Groundwater Modeling
Training materials

Isotope Hydrology Workshop
organized by
Thailand Institute of Nuclear Technology (TINT)

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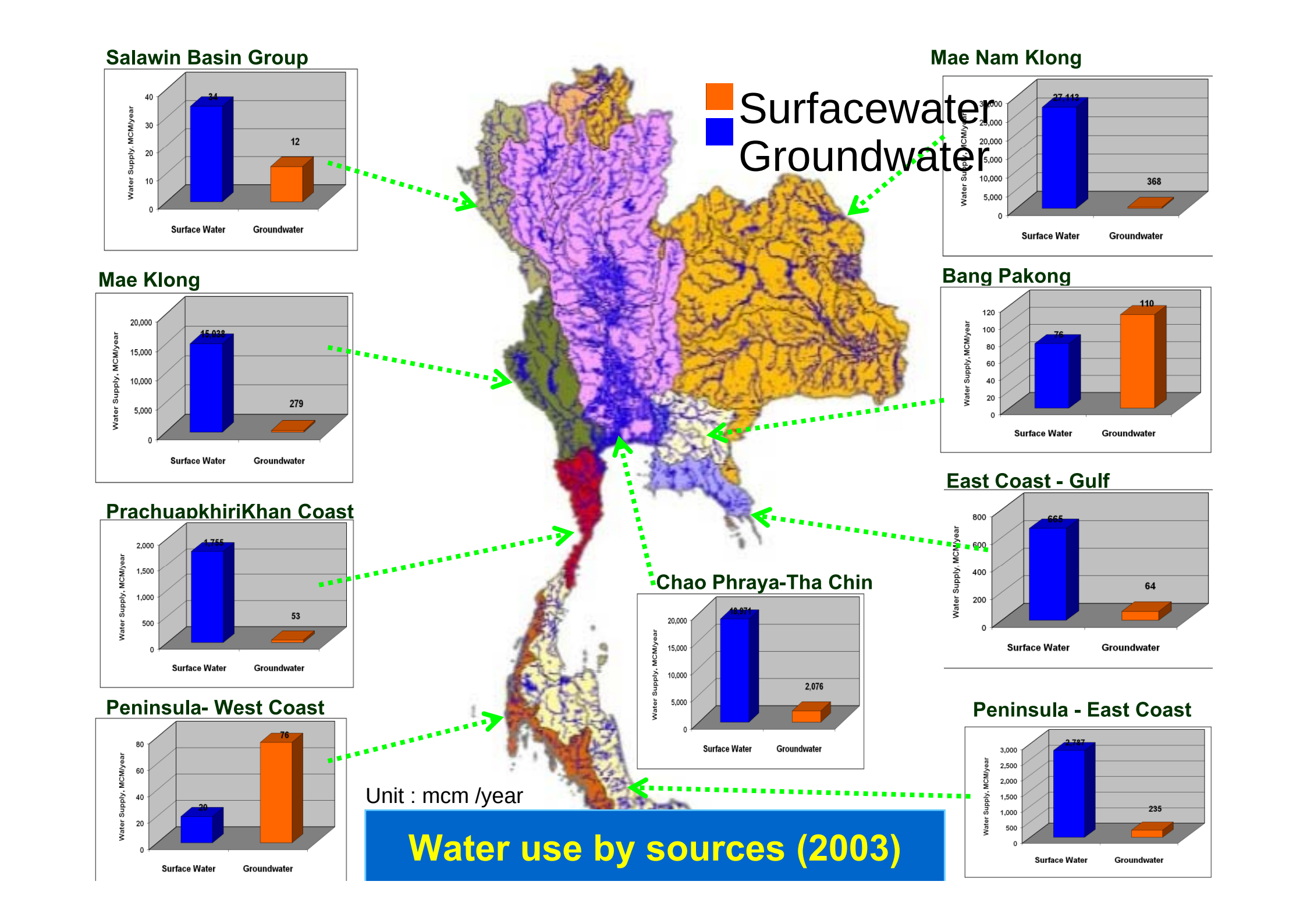
Content

- Part 1 Introduction
- Part 2 GW Modeling
- Part 3 Application cases
- Part 4 Future trends

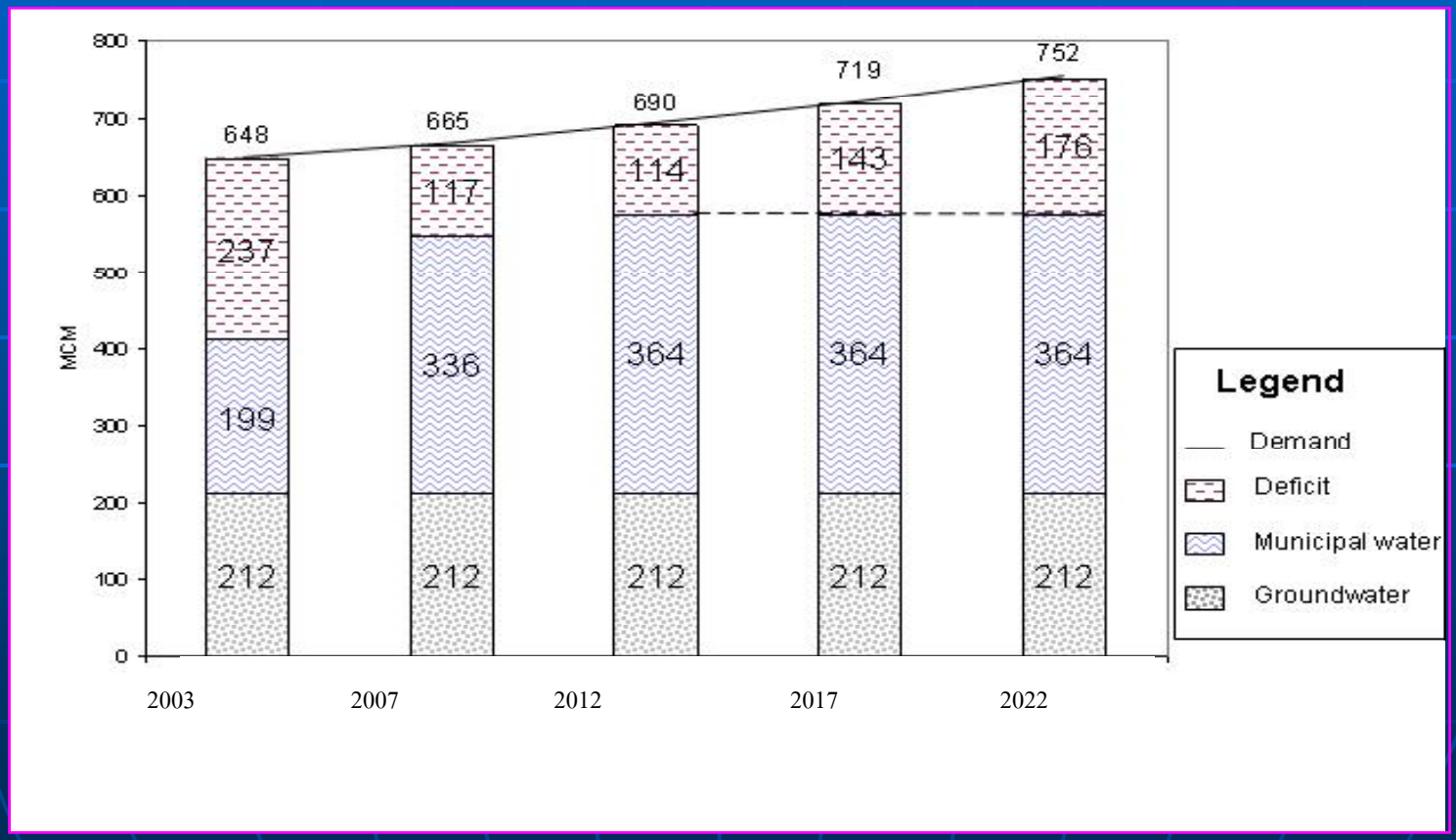
Part 1 Introduction

- Water Problem
- GW study necessity
- GW model necessity as tools


Salawin Basin Group
Water Supply, MCM/year
34
12
Surface Water
Groundwater
Surfacewater
Groundwater
Mae Nam Klong
27,113
368
Surface Water
Groundwater
Mae Klong
15,038
279
Surface Water
Groundwater
Bang Pakong
76
110
Surface Water
Groundwater
PrachuapkhiriKhan Coast
1,755
53
Surface Water
Groundwater
East Coast - Gulf
665
64
Surface Water
Groundwater
Chao Phraya-Tha Chin
18,971
2,076
Surface Water
Groundwater
Peninsula- West Coast
20
76
Surface Water
Groundwater
Peninsula - East Coast
2,787
235
Surface Water
Groundwater
Unit : mcm /year
Water use by sources (2003)

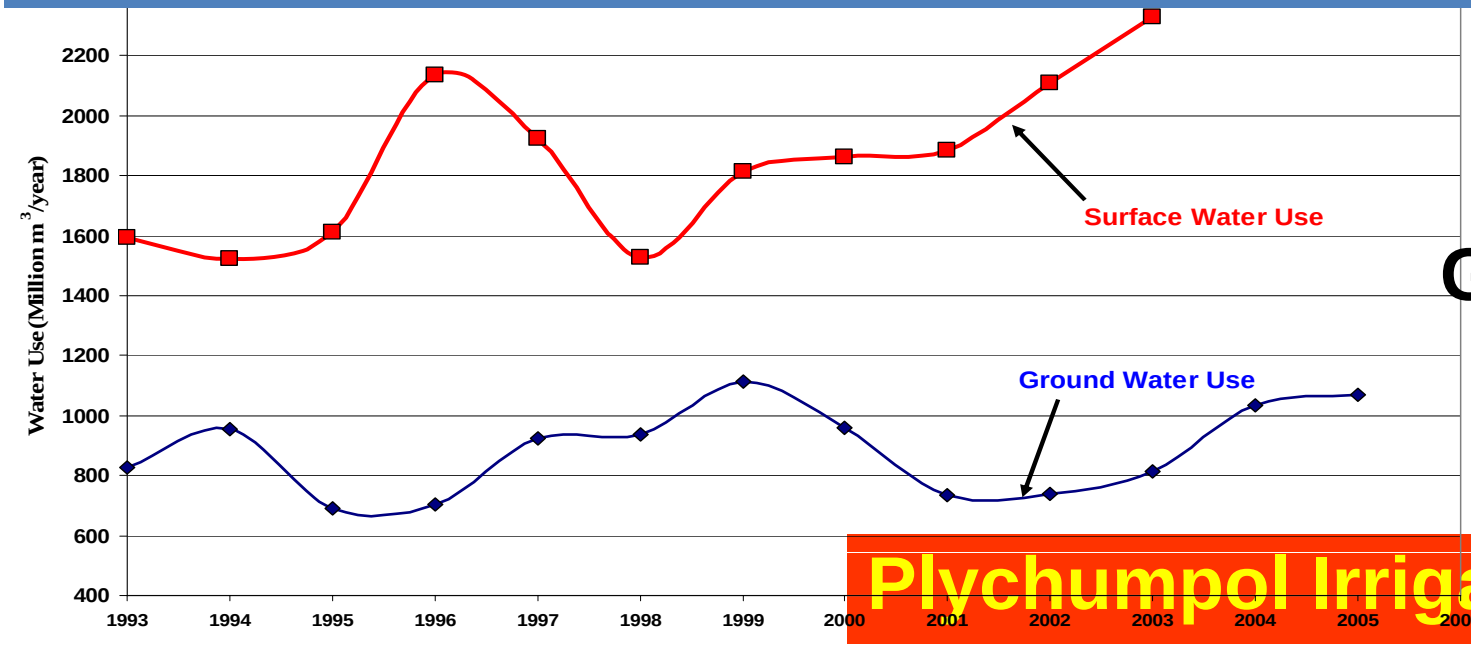
Water Problem

- Demand increase



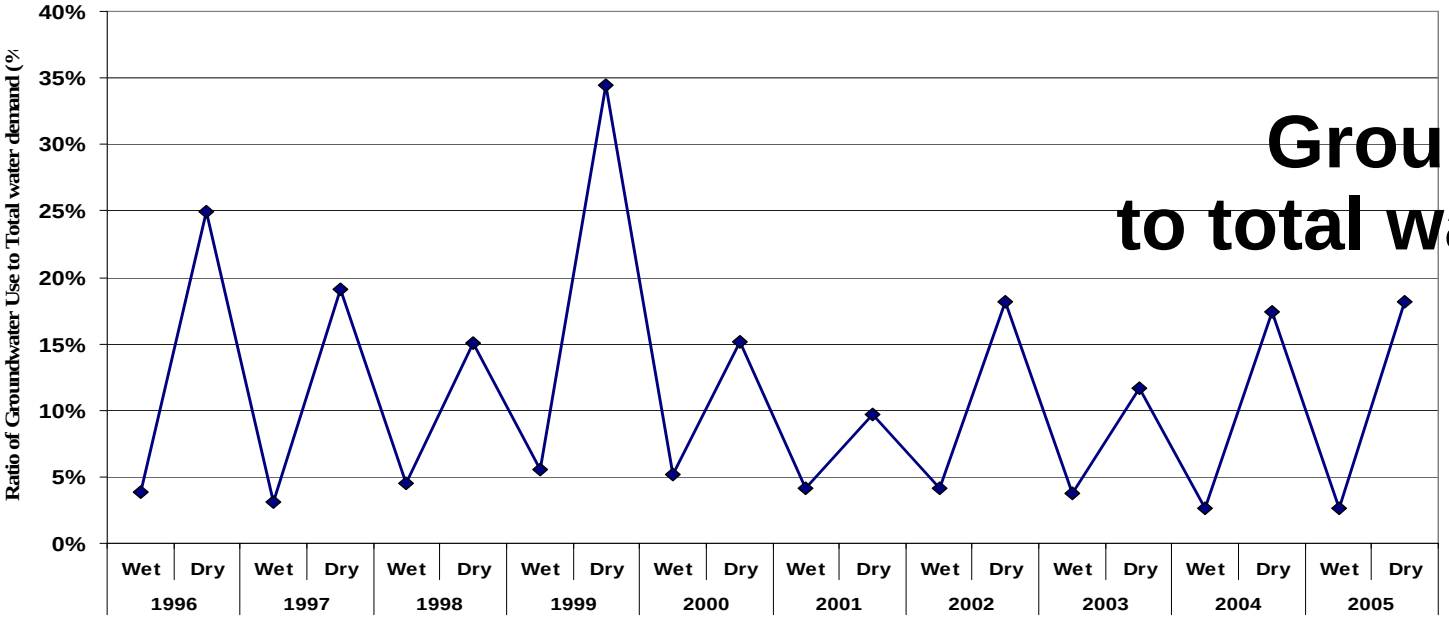
Bangkok Metropolitan and its vicinity water use

Groundwater dependency



Surface and Groundwater Use

Plychumpol Irrigation project



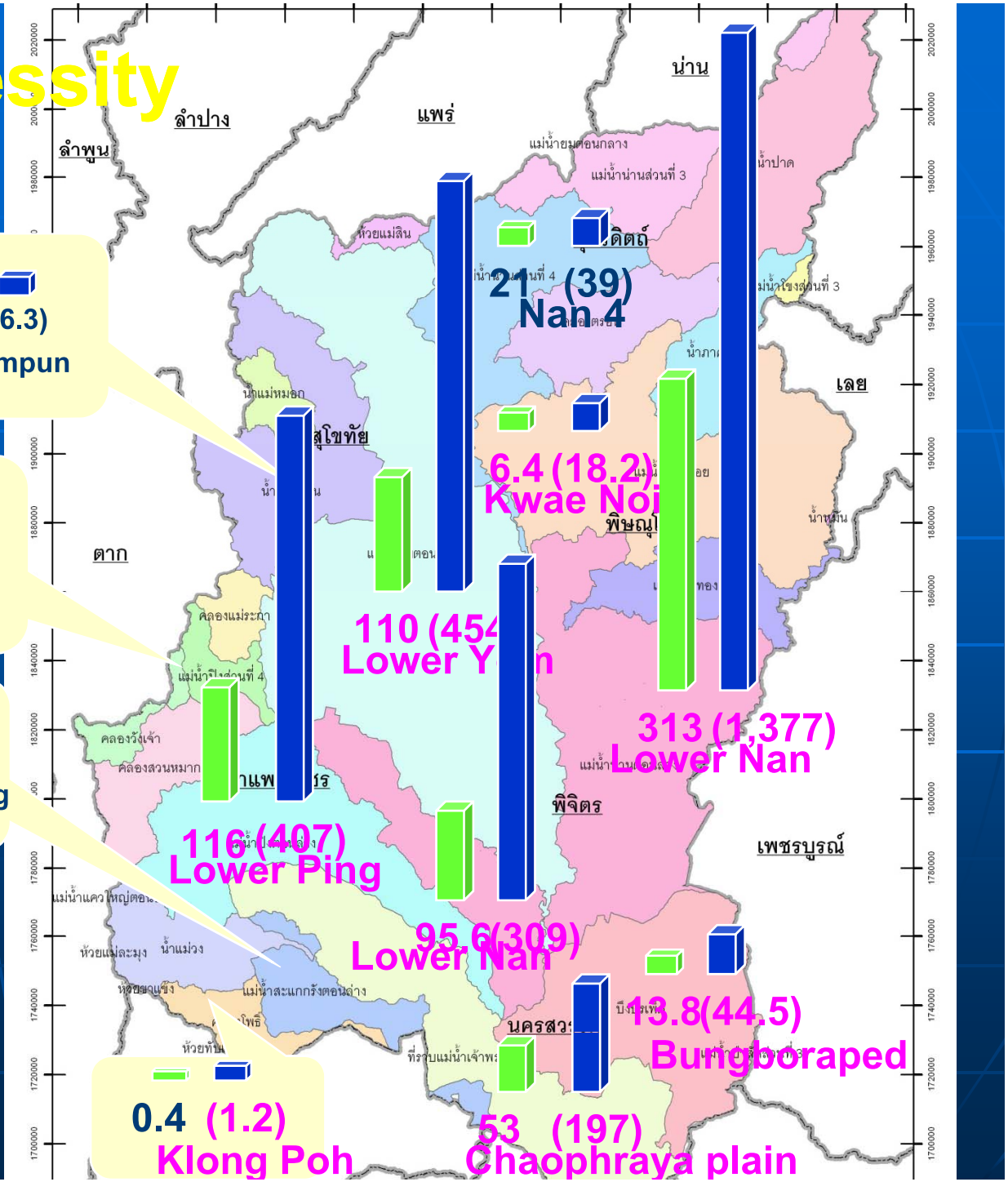
Ratio of Groundwater Use to total water demand

GW study necessity

- potential study
- surface water interaction
- contamination

GW study necessity

GW potential study in sub-basins



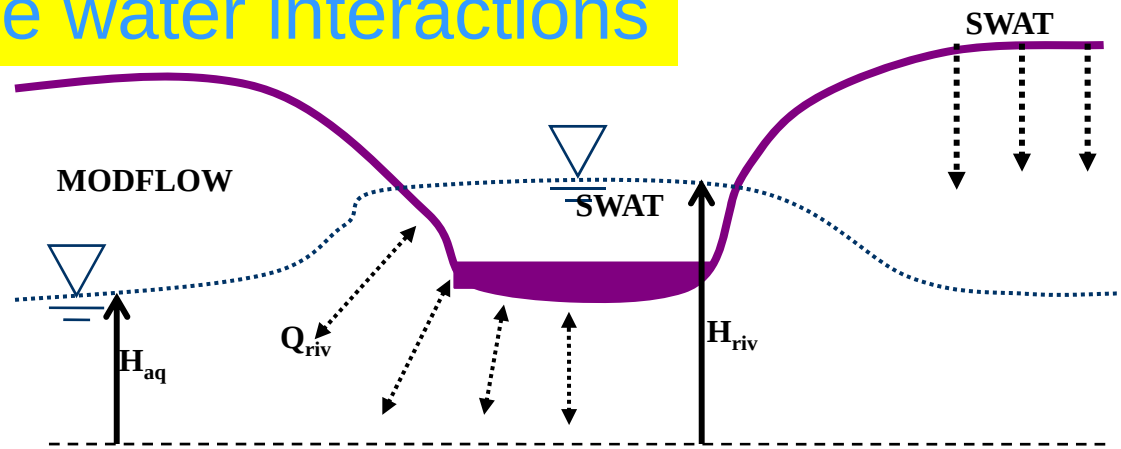
- Groundwater use in 2003
- (Potential)
- Unit : mcm/year

