WRA 經濟部水利署

國立臺灣大學 氣候天氣災害研究中心
Center for Weather Climate and Disaster Research

The Project of Adaptation Enhancement for Flood Mitigation due to Climate Change: A Case Study of Kaoping River



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Outline

1. Overview
2. The scenarios of hydrological conditions
3. The Impact Assessment of Flood Prevention System of Kaopig River
4. Preliminary Vulnerability and Risk Evaluation
5. Action plan
6. Conclusions

1.Overview

Objective

Origin

Climate change has brought huge impacts to the whole world. Those impacts include:

- Severe floods
- Spatial land change
- change of hydrological conditions
- etc..

Flood-prevention works needs to be re-evaluated

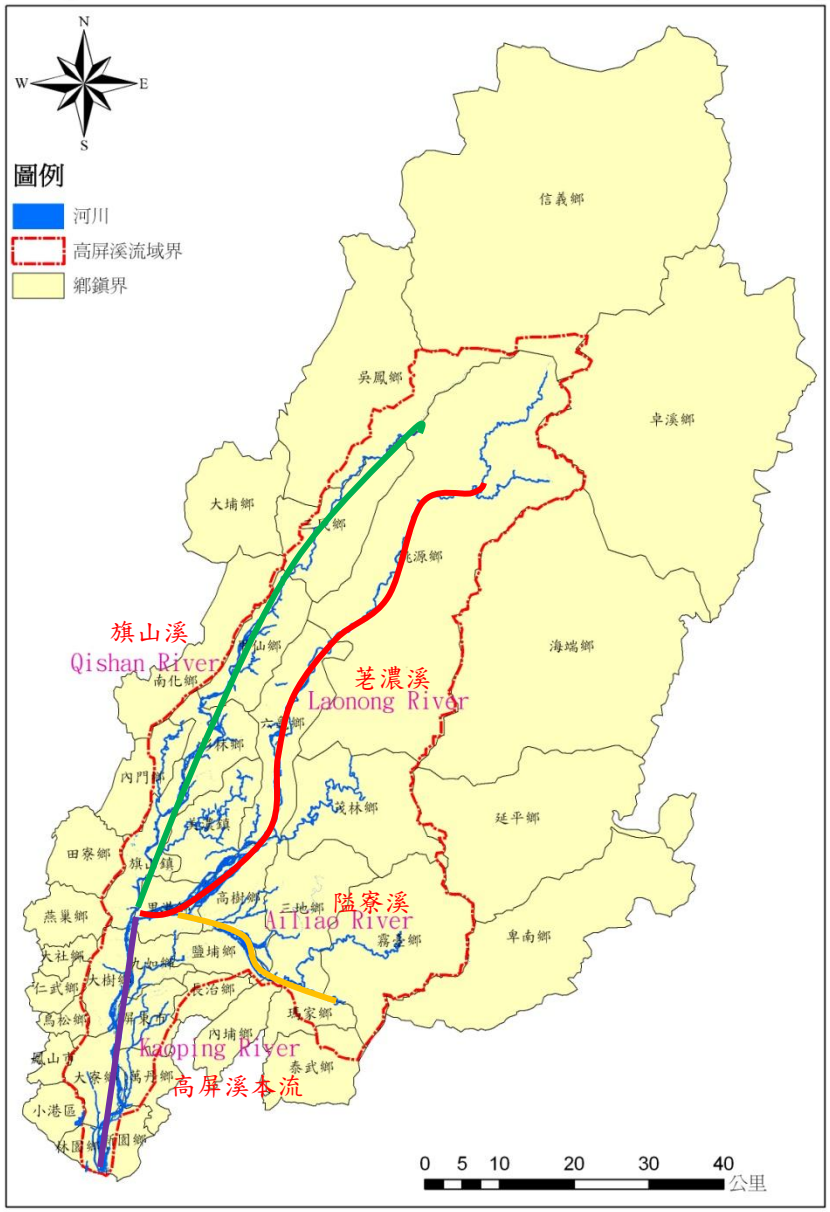
Kaoping weir
高屏溪攔河堰

Shuangyuan Bridge
(雙園大橋)

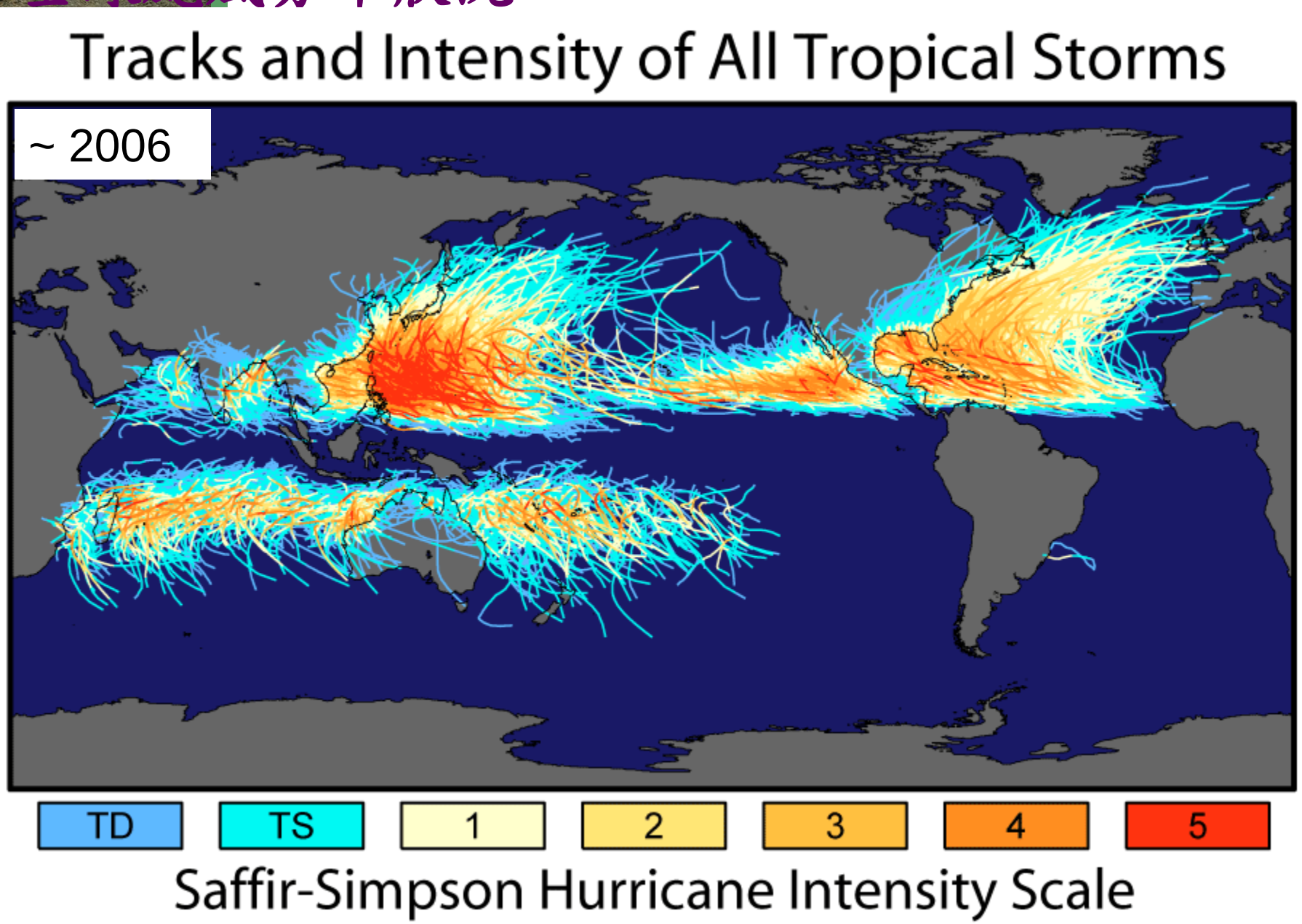
Objective

- Evaluate impacts of flood-prevention works of Kaoping River due to climate change
- Risk evaluation of flood-prevention works
- Strategies and action plans for improving adaptation capacity of flood-prevention works due to climate change

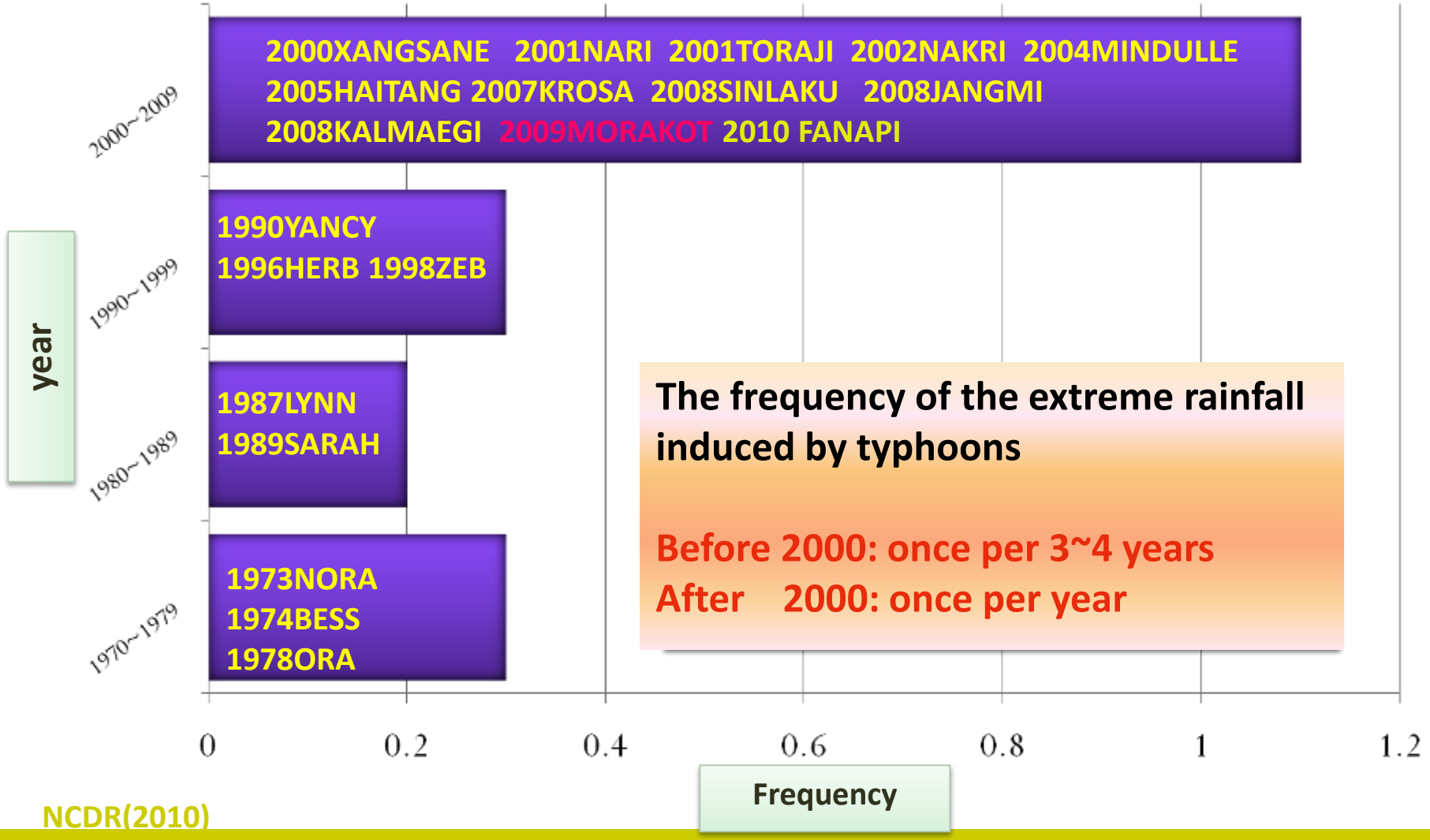
Study Area-Kaoping River



全球颱風分布狀況


Tracks and Intensity of All Tropical Storms
~ 2006
TD
TS
1
2
3
4
5
Saffir-Simpson Hurricane Intensity Scale

