Integrated surface-groundwater analysis considering groundwater use in Pyoseon region, Jeju island, Korea

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Content

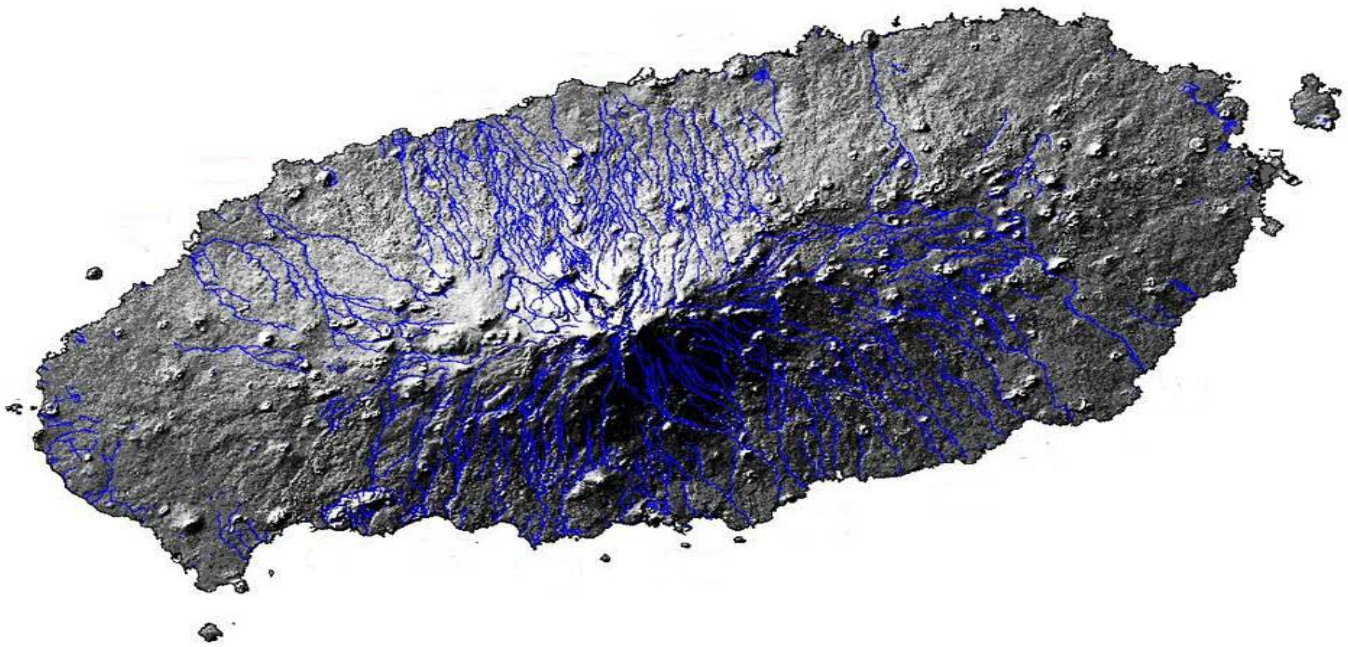
- Background & Purpose
- Integrated SWAT-MODFLOW
- Application to Pyoseon watershed
- Results of simulation
- Conclusion

Background

- Jeju island is the region where the highest rainfall occurs in Korea
- The average annual rainfall of the island is about 1,975mm which is the 1.5 times larger than the mean value of 1,283mm for the Korean mainland (Won, 2004).
- However, the island has suffered from water shortages mainly due to lacking large perennial rivers and streams
- Main water resources is groundwater

BACKGROUND

- The streams in jeju island



Surface water condition

(a) upstream

(b) midstream

(c) downstream

Most of streams in upper region of watersheds show dried characteristics by means of large portion of recharge which goes to the deep aquifer
: no baseflow in the upper area of watershed (losing stream).

On the contrary, groundwater discharge is more and more increasing as approaching to the downstream near to sea.

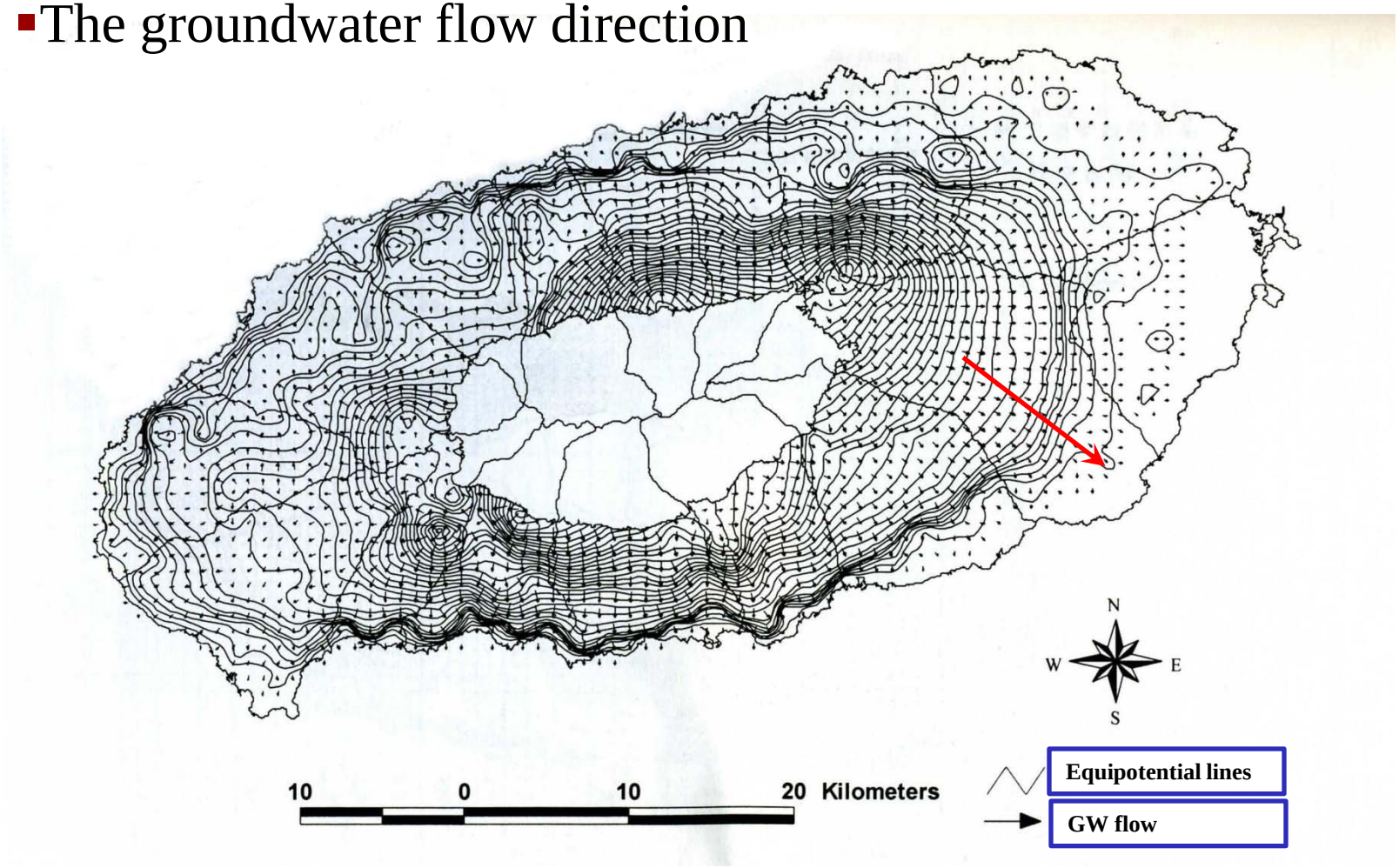
Hydrogeology

Jeju island is mainly consisted of volcanic rocks including highly permeable basalts.

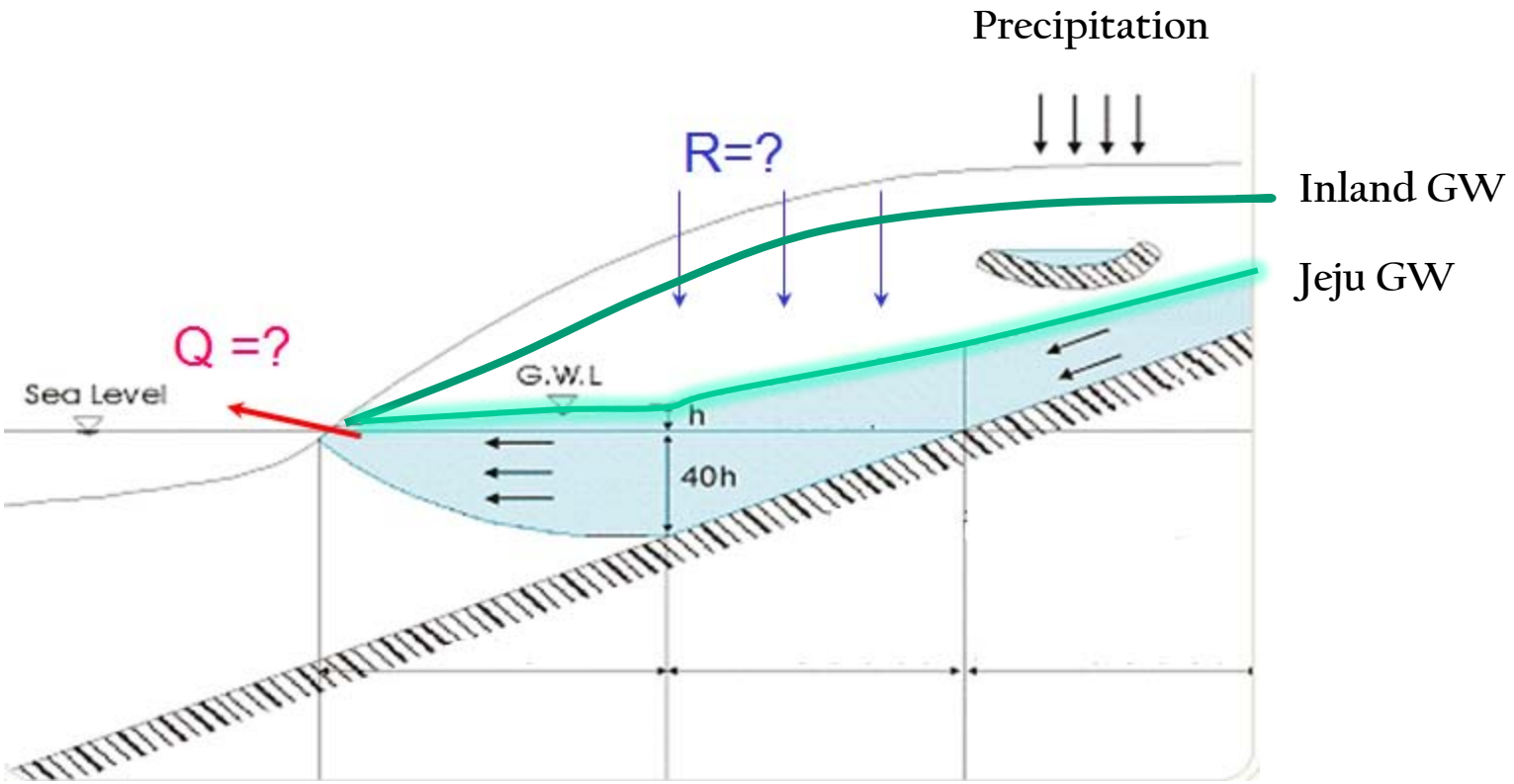
Mean transmissivity of permeable formations
: 2,008 m^2/day (K-Water, 2003)

A number of production wells have been installed.

