An integrated Risk Assessment on bridges

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&

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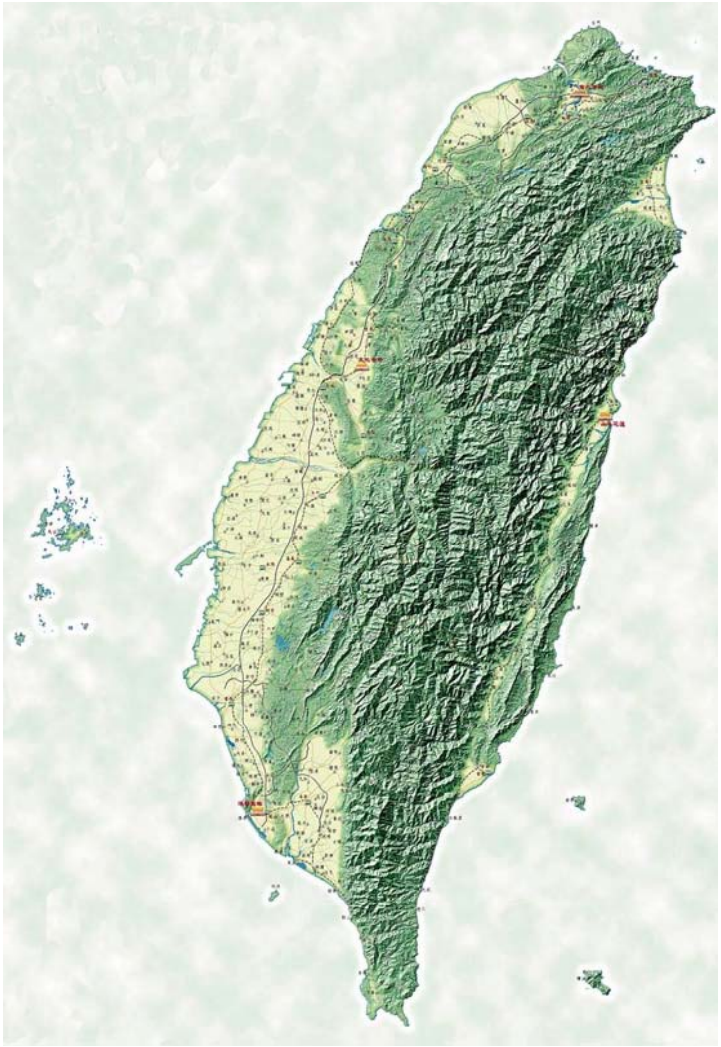
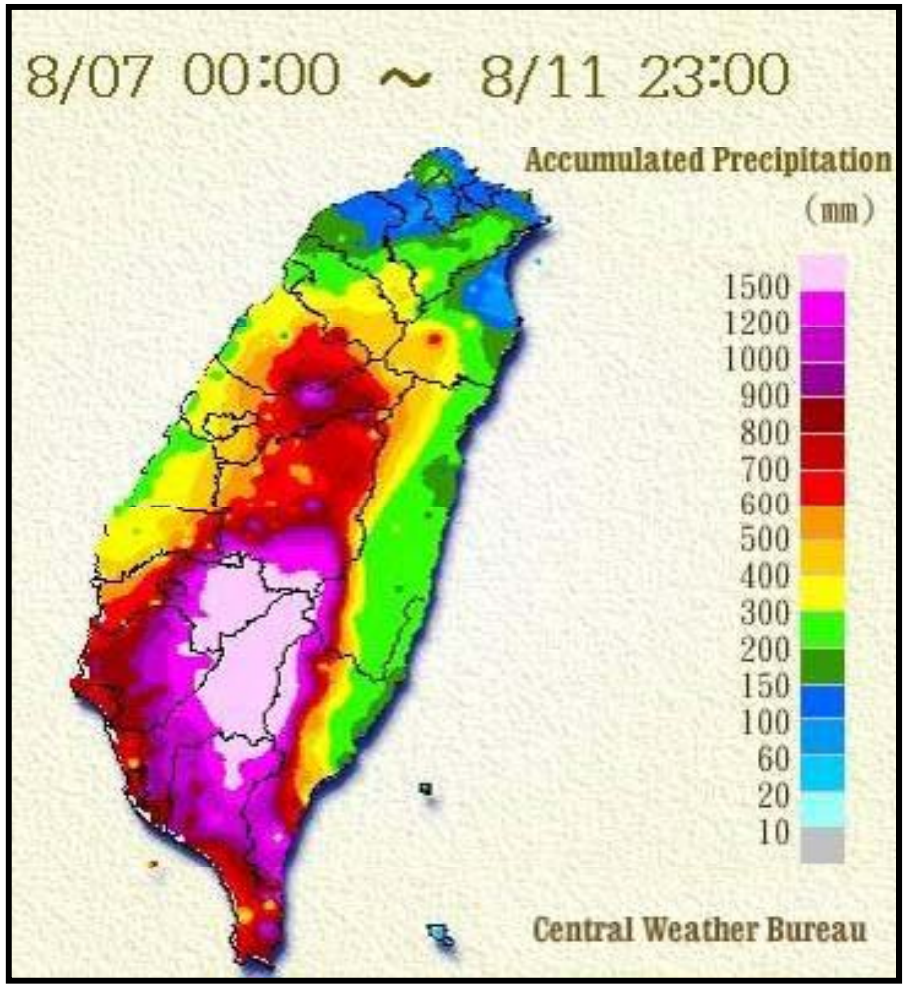
National Central University

Lessons Learned from

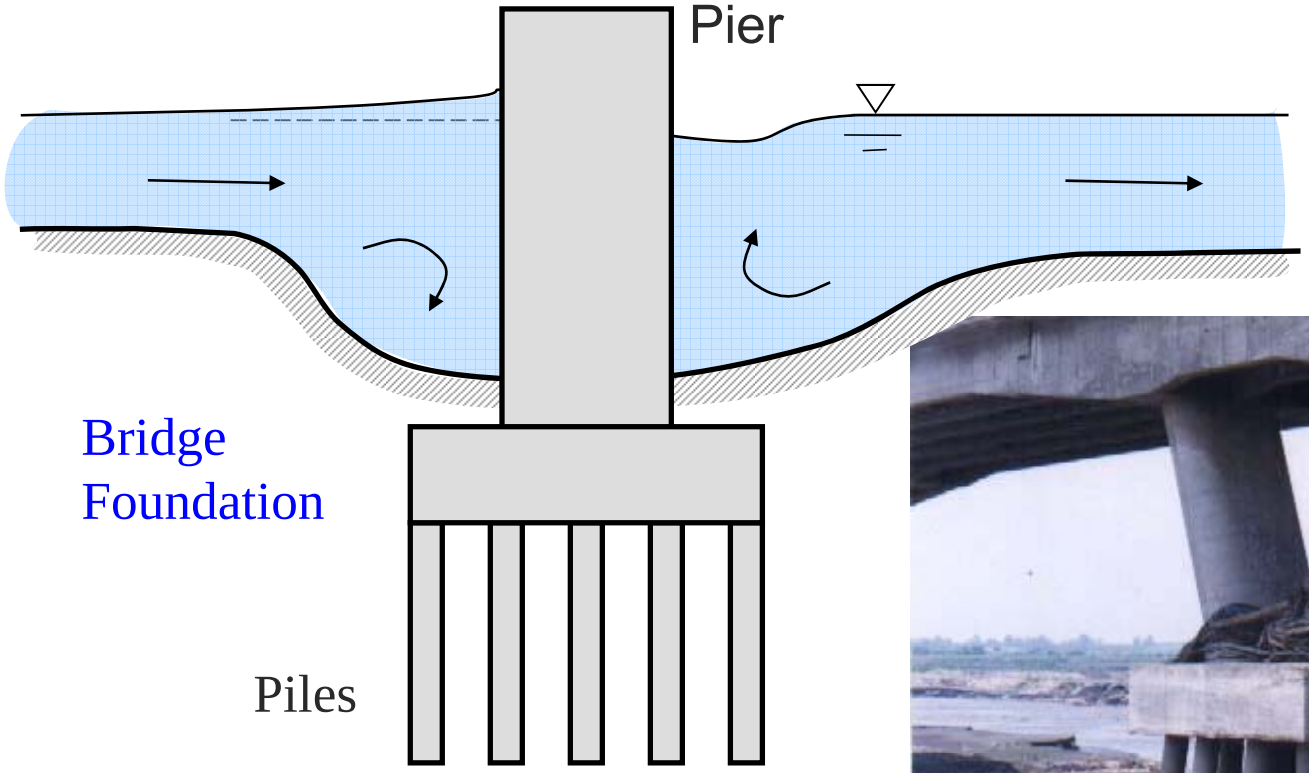
Extreme Natural Disasters

多重災害威脅下之
路-橋-山-河並治
collaborative mechanism of mountain-river-road-bridge management systems under the threaten of muti-hazard



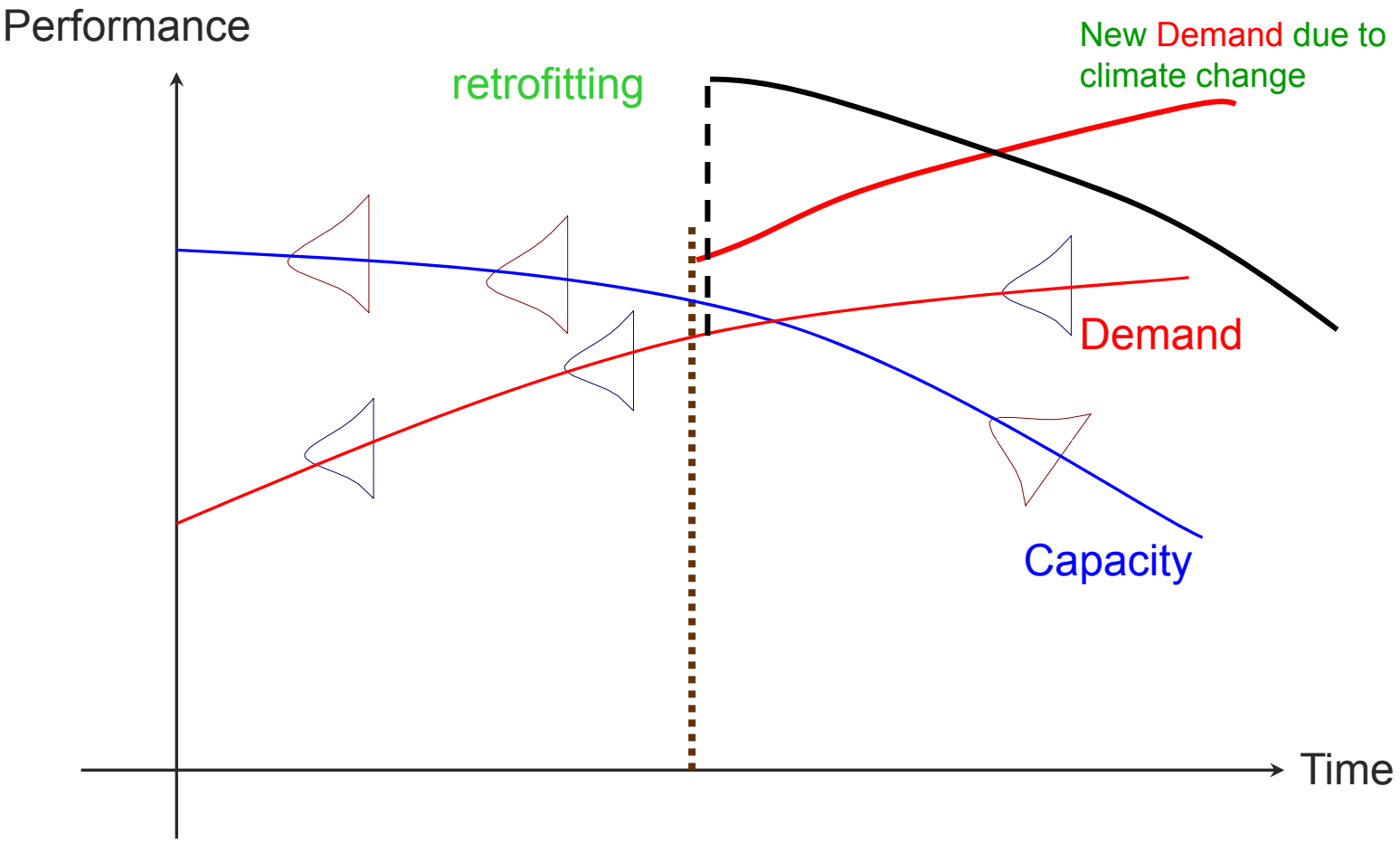


Bridge Pier Scouring

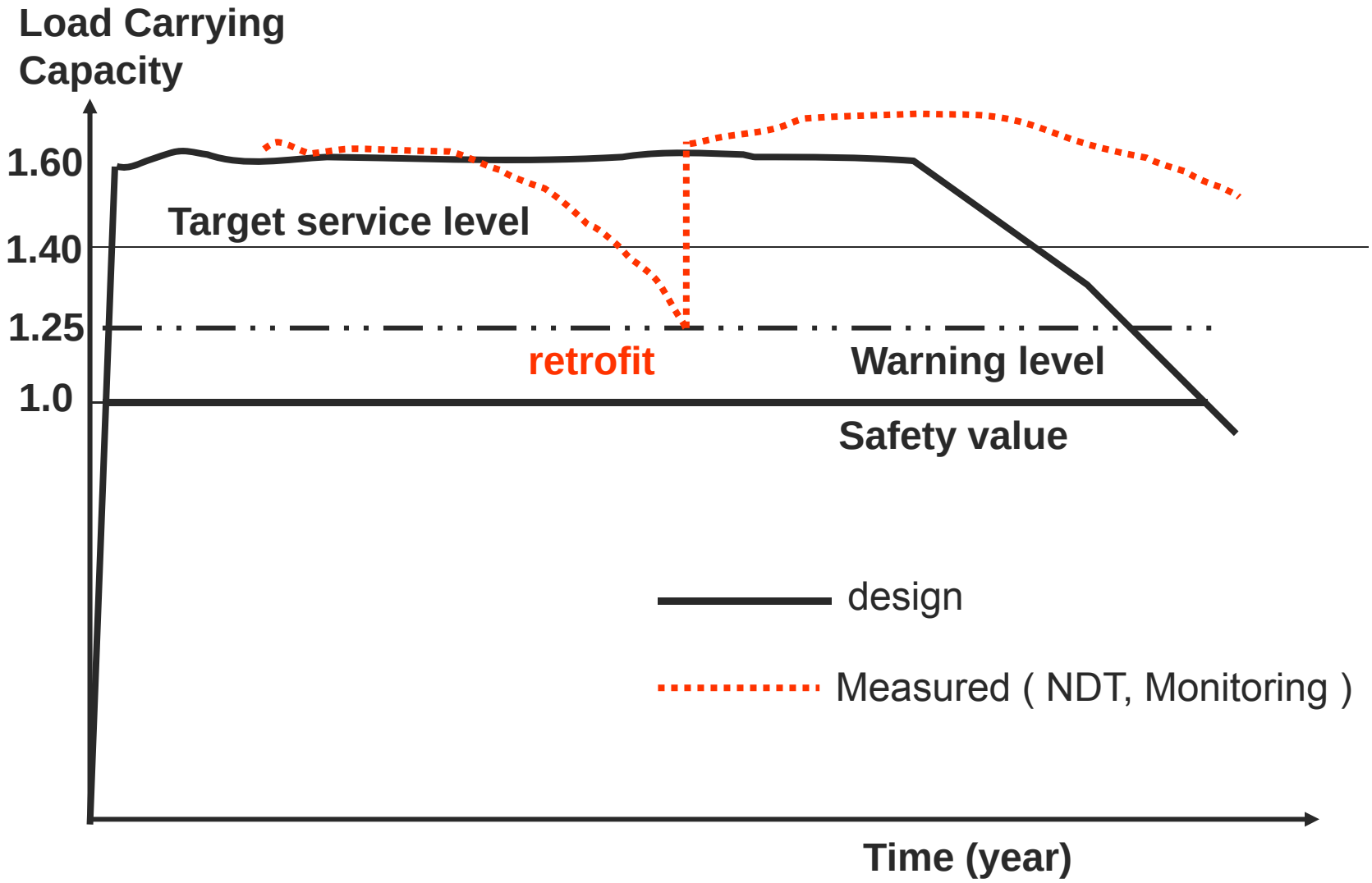


濁水溪自強大橋, 1998

Reliability-Based
Health Diagnosis/ Prognosis

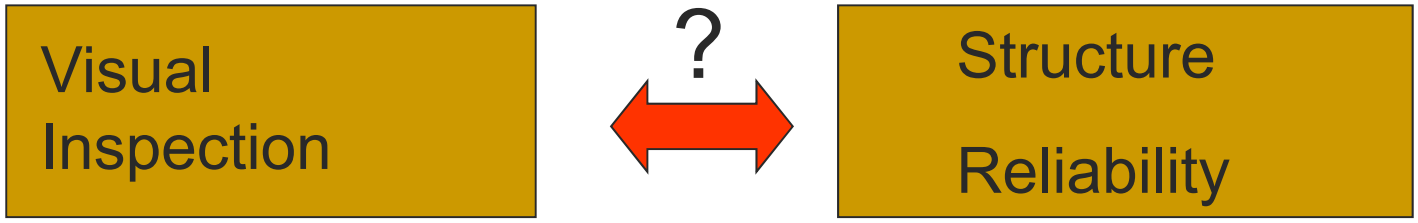


Life-Cycle Maintenance, Monitoring and Management of Bridges



Civil Engineering Diagnostics

Engineers have to understand the reasons of causing damage and hazard of the system as well as their impact to the structural reliability in order to make cost-effective strategies of management.

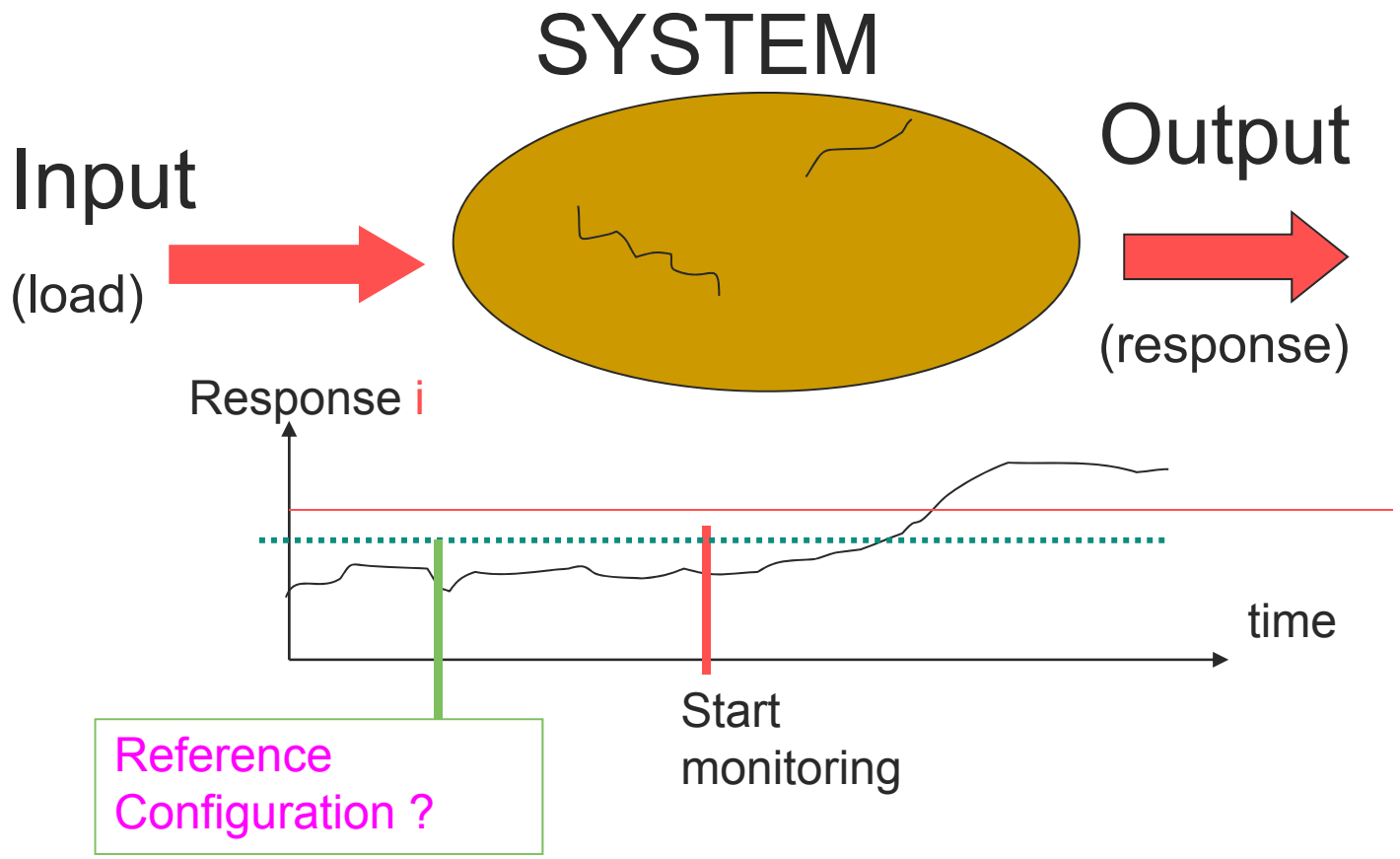


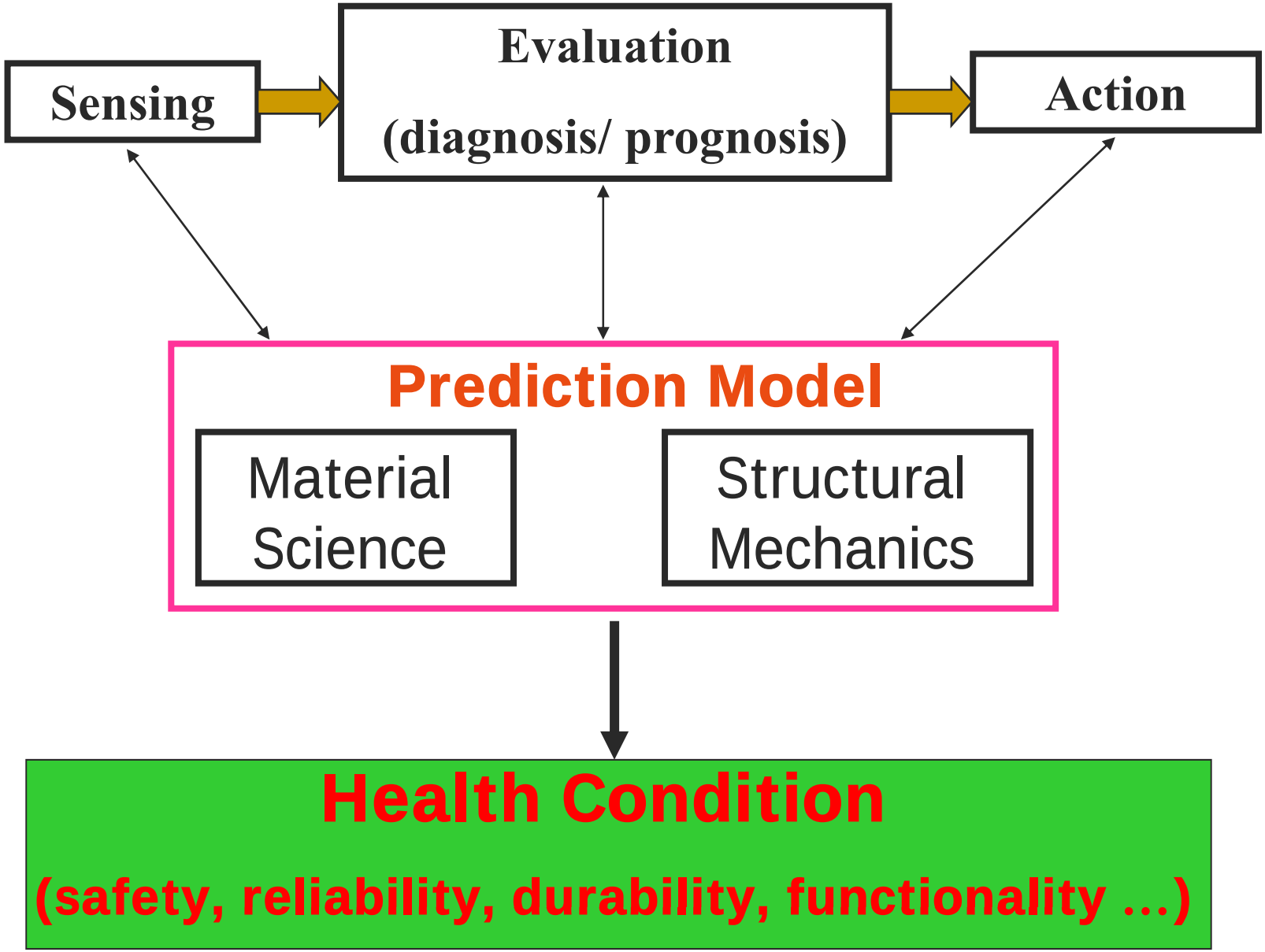
How do we fill this gap ?

Integrated Solutions from **NDT/Monitoring/ Analysis**

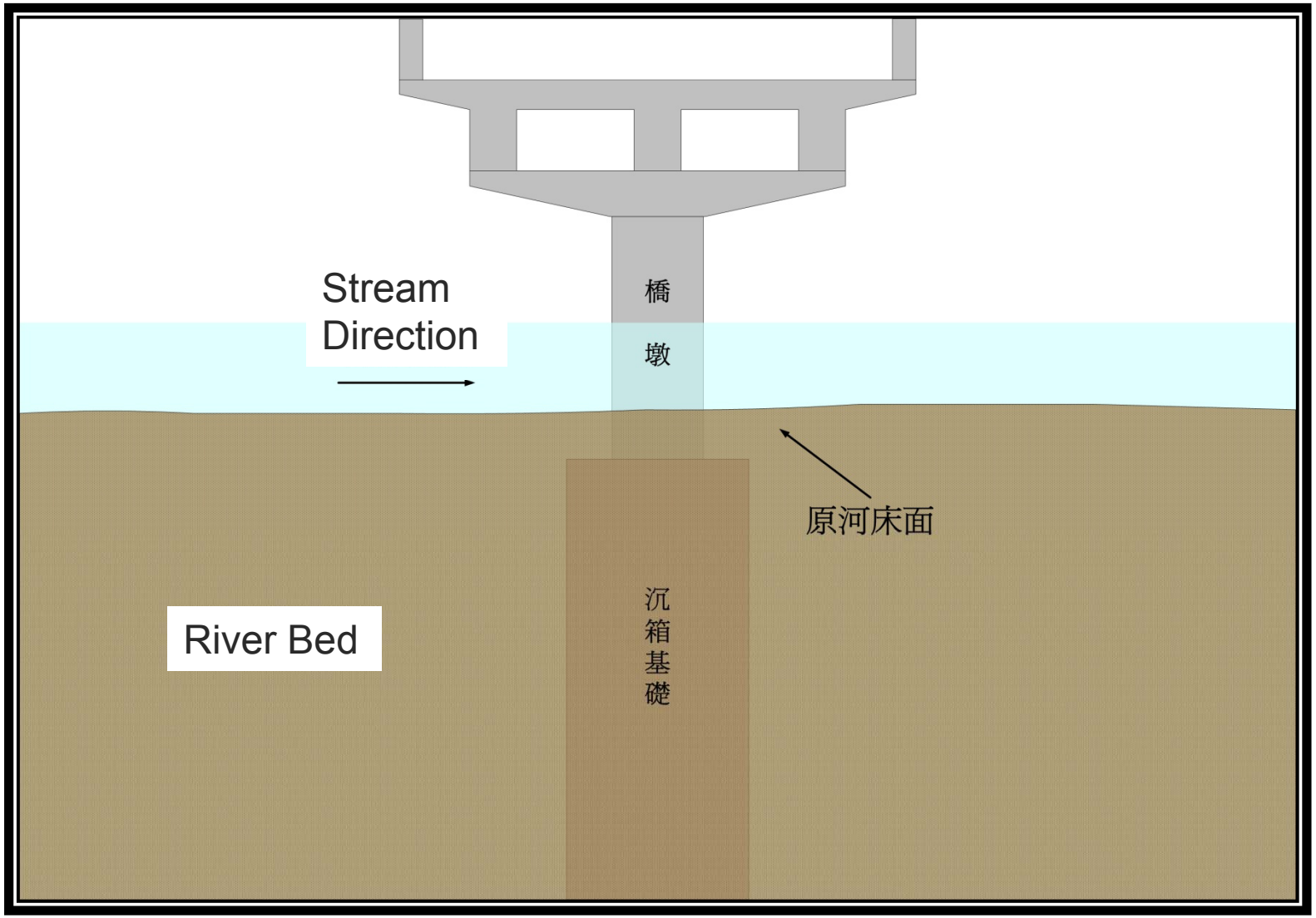
to **Decision Making**

System Identification

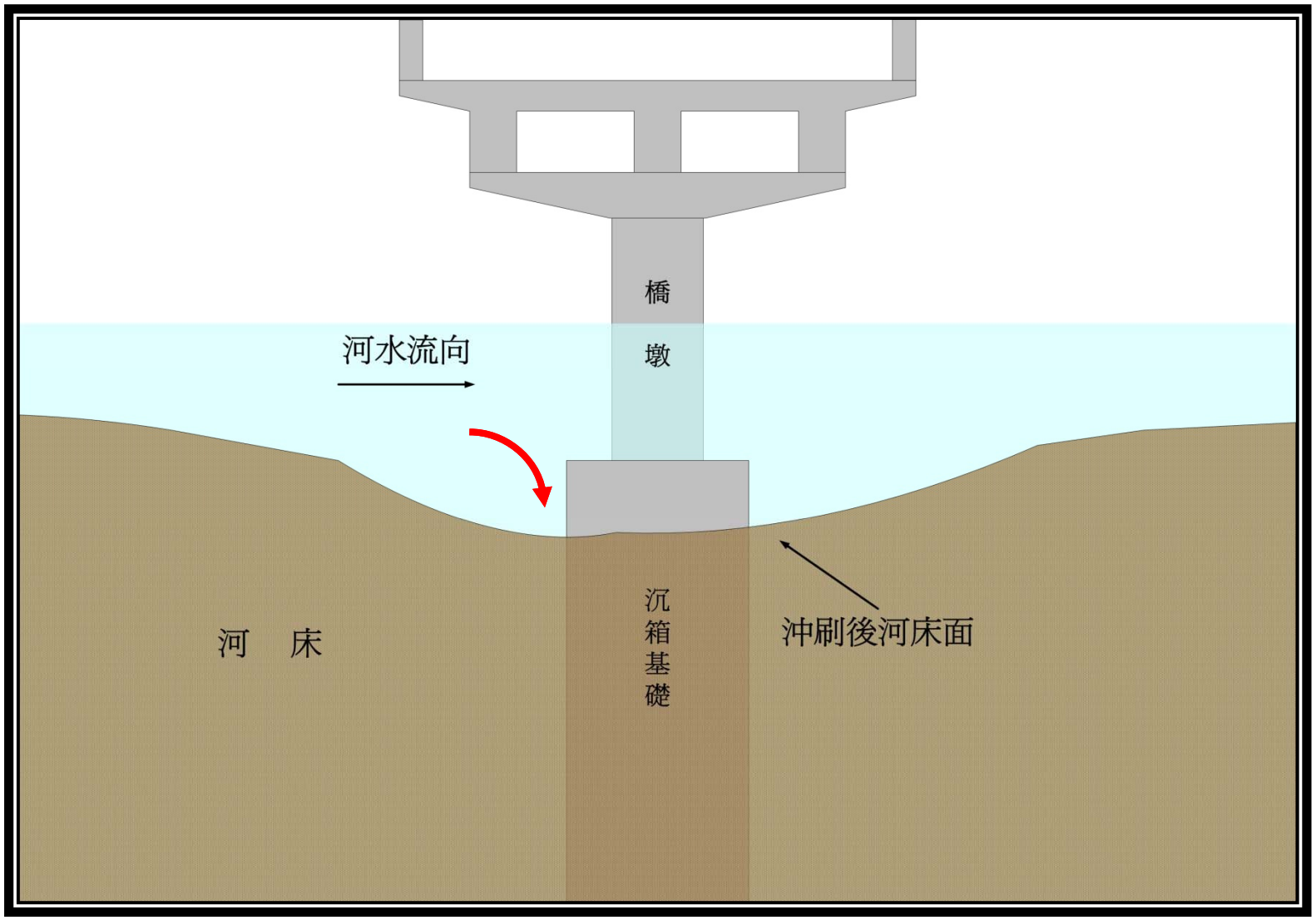



Sensing
Evaluation
(diagnosis/ prognosis)
Action
Prediction Model
Material Science
Structural Mechanics
Health Condition
(safety, reliability, durability, functionality …)