Frequency of the extreme rainfall induced by typhoons (the top 20 of the rainfall index between 1970 and 2009)

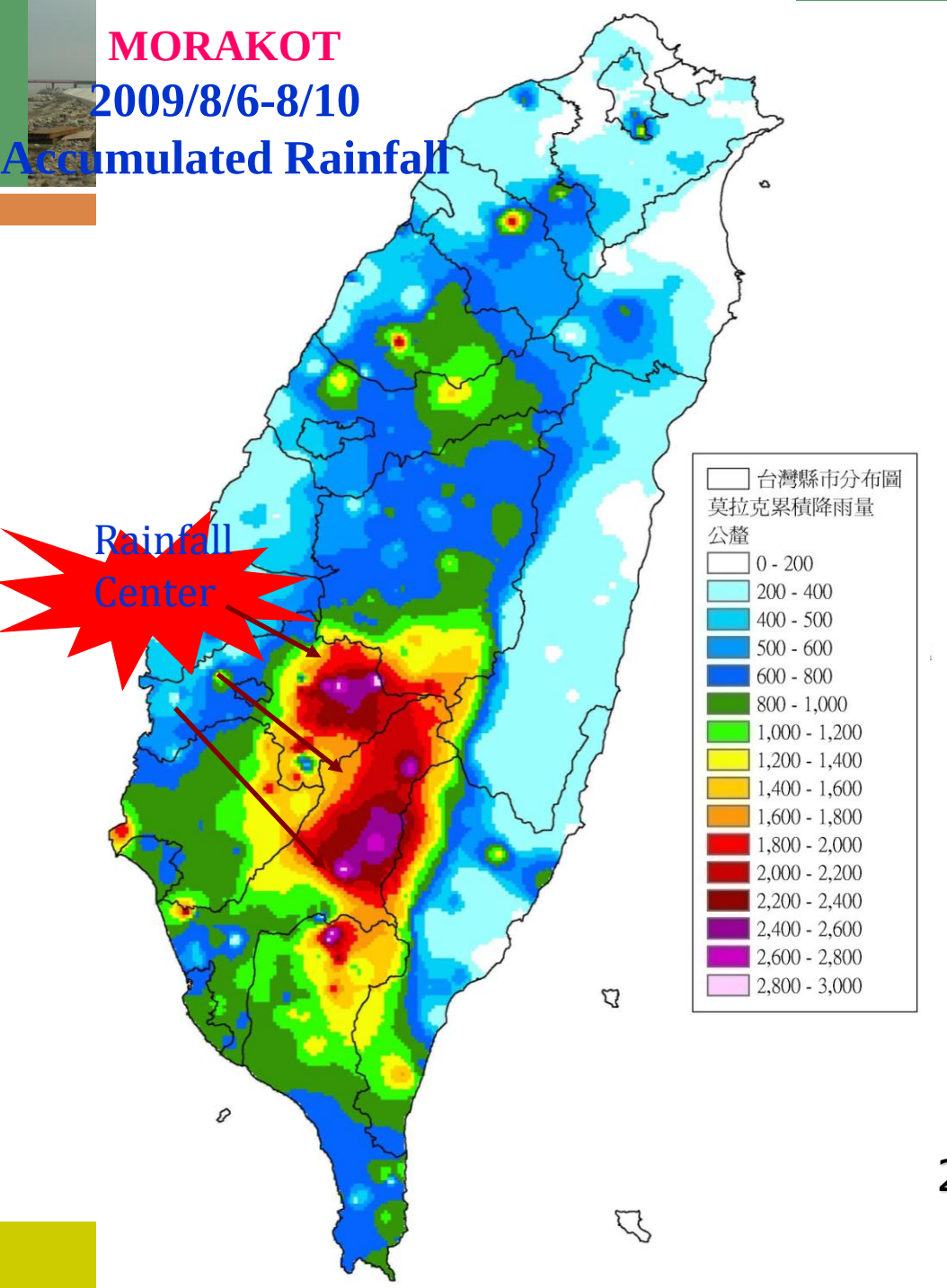


The frequency of the extreme rainfall induced by typhoons

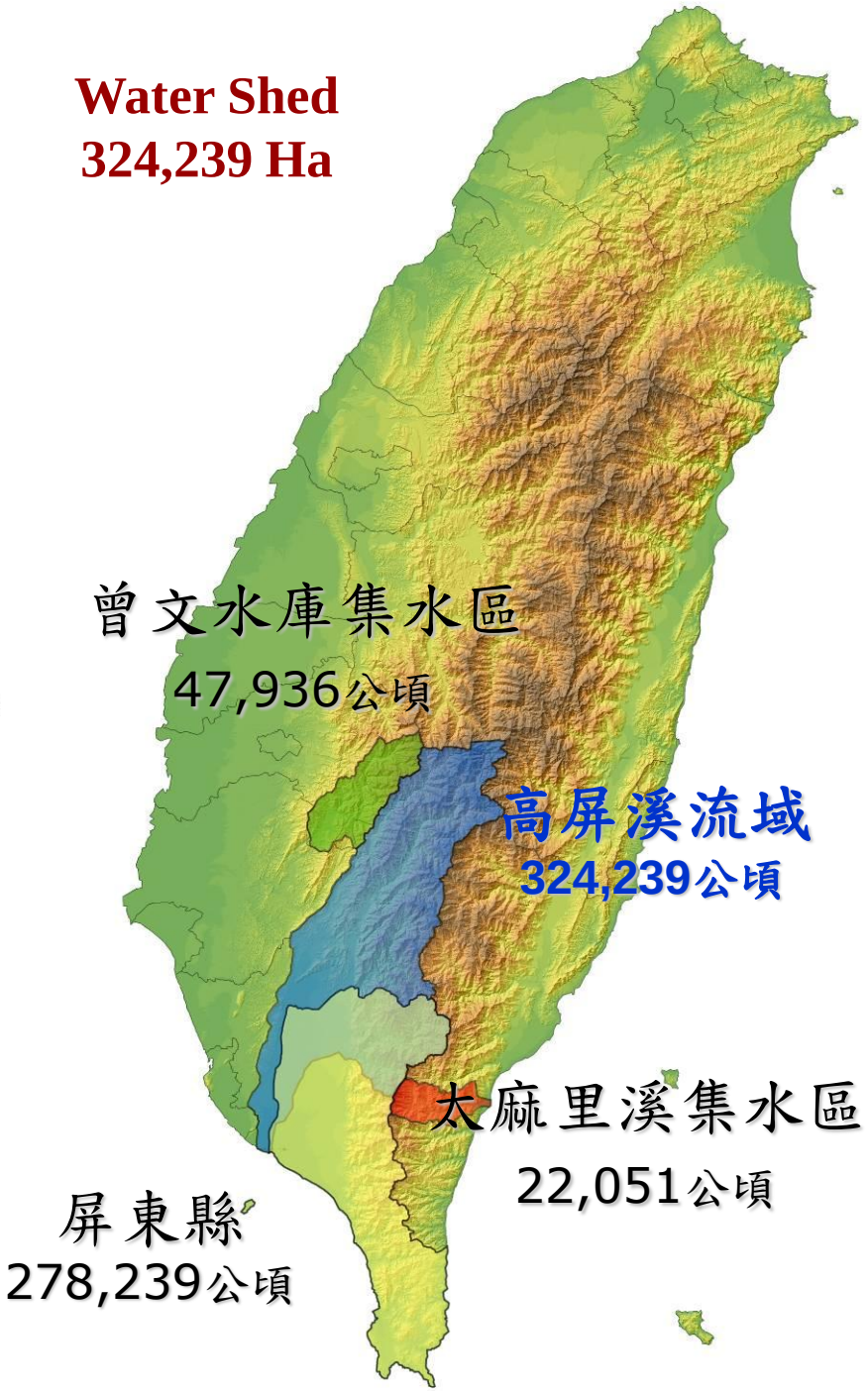
Before 2000: once per 3~4 years
After 2000: once per year