- The groundwater flow direction



- Deep recharge and discharge



- **Surface water measurements : Very hard**

Overview

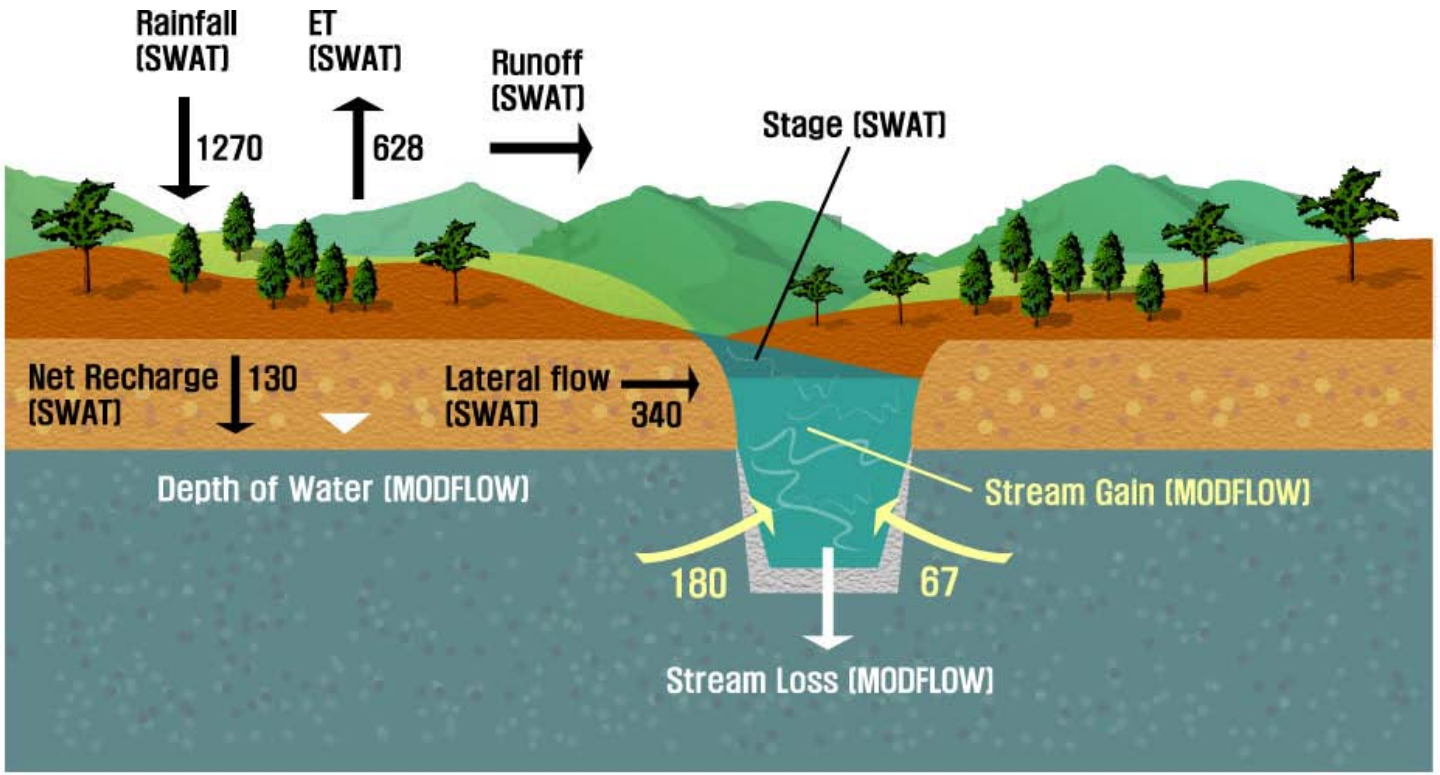
- ✓ SWAT(Arnold, 1993; Arnold, 1995) is widely used long term runoff model.
- ✓ SWAT' groundwater model is a semi-distributed type and thus the distributed parameters such as hydraulic conductivity and output (groundwater level) distributions could not be represented.
- ✓ The conventional groundwater flow analysis performed by MODFLOW(McDonald and Harbaugh, 1988) often overlooks the accuracy of the recharge rates.

Integrated SWAT-MODFLOW model

- ✓ Development of subroutine for exchanging characteristics between HRU(Hydrologic Response Unit) of SWAT and CELL of MODFLOW
- ✓ On the basis of these stable platforms, the groundwater module in SWAT is replaced by MODFLOW
- ✓ Then, SWAT-MODFLOW is capable of simulating spatial-temporal GW recharge and stream-aquifer interactions by RIVER package in MODFLOW