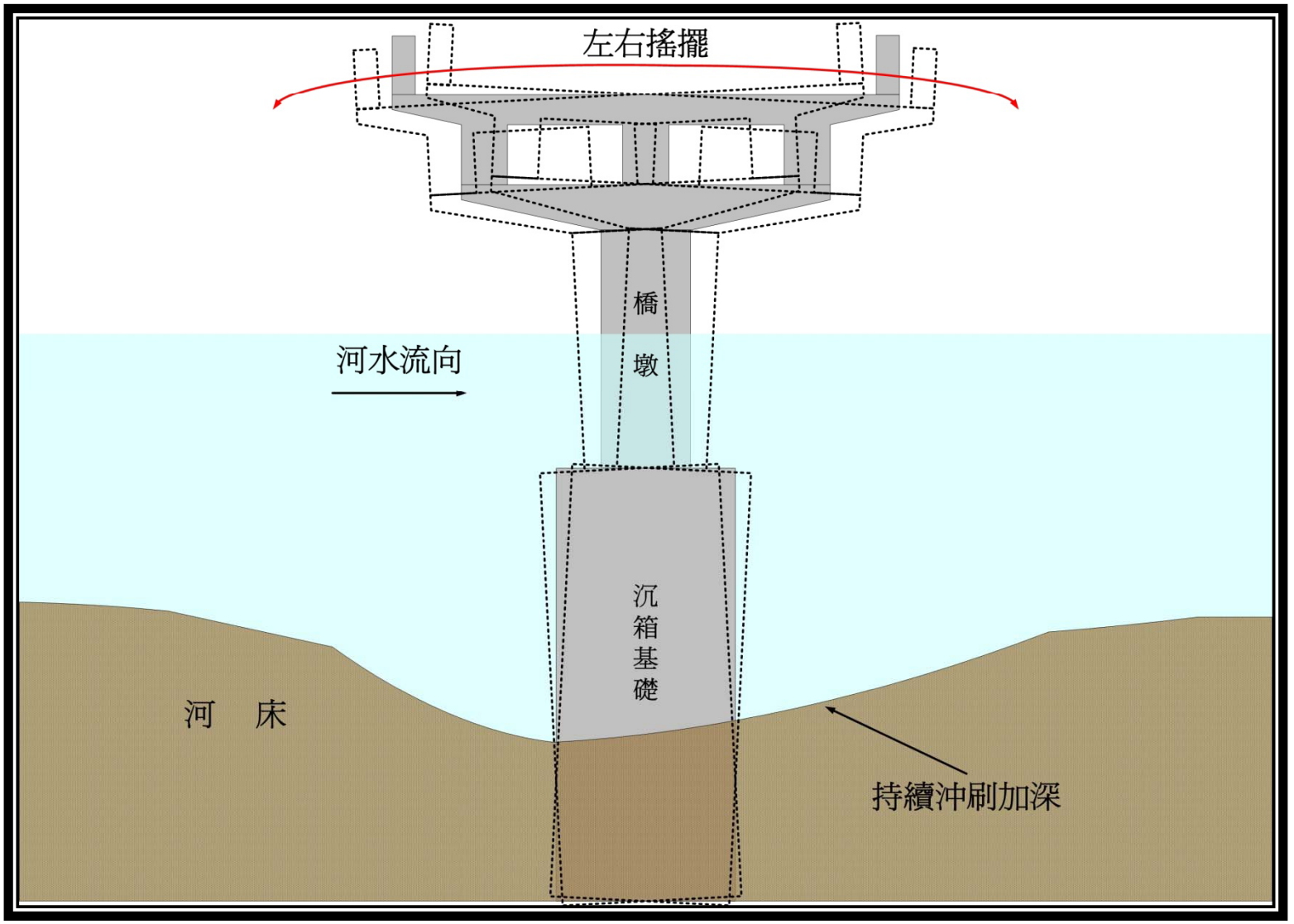
Initial State



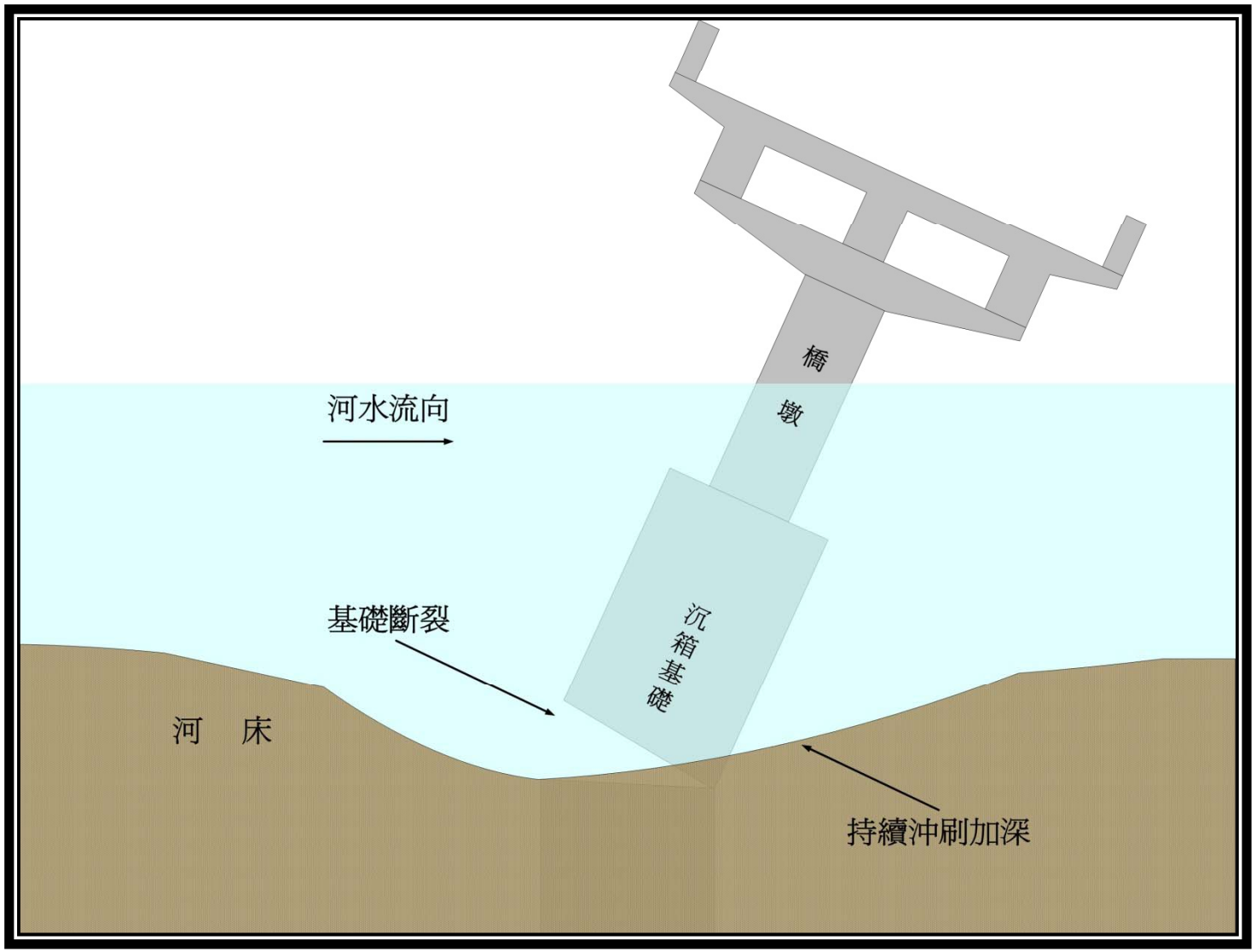
Scouring at Pier



Instability of Bridge



Failure & Collapse of Bridge

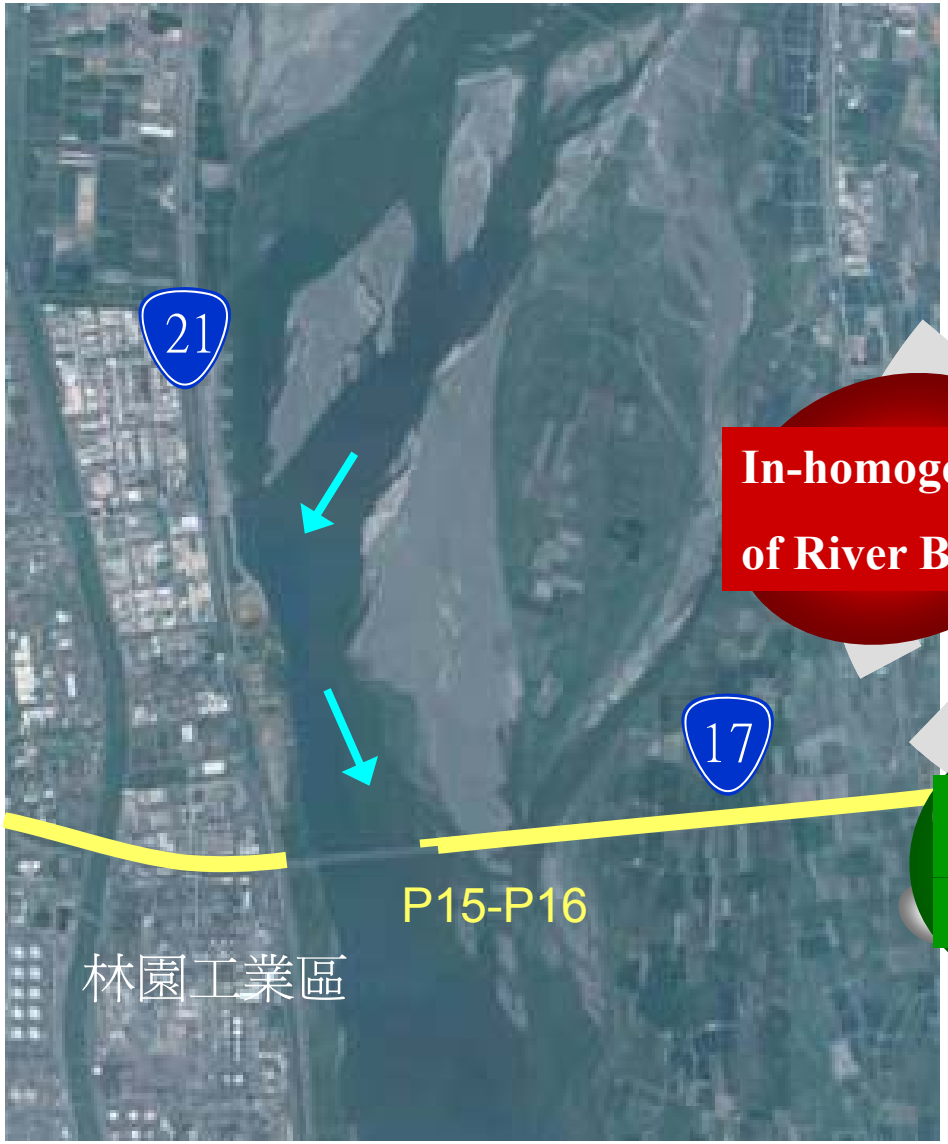


Forensic Study of Collapsed Bridge

Collapse of Shuan-Yuan Bridge

波狀水躍

Possible Causes of Bridge Failure



Drifting Woods

Short Span

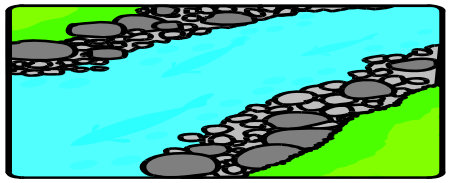
In-homogeneity of River Bed

Causes of Failure

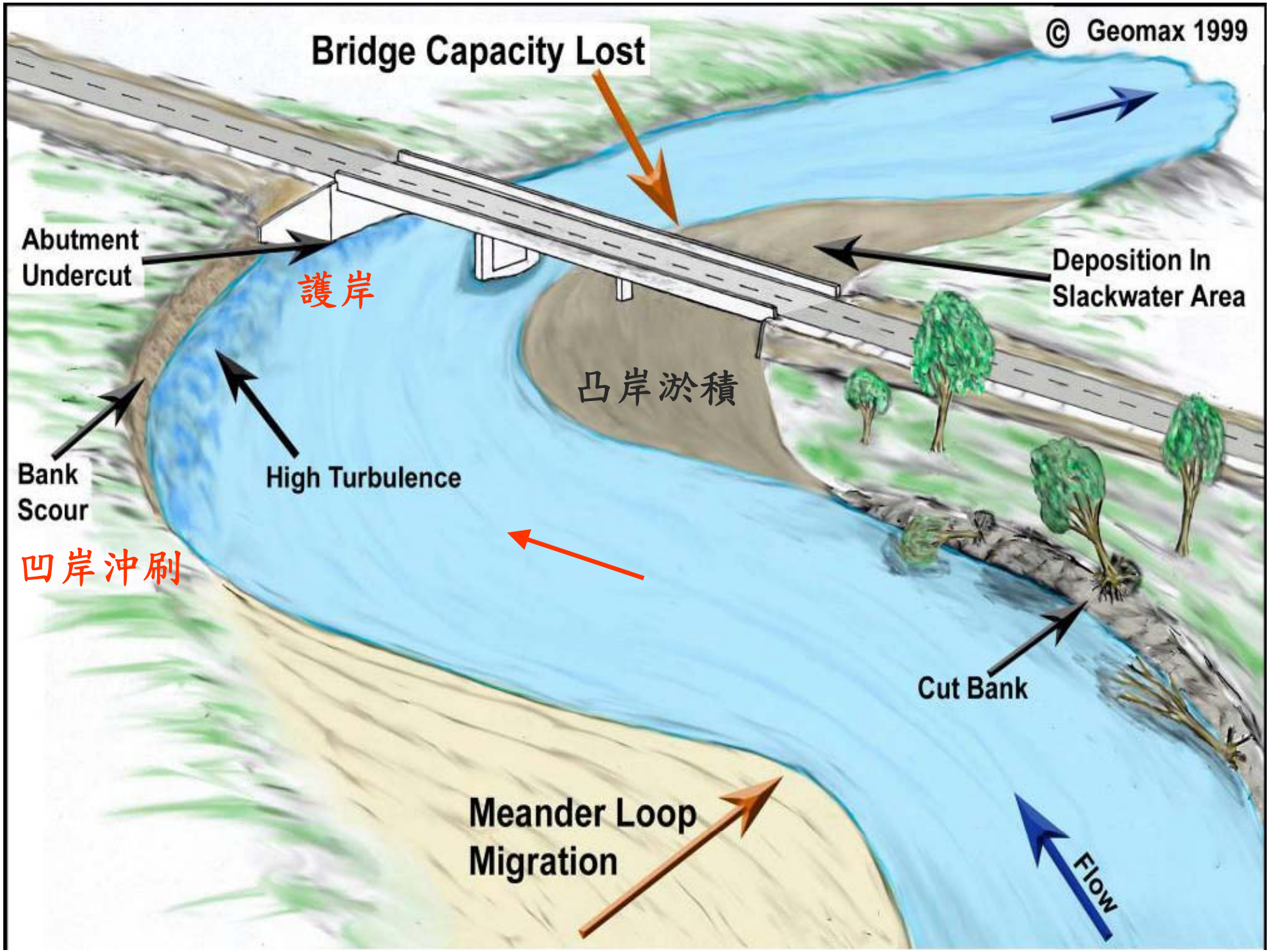
Small Pile Diameter

Tide Force

Scouring Dynamics

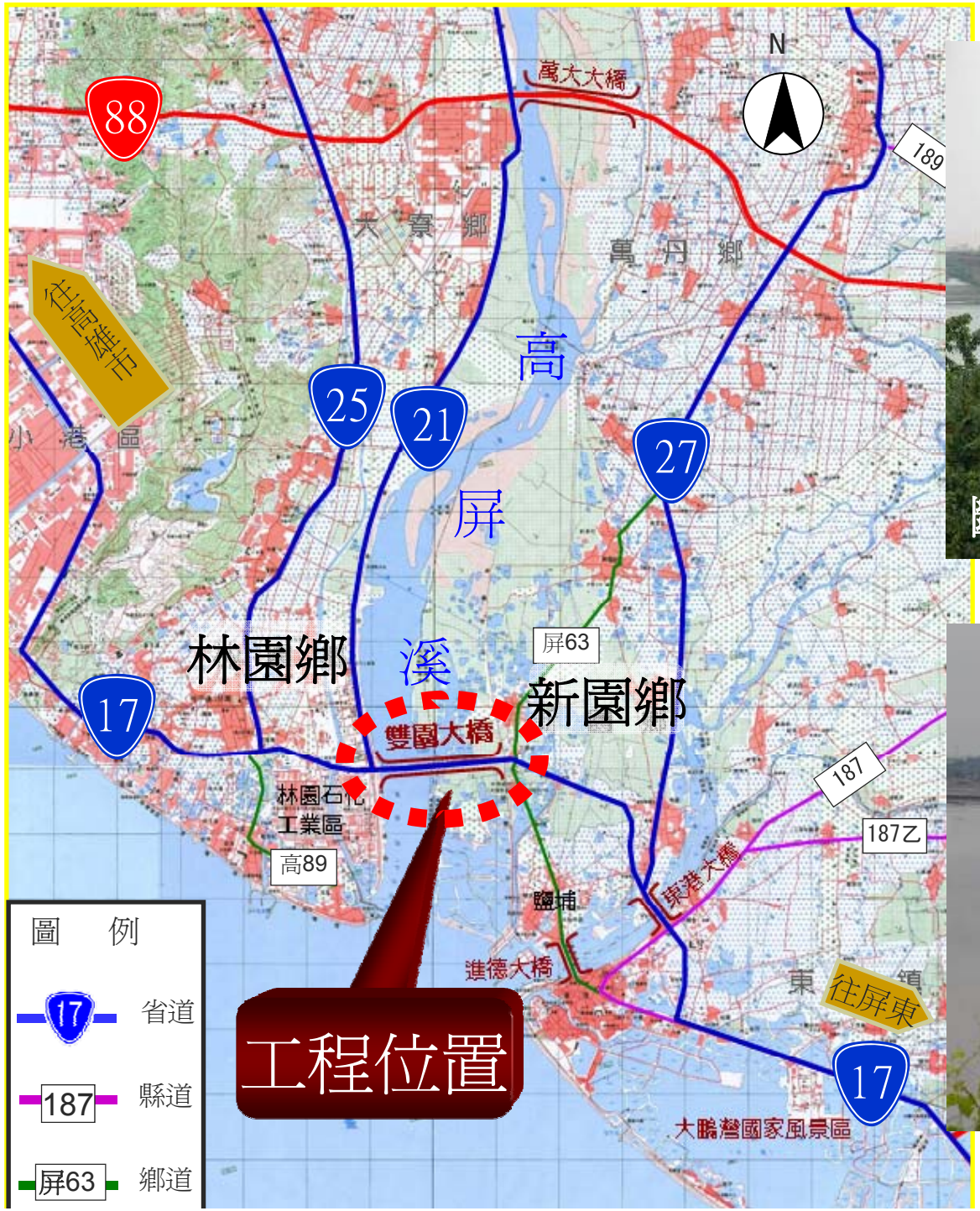


Data Collection


© Geomax 1999
Bridge Capacity Lost
Abutment Undercut
護岸
Deposition In Slackwater Area
凸岸淤積
Bank Scour
High Turbulence
凹岸沖刷
Cut Bank
Meander Loop Migration
Flow

Shun-Yuan Bridge Collapsed on August 8, 2009

(North Bound P1~P14 and South Bound P1~P16)


N
萬大大橋
88
189
大寮鄉
萬丹鄉
往高雄市
高
25
21
27
屏
小港區
林園鄉
溪
屏63
新園鄉
17
雙園大橋
林園石化
工業區
高89
187
187乙
鹽埔
東港大橋
進德大橋
東
往屏東
17
大鵬灣國家風景區
圖 例
省道
縣道
屏63
鄉道
工程位置


斷橋前照片97.12.21


斷橋後照片98.8.21

Basic Data of Bridge from Taiwan-BMS

幾何資料					
橋梁總長	2082.8米	A1進橋版長度	340米	A2進橋版長度	177米
淨寬	2@9.5米	橋版投影面積	35411平方米	總車道數	4
總橋孔數	68	最大跨距	30.6米	跨距分配	2@31.60+66@30.60
最高橋墩高度	9.2米	最低橋上淨高	橋上無跨越物	最低橋下淨高	7.0米

結構資料(梁式橋)						
主梁	材質	預力混凝土	型式	I型梁	每跨斷面數量	3根
橫梁	材質	鋼筋混凝土	型式	中隔版	間距	10米
橋面板	材質	鋼筋混凝土	鋪面材質	瀝青混凝土(AC)		
橋墩	材質	預力混凝土	型式	單柱式	基礎型式	樁基礎
	最深基礎深度	50米	最淺基礎深度	35米	橋基保護工法	無
橋臺	材質	鋼筋混凝土	型式	懸臂式	基礎型式	樁基礎
配件	伸縮縫型式	齒型鋼錨碇具排氣孔鋼板	支承型式	合成橡膠支承	翼牆型式	重力式

設計資料					
設計活載重	HS20	地盤種類	粉土質砂土、粉土質黏土、細中砂	防落橋長度	0.7米
防震設施	無	設計水平地表加速度	0.23g	地震分區	地震乙區

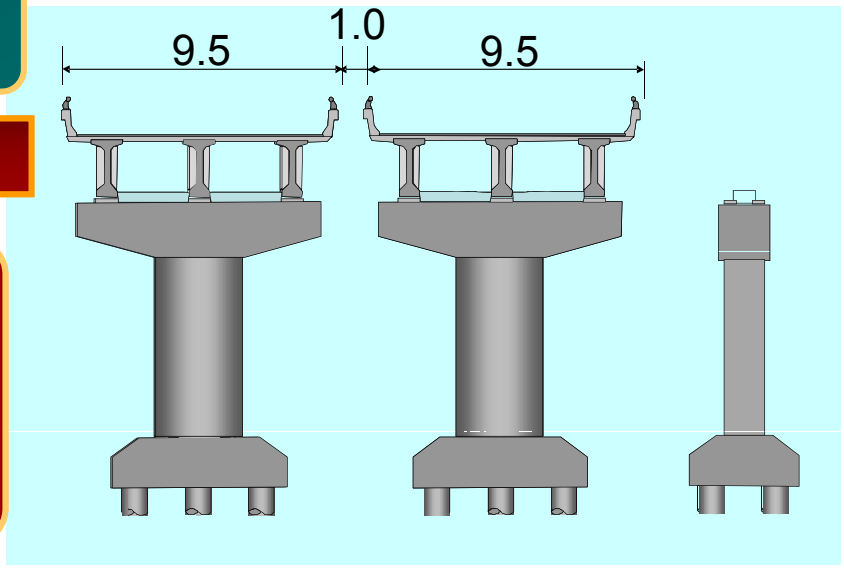
資料來源：交通部全國橋梁管理系統

Length: 2082.8M

First Generation :Bridge ：up stream

Constructed in 1974

- RC reversed circulation piles，
- Diameter of the upper portion of 10M is 90CMφand 76CMφfor the remaining part



Second Generation :Bridge ：dowm stream

Constructed 1981

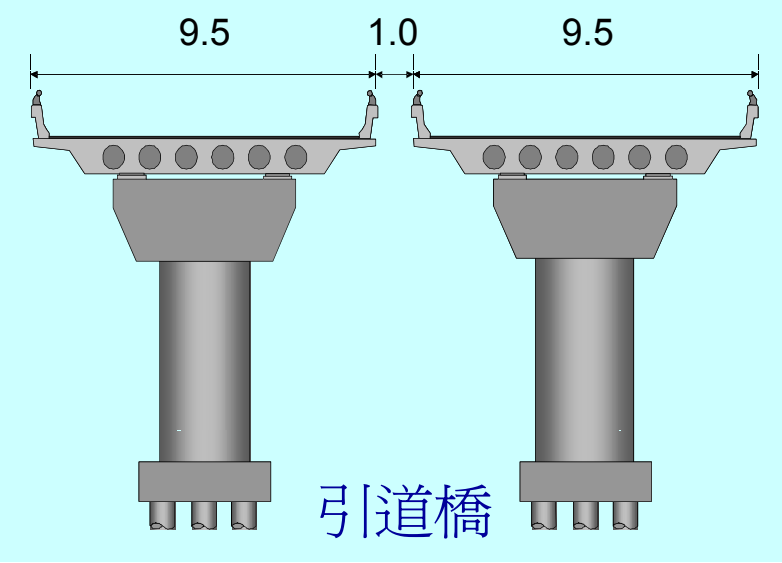
- same type foundation as the first
- generation

Record of Retrofit

- 下游側主橋因鹽害(Corrosion)，故曾於2001年抽換部分預力梁(30跨)
- 位於深槽之橋墩基礎(P5~P14、P22~P25、P30計30座)以基樁補強，每座基礎補4支90CMφ之RC基樁長50M

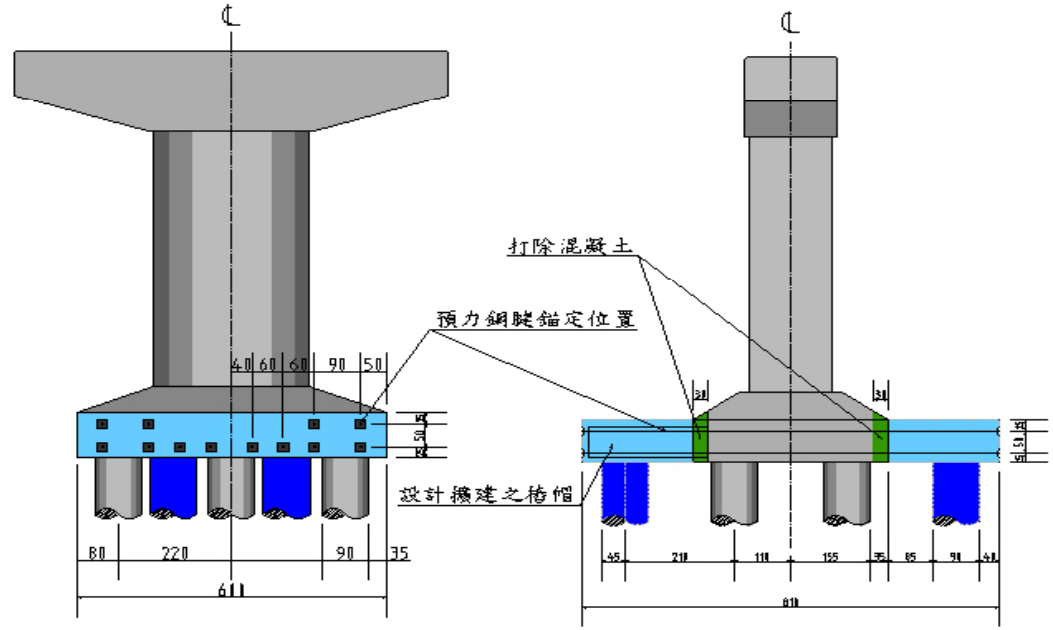
屏東端引道橋

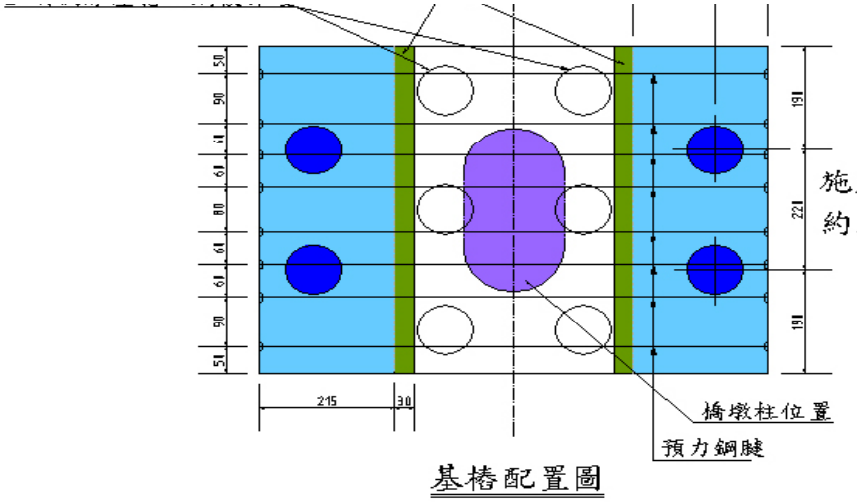
- 上部結構爲三跨連續空心版梁橋
- 跨徑15M，全長277M
- 固定端橋墩基礎配置5支76CMφ RC基樁，活動端爲4支

