valid in China?/!

Position of This Case Study

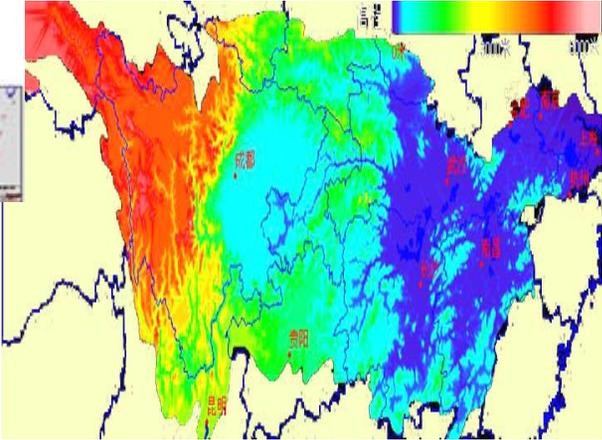


world



China

Yangtze River



Position of This Case Study



Yangtze River



Anqing Dike Ring

How To Combat Floods?



[1998BBC] The decisive battle to beat the flood has begun, and danger may appear at any time, especially around the inland lakes, above the warning level.

Some 3,500 local people are now defending the dikes while soldiers and armed police officers are on standby for rescue work.





Flood MovieA

Flood MovieB

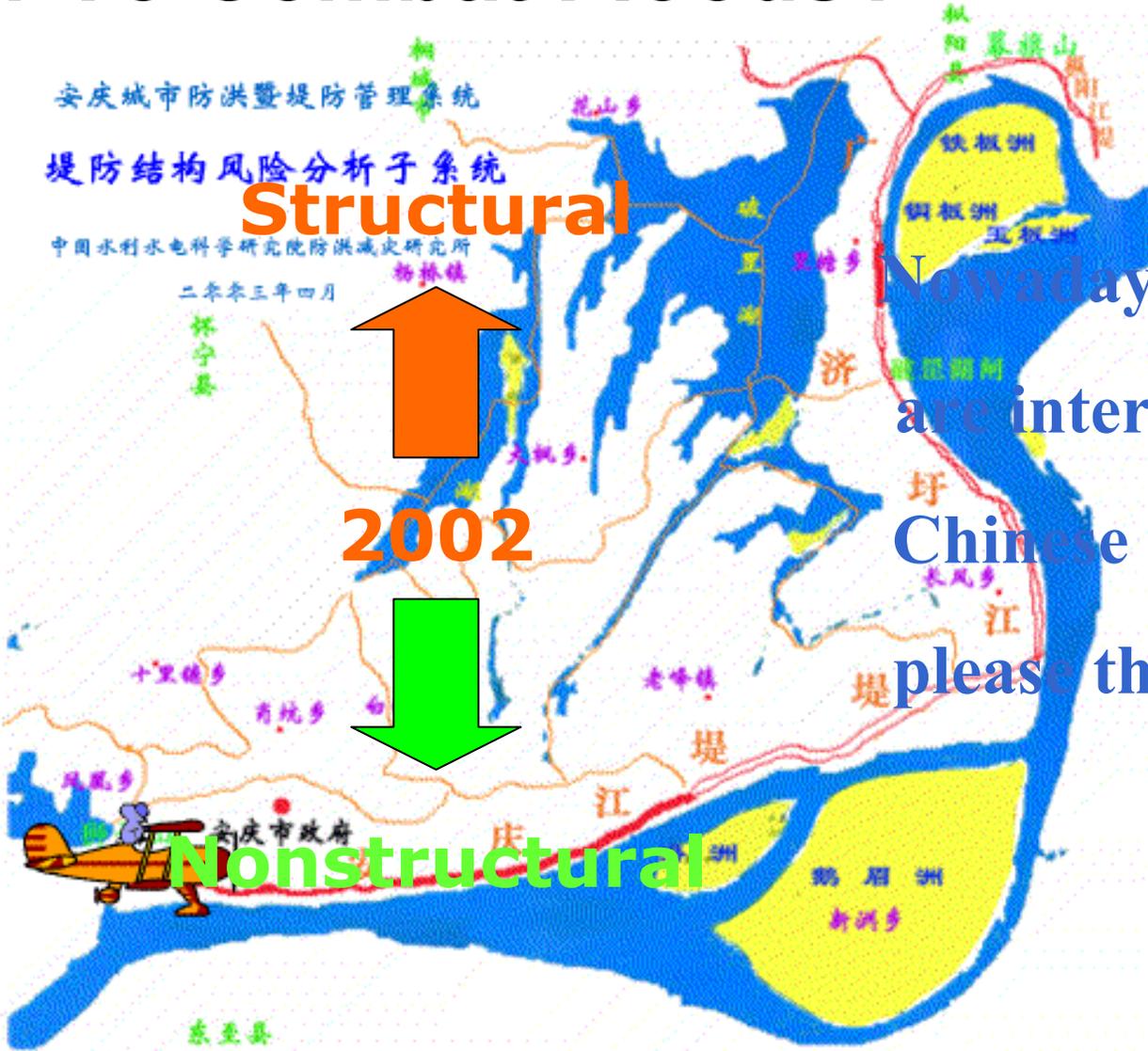
How To Combat Floods?



For Yangtze river alone, some 29 billion yuan (EURO **3.4 billion**) was earmarked during the 1998-2002 period to strengthen 3000 kilometer-long major levees shielding vast area along the river's middle and lower reaches.

In this case, Wang (Minister of water resources) said confidently that “ in the next **50 to 100** years, there will be no need for China to launch another large-scale reinforcement of the levees”

How To Combat Floods?



Nowadays, If you are interested in Chinese market, please thinking?

Coming up next.....



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Structure Risk

- ⌘ Loading Z ; Strength \hat{Z}
- ⌘ completely independent
- ⌘ Structural risk

$$R = P(Z \geq \hat{Z}) = \iint_{Z \geq \hat{Z}} f_z(Z) f_{\hat{z}}(\hat{Z}) dZ d\hat{Z}$$

Structure Risk Analysis

⌘ Sliding R_s

$$R_s = P(M_s > M_r) = \int_{M_r}^{\infty} f(M_s) dM_s$$

$$R_s = \sum_{i=1}^N F_S(H_{is}) \cdot \Delta F_0(H_{is})$$

$F_S(H_{is}) = \int_{M_r}^{\infty} f(M_{si}/H) dM_s$ is probability of sliding moment

larger than resisting moment at a certain WL H_{is}

$\Delta F_0(H_{is})$ the probability of i segment the frequency exceedance curves of water levels

N is the number of segment of curve of flood water level

Structure Risk Analysis

⌘ Piping R_p

$$R_p = P(J > J_c) = \int_{J_c}^{\infty} f(J) dJ$$

$$R_p = \sum_{i=1}^N F_J(H_{is}) \cdot \Delta F_0(H_{is})$$

$$F_J(H_{is}) = \int_{J_c}^{\infty} f(J / H) dJ \quad \text{is probability of seepage gradient}$$

larger than critical seepage gradient at a certain WL

$\Delta F_0(H_{is})$ the probability of i segment the frequency exceedance curves of water levels

Structure Risk Analysis

⌘ Calculating of failure of probability

$$F_S(H_{is}) = \int_{M_r}^{\infty} f(M_s / H) dM_s$$

$$F_J(H_{is}) = \int_{J_c}^{\infty} f(J / H) dJ$$

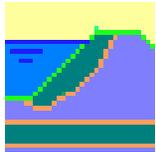
⌘ Total risk degree

$$R = R_s + R_p$$

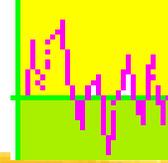
Failure Modes

Modes	Dam (China)	Yangtze
Piping	38	54.5
Overtopping	30	
Stability inner slope		15
Stability outer slope	15	
Erosion inner slope		10
Erosion outer slope		
Overflow		

Limit State Equation

Failure mode	Limit state equation	Icon
Overtopping	$z_1 = h_0 - h_w - h_s - e$	
Piping	$z_2 = \gamma_{nk} d_{ks} - \gamma_w h_{ap} + \gamma_{sb} t_{sb}$	
Sliding	$z_3 = F_{SL} - 1 = M_r / M_o - 1$	

Calculation Methods



J-C method (FORM)

Monte Carlo method

Detailed information about these methods

can be found in related literatures

Monte Carlo Method

Involves these following steps

- ⌘ (1) Probabilistic distribution models and distribution parameters of the variables related to reliability analysis are determined;
- ⌘ (2) Normally distributed random numbers; The first random sampling of all variables is done, and the result is used in the reliability function;
- ⌘ (3) Repeat random sampling independently for the total number of simulations , and then failure probability is estimated.

Monte Carlo Method

$$P_f = P(g(x_1, x_2, \dots, x_n) \leq 0)$$

$$I(g(x_1, x_2, \dots, x_n)) = \begin{cases} 1, & g(\cdot) \leq 0 \\ 0, & g(\cdot) > 0 \end{cases}$$

$$\hat{P}_f = \frac{1}{N} \sum I(g(x_1, x_2, \dots, x_n) \leq 0) = \frac{M}{N}$$

M is the number that $g(\cdot) \leq 0$

N Is the total number of simulations

Theory Demonstration

Programme Display

Coming up next.....



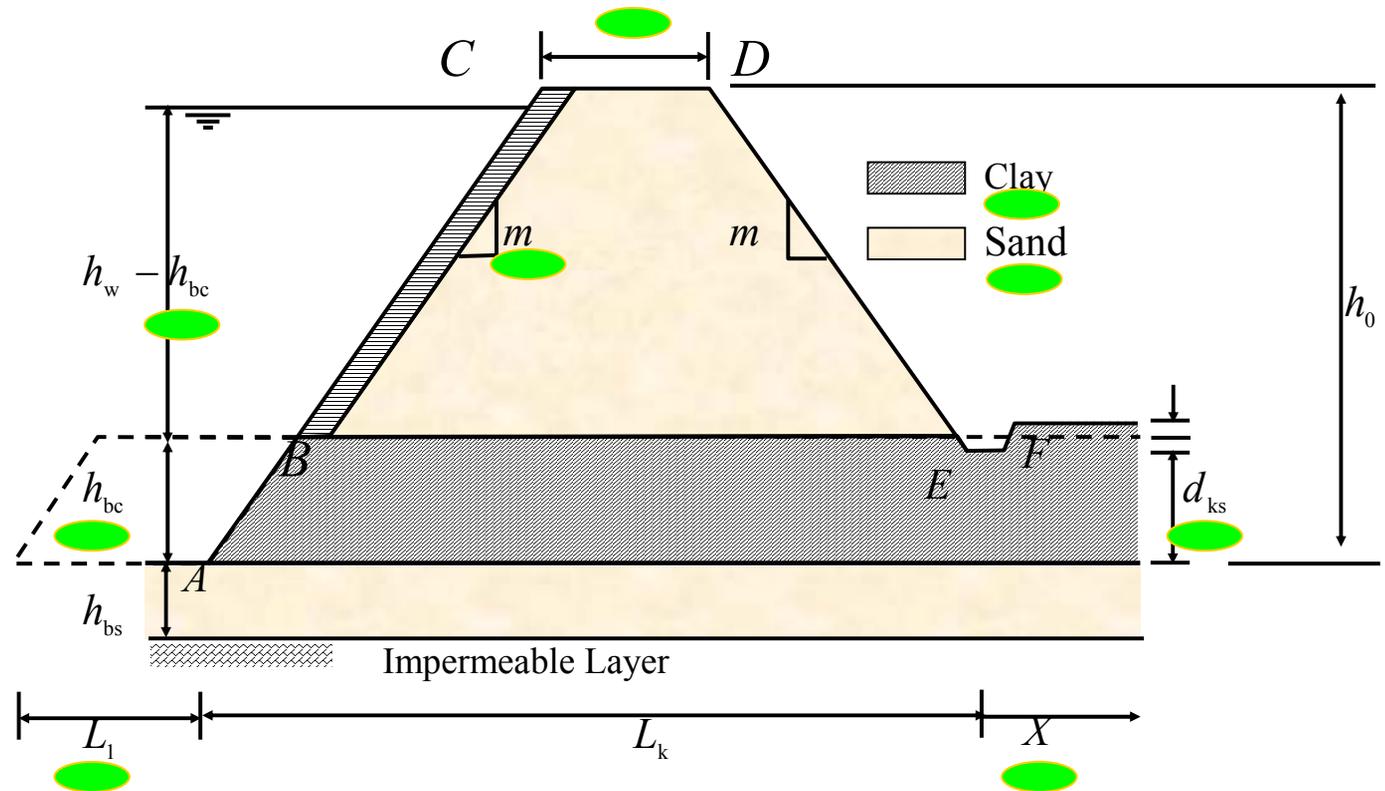
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3 Safety evaluation on individual dike section



Inclined Facing Embankment

Typical Dike Section Used This Study



An idealized cross section with inclination facing on two-phase fluvial facies basement

Geometry and Geotechnical Parameters

Variable Description		Unit	Type	Mean value	Standard Deviation
h_{bc}	Thickness of clay	m	DV	3.5	
L_1	Width of foreland	m	DV	0.0	
m	Slope ratio		DV	2.5	
w	Crest width	m	DV	5.0	
t_{sb}	Thickness of piping-berm	m	DV	0	
X	Width of piping-berm	m	DV	0	
h_0	Height	m	DV	11.0	
h_{bs}	Thickness of sand	m	DV	2.5	
γ_{nk}	Buoyant unit weight of clay	kN/m ³	DC	9.0	
γ_w	Unit weight of water	kN/m ³	DC	10.0	
γ_{sb}	Bulk gravity of piping-berm	kN/m ³	DC	18.0	
d_{ks}	Effective thickness of clay	m	RV	3.5	0.7
h_w	Flood water level	m	RV	8.3	0.9
k_c	Permeability coefficients of clay	m/s	RV	10 ⁻⁸	2*10 ⁻⁸
k_s	Permeability coefficients of sand	m/s	RV	10 ⁻⁵	0.75*10 ⁻⁵

DV--- Design variables; DC--- Deterministic Constants; RV---Random Variables

Modelling of Overtopping Mechanism

$$z_1 = h_0 - h_w - h_s - e$$

h_0	height of dike crest	Normal distribution	11.0m	0.051m
h_w	swash height	exponential distribution	8.34m	0.9m
h_s	surge height	Normal distribution	0.638	0.44
e		Normal distribution		

Overtopping---Result (A)

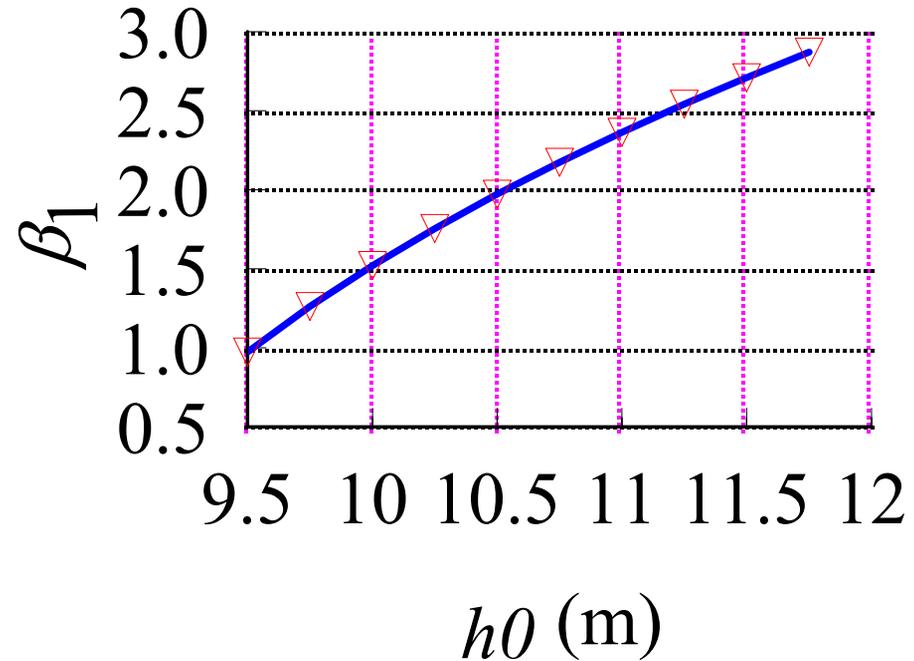
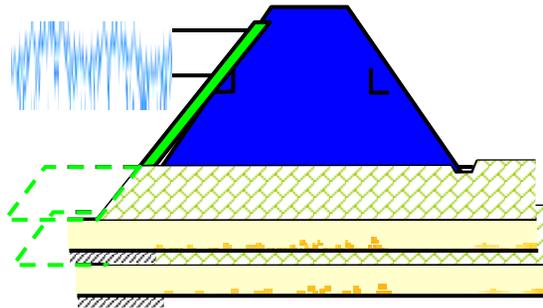
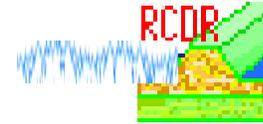


Fig. 2 Relation between height of dike and reliability index

Modelling of Piping Mechanism



safety factor

$$F_{\text{CN}} = \Delta H_{\text{strength}} / \Delta H_{\text{loading}} = \frac{\gamma_{\text{nk}} d_{\text{ks}} + \gamma_{\text{sb}} t_{\text{sb}}}{\gamma_{\text{w}} h_{\text{ap}}}$$

residual head of weak permeable stratum

$$h_{\text{ap}} = \frac{h_{\text{w}}}{1 + A * L_{\text{k}} + \tanh A * L_1} e^{-AX}$$

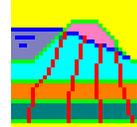
a coefficient

$$A = \sqrt{\frac{k_{\text{c}}}{k_{\text{s}} h_{\text{bc}} h_{\text{bs}}}}$$

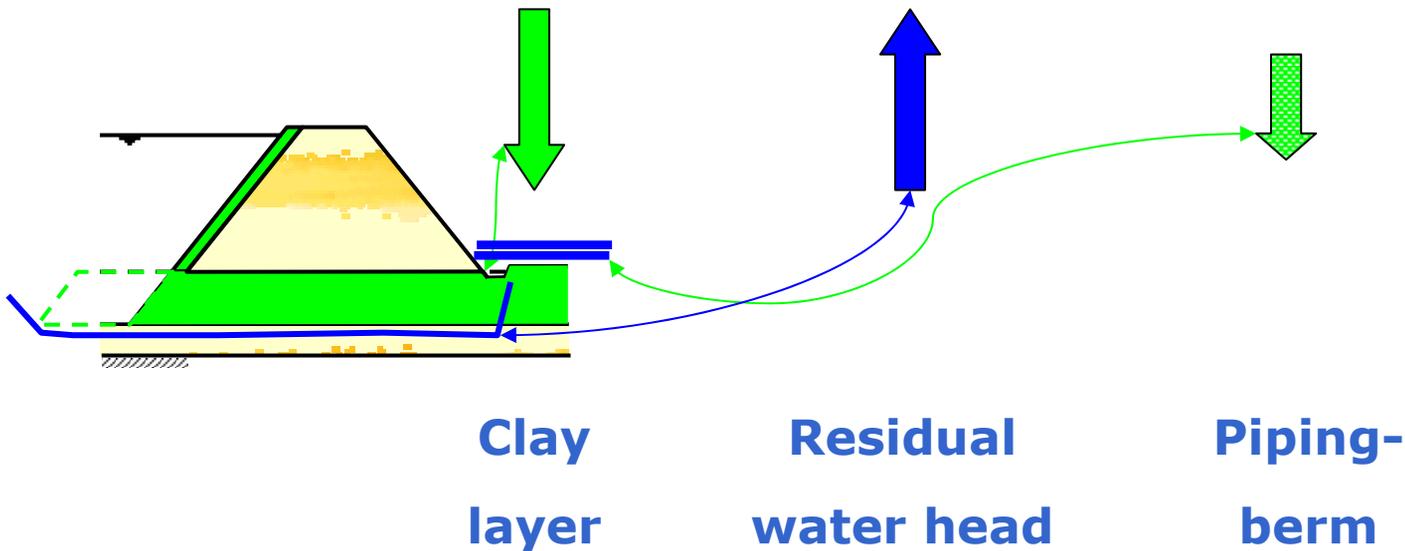
effective seepage path length

$$L_{\text{k}} = 2 * m * h + w + m * h_{\text{bc}}$$

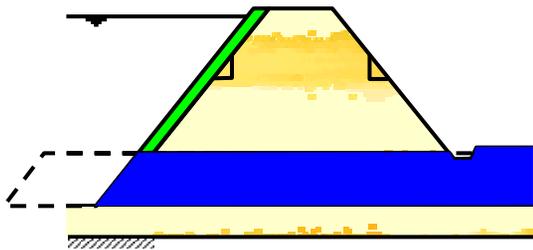
Modelling of piping mechanism



$$z_2 = \gamma_{nk} d_{ks} - \gamma_w h_{ap} + \gamma_{sb} t_{sb}$$



Piping---Result (B)



$$F_{CN} = \frac{\gamma_{nk} d_{ks}}{\gamma_w h_{ap}}$$

$$y = kx$$

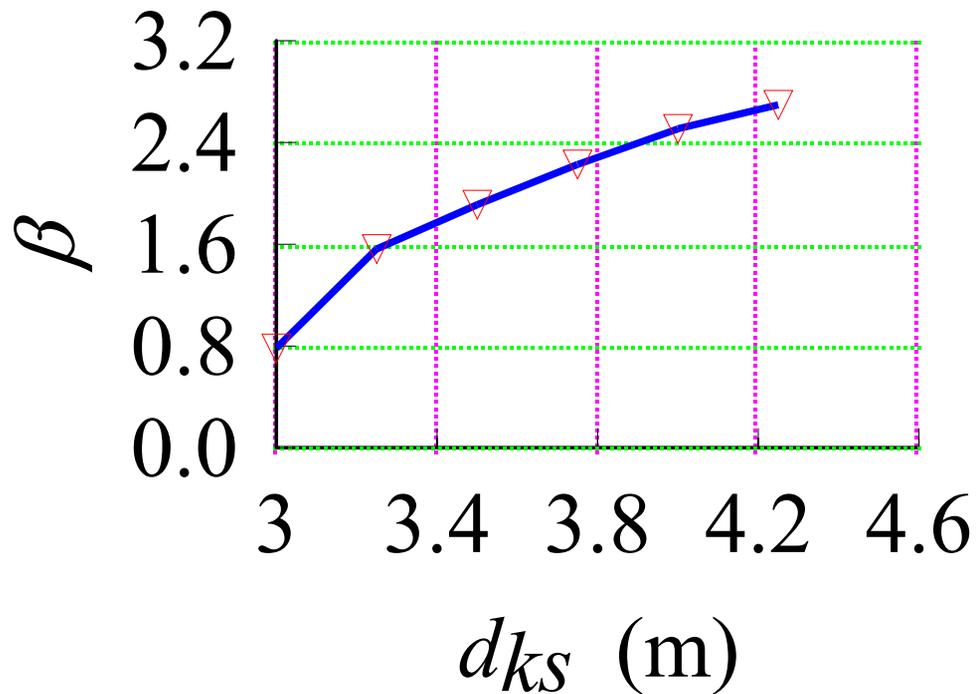


Fig. 3 Thickness of clay stratum

Piping---Result (C)