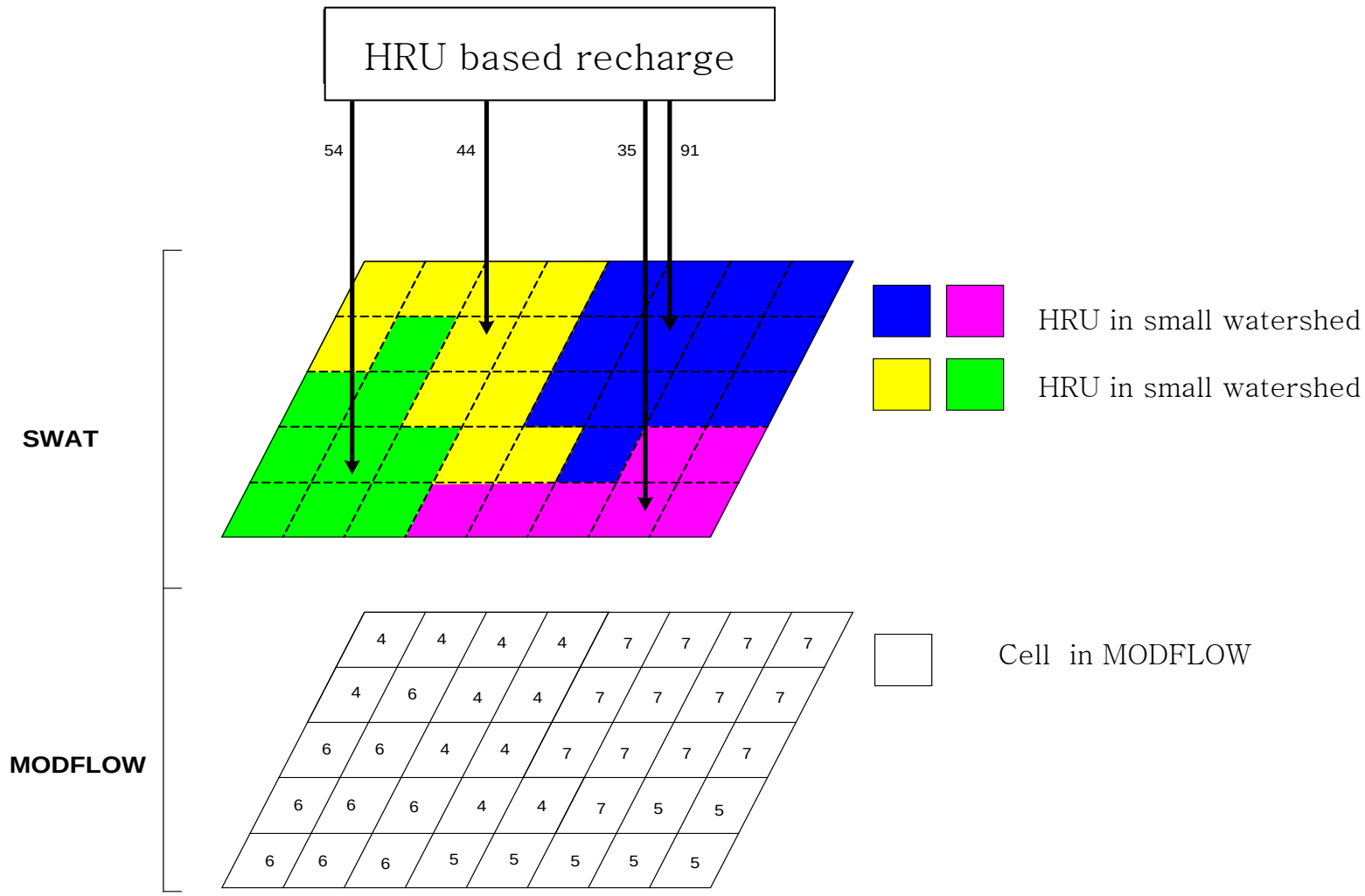
SWAT-MODFLOW

Schematic diagram

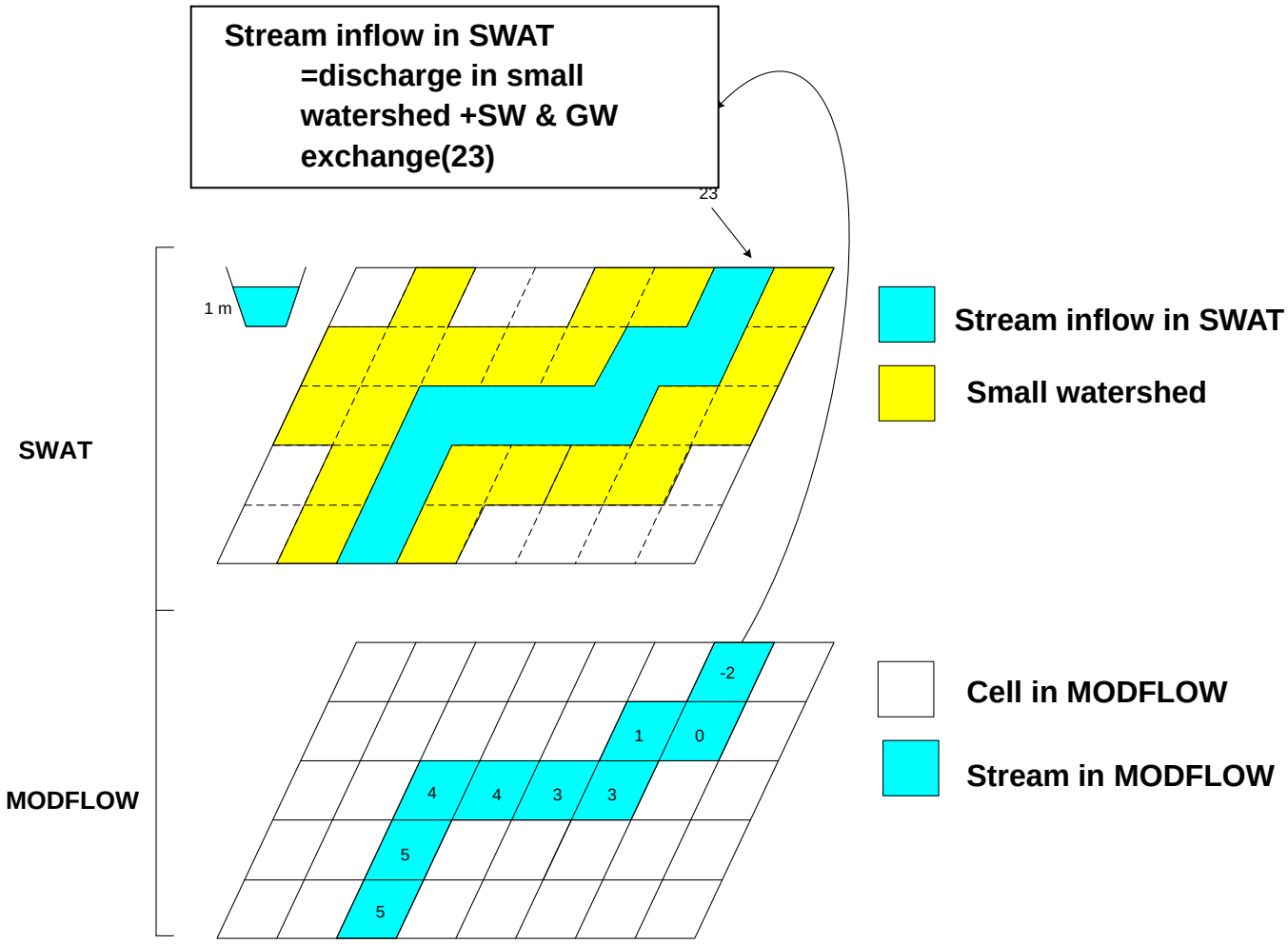


*** Kim et al., Development and application of the integrated SWAT-MODFLOW model, J. of Hydrology (2008)**

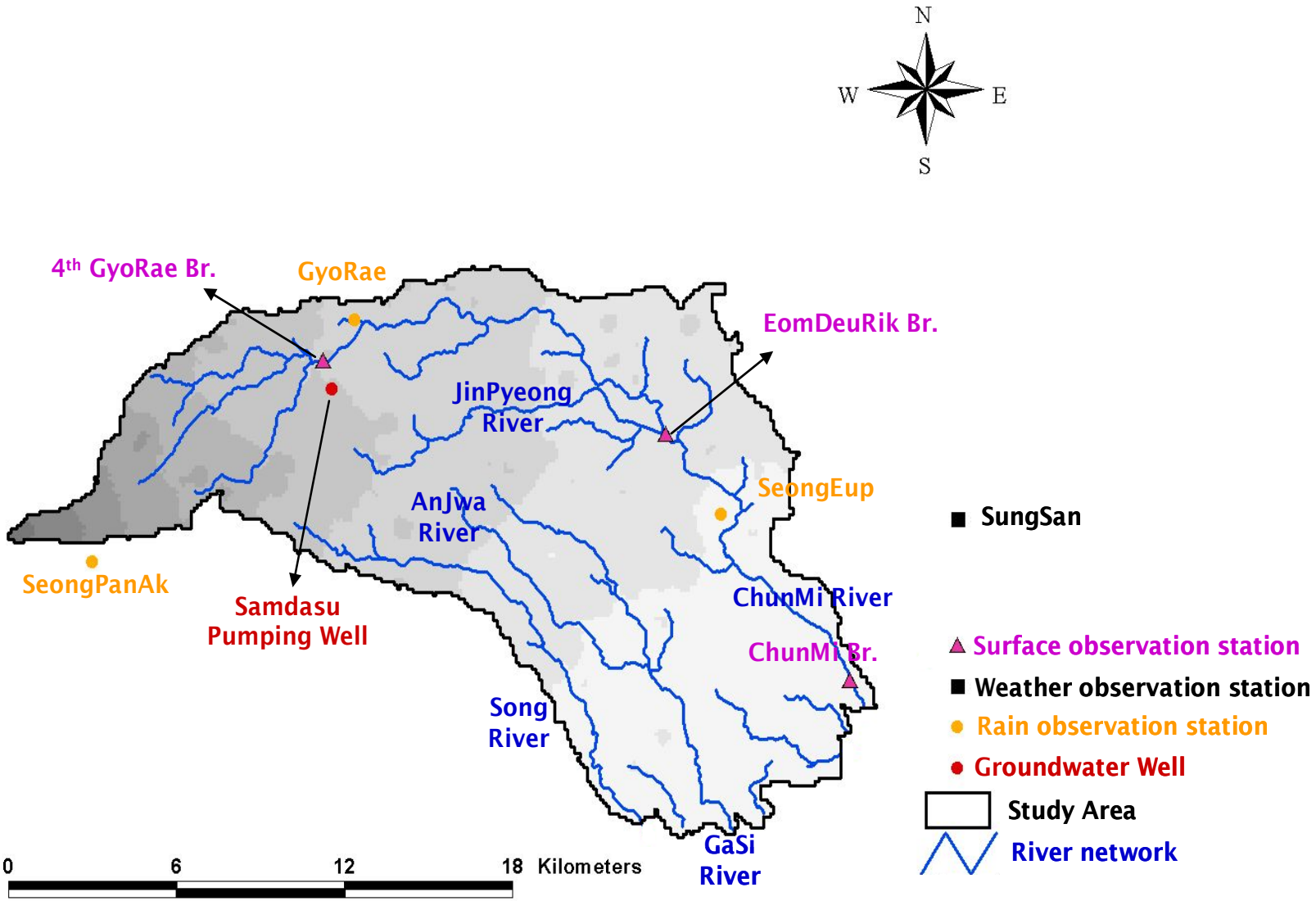
Linking RECHARGE in MODFLOW with SWAT



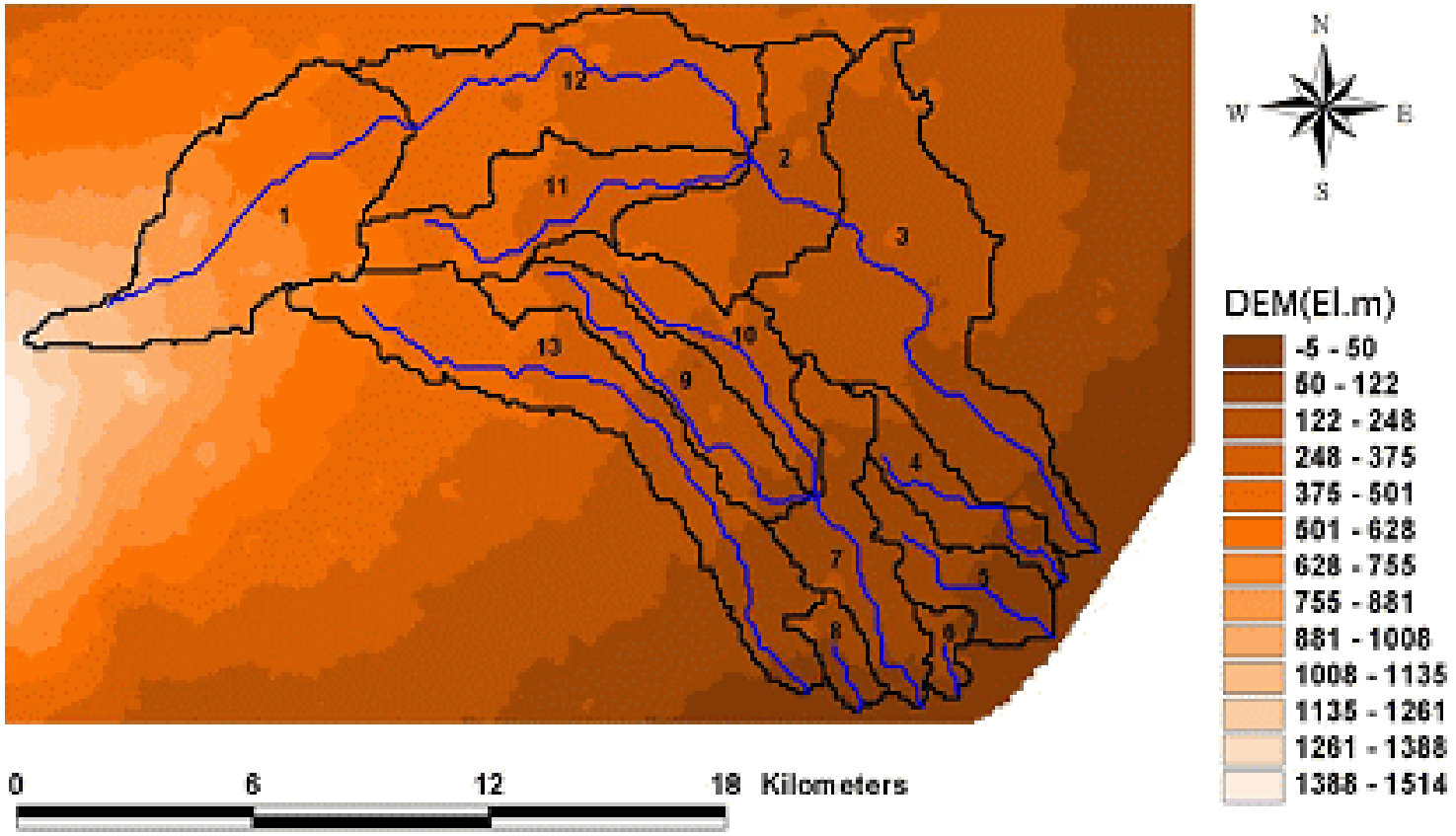
Linking RIVER in MODFLOW with SWAT



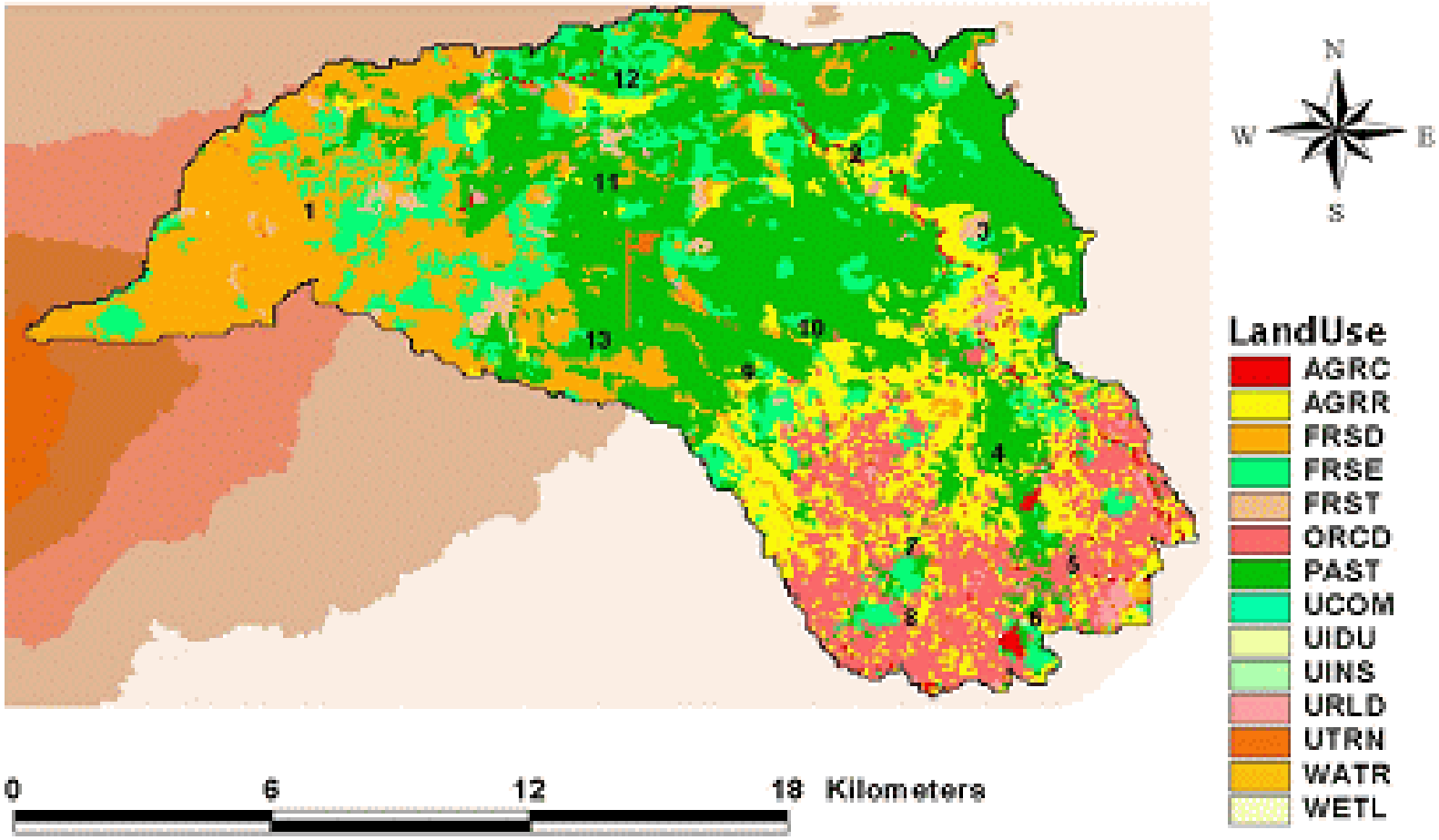
Pyoseon region



DEM


N
W
E
S
1
2
3
4
5
6
7
8
9
10
11
12
13
DEM(El.m)
-5 - 50
50 - 122
122 - 248
248 - 375
375 - 501
501 - 628
628 - 755
755 - 881
881 - 1008
1008 - 1135
1135 - 1261
1261 - 1388
1388 - 1514
0
6
12
18 Kilometers