total 766 (2870) mcm/year

27 % of total potetial

GW study necessity

surface water interactions



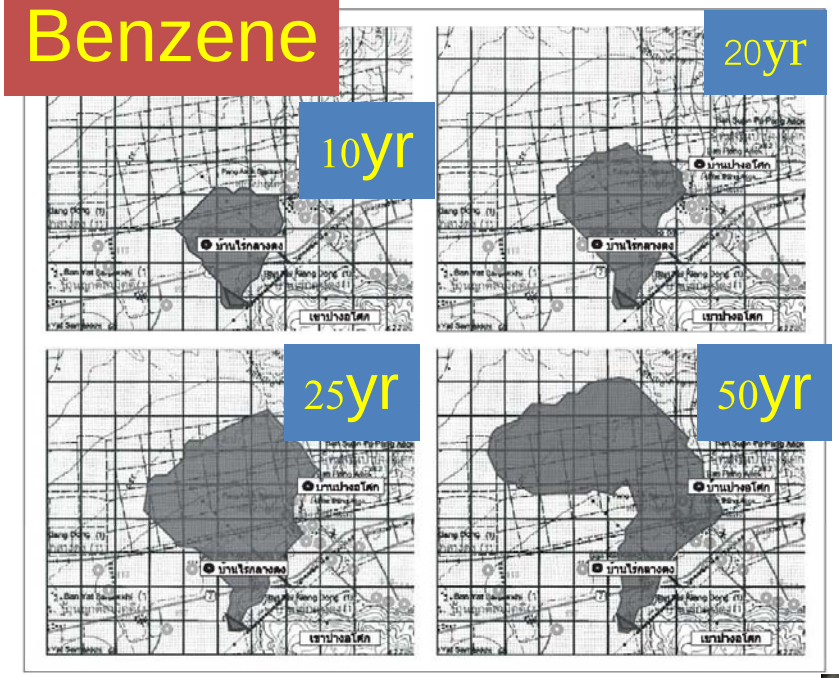
GW Pumping

River/Canal

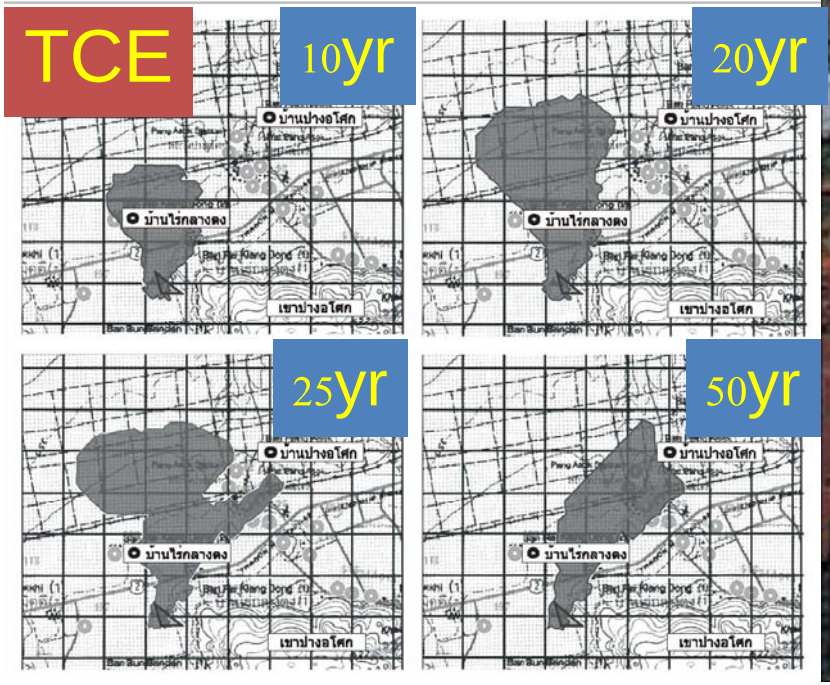
GW study necessity

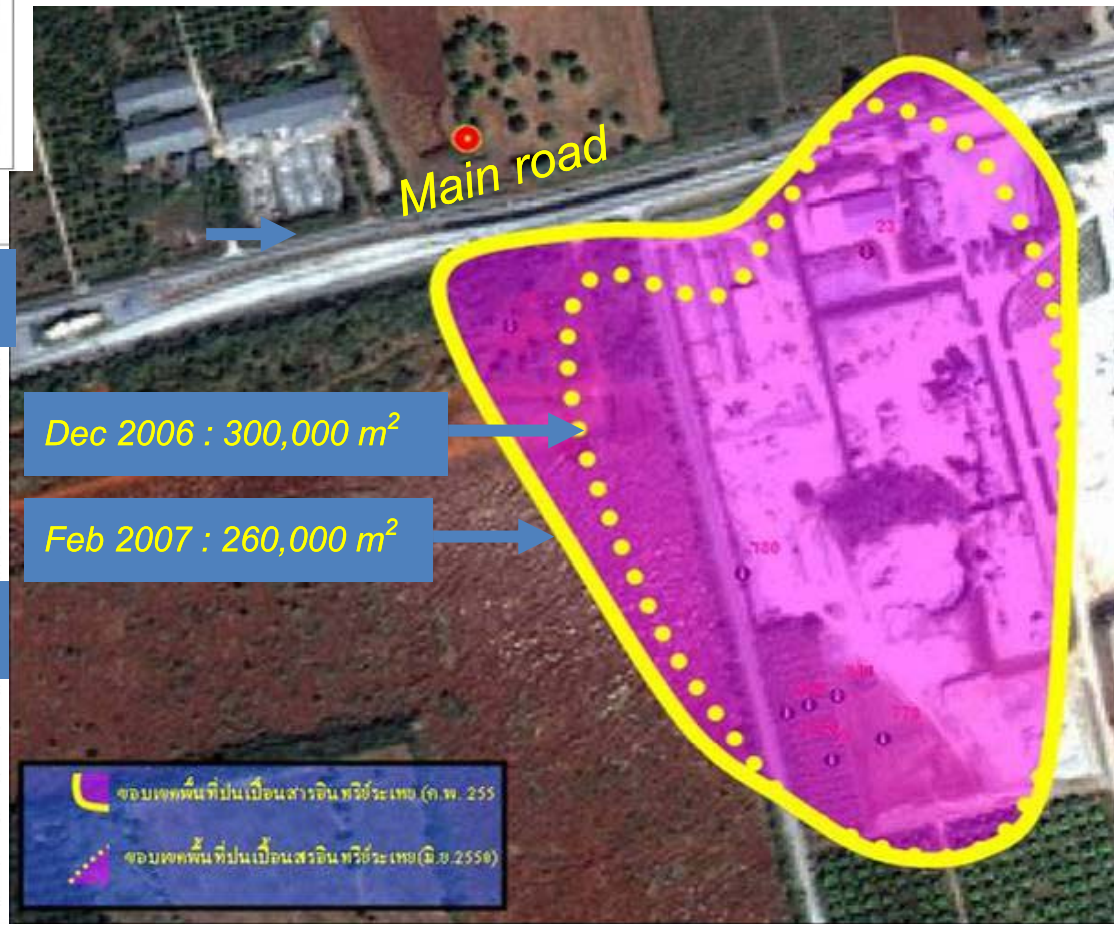
Contamination

Benzene



TCE





GW model necessity as tools

groundwater models are able to provide data on seepage, groundwater flow, chemical/mass movement and natural protection

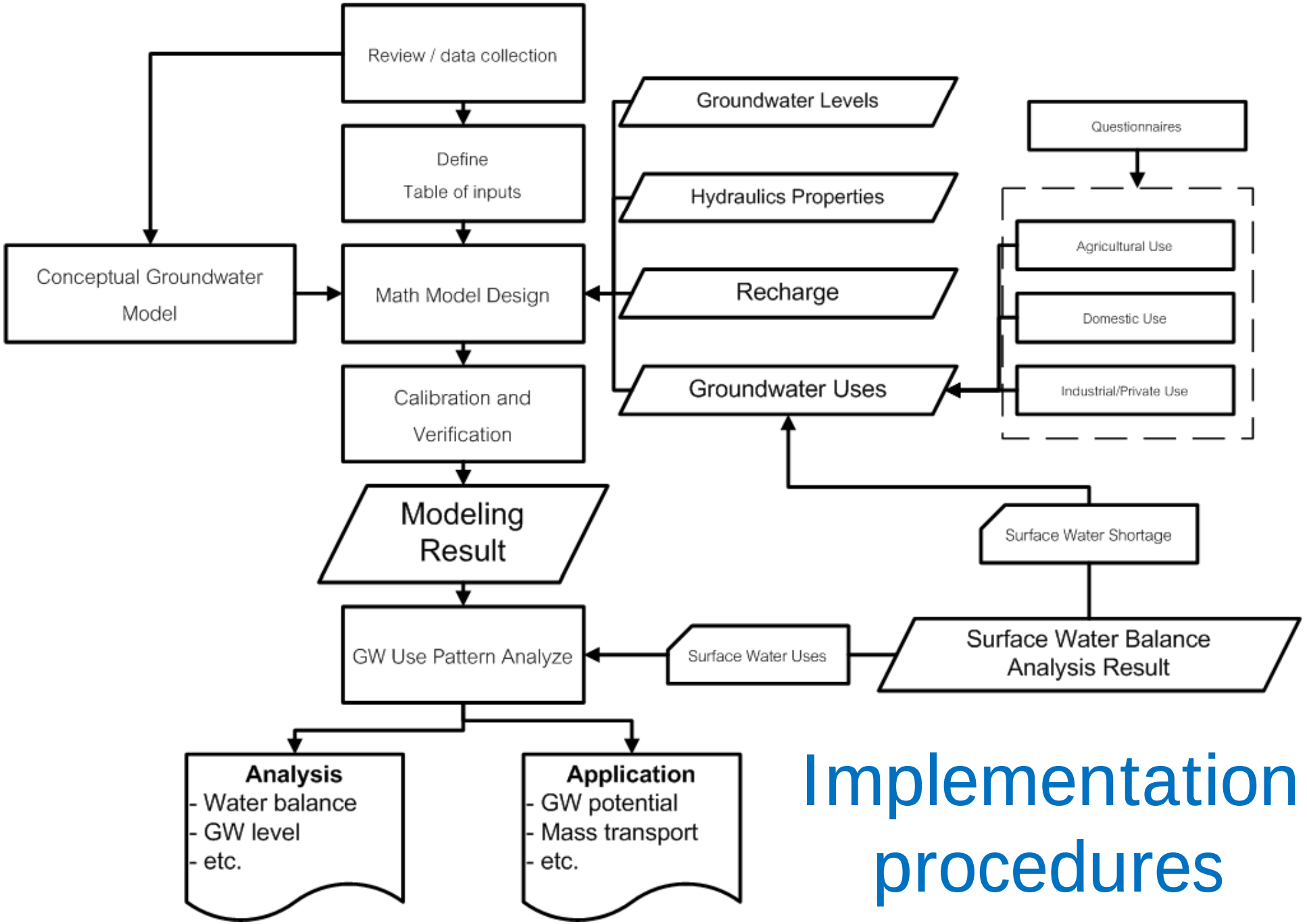
Part 2 GW Modelling

- GW model types
- Implementation procedures
- Model development
- Calibration/validation

GW model types

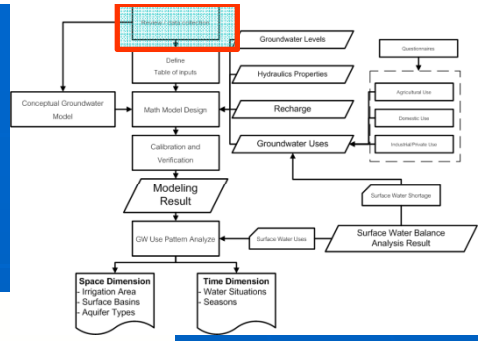
- Groundwater quantity
  - MODFLOW-96, MODFLOW-2000 (saturated)
  - Hydrus 1-D,2-D (variably saturated)

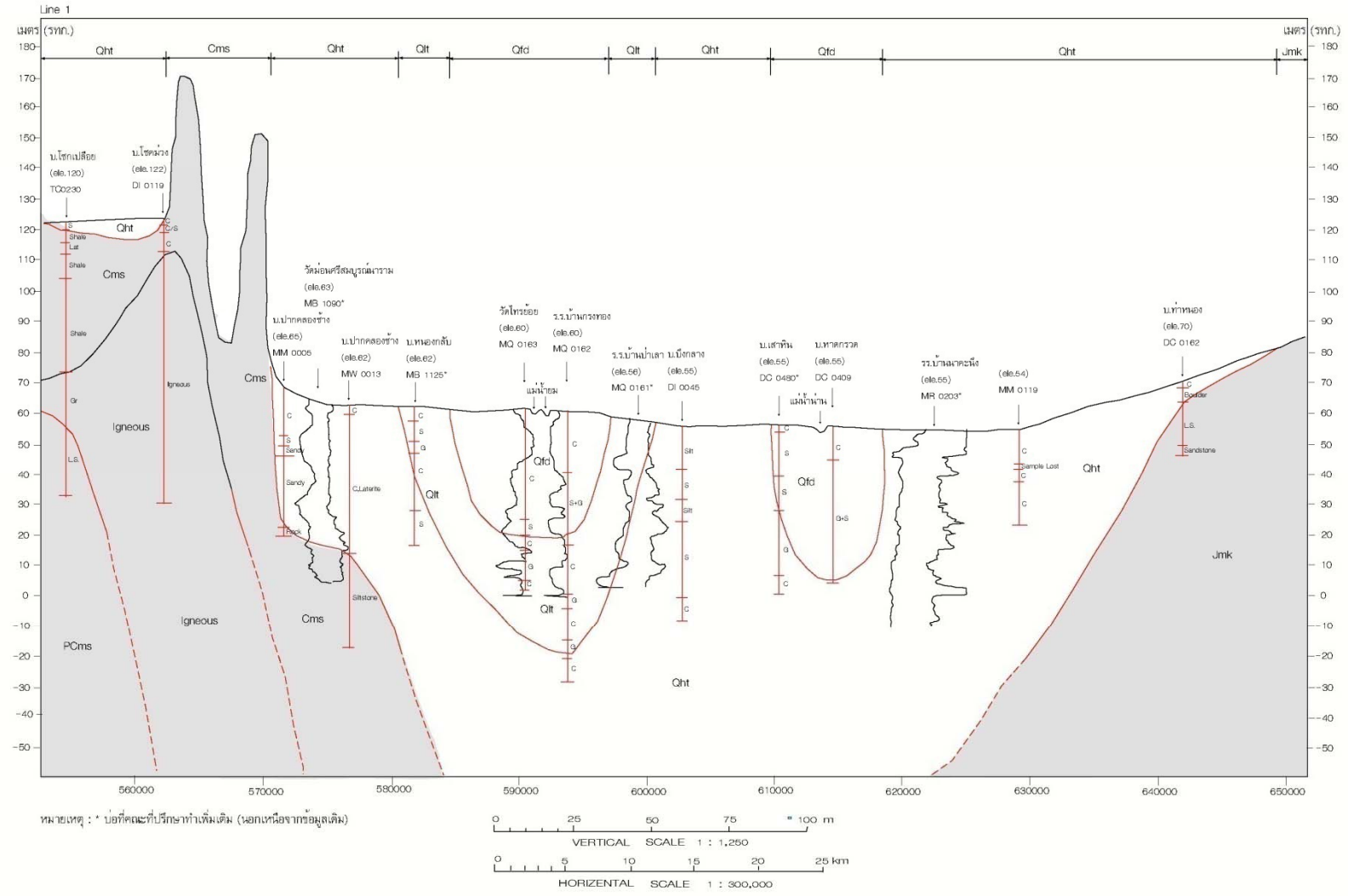
- Groundwater quality
  - MT3D (solute transport)
  - FEMWATER (solute transport, FEM)
  - UTCHEM (multi-phase transport)
  - SUTRA (density-dependent flow)



Implementation procedures

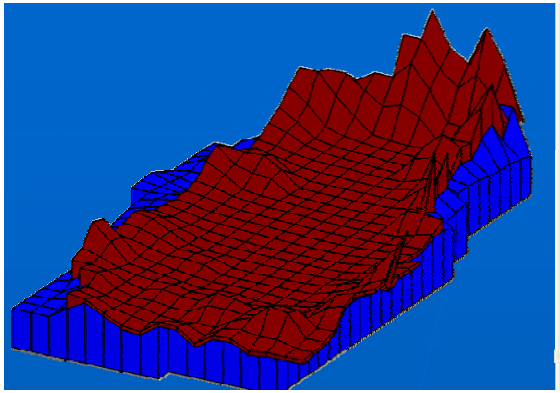
Geological data

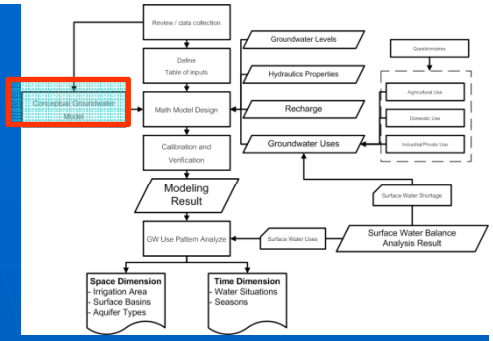




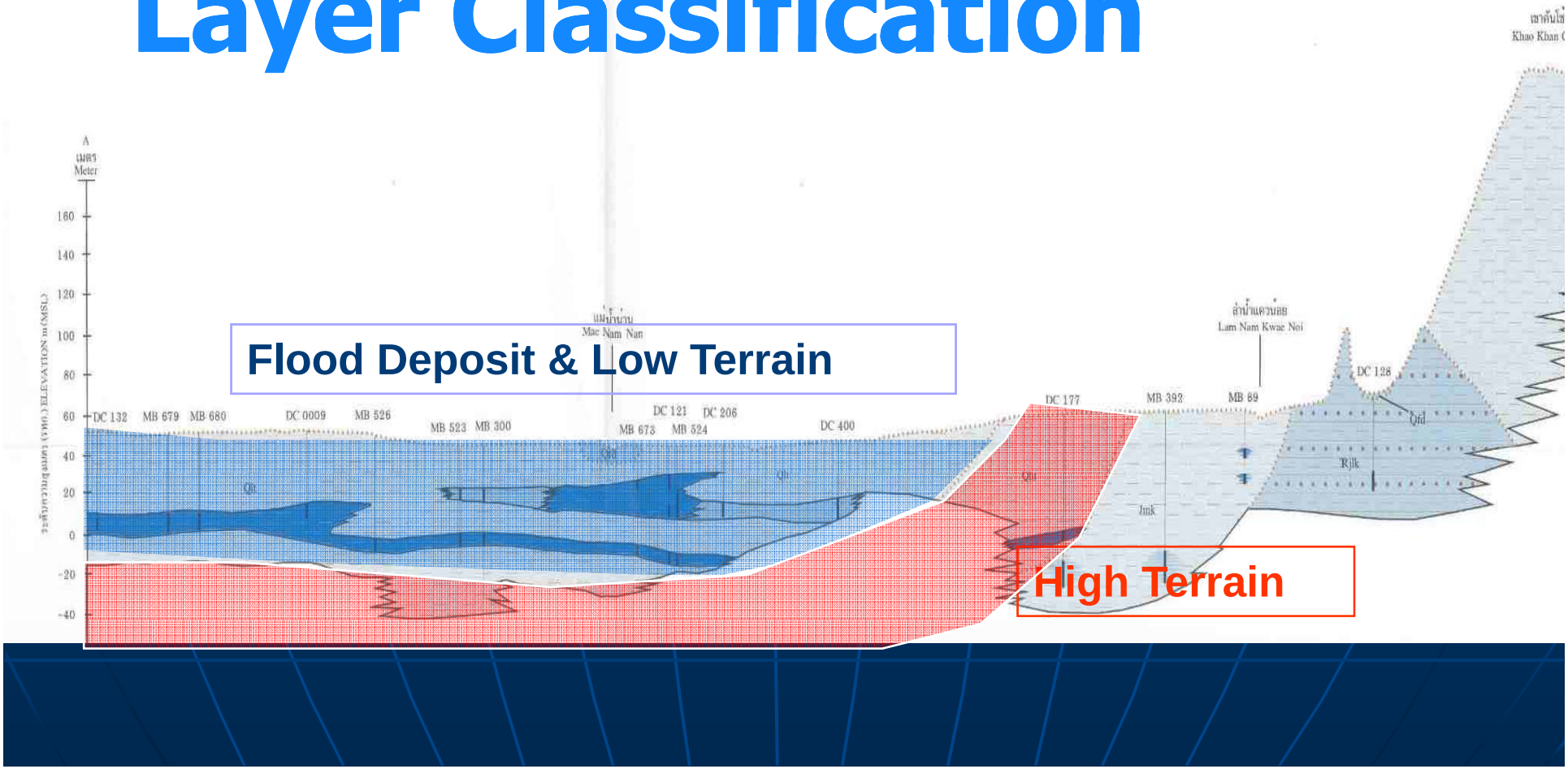
หมายเหตุ : * บ่อที่คณะที่ปรึกษาทำเพิ่มเติม (นอกเหนือจากข้อมูลเดิม)

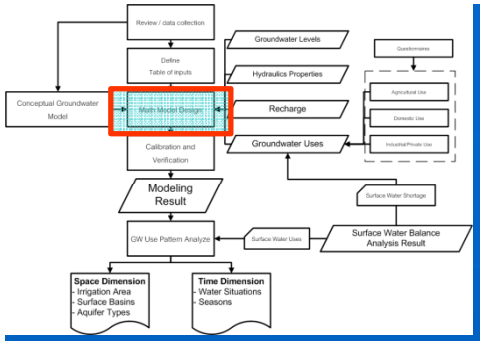
รูปที่ 4.2-2 ภาพตัดขวางทางอุทกธรณีวิทยา Line1





Layer Classification





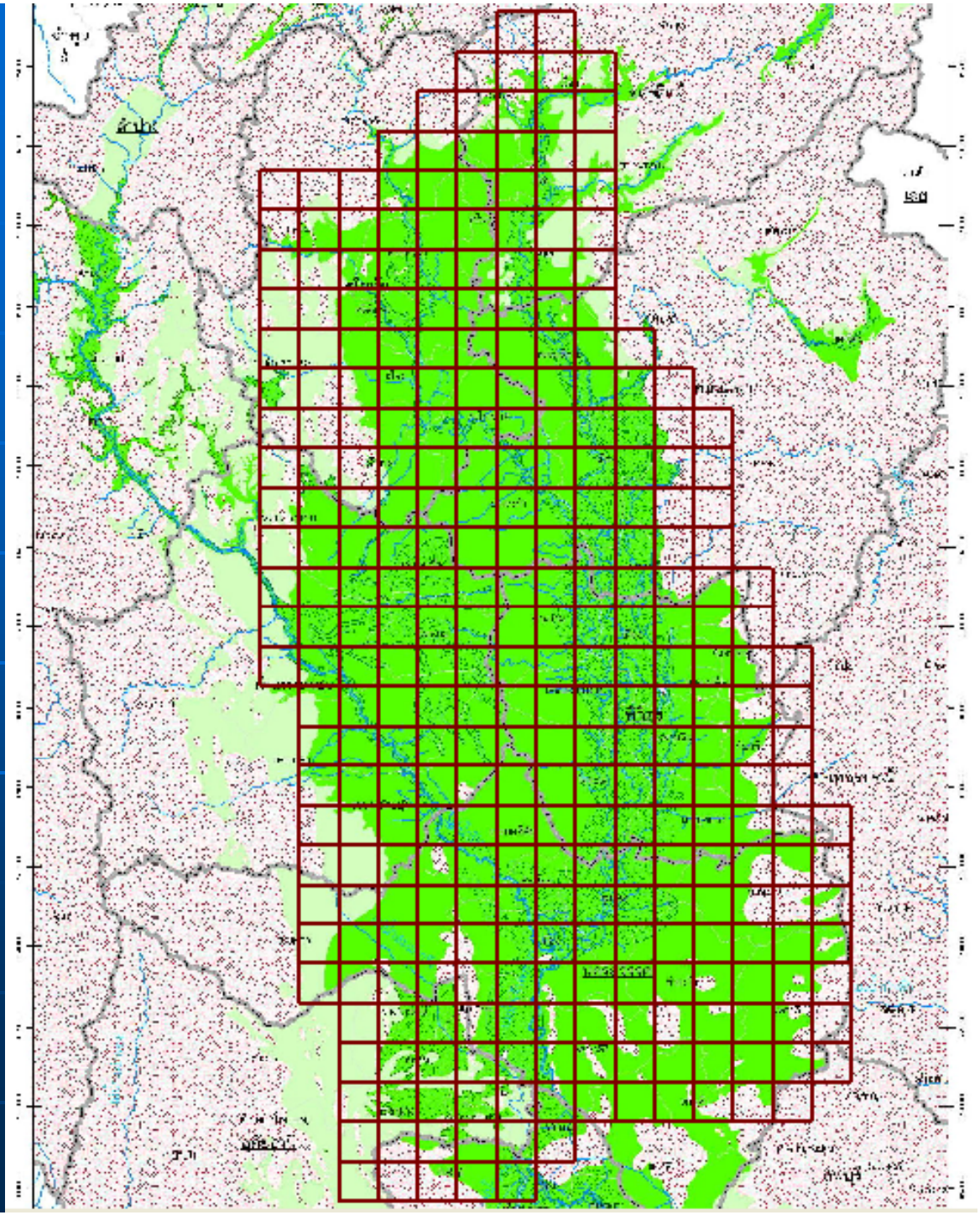
- **Flood Deposit**
- **Low Terrain**

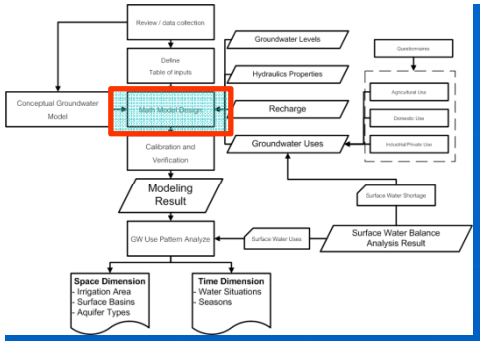
10 km.