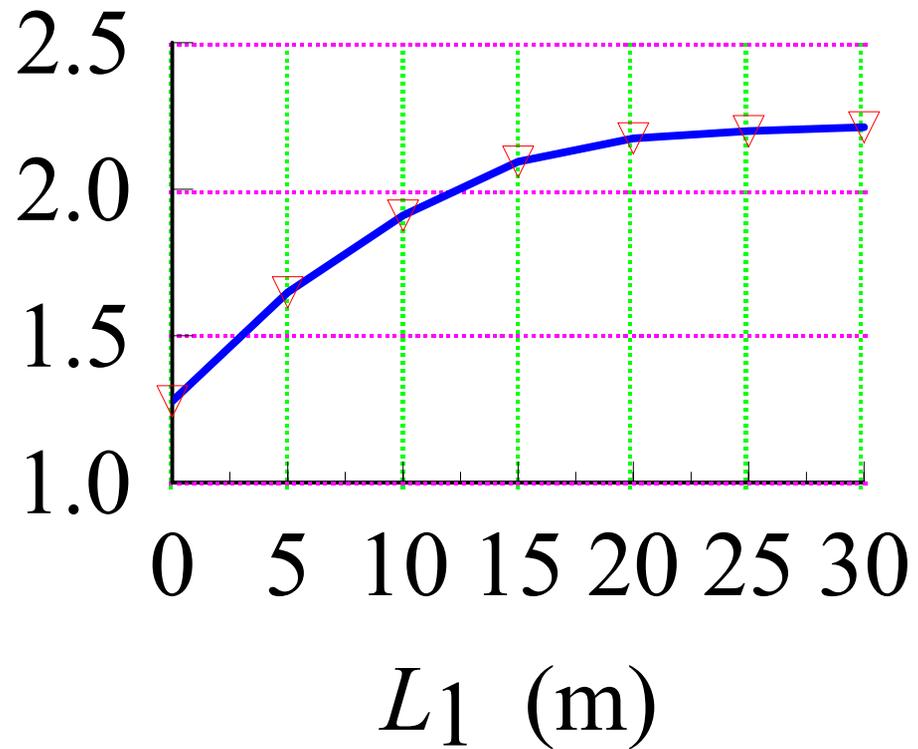
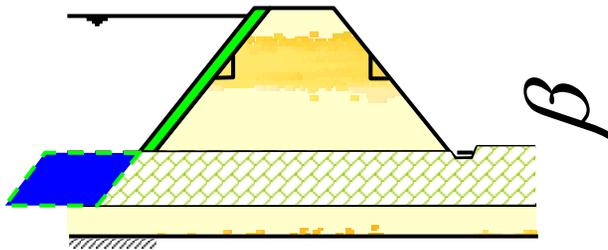
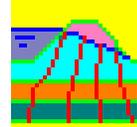
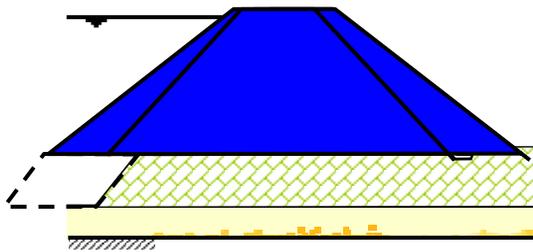
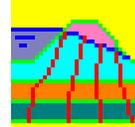


Fig. 4 Width of foreland

Piping---Result (D)



Flattened to 1V on 5H

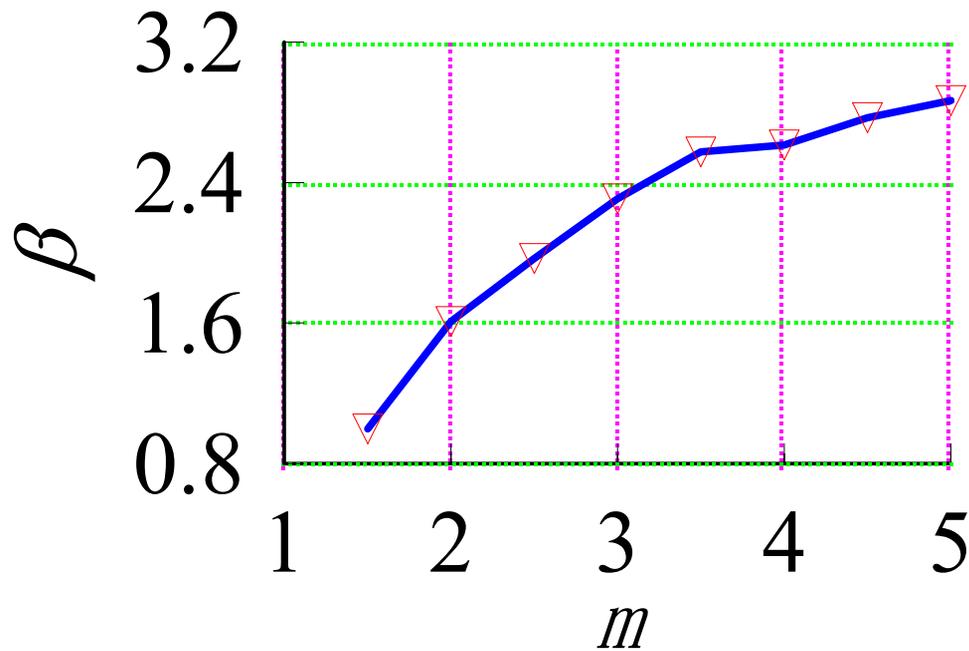
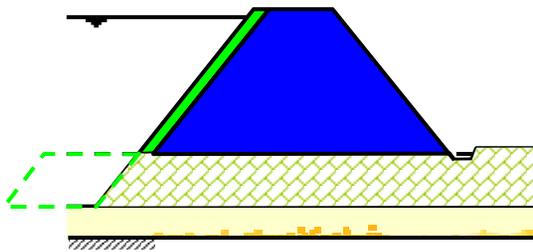


Fig. 5 Slope ratio

Piping--Result (E)



widen

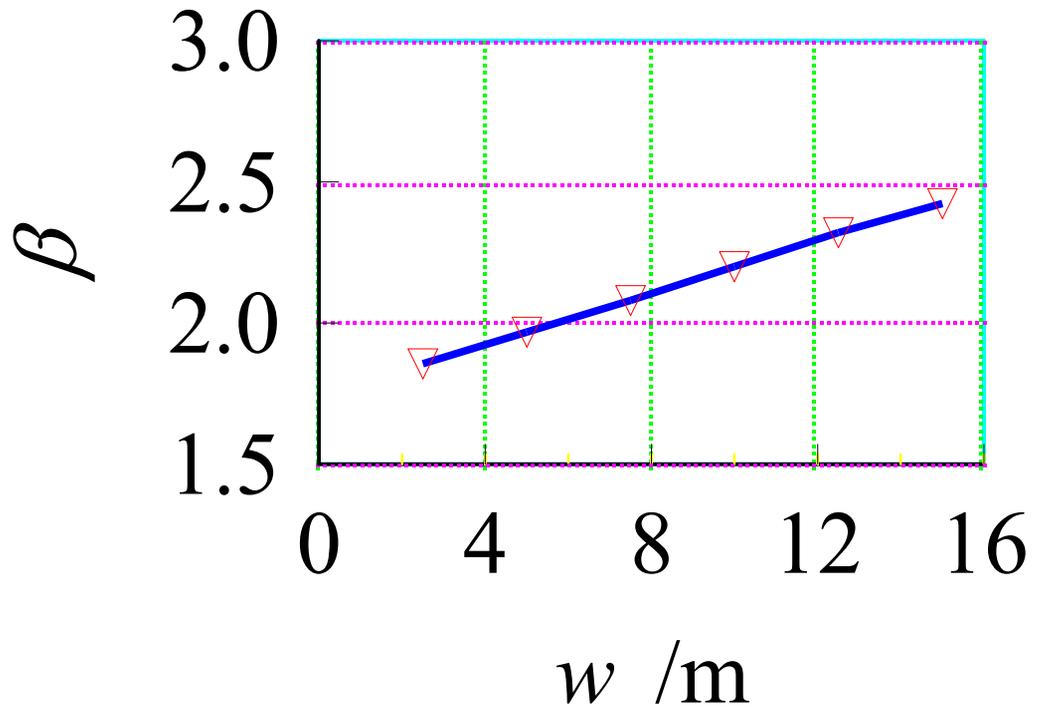


Fig. 6 Crest width

Piping--Result (F)

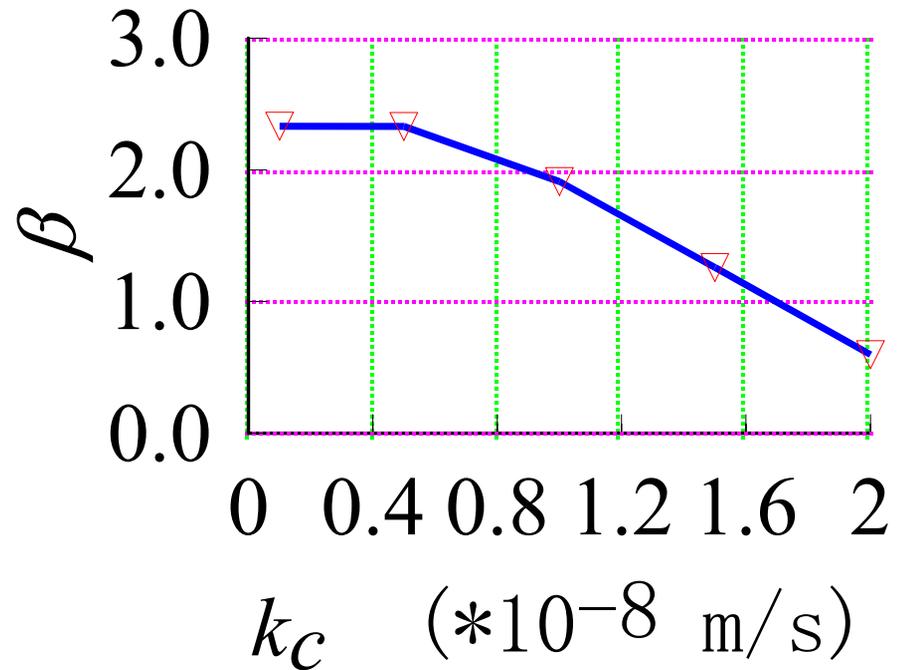
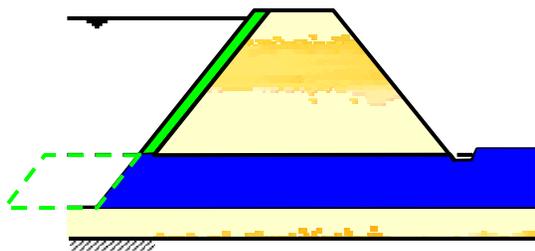
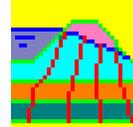


Fig. 7 Permeability coefficient of clay

Piping---Result (G)

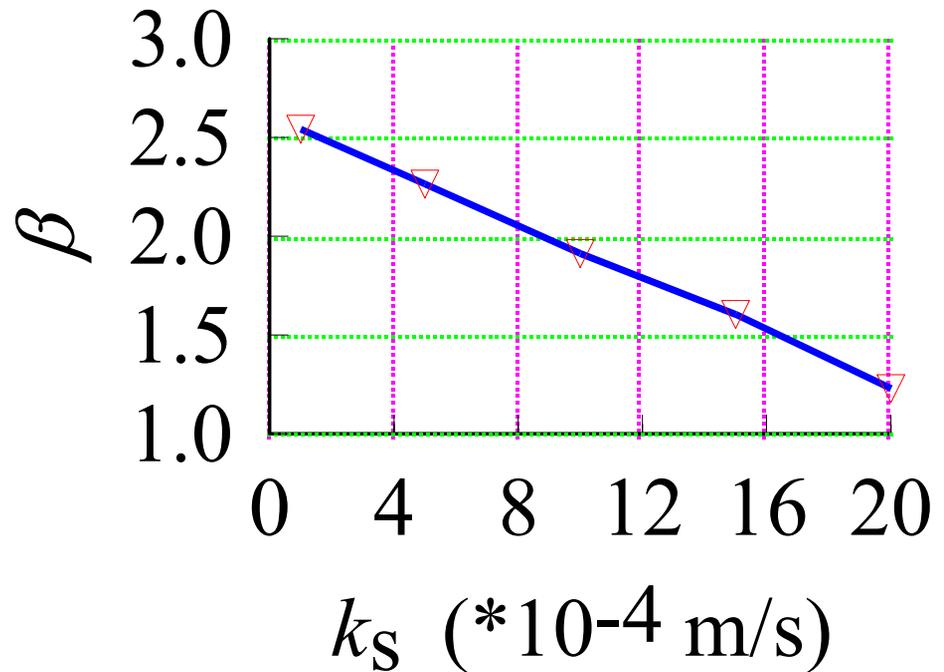
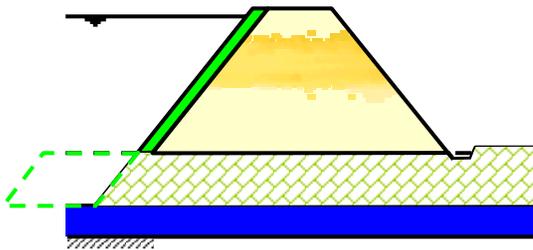


Fig. 8 Permeability coefficient of sand

Piping---Result (H)

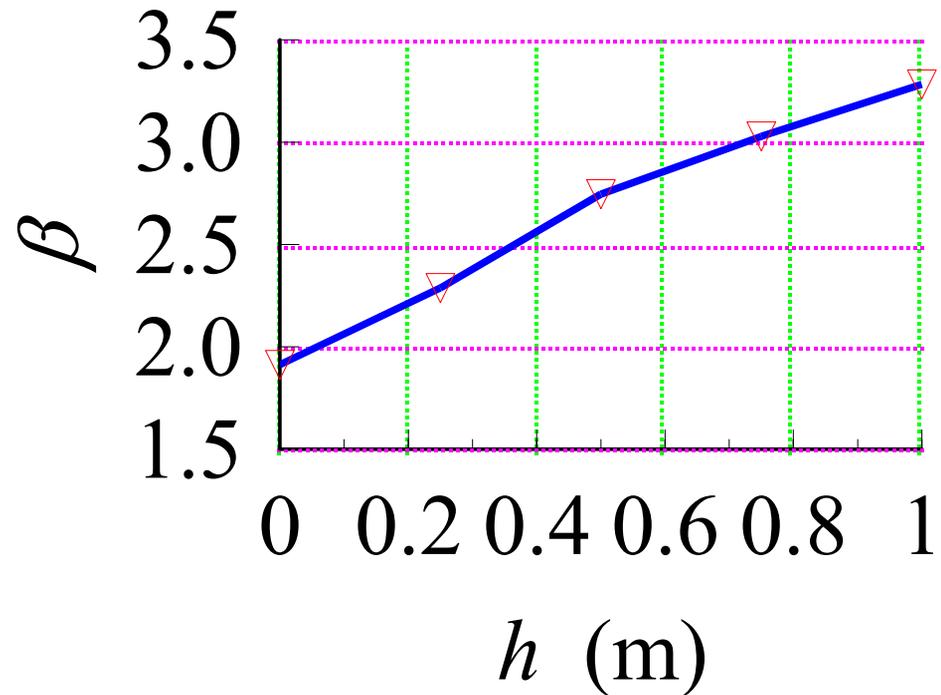
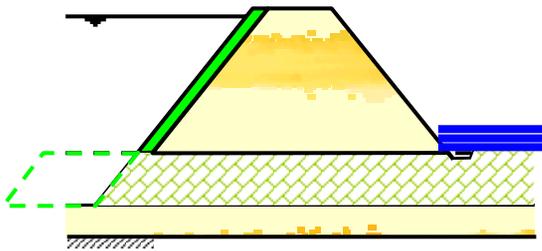
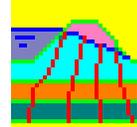


Fig. 9 Thickness of piping-berm

Piping---Result (I)

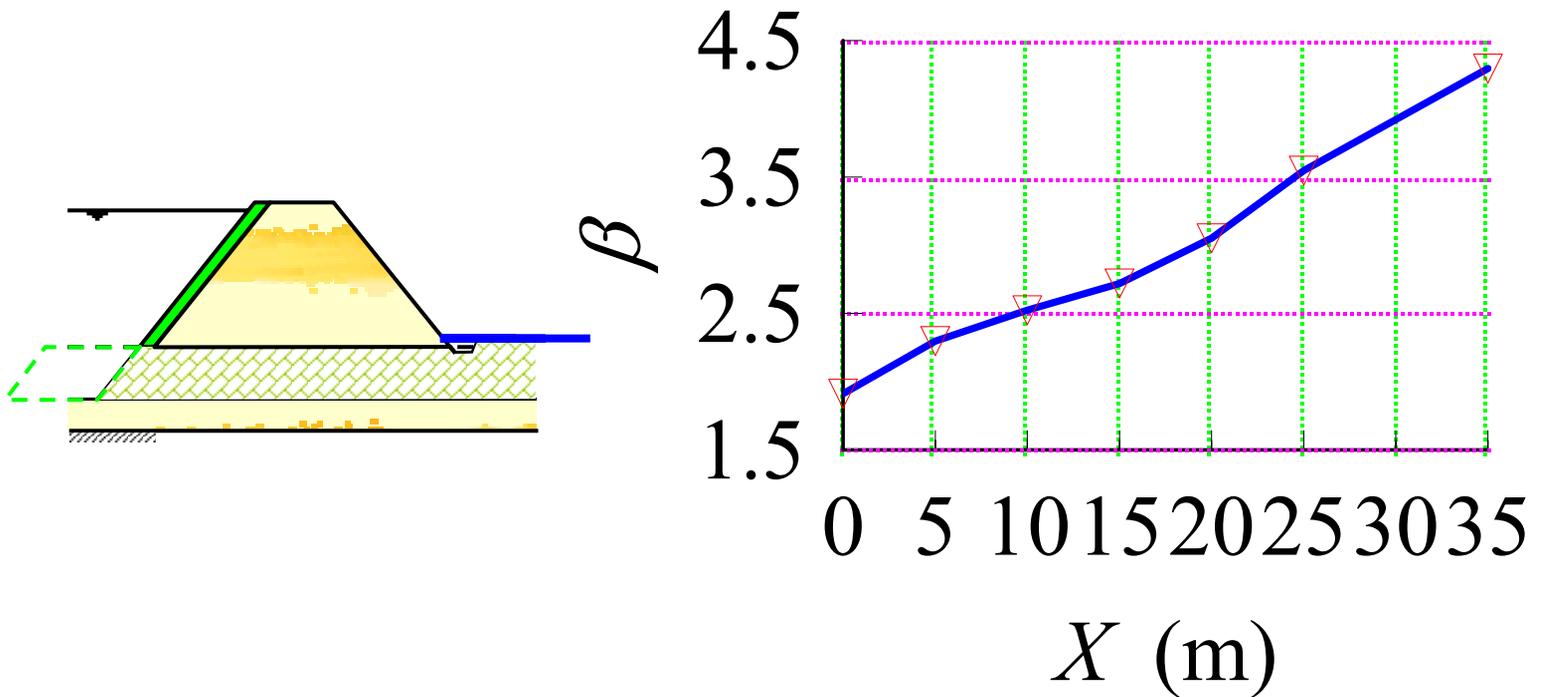
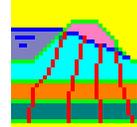
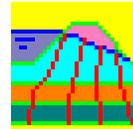
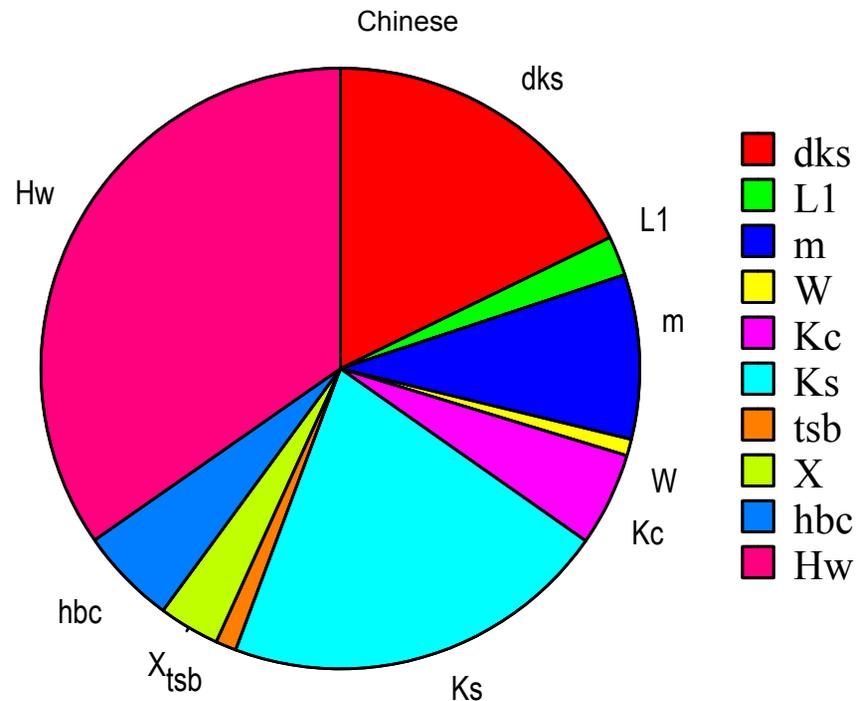


Fig. 10 Width of piping-berm

Piping---Result (J)

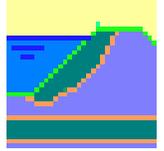


As shown in right Figure, the variables that contribute most to the Reliability index against piping are the water level, thickness of clay layer, seepage coefficient of sand, and the slope ratio.