LAND USE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18 Kilometers
LandUse
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AGRR
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FRSE
FRST
ORCD
PAST
UCOM
UIDU
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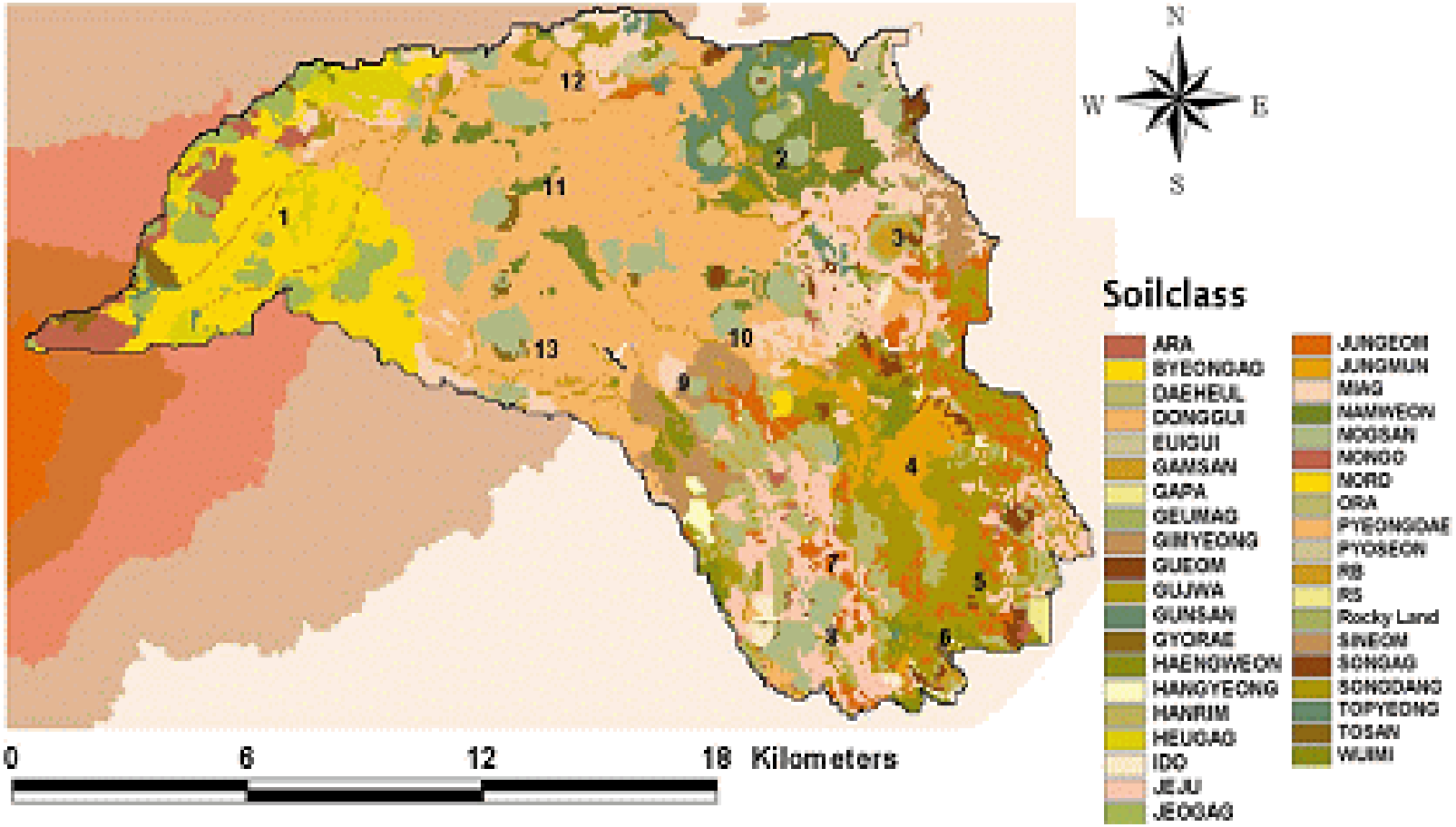
WETL

SOIL CLASS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18 Kilometers
Soilclass
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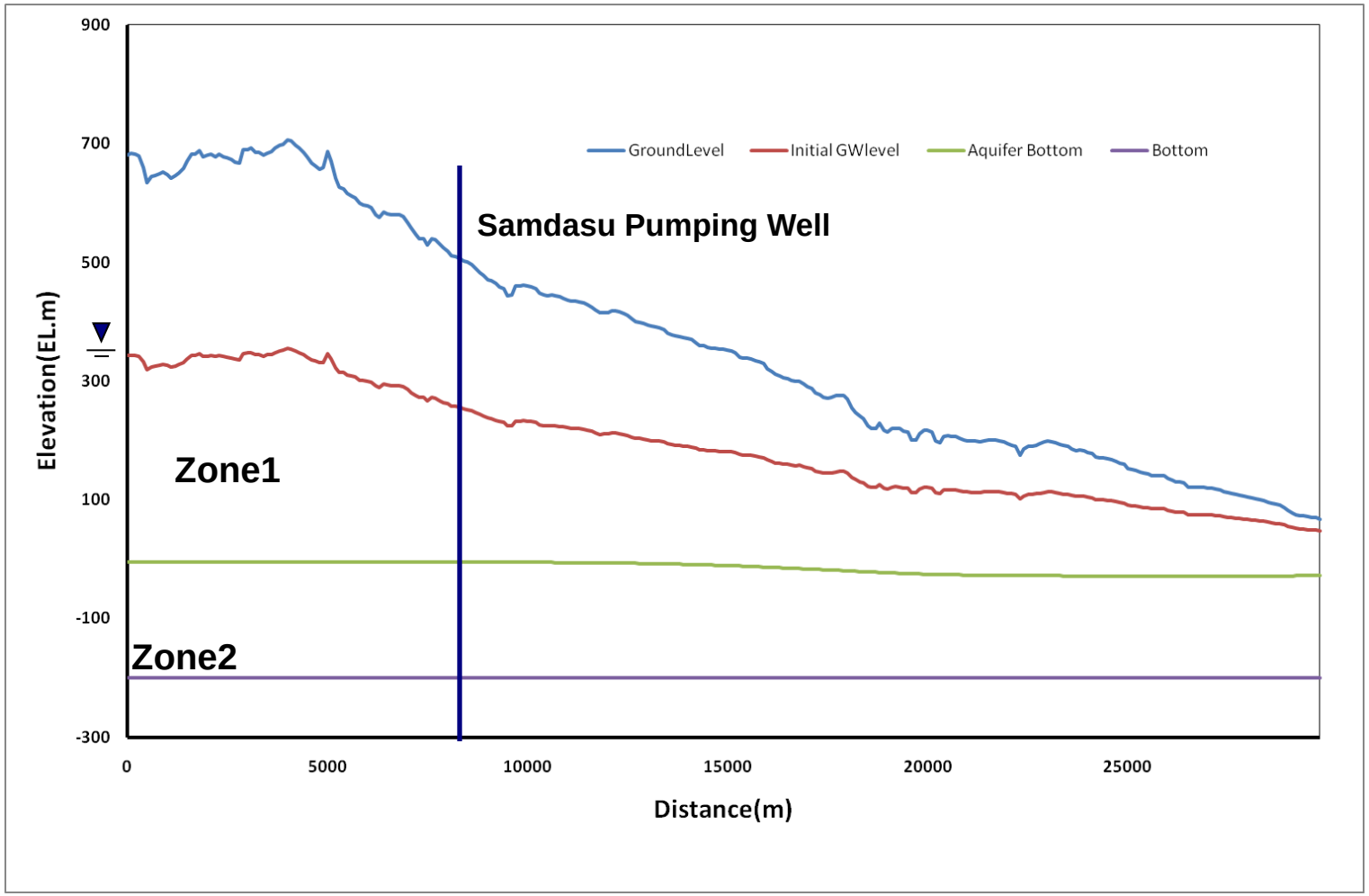
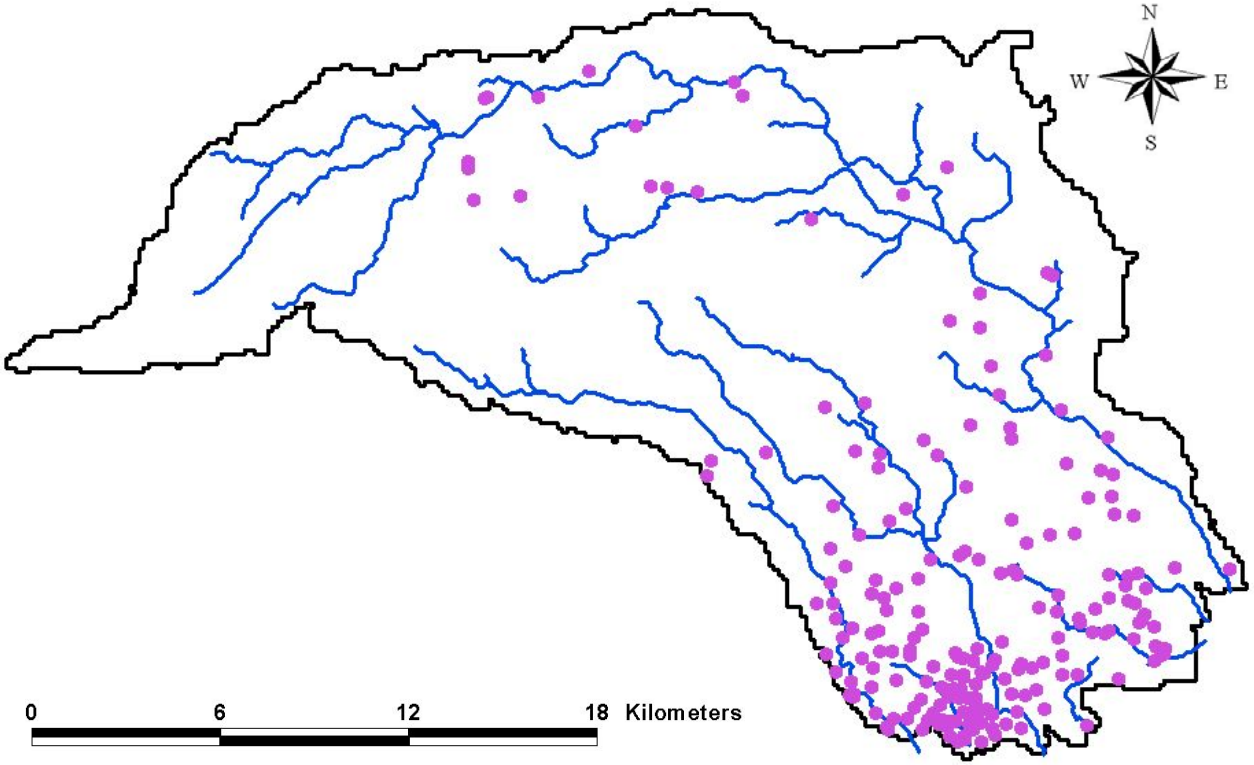
BYEONGAG
DAEHEUL
DONGGUI
EUIGUI
GAMSAN
GAPA
GEUMAG
GIMYEONG
GUEOM
GUJWA
GUNSAN
GYORAE
HAENGWEON
HANGYEONG
HANRIM
HEUGAG
IDO
JEJU
JEOGAG
JUNGEOM
JUNGMUN
MIAG
NAMWEON
NOGSAN
NONGO
NORO
ORA
PYEONGDAE
PYOSEON
RB
RS
Rocky Land
SINEOM
SONGAG
SONGDANG
TOPYEONG
TOSAN
WUMI