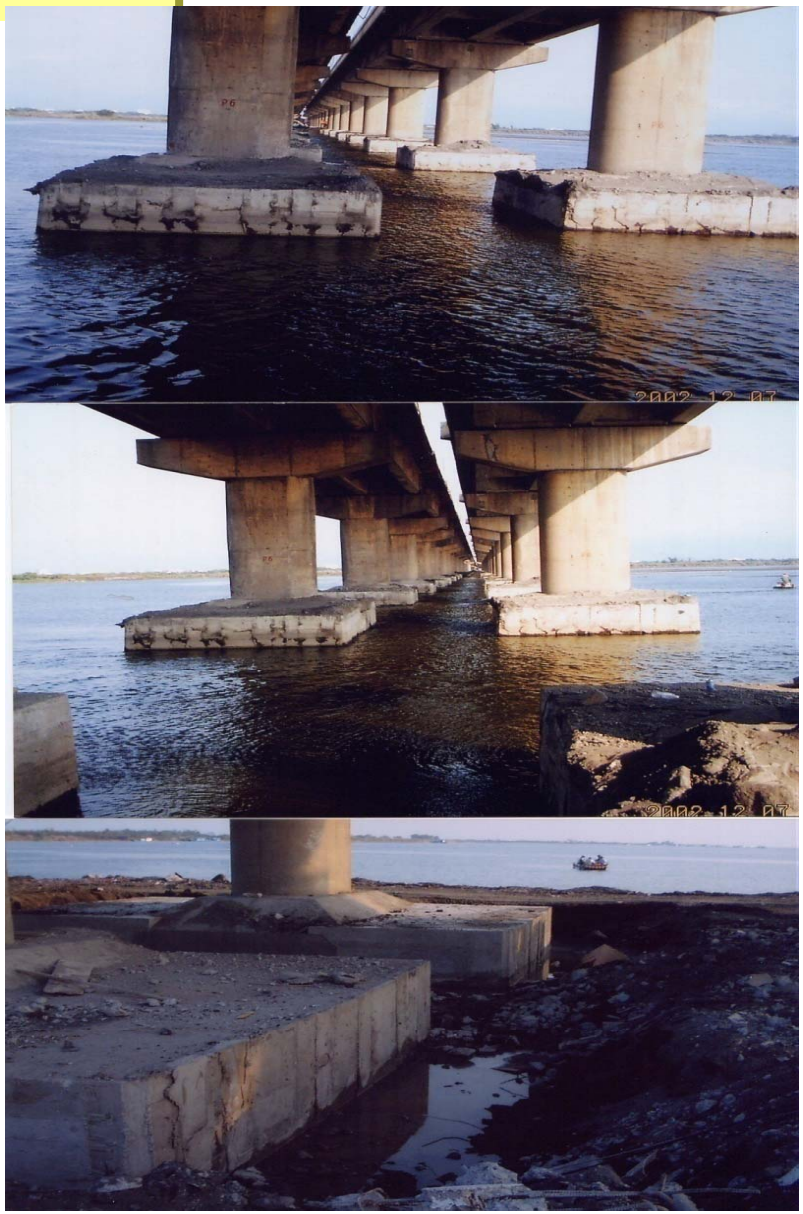


Retrofit of Pier Foundation

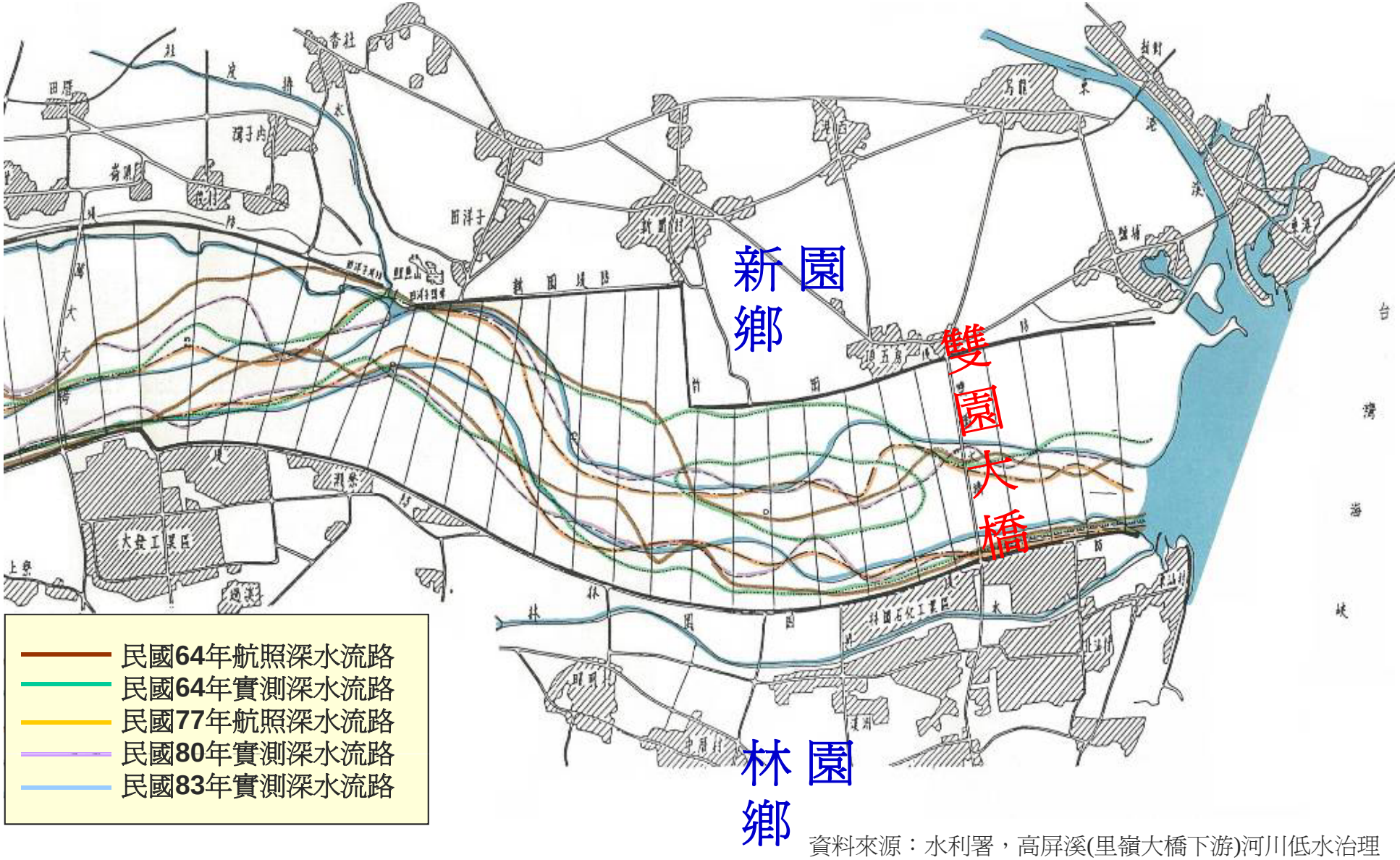
基礎托底補強







Variation of the Route of the Main Channel



資料來源：水利署，高屏溪(里嶺大橋下游)河川低水治理規劃

Cross River Structures in the up and down streams

資料來源：七河局

高屏溪攔河堰

曹公圳攔河堰

資料來源：七河局　　高屏大橋固床工

萬丹攔河堰固床工程(沖毀)

雙園大橋橋址附近河道概況　　資料來源：佚名

橋梁上下游跨河結構物調查

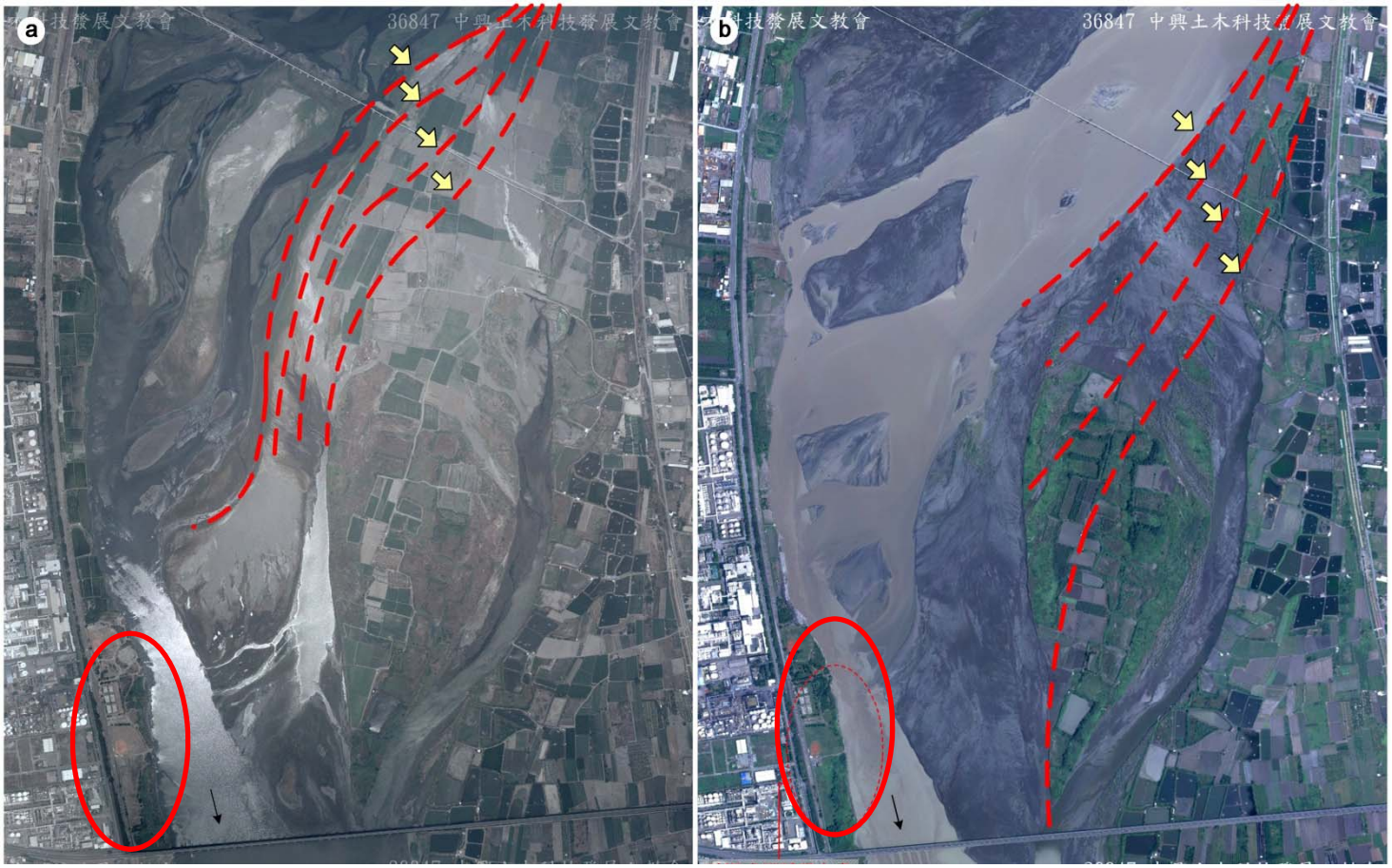
莫拉克颱洪後雙園大橋上游側之跨河構造物

萬大大橋及萬丹攔河堰

萬丹攔河堰上空看往雙園大橋方向

●莫拉克颱風災前、災後影像圖層
Evolution of the River Channel and Sand Bank

雙園大橋上游側左岸高灘地逐漸崩塌退，右岸頂沖區之高灘地亦受側向侵蝕



民國96年4月16日航照　　民國97年9月7日航照

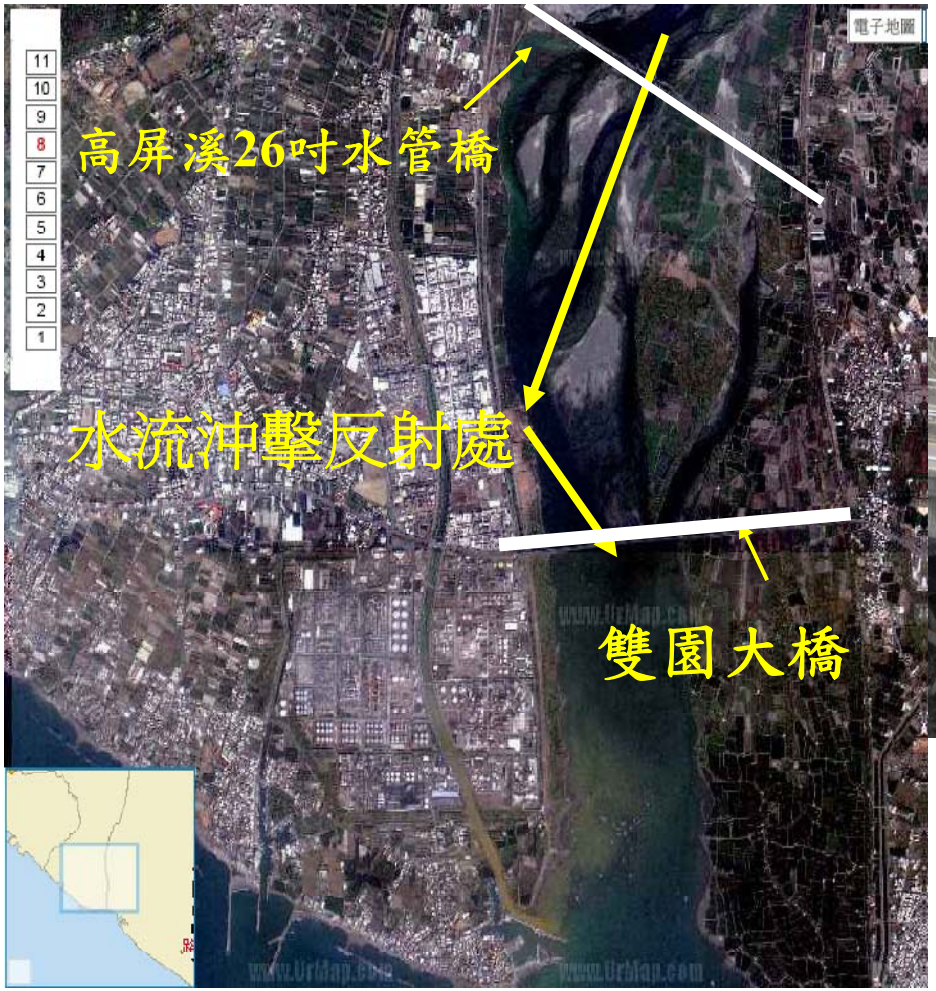
林呈繪製自農航所正射影像底圖

●莫拉克颱風災前、災後影像圖層

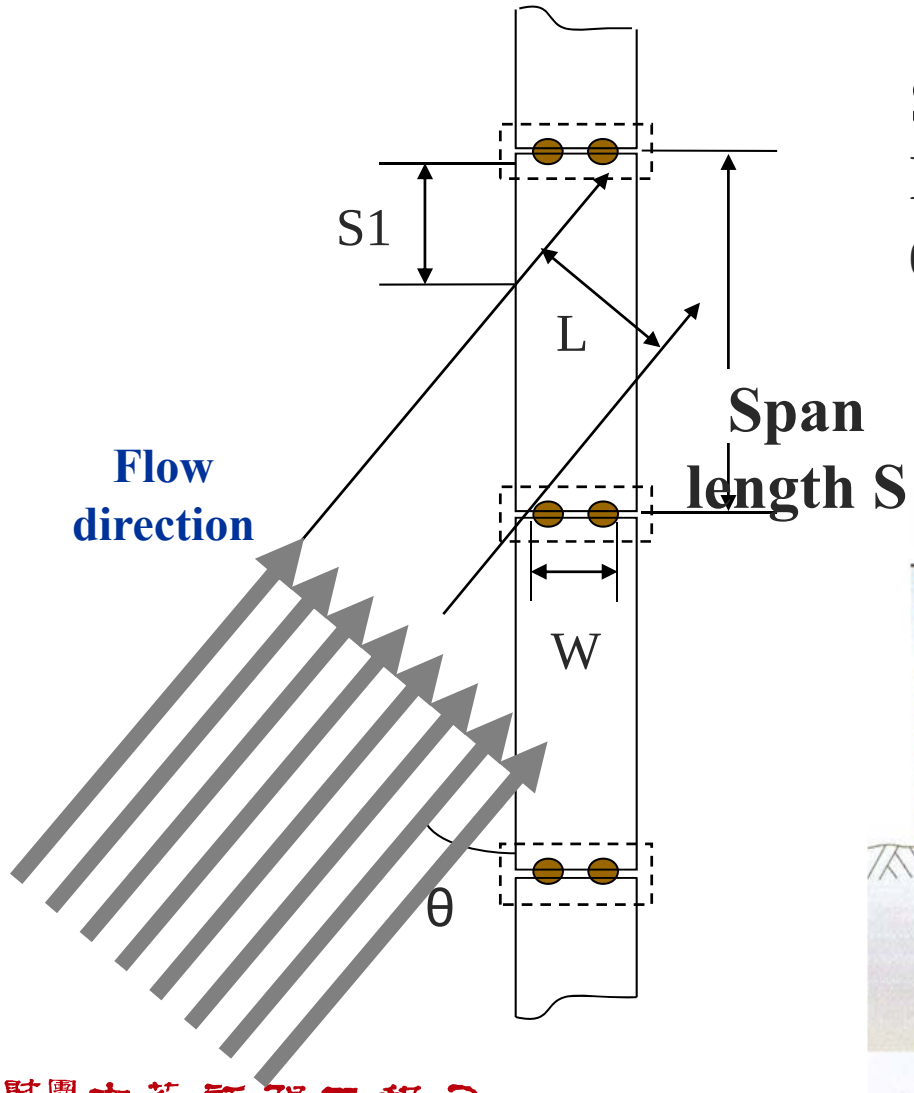
雙園大橋上下游側之河道情況，可見深槽緊臨林園堤防，右岸高灘地幾近沖失

摘自國立成功大學遙測影像處理與地球環境監測實驗室

Possible Causes of Bridge Failure



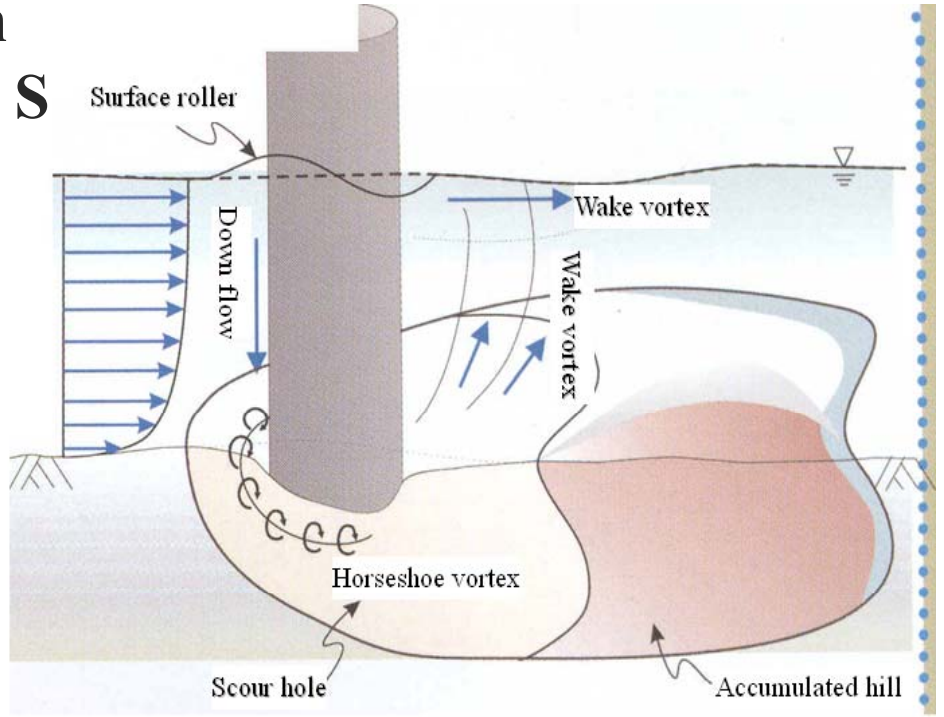
Reduction of the Flow Cross Section



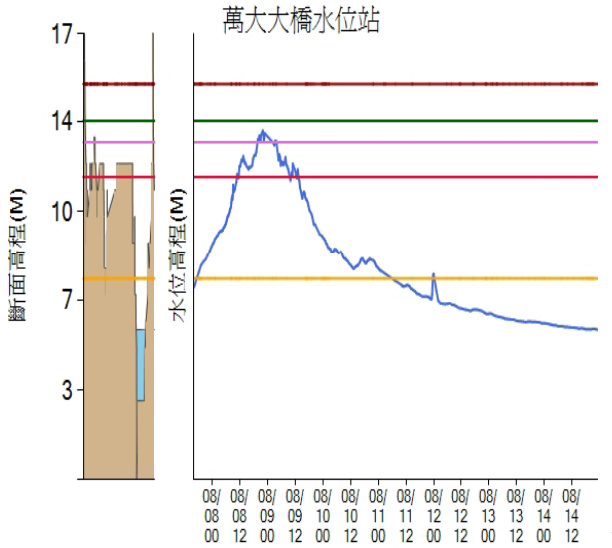
$S1 = W\cot\theta$

$L = (S-S1)\sin\theta = S\sin\theta - W\cos\theta$

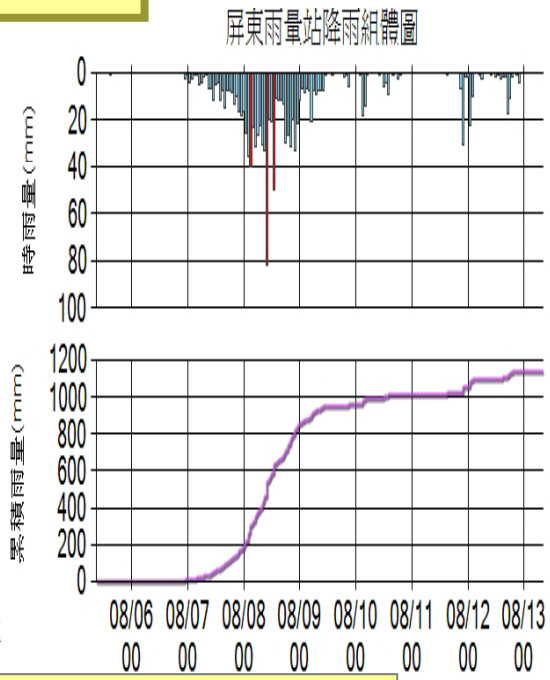
$\theta = \tan^{-1}(W/S)$



莫拉克颱風氣象、水文資料蒐集



萬大大橋水位站水位歷線

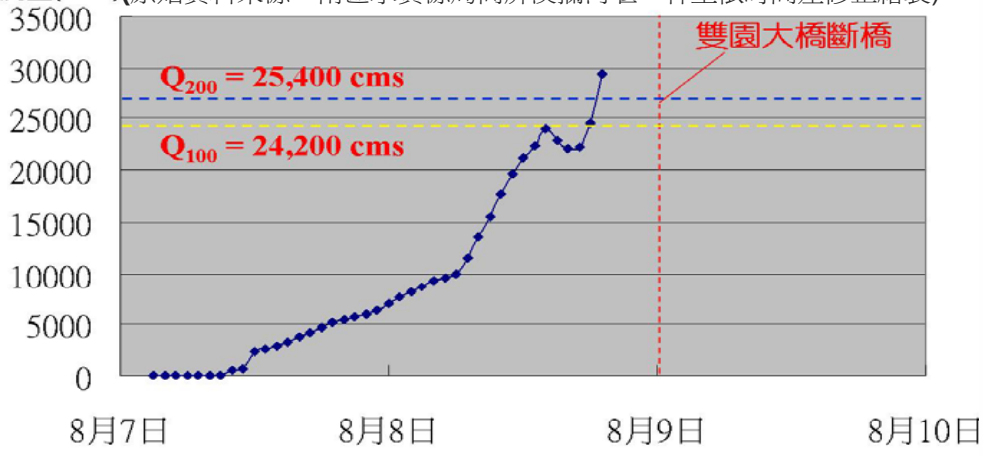


降雨組體圖與累積雨量

資料來源：經濟部水利署災害緊急應變系統

經時間修正後之雙園大橋流量歷線

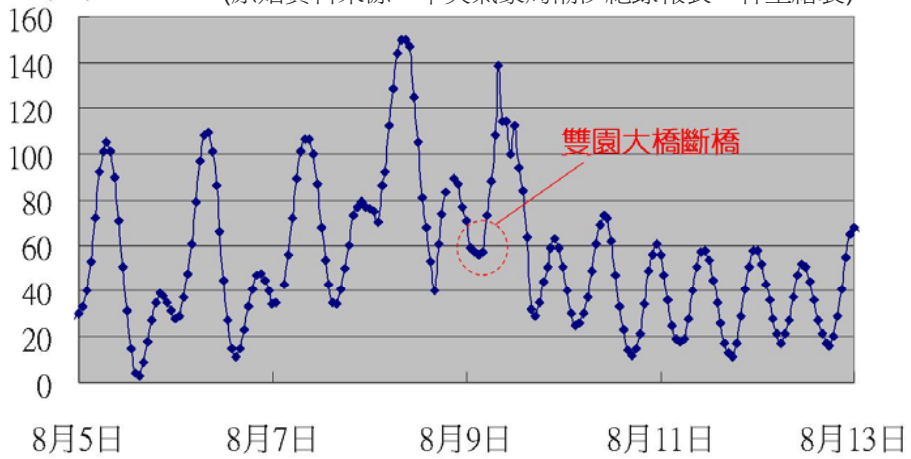
流量(cms)(原始資料來源：南區水資源局高屏溪攔河堰；林呈依時間差修正繪製)



東港潮位站水位資料

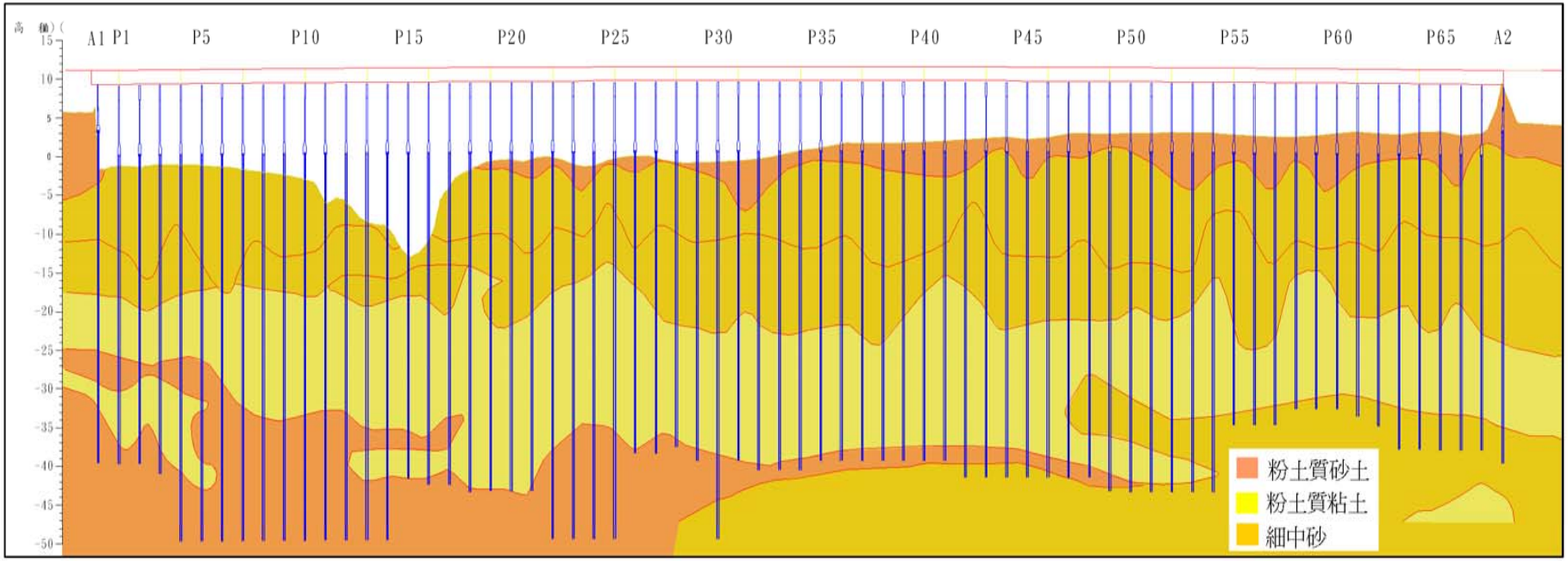
水位(cm)

(原始資料來源：中央氣象局潮汐紀錄報表；林呈繪製)



河床地質與河床高程剖面調查

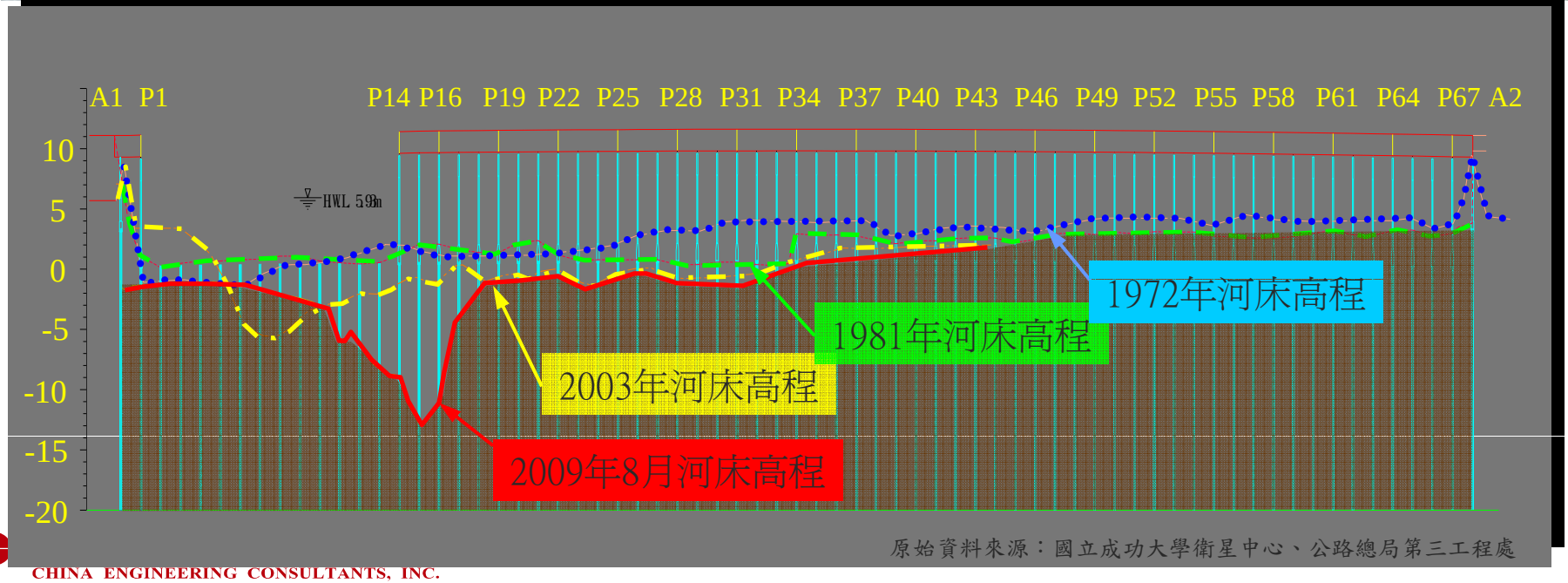
- 土層由砂、礫石及泥組成
- 地表下5米內爲粉土質砂，5~20米爲細中砂，20~40米爲粉土質黏土夾砂，40米以下爲粉土質砂或細中砂
- 良好承載層位於高程-40米以下