Relative influence of the variables on Reliability Index

Modelling of Sliding Stability



simplified Bishop method

$$F_{SL} = \frac{\sum \frac{1}{m_{\alpha i}} [c'_i b_i + (W_i - u_i b_i) \tan \phi'_i]}{\sum W_i \sin \alpha_i}$$

$$m_{\alpha i} = \cos \alpha_i + \frac{\tan \phi'_i \sin \alpha_i}{F_{SL}}$$

$$z_3 = F_{SL} - 1 = M_r / M_o - 1$$

Slope Stability of Dike

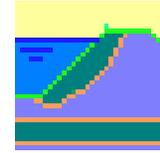
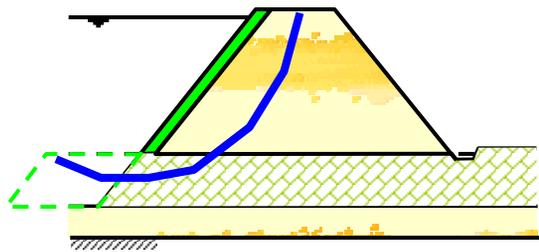
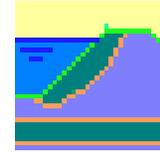


Table 1 Statistic of geotechnical parameters

Symbol	Name/unit	Distribution type	Mean value	Standard deviation
c	Cohensive (kPa)	Normal	12.54	2.8
ϕ	Inner friction angle(0)	Normal	21.58	3.5
γ	Bulk gravity (kN/m ³)	Normal	18.84	3.1

Sliding---Result (K)



β_3

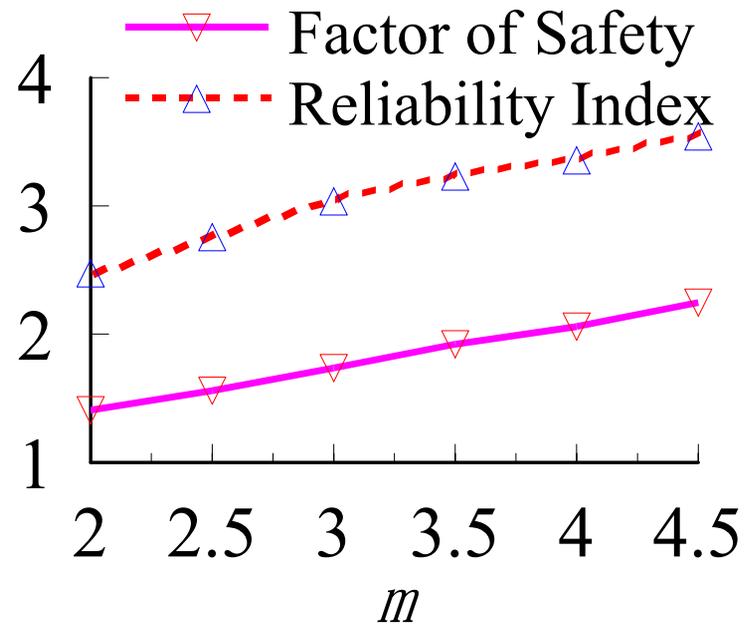
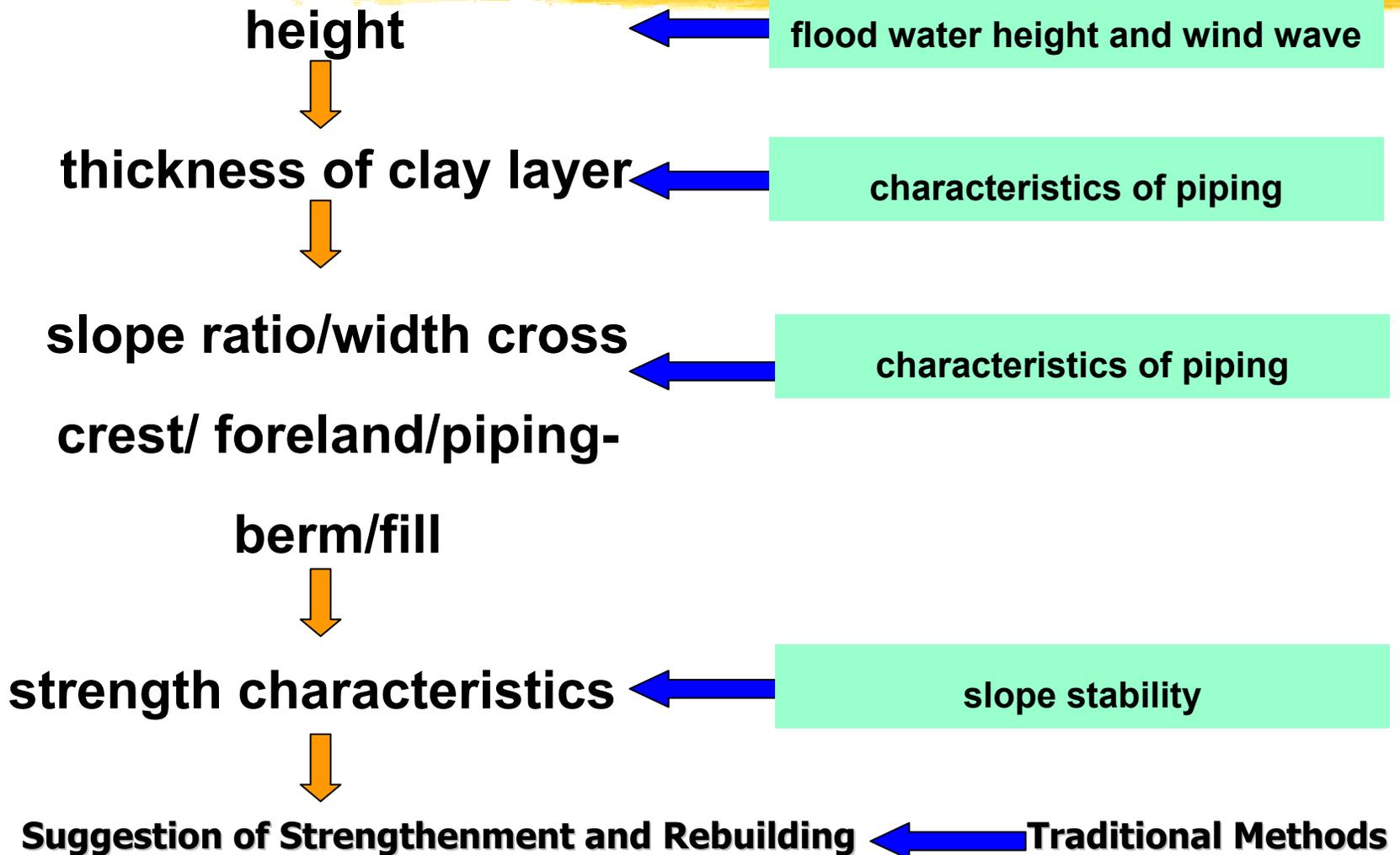
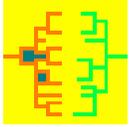


Fig. 11 Influence of slope ratio

Diagram of safety evaluation Process



Some Conclusions---(A) ---case A

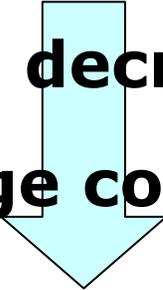


(1) The reliability index of overtopping increases with the height of dike.

(2) The reliability index of seepage stability of dike foundation increases with the slope ratio, width cross crest, width of clay layer of dike foundation, width of foreland, width and thickness of piping-berm behind dike.

Some Conclusions---(B)---case A

(3) The reliability index of seepage stability of dike foundation decreases with the increase of seepage coefficient of clay layer and sand layer.



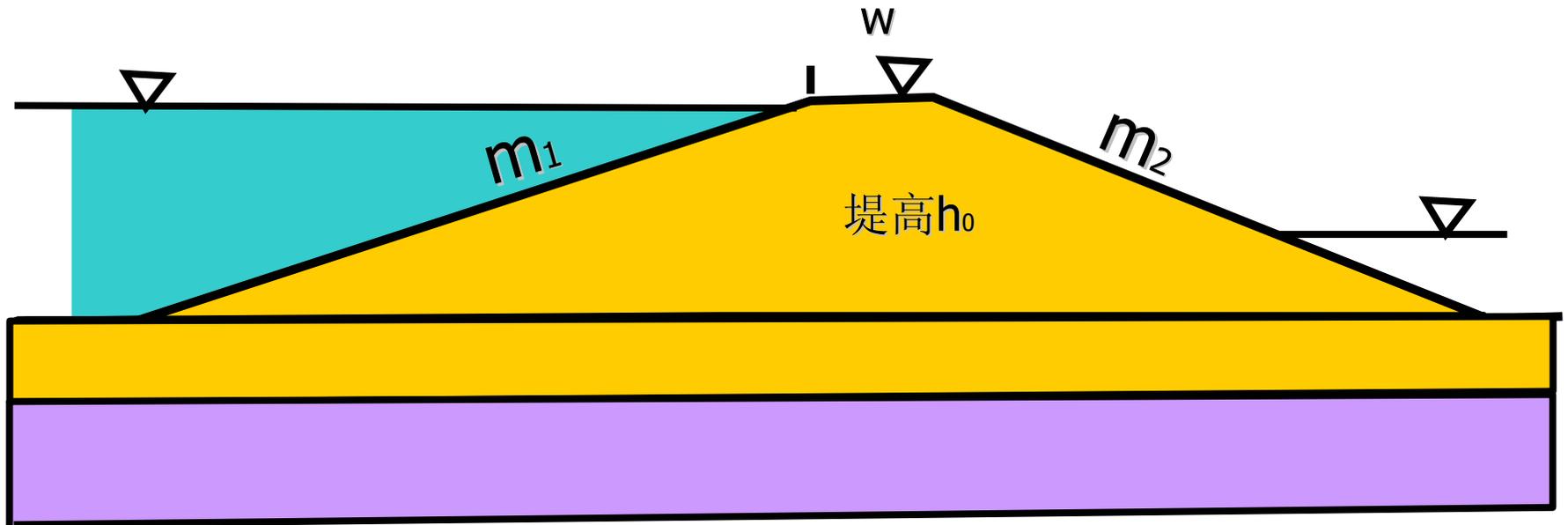
(4) The reliability index of slope stability increases with the slope ratio of dike.

3 Safety evaluation on individual dike section



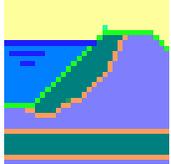
Homogeneous Embankment

typical cross section of dike



Slope ratio=3; Width=7m; Height=10m

Limit State Equation

Failure mode	Limit state equation	Icon
Sliding	$z_1 = F_{SL} - 1 = M_r / M_o - 1$	
Piping	$z_2 = J_c - J$	

$$F_{SL} = \frac{\sum \frac{1}{m_{\alpha i}} [c'_i b_i + (W_i - u_i b_i) \tan \phi'_i]}{\sum W_i \sin \alpha_i}$$

Statistical characteristics of random variables

Stochastic variables	Symbol	Name/unit	Distribution type	Mean value	Standard deviation
x_1	c	Cohensive (kPa)	Normal	12.54	2.8
x_2	ϕ	Inner friction angle(0)	Normal	21.58	3.5
x_3	γ	Bulk gravity (kN/m ³)	Normal	18.84	3.1
x_4	J_c	Critical seepage gradient	Normal	0.55	0.093

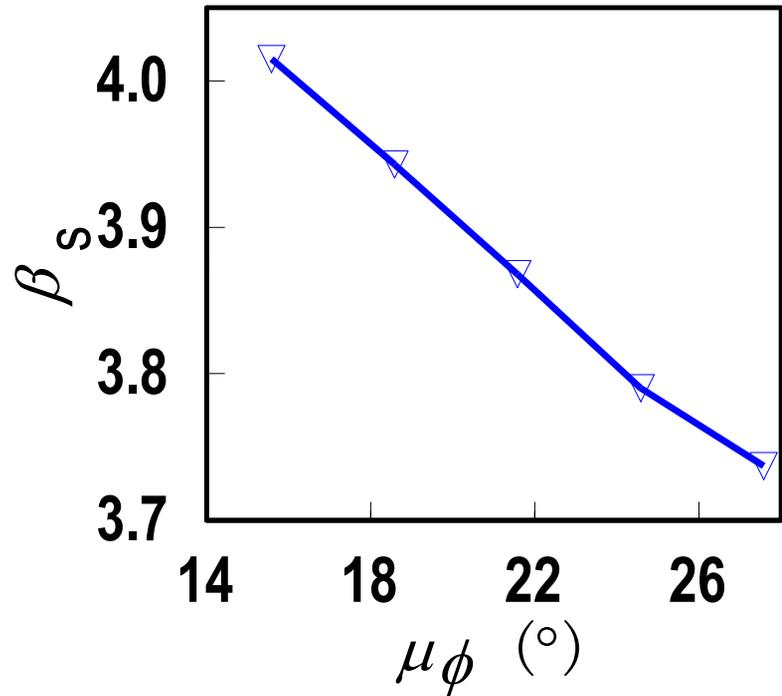
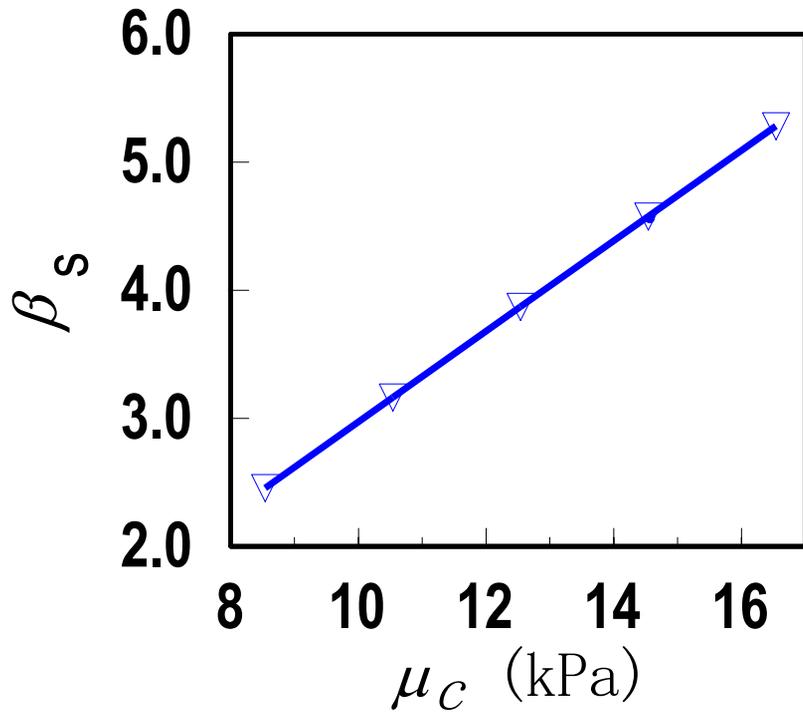
Sensitivity analysis of Geotechnical and Geometry parameters



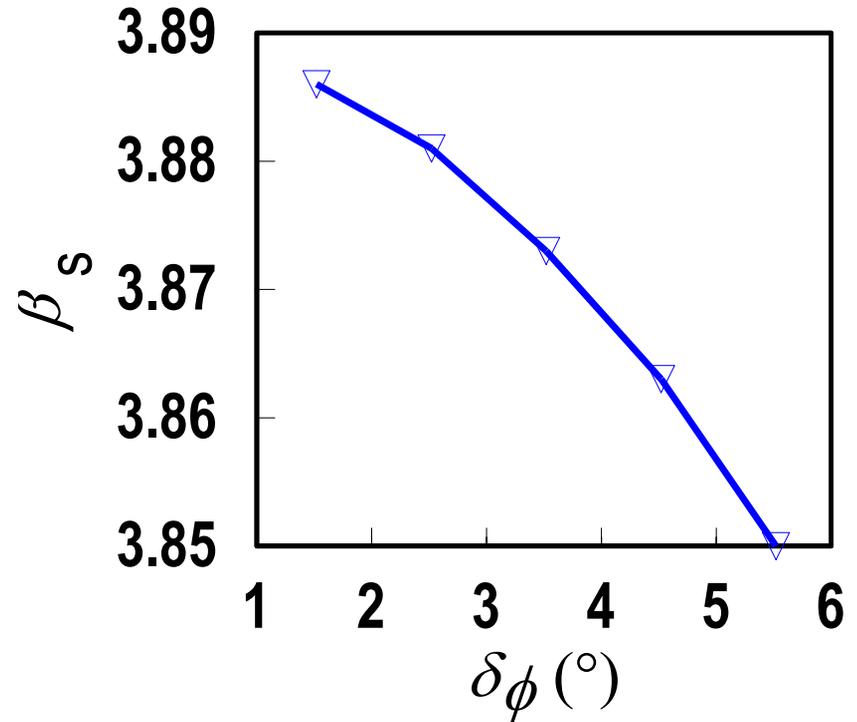
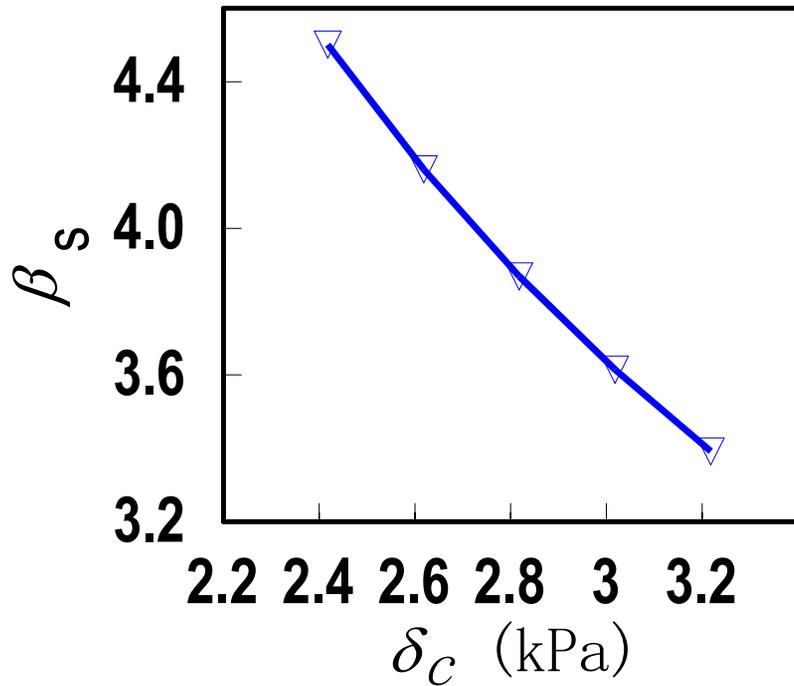
⌘ Geotechnical variables

⌘ Geometry variables

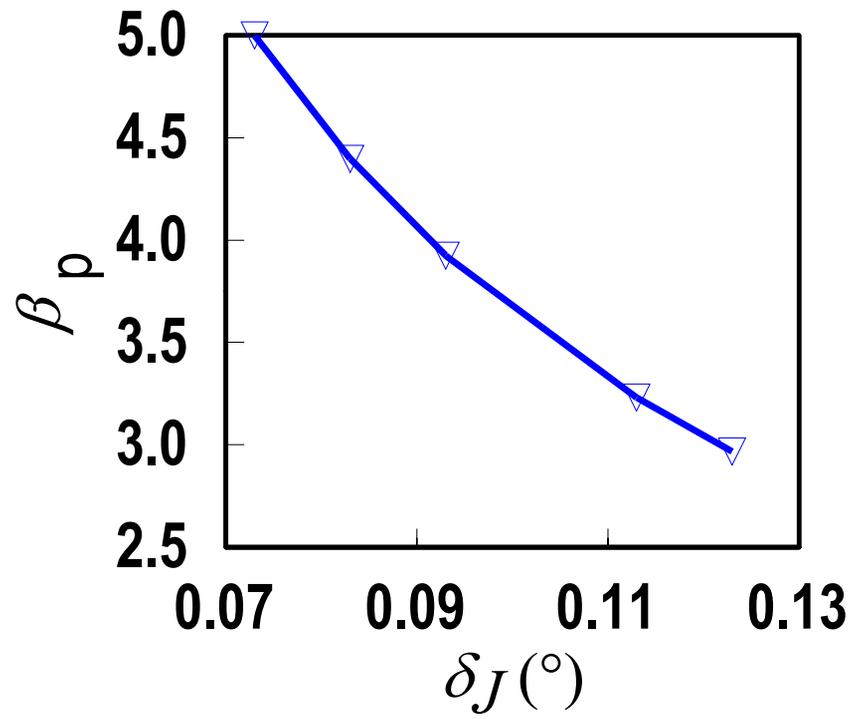
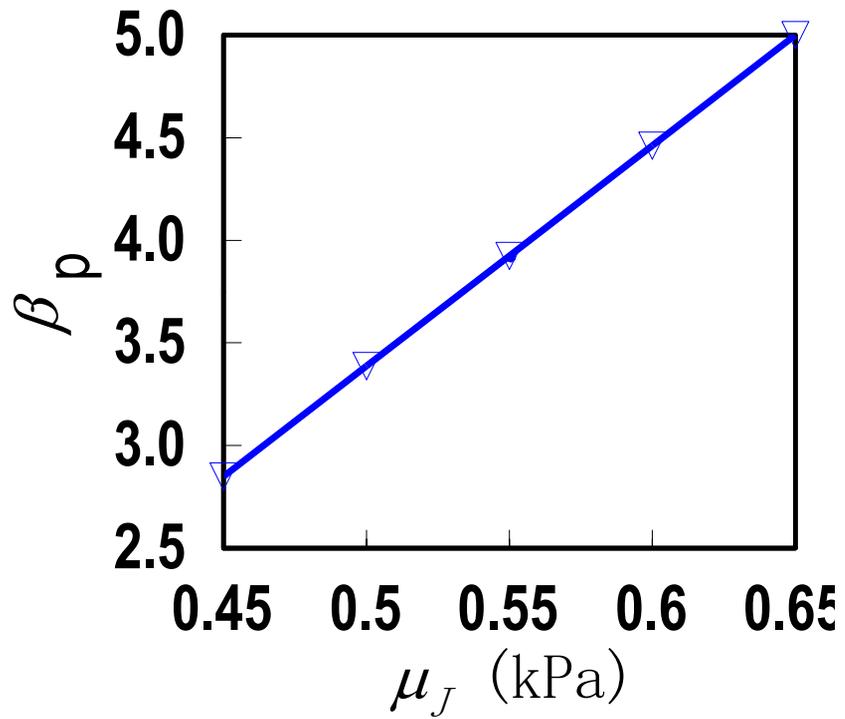
Mean values of C ϕ on β_s



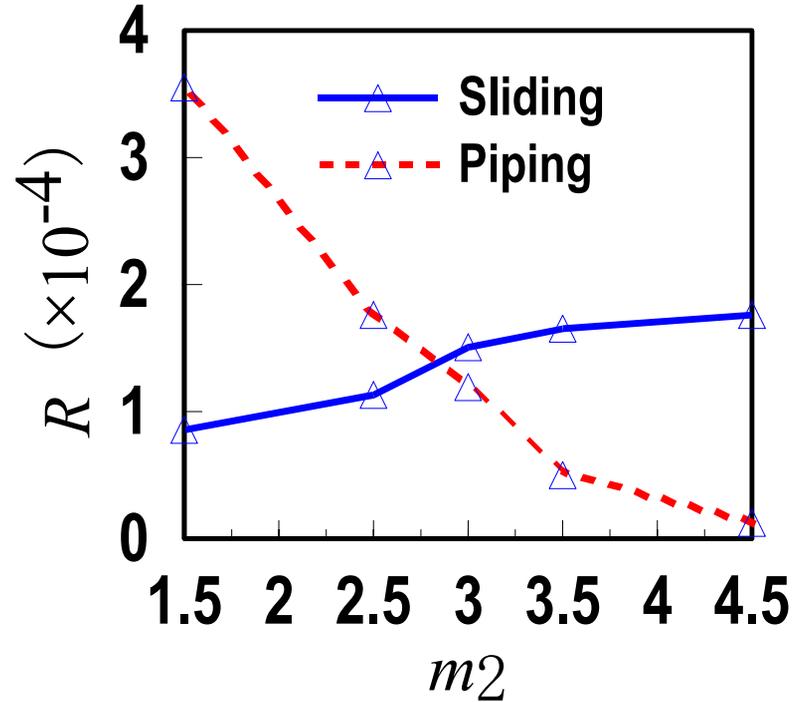
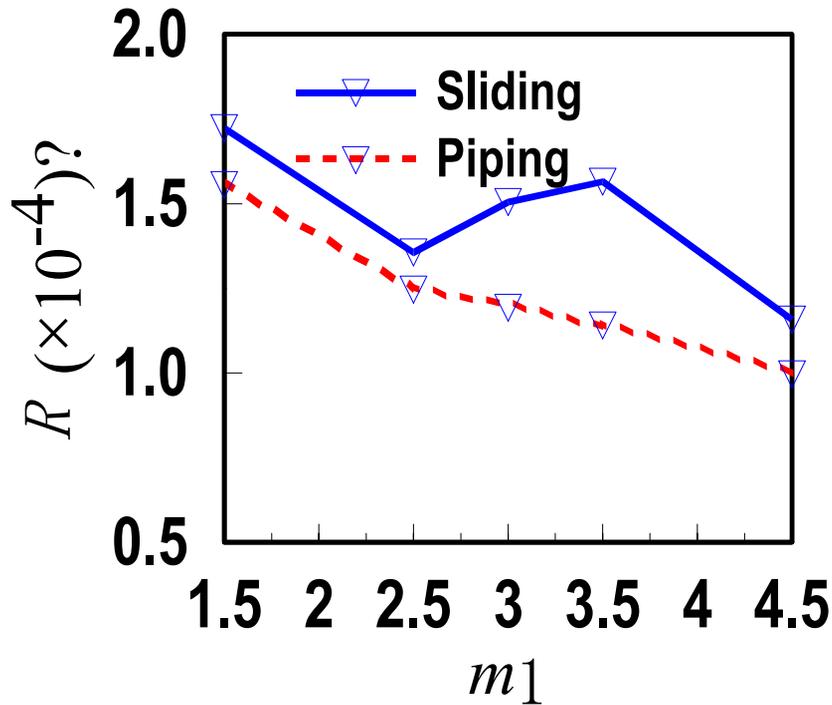
Standard deviation of C ϕ on β_s