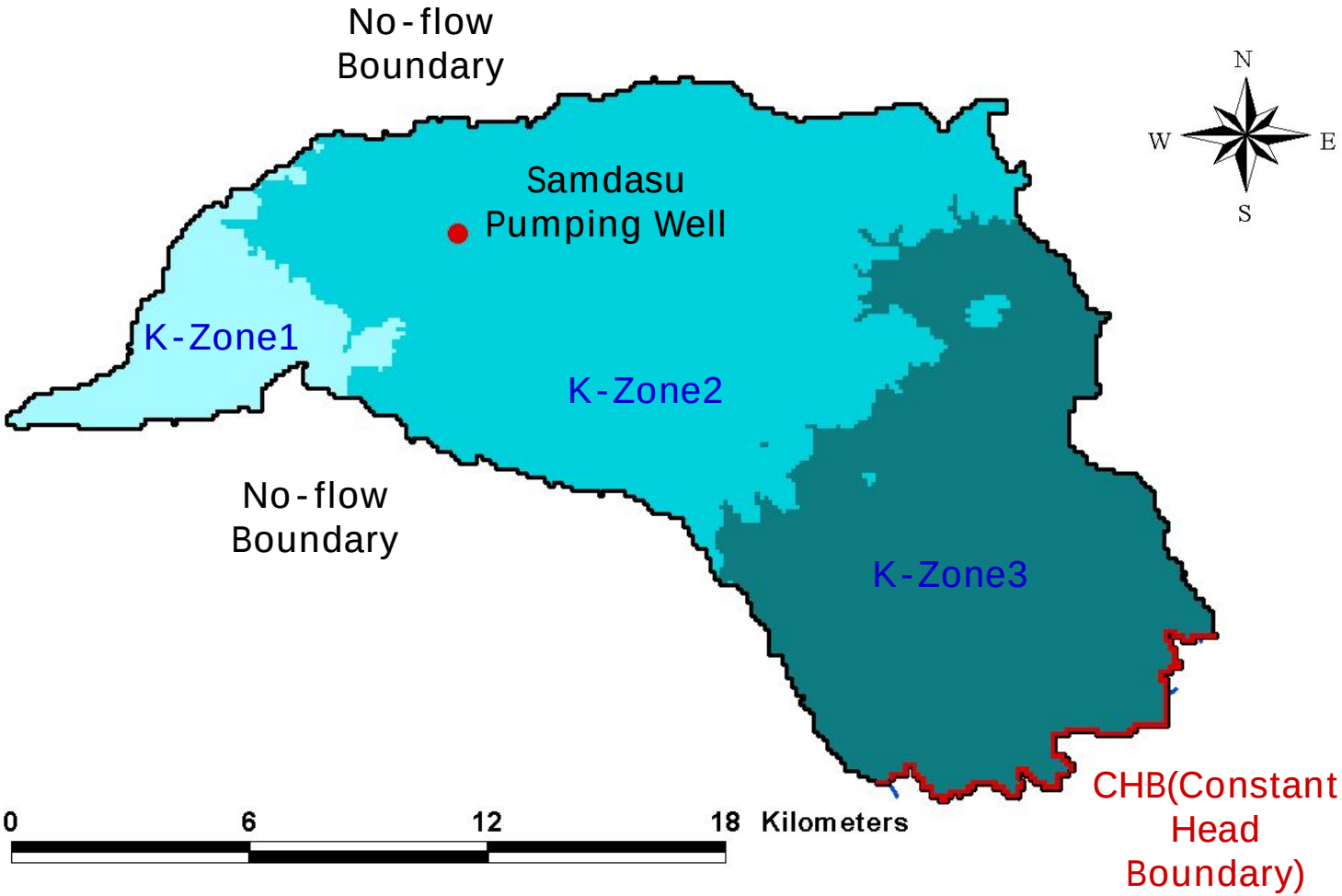
LONGITUDINAL GROUNDWATER LEVEL



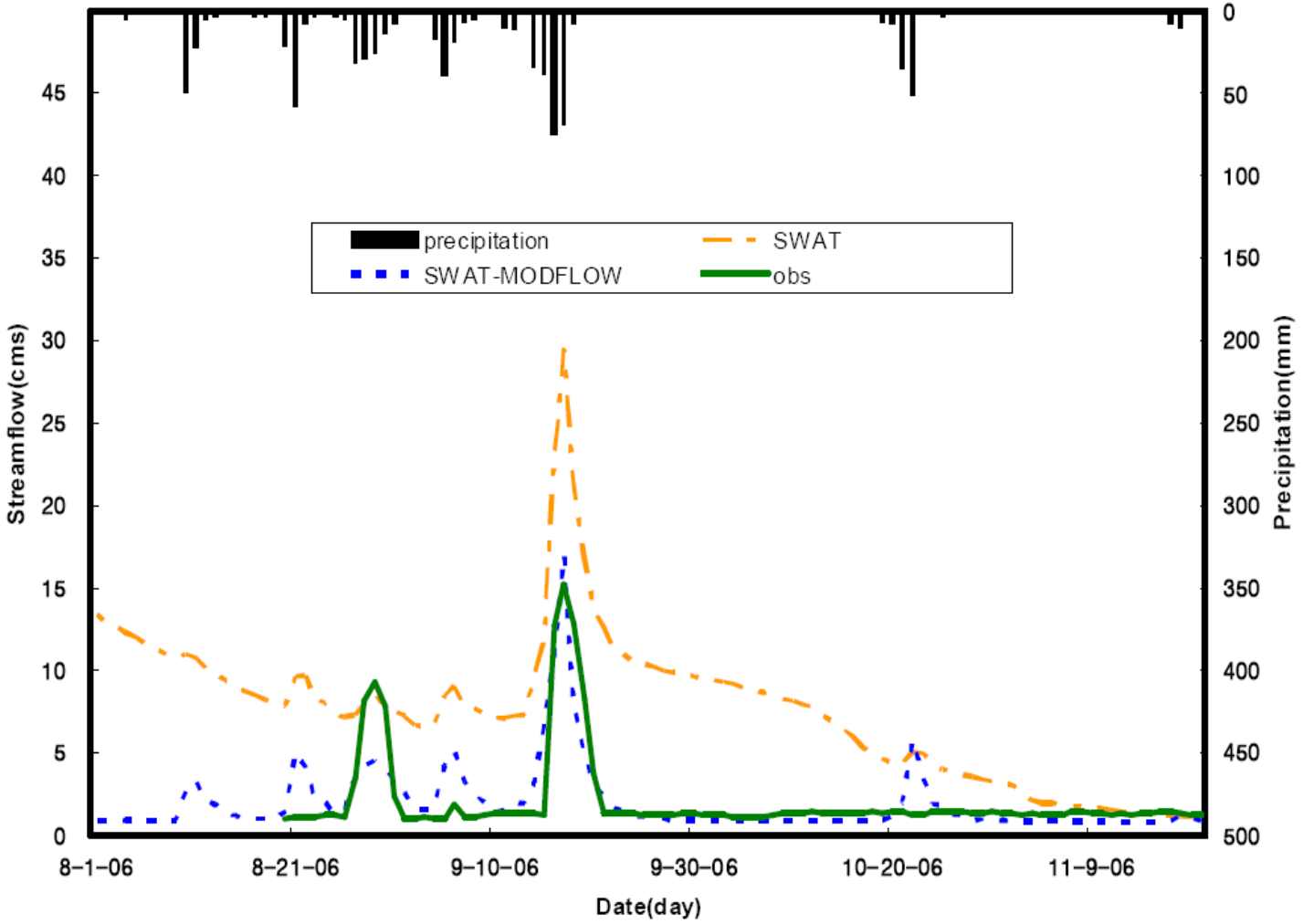
PUMPING WELLS (N=198)



AQUIFER ZONING / BOUNDARY CONDITION

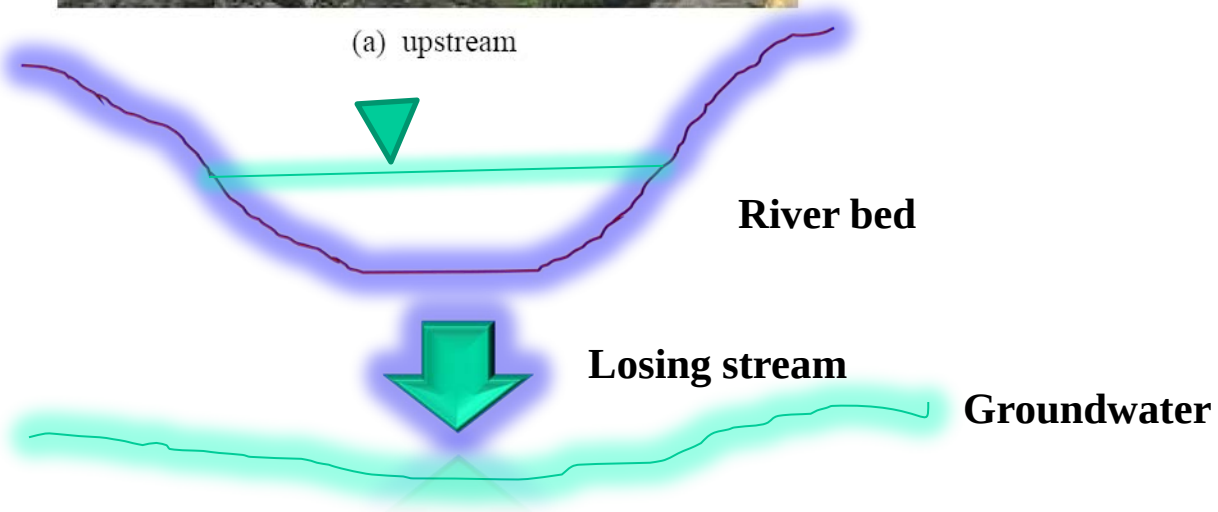


SURFACE RUNOFF SIMULATION (R^2=0.65)