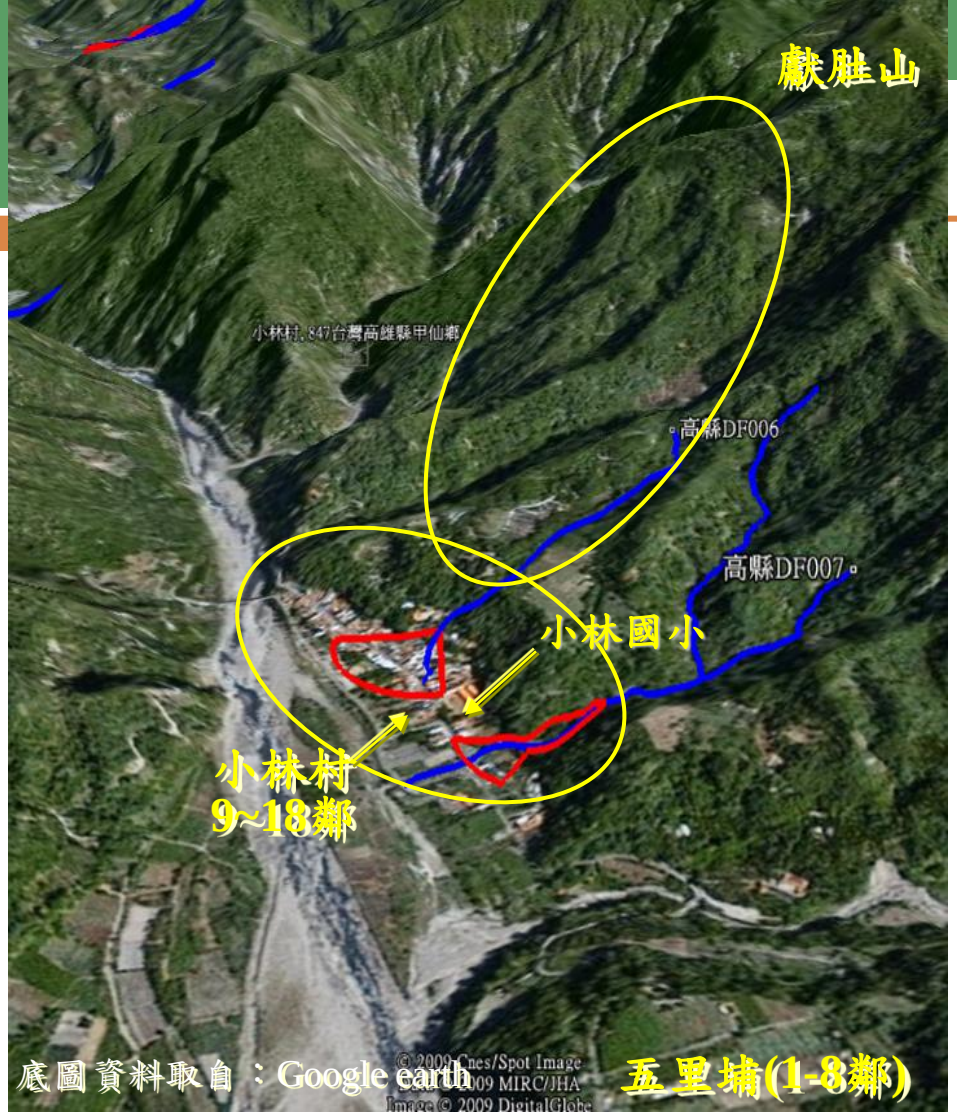
NCDR(2010)

MORAKOT
2009/8/6-8/10
Accumulated Rainfall



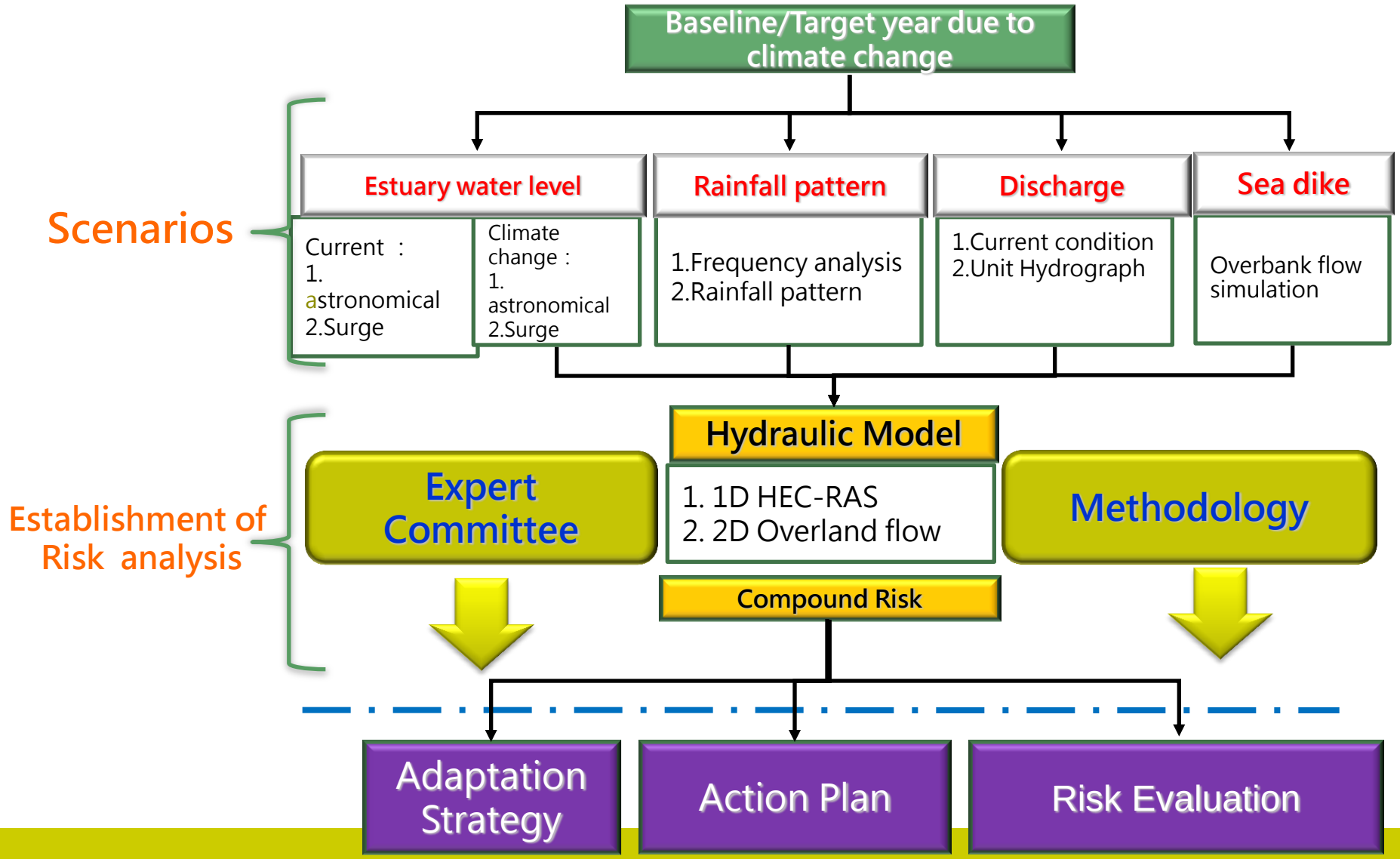
Water Shed
324,239 Ha





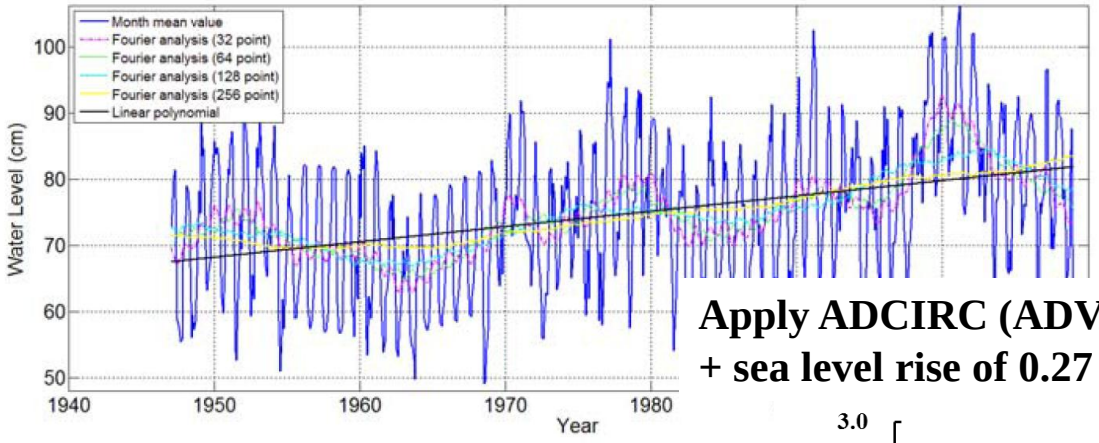
- ✓ 原植被良好(左圖)，藍色線條為土石流潛勢溪流，紅色線條為土石流影響範圍，概估土砂量8萬方，疏散地點為小林國小。
- ✓ 崩塌地點(右圖)為獻肚山走山崩塌，崩塌土砂量950萬方，掩埋小林村9~18鄰。

Work flowchart



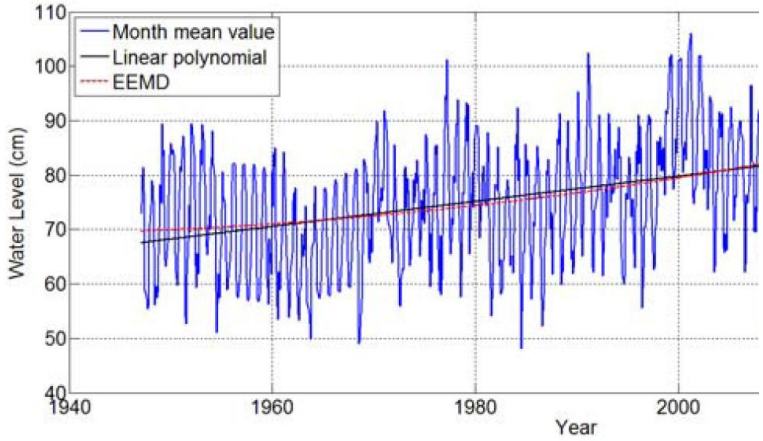
2. The scenarios of hydrological conditions

Scenarios of hydrological conditions -Sea Level Rise of Estuary



The estimated increased sea level rise of south-eastern coast of Taiwan is 18-27 cm in 2039.

Apply ADCIRC (ADVANCED CIRCULATION MODEL) model + sea level rise of 0.27 m.

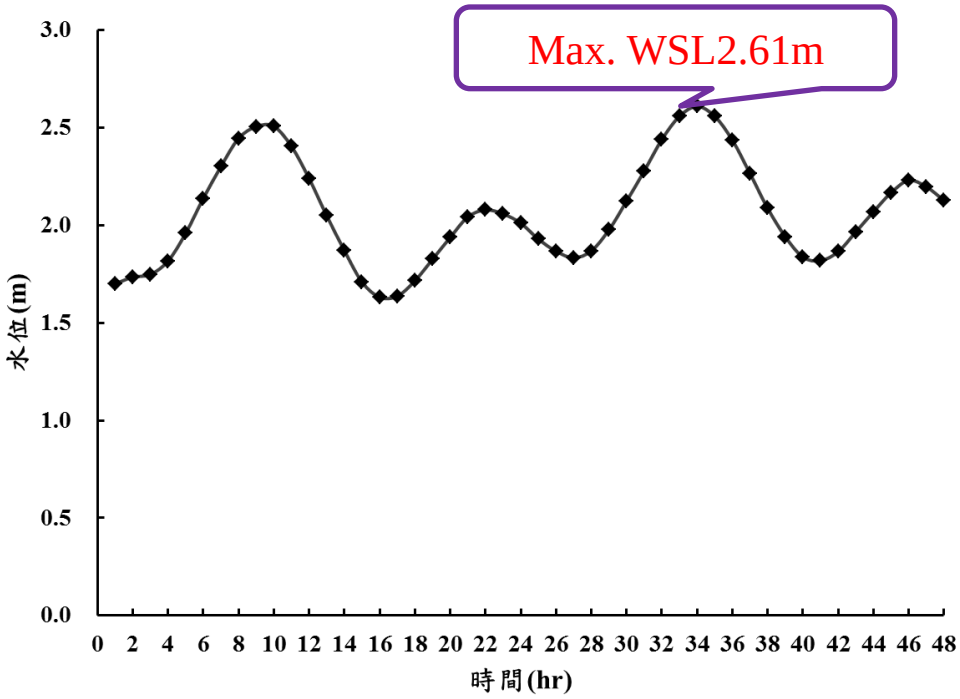


(資料來源: 強化台灣西南地區因應氣候變遷海岸災害調適能

Historical tidal data for 1947 to 2009

(a) Fast Fourier Transform and regr

(b) EEMD and projected for 2039

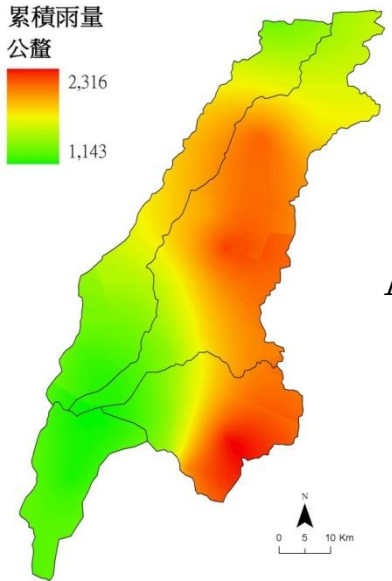


48hr-Water surface level of estuary of Kaoping River due to climate change

Rainfall for different scenarios

48hr-Rainfall-Return period:100yr (2020-2039)