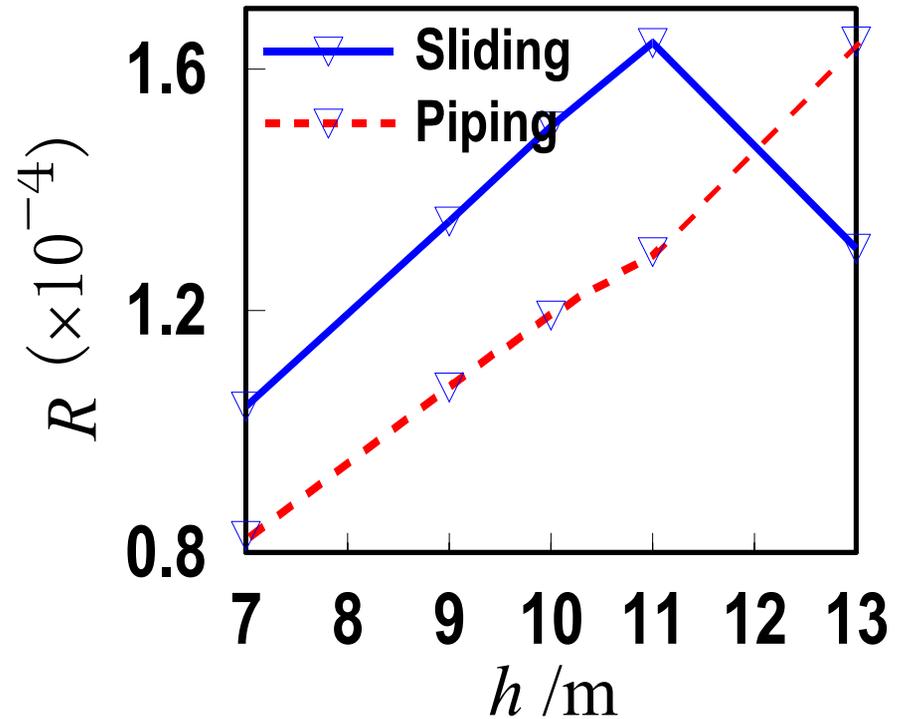
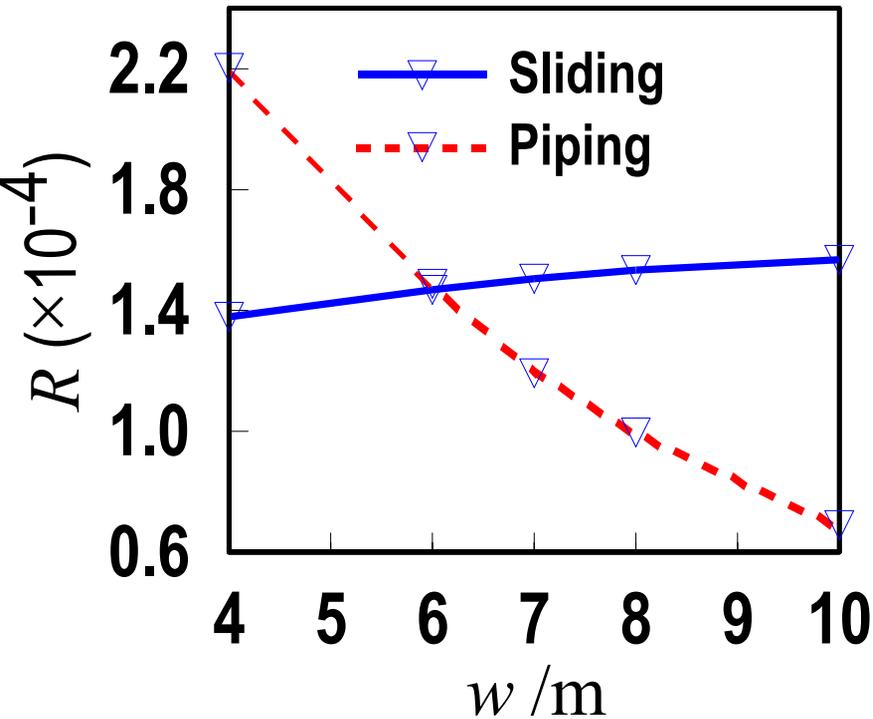
Mean values and SV of J on β_p



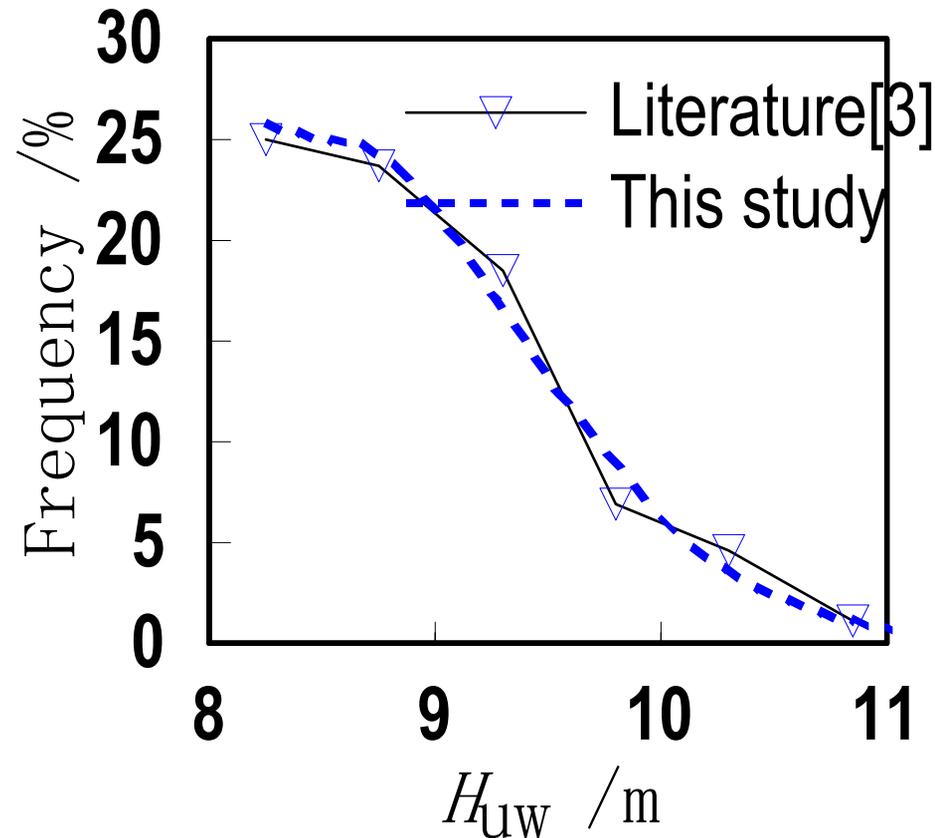
Influence of slope ratio on β_s β_p



Influence of Width and Height on β_s β_p



Frequency of high water elevation



Risk results

Structure risk at various water levels H_{uw}

H_{uw} (m)	Slope instability		Seepage instability		Total
	β	R_s $\times 10^{-4}$	β	R_p $(\times 10^{-4})$	R $(\times 10^{-4})$
8.0	3.89	11.64	4.35	1.59	13.23
8.5	3.88	7.97	4.26	1.88	9.85
9	3.87	3.97	4.07	1.74	5.71
9.5	3.86	1.51	3.92	1.19	2.70
10	3.85	0.51	3.75	0.76	1.27
Sum		25.61		7.16	32.77

Some conclusions---case B

- ⌘ The statistics parameters of shear strength parameters of c , ϕ have some influence on the reliability index against sliding. μ_ϕ is more sensitive than μ_c , δ_ϕ is more sensitive than δ_c .
- ⌘ The statistics parameters of seepage gradient have obvious influence on the reliability index of seepage deformation instability.

Some conclusions---case B

- ⌘ The variation of upstream and downstream slope ratio only has effects on the corresponding slope instability risk. Seepage path prolongs with the increasing of slope ratio, and the risk of piping decreases.
- ⌘ Increasing of width cross the crest has great influence on the risk of seepage deformation instability and has little influence on the risk of slope instability.
- ⌘ The risks of sliding and piping increase with the height of the dike.

Coming up next.....



- ⌘ 1 Object of this study
- ⌘ 2 Structural risk analysis method
- ⌘ 3 Safety evaluation on individual dike section
- ⌘ 4 Safety evaluation on whole dike section**
- ⌘ 5 software SADSS
- ⌘ 6 Some conclusions

Coming up next.....

A thick, horizontal yellow brushstroke underline that spans the width of the slide, positioned below the text 'Coming up next.....'.

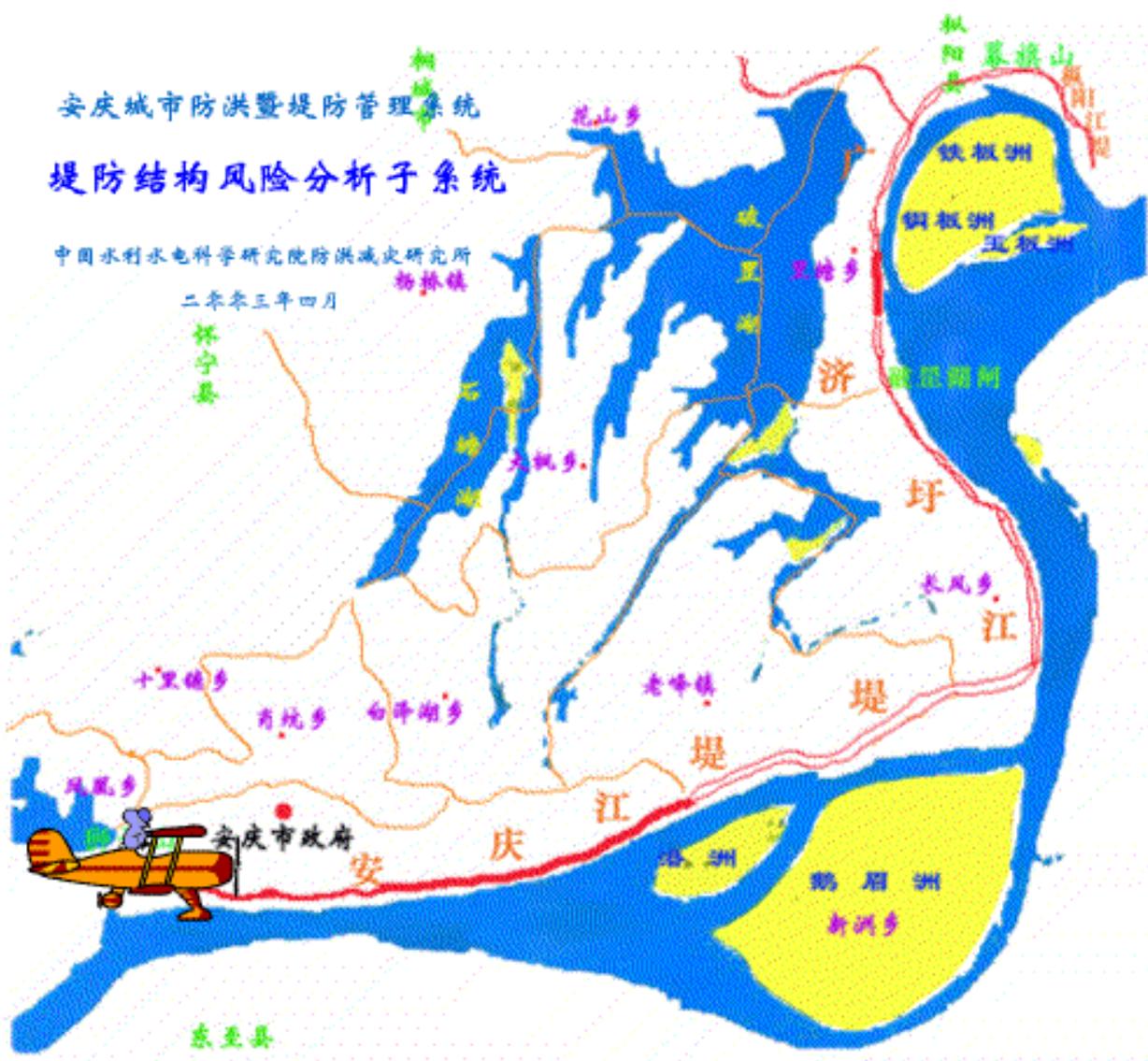
Safety evaluation on whole dike section

Sketch of fault tree of the dike



安庆城市防洪暨堤防管理系统 堤防结构风险分析子系统

中国水利水电科学研究院防洪减灾研究所
二〇〇三年四月



Definition of Anqing flood defence system's boundaries

The cross sectional and statistical properties are assumed to be constant along to section



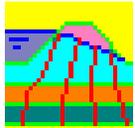
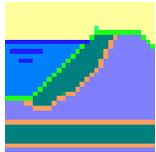
Position of main flood defence components

Component	No. Section		Length (m)	Type of dike	Percent (%)
	Initial position	Terminal			
A	000+000	05+687	5,687	Homogeneous dike of steal-concrete anti-flood wall with foundation treatment	11.26
B	05+687	14+500	8,813	Homogeneous dike with cement soil core	17.45
C	14+500	28+180	13,680	Homogeneous dike with piping berm or relief well	27.08
D	28+180	45+000	16,820	Homogeneous dike	33.31
E	M0+000	M5+000	5,500	Homogeneous dike	10.89

Geometry of every dike subsection



Limit State Equation

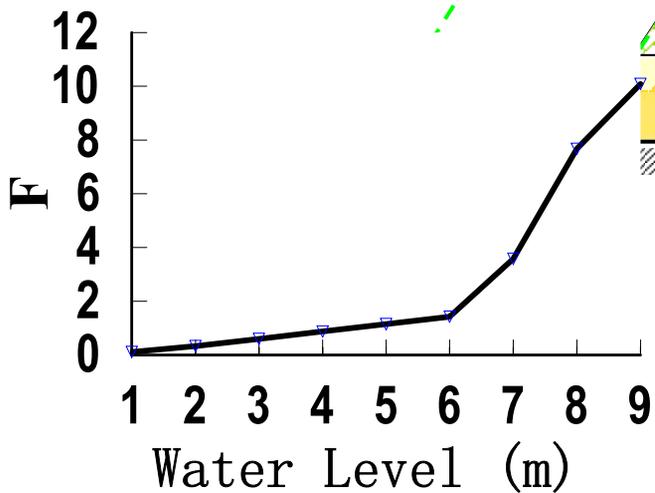
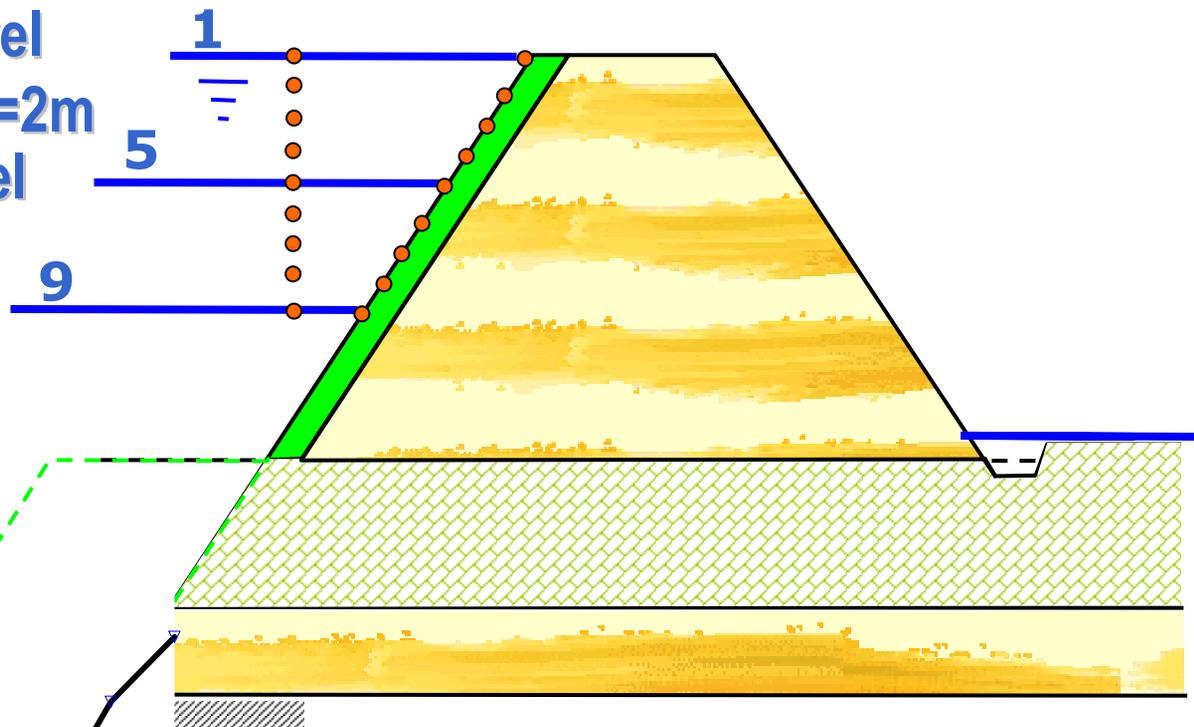
Failure mode	Limit state equation	Icon
Overtopping	$z_1 = h_0 - h_w - h_s - e$	
Piping	$z_2 = \gamma_{nk} d_{ks} - \gamma_w h_{ap} + \gamma_{sb} t_{sb}$	
Sliding	$z_3 = F_{SL} - 1 = M_r / M_o - 1$	



**Statistic characteristic of safety indexes
at various water levels
for the whole dike**

Water levels

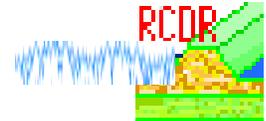
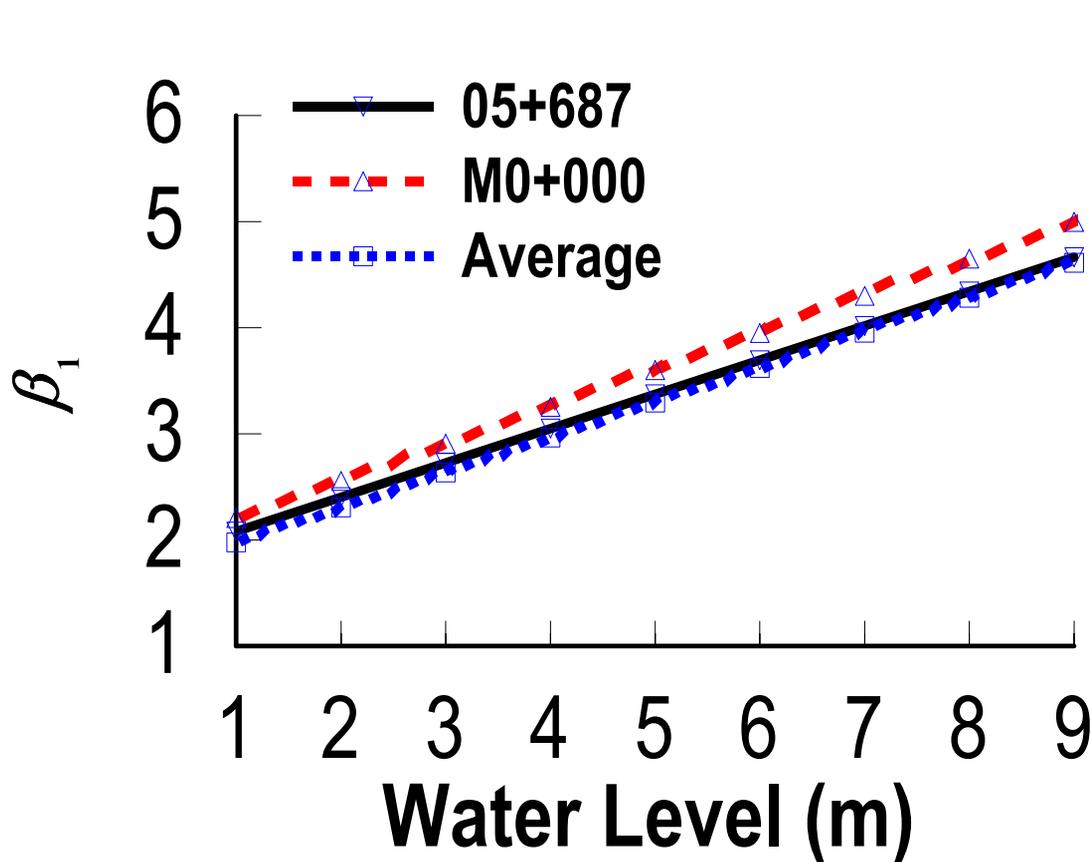
Crest Level
Freeboard=2m
Design Level



Occurrence frequency for each water level

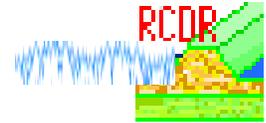
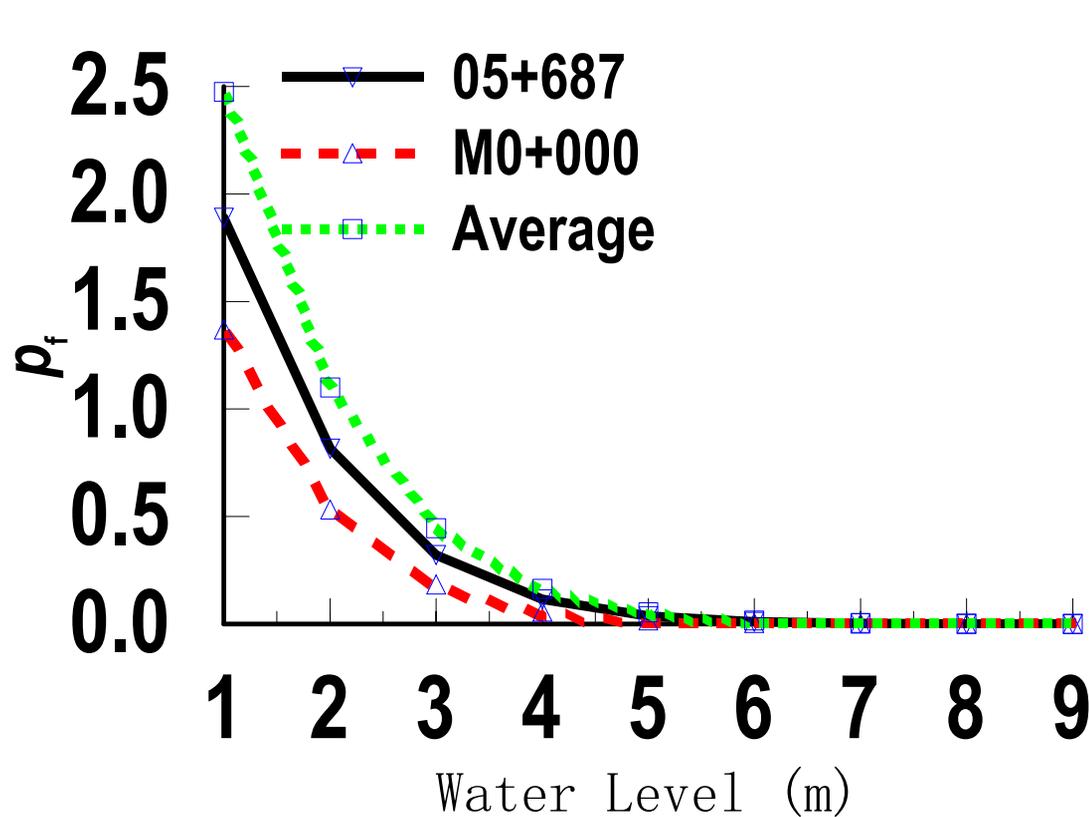
Rank	WL	Frequency	Return Period (ys)
1	21.19	0.001094	914
2	20.79	0.003281	305
3	20.29	0.006016	166
4	19.79	0.00875	114
5	19.29	0.011485	87
6	18.79	0.014219	70
7	18.29	0.035749	28
8	17.79	0.076726	13
9	17.29	0.100912	10

Statistic characteristic of safety indexes---overtopping (1)