工址沿線地層剖面

資料來源：臺灣世曦工程顧問公司

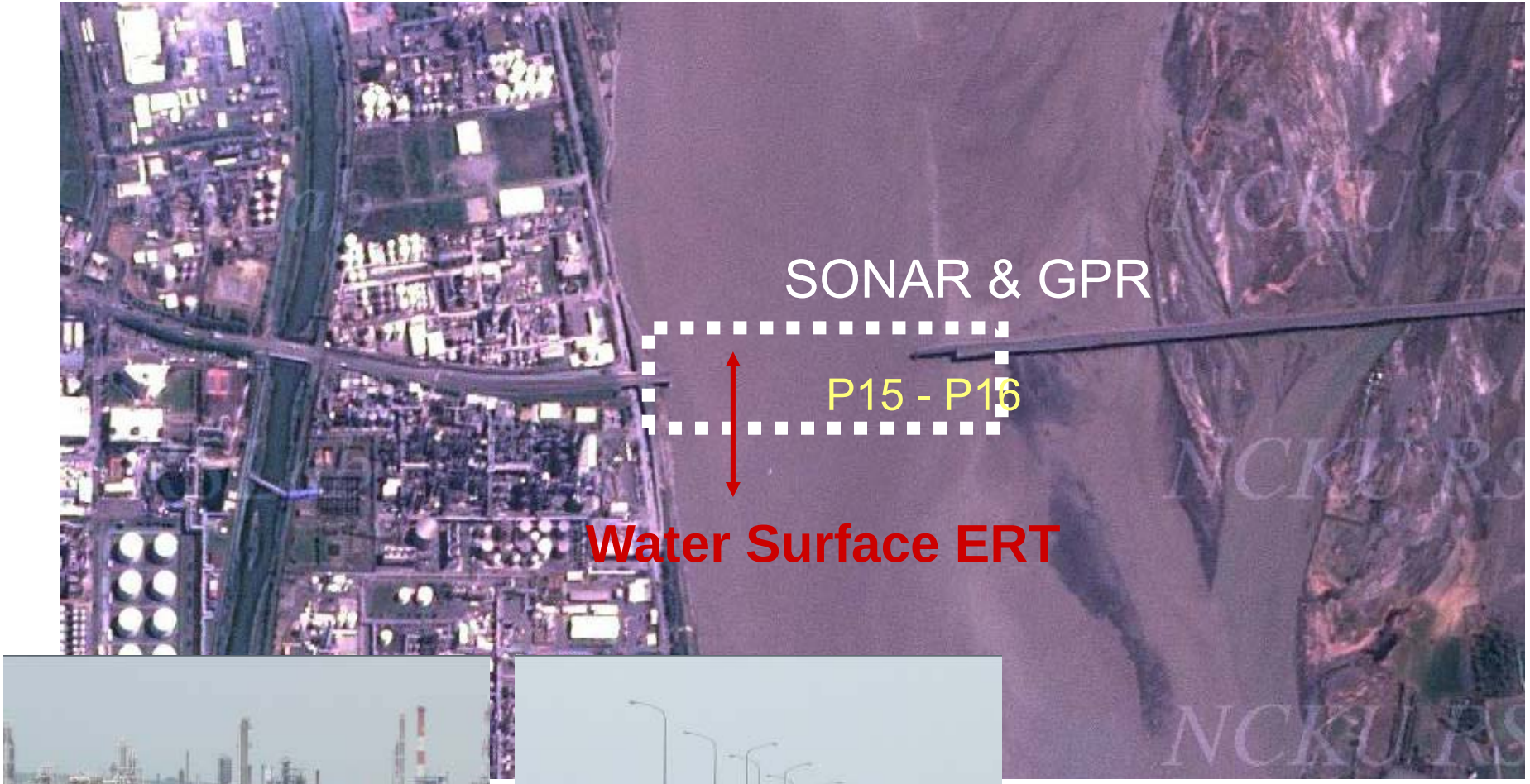
河床地質與河床高程剖面調查



原始資料來源：國立成功大學衛星中心、公路總局第三工程處

Measurements

98.8.28 River Bed Inspection

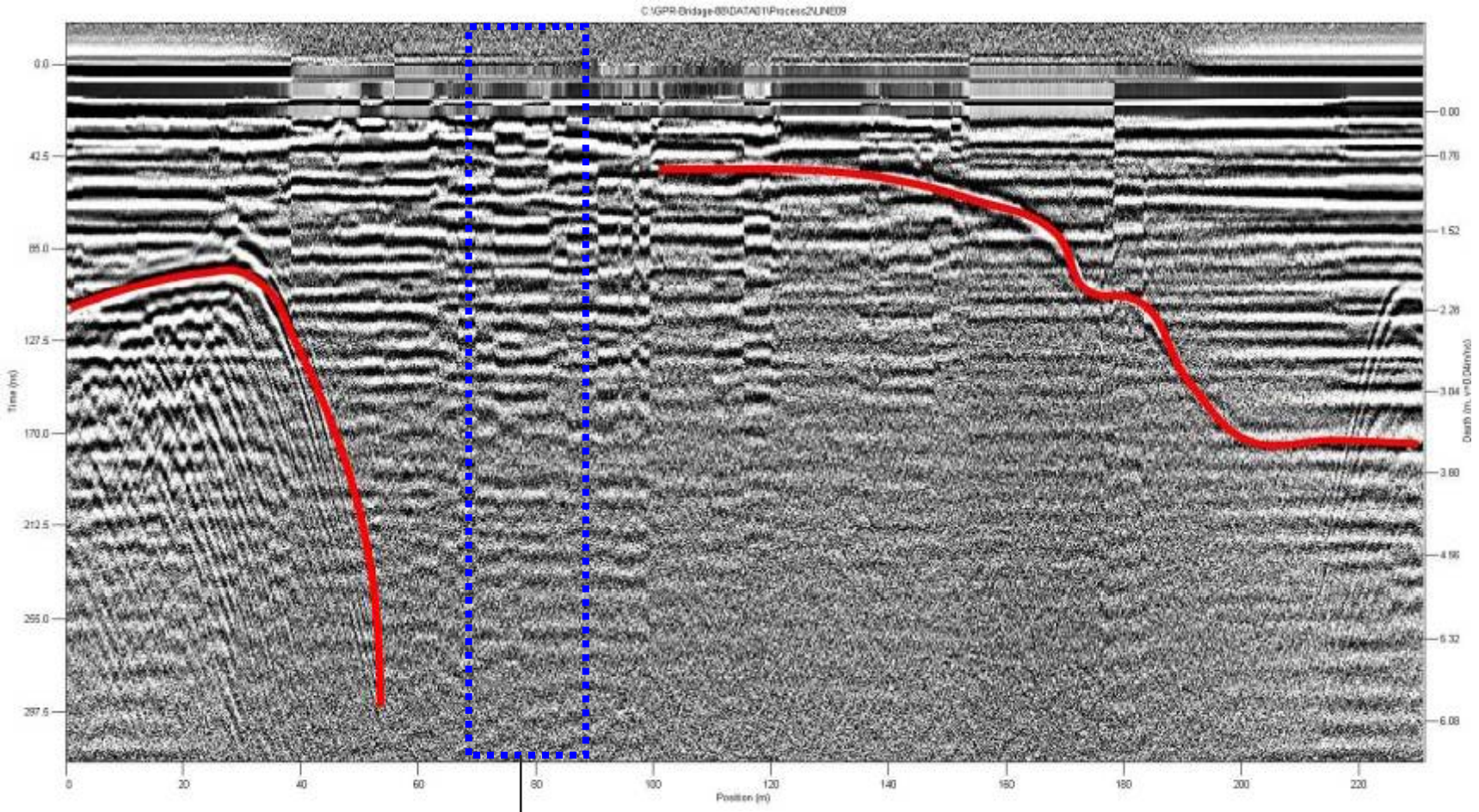


底圖來源：成大衛星中心

GPR and Sonar Inspection

東港端

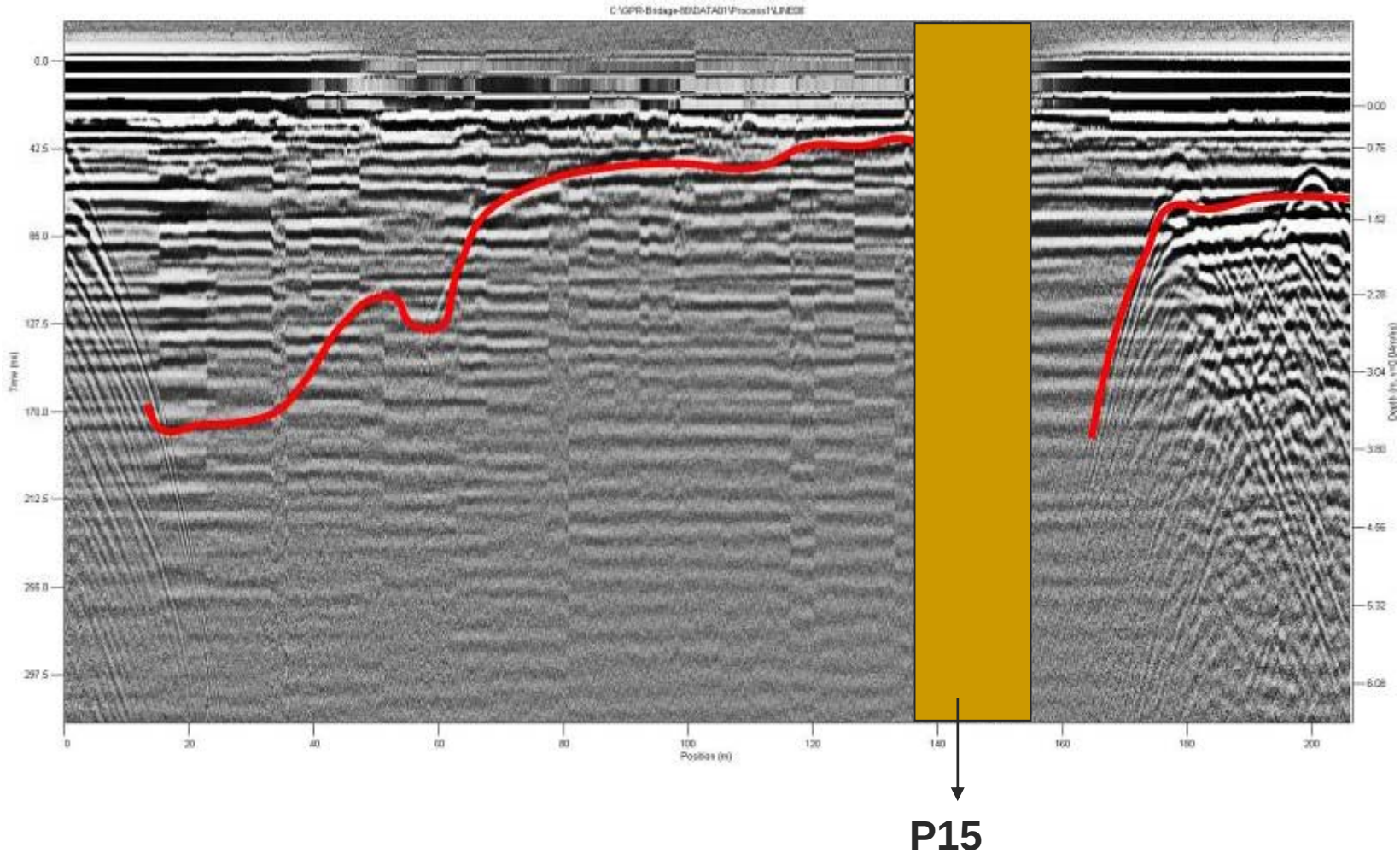
林邊端


C:\GPR-Bridge-88\DATA01\Process2\LIN009
0.0
42.5
85.0
127.5
170.0
212.5
255.0
297.5
Time (ns)
0
20
40
60
80
100
120
140
160
180
200
220
Position (m)
0.00
0.76
1.52
2.28
3.04
3.80
4.56
5.32
6.08
Depth (m, v=0.04m/ns)

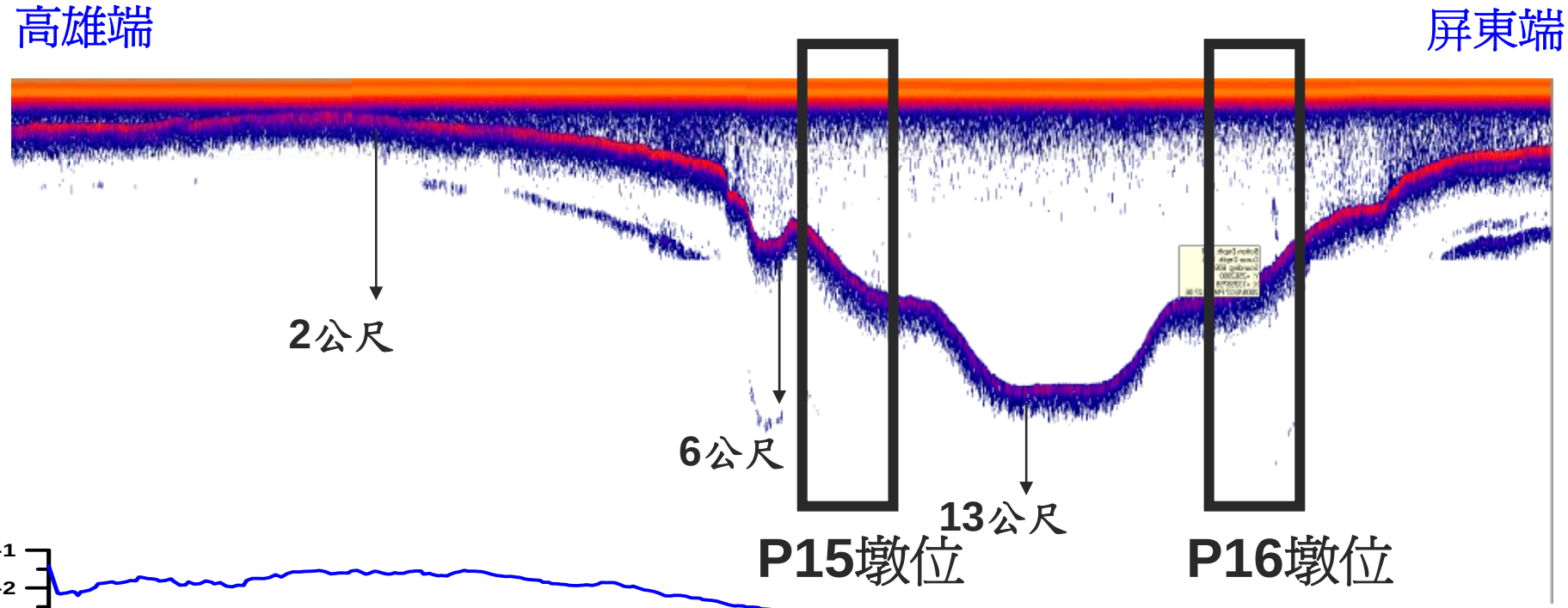
P15

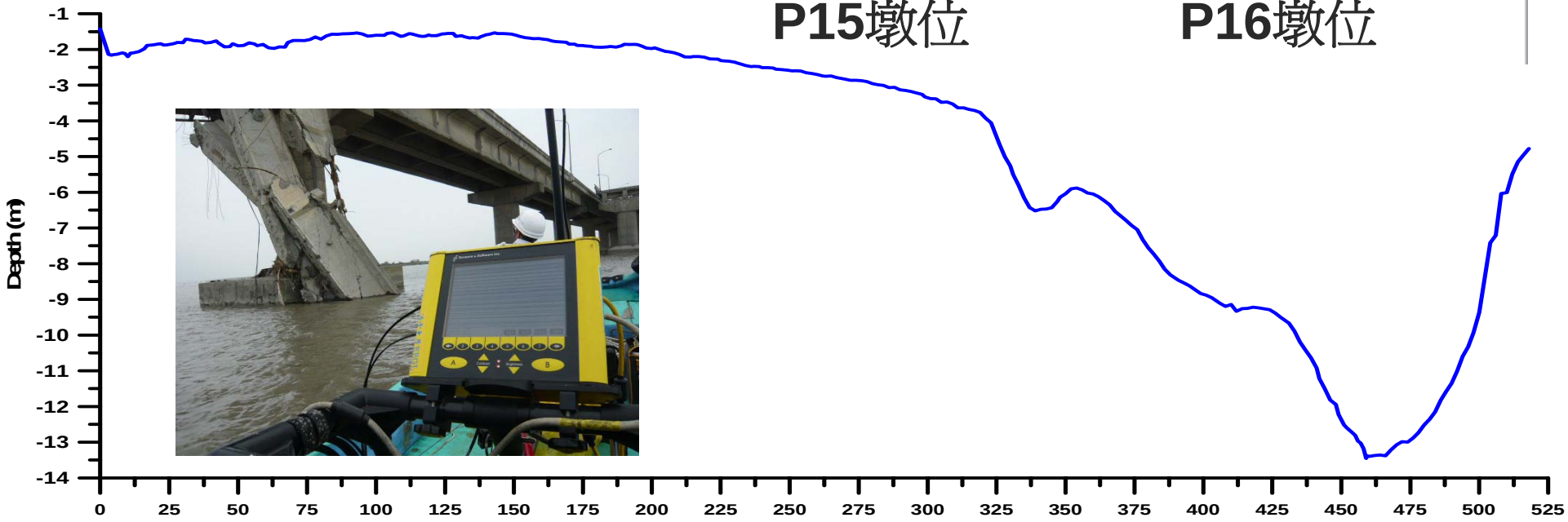
林邊端

東港端


0.0
42.5
85.0
127.5
170.0
212.5
255.0
297.5
Time (ns)
0
20
40
60
80
100
120
140
160
180
200
Position (m)
0.00
0.76
1.52
2.28
3.04
3.80
4.56
5.32
6.08
P15

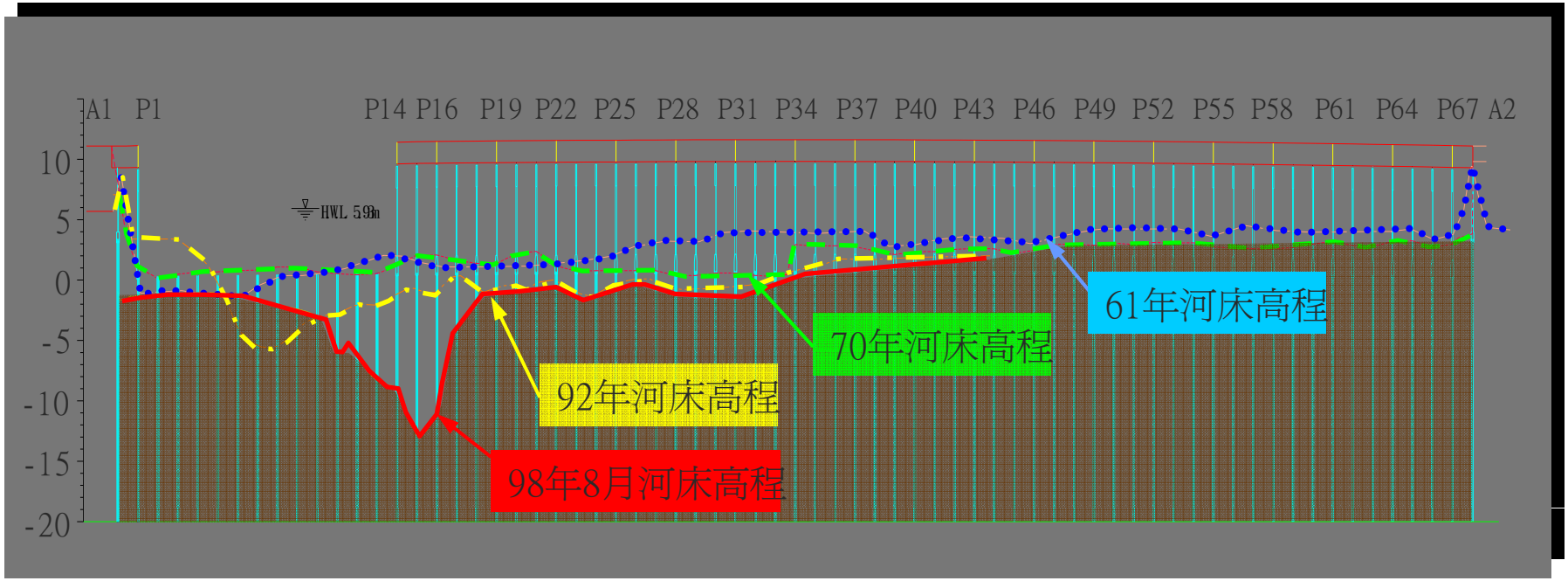
Profile of River Bed



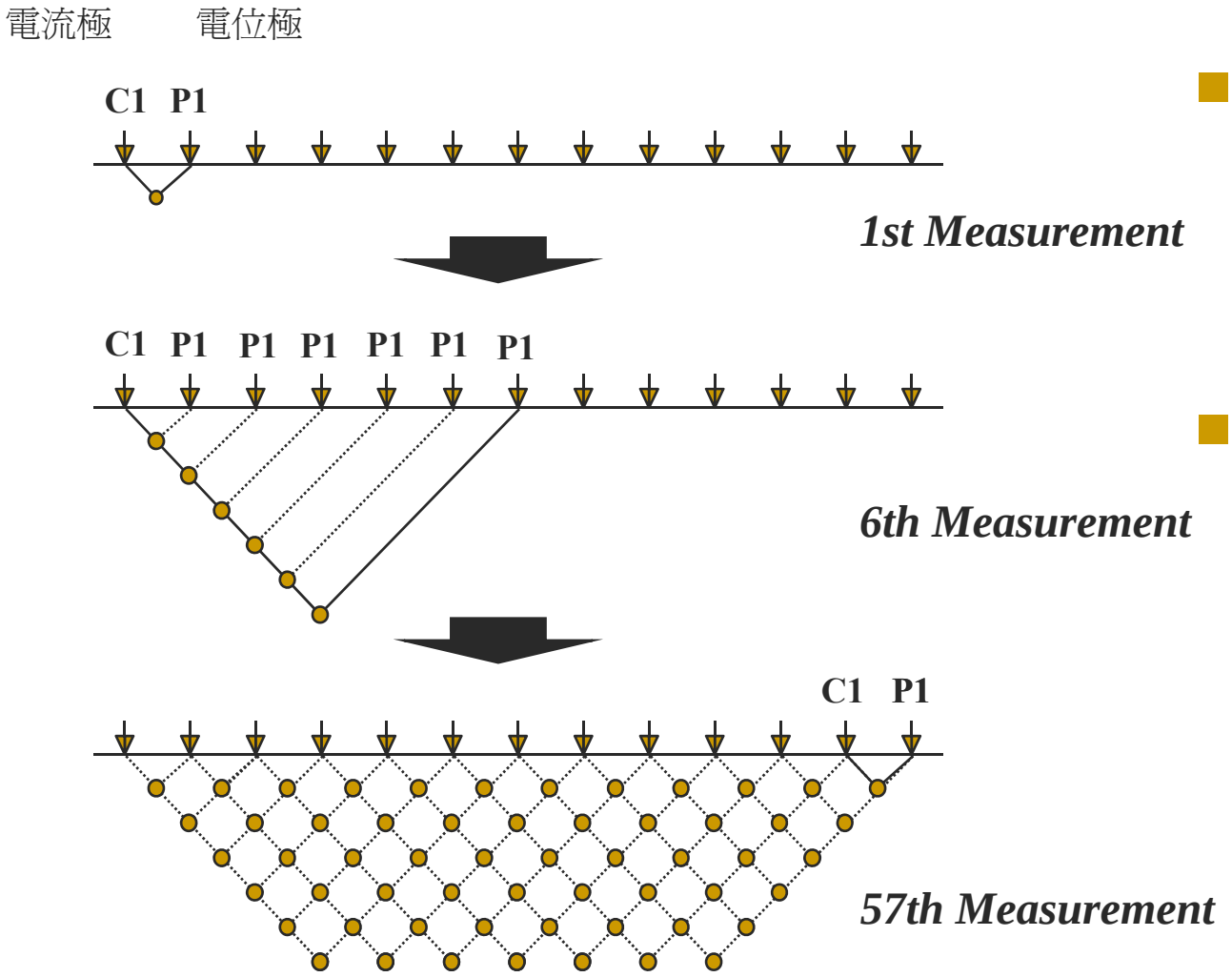


河床沖刷變化


往高雄縣林園鄉
高屏溪
往屏東縣新園鄉
P1
A1
P14
P34
P67
A2
橋梁平面圖


A1 P1 P14 P16 P19 P22 P25 P28 P31 P34 P37 P40 P43 P46 P49 P52 P55 P58 P61 P64 P67 A2
10
5
0
-5
-10
-15
-20
HWL 59m
92年河床高程
98年8月河床高程
70年河床高程
61年河床高程

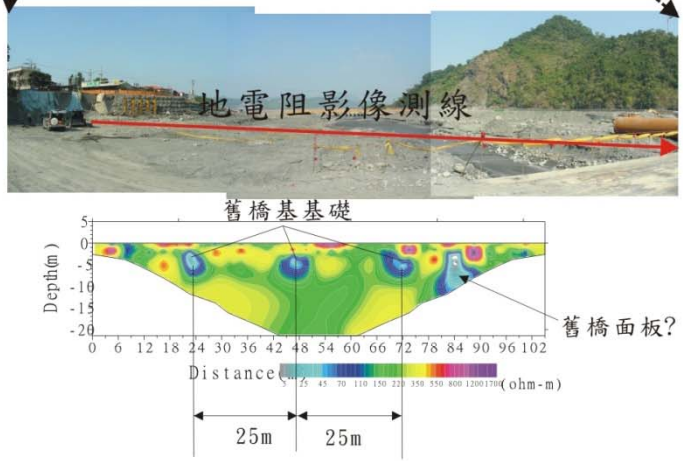
Electrical Resistivity Tomography (ERT)



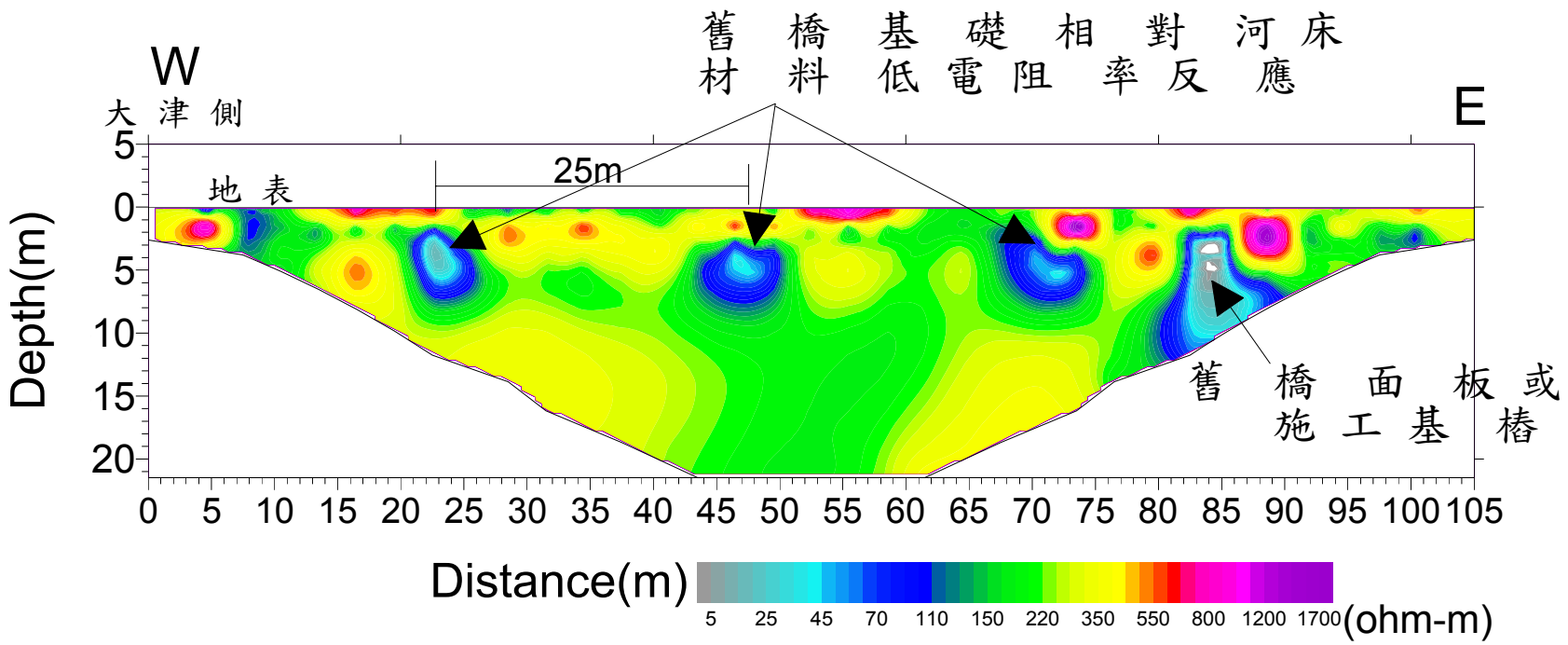
- 沿既定斷面掃描地層電阻率。
- 藉分析電阻率變化，研判地下物之形貌。

大津橋

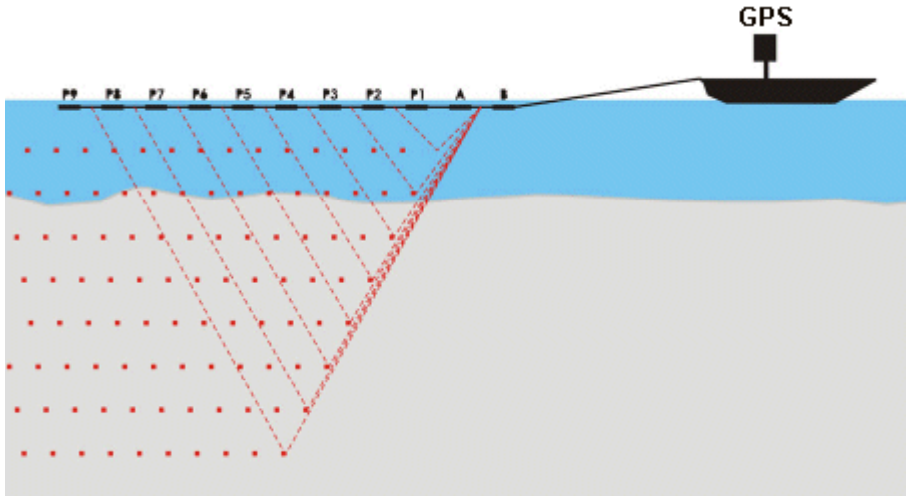
大津橋



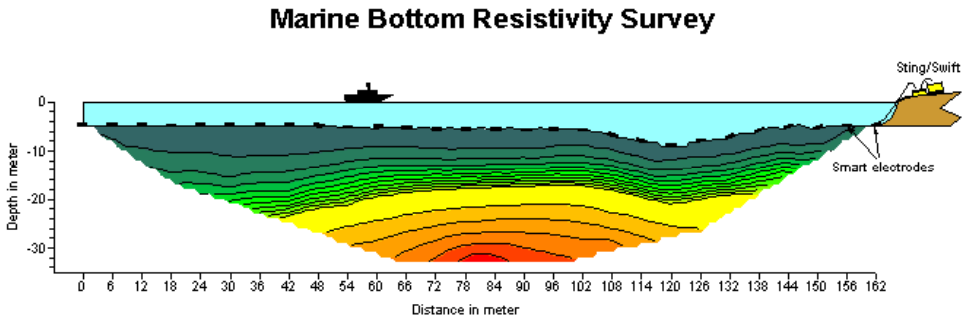
2009/12/11大津橋舊址施測


舊 橋 基 礎 相 對 河 床
材 料 低 電 阻 率 反 應
W
大 津 側
E
地 表
25m
舊 橋 面 板 或
施 工 基 樁
Depth(m)
5
0
5
10
15
20
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105
Distance(m)
5 25 45 70 110 150 220 350 550 800 1200 1700 (ohm-m)