Cumulative Rainfall (mm) / Scenario \ Station	Jiasian(2) [甲仙(2)]	Pingtung(5) 屏東(5)	Xinfeng(新豐)	Yushan(玉山)
A1B	1371.98	1143.43	1163.52	569.72
A2	1457.30	1205.66	1197.79	644.11
B1	1466.05	1153.16	1154.14	590.61



A1B

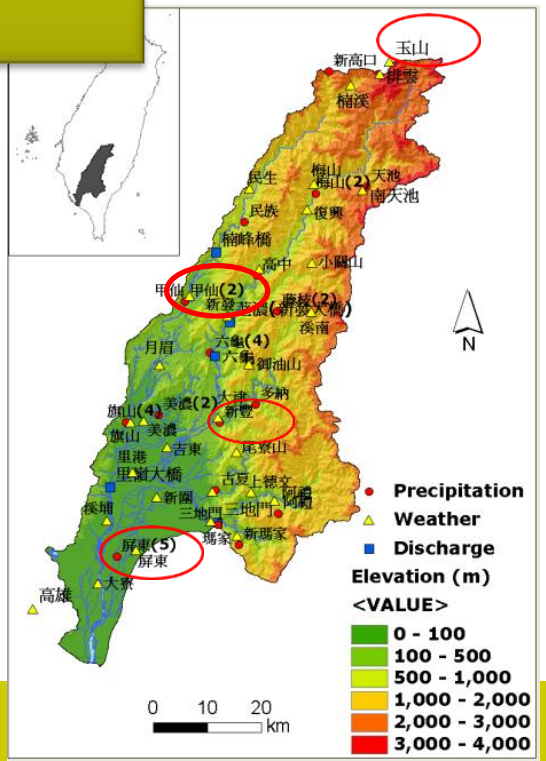
Pointed Rainfall to Areal Rainfall

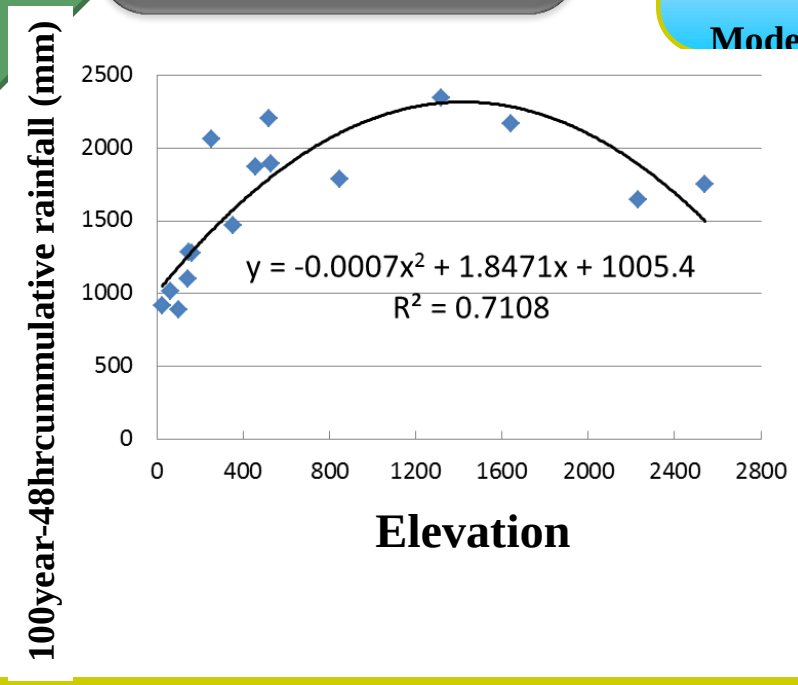
Rainfall data of GCM:
Yushan (玉山), Xinfeng (新豐), Jiasian (2)(甲仙(2)), and Pingtung(5) (屏東(5))

- 48-hr cumulative rainfall vs. elevation
- Thiseen method for weighting.

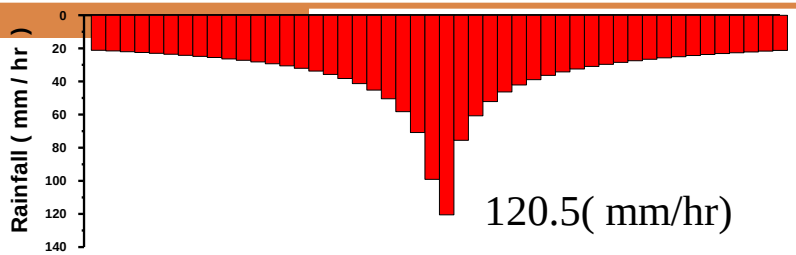
Rainfall Distribution

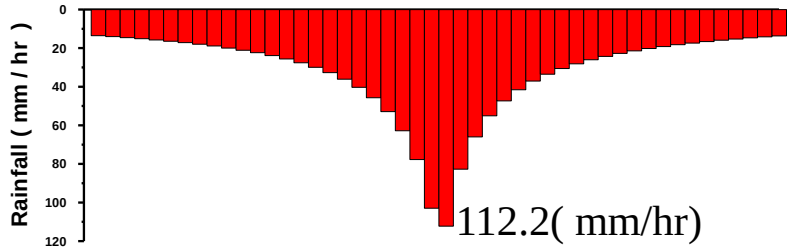
- Rainfall-Runoff Model
- Overland flow
- Sediment Model