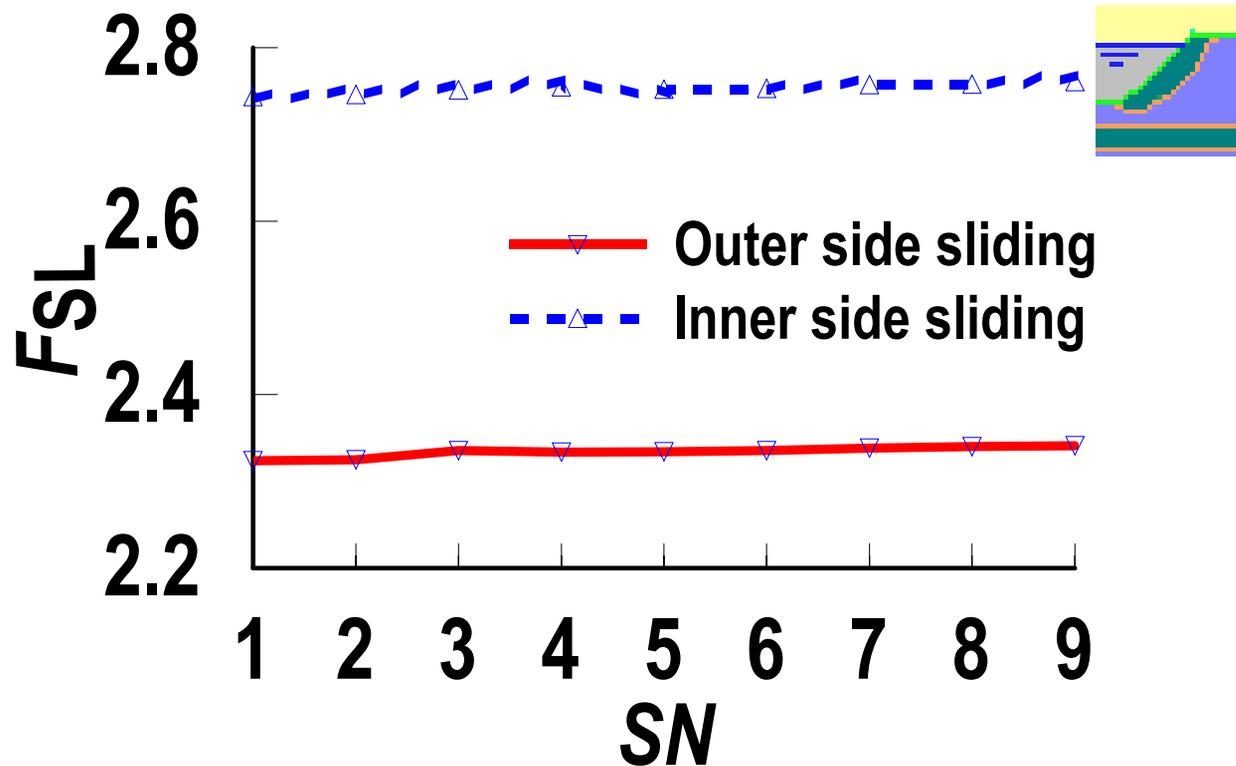
Reliability index against overtopping

Statistic characteristic of safety indexes---overtopping (2)



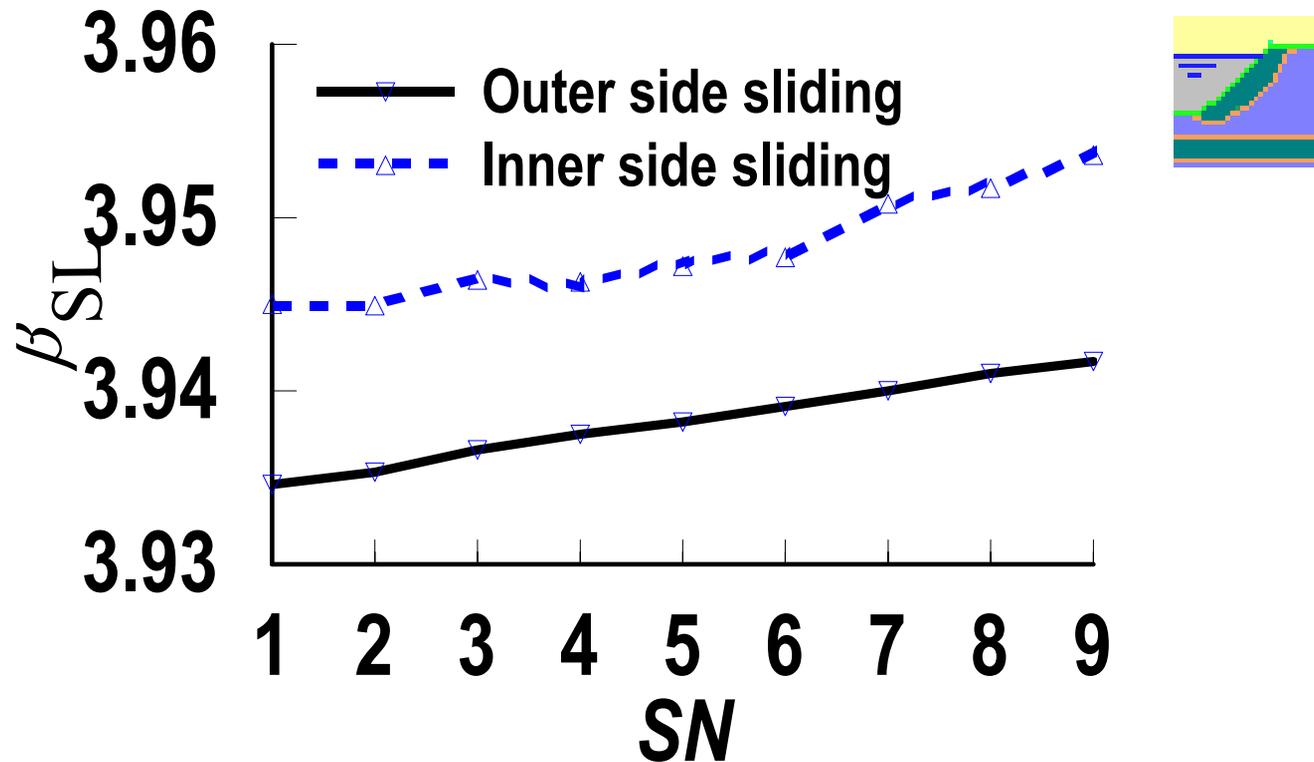
Probability of failure of overtopping

Statistic characteristic of safety indexes---Sliding (1)



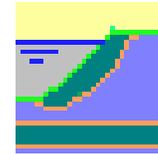
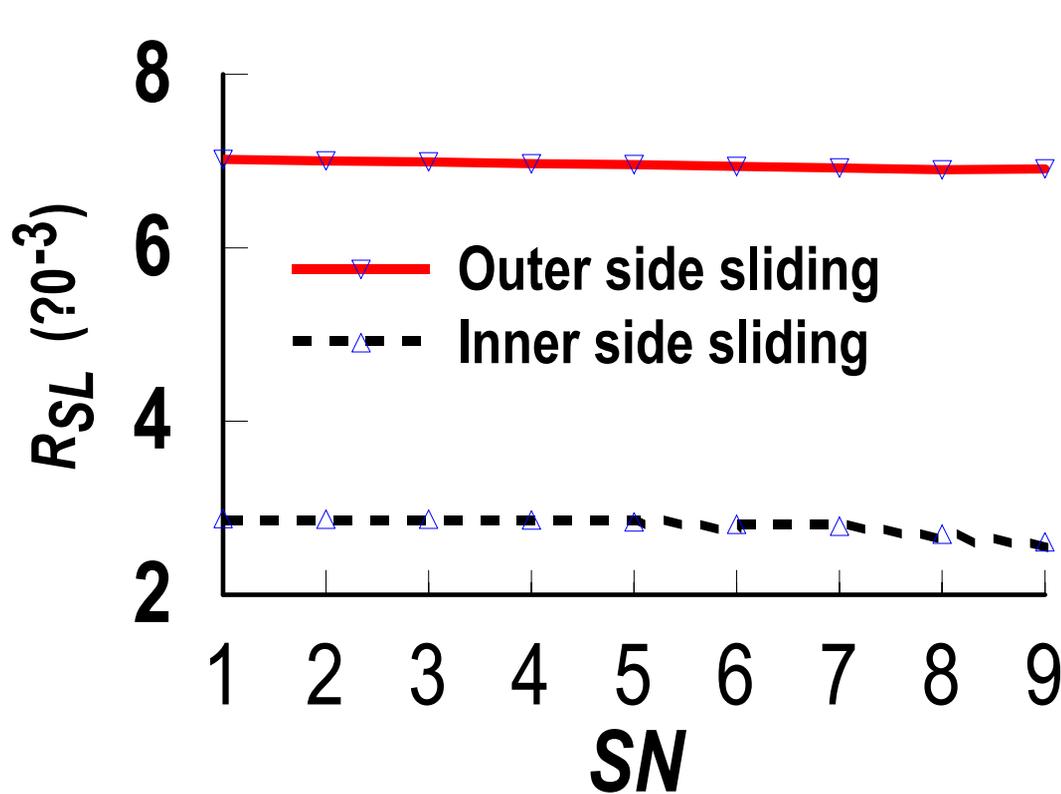
Safety factor against sliding

Statistic characteristic of safety indexes---Sliding (2)



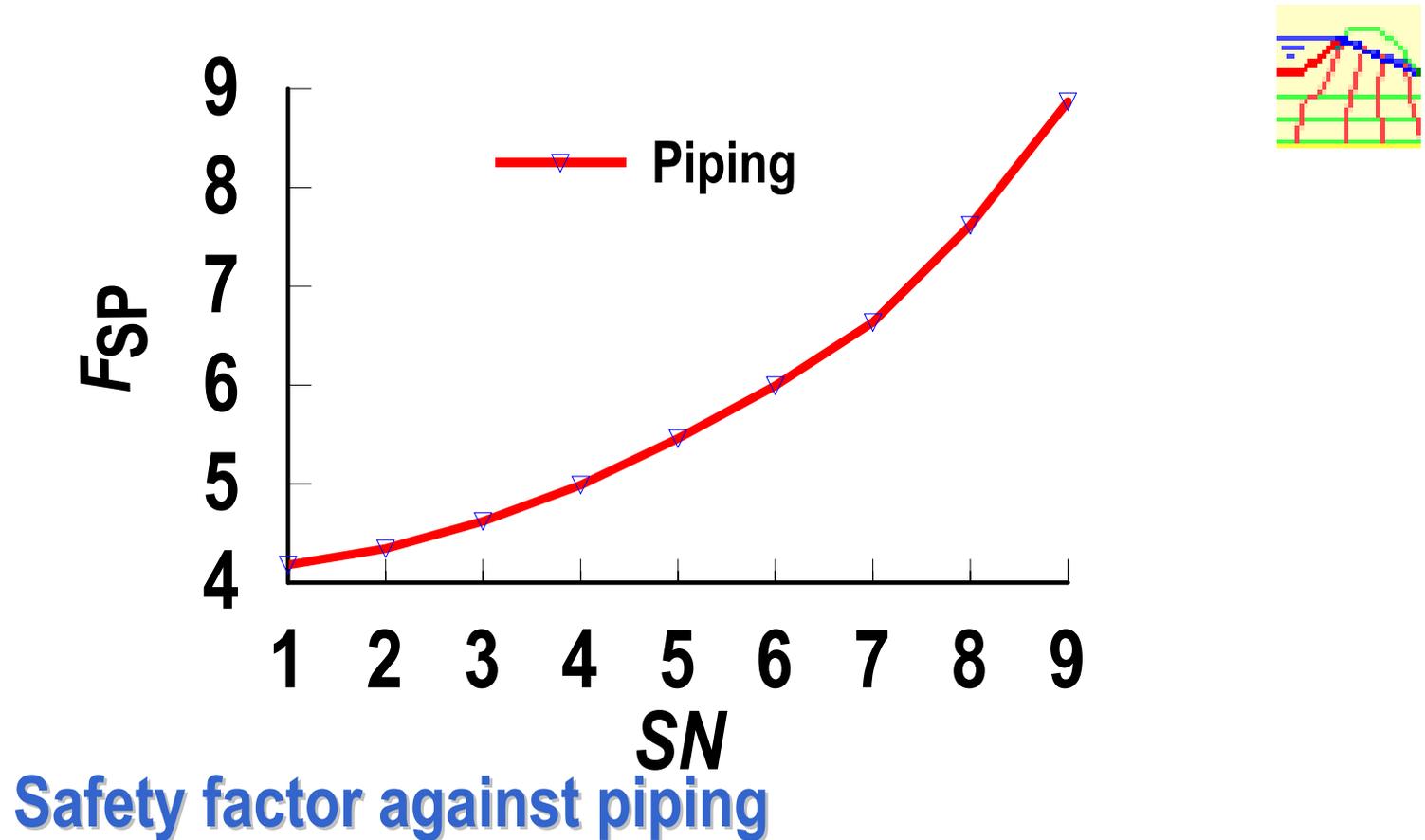
Reliability index against sliding

Statistic characteristic of safety indexes---Sliding (3)

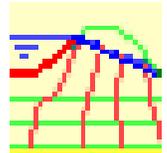
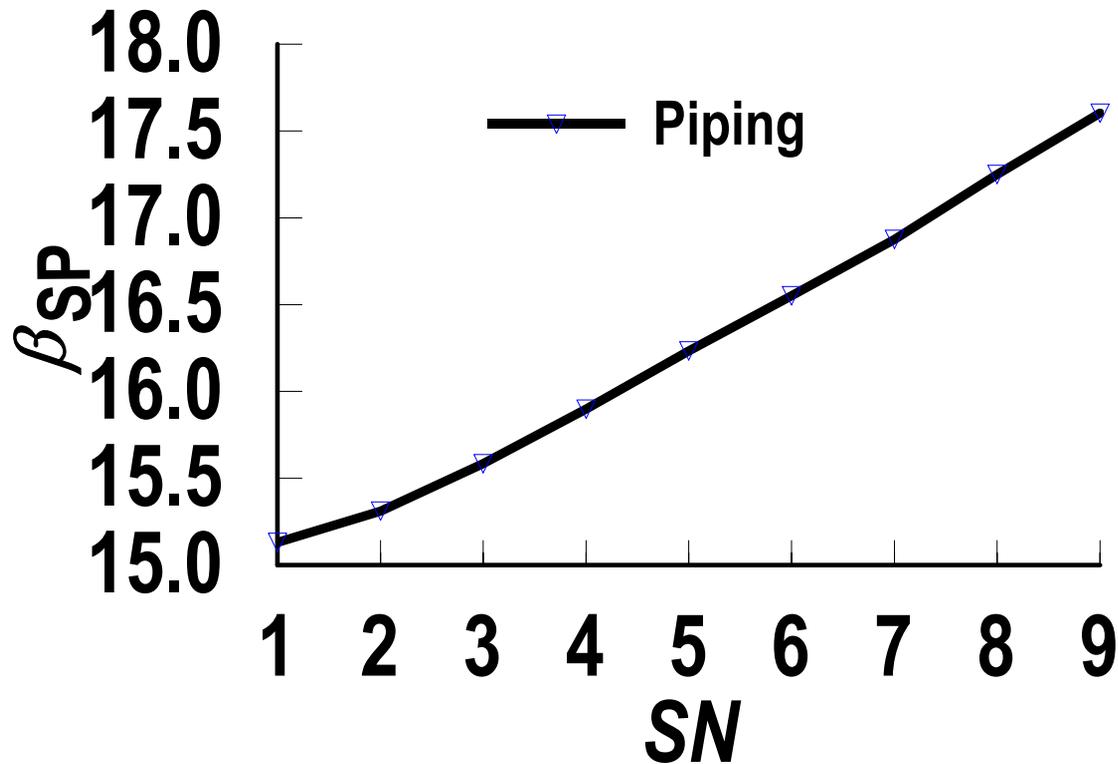


Risk degree of sliding

Statistic characteristic of safety indexes---Piping (1)

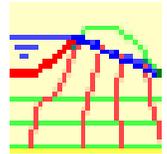
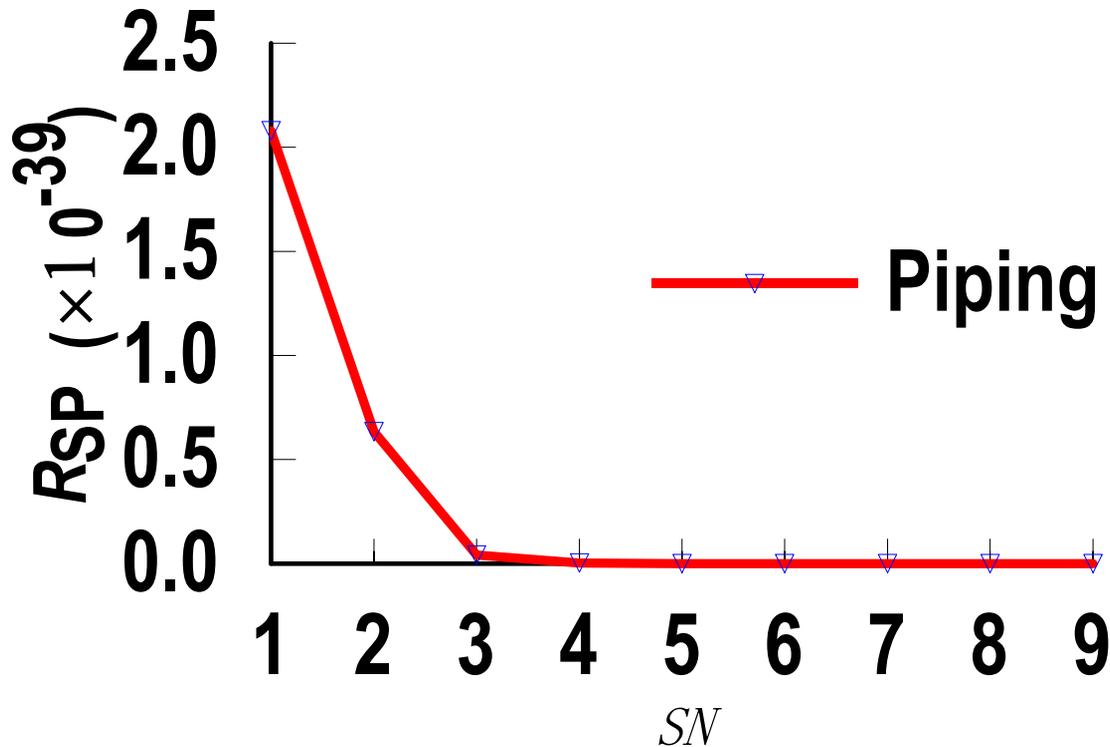


Statistic characteristic of safety indexes---Piping (2)



Reliability index against piping

Statistic characteristic of safety indexes---Piping (3)



Risk degree of piping

Conclusions from this section

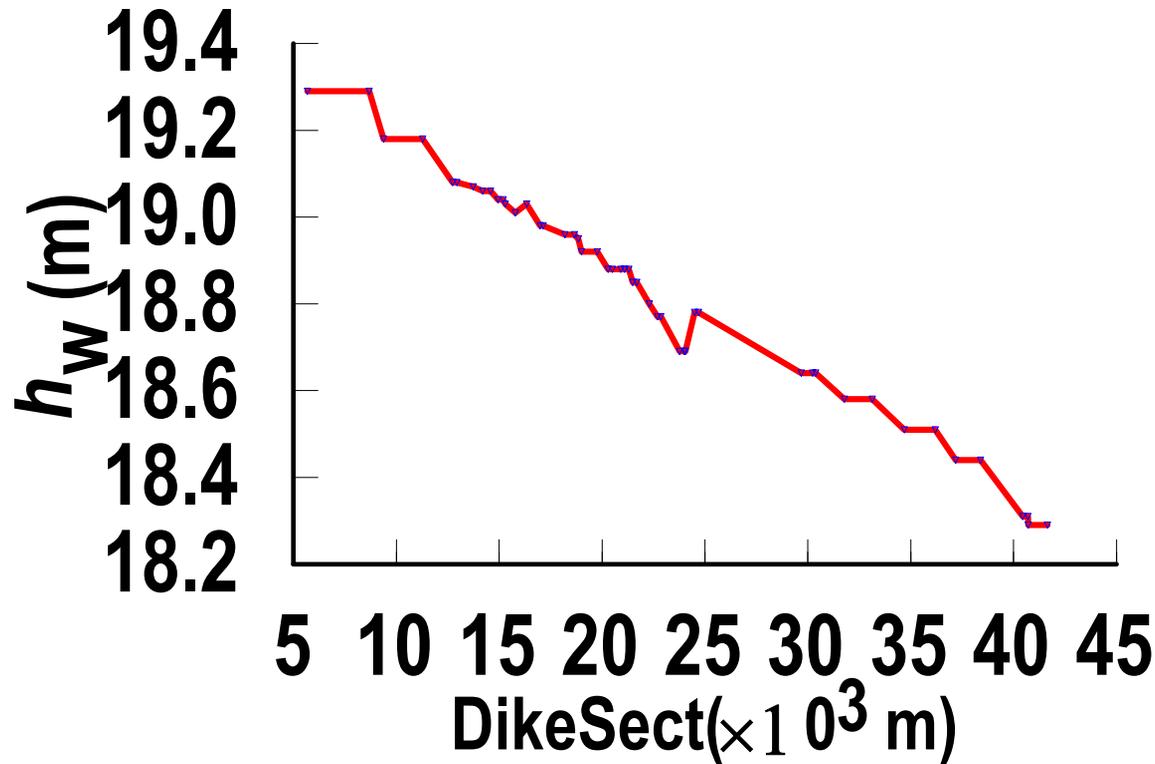
- 1) Multi-evaluation index for safety of more than fifty dike subsections can meet the design standard, and the risk degree of potential damage is considerable little, especial for seepage instability.
- 2) The total risk of upstream sliding for whole dike section in design water level is 0.696×10^{-2} , yet it is 0.702×10^{-2} in first water level (almost equal to the crest height of dike). The risk degree decrease by around 0.02% with a decreasing of water level for each 0.5m.
- 3) For seepage instability, the risk degree of design water level is 2.94×10^{-44} , and it is 2.08×10^{-39} in first water level. It can be seen that the risk degree reduce by 10 to 100 times when the water level is decreased by 0.5m.