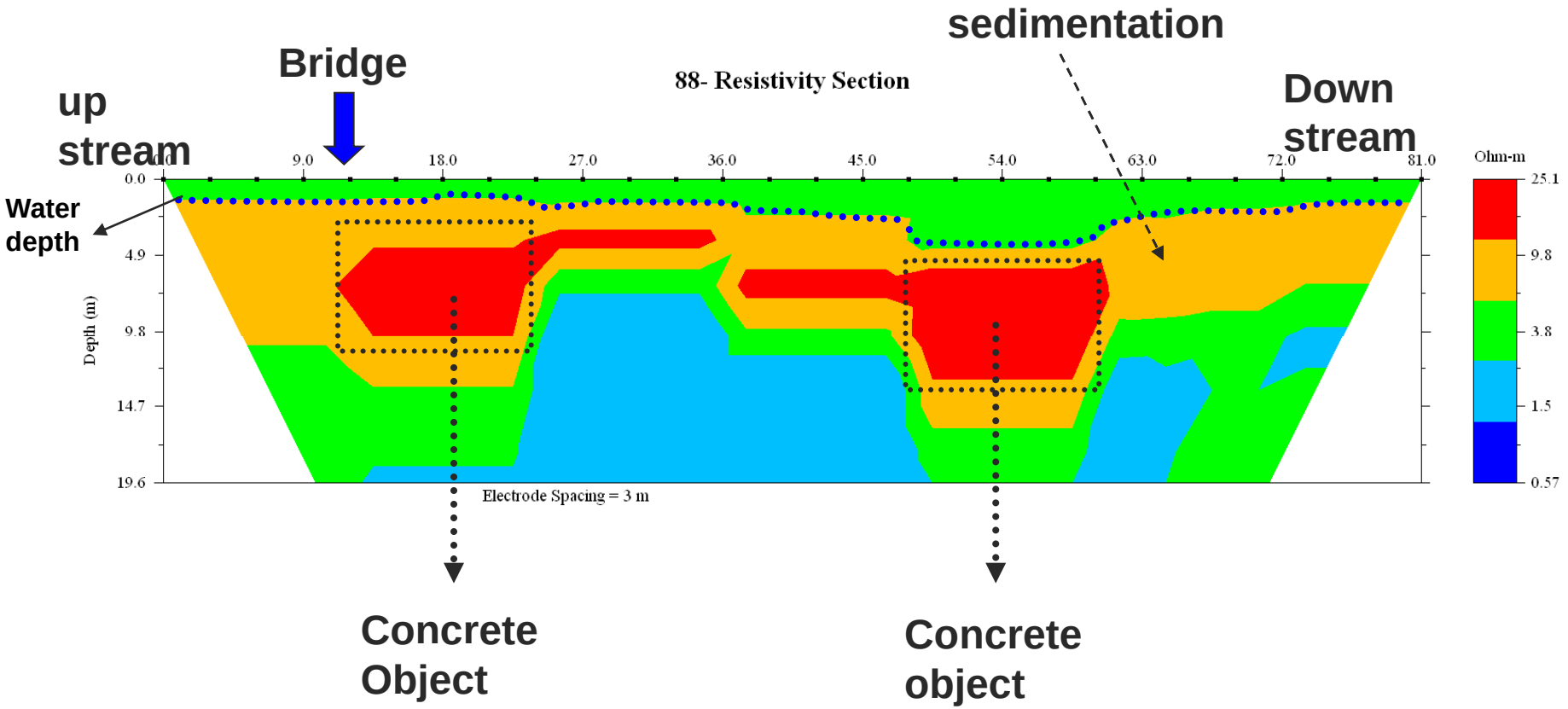

2009/08/28


GPS
P9
P8
P7
P6
P5
P4
P3
P2
P1
A
B


2009/08/28


Marine Bottom Resistivity Survey
Sting/Swift
Smart electrodes
Depth in meter
0
-10
-20
-30
0 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96 102 108 114 120 126 132 138 144 150 156 162
Distance in meter

ERT Map of the Shuang-Yuan Bridge at P2 at August 28, 2009



UAV (unman aerial vehicle) (MD4-200)

執行單位：

迅聯科技公司

Picturing of the Disaster Area by UAV

3D Laser Scanning (LiDar)

3D Laser Scanning

執行單位：

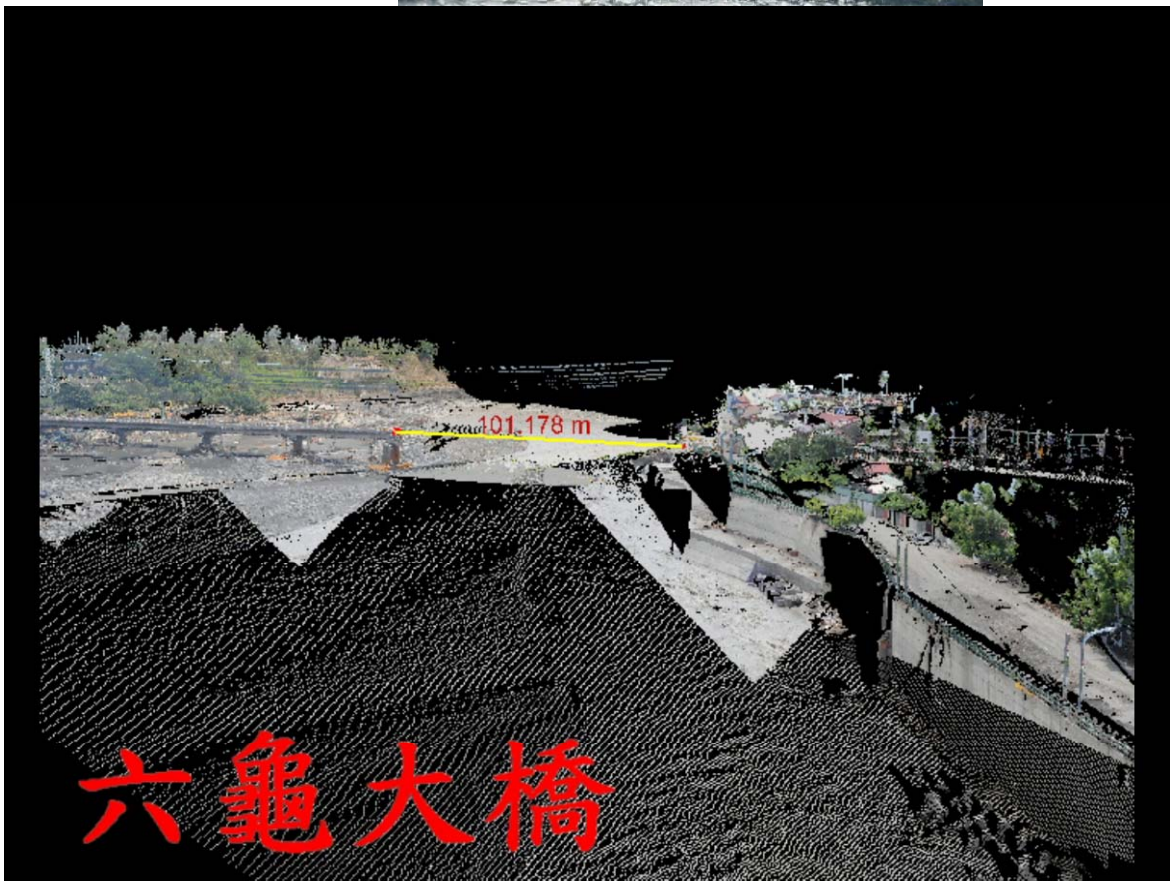
中國科技大學

清雲科技大學

自強工程顧問公司

已完成五座橋梁

- 雙園大橋
- 六龜大橋
- 新旗尾橋
- 旗尾橋
- 大津橋



Bridge Failure and Collapse Analysis

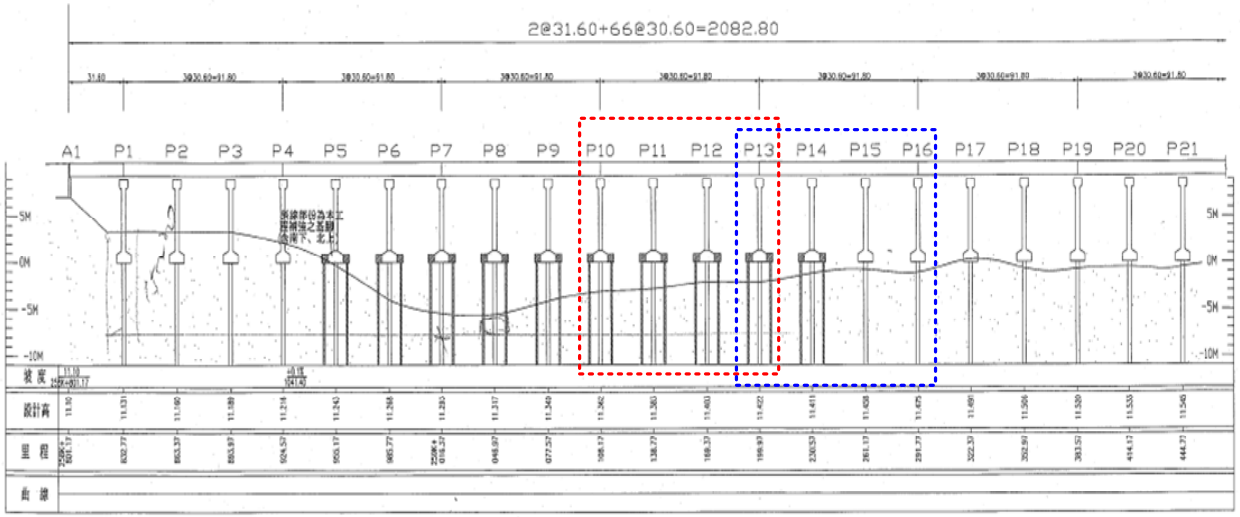
pushover analysis

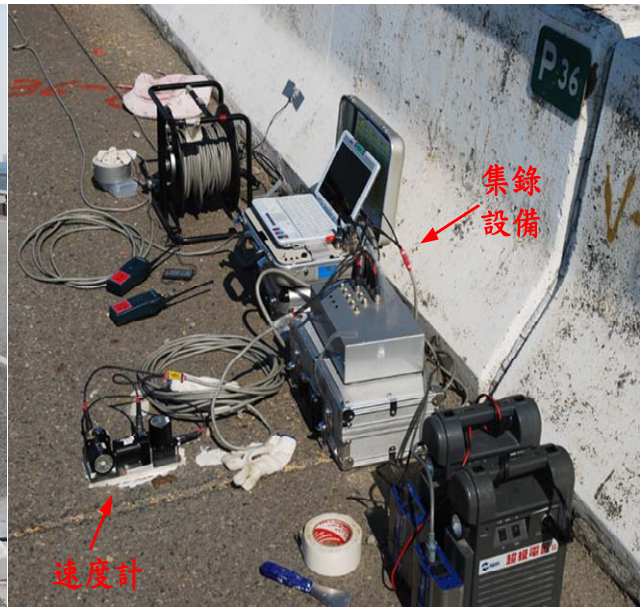
Construct the structural models of P10~P13 and P13~P16

Ambient Vibration Measurement

Hydraulic Force applied on pier and piles

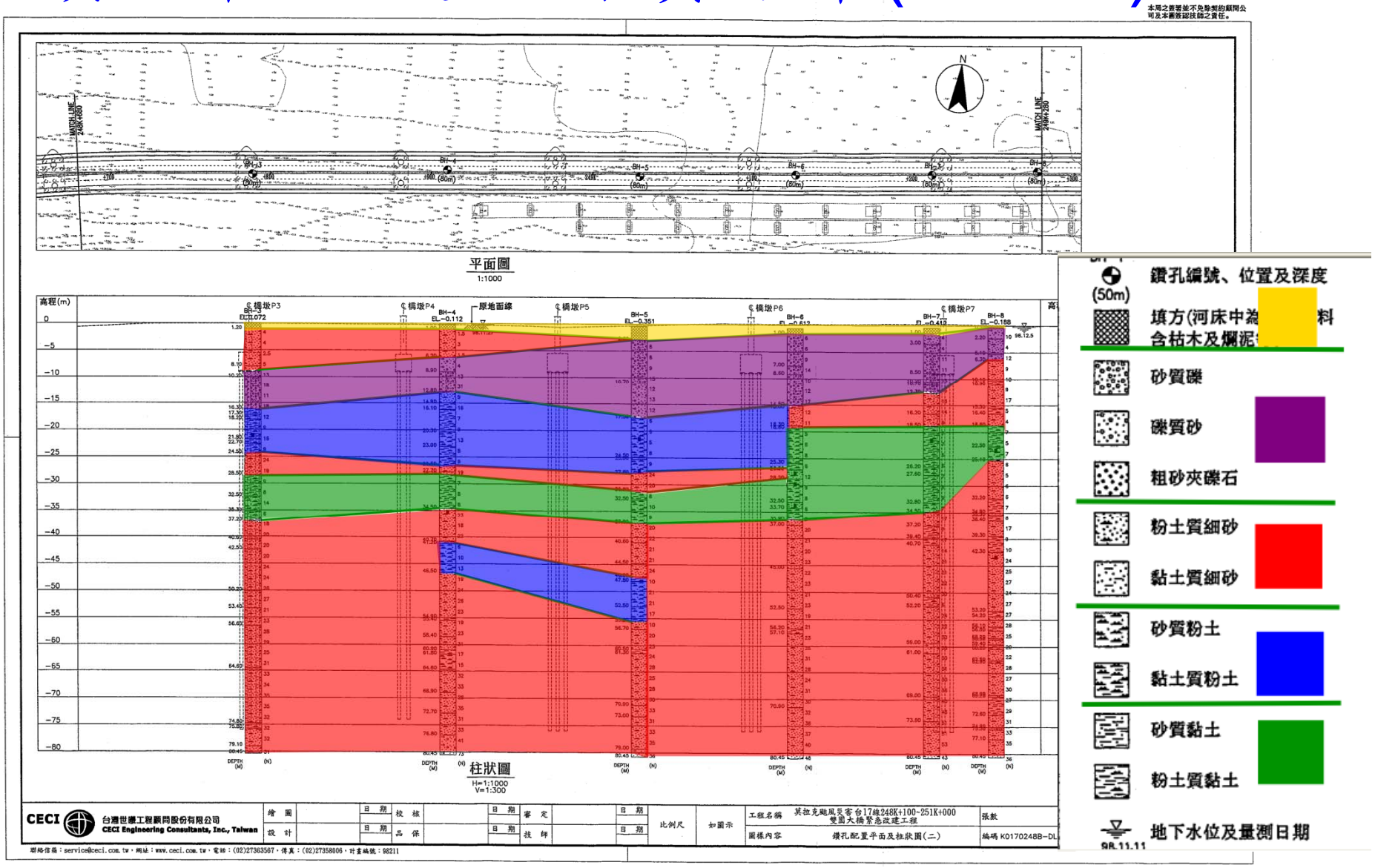
Bridge collapse analysis (displacement control)



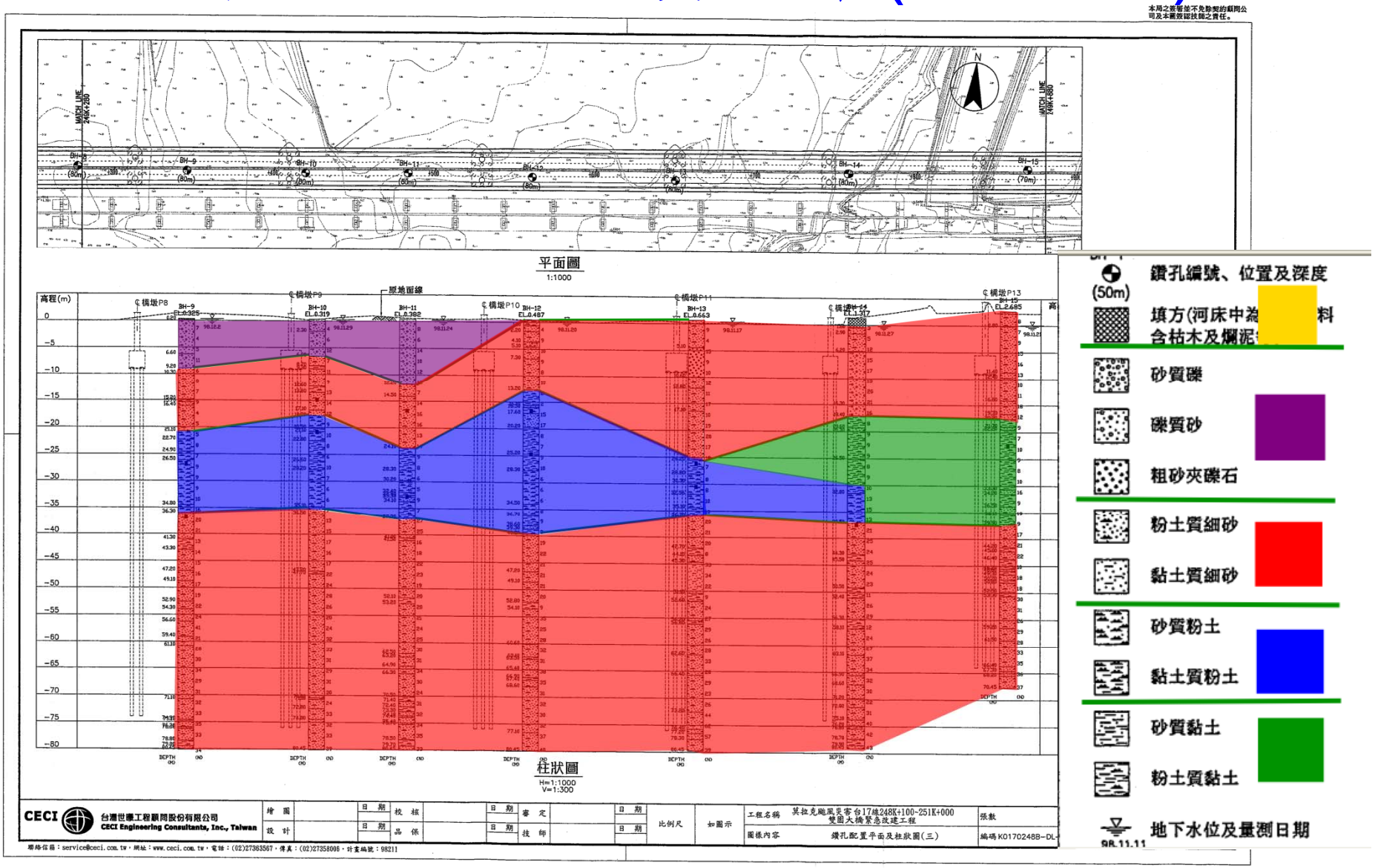


Modeling

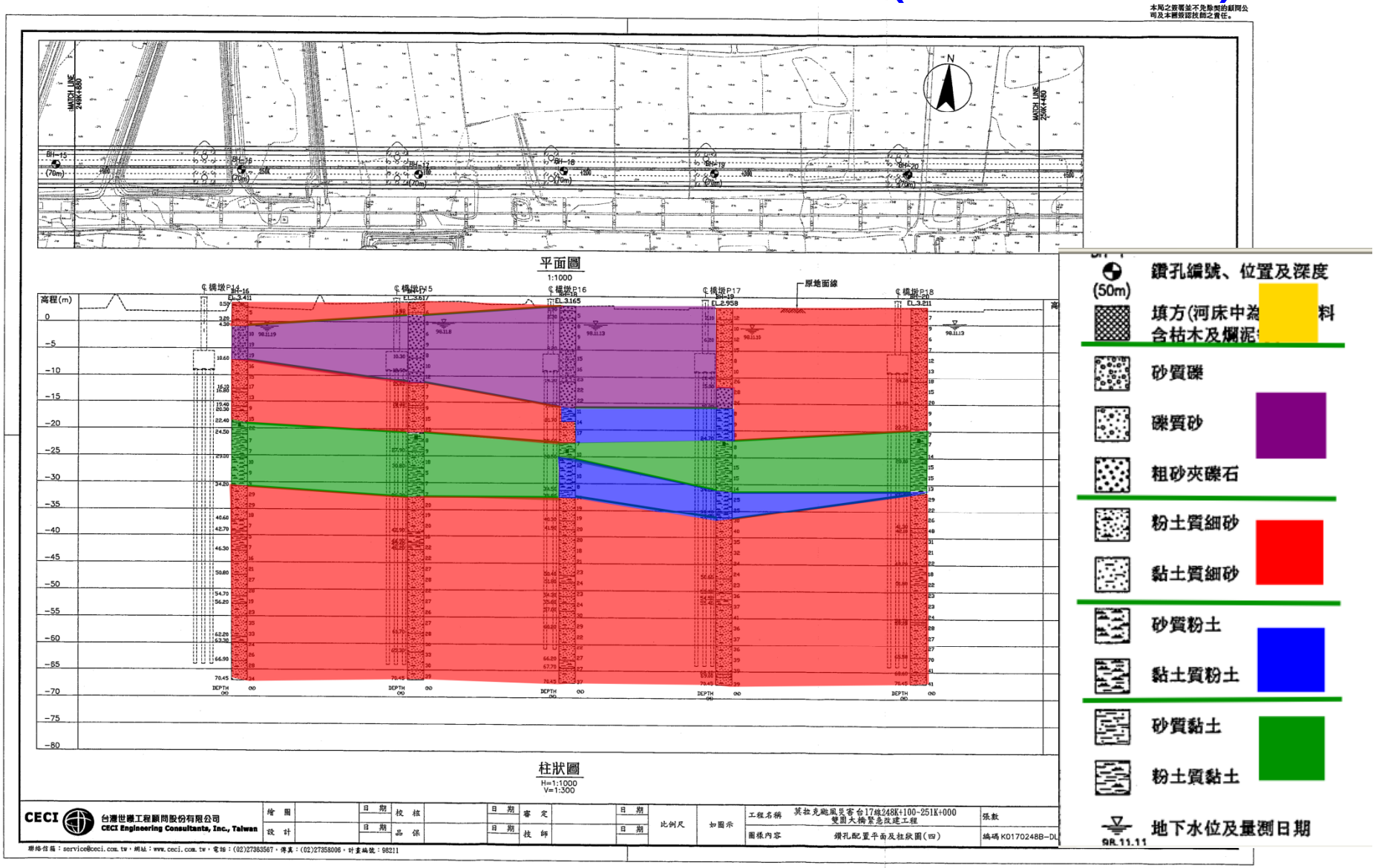
鑽孔平面配置—床質分布(P3-P7)



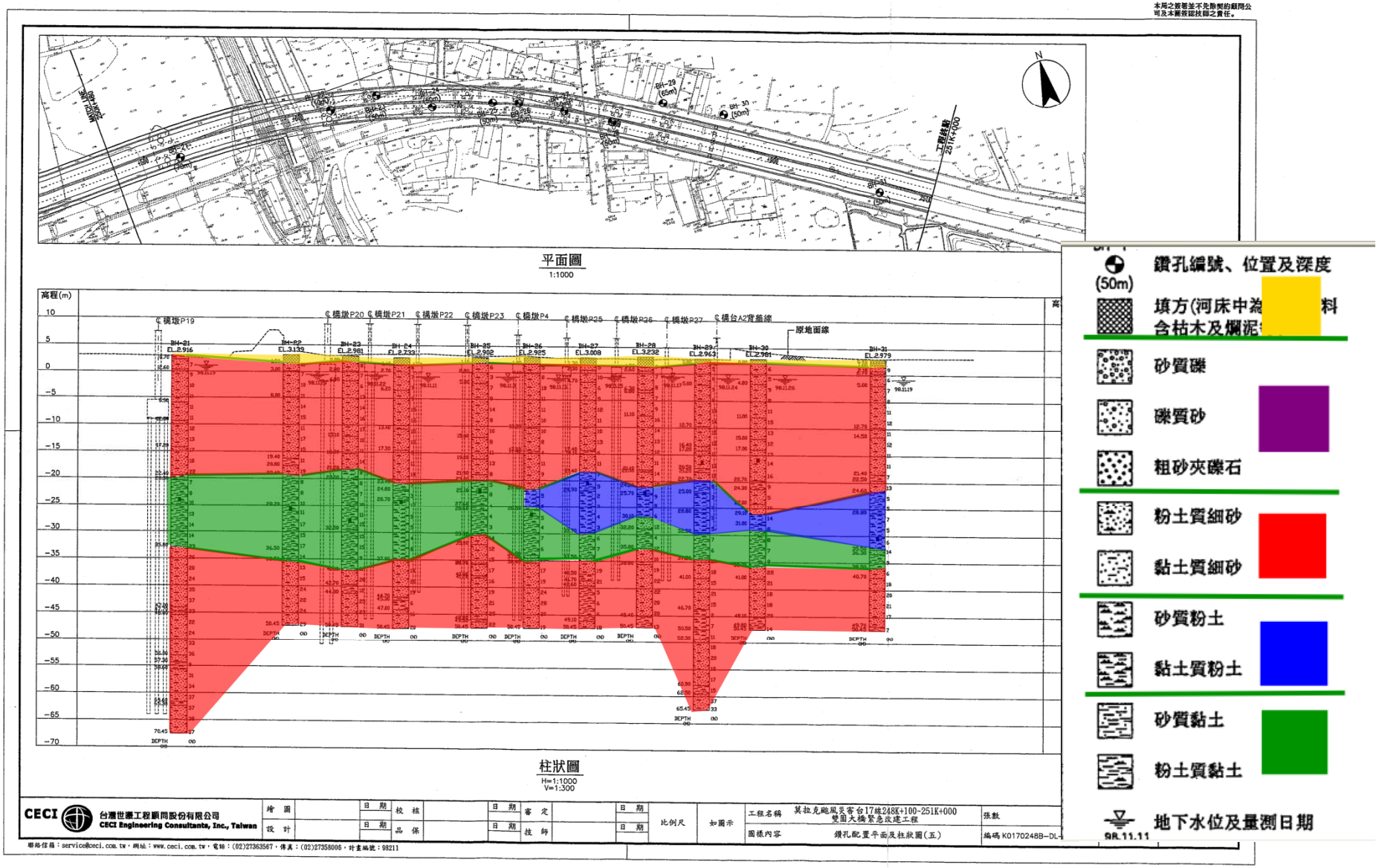
鑽孔平面配置—床質分布(P8-P13)



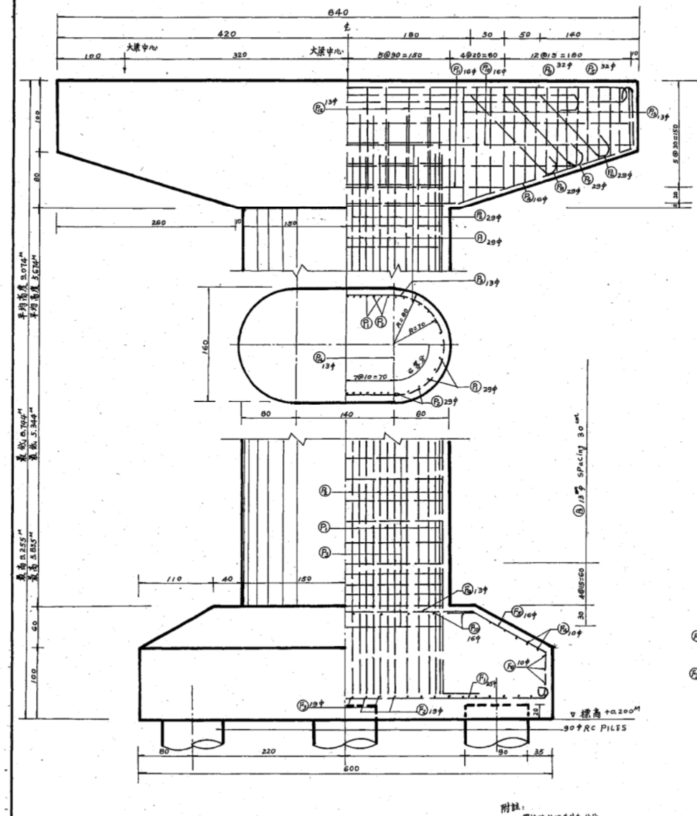
鑽孔平面配置—床質分布(P14-P18)



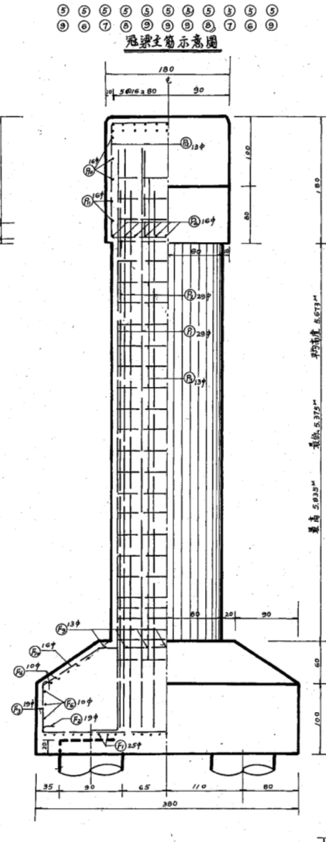
鑽孔平面配置—床質分布(P19-P27)