10 km

15 by 30 grids
320 Grids Total

Layer1 Grid

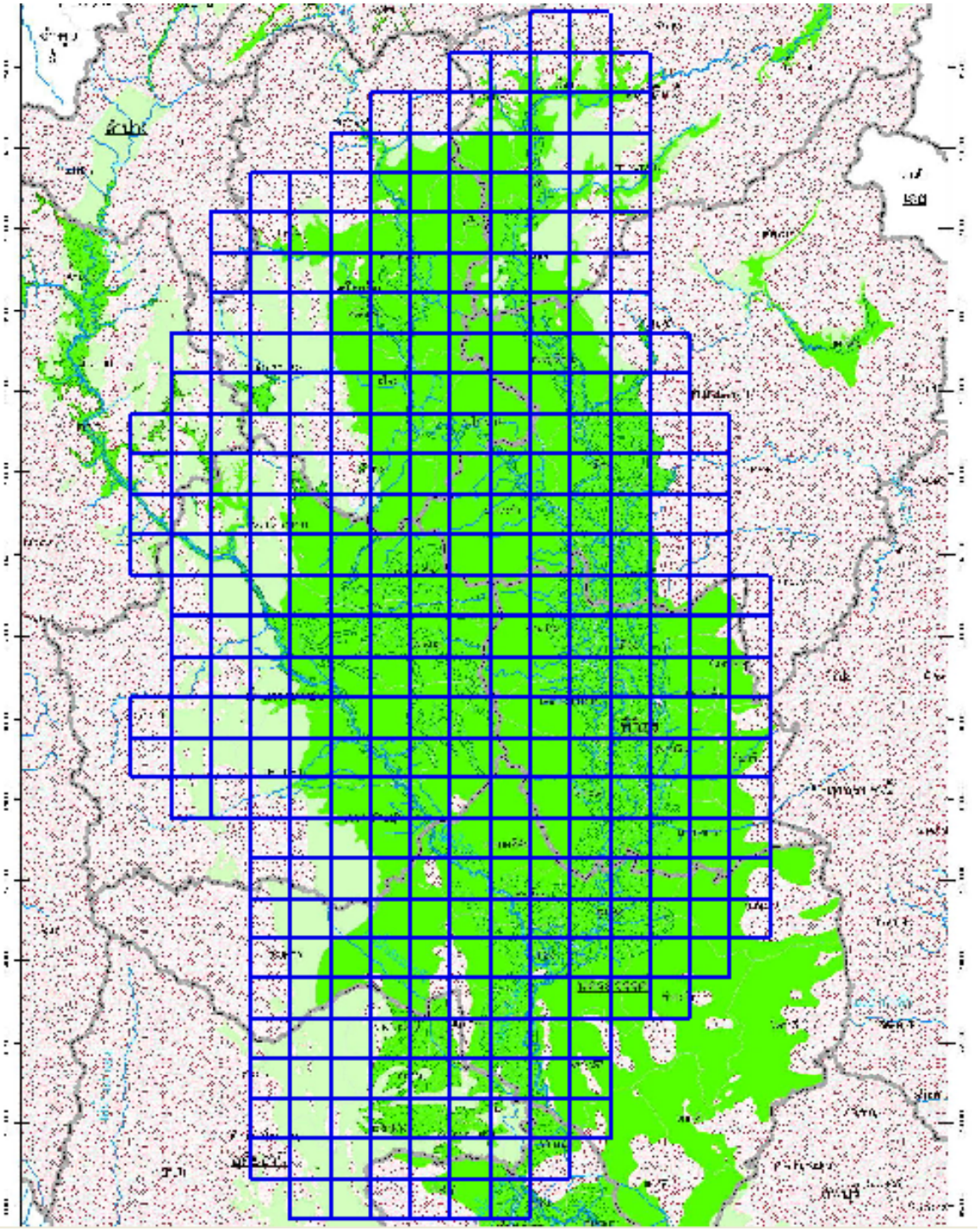


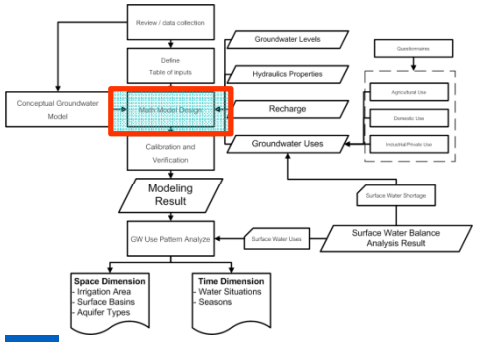


- **High Terrain**

16 by 30 grids
346 Grids Total

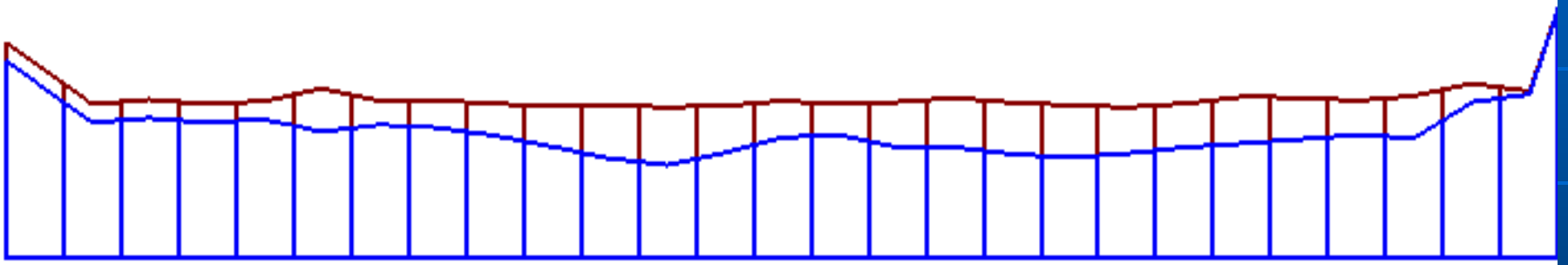
Layer2 Grid





S

N

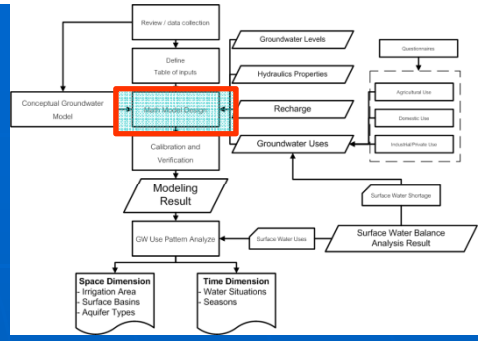


Z

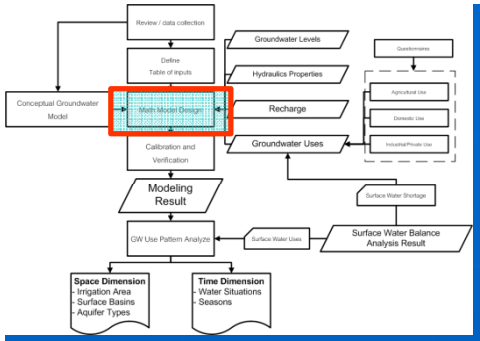
Y

Grid Cross-section N-S

Boundary conditions



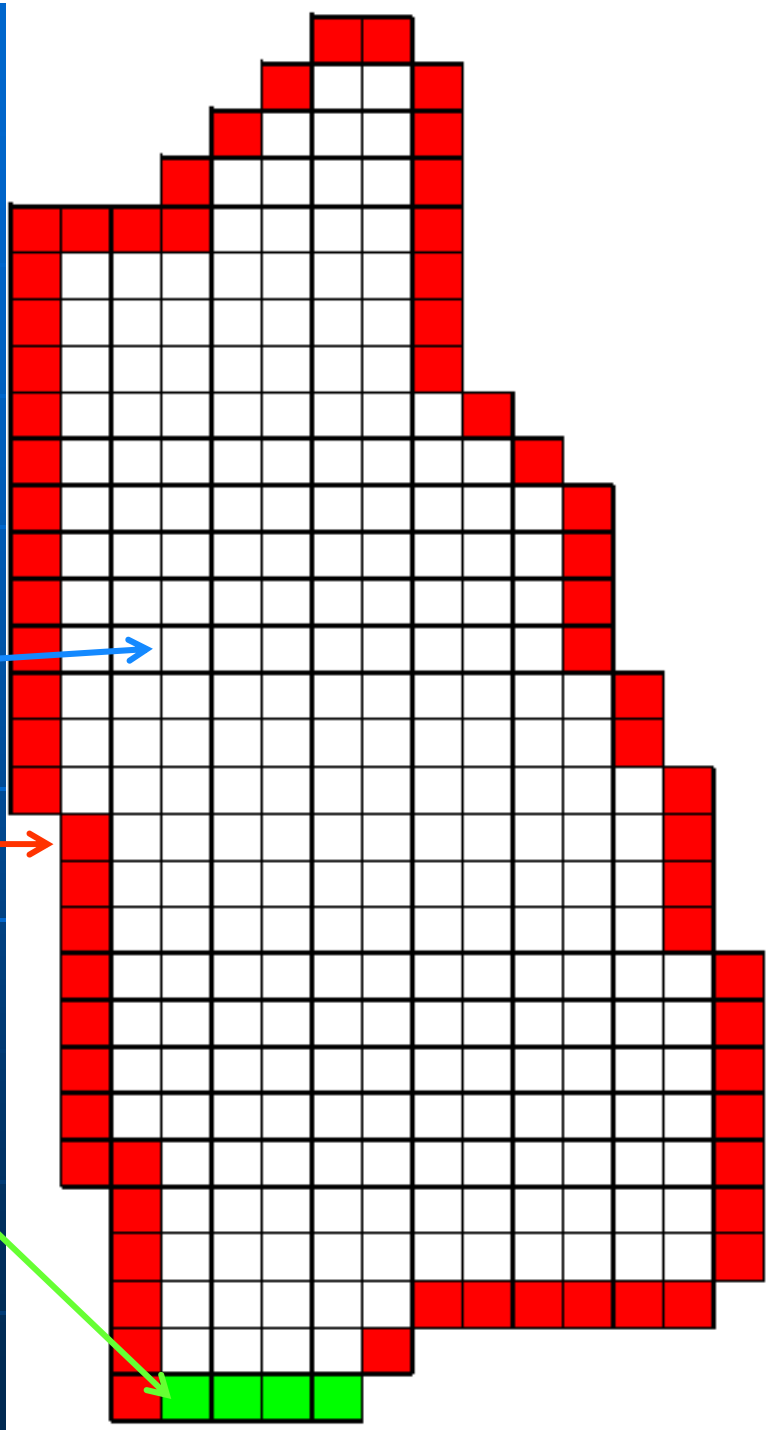
- In/out flow condition
- No-flow condition
- Fixed head
- Fixed gradient



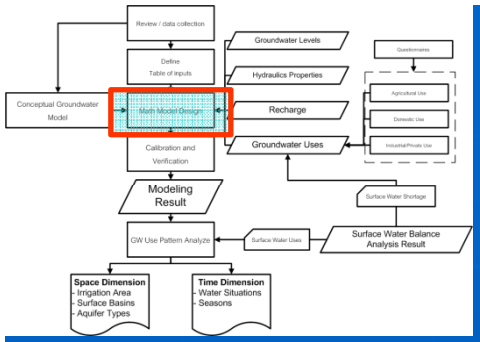
Active cell

Inflow boundary

Outflow boundary



Flow Boundary



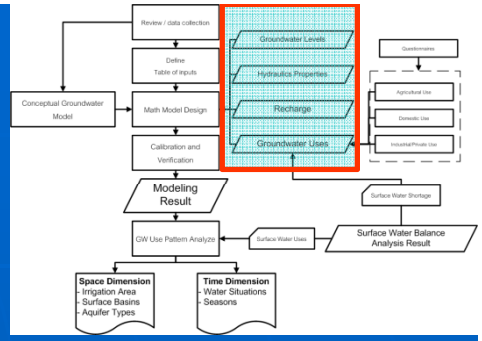
Gradient, i=0.0025 m/m

$Q=KiA$

Gradient, i=0.0018 m/m

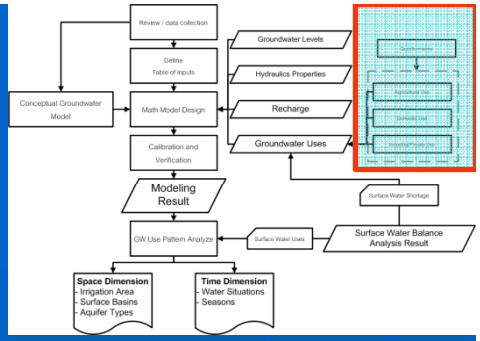
Lateral Flow In Calculation

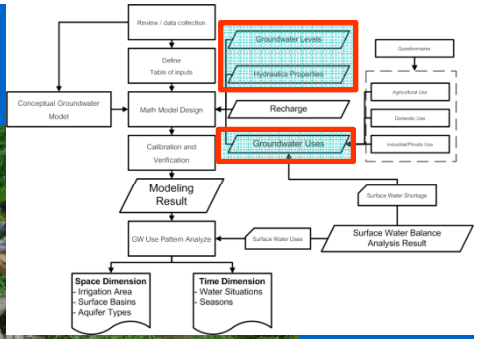
Input parameters



- Well Distribution
- Kinds of Well Consumption
- Pumping test
- Recharge rate
  (by test / survey / statistical method)