Distribution of evaluation indexes for a whole dike at different water levels

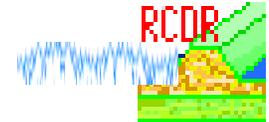
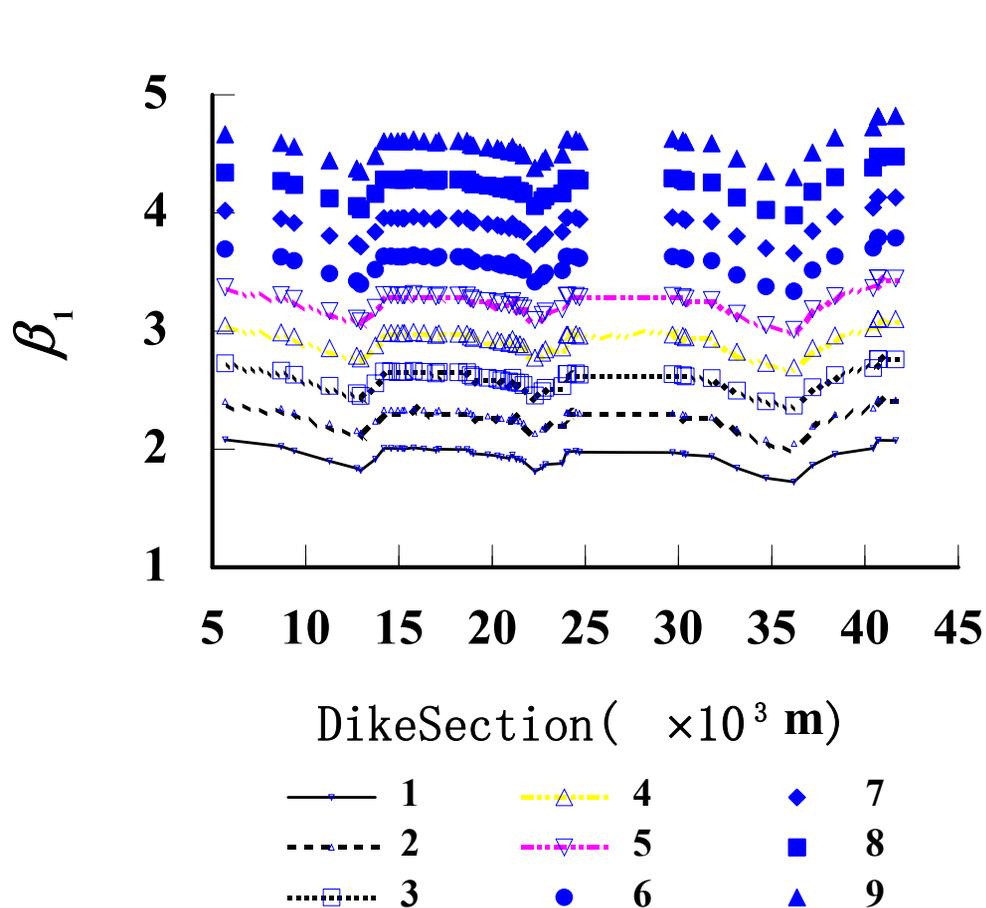
Distribution of evaluation indexes

---Design water level (WL)



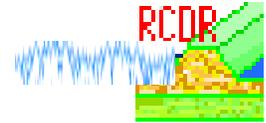
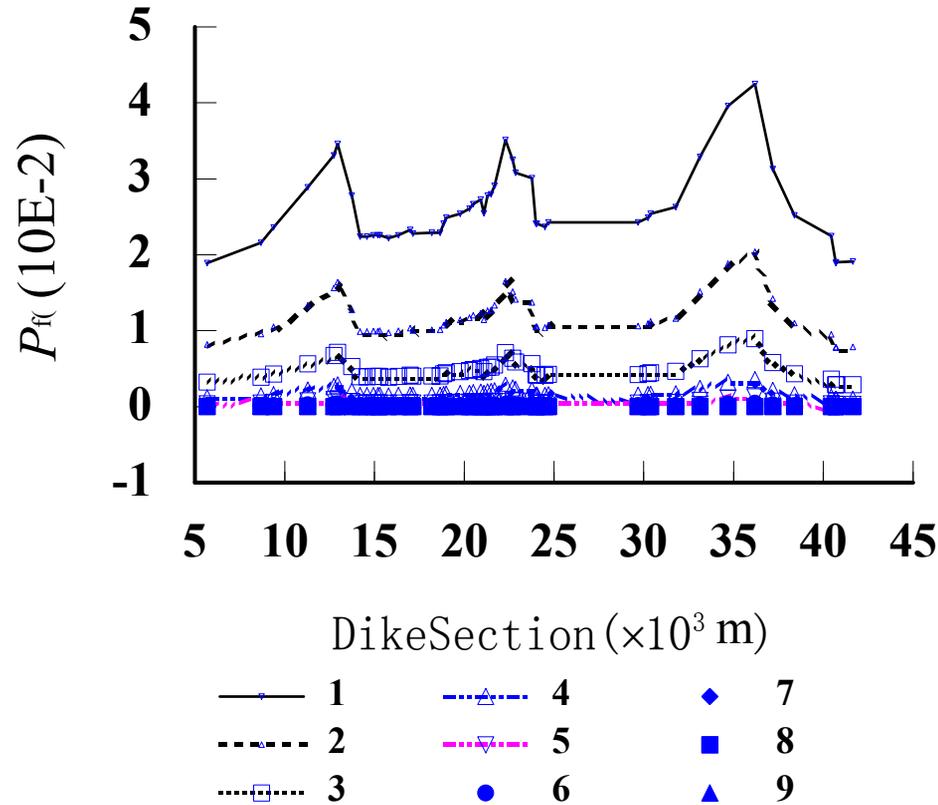
Distribution of Design Water level for whole dike section

Distribution of evaluation indexes ---overtopping (1)



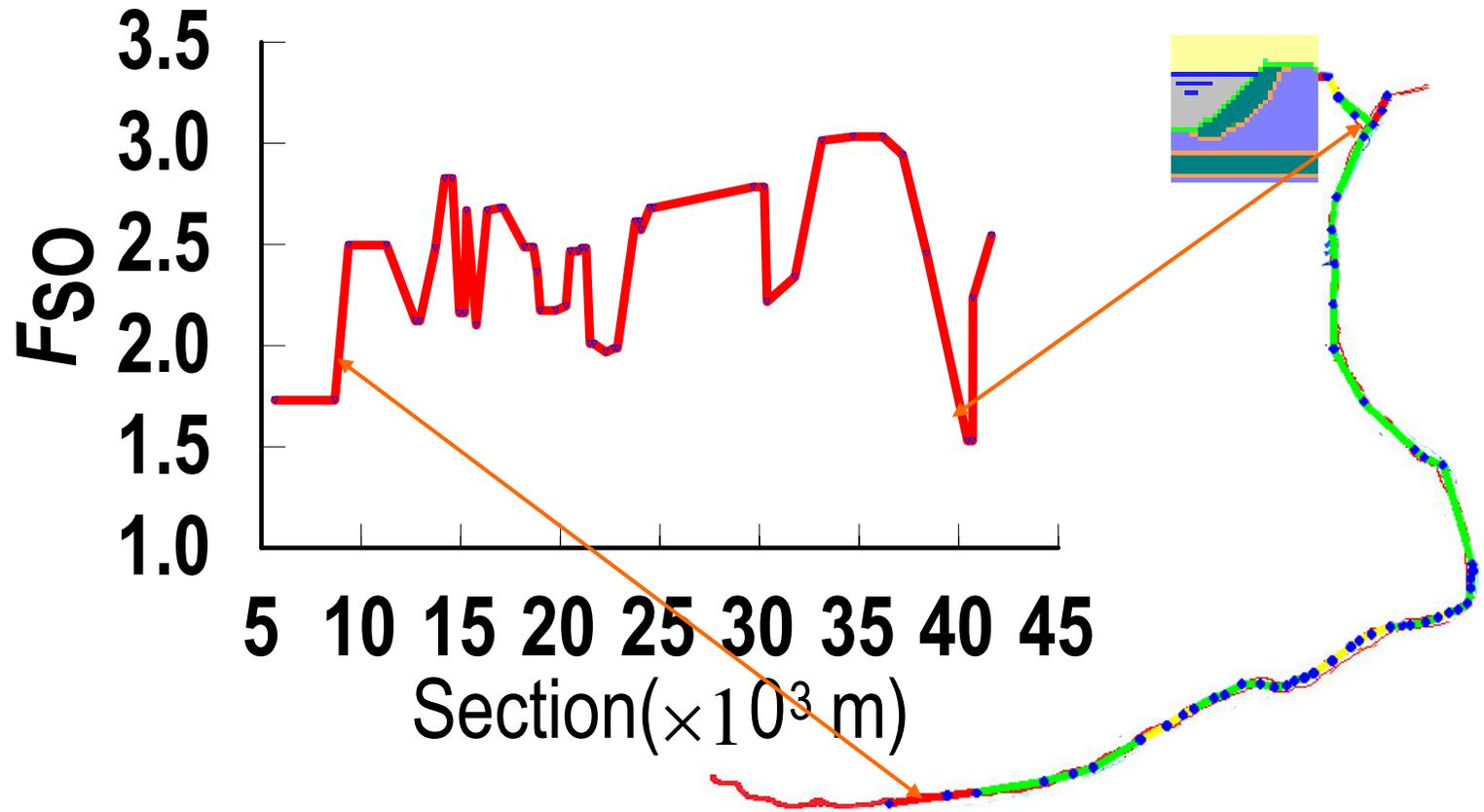
Distribution of Reliability index against overtopping at different WL

Distribution of evaluation indexes ---overtopping (2)



Probability of failure of overtopping

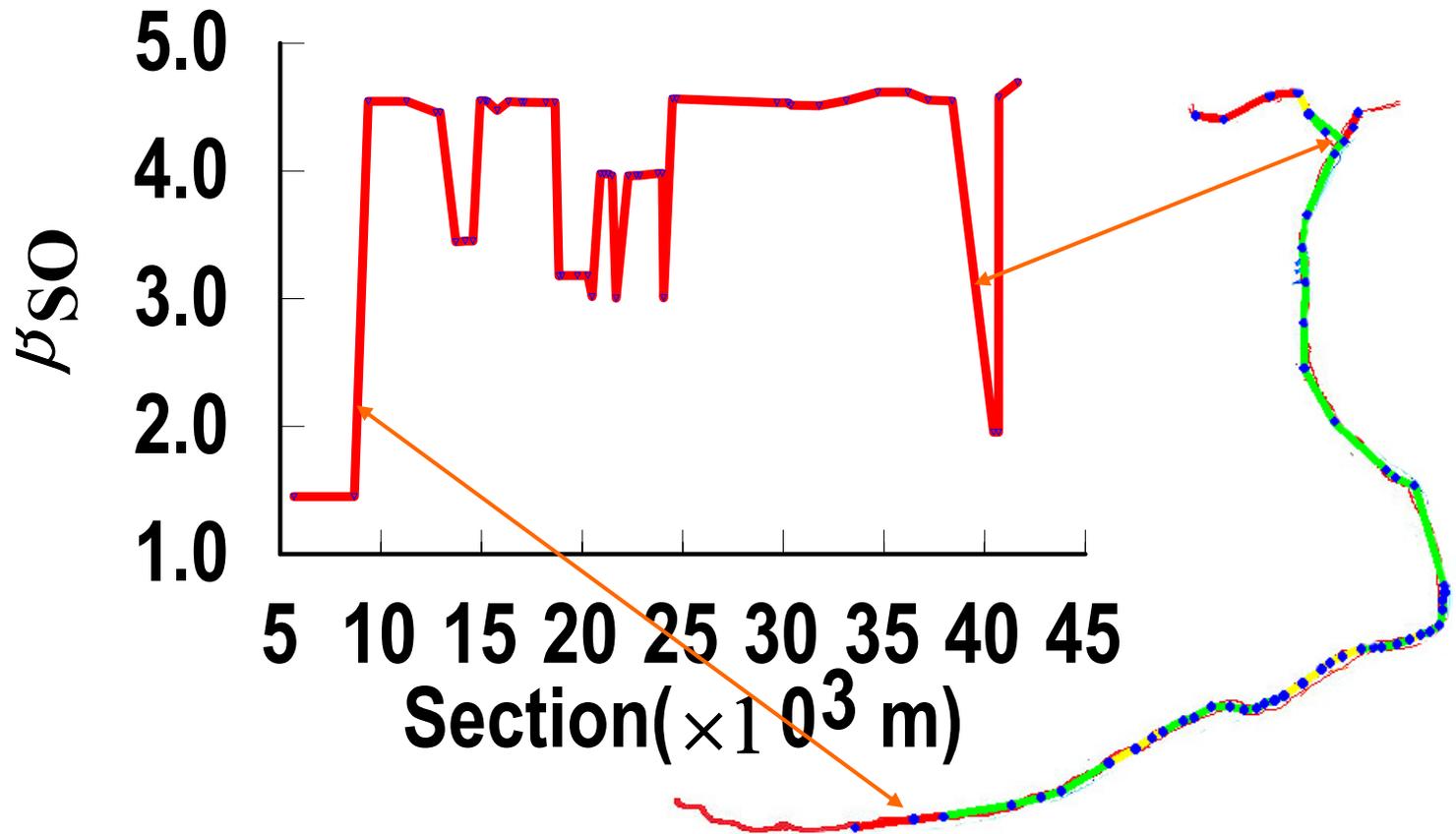
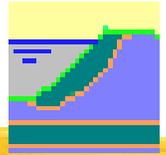
Distribution of evaluation indexes ---outer slope stability (1)



Distribution of safety factor of outer slope stability

Distribution of evaluation indexes

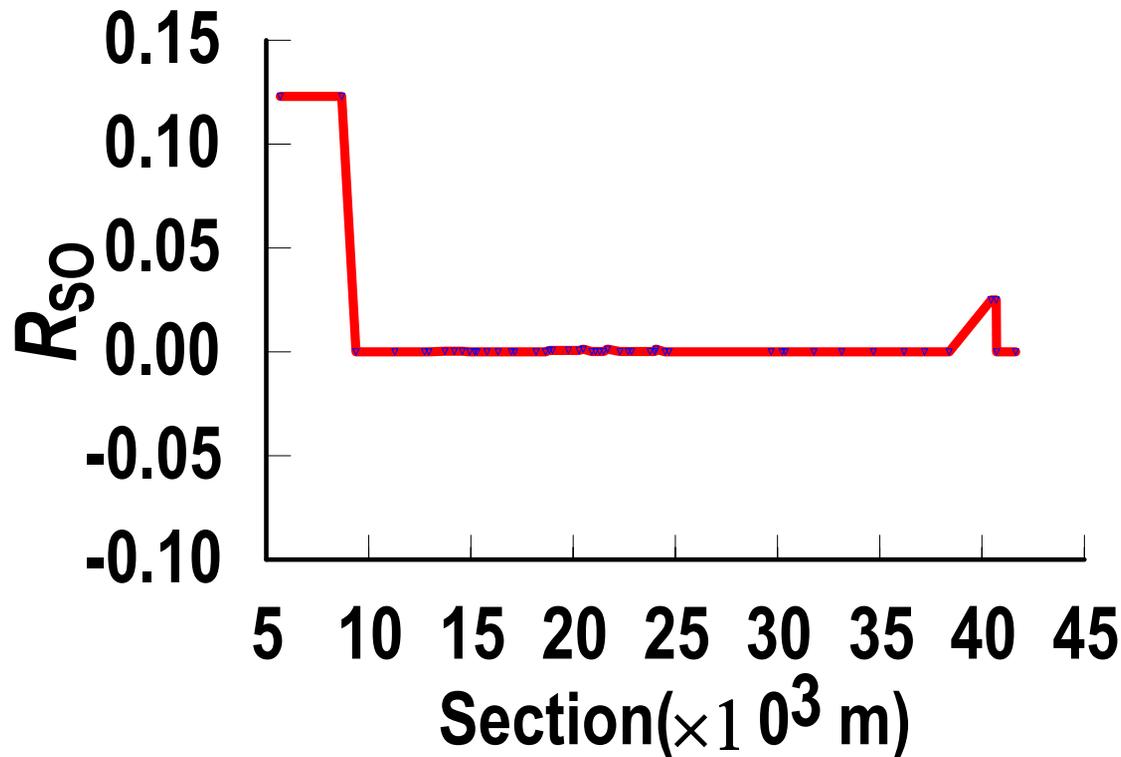
---outer slope stability (2)



reliability index of outer slope stability

Distribution of evaluation indexes

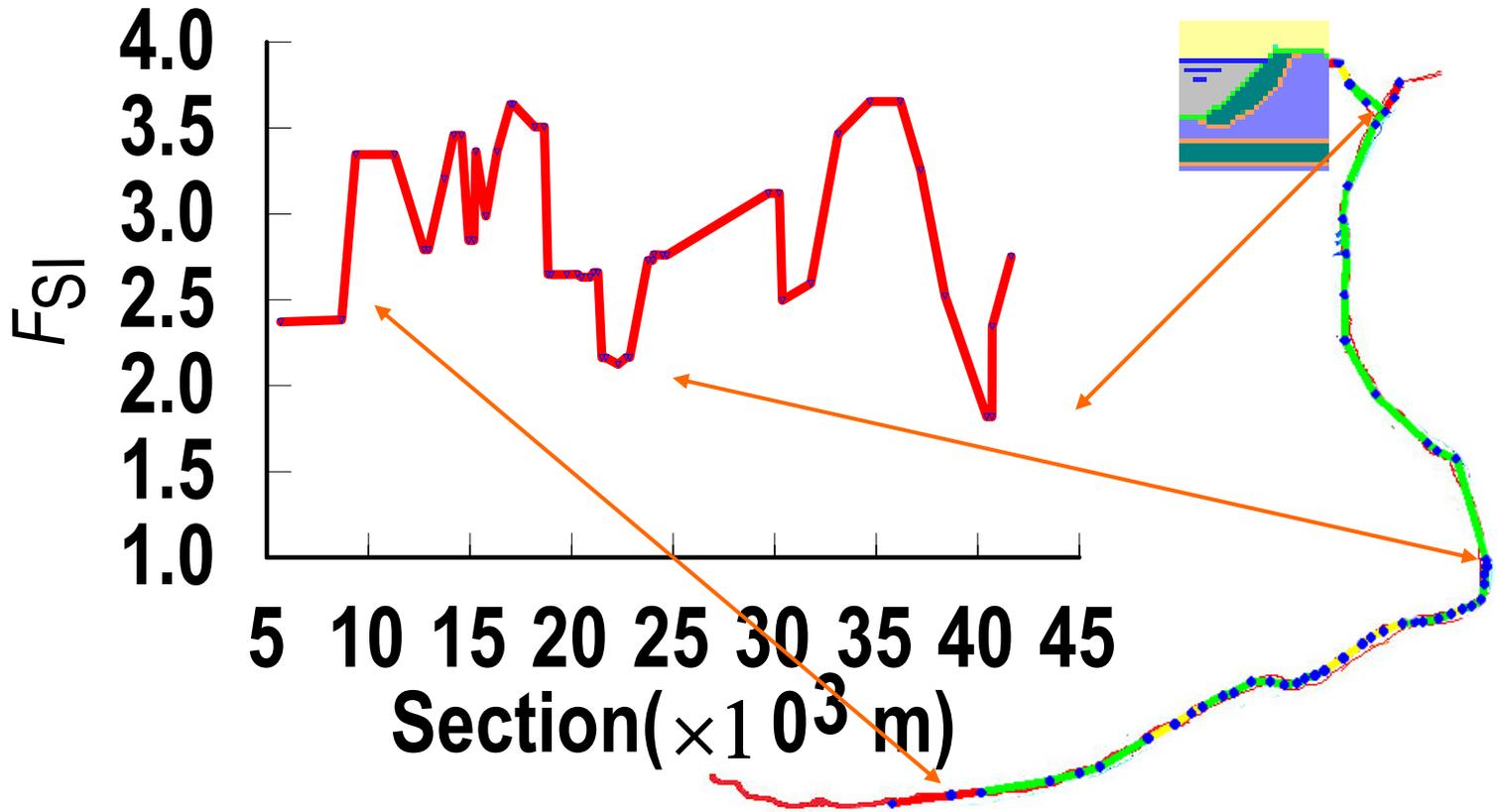
---outer slope stability (3)



Distribution of risk degree of outer slope stability

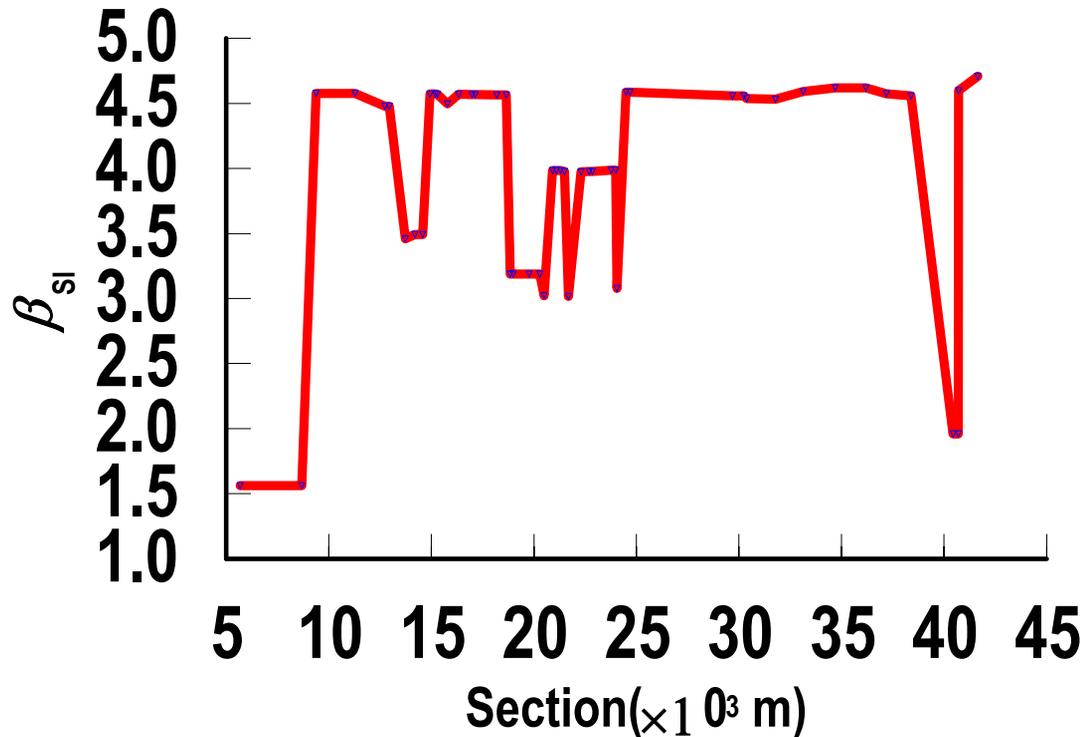
Distribution of evaluation indexes

---inner slope stability (1)



safety factor of inner slope stability

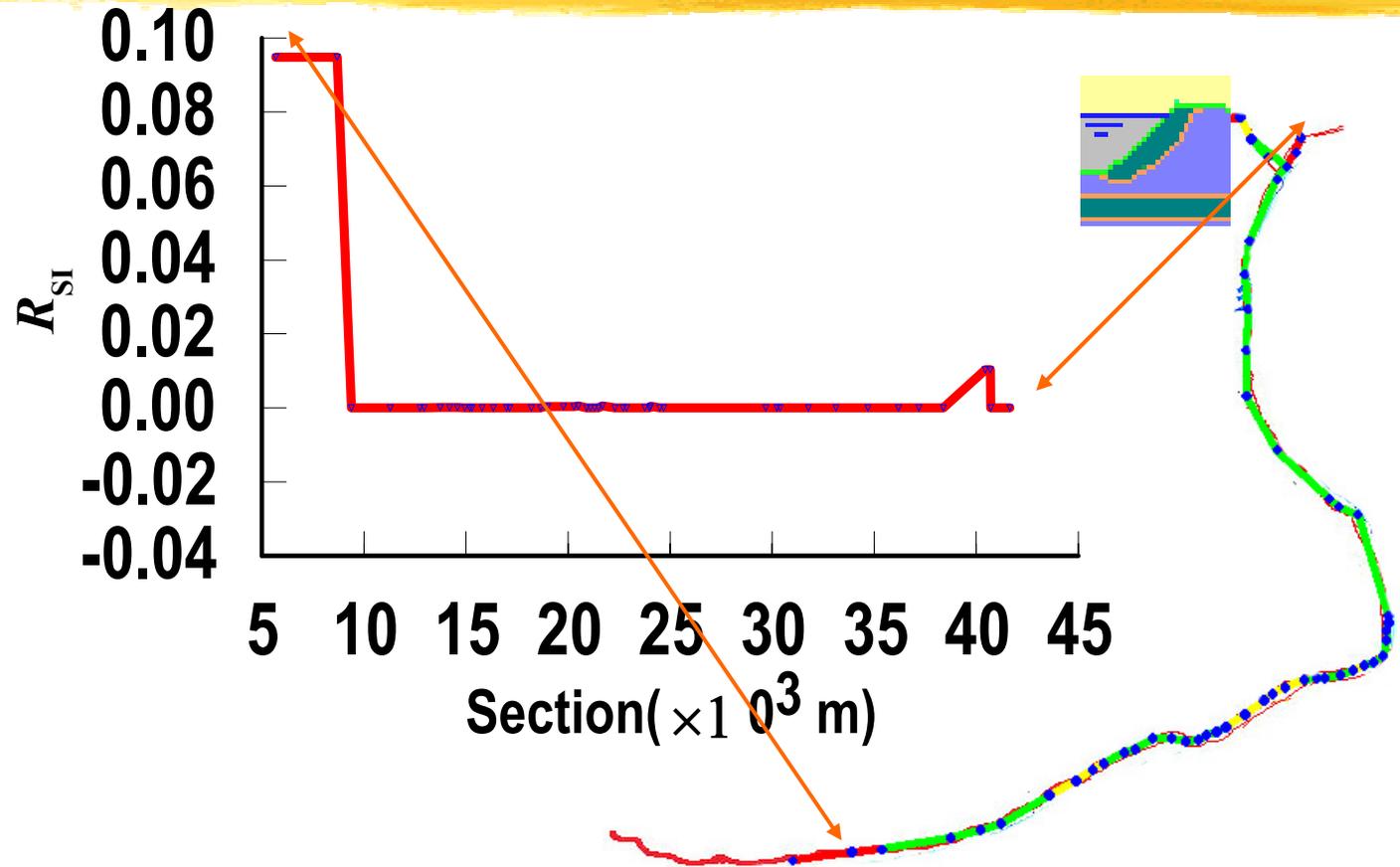
Distribution of evaluation indexes ---inner slope stability (2)