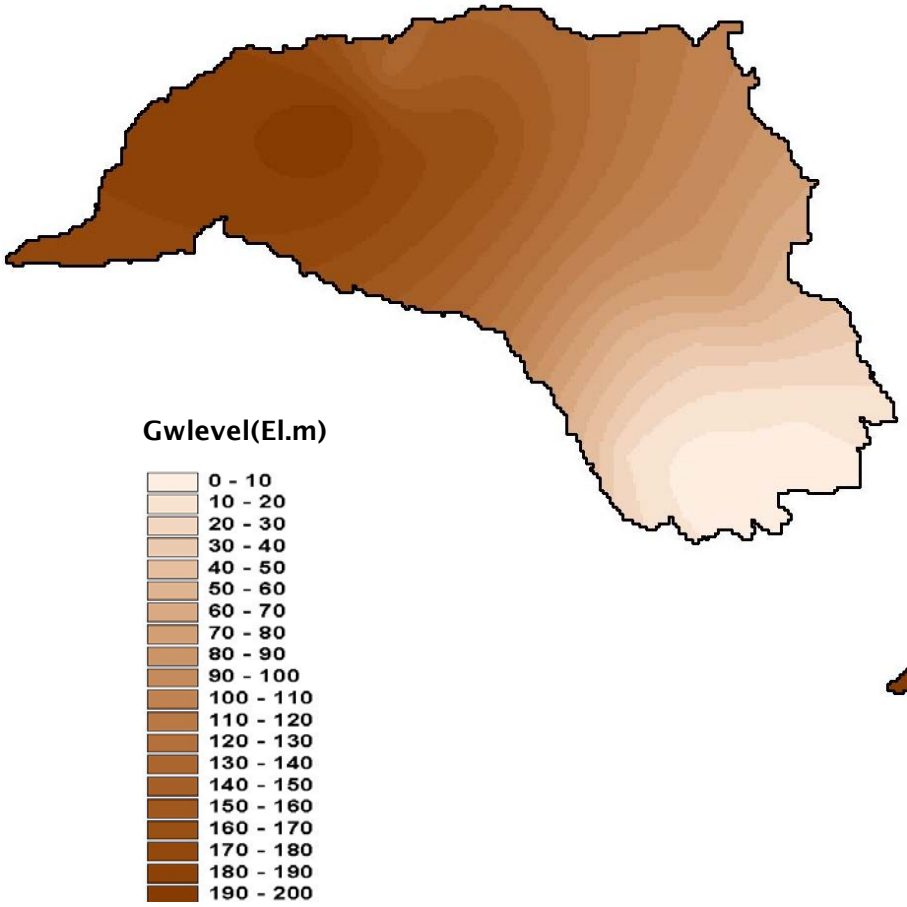
SEPARATION of SW / GW

(a) upstream

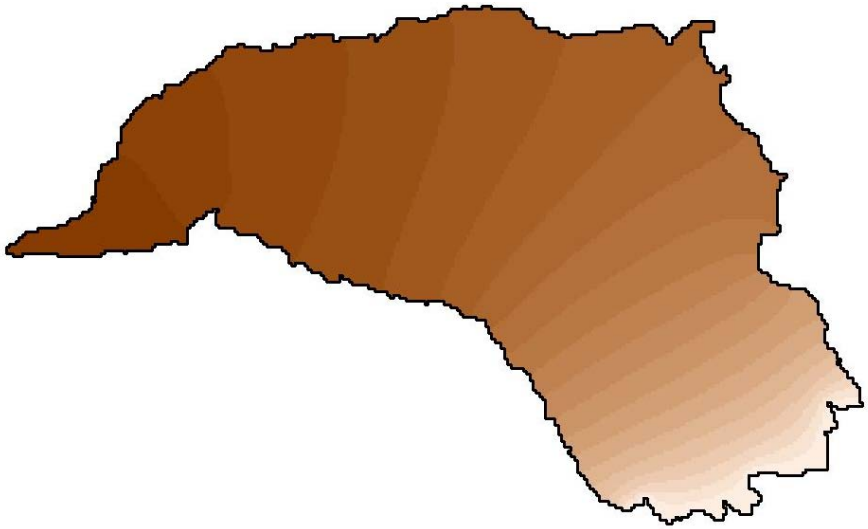


GW CALIBRATION

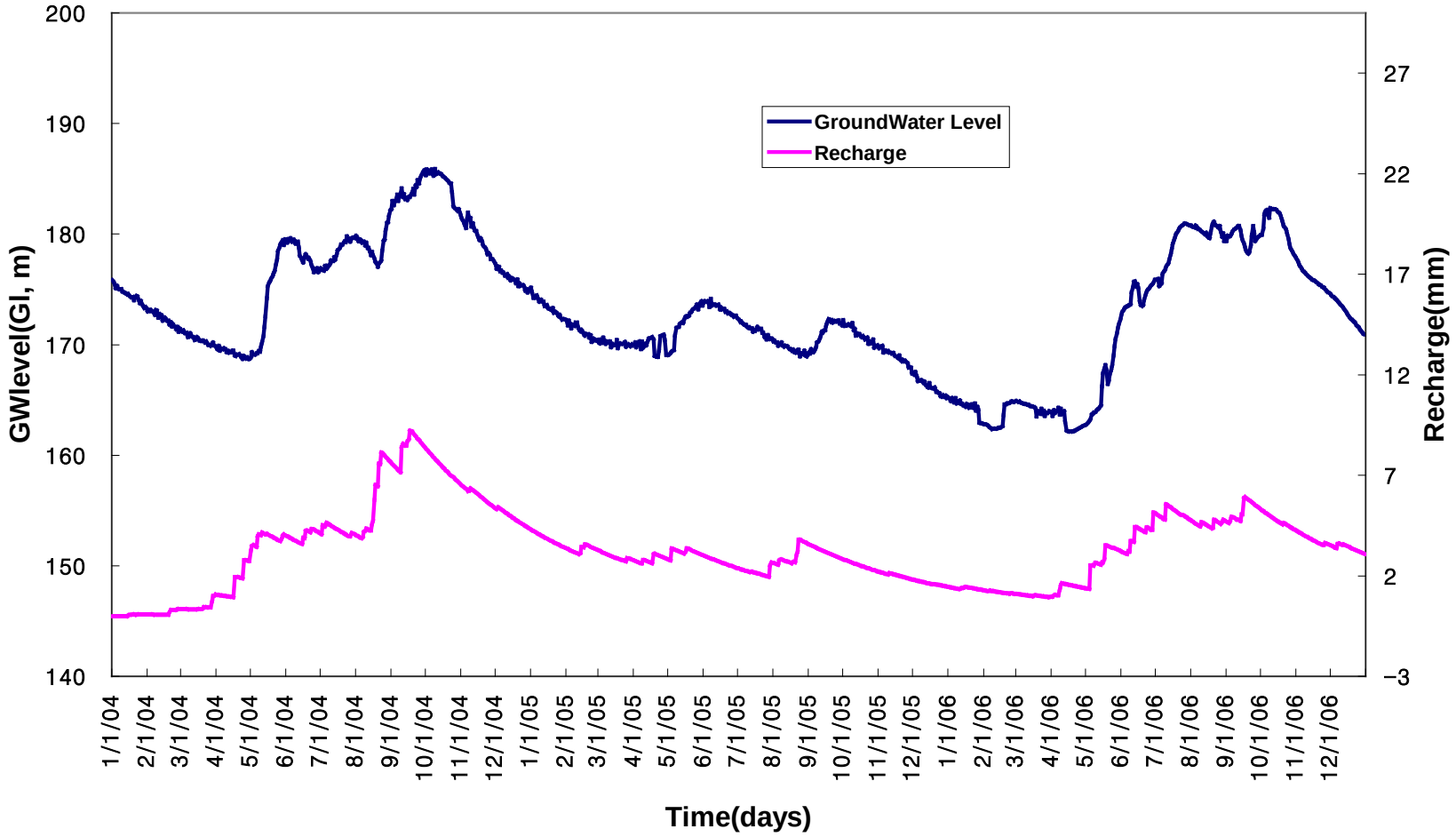
OBS.



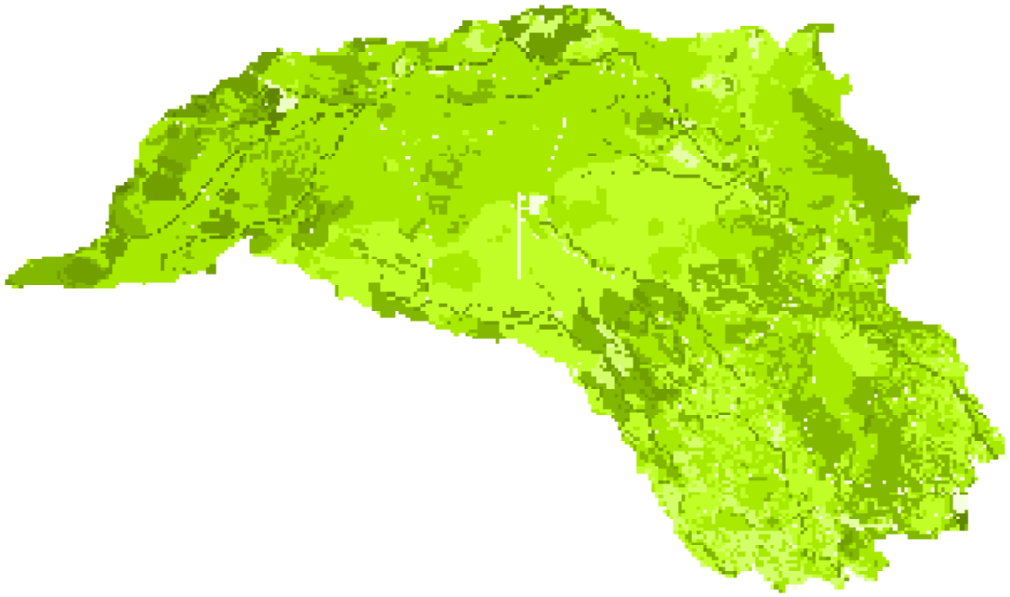
CAL.

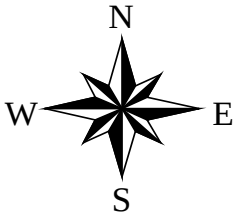


SIM. RECHARGE vs GW LEVEL (R=0.87)



DISTRIBUTED GW RECHARGE (OCT. AVE.)





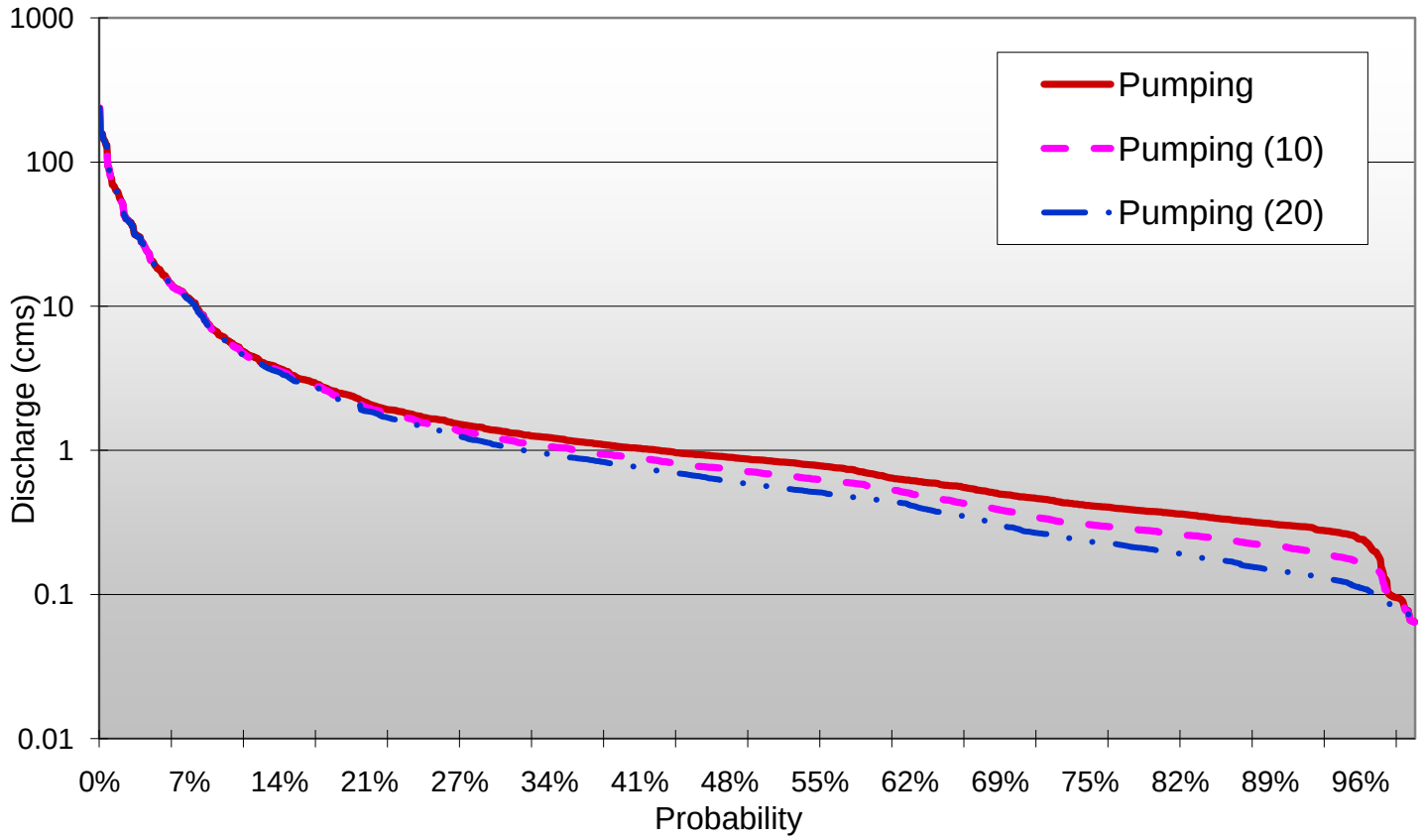
Re-10

- 0 - 34
- 35 - 68
- 69 - 102
- 103 - 136
- 137 - 170
- 171 - 204
- 205 - 238
- 239 - 272
- 273 - 306
- No Data

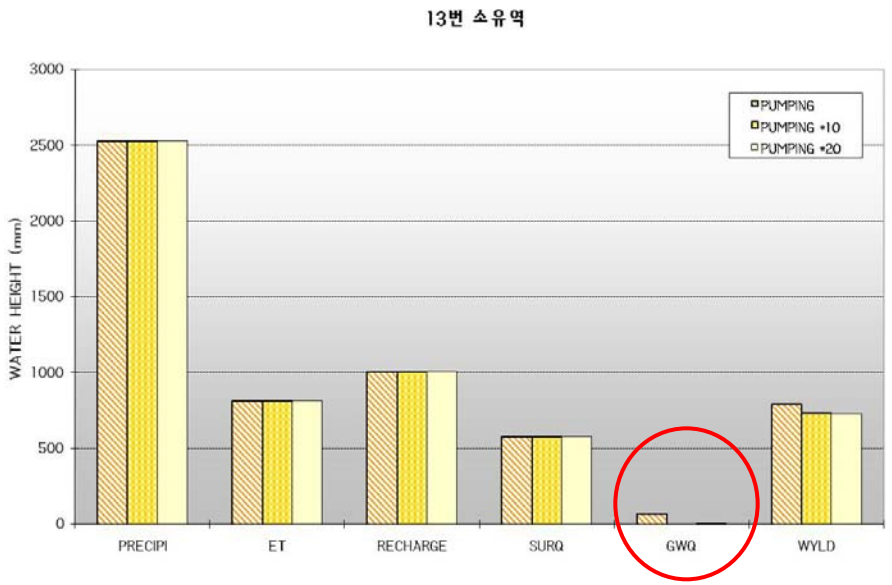
FDCs with various PUMPING scenarios

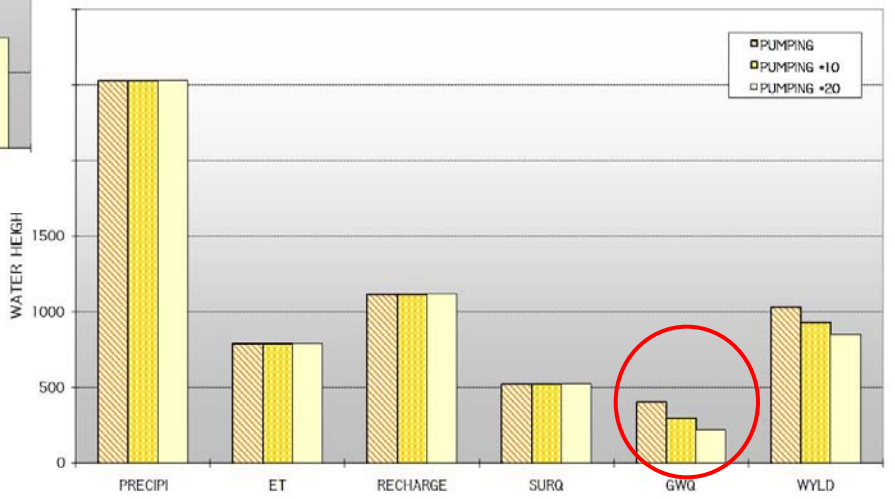
Q (Current rate) / 10Q / 20Q

: Low flow rate 0.18CMS -> 0.15CMS -> 0.10CMS reduces 17%, 45% respectively



Water Budget change (3, 13 subwatersheds)