雙園橋橋墩設計圖



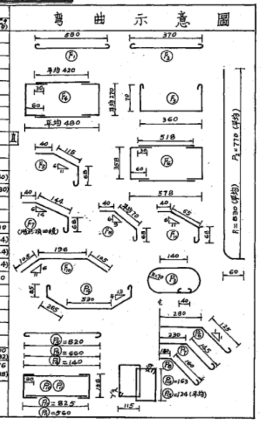
固定端橋墩立視圖 1:30



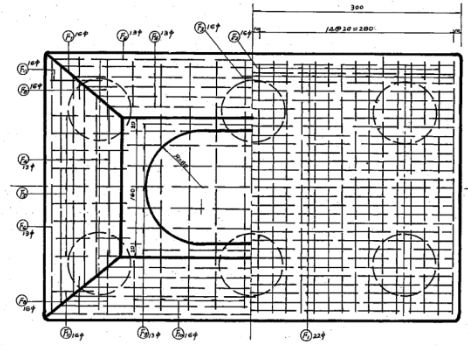
固定端橋墩側視圖 1:30

橋墩鋼筋表（每座）

符號	直徑 (mm)	直長 (M)	X 或 2X	全長	根數	全長 (M) 10mmφ	13mmφ	16mmφ	25mmφ (19mmφ)	32mmφ (29mmφ)
F1	25φ	5.80	0.62	6.42	29				186.18	
F2	19φ	3.70	0.48	4.18	14				(58.52)	
F3	19φ	5.00	0.48	5.48	16				(87.68)	
F4	10φ	16.20		16.20	5	81.00				
F5	16φ	2.23	0.20	2.43	18			43.74		
F6	10φ	19.92		19.92	3	59.76				
F7	16φ	2.52	0.20	2.72	4			10.88		
F8	16φ	1.78	0.20	1.98	8			15.84		
F9	13φ	3.80		3.80	7		26.60			
F10	16φ	4.06		4.06	10			40.60		
F11	16φ	1.73	0.20	1.93	4			7.72		
P1	29φ	8.90		8.90	26					(231.40)
P2	29φ	8.30		8.30	26					(215.80)
P3	13φ	7.60	0.32	7.92	26		205.92			
P4	16φ	10.30	0.40	10.70	11			117.70		
P5	32φ	8.20	0.80	9.00	11					99.00
P6	29φ	8.10	0.72	8.82	2					(17.64)
P7	29φ	7.50	0.72	8.22	2					(16.44)
P8	29φ	6.80	0.72	7.52	2					(15.04)
P9	32φ	6.60	0.80	7.40	5					37.00
P10	16φ	22.06		22.06	3			66.18		
P11	16φ	16.76		16.76	2			33.52		
P12	13φ	11.52		11.52	11		126.72			
P13	13φ	9.96		9.96	32		318.72			
P14	13φ	1.40	0.32	1.72	78		134.16			
長度小計						140.76	812.12	336.18	186.18 (146.20)	136.00 (496.32)
重量合計	5,858.64					78.68	807.25	521.08	741.00 (327.49)	871.76 (2511.38)
附註	1. 重量未包括損耗在內 2. 全長 L=ℓ+2X									

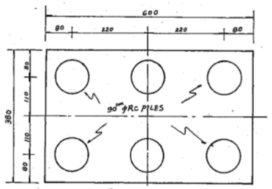


彎曲示意圖



頂表面配筋　底面配筋

基腳平面圖 1:30



基樁配置圖 1:60

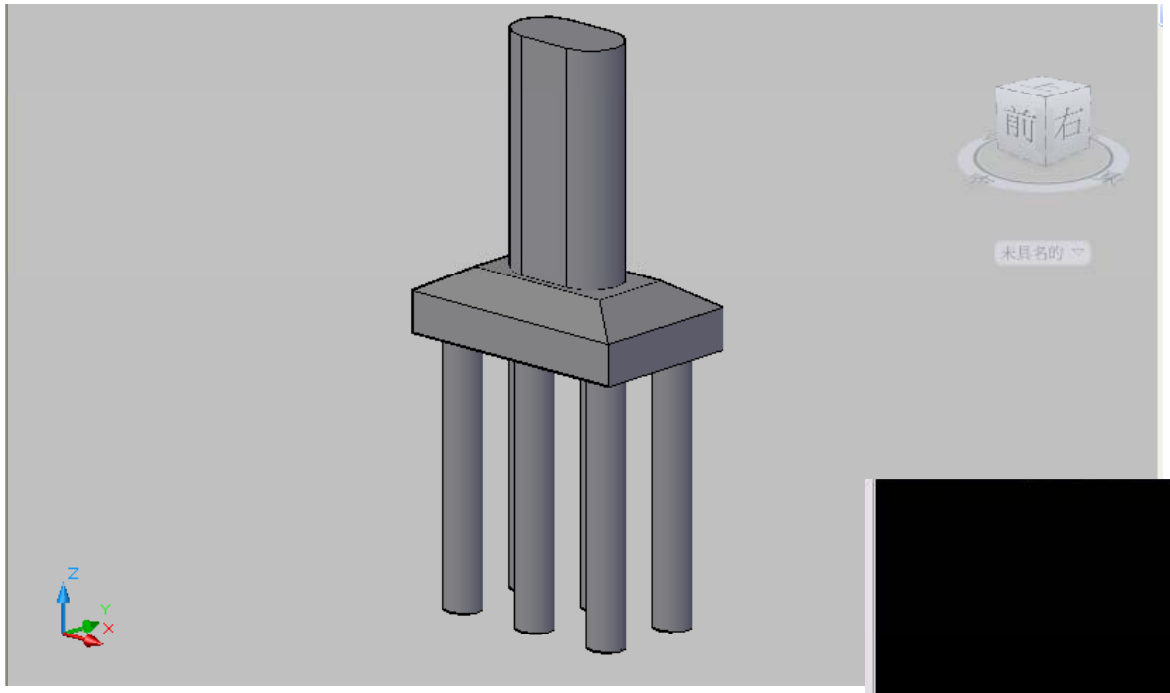
附註：
1. 單位除註明者外為公分。
2. 混凝土強度 $f_c' = 210\ kg/cm^2$
   鋼筋強度 $f_s = 1400\ kg/cm^2$
3. 地震係數 $K_h = 0.12$
4. 基樁設計詳見圖 (9/15)
5. 冠梁頂支承台座設計詳見圖 (12/15)
6. 所有稜角線均須設 3cm 截角面。
7. 修建橋墩如有損壞現有堤防護岸設備時，修復費用不另給價。
8. 參照已完成双園大橋竣工圖設計。

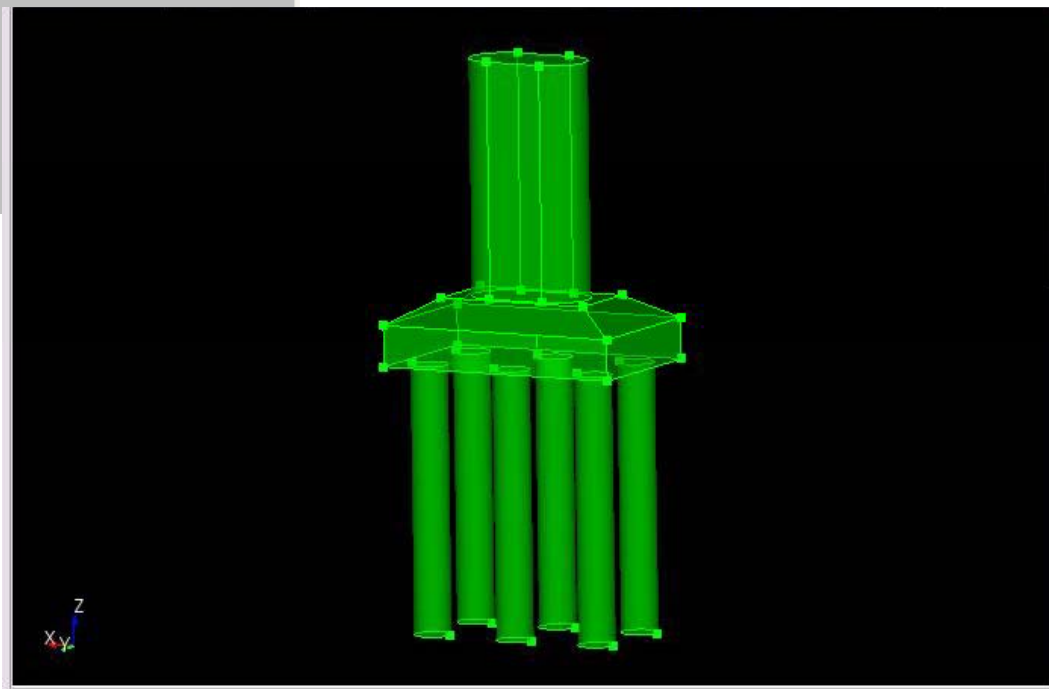
A0009

公路局第三區工程處	工程名稱　台17線高屏溪崙頂路双園大橋擴建工程	繪圖　胡永佳	校對　陳逢孝	處長	日期　68.8	圖號 7/15
	圖樣內容　固定端橋墩設計圖	設計　史炳南	課長		總張數　15	

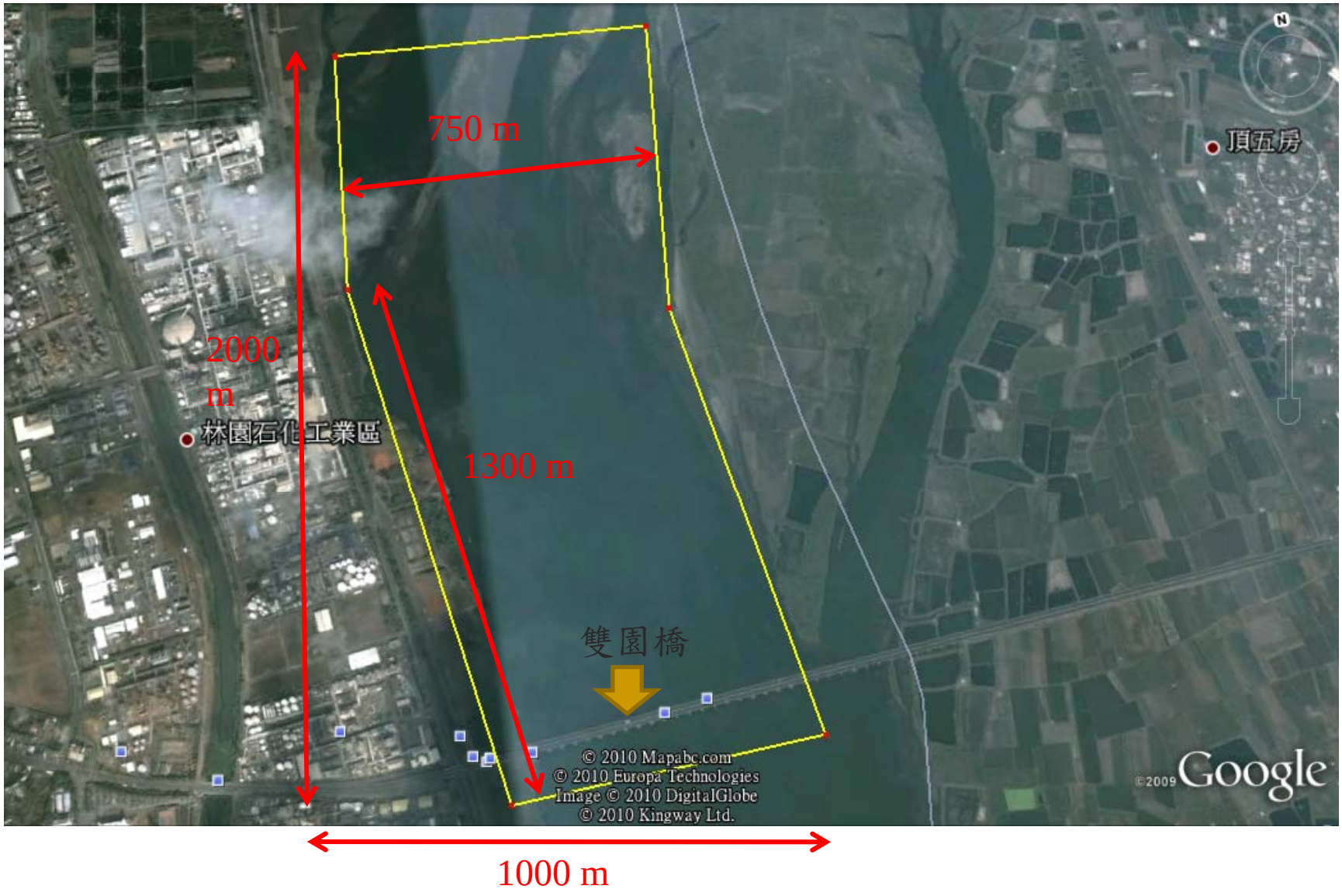
2/18

雙園橋橋墩模型建立



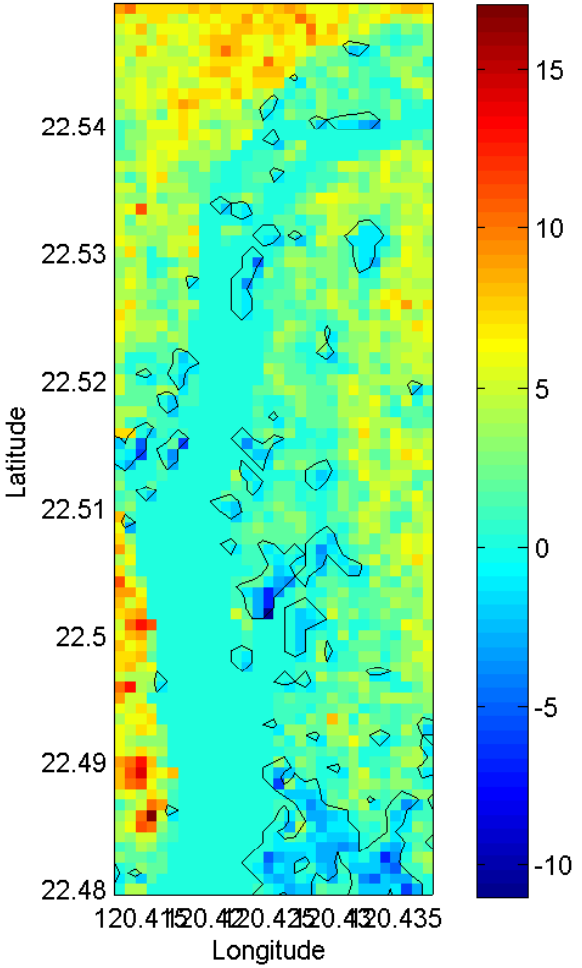


Domain of Simulation



地形假設

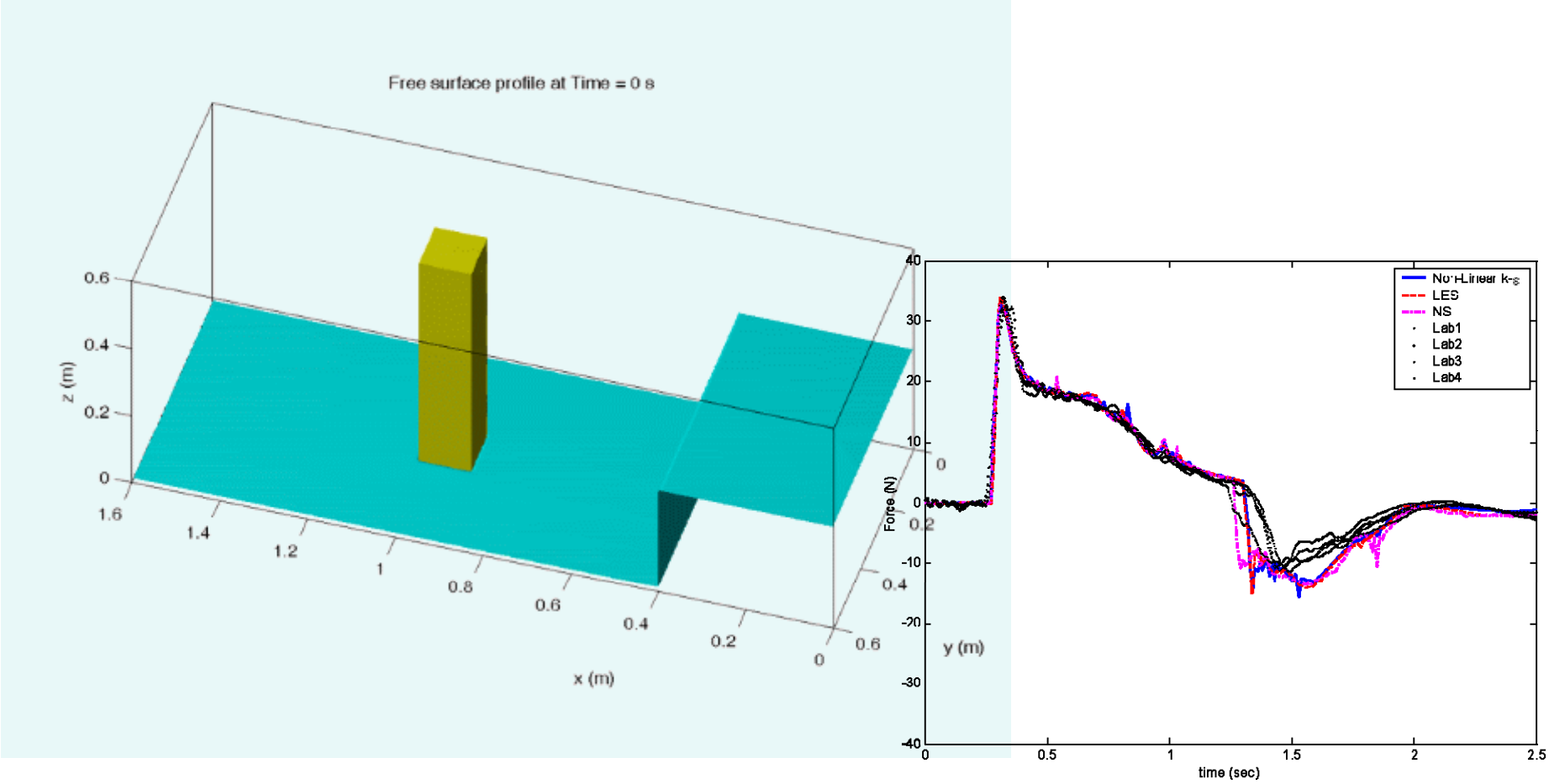
CGIAR Consortium for Spatial Information (CGIAR-CSI)



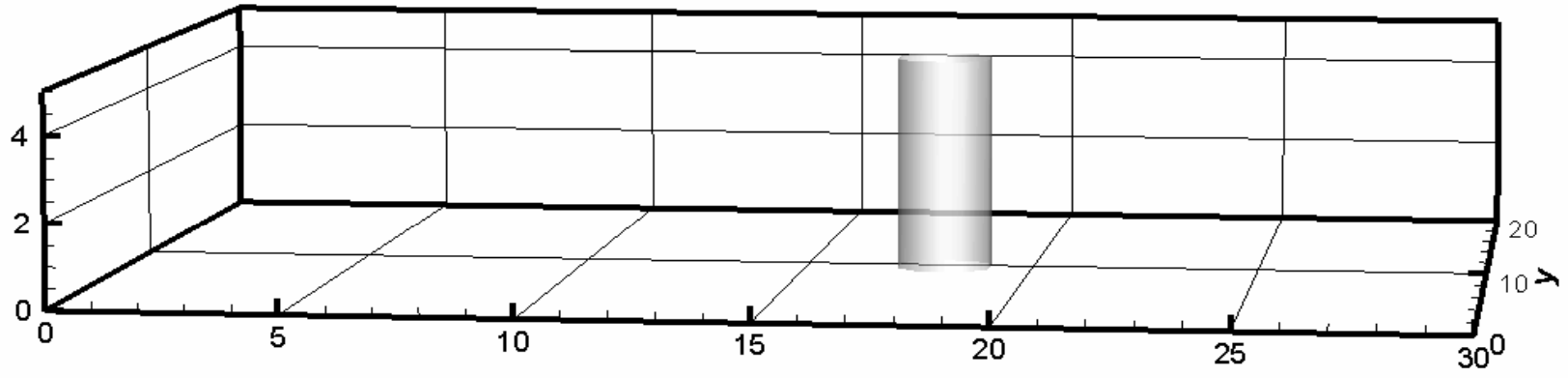
Numerical Simulation

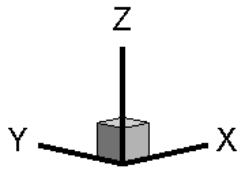
3D Simulation of the Fluid-Structure Interaction

(hydraulic jump, Turbulence, Impact, splash…)



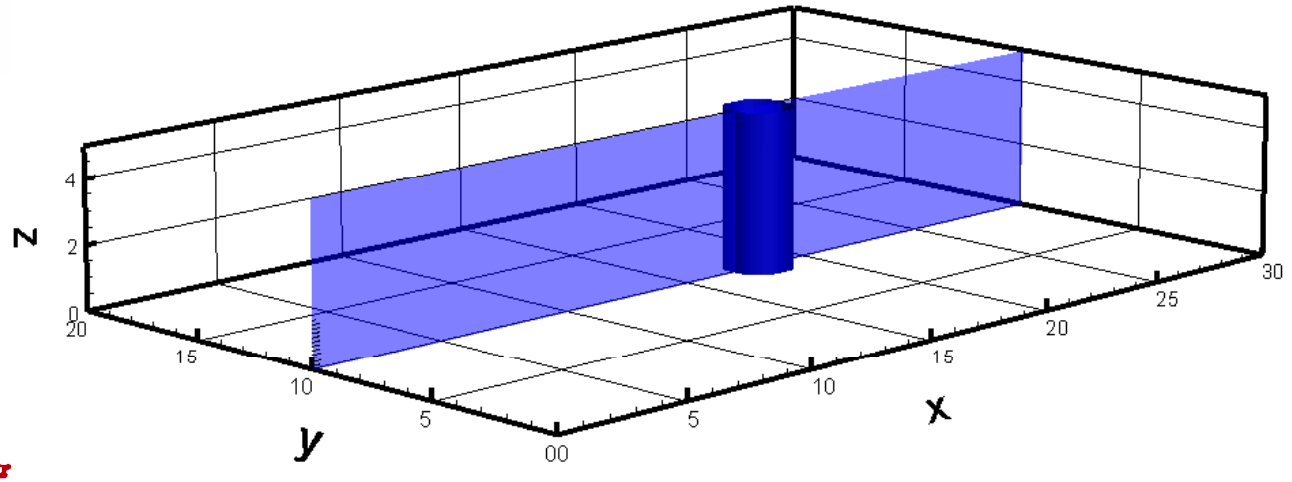
Loading history applied on Pier





Time = 0

Pier impacted by flood



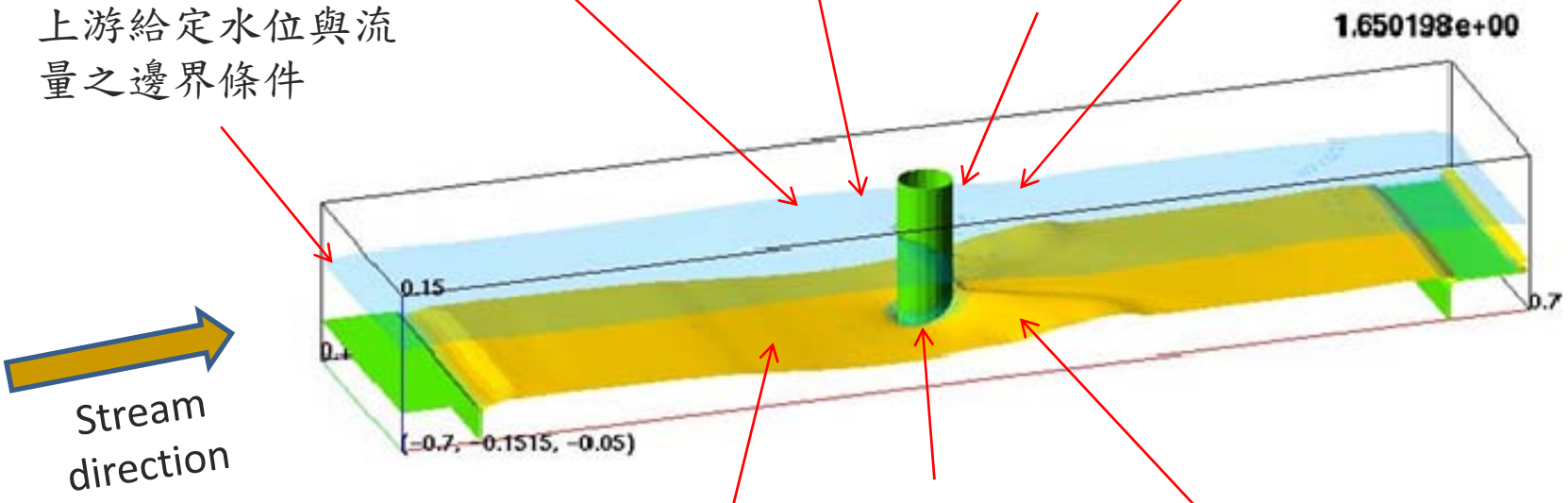
3D Simulation of the Fluid-Structure Interaction

(hydraulic jump, Turbulence, Impact, splash…)