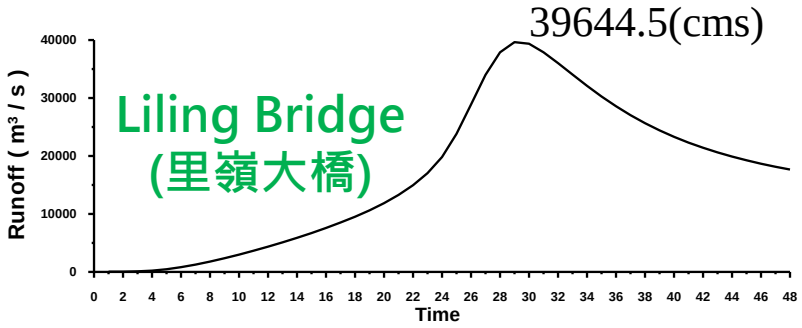


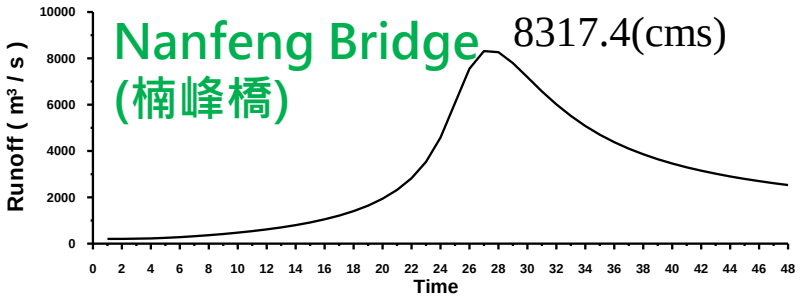


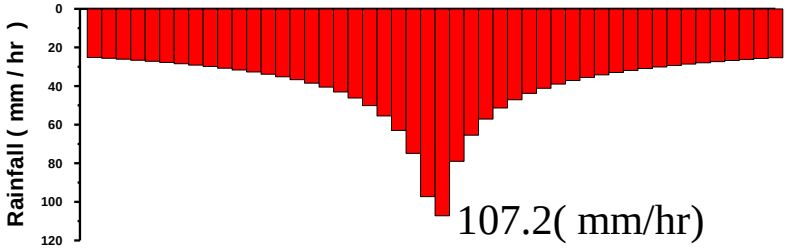
Discharge due to Climate Change

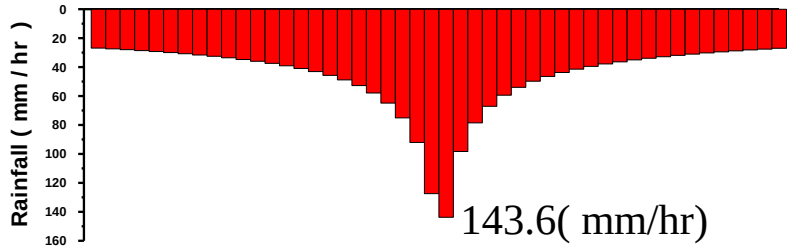


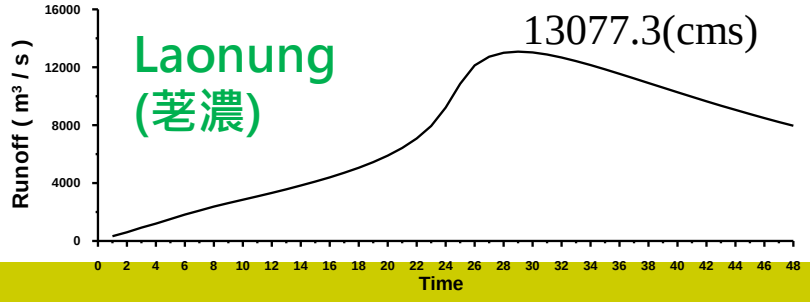


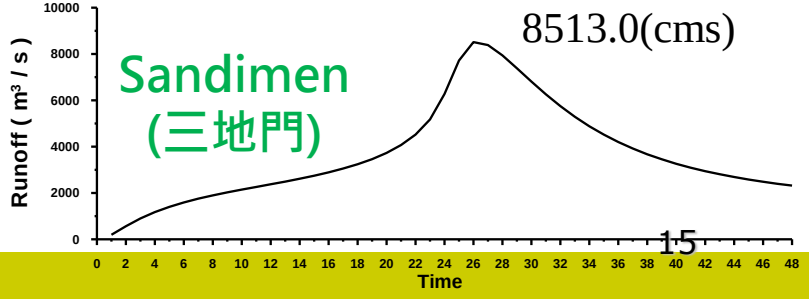






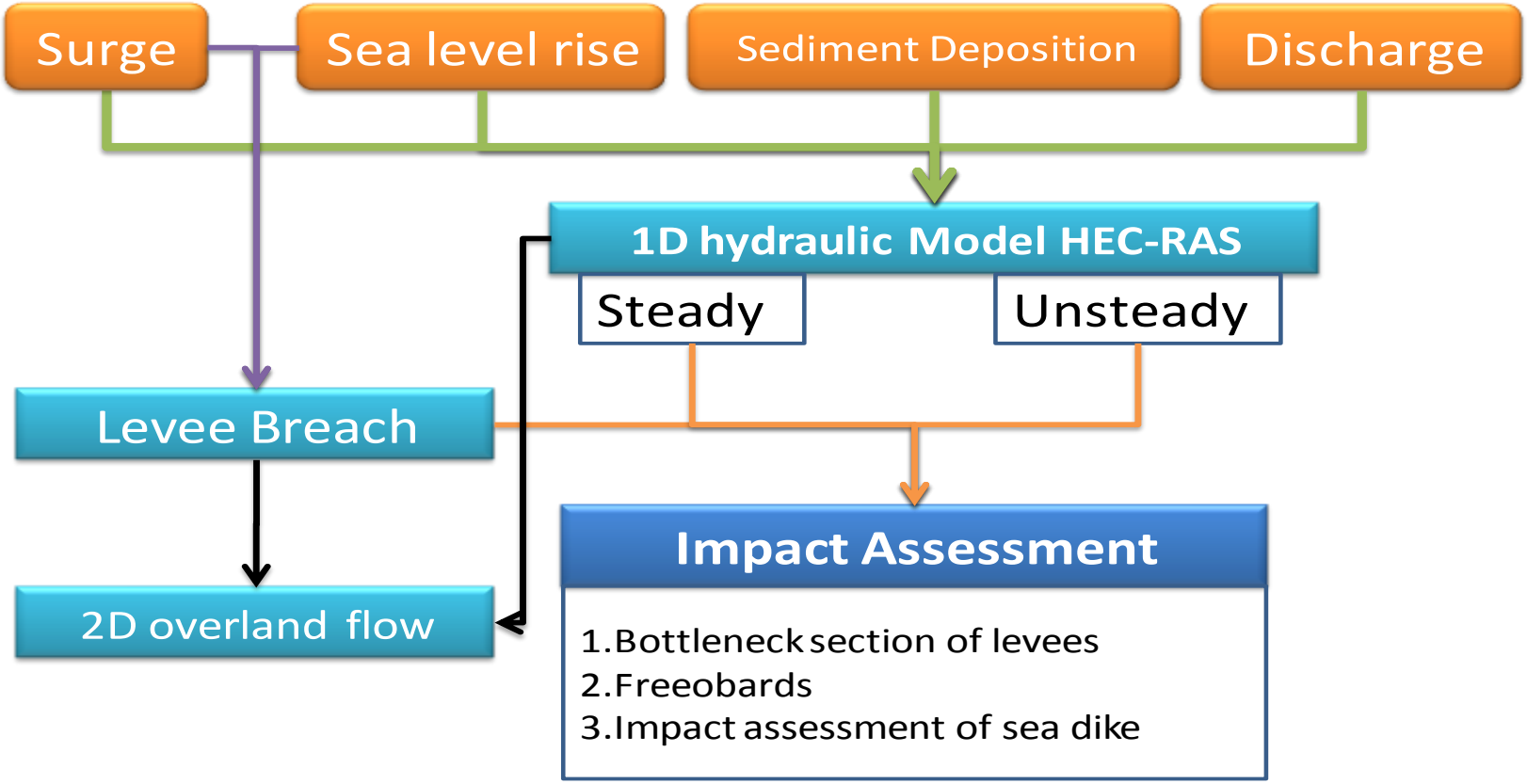






3.The Impact Assessment of flood-prevention works

Flow Chart Evaluations of Flood-Protection works

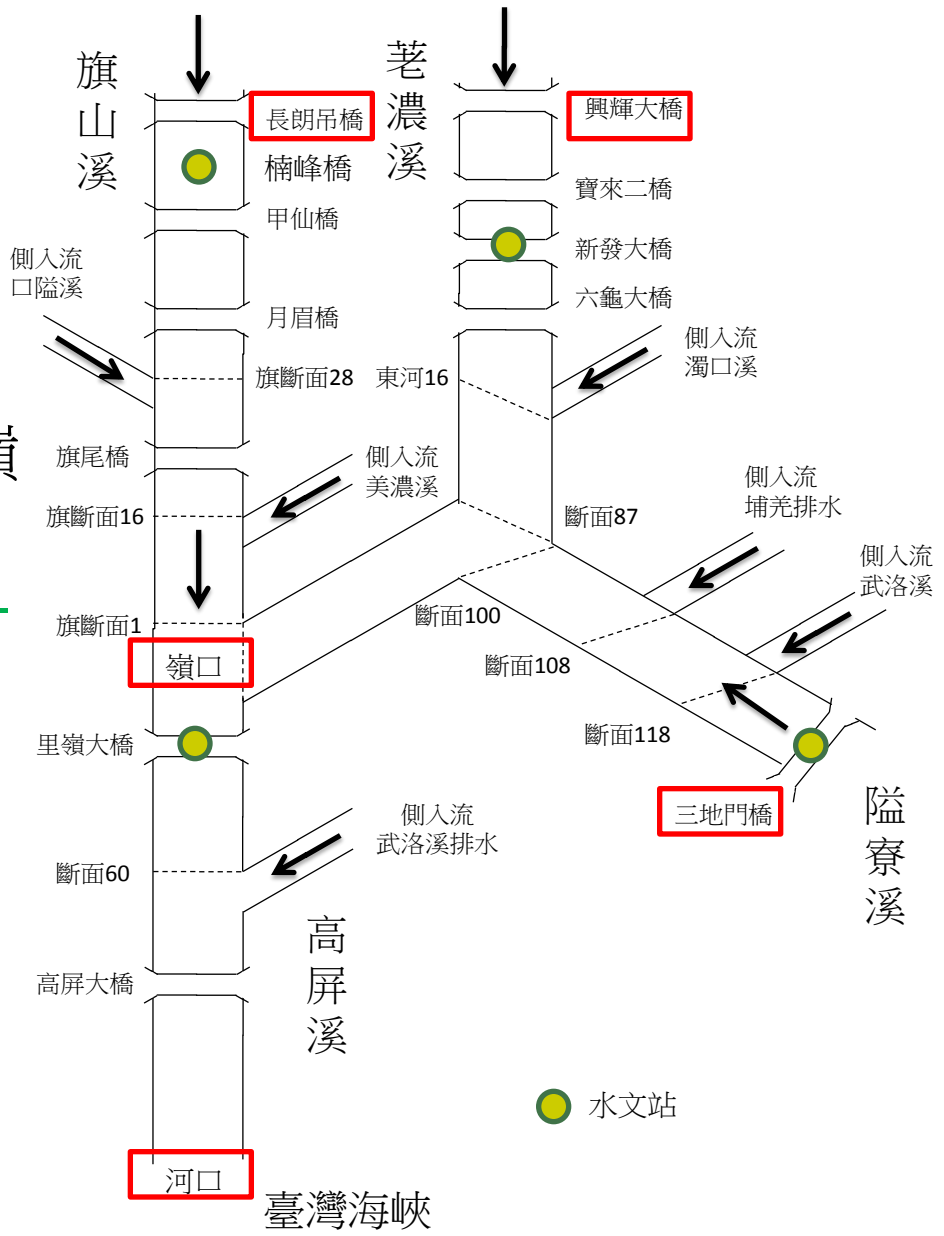


Study Area

Kaoping River, Qishan River(旗山溪),Laonnog River(荖濃溪), and Ailiao River(隘寮溪).

- Kaoping River Mouth-lingkou(嶺口)。
- Laonnog River：Lingkou(嶺口)-Henfield Bridge(興輝大橋)
- Qishan River:Lingkou-Changlang suspension bridge(長朗吊橋)
- Ailiao River:Zaixing he-Sandimen Bridge(三地門橋).。