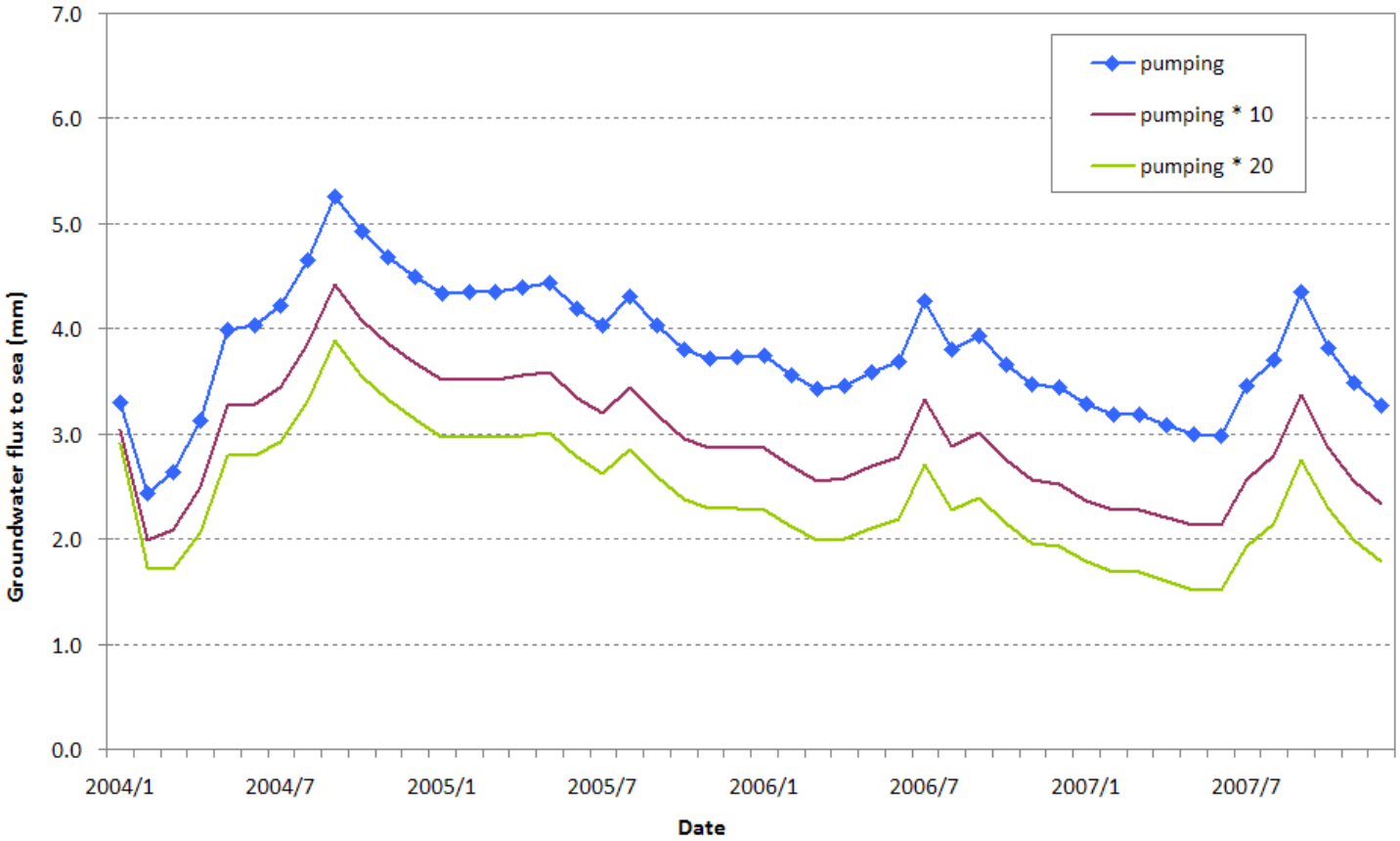




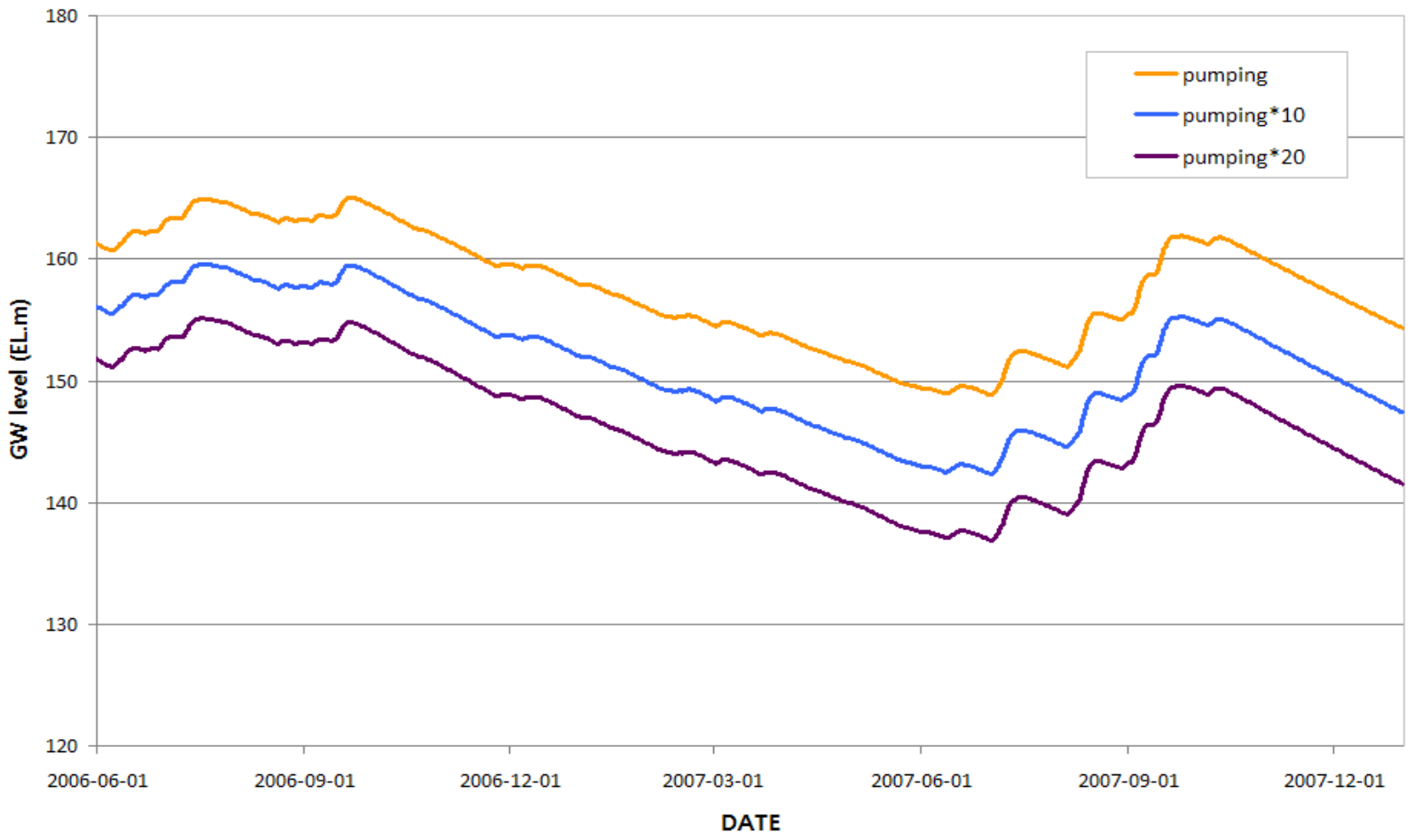
Sustainable additional groundwater resources