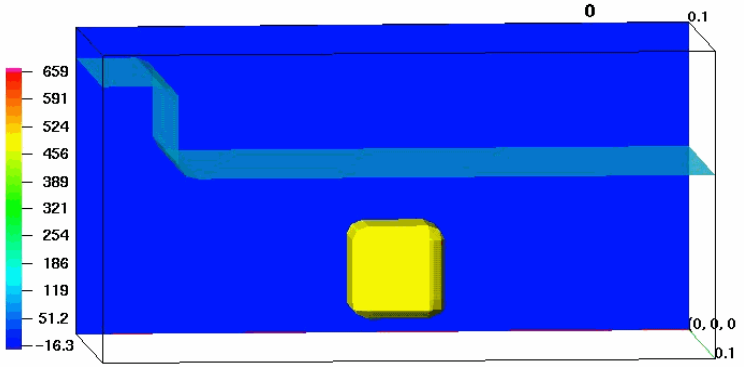
Scouring Pit

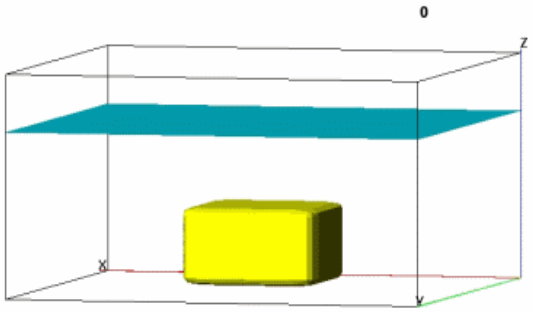
上游給定水位與流量之邊界條件

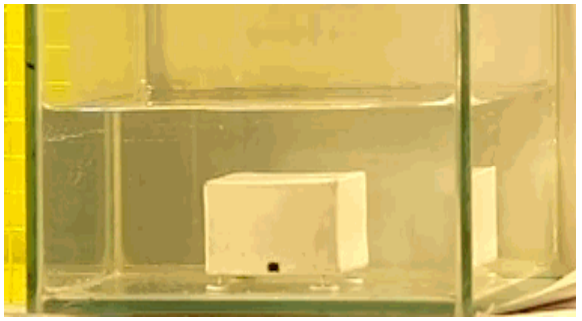
墩前壅水　橋墩水位　跌水　水躍



Solid-Fluid Interaction







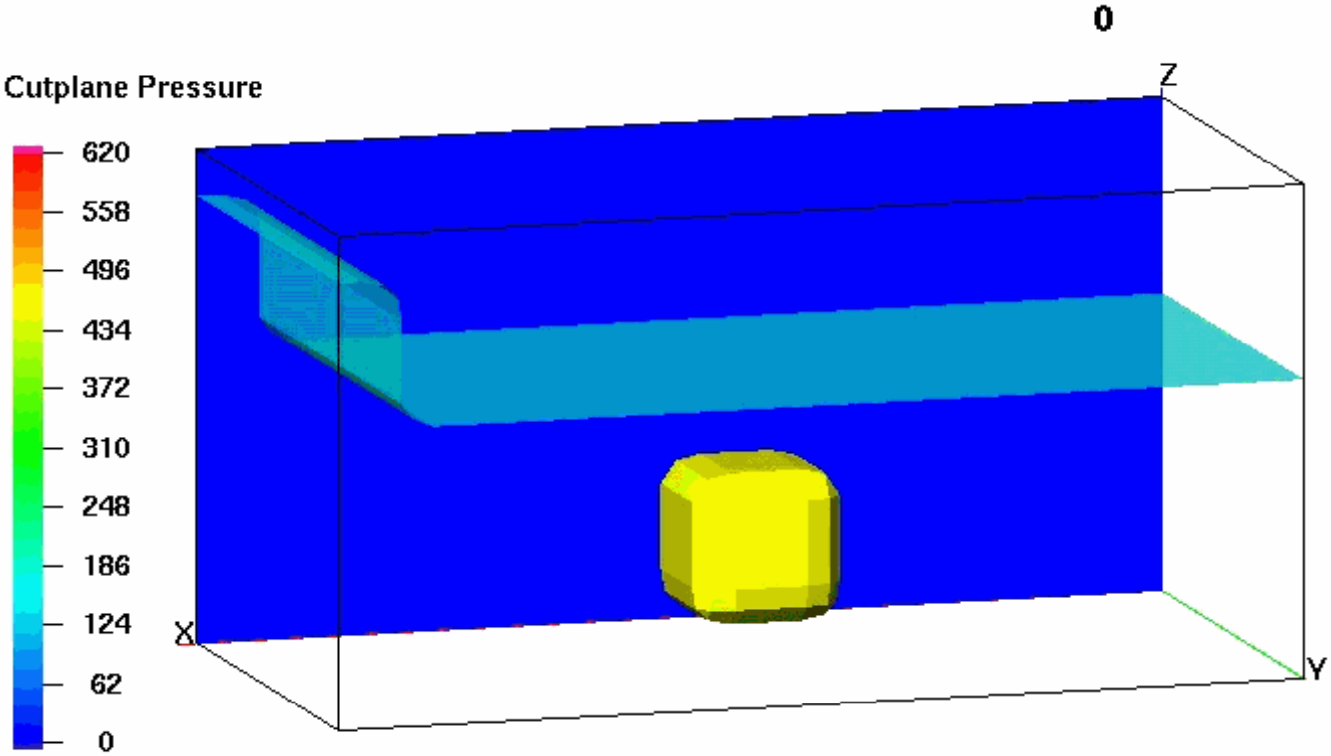
潰壩之浮體模擬

密度 800kg/m^3

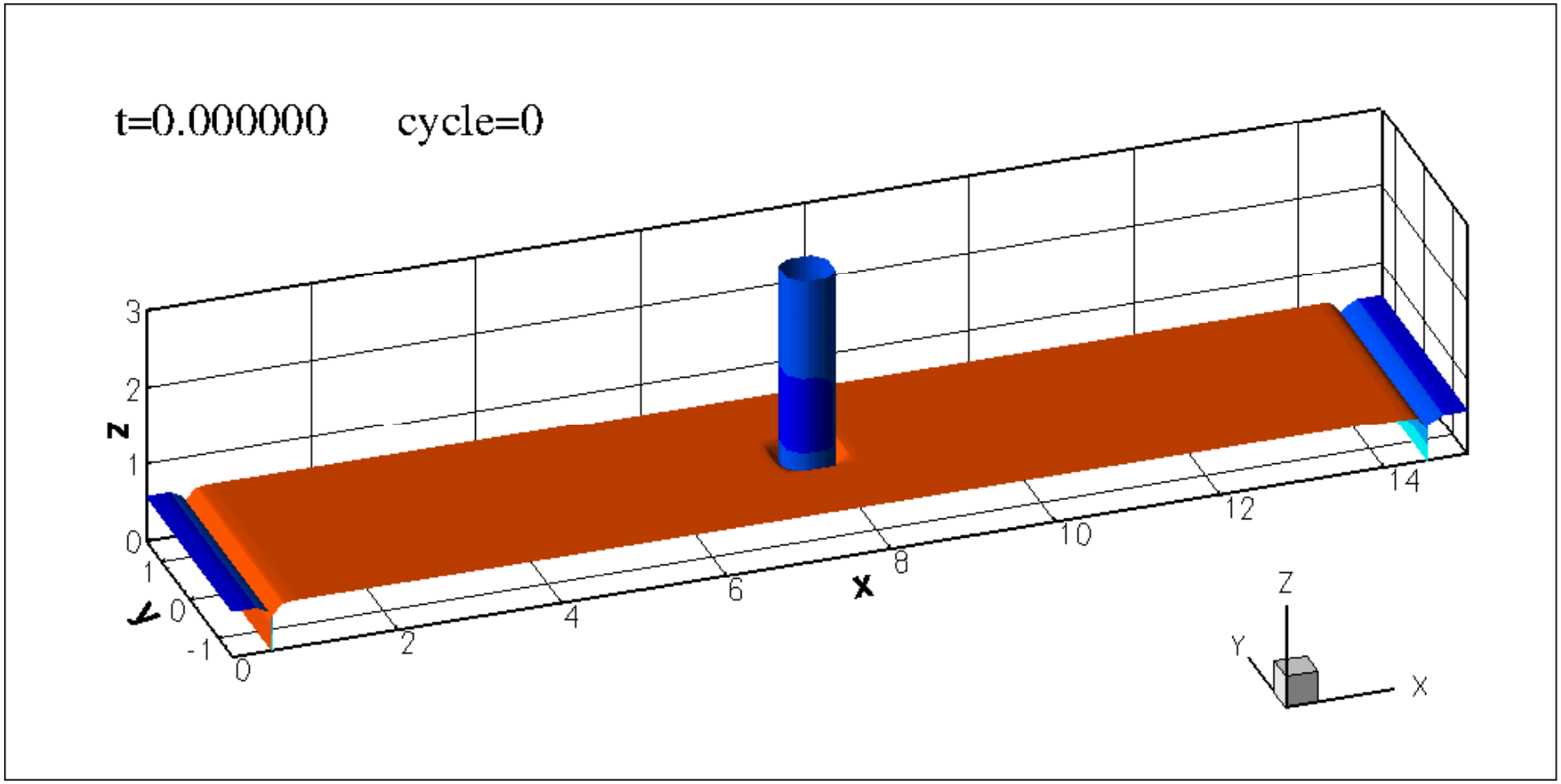
水壩高 9 cm

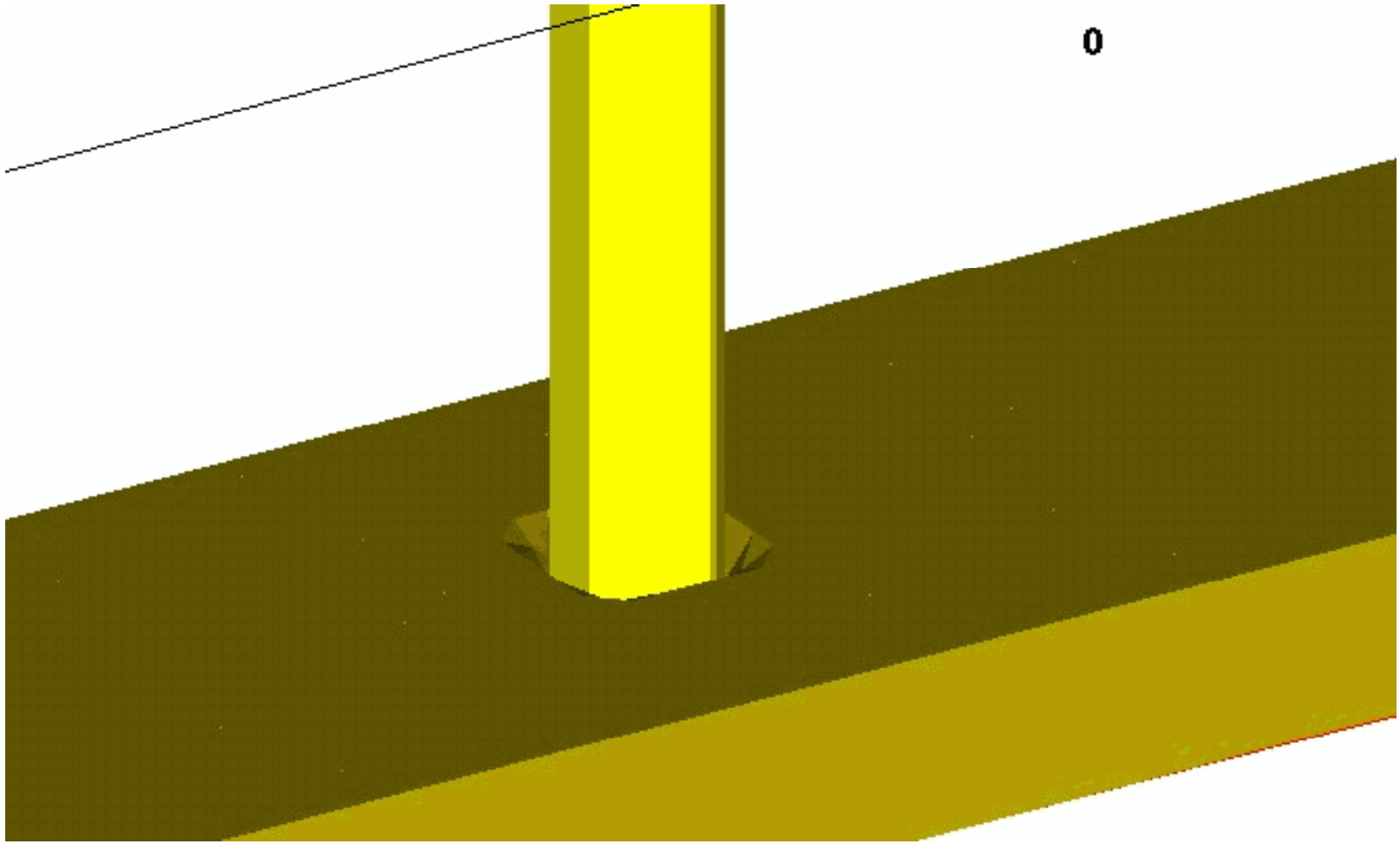
水壩寬 1.25

水深 6 cm



Stream Lines

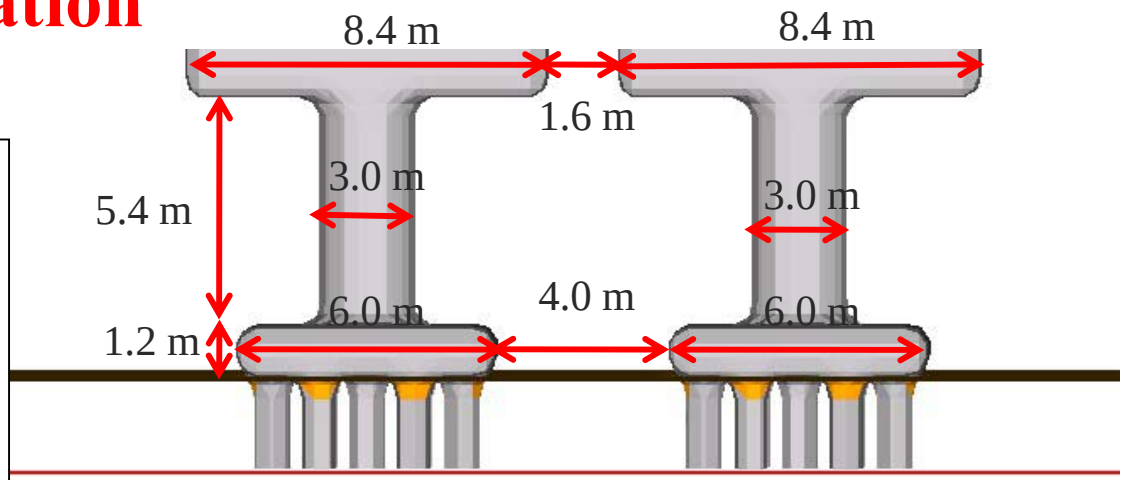


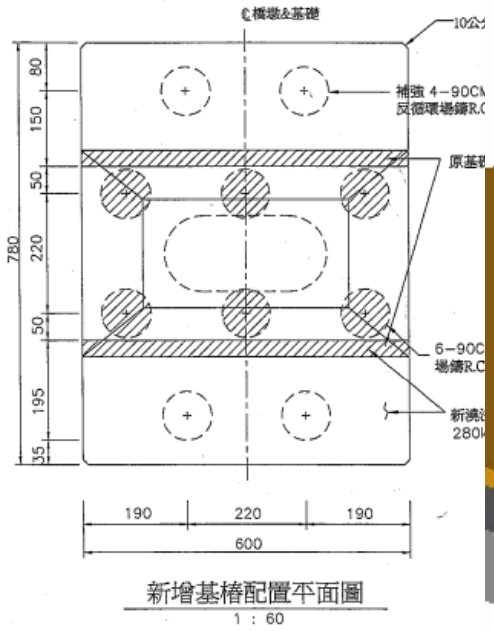

0

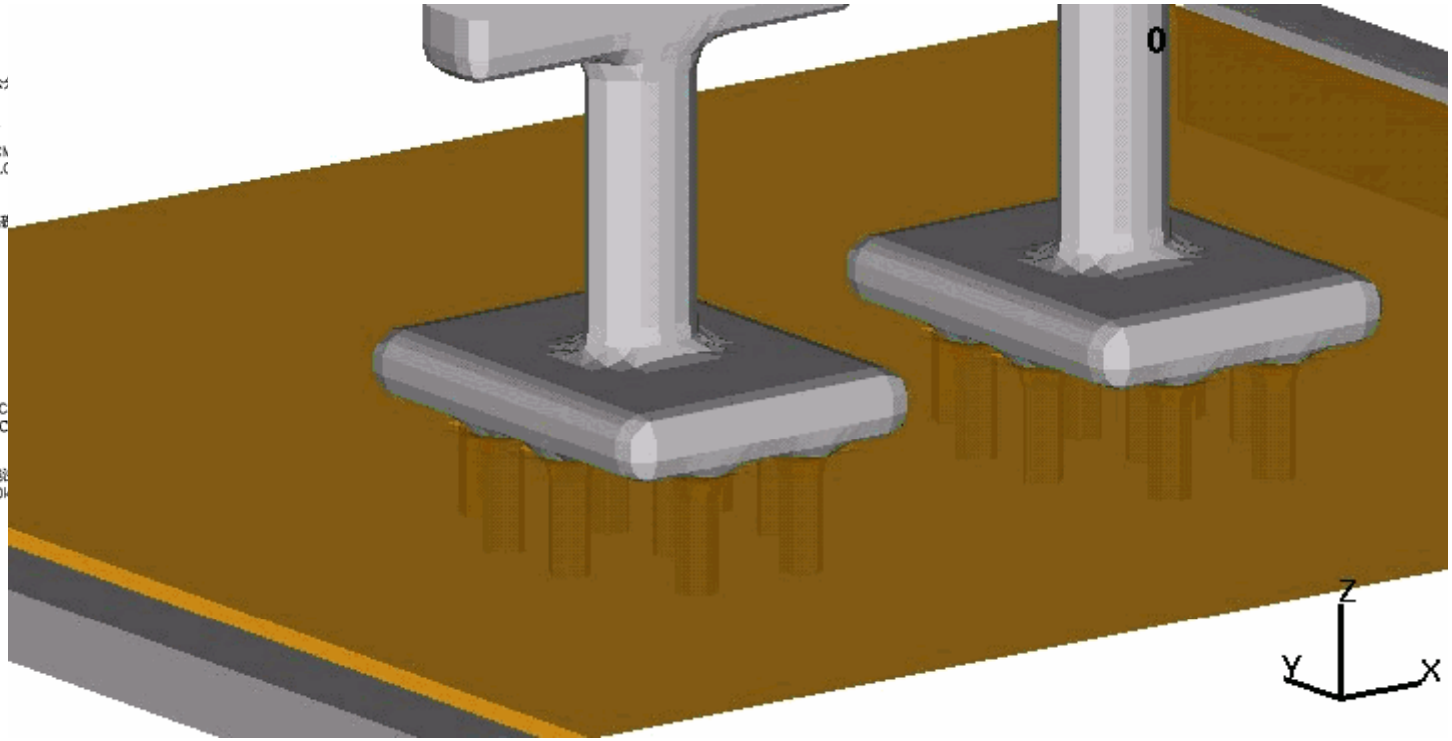
Local Scouring Simulation

Parameters：

網格：120×96×30
Domain：40×32×10 (m)
Soil density：1.8 × 10^3 kg/m^3
Soil viscosity：1000 Pa · s
Flow speed：6 m/s
Initial water depth：2.5 m



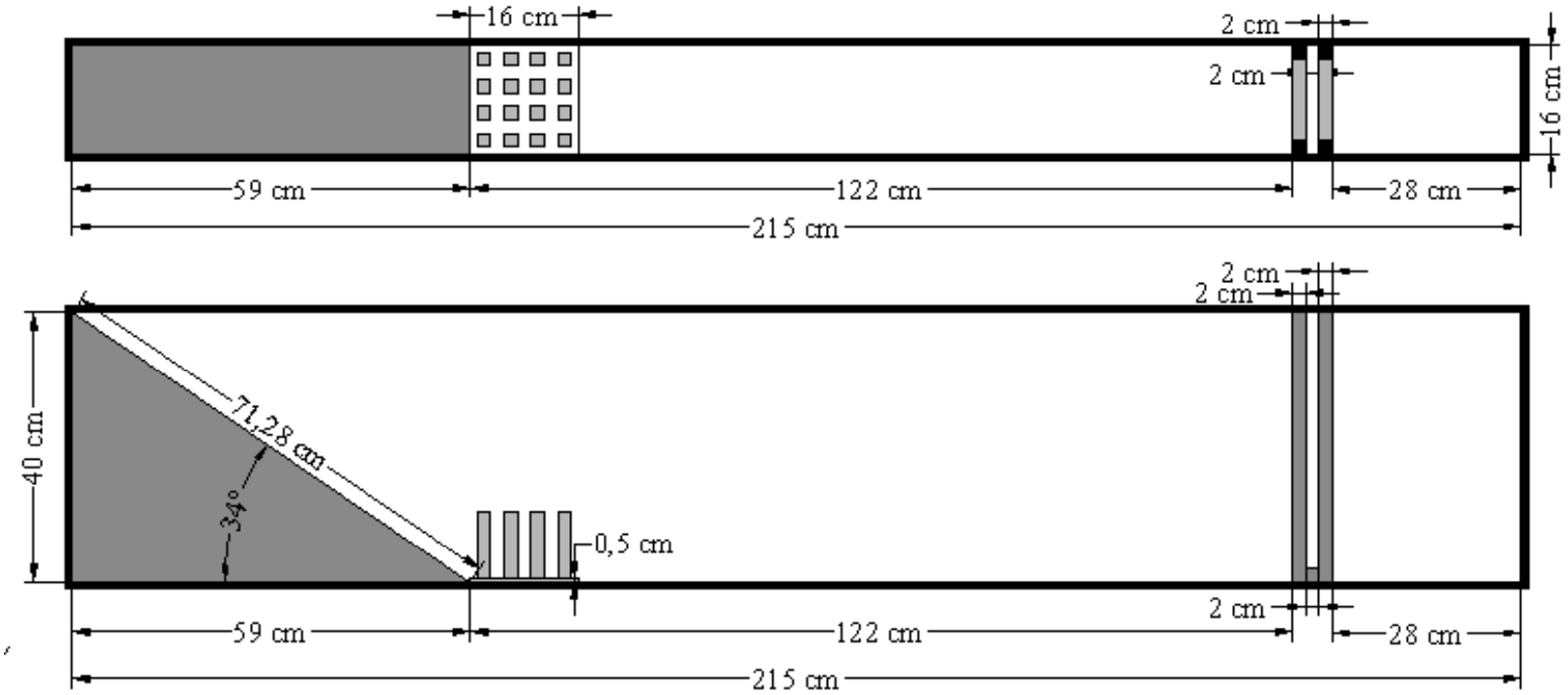




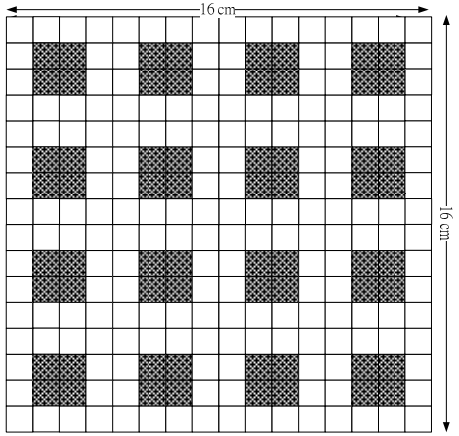
Dam Break Experiment

渠槽主體：2.15 m、0.16 m、0.4 m (長寬高)
蓄水槽段：0.28 m
止水條：0.02 m
斜板長度：0.71 m
斜板與底床夾角：34°

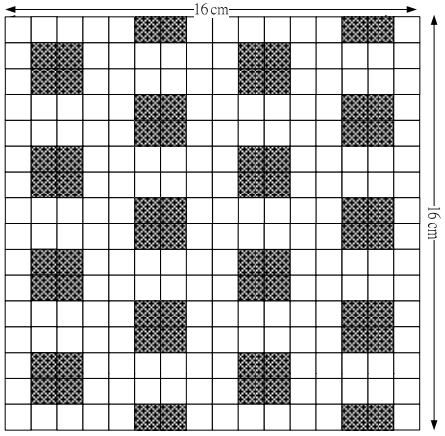
陣列排列方式：正交排列、交錯排列
陣列區大小：0.16 × 0.16 m^2
方柱尺寸：0.02 × 0.02 m^2
方柱間距：0.02 m



Experimental Design



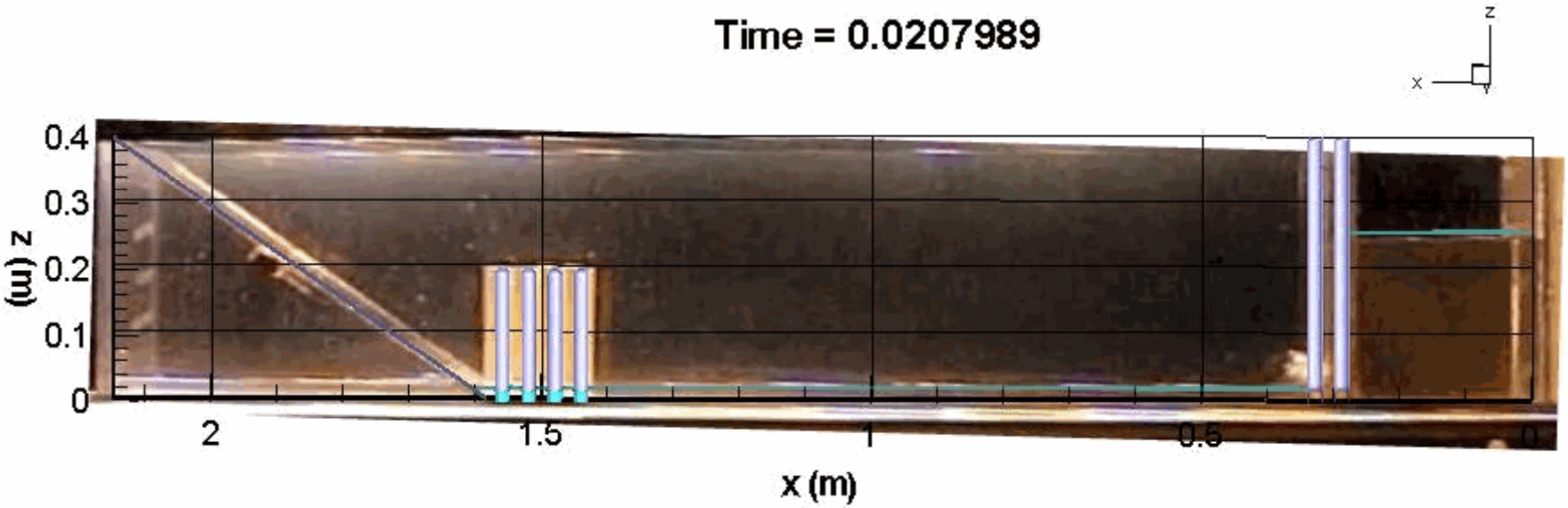
Aligned (2 cm interval)



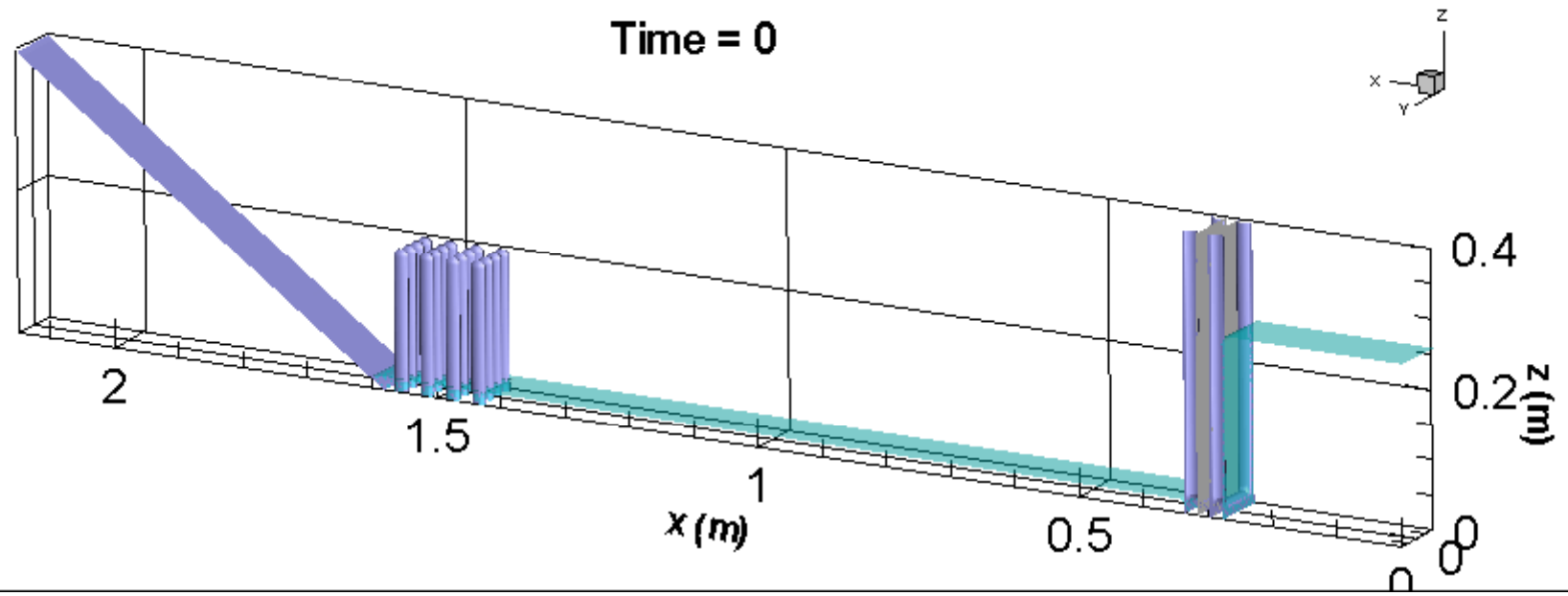
Alternate (2 cm interval)

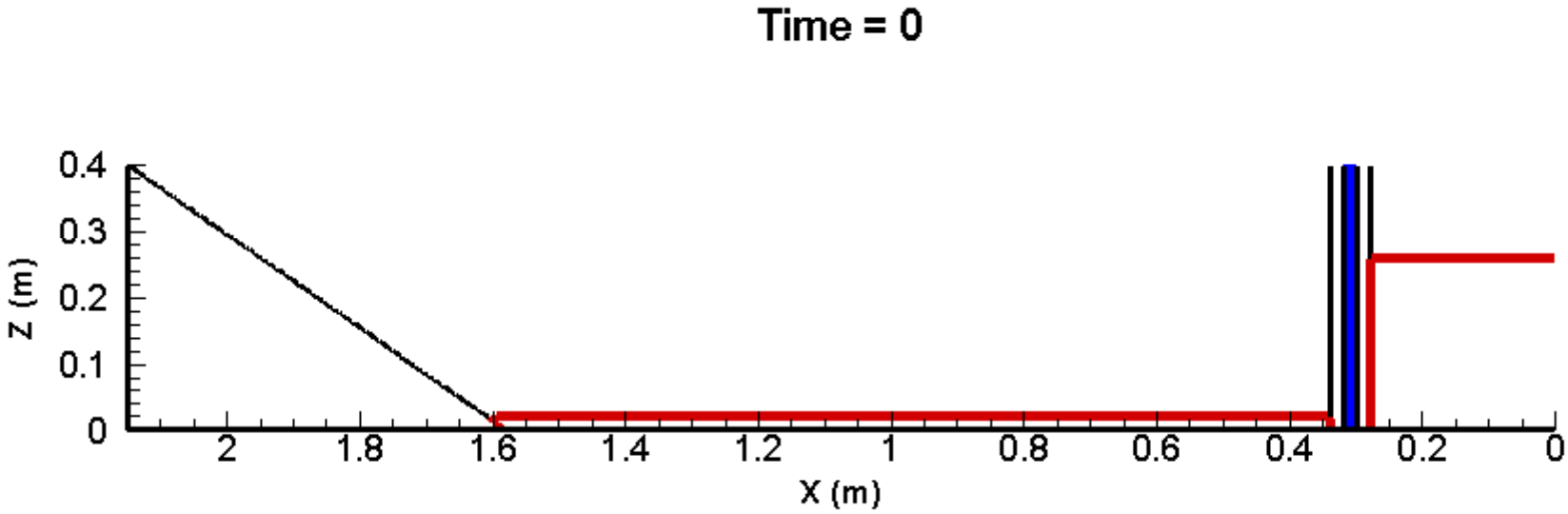
cond. / case	Column height（m）	Initial water level（m）	Dam water level（m）	Pile arrangement
A	0.1	0.02	0.26	alternate
B	0.1	0.02	0.26	aligned
C	0.2	0.02	0.26	aligned

Water Surface Verification



cond. / case	Column height（m）	Initial water level（m）	Dam water level（m）	Pile arrangement
A	0.1	0.02	0.26	alternate
B	0.1	0.02	0.26	aligned
C	0.2	0.02	0.26	aligned

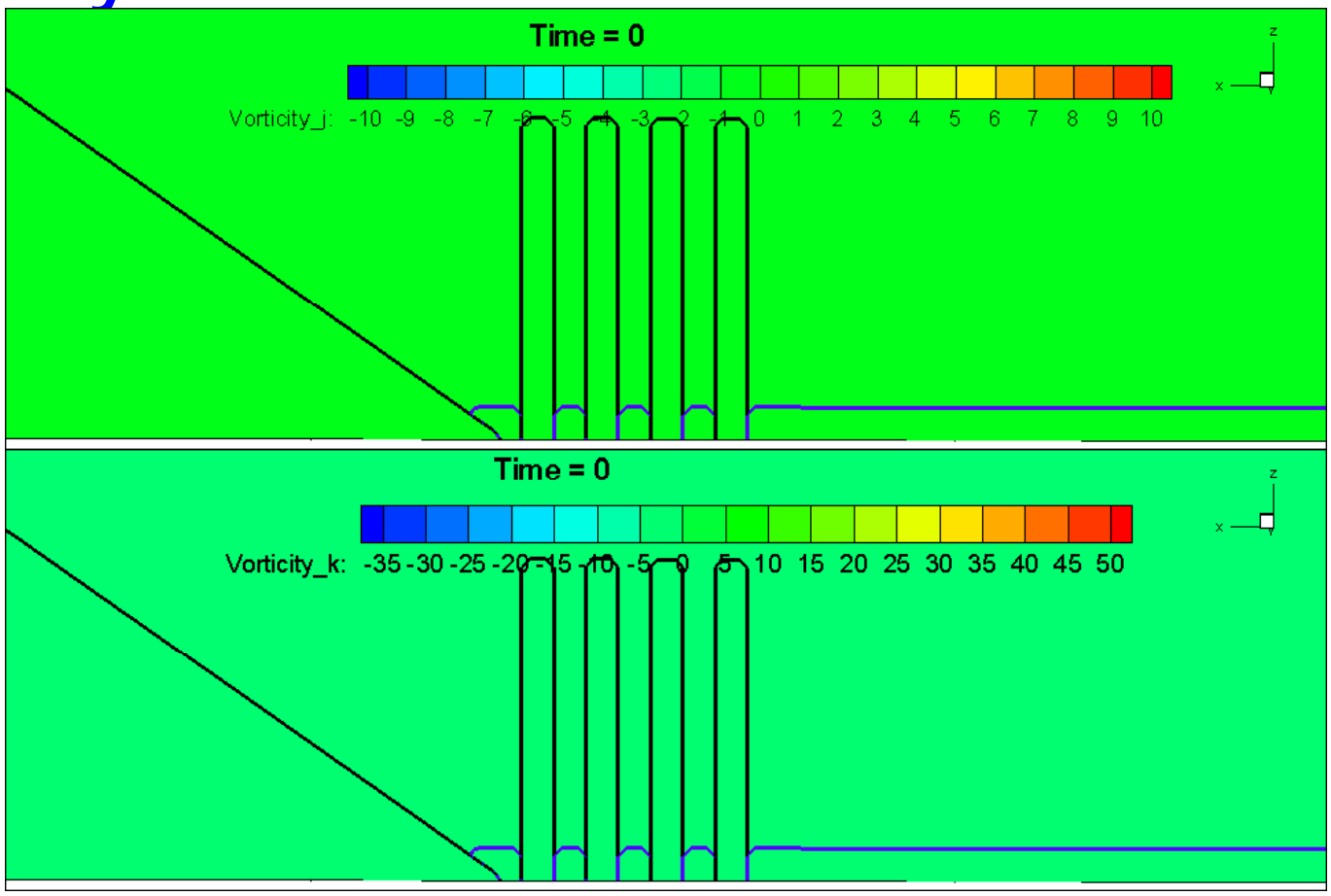

Time = 0
Z
X
Y
0.4
0.2
z (m)
0
0
2
1.5
1
0.5
x (m)