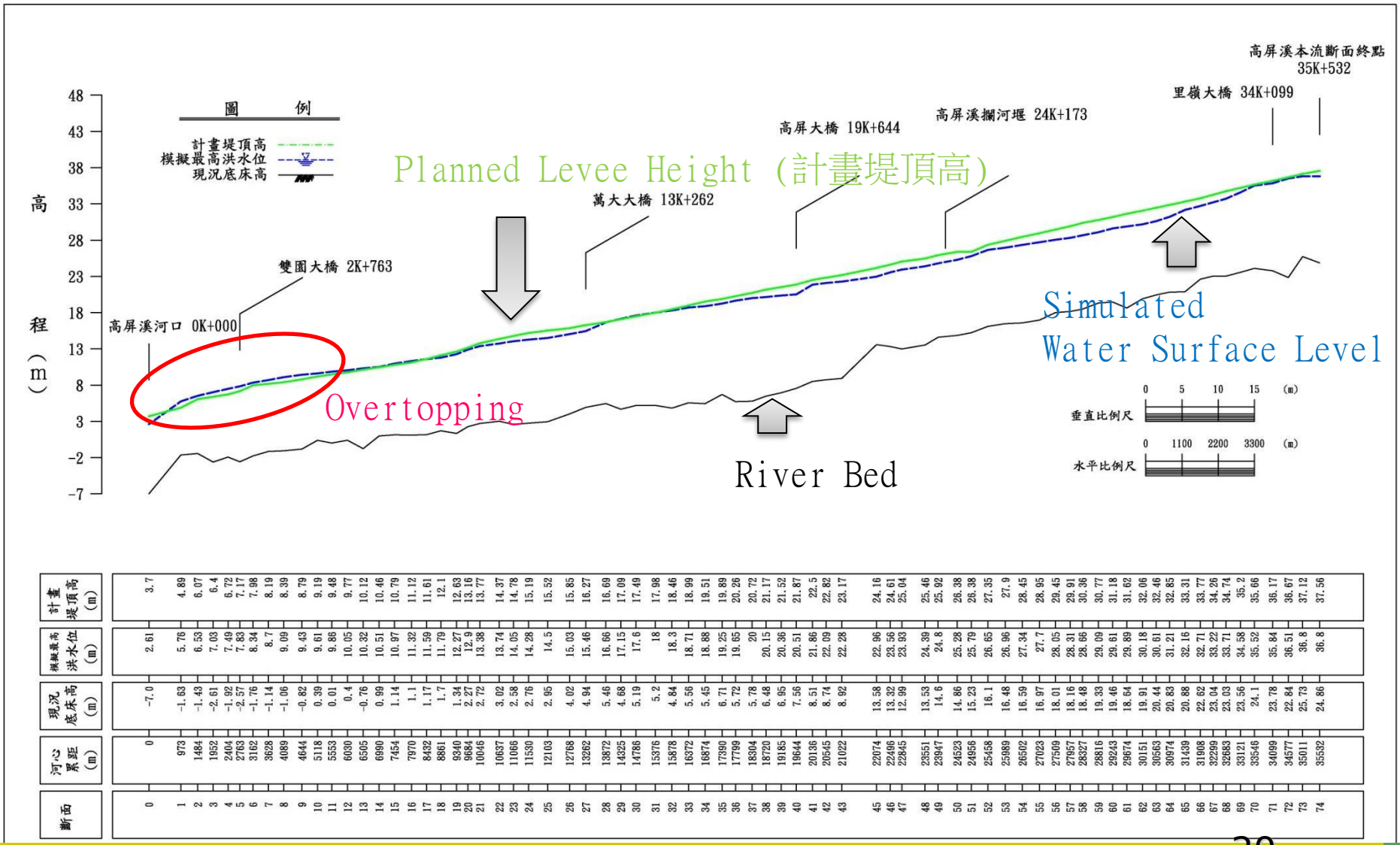
Map of boundaries



Discharge increase due to Climate Change

Watershed	Control point	Designed (Q_{100})(1)	A1B Simulated (Q_{100})(2)	(2)/(1)
Kaoping River 本流	Jiou cyu-tang (九曲堂站)	26,800	41,435	155%
Laonnog River 荖濃溪	Li gang Bridge(里港大橋)	21,100	30,582	145%
	Confluence of Laonnog River and Ailiao River (荖濃溪與隘寮溪合流前)	14,200	19,998	141%
	Laonung Bridge(新發大橋)	9,240	13,068	141%
Qishan River 旗山溪	Exit of Qishan (旗山溪出口)	7,780	10,540	135%
	Yuemei (月眉站)	5,990	8,275	138%
Ailiao River 隘寮溪	Exit of Ailiao River (隘寮溪出口)	8,600	11,133	129%
	Sandimen (三地門站)	6,150	8,513	138%

Koaping River A1B-100yr-return-period Water Surface Level



斷面	河心累距 (m)	現況底床高 (m)	模擬最高洪水位 (m)	計畫堤頂高 (m)
0	0	-7.0	2.61	3.7
1	973	-1.63	5.76	4.89
2	1484	-1.43	6.53	6.07
3	1952	-2.61	7.03	6.4
4	2404	-1.92	7.49	6.72
5	2763	-2.57	7.83	7.17
6	3162	-1.76	8.34	7.98
7	3628	-1.14	8.7	8.19
8	4089	-1.06	9.09	8.39
9	4644	-0.82	9.43	8.79
10	5118	0.39	9.61	9.19
11	5553	0.01	9.86	9.48
12	6030	0.4	10.05	9.77
13	6505	-0.76	10.32	10.12
14	6990	0.99	10.51	10.46
15	7454	1.14	10.97	10.79
16	7970	1.1	11.32	11.12
17	8432	1.17	11.59	11.61
18	8861	1.7	11.79	12.1
19	9340	1.34	12.27	12.63
20	9684	2.27	12.9	13.16
21	10046	2.72	13.38	13.77
22	10637	3.02	13.74	14.37
23	11066	2.58	14.05	14.78
24	11530	2.76	14.28	15.19
25	12103	2.95	14.5	15.52
26	12768	4.02	15.03	15.85
27	13262	4.94	15.46	16.27
28	13872	5.45	16.66	16.69
29	14325	4.68	17.15	17.09
30	14786	5.19	17.6	17.49
31	15376	5.2	18	17.98
32	15878	4.84	18.3	18.46
33	16372	5.56	18.71	18.99
34	16874	5.45	18.88	19.51
35	17390	6.71	19.25	19.89
36	17799	5.72	19.65	20.28
37	18304	5.78	20	20.72
38	18720	6.48	20.15	21.17
39	19185	6.95	20.36	21.52
40	19644	7.56	20.51	21.87
41	20136	8.51	21.86	22.5
42	20545	8.74	22.09	22.82
43	21022	8.92	22.28	23.17
45	22074	13.58	22.96	24.16
46	22496	13.32	23.56	24.61
47	22845	12.99	23.93	25.04
48	23551	13.53	24.39	25.46
49	23947	14.6	24.8	25.92
50	24523	14.86	25.28	26.38
51	24956	15.23	25.79	26.38
52	25458	16.1	26.65	27.35
53	25989	16.48	26.96	27.9
54	26502	16.59	27.34	28.45
55	27023	16.97	27.7	28.95
56	27509	18.01	28.05	29.45
57	27957	18.16	28.31	29.91
58	28327	18.48	28.66	30.36
59	28816	19.33	29.09	30.77
60	29243	19.46	29.61	31.18
61	29674	18.64	29.89	31.62
62	30151	19.91	30.18	32.06
63	30563	20.44	30.61	32.46
64	30974	20.83	31.21	32.85
65	31439	20.88	32.16	33.31
66	31908	22.62	32.71	33.77
67	32289	23.04	33.22	34.26
68	32683	23.03	33.71	34.74
69	33121	23.56	34.58	35.2
70	33546	24.1	35.52	35.66
71	34099	23.78	35.84	36.17
72	34577	22.84	36.51	36.67
73	35011	25.73	36.8	37.12
74	35532	24.86	36.8	37.56

Reach of Overbank and Inefficient Free Board

Watershed		A1B
Kaoping River 高屏溪本流	Overbank	19
	Inefficient free board	46
Laonnog River 荖濃溪	Overbank	4
	Inefficient free board	15
Qishan River 旗山溪	Overbank	6
	Inefficient free board	17
Ailiao River 隘寮溪	Overbank	1
	Inefficient free board	9
Total	Overbank	30
	Inefficient free board	87

4.Preliminary Vulnerability and Risk Evaluation

Risk Matrix

Risk Matrix

水災風險程度

$$R = H \times V$$

Where, R：Risk (風險), presented by Risk Matrix
H：Hazard(危險度)Hazard
V：Vulnerability(脆弱度)

Hazard危險度

Vulnerability 脆弱度	Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Very low (1)	(1)	(2)	(3)	(4)	(5)
Low (2)	(2)	(4)	(6)	(8)	(10)
Medium (3)	(3)	(6)	(9)	(12)	(15)
High (4)	(4)	(8)	(12)	(16)	(20)
Very high (5)	(5)	(10)	(15)	(20)	(25)

➢Relative Hazard/ Vulnerability
➢相對危險等級/脆弱度等級

Very high	5	Top20%
High	4	Top20～40%
Medium	3	Top40～60%
Low	2	Bottom20-40%
Very low	1	Bottom20%

➢Relative Risk(相對風險等級)

Very high	>20	Top20%
High	14~20	Top20～40%
Medium	10~14	Top40～60%
Low	5~9	Bottom20-40%
Very low	1~4	Bottom20%

Risk of Levee

堤防護岸因子權重結果

風險 (Risk) = 危險度 (Hazard)

- Historical Levee Breach No. 0.30
- Unit Stream Power 0.19
- Deposition or Scouring 0.20
- Debris wood 0.09
- Water Surface Elevation 0.22

×

脆弱度 (Vulnerability) 0.42

- Condition of levee 0.24
  - Protection Work 0.22
  - Location of flood plain
  - Location of main channel 0.36
- Location of levee 0.28
- Type of levee 0.19
- Age of levee 0.14
- Affiliated Structures 0.32
  - Pumping Station 0.15
  - Gate 0.28
  - Drainage 0.4

Questionnaire

- Samples no. : 35, male -30; femail-5
- Age：20-29 yrs. old：4；30～39 yrs. old ：14人；> 40 yrs. old ：17