Groundwater well exploration

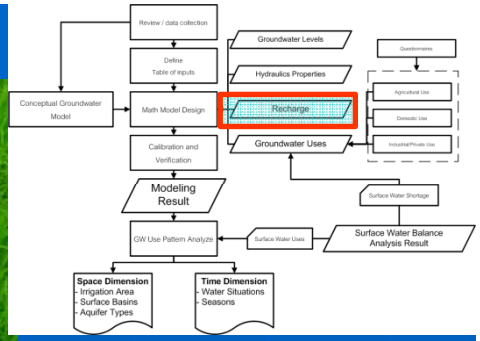




Questionary
Pumping test

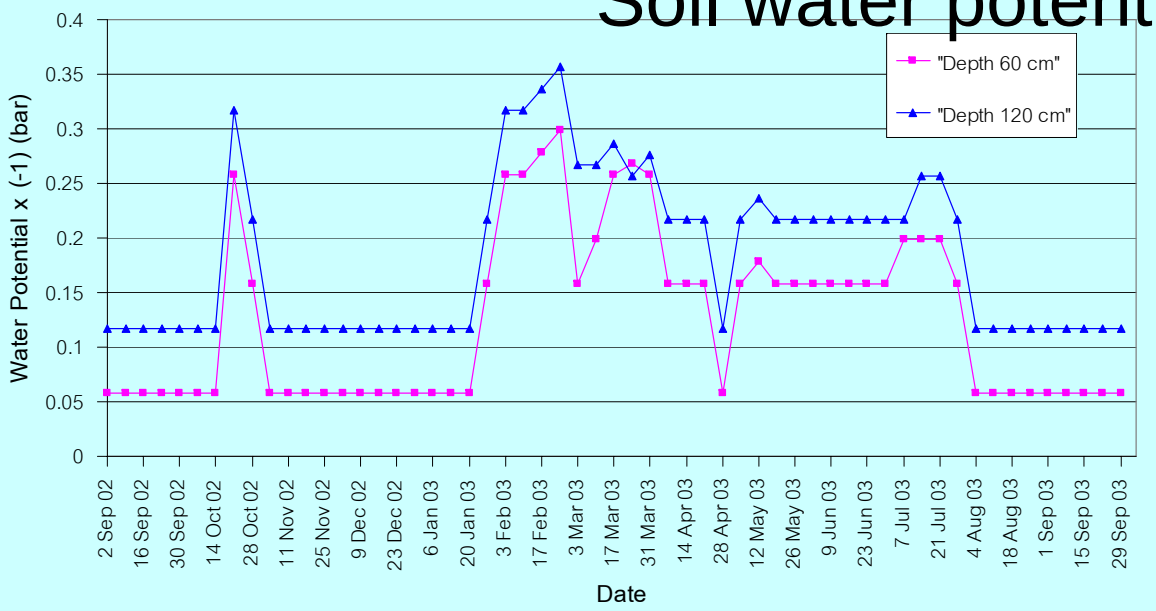
Streamflow measurement

Field activities

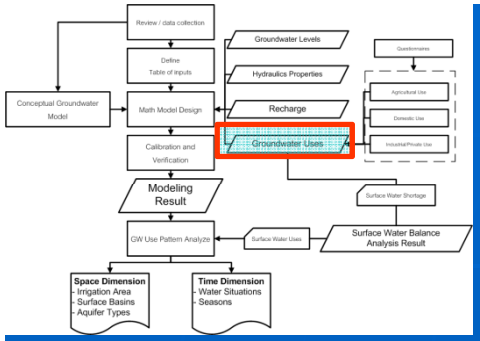


Soil infiltration test

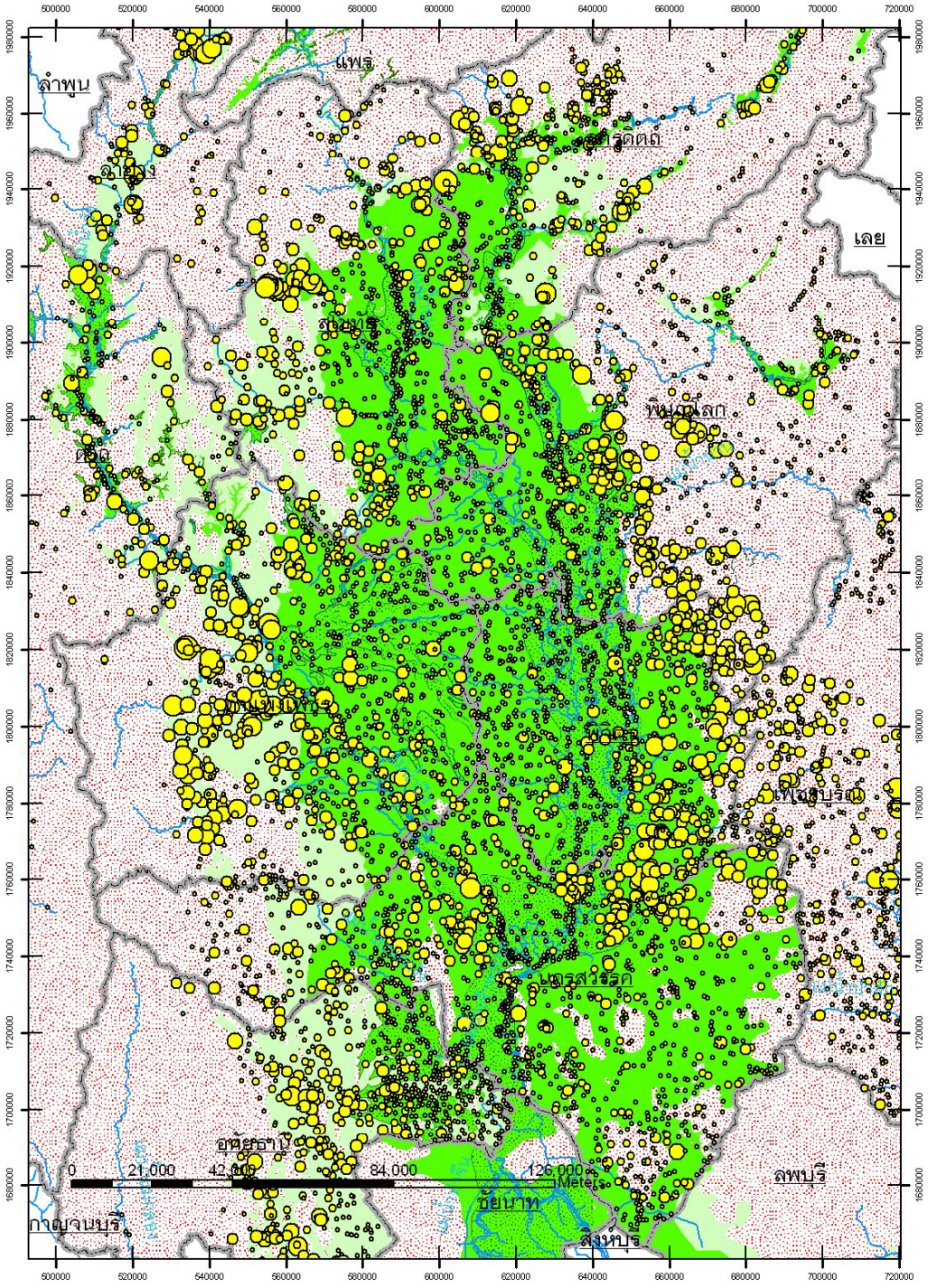
Soil water potentia



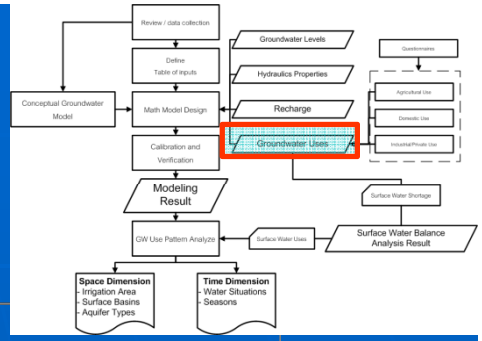
Field activities

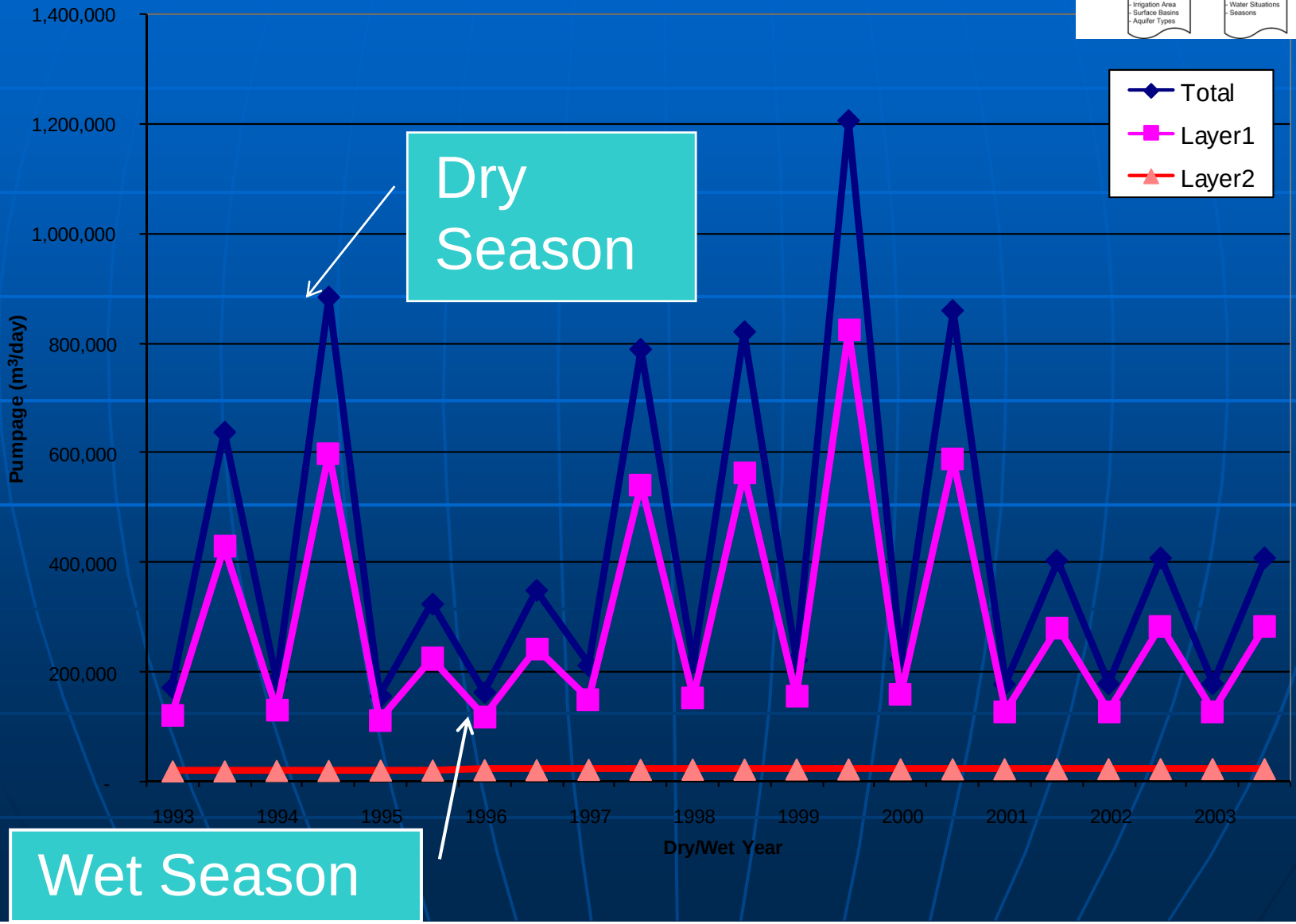


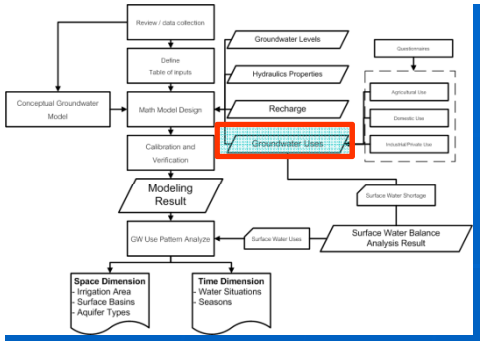
Well Distribution



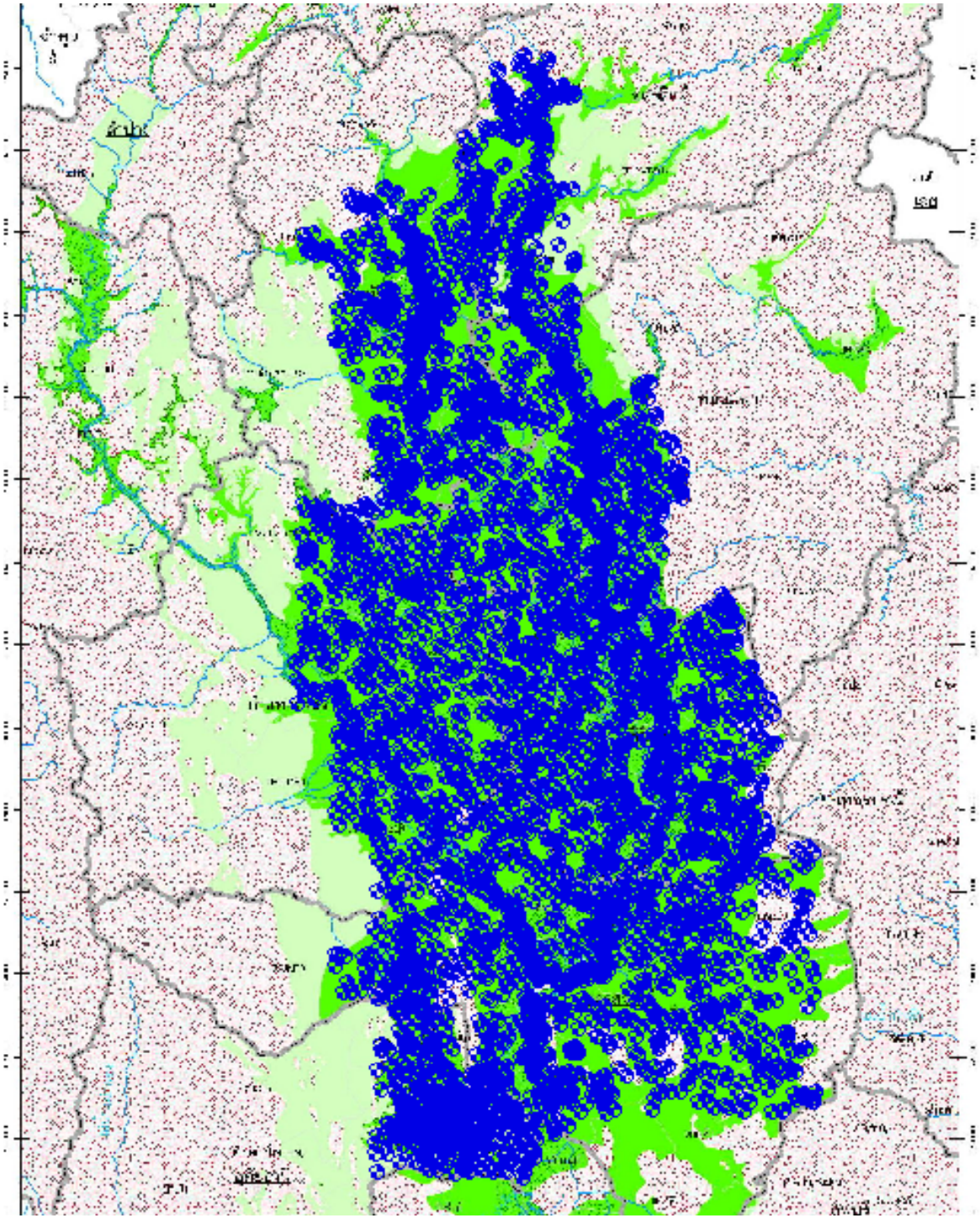
Total Groundwater Extraction

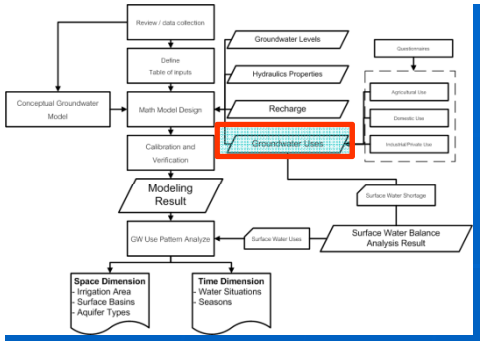




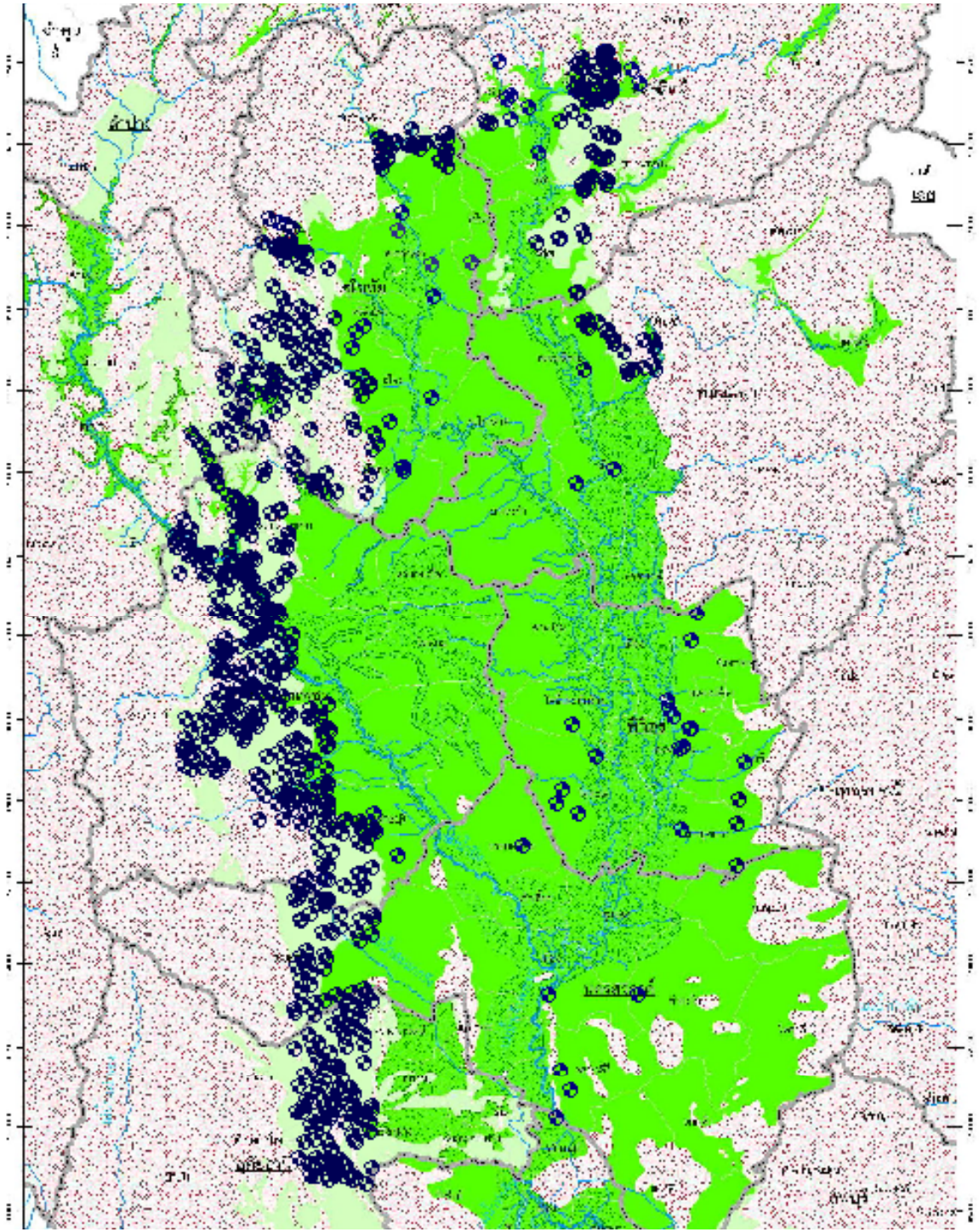


Layer1 model pumpage

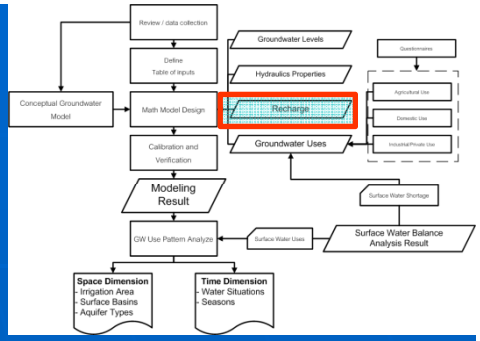




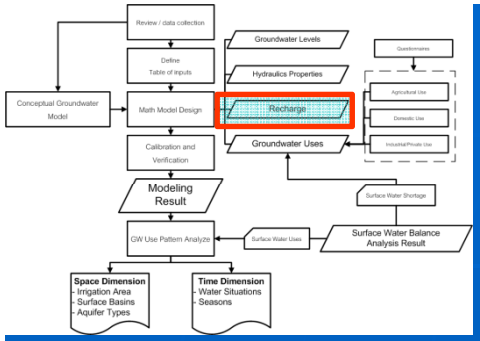
Layer2 model pumpage



Recharge

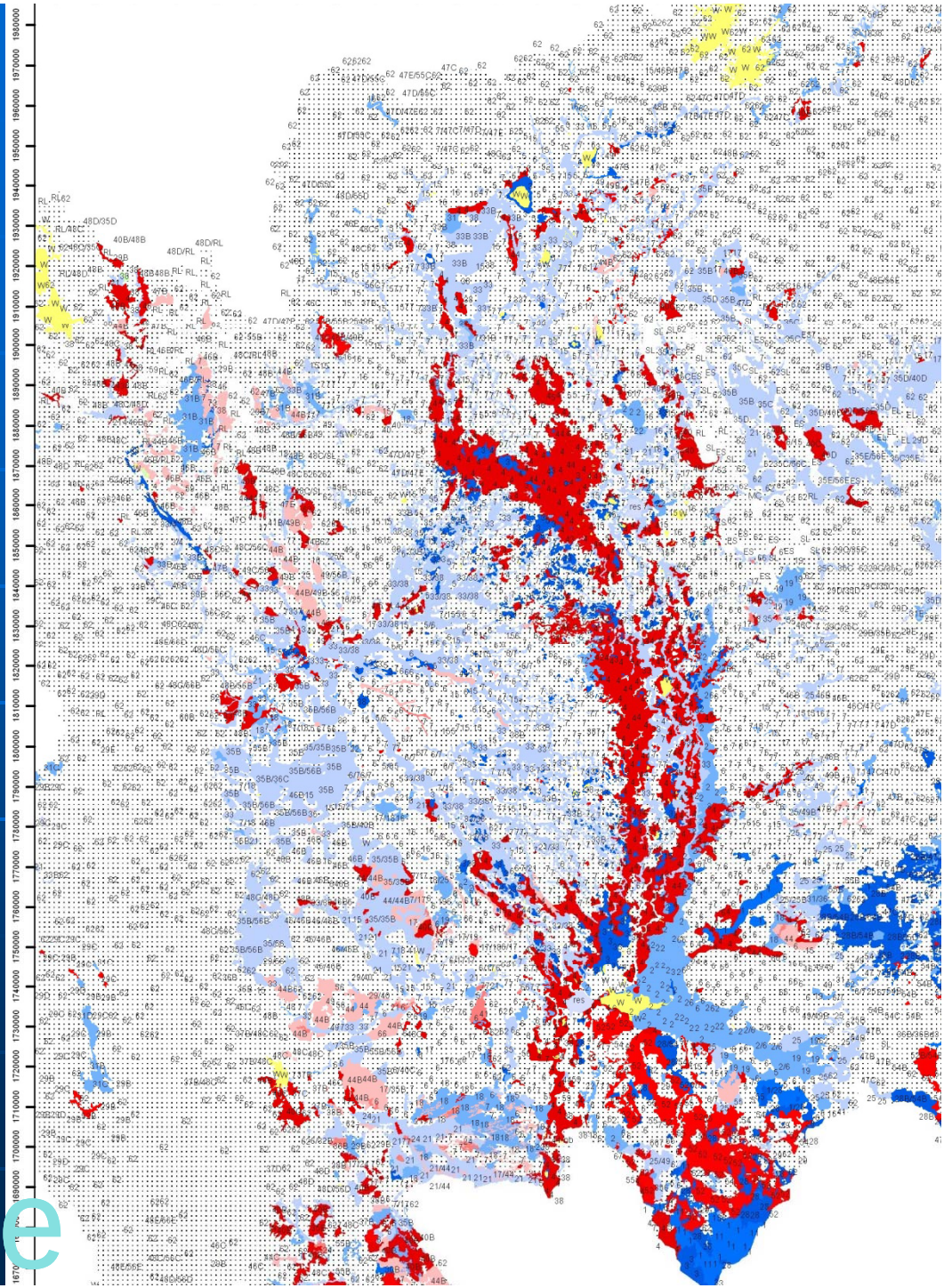


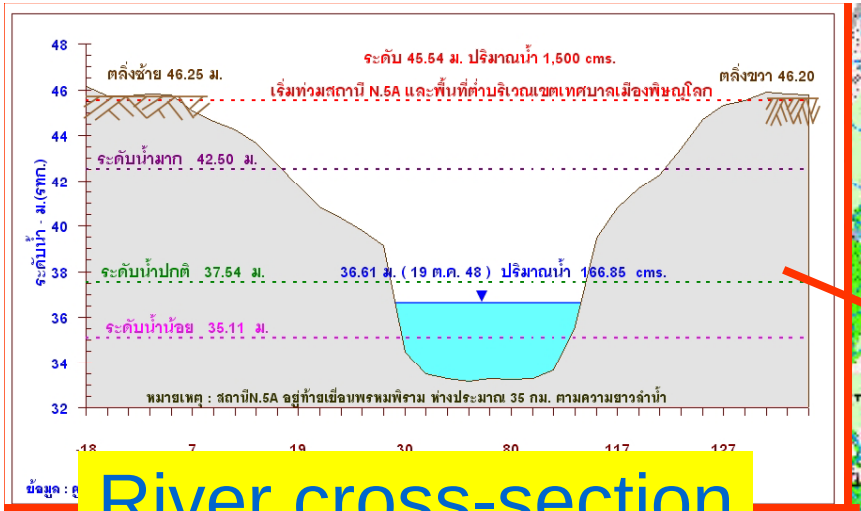
- Areal Recharge
  - Soil Types
  - Rainfall
- Channel Recharge
  - River bottom bed
  - Section
  - River Stage