reliability index of inner slope stability

Distribution of evaluation indexes

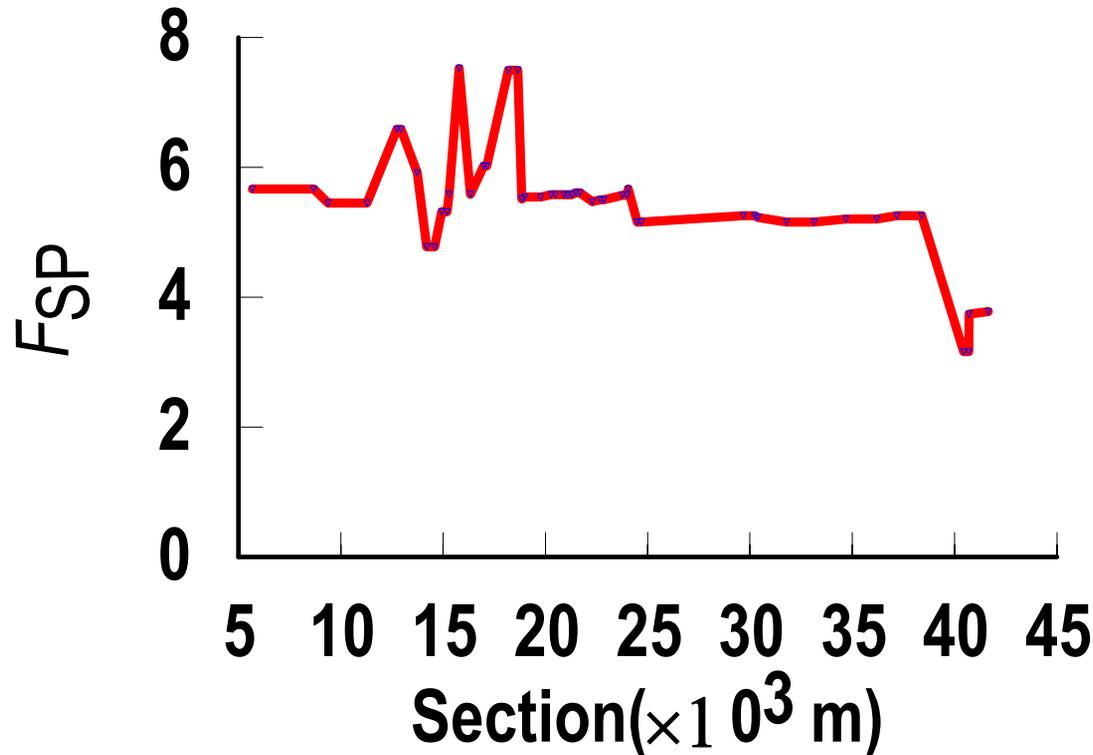
---inner slope stability (3)



Risk degree of inner slope stability

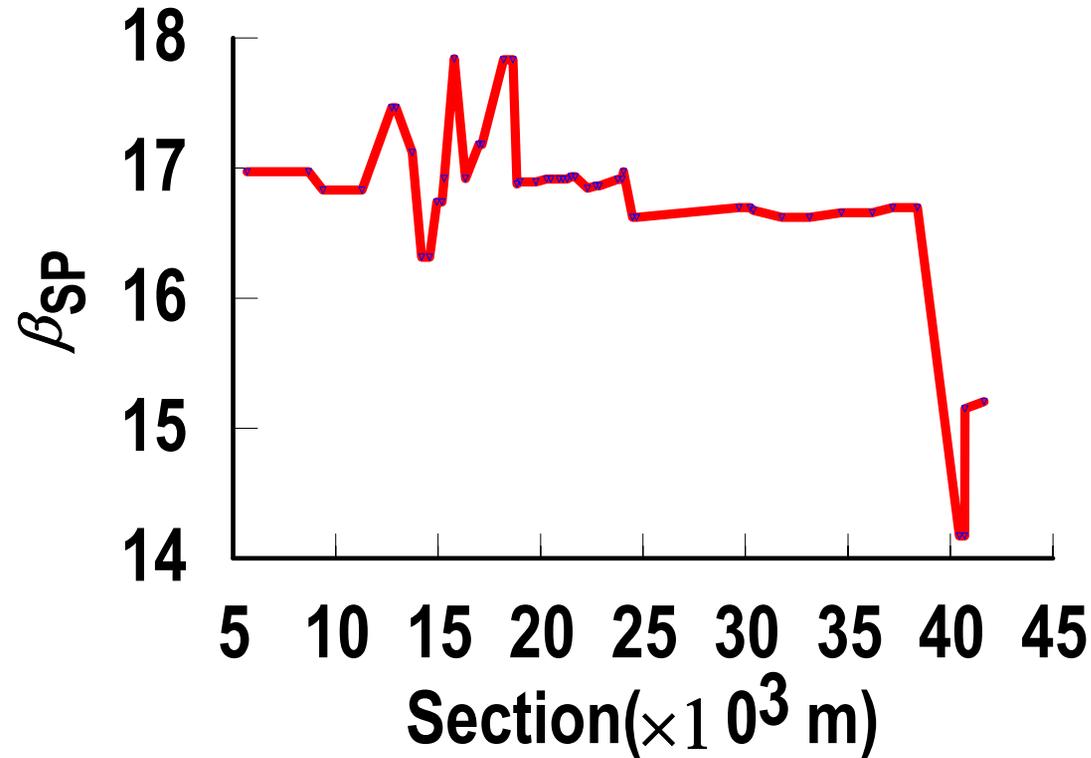
Distribution of evaluation indexes

---piping (1)



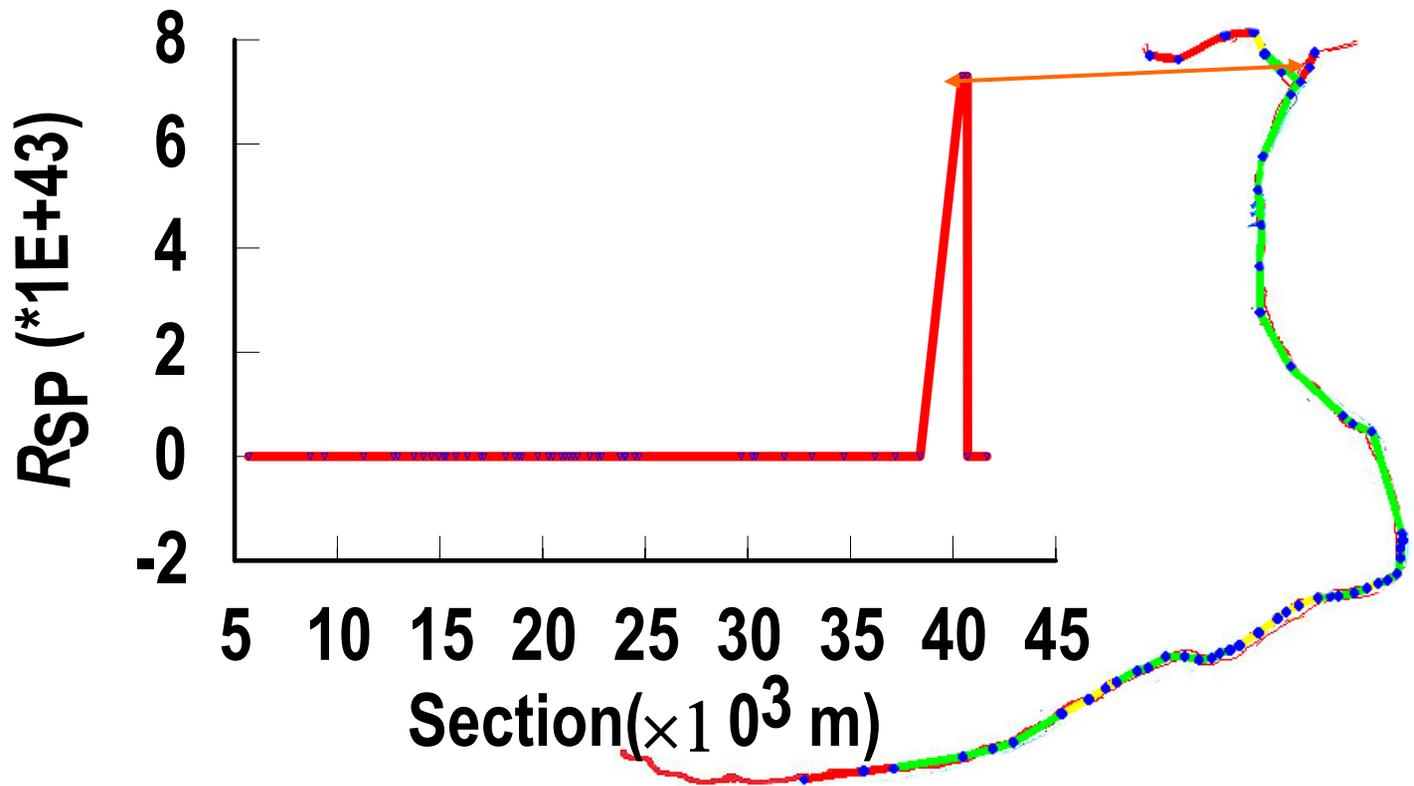
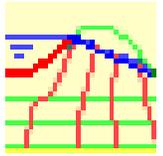
safety factor against piping

Distribution of evaluation indexes ---piping (2)



reliability index against piping

Distribution of evaluation indexes ---piping (3)



risk degree of piping

Coming up next.....



Combination of the failure probabilities

Combination of failure probabilities

For sections:

- can be expressed by the formula of a series system:

$$P\{\text{section fails}\} = P\{Z_1 < 0 \text{ or } Z_2 < 0 \text{ or } Z_3 < 0 \text{ or } Z_4 < 0\}$$

- The fundamental lower and upper bounds are given by:

$$\max_i P\{Z_i < 0\} \leq P\{\text{section fails}\} \leq \sum_{i=1}^4 P\{Z_i < 0\}$$

For the whole dike:

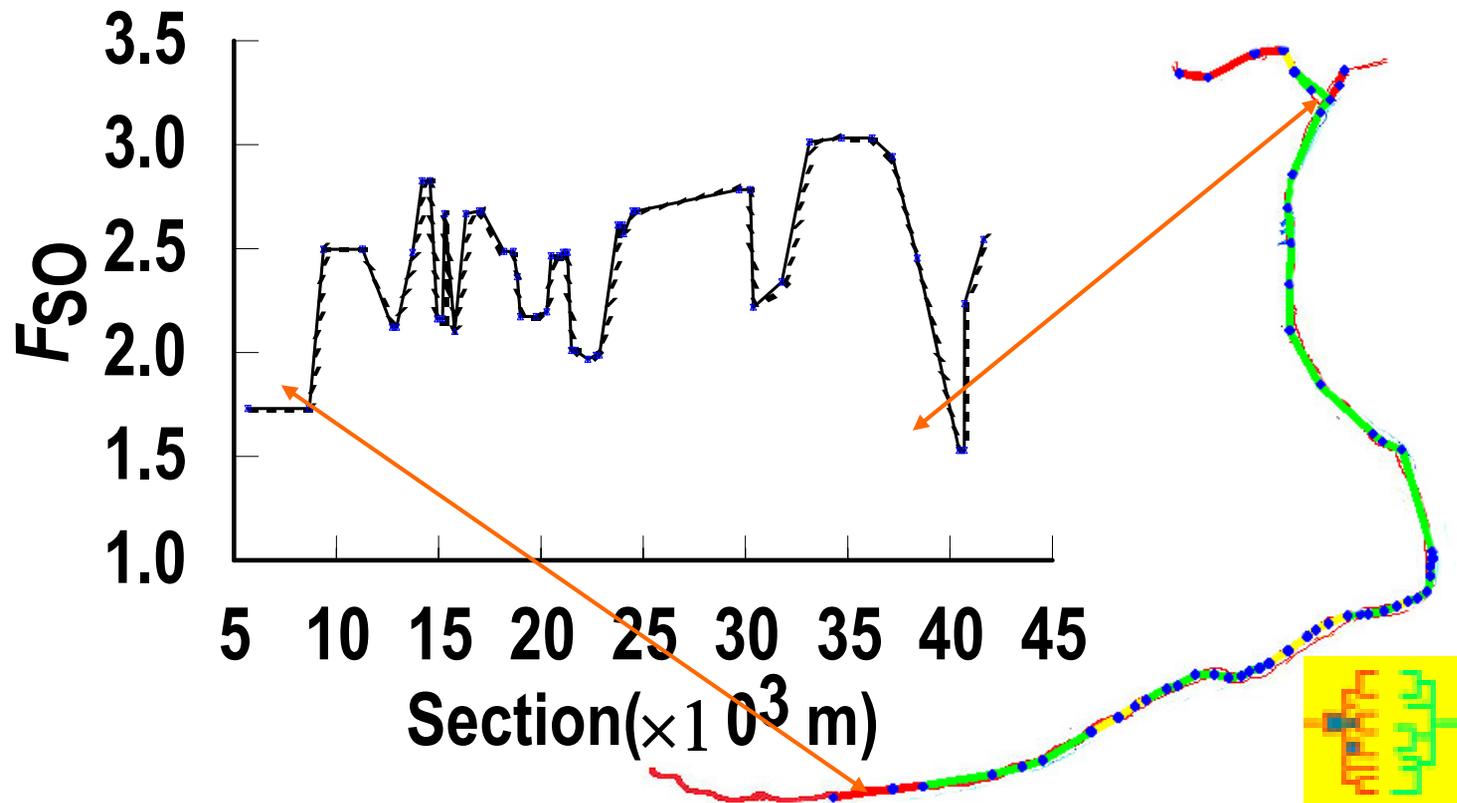
- A series system with 55 consecutive segments:

$$P\{\text{dike fails}\} = P\{Z_1 < 0 \text{ or } Z_2 < 0 \text{ or } Z_3 < 0 \text{ or } Z_4 < 0 \text{ or } \dots \text{ or } Z_{55} < 0\}$$

- The fundamental lower and upper bounds:

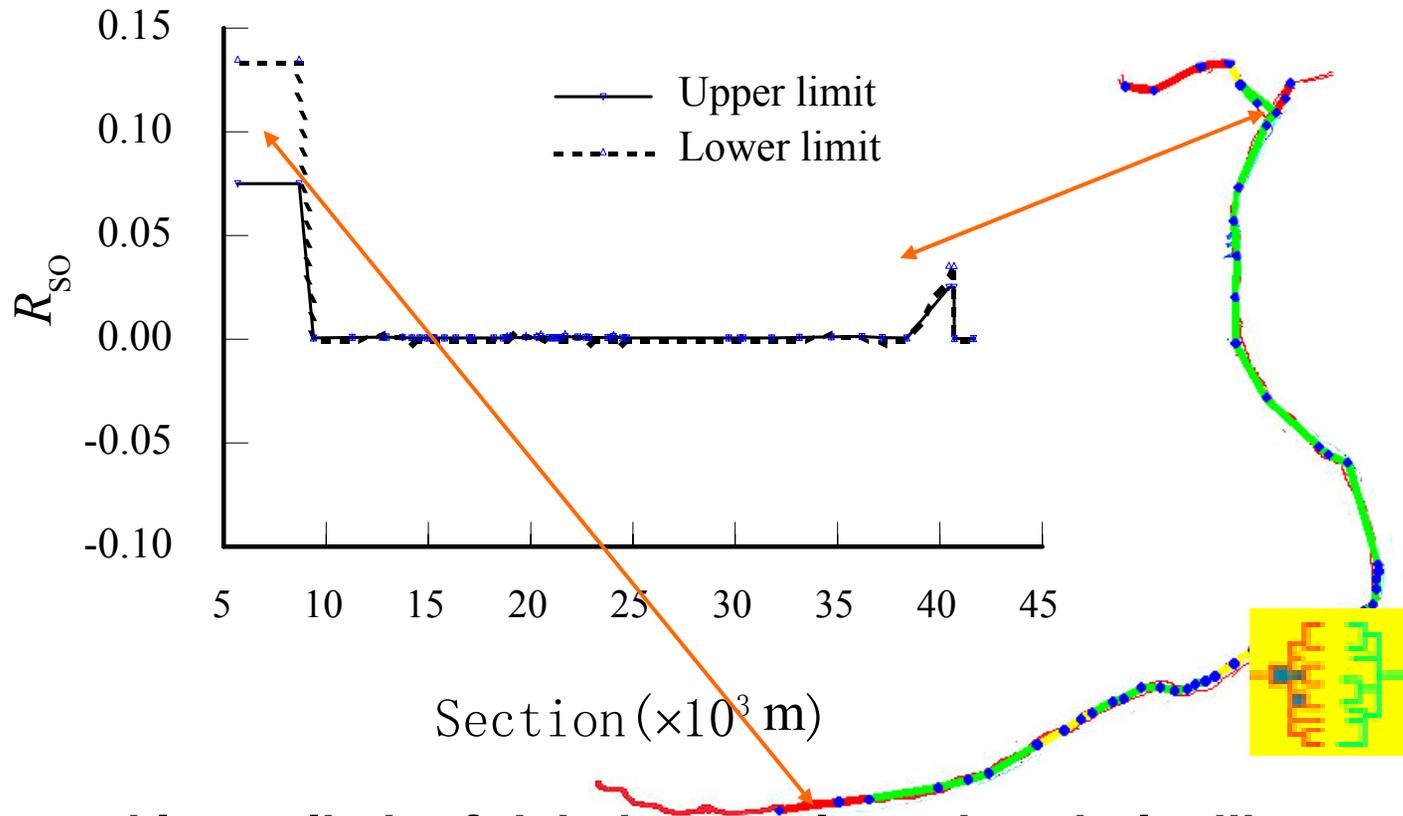
$$\max_i P\{Z_i < 0\} \leq P\{\text{dike fails}\} \leq \sum_{i=1}^{55} P\{Z_i < 0\}$$

Combination of the failure probabilities---safety factor



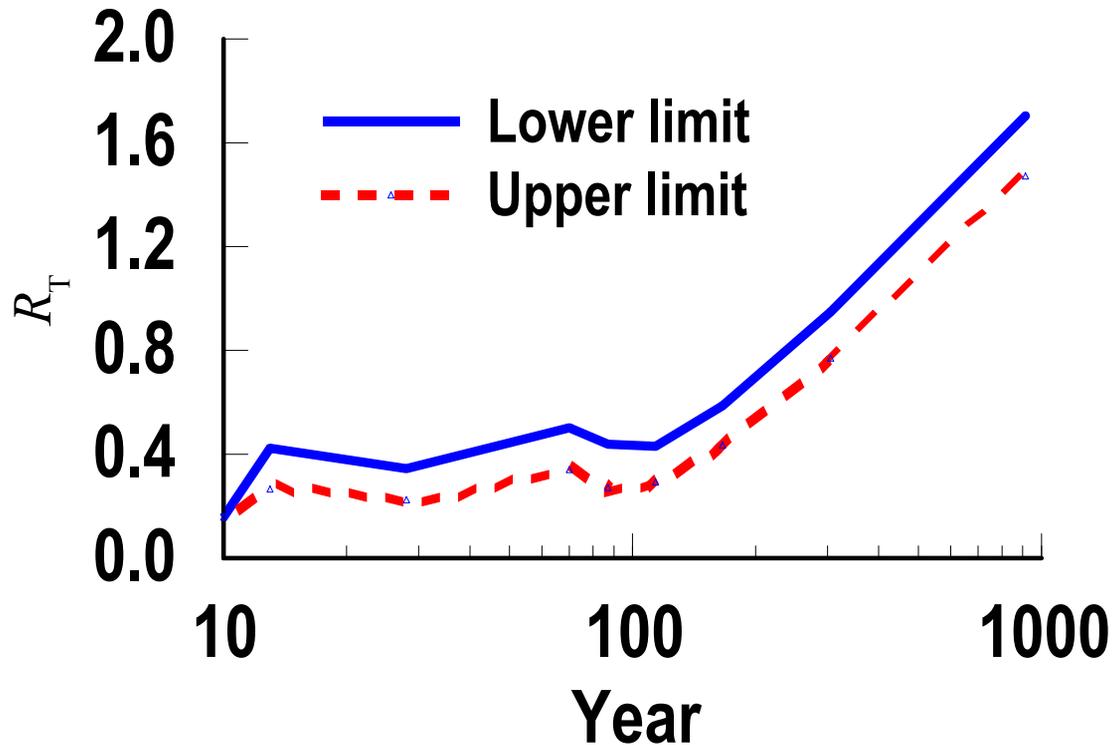
Distribution of the upper and lower limit of safety factor

Combination of the failure probabilities---risk degree



the upper and lower limit of risk degree along the whole dike

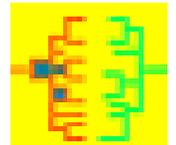
Combination of the failure probabilities---relation



The relation of upper and lower limit of risk degree with return period

Overall failure probabilities of the dike

Rank	WL	Return period of WL (years)	Overall failure probability	
			Lower boundary	Upper boundary
1	21.19	914	1.7042	1.4716
2	20.79	305	0.9474	0.7702
3	20.29	166	0.5862	0.4347
4	19.79	114	0.4306	0.2924
5	19.29	87	0.4382	0.2718
6	18.79	70	0.5017	0.3405
7	18.29	28	0.3450	0.2246
8	17.79	13	0.4232	0.2654
9	17.29	10	0.1578	0.1577



Conclusions from this section



- 1) **The weakest point can be found: the reliability method provides estimates of the probability of failure of the flood defence system, identifies weak system components and identifies which parameters contribute most to the probability of failure.**
- 2) **Section 05+687 and M0+000 turn out to be the weakest link**

Coming up next.....