Hazard of Levee

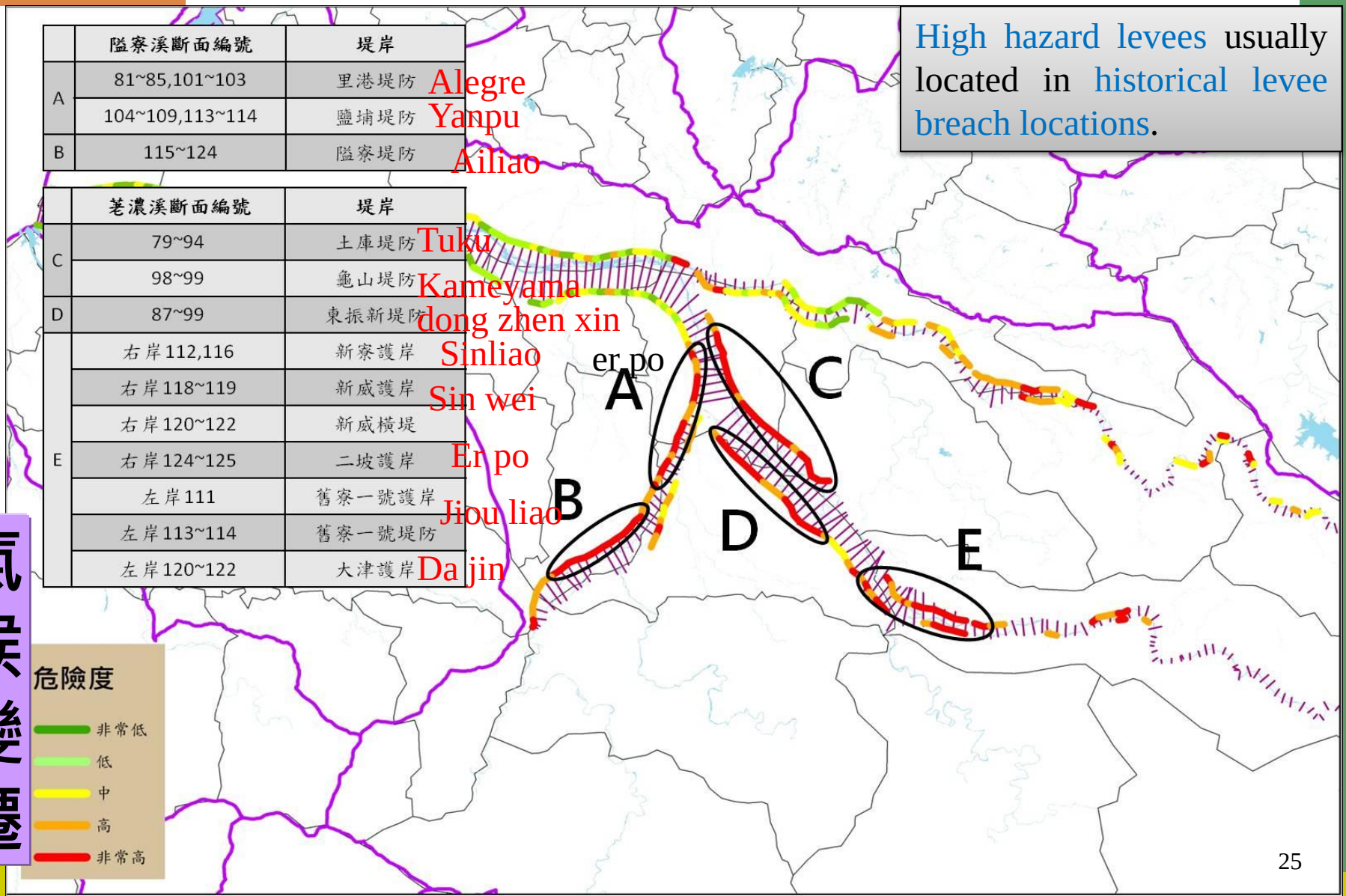
堤防護岸危險度圖

氣候變遷

	隘寮溪斷面編號	堤岸
A	81~85,101~103	里港堤防
	104~109,113~114	鹽埔堤防
B	115~124	隘寮堤防

	荖濃溪斷面編號	堤岸
C	79~94	土庫堤防
	98~99	龜山堤防
D	87~99	東振新堤防
E	右岸112,116	新寮護岸
	右岸118~119	新威護岸
	右岸120~122	新威橫堤
	右岸124~125	二坡護岸
	左岸111	舊寮一號護岸
	左岸113~114	舊寮一號堤防
	左岸120~122	大津護岸

Alegre
Yanpu
Ailiao
Tuku
Kameyama
dong zhen xin
Sinliao
Sin wei
Er po
Jiou liao
Da jin

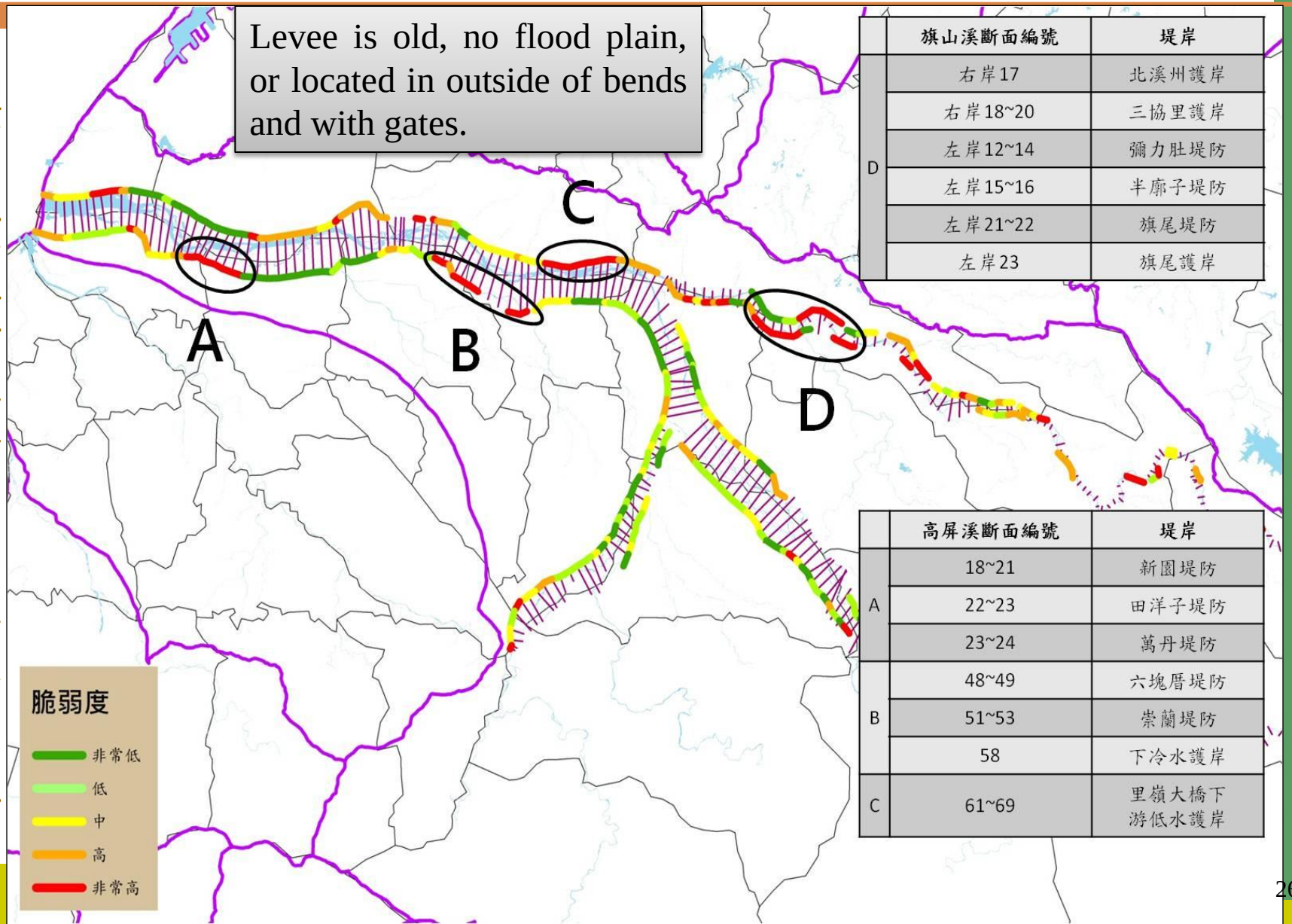


High hazard levees usually located in historical levee breach locations.

Vulnerability of Levee (Now)

堤防護岸脆弱度圖（高屏溪主流）

Levee is old, no flood plain, or located in outside of bends and with gates.



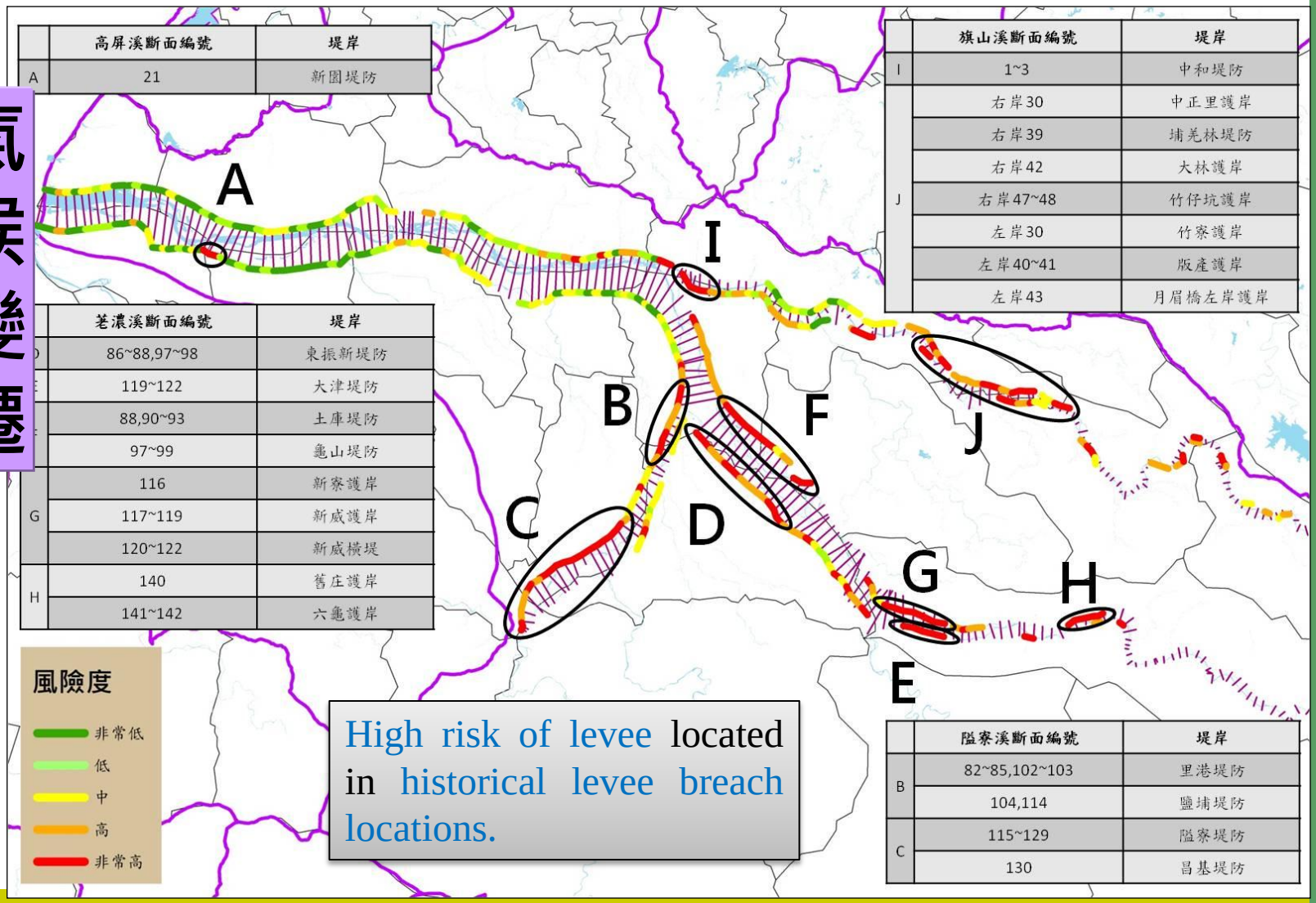
	旗山溪斷面編號	堤岸
D	右岸17	北溪州護岸
	右岸18~20	三協里護岸
	左岸12~14	彌力肚堤防
	左岸15~16	半廓子堤防
	左岸21~22	旗尾堤防
	左岸23	旗尾護岸

	高屏溪斷面編號	堤岸
A	18~21	新園堤防
	22~23	田洋子堤防
	23~24	萬丹堤防
B	48~49	六塊厝堤防
	51~53	崇蘭堤防
	58	下冷水護岸
C	61~69	里嶺大橋下游低水護岸

Risk of Levee due to Climate Change

堤防護岸風險度圖（高屏溪主流）

氣候變遷



	高屏溪斷面編號	堤岸
A	21	新園堤防

	荖濃溪斷面編號	堤岸
D	86~88,97~98	東振新堤防
E	119~122	大津堤防
F	88,90~93	土庫堤防
	97~99	龜山堤防
G	116	新寮護岸
	117~119	新威護岸
	120~122	新威橫堤
H	140	舊庄護岸
	141~142	六龜護岸

	旗山溪斷面編號	堤岸
I	1~3	中和堤防
J	右岸30	中正里護岸
	右岸39	埔羌林堤防
	右岸42	大林護岸
	右岸47~48	竹仔坑護岸
	左岸30	竹寮護岸
	左岸40~41	版產護岸
	左岸43	月眉橋左岸護岸

	隘寮溪斷面編號	堤岸
B	82~85,102~103	里港堤防
	104,114	鹽埔堤防
C	115~129	隘寮堤防
	130	昌基堤防

5. Action Plan

Action Plan

◆**Objective**

This action plan mainly aims on **non-structural measures and necessary structural measures**. It is based on the existed hydraulic structures for improvement and enhancement. The objective of this action plan：

Important reach of Kaoping River is not overflowed when encountering discharge of return period of 100 years (Q_{100})due to A1B scenario.