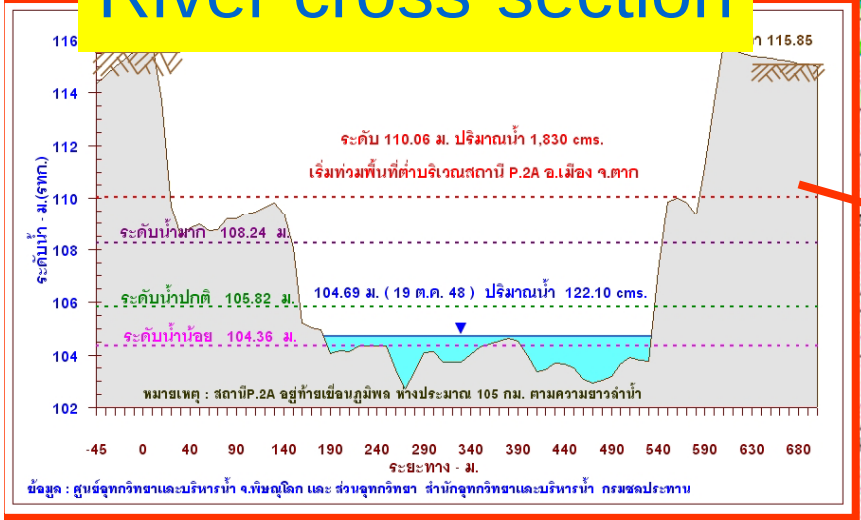
Infiltration rate (% of rainfall)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
1.0

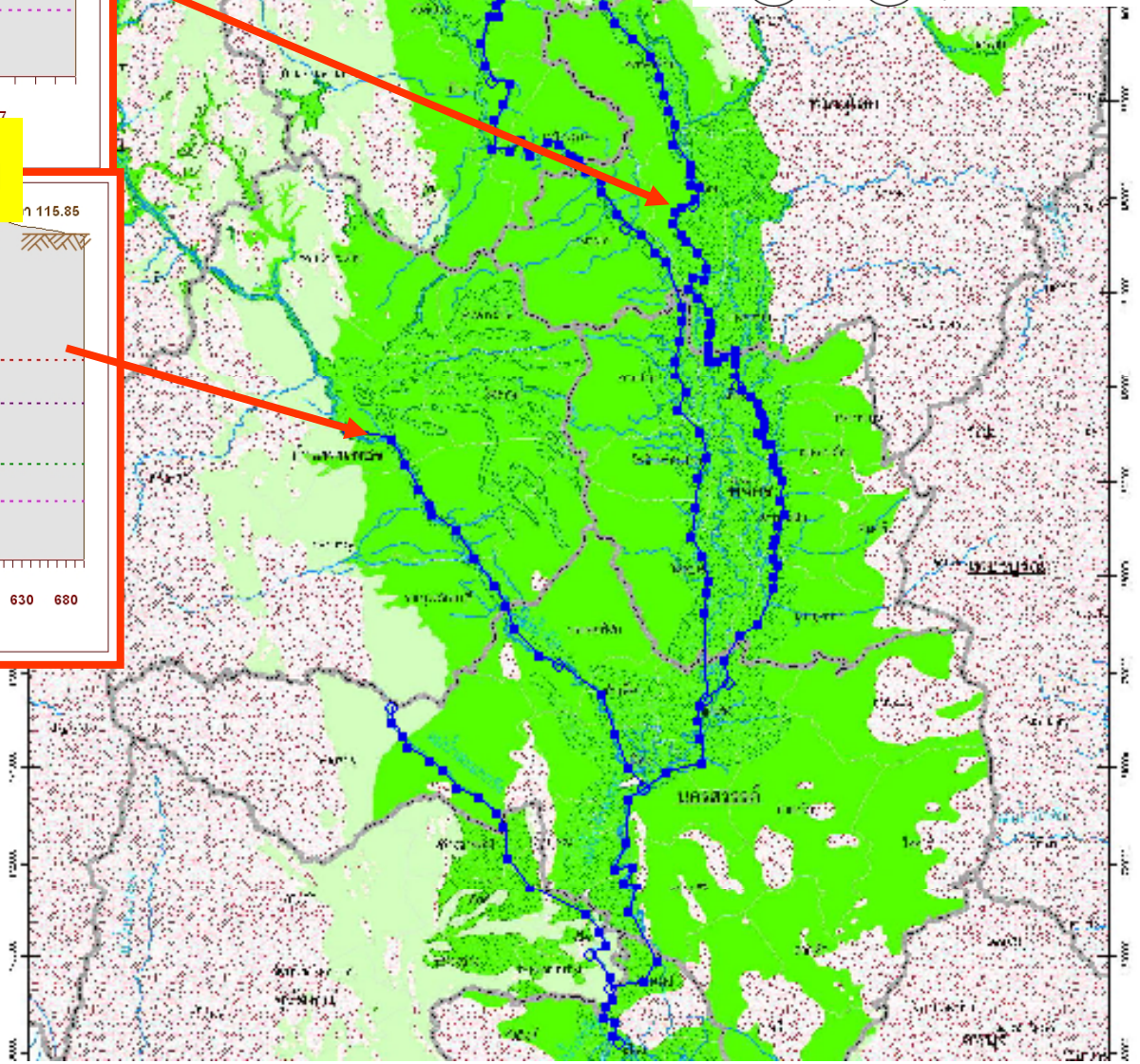
Top Soil Classified Zone





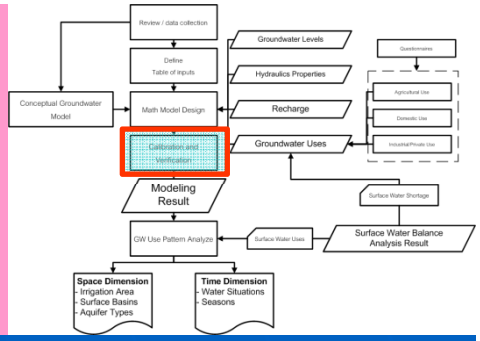
River cross-section





Main River Paths

Calibration and verification



1. Steady Calibration : 2003
2. Transient Calibration : 1993-2003
3. Model Verification :2003 - 2005

1993 -> Starting Head

1.Steady - > K

1993

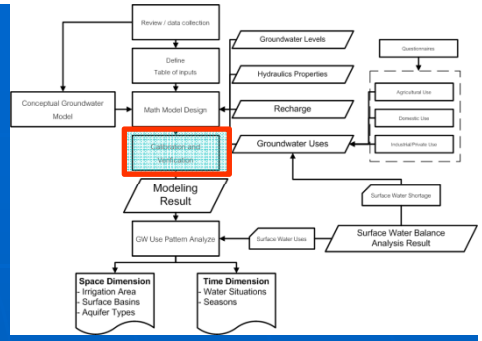
3.Transient -> Spec. Storage

2003

2005

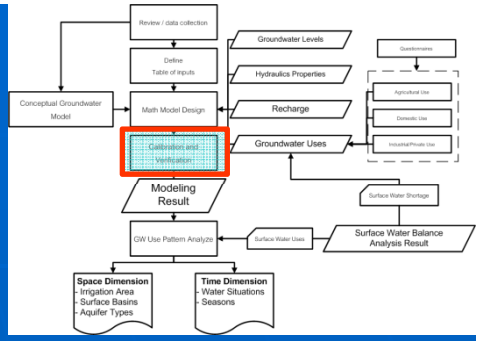
4.Verification

Calibration Target



- Steady State
  - Horizontal Hydraulic Conductivity/Transmissivity
  - Inflow
- Transient State
  - Specific Storage

Observed-Head Data Set

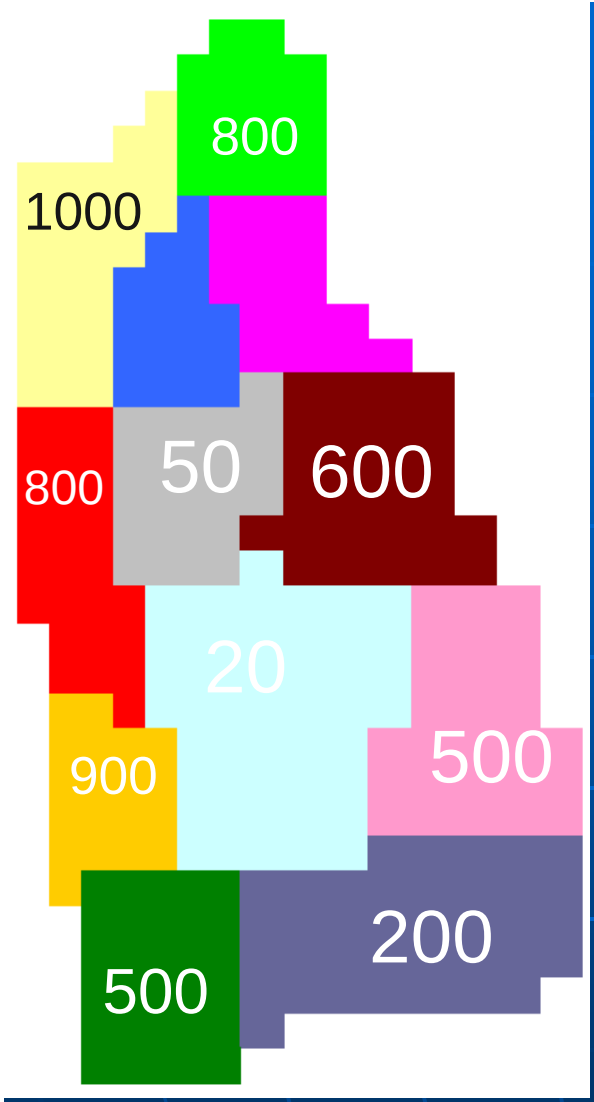


Steady : Dry season 2003

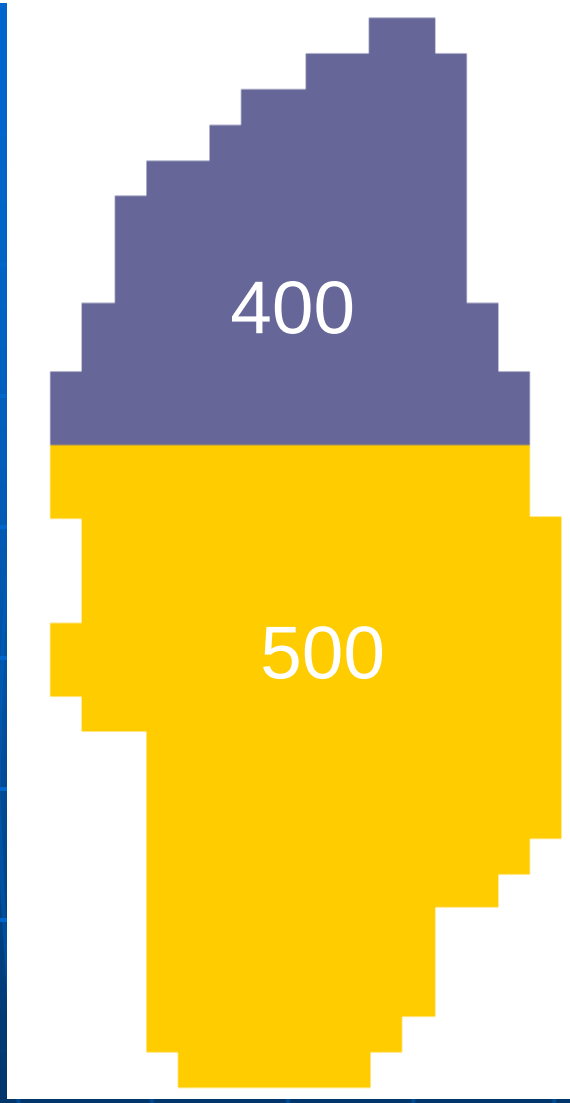
Transient :1993-2003

Unit : observed wells

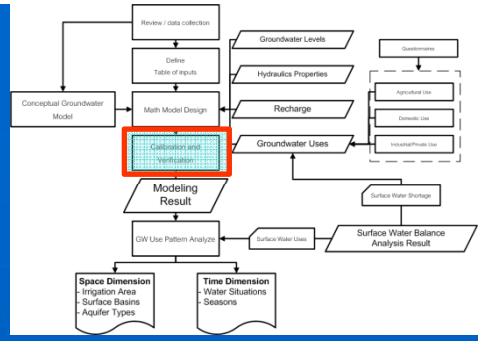
State	Layer1	Layer2	Total
Steady	93	13	106
Transient	135	10	139



L1



L2

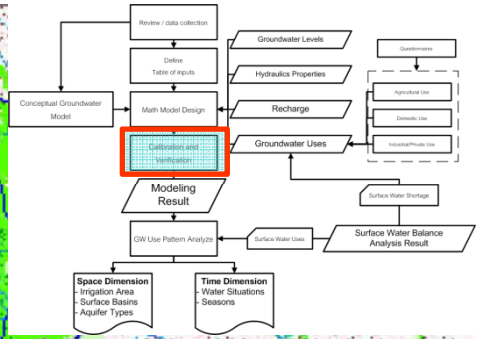


Transmissivity

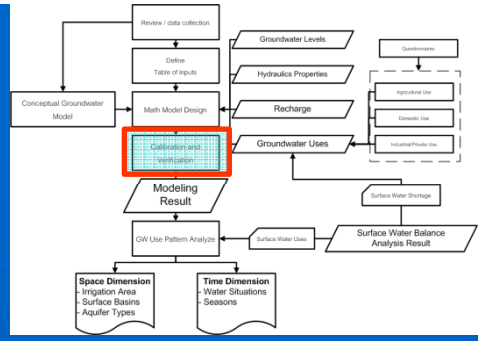
Unit : m^2/day

Transmissivity. Calibrated zones

Steady Verification: Layer1, 2003



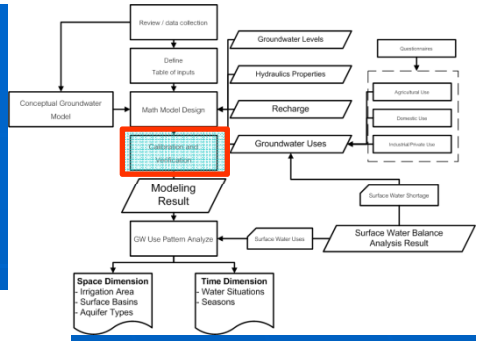
Calculation Error Summary (m.)

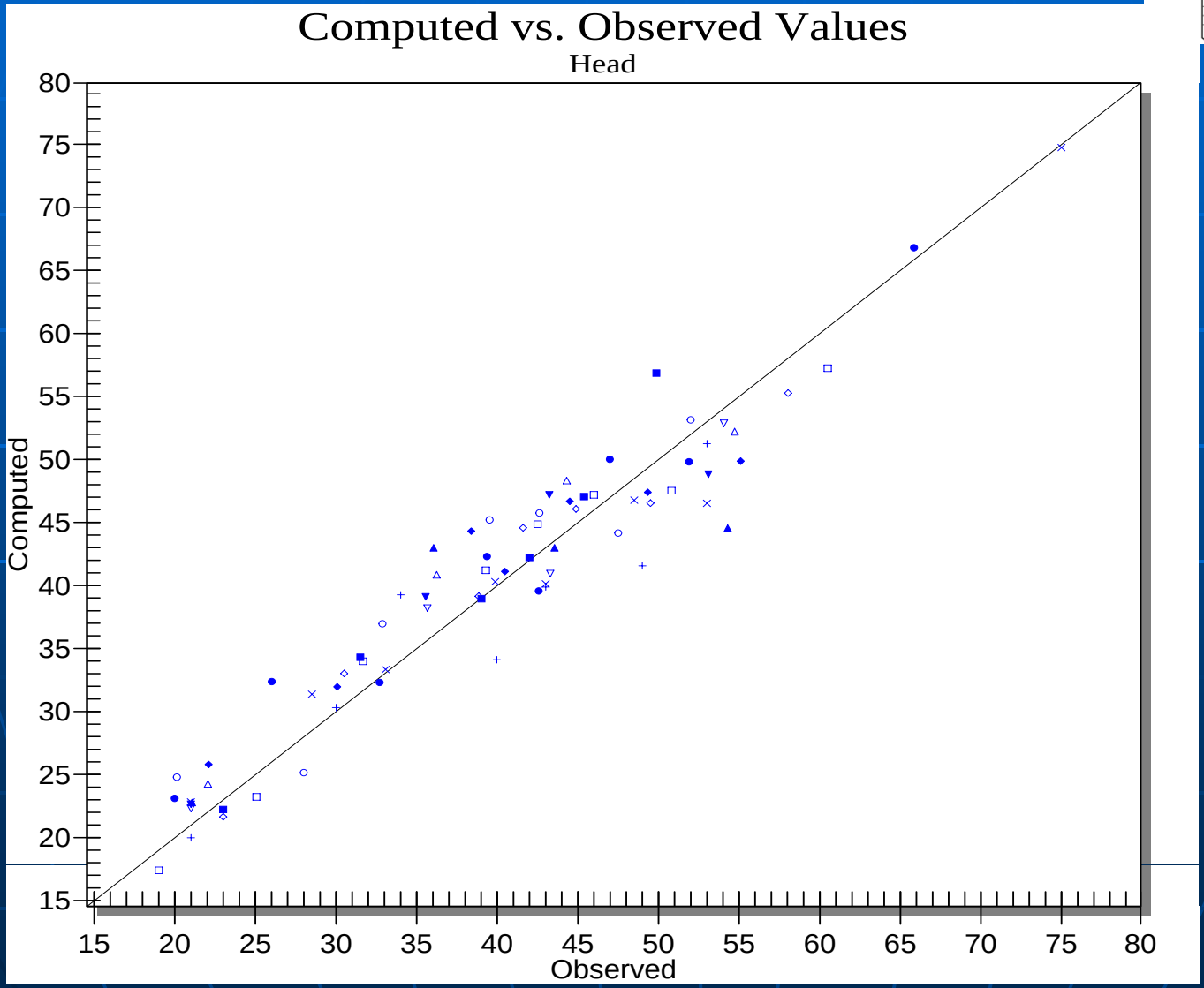


Transient State
1993-2003

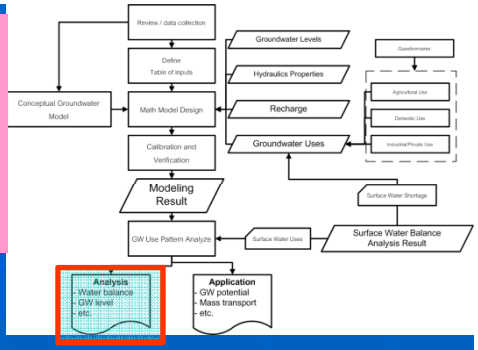
Layer	Mean	Abs. Mean	Root Mean Square
Layer1	4.51	6.08	7.60
Layer2	6.16	5.68	7.60

Steady State Error Summary Layer 1





Modeling Result



Groundwater Balance
(Dry season, 2003: Drought Year)