Time = 0
0.4
0.3
0.2
0.1
0
Z (m)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
X (m)

Velocity & Vortex Fields

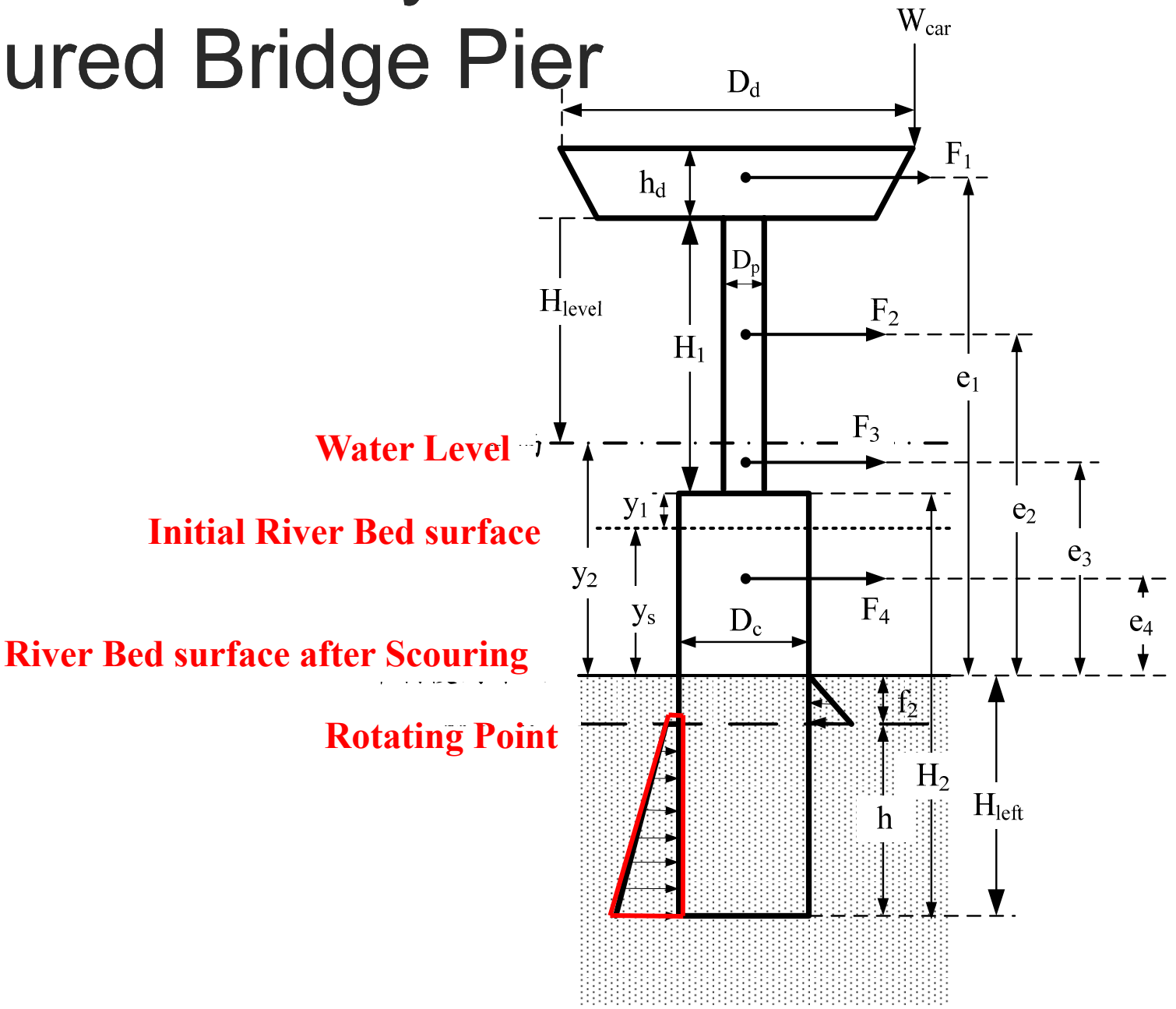
Velocity (j)

vortex(k)

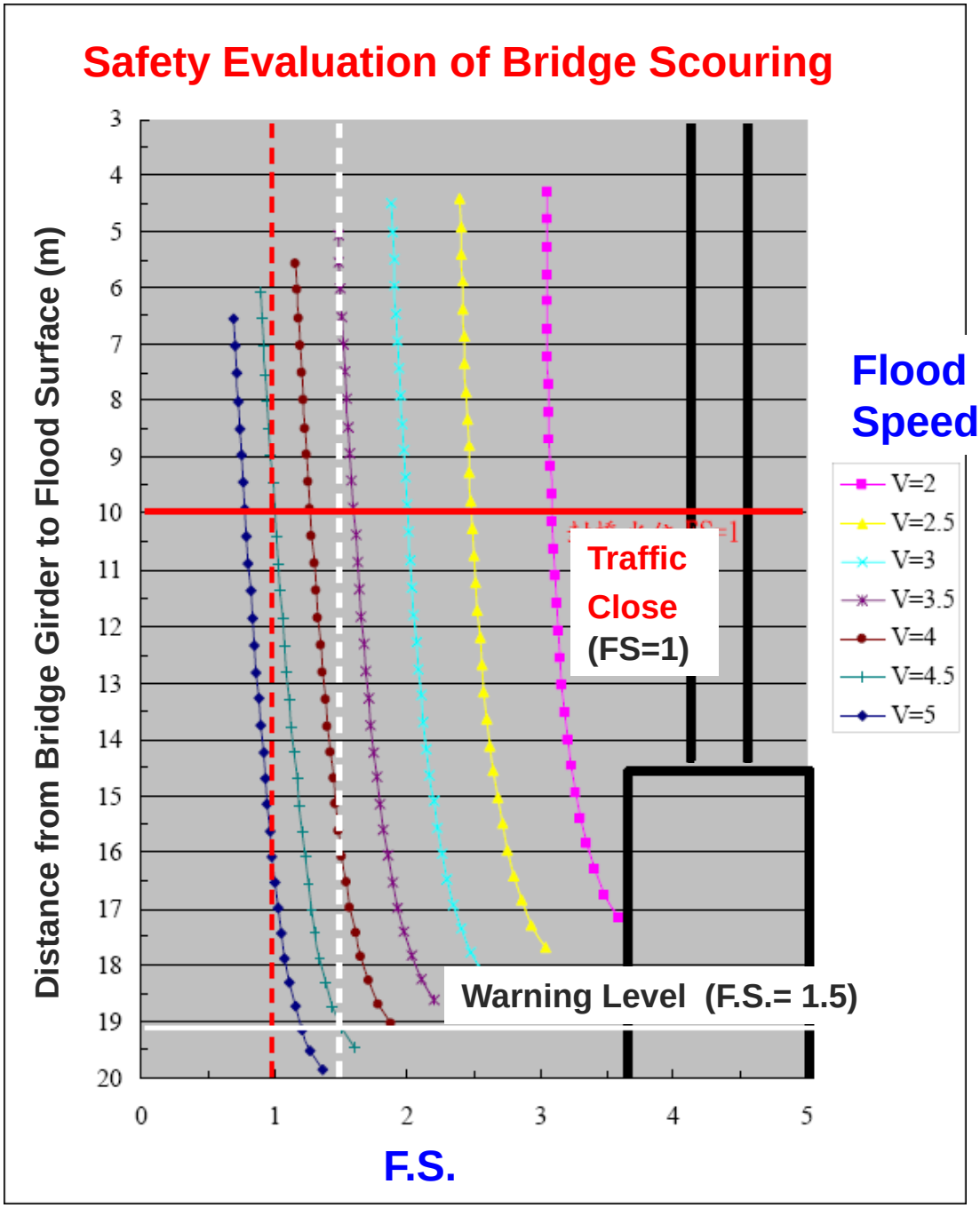


cond. / case	Column height (m)	Initial water level (m)	Dam water level (m)	Pile arrangement
A	0.1	0.02	0.26	alternate
B	0.1	0.02	0.26	aligned
C	0.2	0.02	0.26	aligned

Pushover Analysis of Scoured Bridge Pier



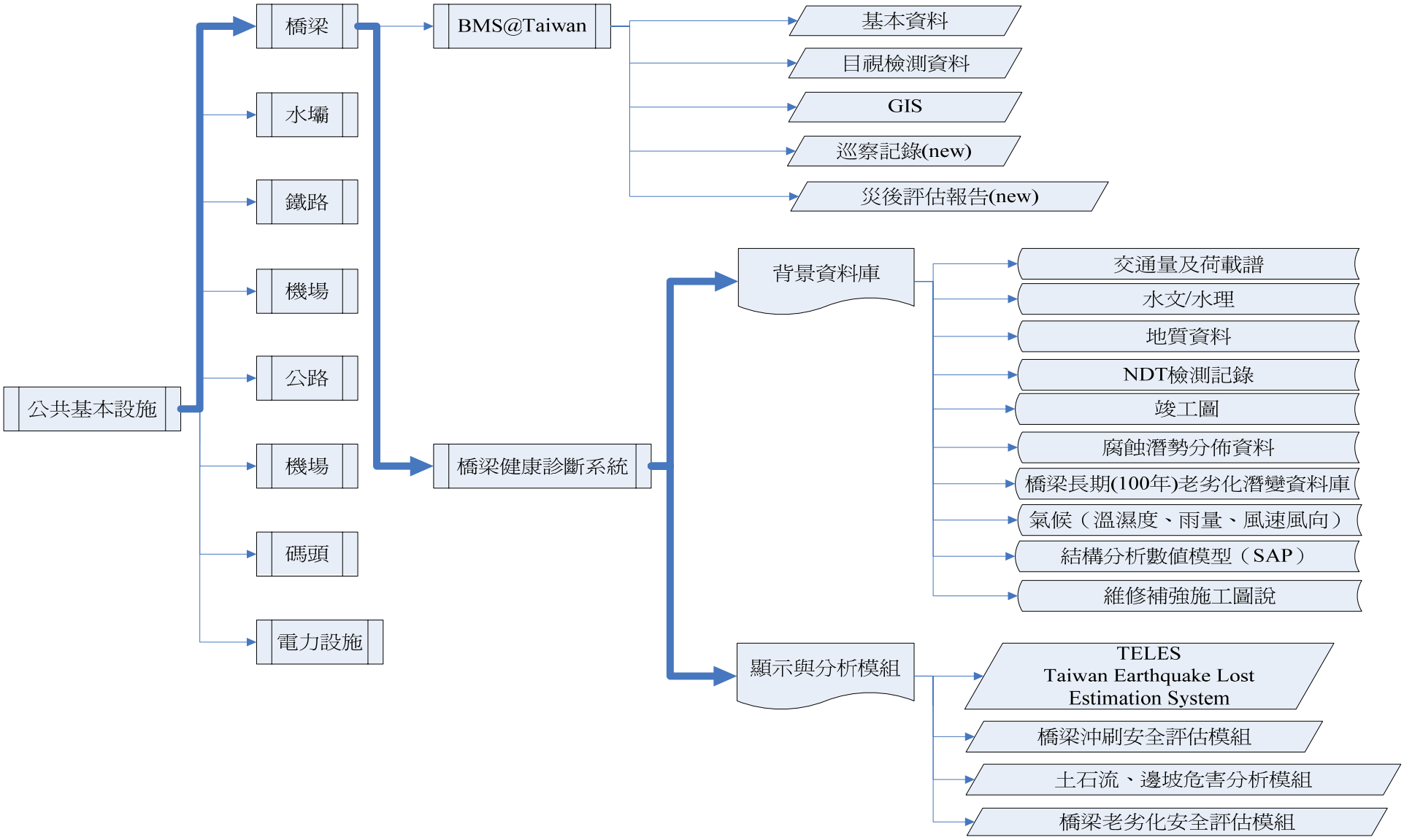
Flood Water Level vs. Factor of Safety



Platform of Risk Management

道路橋梁防災預警資訊管理系統

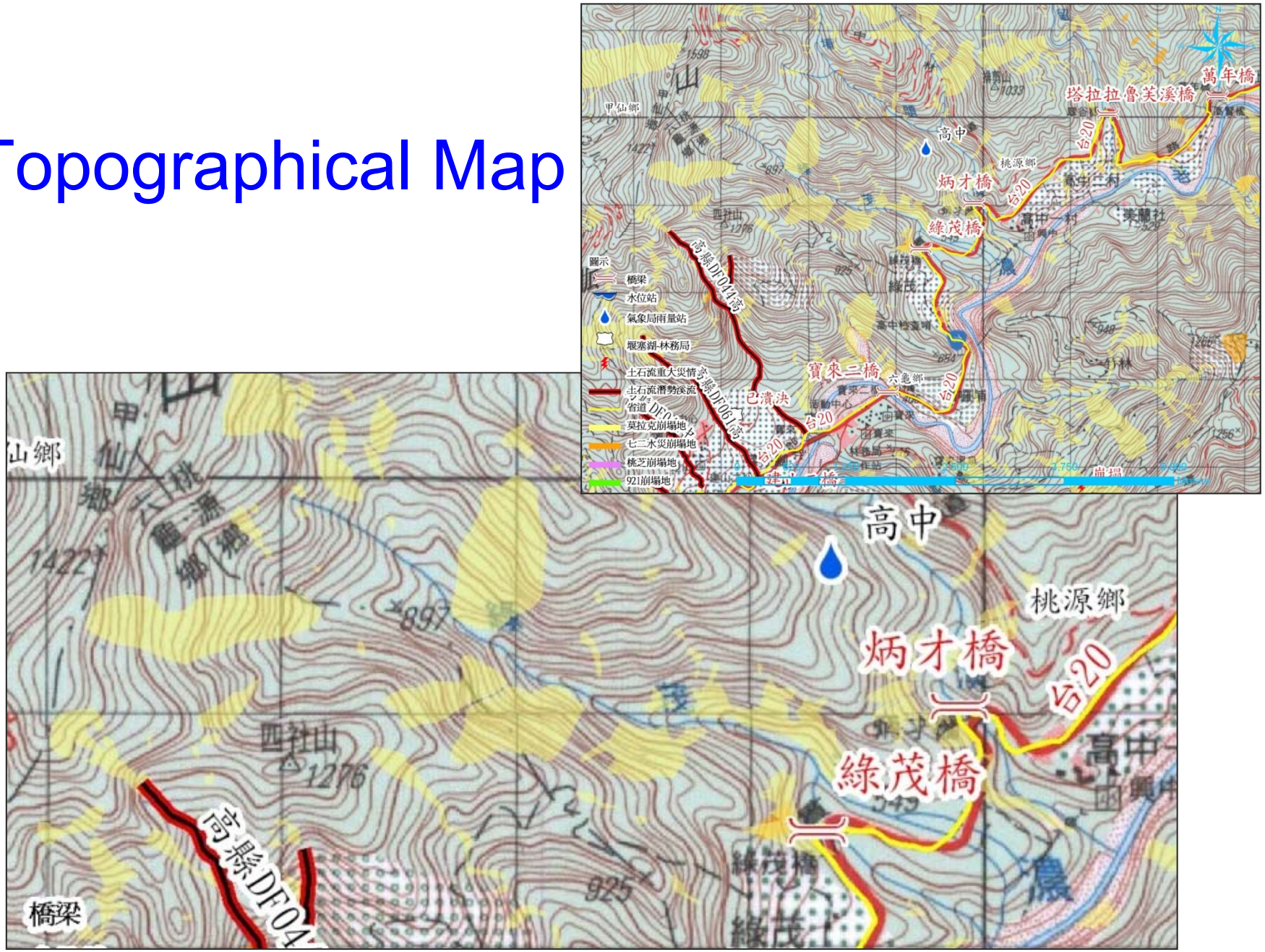
Road & Bridge Multi-Hazard Prevention and Mitigation Information System



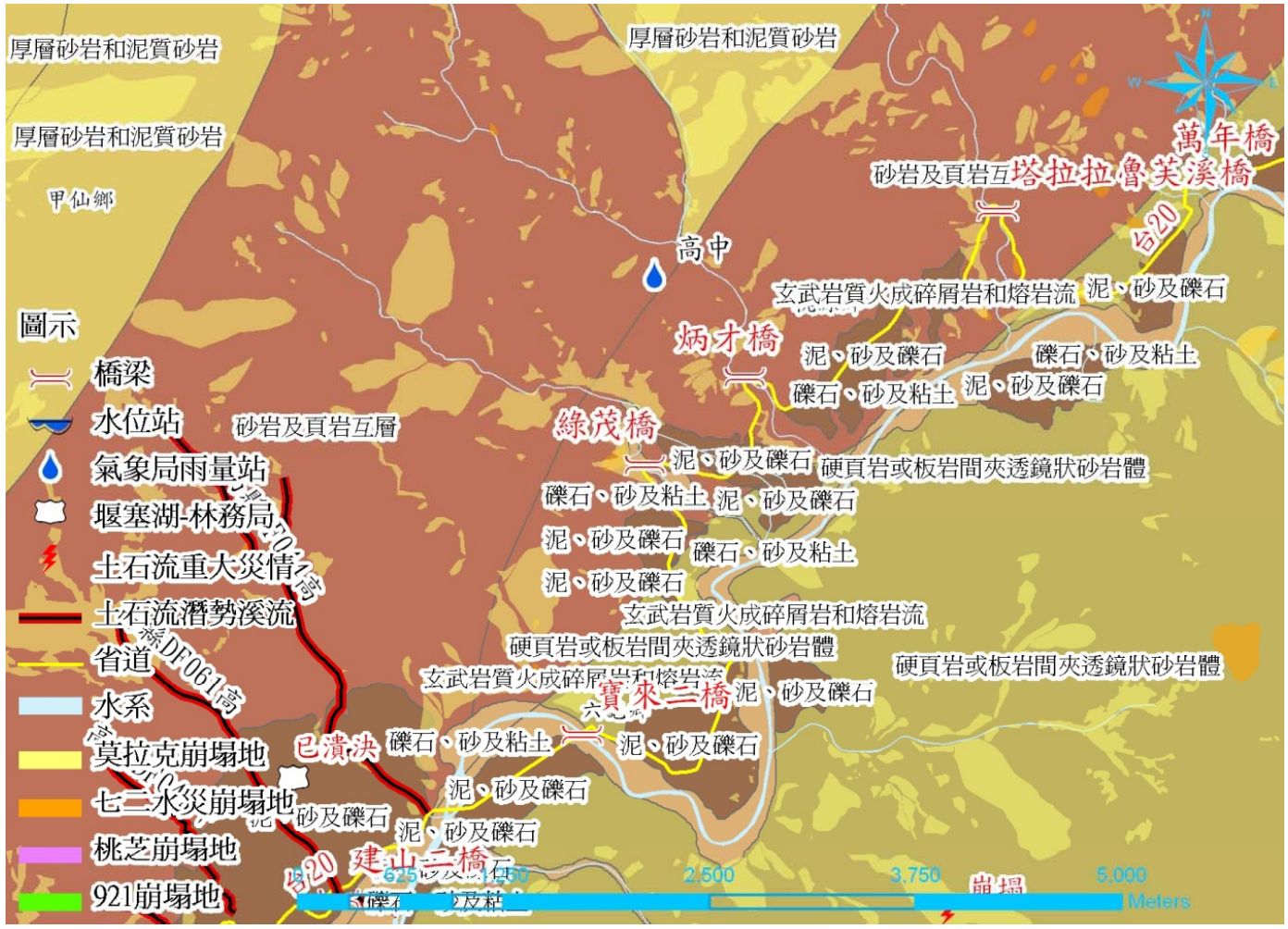
Google Map

大崎頂
腳帛寮
擔橫山
旗山忠烈祠
秋涼山
頭林
北勢
旗山鎮
五岑埔
下清水
清水
內寮
大窩
泉水窩
榕樹窩
福安
美濃民俗村
崙仔頂
旗山
旗尾
楊寮
義德街
永福街
復興東街
大同路
延平二路
中興路二段
福義街
旗屏路
新旗南橋

Topographical Map



Geological Map

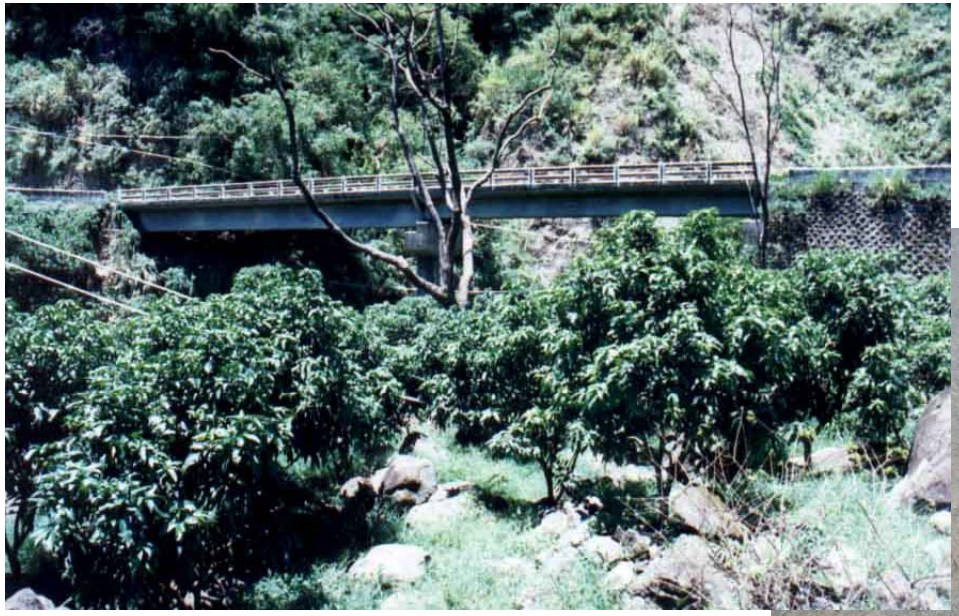


Satellite Images

Before Disaster

After Disaster

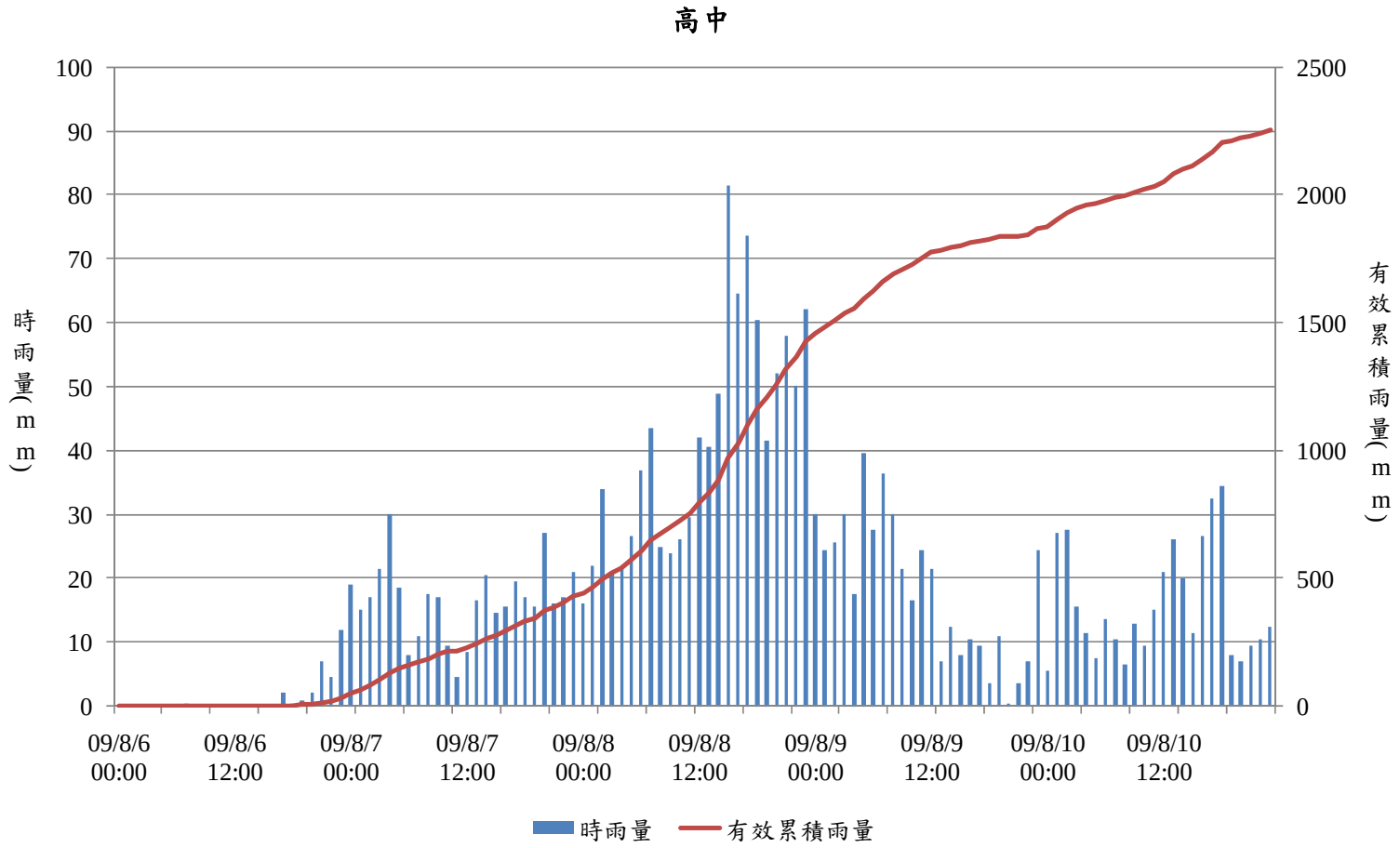
Photos of Bridge



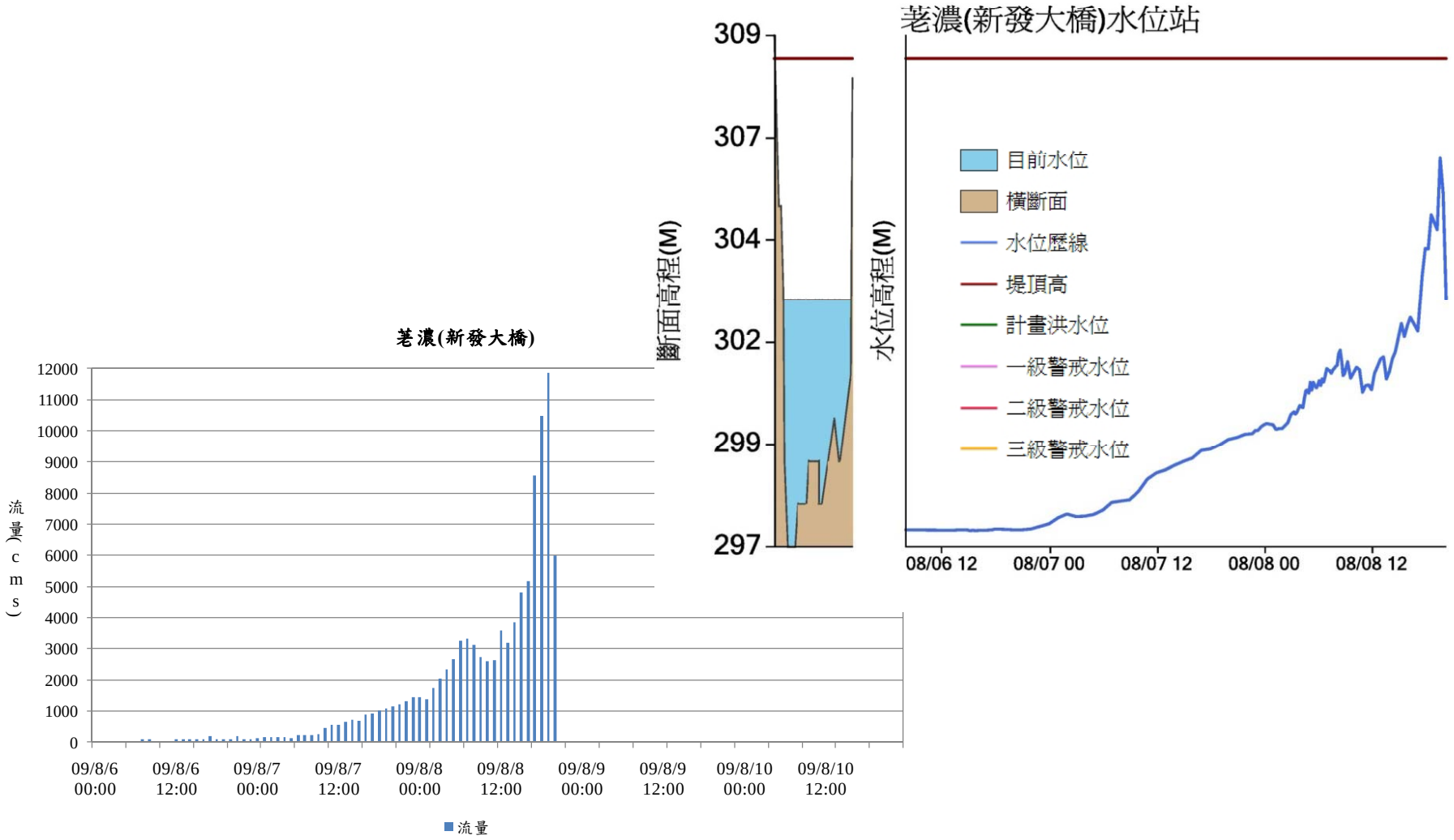
Before Disaster

After Disaster

Accumulated Precipitation



Water Level and Discharge



Structural health diagnosis & Prognosis

by

Data Management System

+

Measurements + Numerical Simulations

+

Reliability & Risk Analysis

Thanks for your attention.