◆**Time Span**

- **Near(2012-2039)**

Action Plans

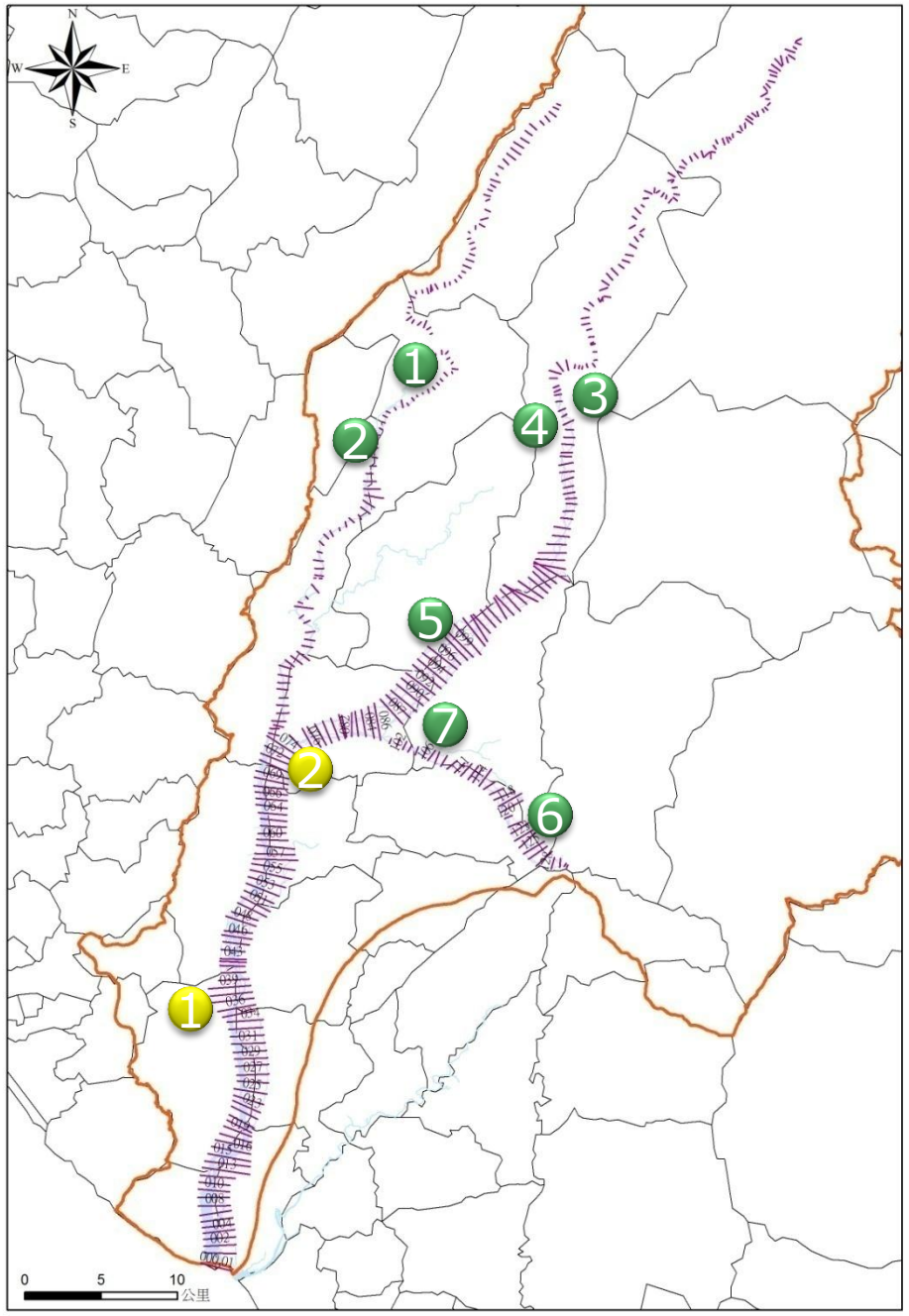
	Plan A	Plan B
structural measures	Upstream-7 overflow area	Dredge 1m deep of main stream
	Middle/downstream 2 retention basins	Upstream-4 overflow area
non-structural measures	-Evacuation Assistant -Evacuation drill -Flood gate panels	-Evacuation Assistant -Evacuation drill -Flood gate panels
Total Cost	0.65 billion NTD	10.2 billion NTD

Plan A-Locations

- 方案1

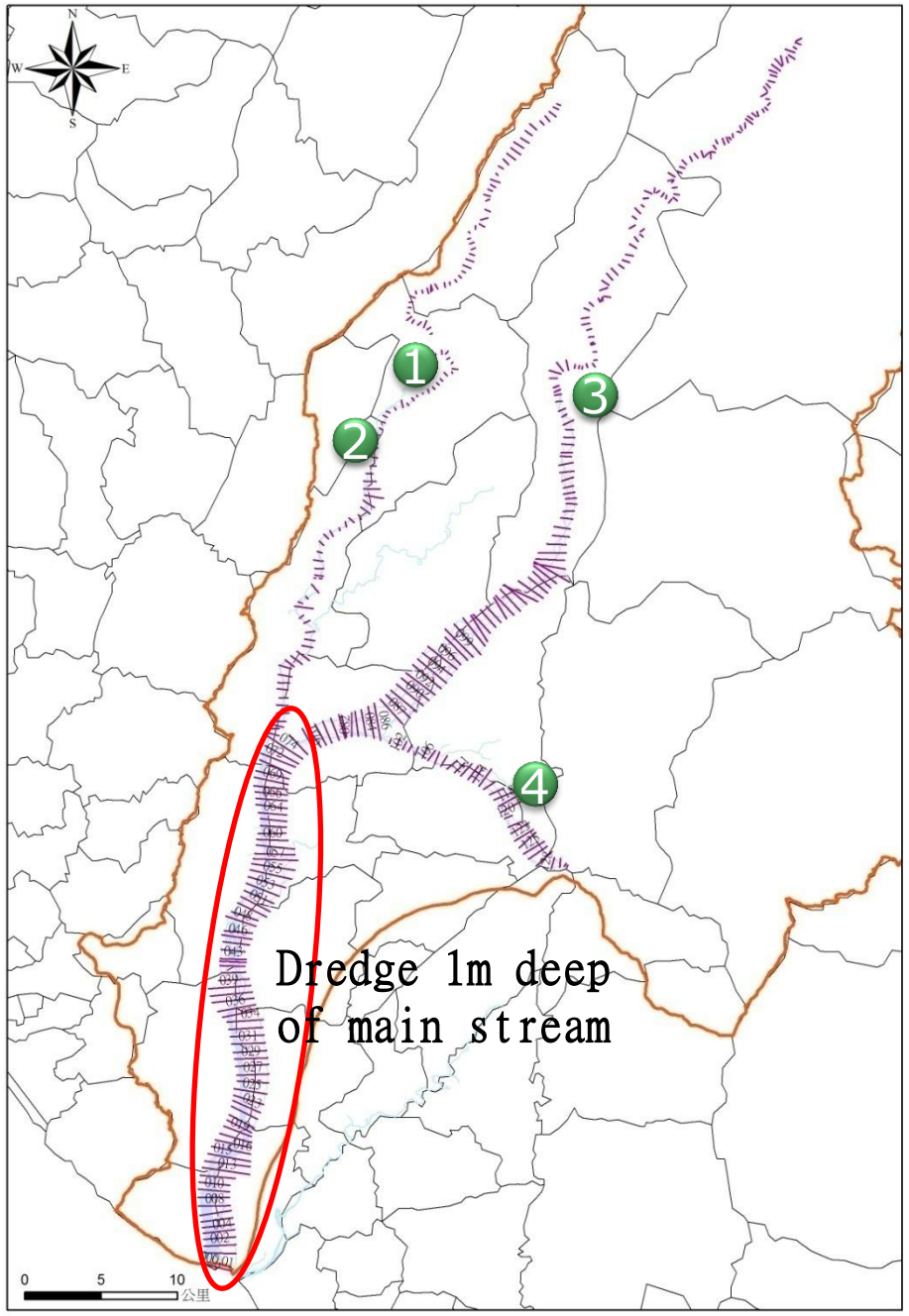
-Upstream-7 overflow area ❶❷❸❹❺❻❼

-Middle/downstream 2 retention basins ❶❷



Plan B-Locations

- 方案2
- Upstream-4 overflow area ❶❷❸❹
- Dredge 1m deep of main stream (red circled)



Difference between Plan A and B

Original A1B					
Item/River	**Mainstream**	**Laonnog**	**Qishan**	**Ailiao**	**Total**
Insufficient free board	46	15	17	9	87
Overbank	19	4	6	1	30
Flooded Area	565Km^2				
No. of Evacuation Assistants	0	0	0	0	0
Plan A (Overflow Area+ Retention Basin)					
Insufficient free board	5	4	2	5	16
Overbank	0	0	3	1	4
Flooded Area	50Km^2 (515Km^2 reduced)				
No. of Evacuation Assistants	50(人)	50(人)	50(人)	50(人)	200(人)
Plan B (Overflow Area+ Main Stream Dredge 1m deep)					
Insufficient free board	1	6	2	0	9
Overbank	0	0	1	0	1
Flooded Area	20Km^2 (545Km^2 reduced)				
No. of Evacuation Assistants	100(人)	100(人)	100(人)	100(人)	100(人)

6.Conclusions

Conclusion

- The simulated Q_{100} for A1B is about 1.3~1.55 times of planned Q .
- For A1B scenario, the risk of villages of middle and downstream of Kaoping River is increasing。
- Plan A (Upstream-7 overflow area+ Middle/downstream 2 retention) : the flooded area reduces 515Km^2, locations of insufficient freeboard reduces 82%, locations of overbnak reduces 86%, and costs 0.65 billion NTD。
- Plan B (Upstream-4 overflow area+ 1m dredge deep) : the flooded area reduces 515Km^2, locations of insufficient freeboard reduces 90%, locations of overbnak reduces 96%, and costs 10.2 billion NTD。

Thanks for your attention

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