Pumpage
1,172,000

Recharge
1,056,000

Boundary
150,000

Boundary
200,000

Layer1

Pumpage
125,000

Recharge
32,000

Aquifer to Aquifer
66,000

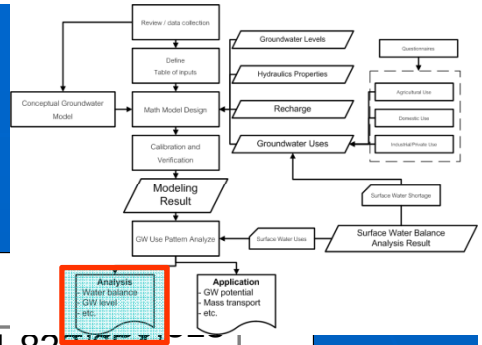
Boundary
3,000

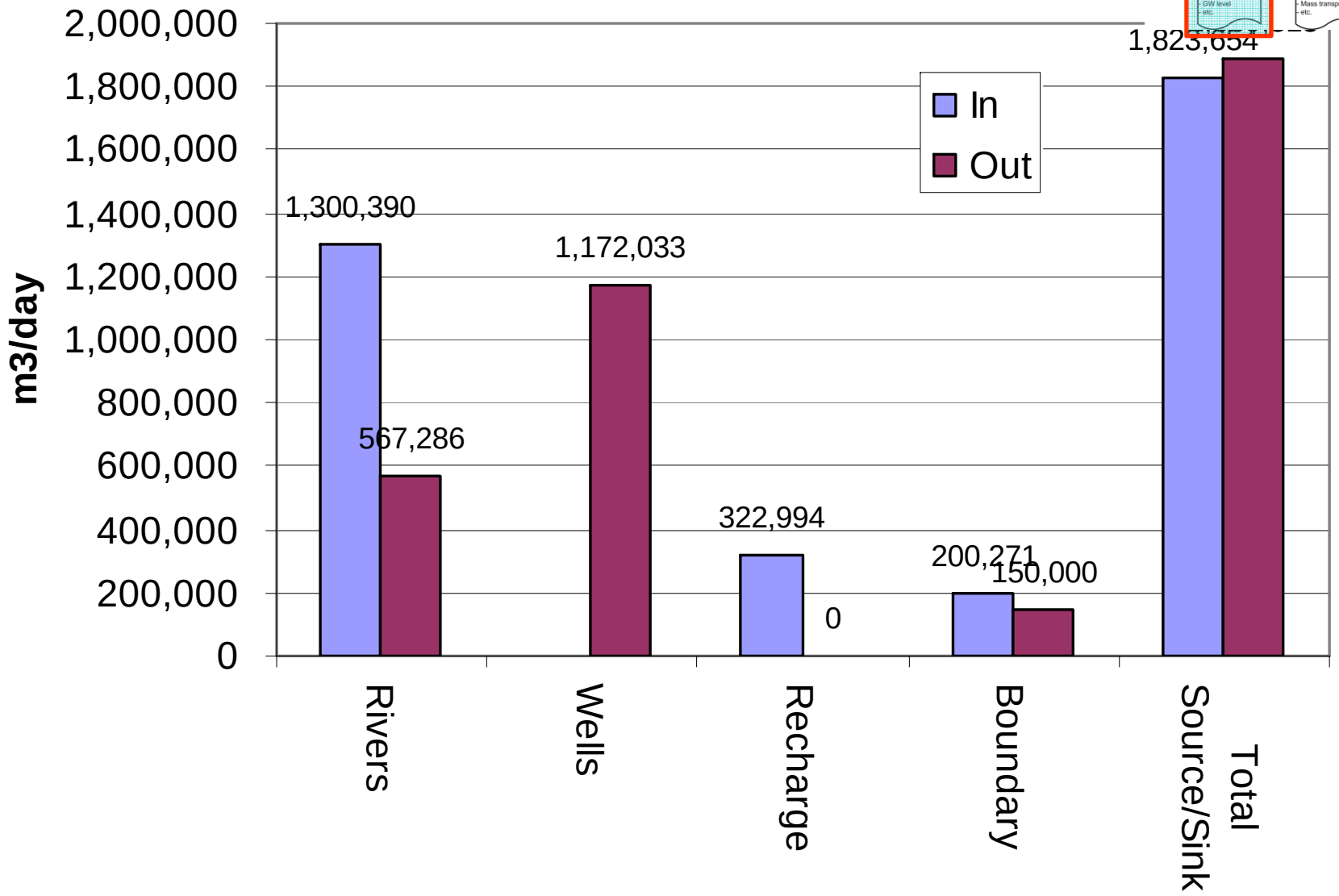
Boundary
162,000

Layer2

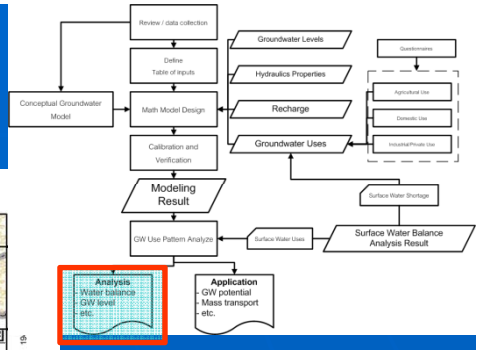
Unit : m^3/day

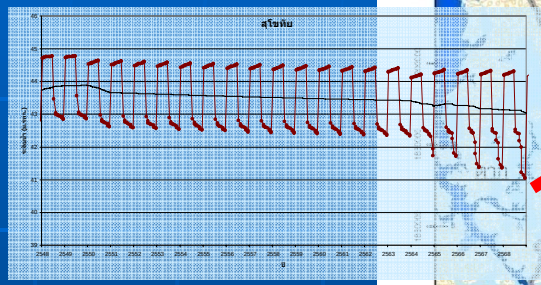
Layer1 Flow Interaction

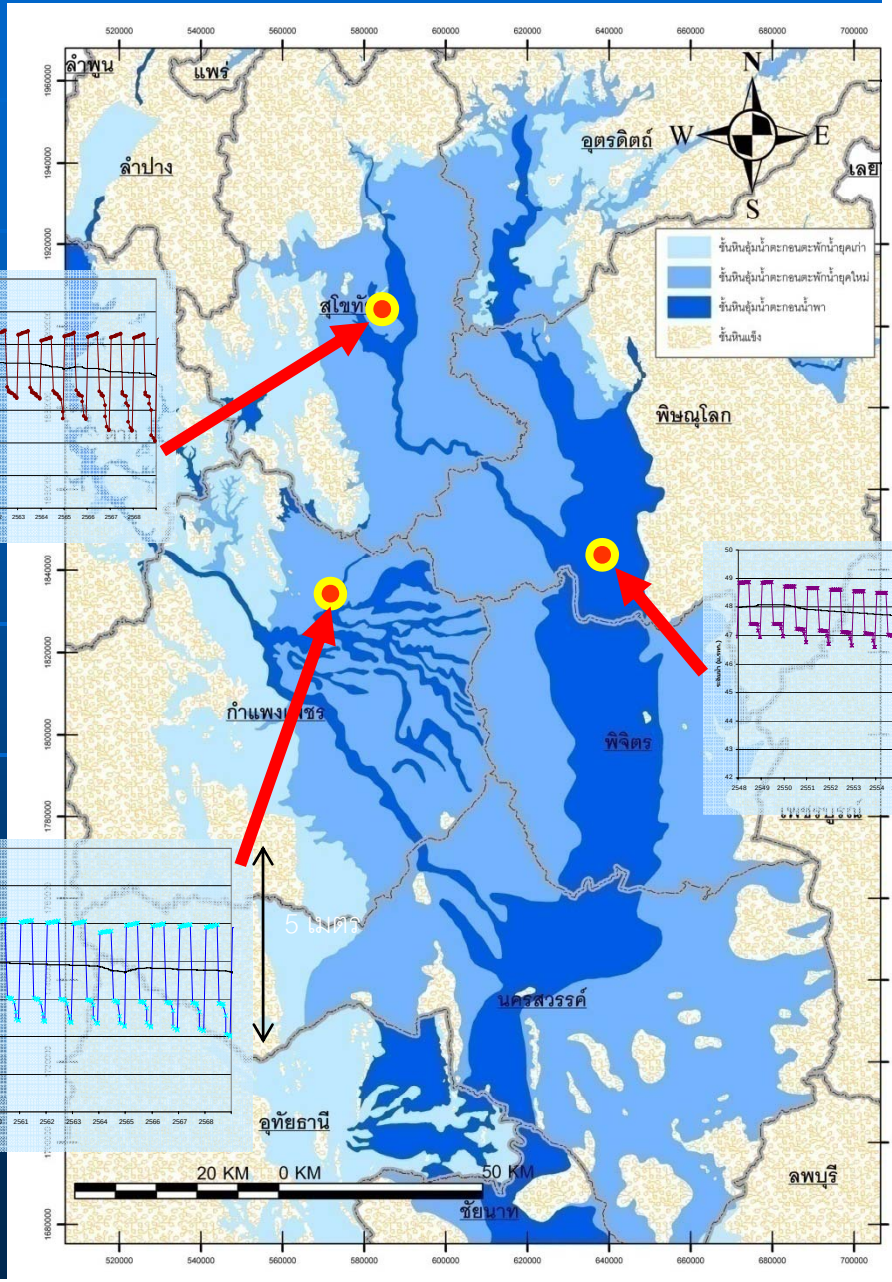


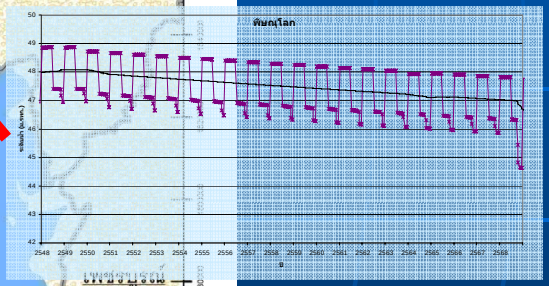


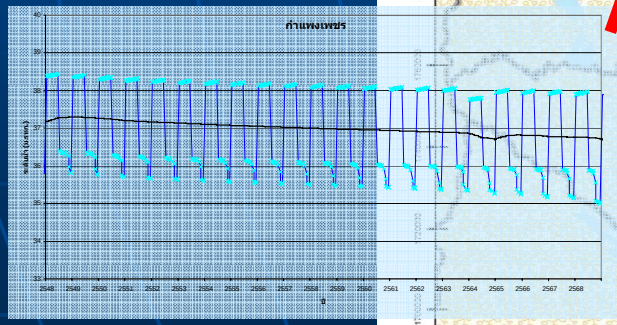
Groundwater Level



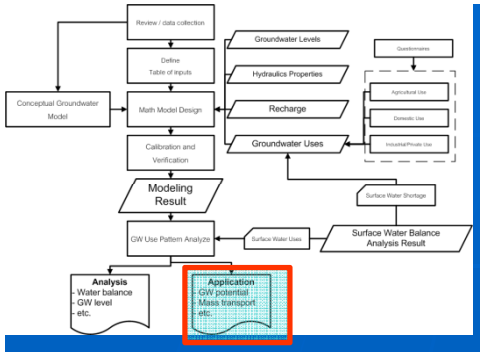






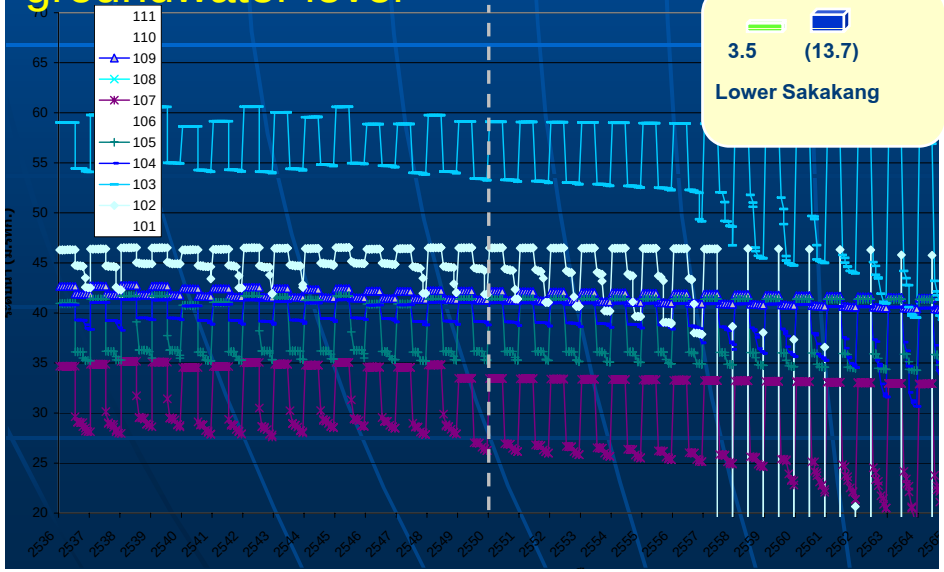


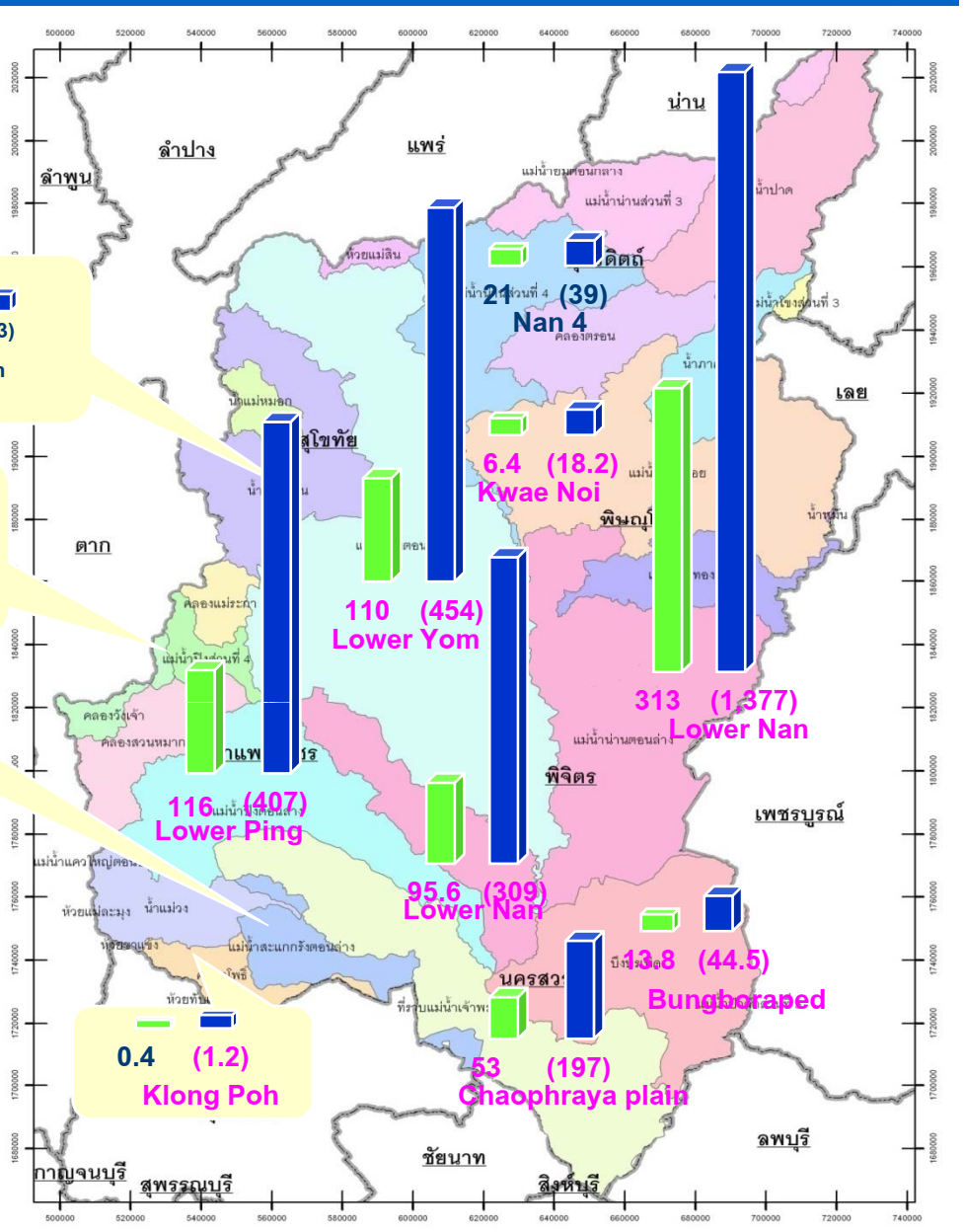
Analysis / Application



Groundwater potential investigation

Simulated future groundwater level

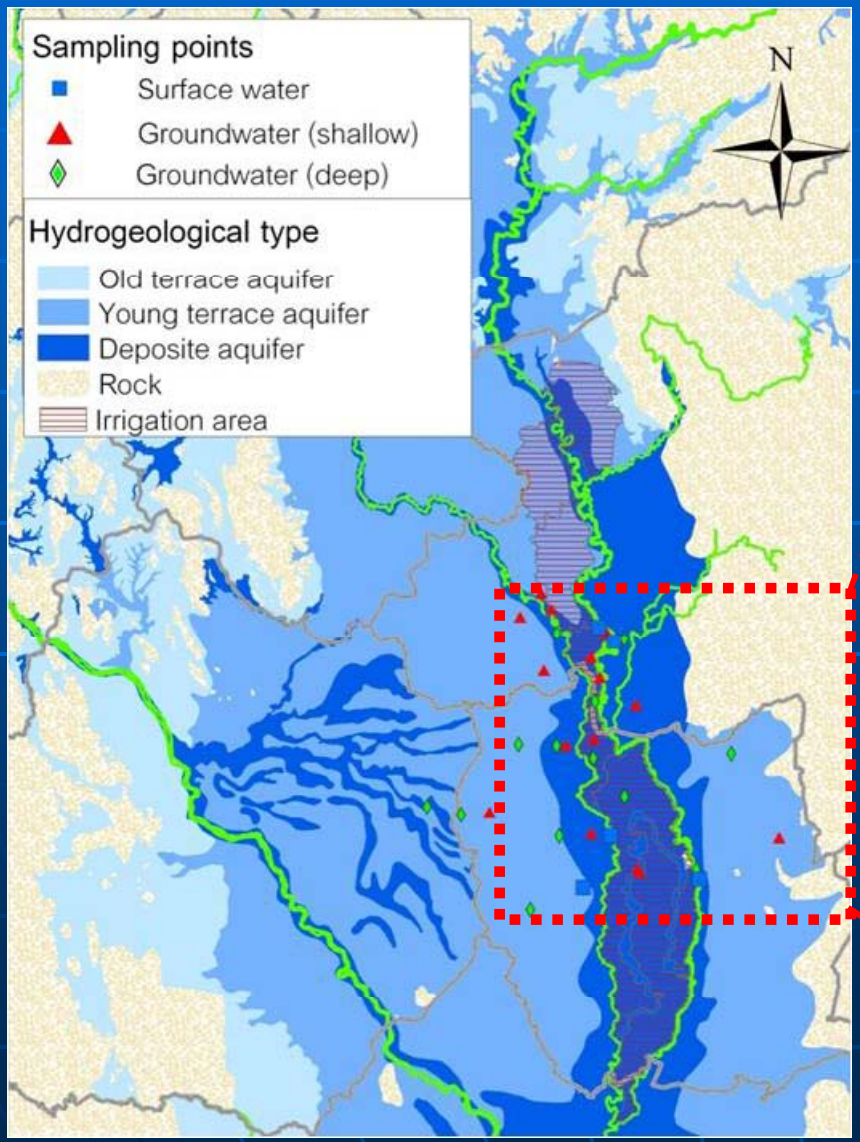




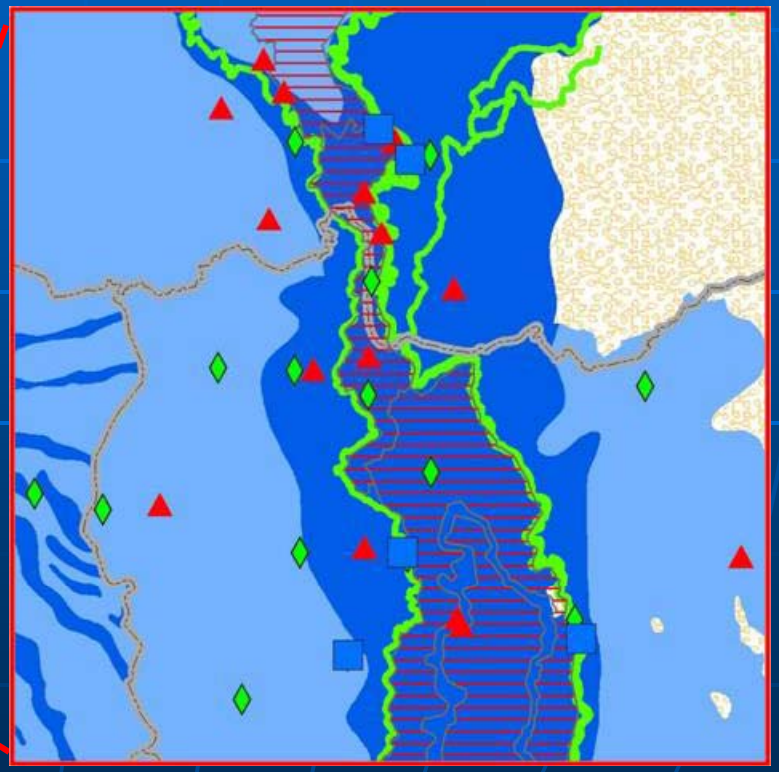
Part 3 Application cases

- Isotope Application
- Climate Change Impacts Assessment

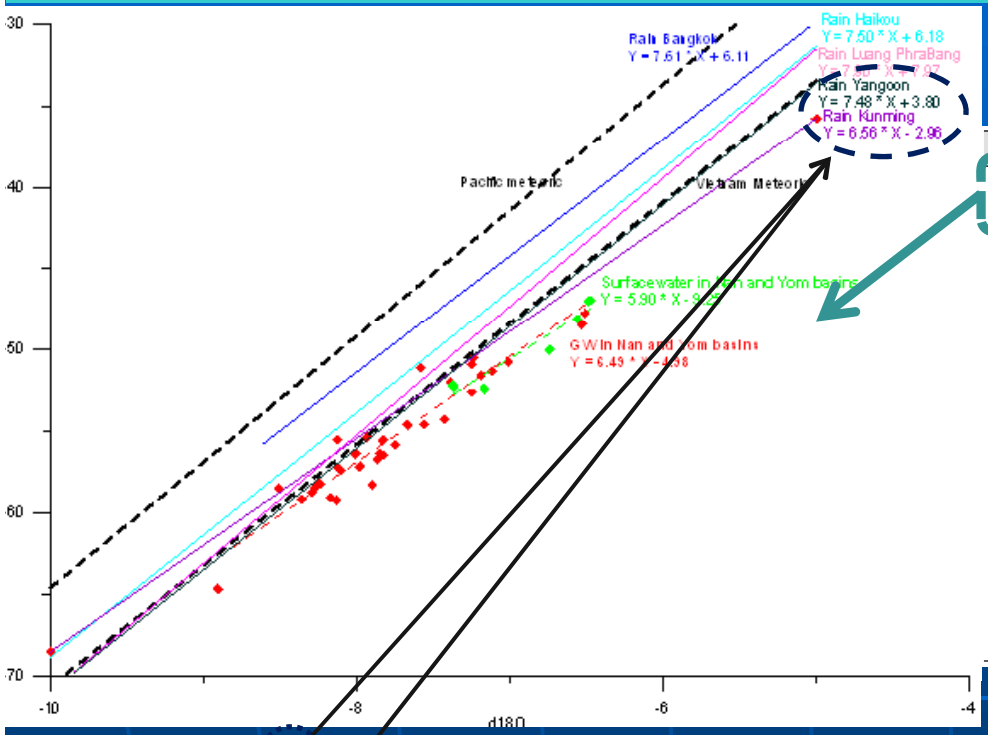
(1) Isotope Application



Location of samples

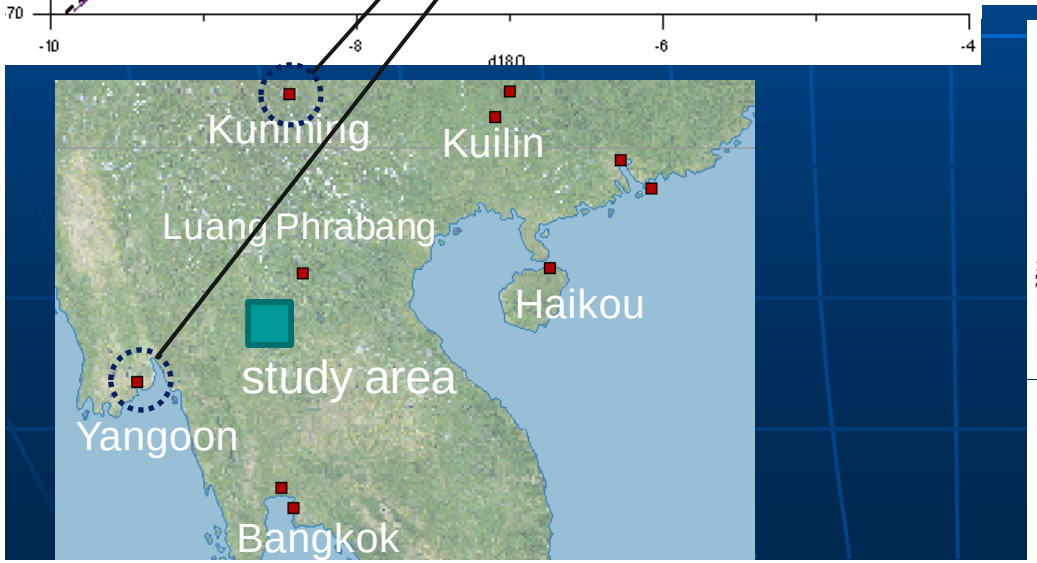


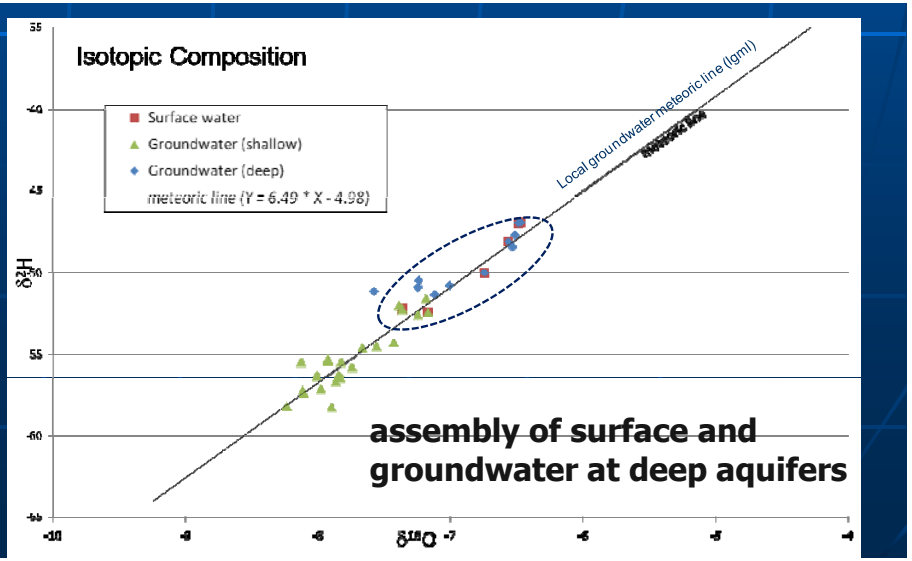
Isotope Application



Comparison of meteoric line.