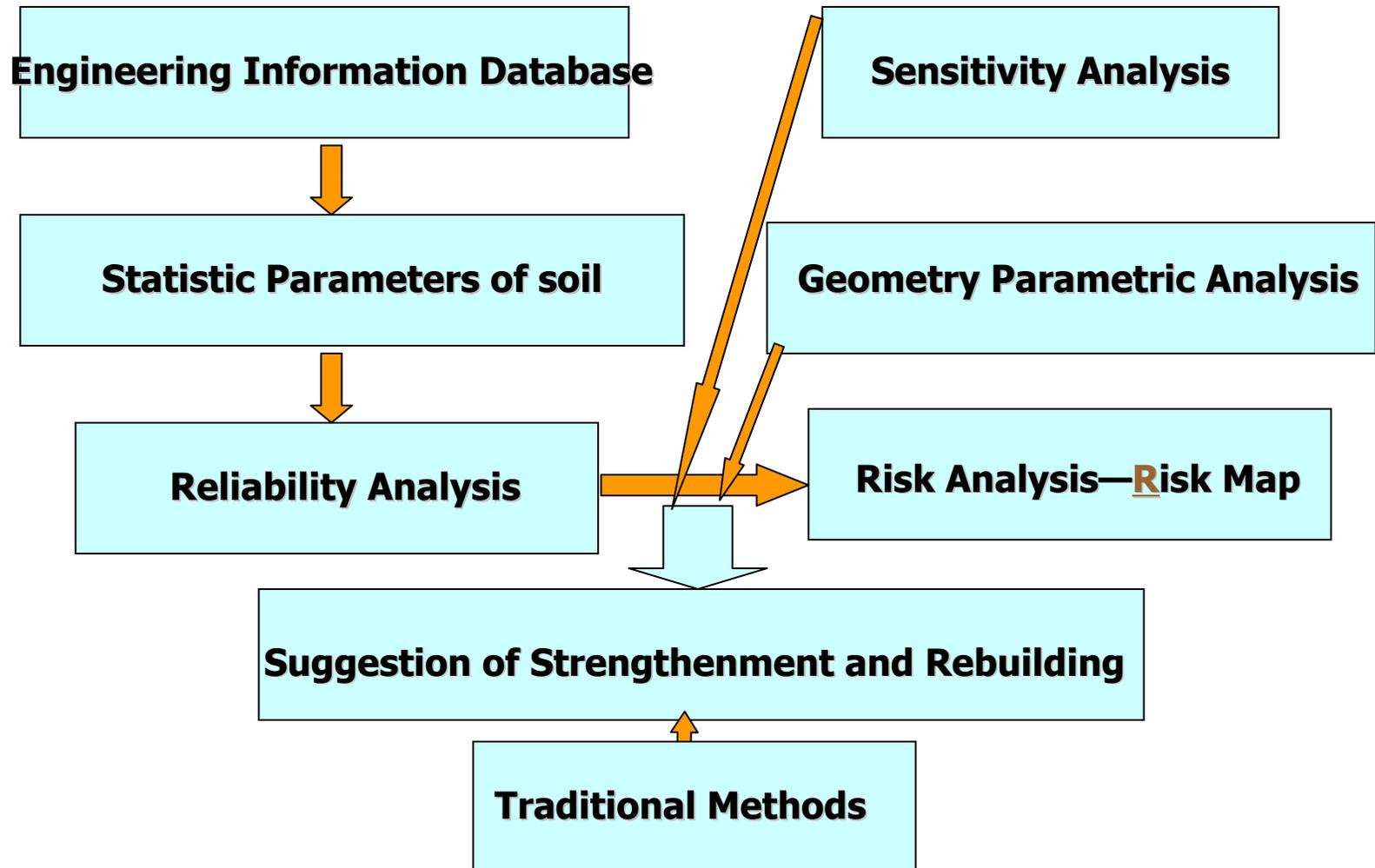
- ⌘ 1 Object of this study
- ⌘ 2 Structural risk analysis method
- ⌘ 3 Safety evaluation on individual dike section
- ⌘ 4 Safety evaluation on whole dike section
- ⌘ **5 software SADSS**
- ⌘ 6 Some conclusions



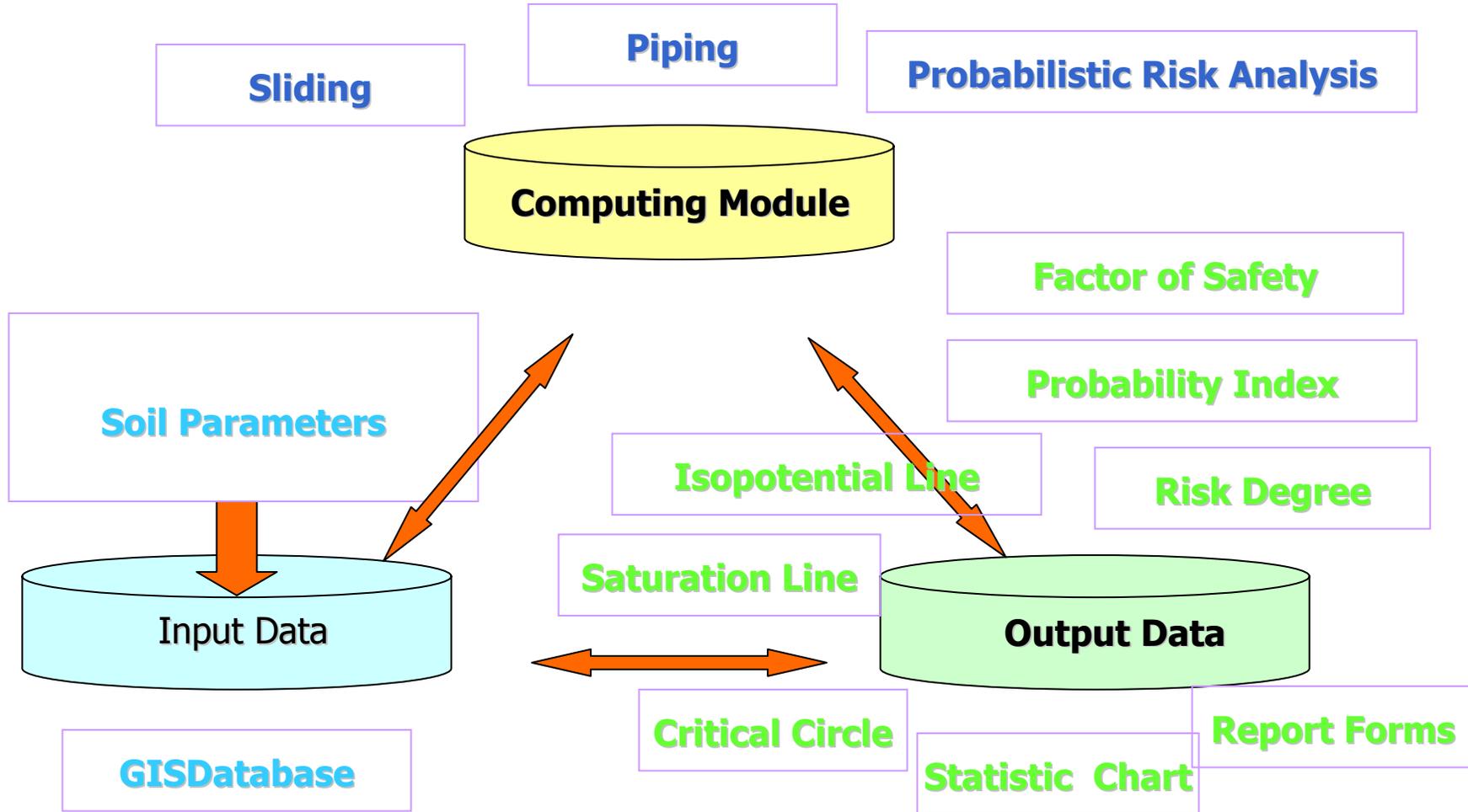
**software system
on whole dike section**

SADSS

Diagram of Risk Analysis Process



Functional Modulus

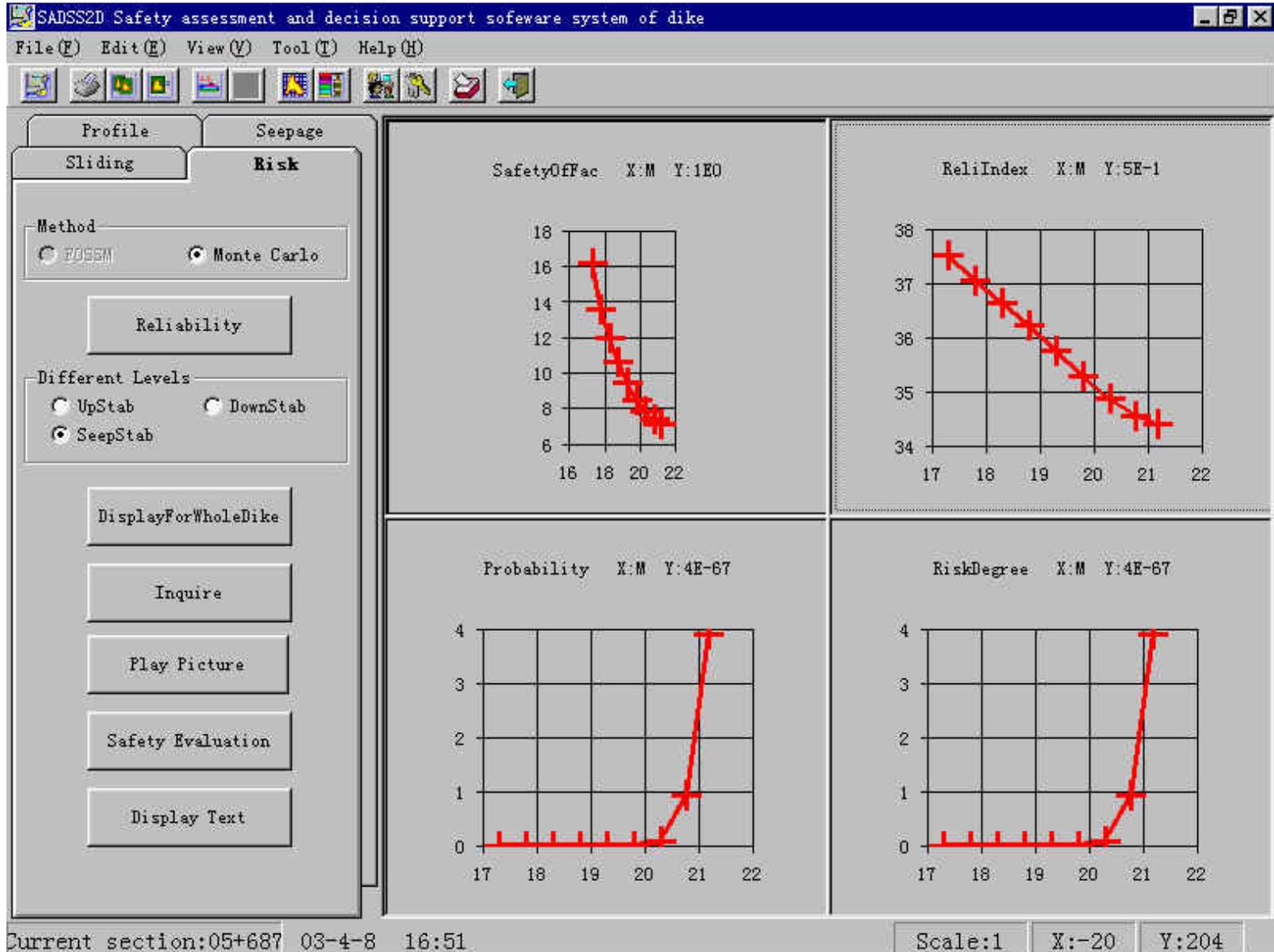


安庆全堤段风险分析及安全评估成果展现



东至县

SADSS---Various evaluation index



For Each Dike Subsection



DisplayMode		Unsafe BasicSa Safety
<input type="radio"/> Numeric	<input checked="" type="radio"/> Graded	
DisplayOption		
<input checked="" type="radio"/> UpStab	<input checked="" type="radio"/> SafetyF	
<input type="radio"/> DnStab	<input type="radio"/> ReliIndex	
<input type="radio"/> SpStab	<input type="radio"/> RiskDeg	
WLevel		
5		
<p>DesignWLevel</p>		

SADSS---Safety grade and technical standard



Technical Criterion of safety ev... ✕

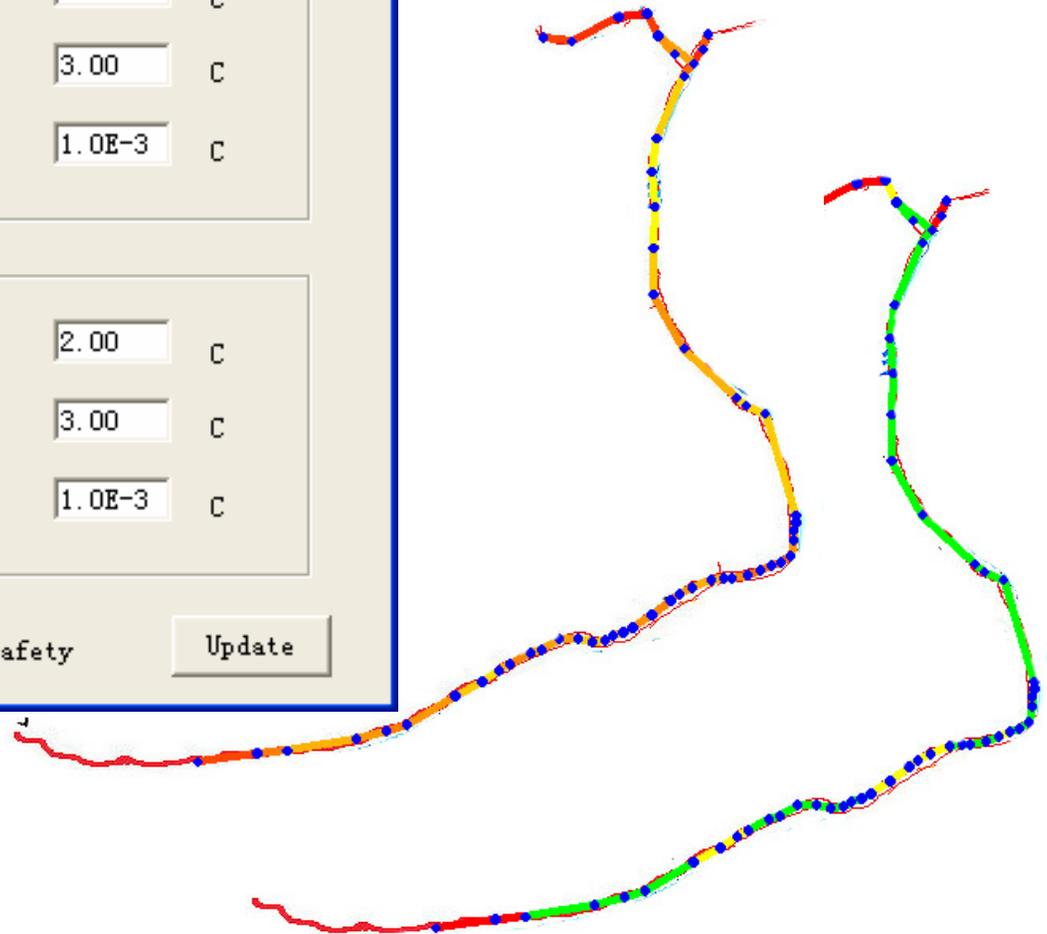
Sliding

SafetyFac	A	<input type="text" value="1.50"/>	B	<input type="text" value="1.30"/>	C
RelibIndex	A	<input type="text" value="3.80"/>	B	<input type="text" value="3.00"/>	C
RiskDegree	A	<input type="text" value="1.0E-5"/>	B	<input type="text" value="1.0E-3"/>	C

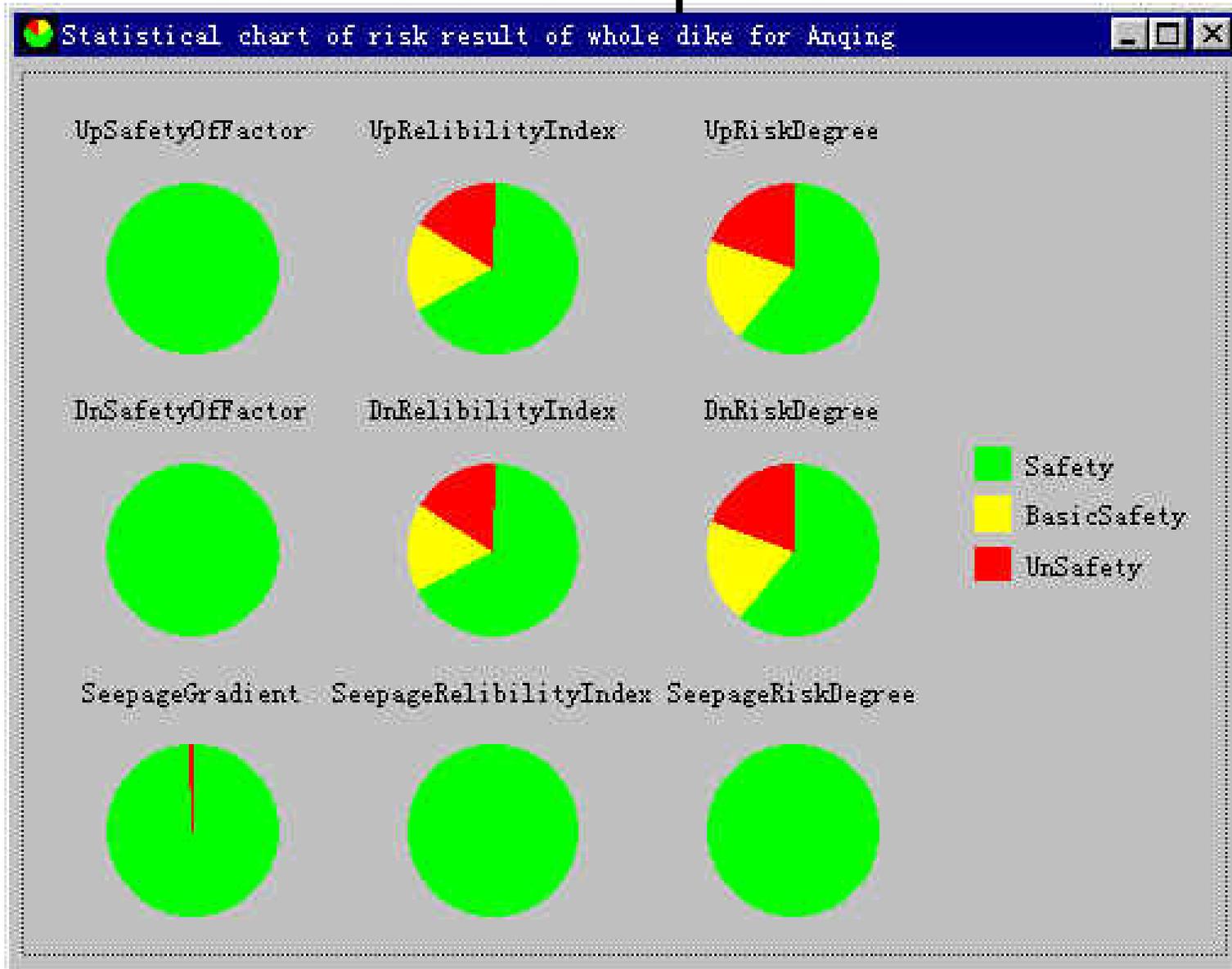
Seepage

SafetyFac	A	<input type="text" value="3.00"/>	B	<input type="text" value="2.00"/>	C
RelibIndex	A	<input type="text" value="3.80"/>	B	<input type="text" value="3.00"/>	C
RiskDegree	A	<input type="text" value="1.0E-5"/>	B	<input type="text" value="1.0E-3"/>	C

Note: A: Safety B: Basic Safety C 级: Unsafety Update



SADSS---Statistic pie chart



SADSS---Statistic report forms



工程风险评估简明报表

缩放 100%

工程风险评估简明报表

水位级数: 1

上游稳定	安全系数			可靠度指标			风险度		
	A级	B级	C级	A级	B级	C级	A级	B级	C级
堤段长度 /M	40405	0	800	29765	5970	5470	28315	8220	4670
百分比 /%	98.06	0	1.94	72.24	14.49	13.28	68.72	19.95	11.33

下游稳定	安全系数			可靠度指标			风险度		
	A级	B级	C级	A级	B级	C级	A级	B级	C级
堤段长度 /M	41205	0	0	29065	6670	5470	28865	7670	4670
百分比 /%	100	0	0	70.54	16.19	13.28	70.05	18.61	11.33

渗流稳定	安全系数			可靠度指标			风险度		
	A级	B级	C级	A级	B级	C级	A级	B级	C级
等级类型	A级	B级	C级	A级	B级	C级	A级	B级	C级

页: 1



SADSS---Data inquiry

Inquirement of results for whole dike

Beginning: 05+687
End: M5+248
WLevel: 1

DisplayOption:
 UpStab SafetyF
 DnStab ReliIndex
 SpStab RiskDeg

EvalGrade: A

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Section	UpReliIndex	UpRisk	DnSafety	DnReliIndex	DnRisk	SpSafety	SpReliIndex	SpRisk
30+387	4.5124	.0000031539	3.2308	4.5336	.000285	.1358	17.123	4.9276E-66
31+787	4.5088	.0000032076	3.3608	4.5285	.000292	.1349	17.1421	3.5505E-66
33+137	4.5484	.0000026591	4.4841	4.5879	.000220	.1349	17.1421	3.5505E-66
34+687	4.5932	.0000021471	4.7303	4.6162	.000192	.1339	17.1632	2.4657E-66
36+187	4.5932	.0000021471	4.7303	4.6162	.000192	.1339	17.1632	2.4657E-66
37+187	4.5532	.000002599	4.2066	4.5698	.000240	.1356	17.1272	4.5816E-66
38+387	4.5451	.0000027018	3.2548	4.5509	.000262	.1356	17.1272	4.5816E-66
40+439	1.9519	.025109	1.8072	1.9538	.024995	.2029	15.7014	7.2857E-56
40+687	1.9519	.025109	1.8072	1.9538	.024995	.2029	15.7014	7.2857E-56
40+709	4.5766	.0000023253	3.0364	4.5909	.000217	.1703	16.3921	1.0734E-60
41+644	4.6907	.0000013398	3.5622	4.7029	.000126	.171	16.3773	1.3698E-60
M0+000	3.1498	.00080521	2.5818	3.5694	.001763	.1767	16.2565	9.8991E-60
M0+948	2.8221	.0023506	2.6095	2.8462	.002180	.1068	17.7374	1.0633E-70
M1+748	1.7903	.03617	2.1976	1.8001	.035403	.1249	17.3539	9.0789E-68
M2+448	2.9302	.0016693	2.4917	2.9474	.001579	.1496	16.8306	7.1718E-64
M3+548	3.2063	.00066255	4.1292	3.1008	.009511	.0779	18.3496	1.6375E-75
M5+248	3.9659	.000036039	2.8028	4.523	.000295	.1151	17.5615	2.3921E-69
Maximum	4.6907	0.0414	4.7303	4.7029	0.1431	0.2029	18.3496	0.0000
Minimum	1.7282	0.0000	1.8072	1.0572	0.0000	0.0779	15.7014	0.0000
MeanVal	3.8395	0.0033	3.5649	3.8469	0.0070	0.1365	17.1090	0.0000
Deviation	0.8647	0.0100	0.7337	0.9386	0.0275	0.0216	0.4572	0.0000

SADSS---system demonstration



Demonstration of results

Photo/Mesh/Profile/Seepage/Stability

Demonstration of System function

Conclusions

- 1) As we known, the deterministic method has been using in the active code of designing of dikes and revetments. In this case, it is a difficult task to transform and extend the new method. It is no doubt that the non-deterministic associated with the deterministic method will be rather scientific methods and means to assess the safety of dike, at least in recent years.**
- 2) Probabilistic risk analysis is the up-to-date research field of safety assessment techniques of dike. Probability techniques are rational means to quantity and incorporate uncertainty into safety analysis and design.**
- 3) The development of the software system for safety management and risk assessment of dike is helpful to the design, maintenance, safety evolution of river levee and revetment in China.**

Areas for Further Study



- ⌘ **Cost-benefit analyses** in a probabilistic framework should be performed in the future, for the proposed existing dike improvement
- ⌘ Shortcoming ---**data collect?/!**
- ⌘ Flood duration. Some levees may be subjected to significant water heights for many months. When this occurs, the phreatic surface within the levee will rise, increasing pore pressure and increasing the risk of failure due to under-seepage and slope stability. **Time dependent?**
- ⌘ **Length effect/spatial effect**

谢谢各位同仁

谢谢
光临

Thanks

谢谢
光临



Cooperation

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Acknowledgement





It is still developing---

Welcome you to enjoy this study---

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