Location	Meteoric line
Surface water: Northern Thailand (This study)	$\delta^2D = 5.90 \times \delta^{18}O - 9.25$
Groundwater: Northern Thailand (This study)	$\delta^2D = 6.49 \times \delta^{18}O - 4.98$
Bangkok, Thailand	$\delta^2D = 7.67 \times \delta^{18}O + 6.88$
Global	$d^2D = 8 \times \delta^{18}O + 10$
Northern hemisphere	$\delta^2D = (8.1 \pm 1) \times \delta^{18}O + (11 \pm 1)$
Maritime	$\delta^2D = 8 \times \delta^{18}O + 22$
Mediterranean/Middle East	$\delta^2D = (8 \pm 0.1) \times \delta^{18}O + (12.1 \pm 1.3)$
Tropical Island	$\delta^2D = (4.6 \pm 0.4) \times \delta^{18}O \ (12.1 \pm 1.3)$
North eastern Brazil	$\delta^2D = 6.4 \times \delta^{18}O + 5.5$
Northern Chile	$\delta^2D = 7.9 \times \delta^{18}O + 9.5$
Groundwater : Taipei, Taiwan	$\delta^2D = 8.2 \times \delta^{18}O + 11.6$
Groundwater : Shaanxi Province, China	$\delta^2D = 7.85 \times \delta^{18}O + 12.94$
Groundwater : Pacific Ocean, Japan, East China, South Korea	$\delta^2D = 7.73 \times \delta^{18}O + 12.7$
Groundwater : NAM ĐỊNH, Vietnam	$\delta^2D = 7.44 \times \delta^{18}O + 3.755$





Isotope Application

- **Isotopic compositions of surface and groundwater are similarly in dry season.**
- **Precipitation in the Yom and Nan river basins are not related to precipitation in Bangkok but it may be from the same sources as of Kunming's and Yangoon's.**
- **Seasonal change in groundwater and surface water fingerprints requires the second set of samples was collected in rainy season during July to August to compare seasonal effects on groundwater recharge.**

(2) Climate Change Impacts Assessment

Condition of simulate groundwater

Periods

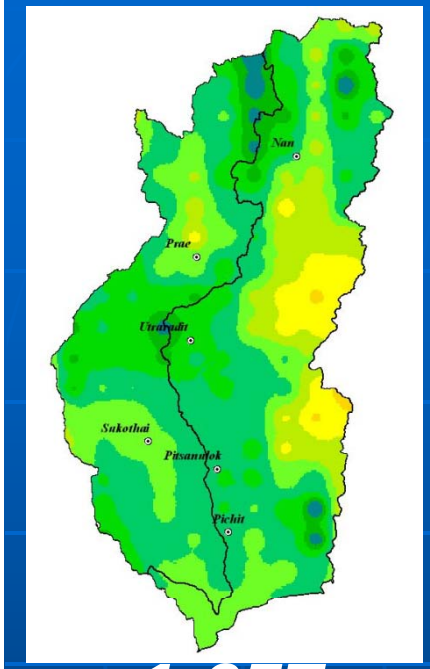
Past:	1982 – 2005	(Real Data)
Near Future:	2015 – 2039	Downscaled MRI GCM
Future:	2075 – 2099	Downscaled MRI GCM

Seasonal

Wet (May - October) Dry (November - April)

Water Year

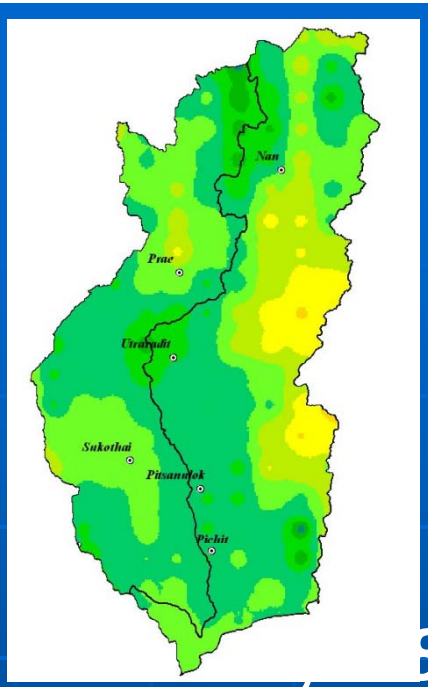
Wet, Normal, Dry and Severe Year depend on the actual storage of Sirikit Dam (considered the irrigation water demand from paddy only)



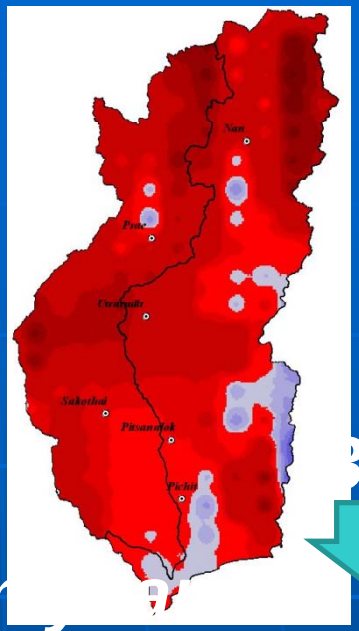
1,657 mm/

MRI-Present

(1979-2006)



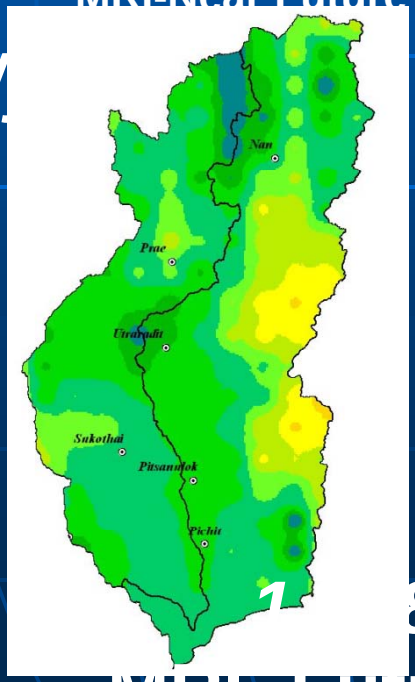
MRI-Near Future



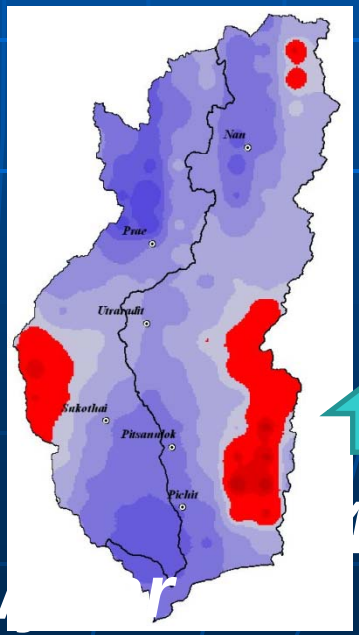
%Diff_Near Future-Present

%Diff_Present&NearFuture
20.00 - 50.00
15.00 - 20.00
10.00 - 15.00
8.00 - 10.00
6.00 - 8.00
4.00 - 6.00
2.00 - 4.00
1.00 - 2.00
-1.00 - 1.00
-2.00 - -1.00
-4.00 - -2.00
-6.00 - -4.00
-8.00 - -6.00
-10.00- -8.00
-15.00 - -10.00
-20.00 - -15.00
-30.00 - -20.00

Rainfall, mm/year
200 - 600
601 - 800
801 - 1000
1001 - 1200
1201 - 1400
1401 - 1600
1601 - 1800
1801 - 2000
2001 - 2200
2201 - 2800
2801 - 3000
3001 - 5000
No Data

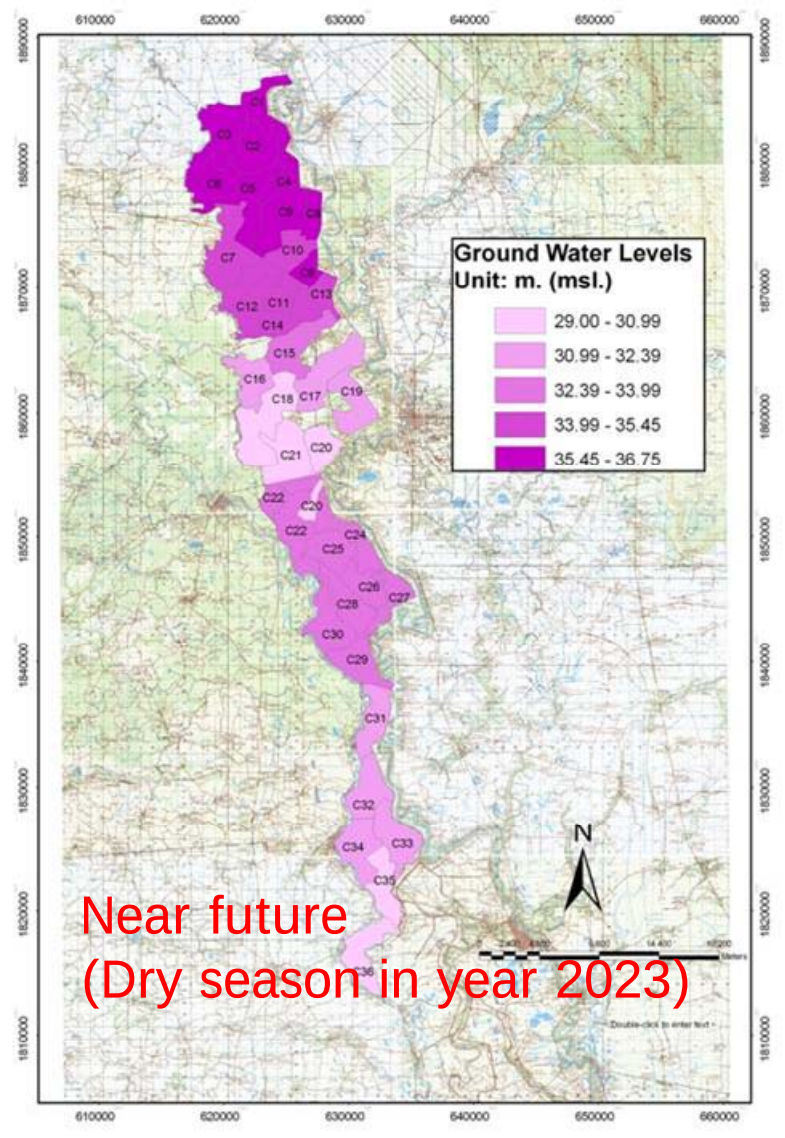


MRI- Future

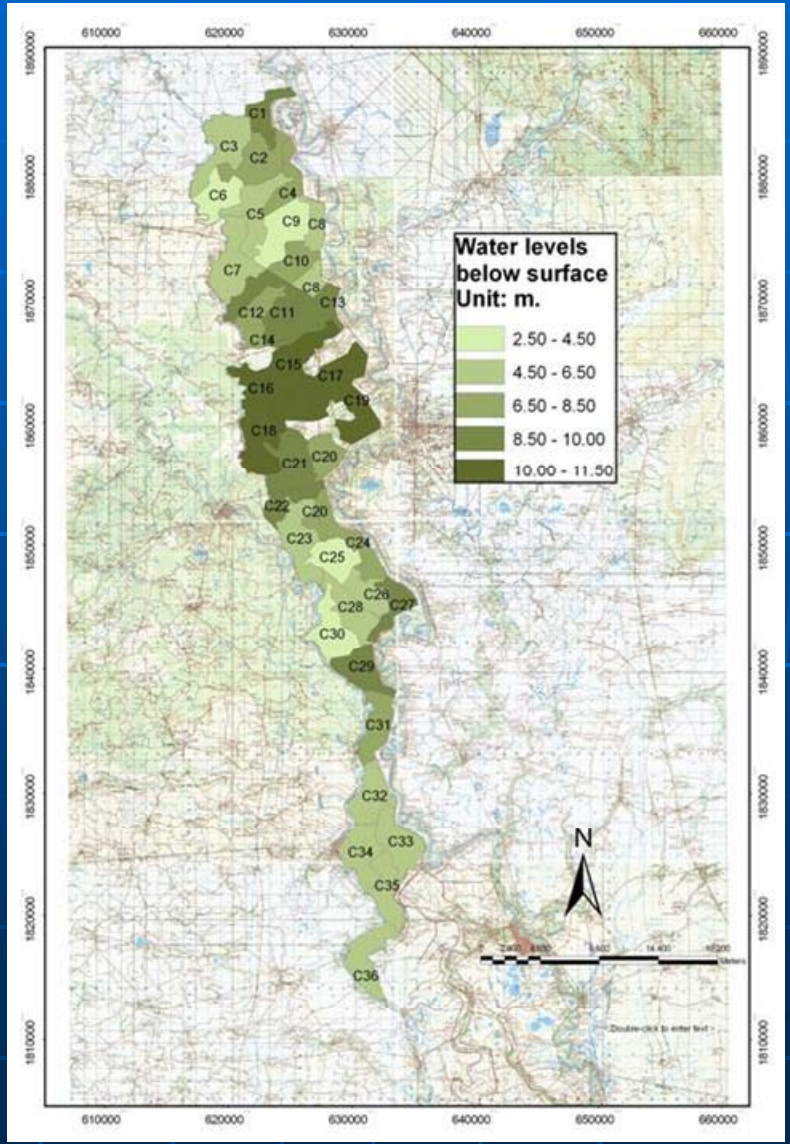


%Diff_Future-Present

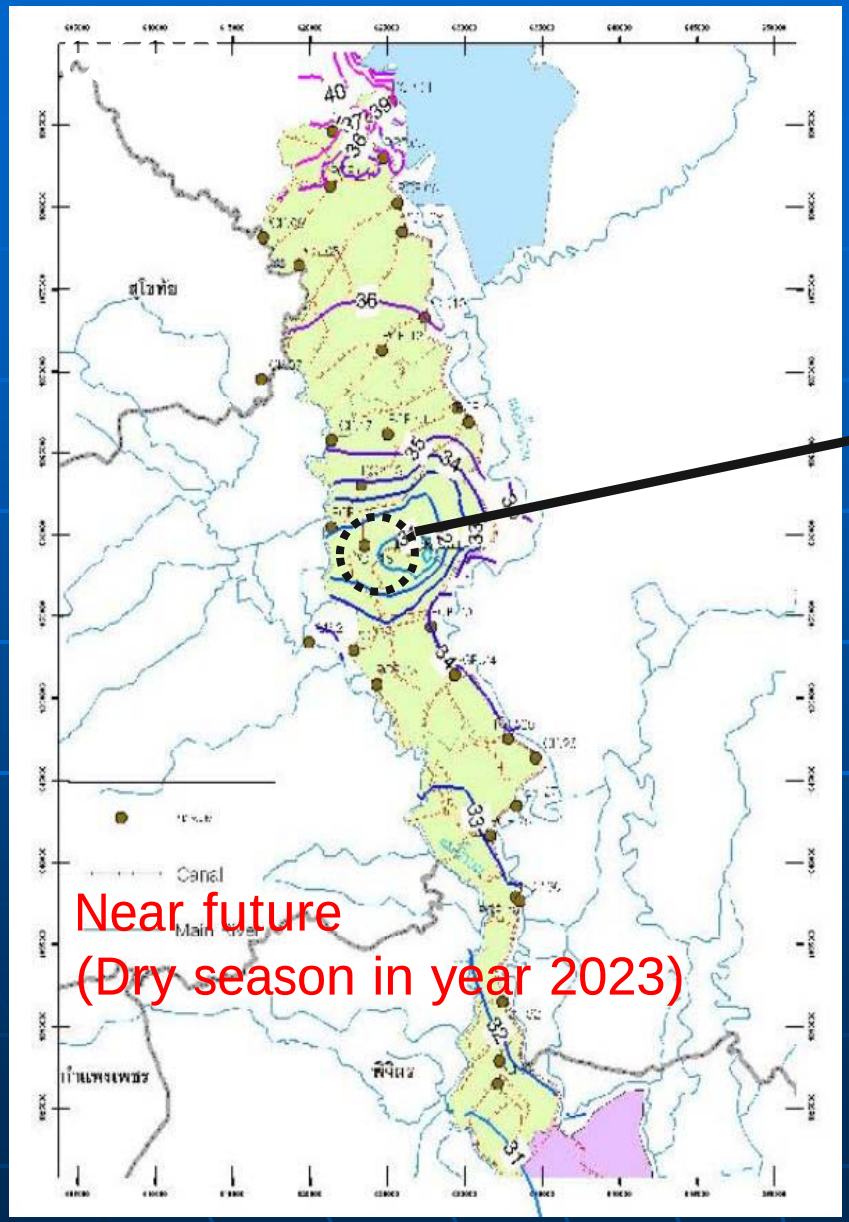
Water level

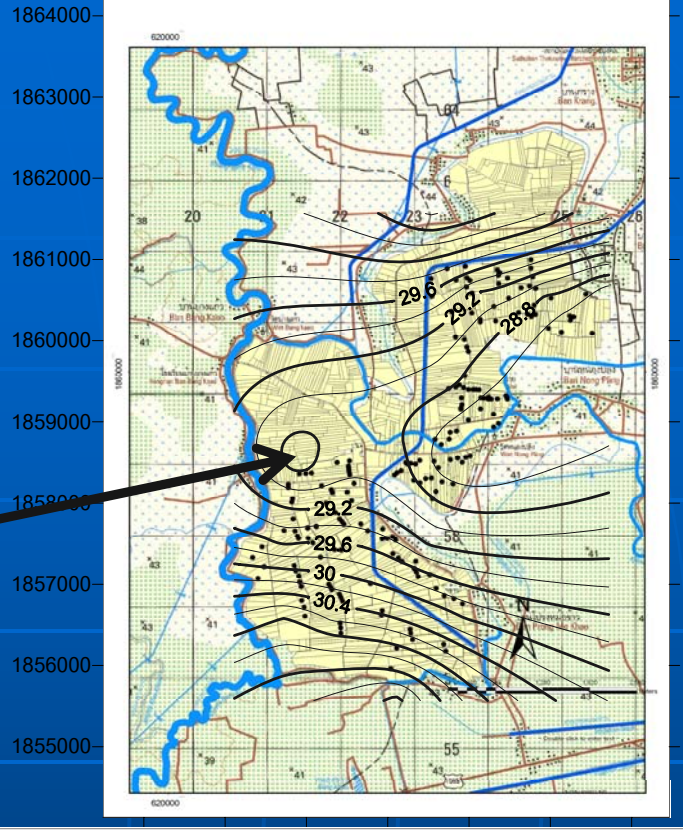


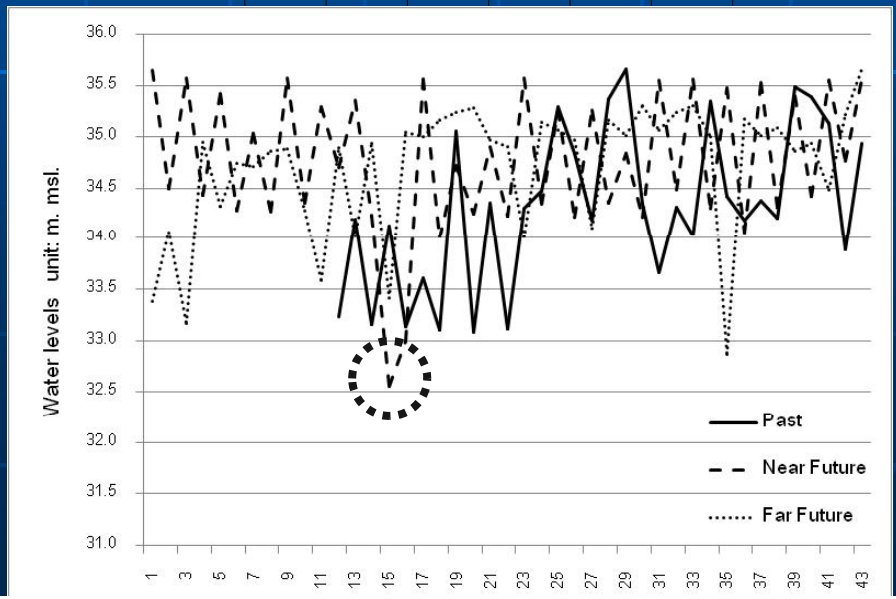
Area below ground surface over 10 m.



Location of critical



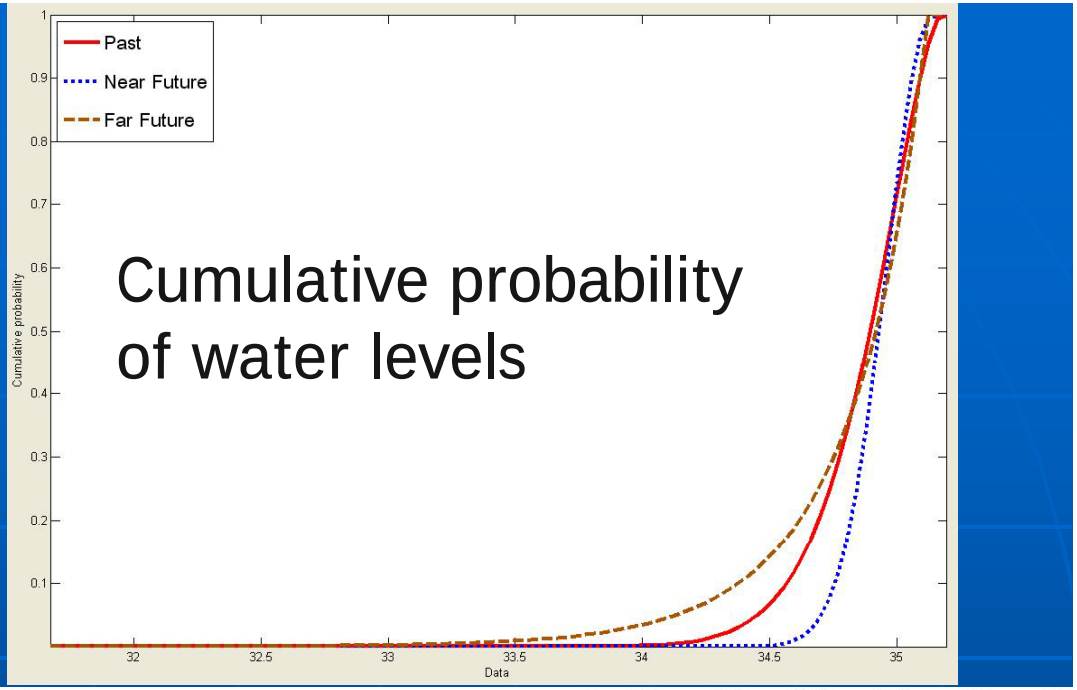


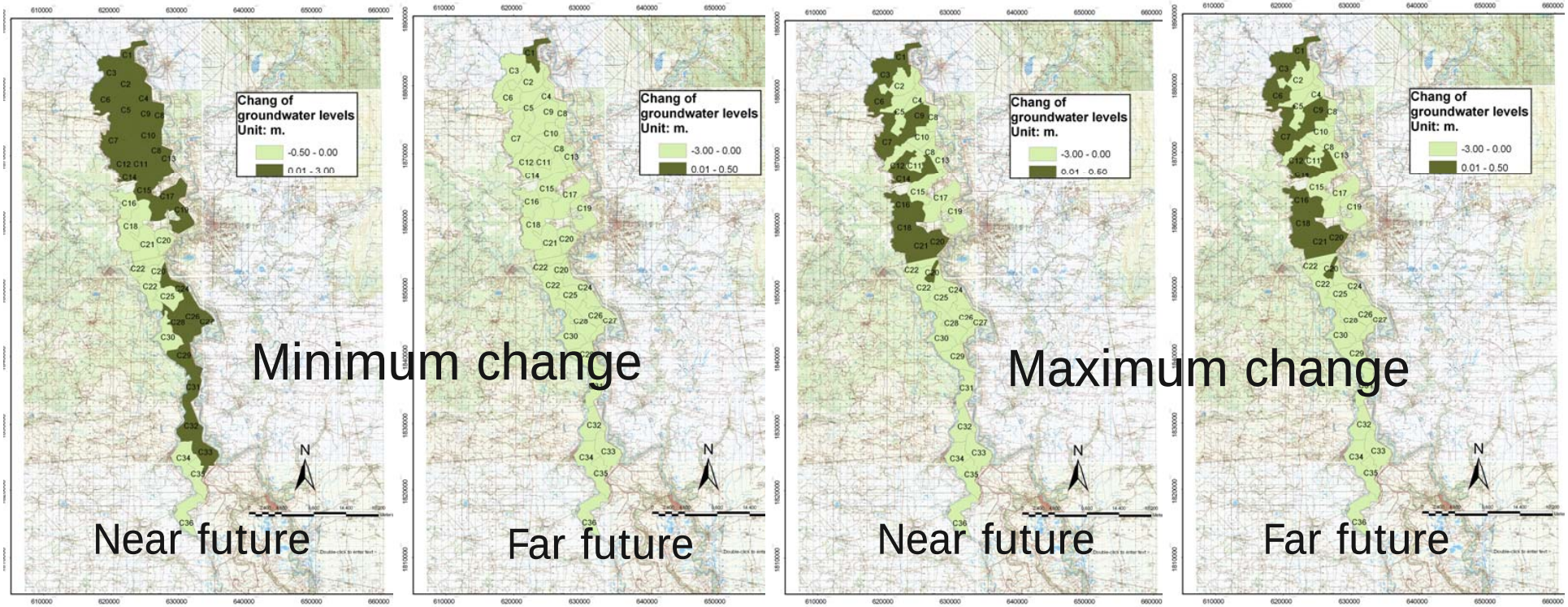


Change of water levels

Change (-)

Change (+)

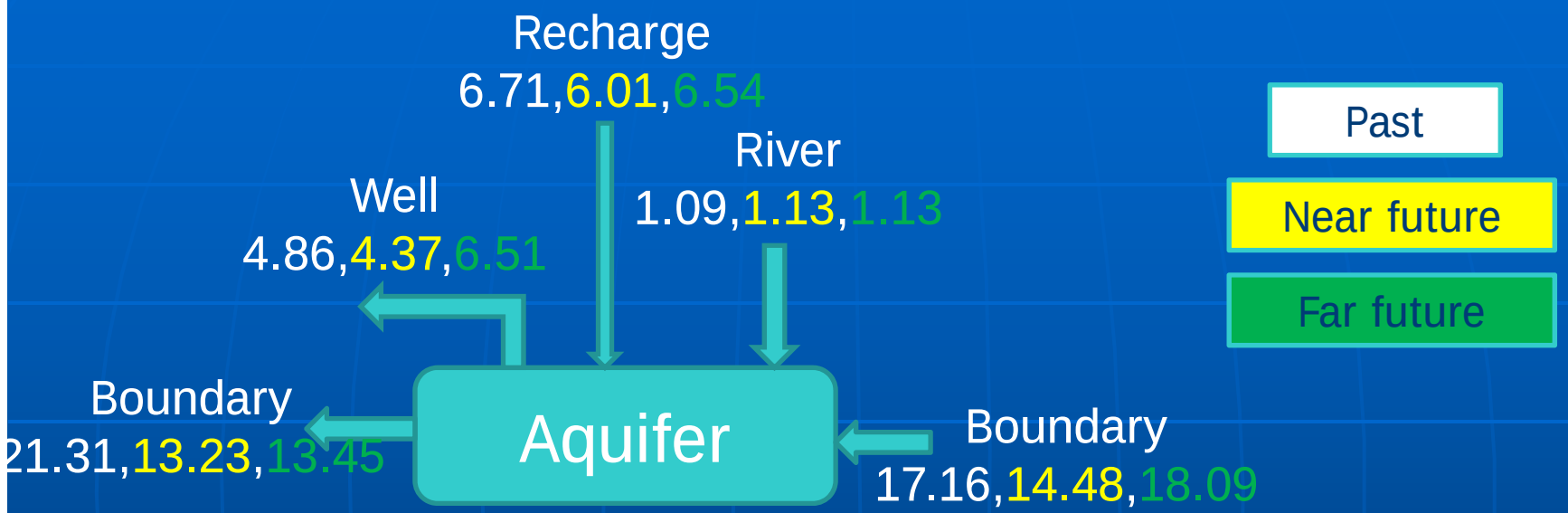




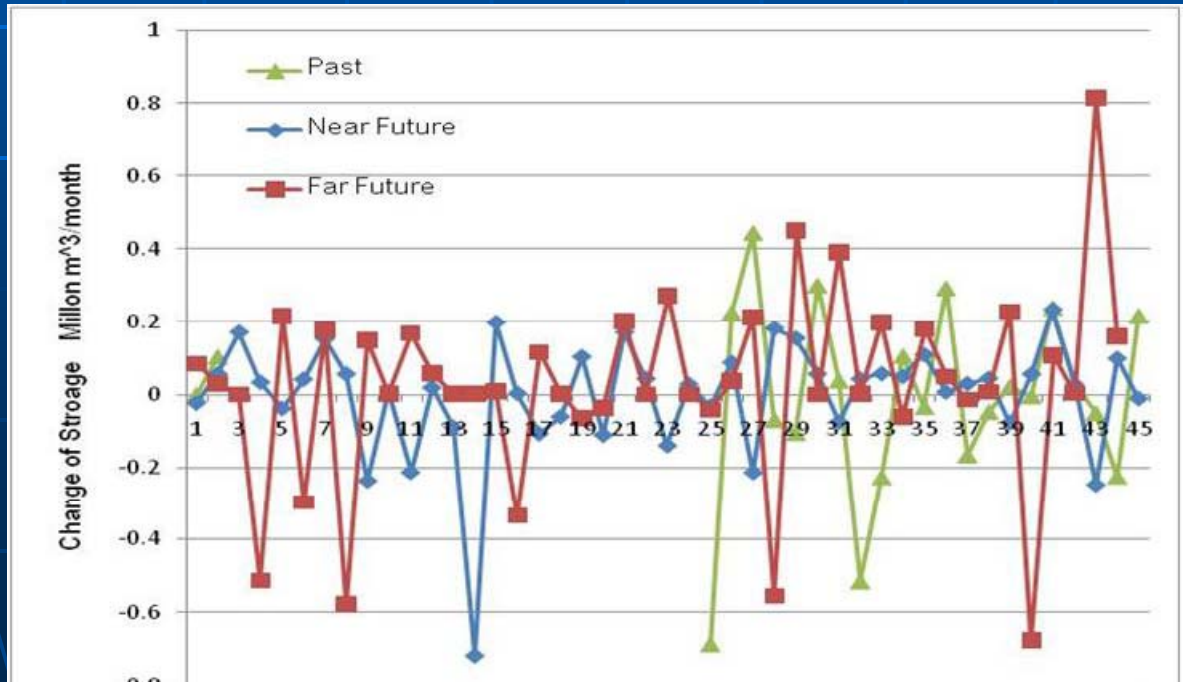
Modeling conclusion

Groundwater flow	Pumpage (millon m^3/month)					
	Past		Near Future		Far Future	
	Flow in	Flow out	Flow in	Flow out	Flow in	Flow out
Groundwater Basin	17.16	21.37	14.48	13.23	18.09	13.45
River	1.09	0.05	1.13	0.03	1.13	0.03
Wells	-	4.86	-	4.37	-	6.51
Recharge	6.71	-	6.01	-	6.54	-
Total (rainy)	24.96	26.29	21.62	17.64	25.76	19.99
Groundwater Basin	15.82	17.95	18.99	17.82	26.11	25.68
River	1.13	0.05	1.06	0.13	1.09	0.09
Wells	-	7.92	-	8.95	-	8.24
Recharge	0.940	-	1.738	-	2.114	-
Total(dry)	17.89	25.92	21.78	26.90	29.31	34.00

Groundwater Balance



Unit : million m^3/month



Climate Change Impacts Assessment

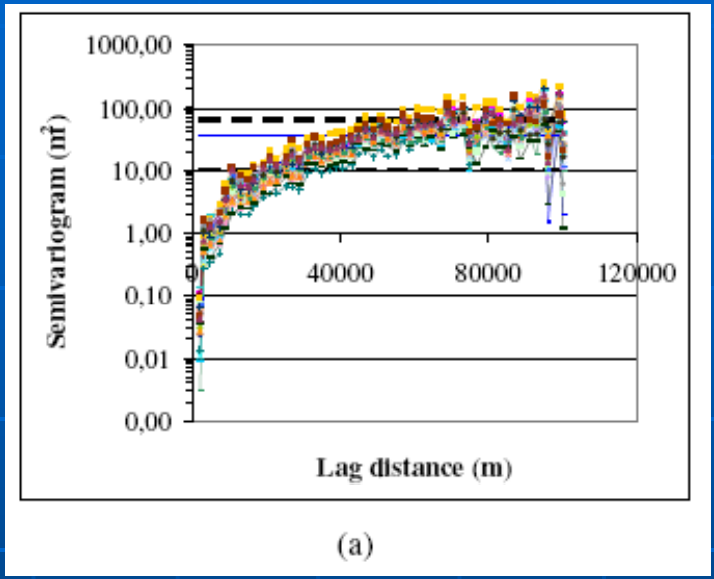
- Trend of rainfall in dry season increase (near future & far future) may not effect in groundwater use and water levels.
- Groundwater levels below 10 m in critical year in zone C15, C16, C17, C18 and C19.
- Trend of change of storage in groundwater both of near future and far future will increase.

Part 4 Future trends

- New technologies
- New Area
- New Applications

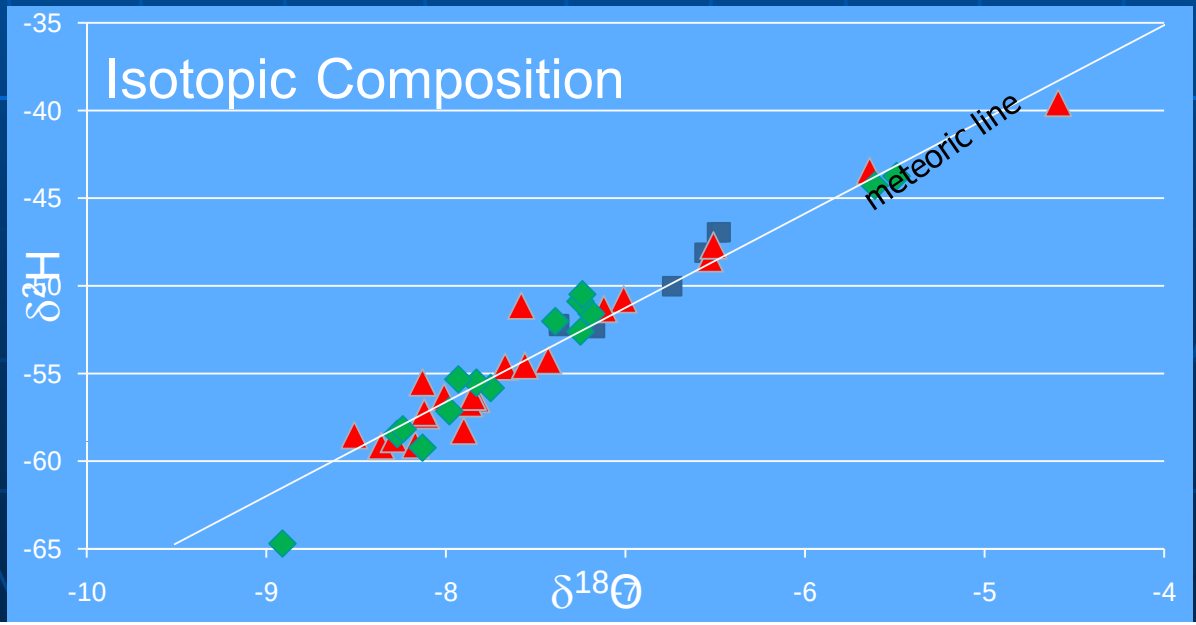
New technologies

- Stochastic



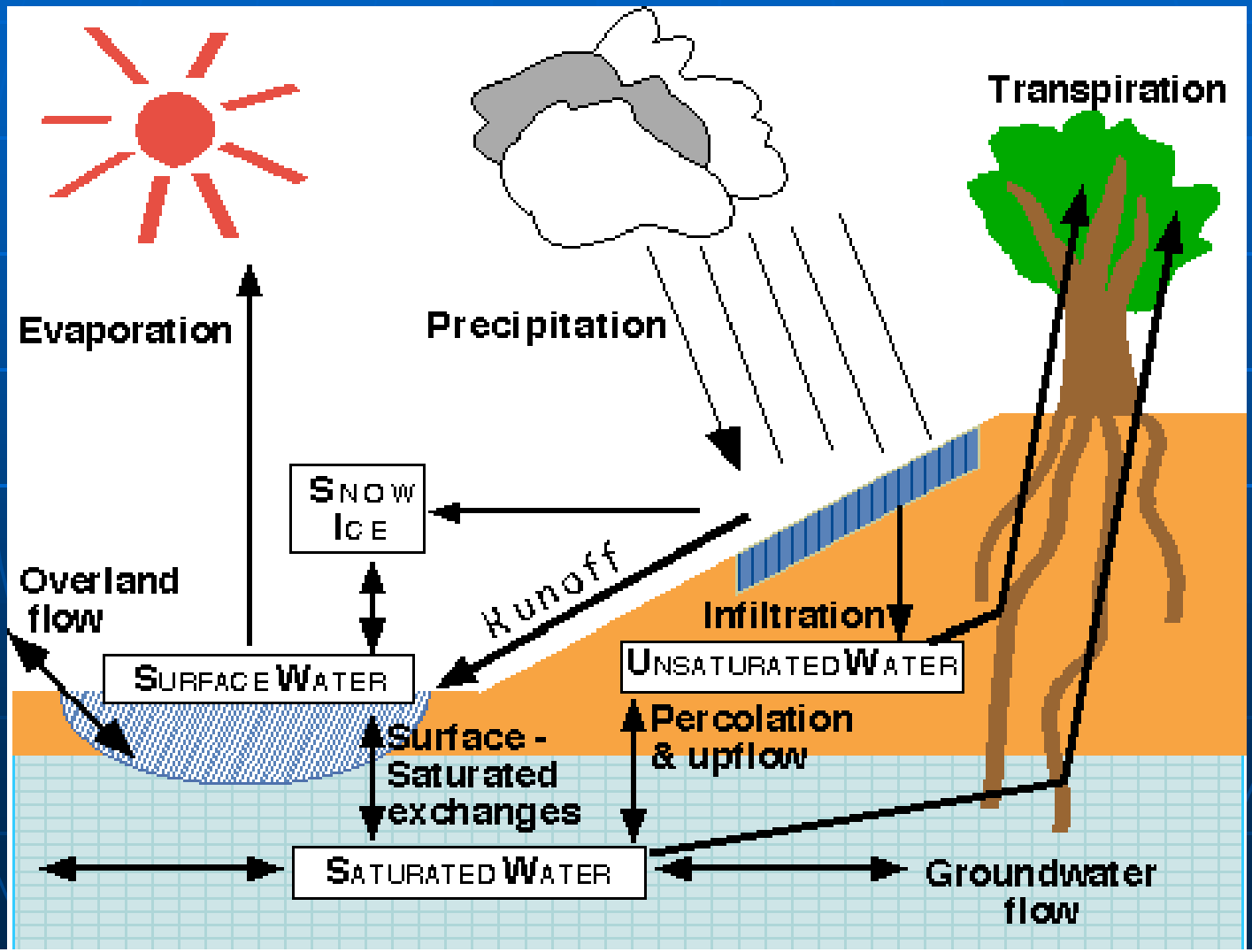
Simulated variograms of groundwater table

- Isotope



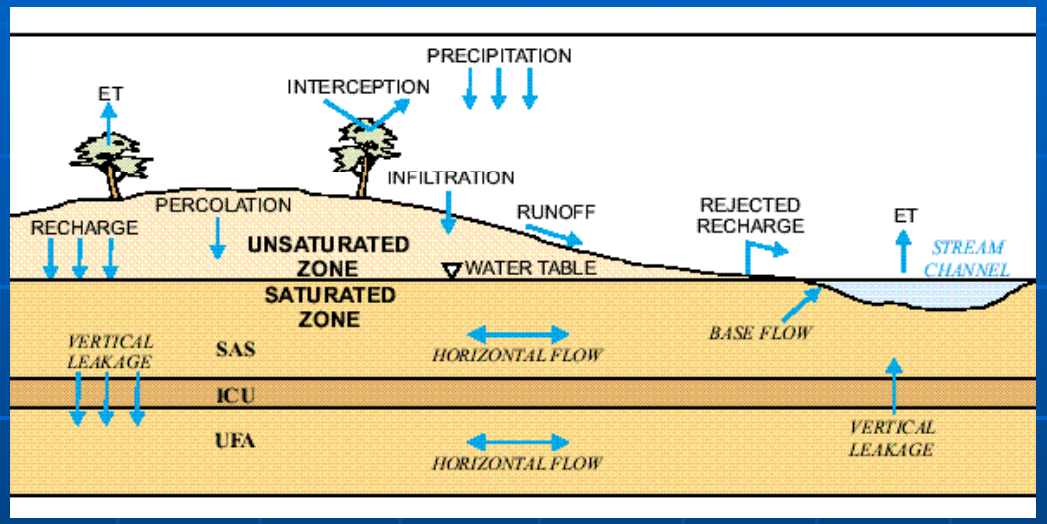
New Area

- Unsaturated zone



New Applications

- Integrated with surface water



- Contamination issues

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Website

www.watercu.eng.chula.ac.th

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