10Q / 20Q reduces the groundwater to Sea

: secures 60Mm^3 /1000Mm^3

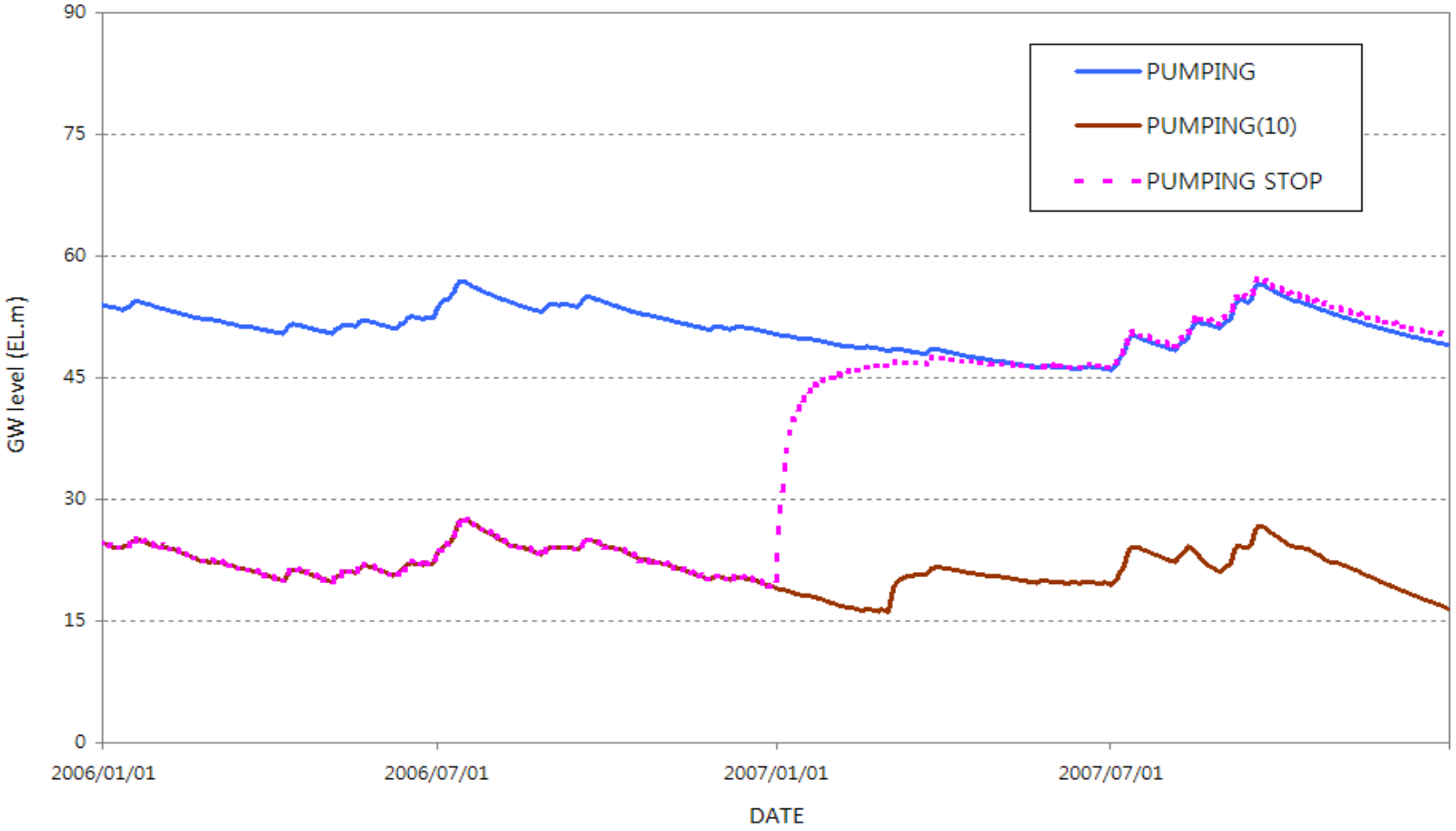


GW level variations



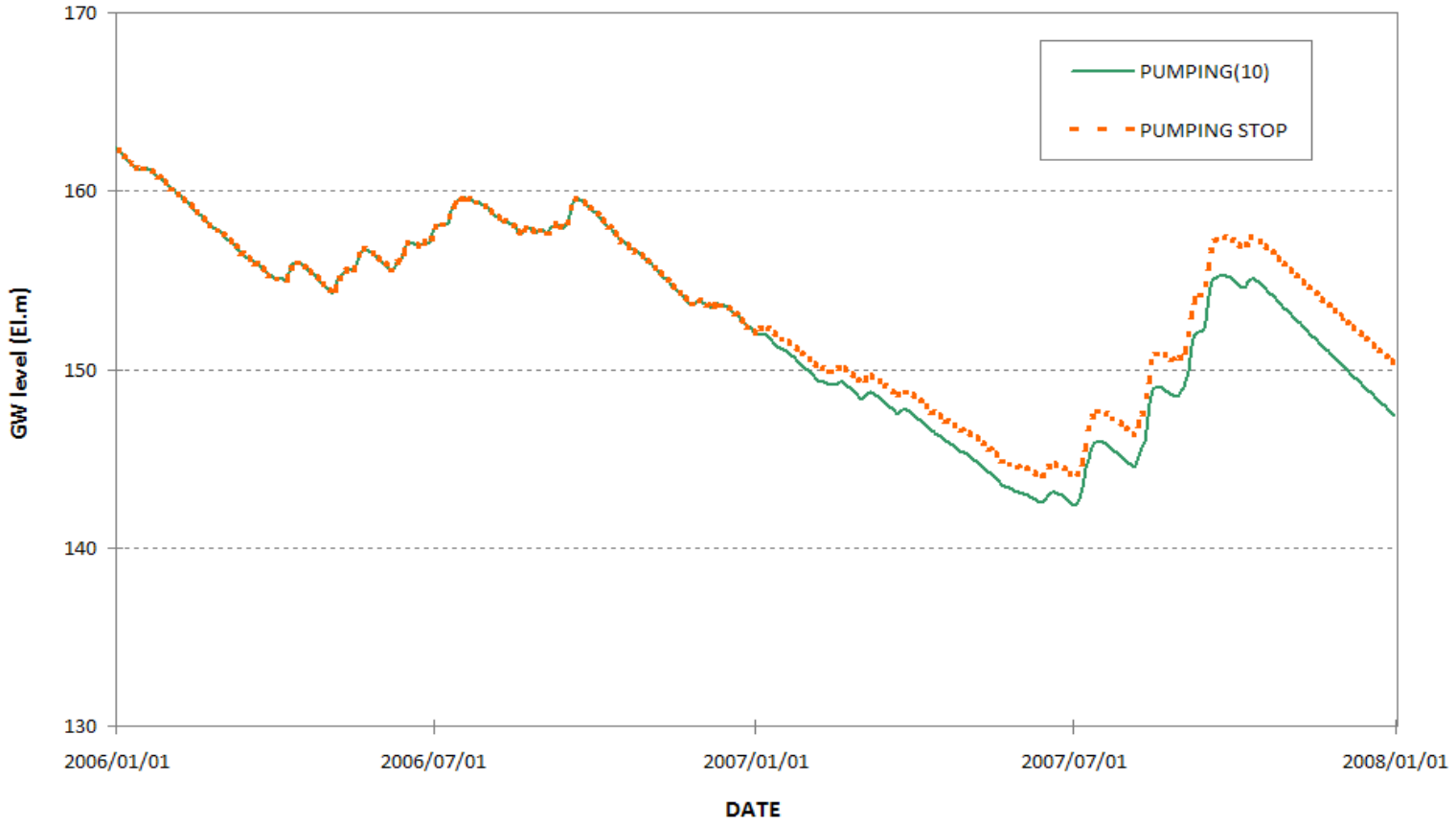
GW recovery in alluvial aquifer

10Q -> Stop : Prompt recovery

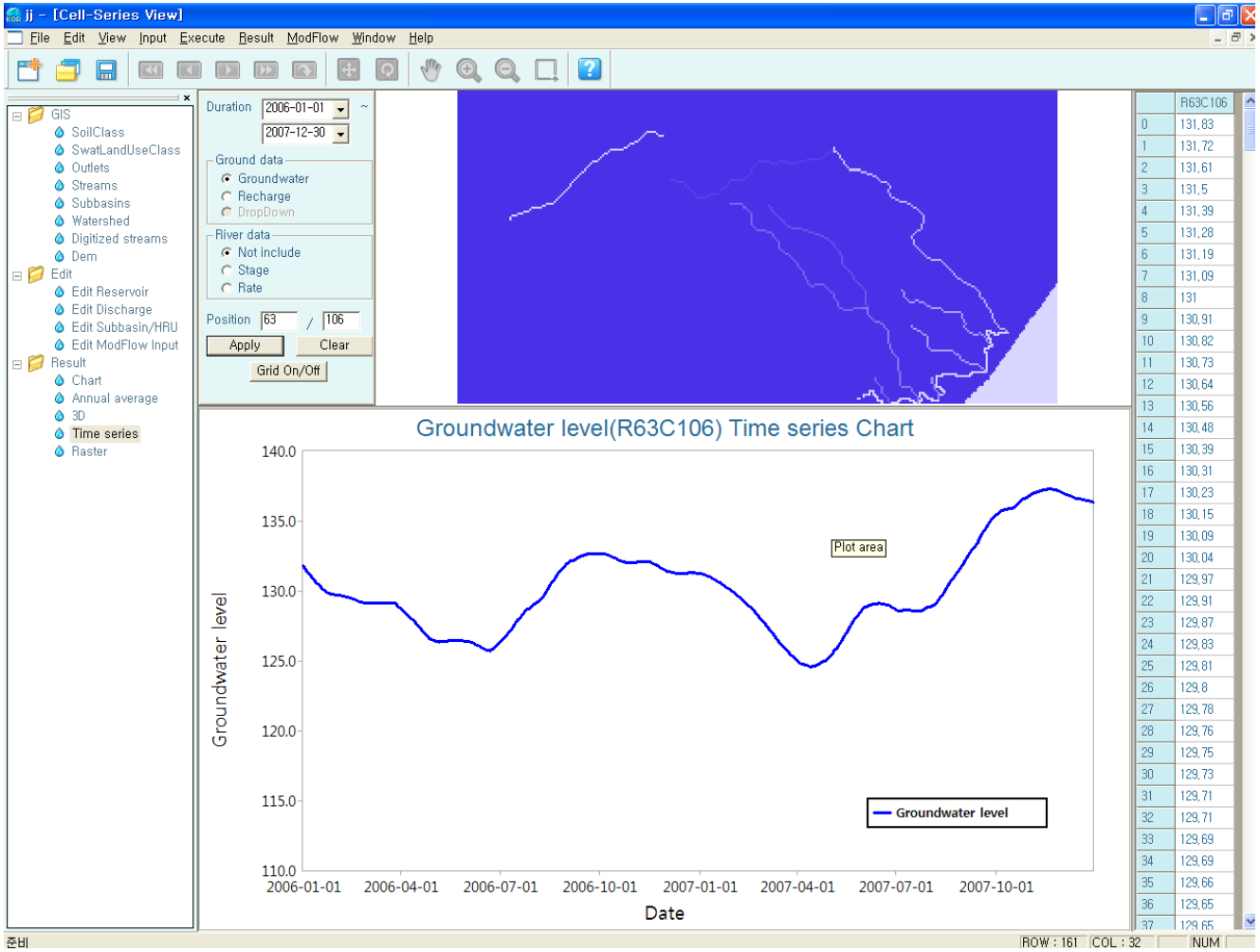


GW recovery in rock aquifer

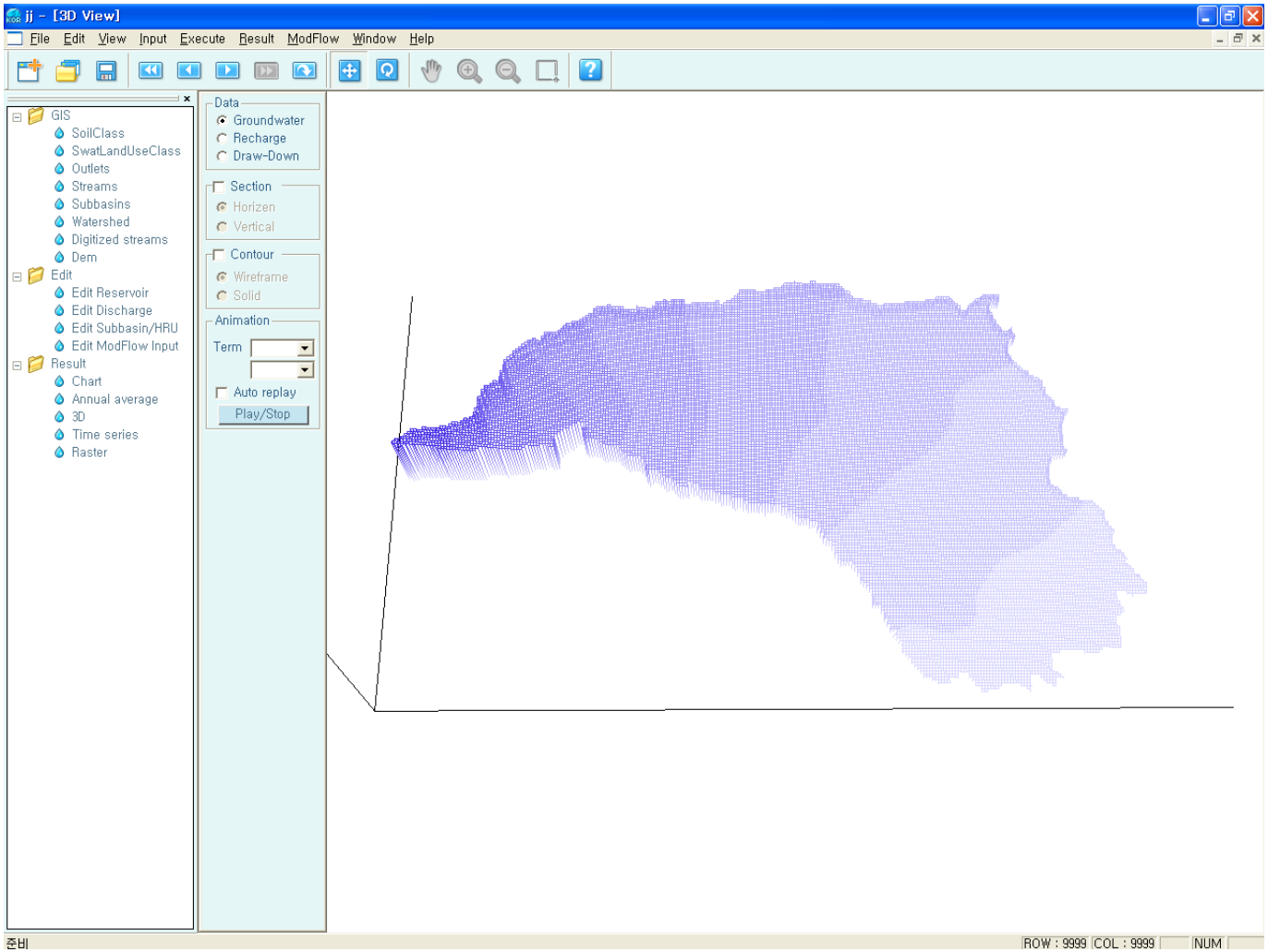
10Q -> Stop : Slow recovery



GW Time series at a single cell (SWAT-K)



GW level distribution (SWAT-K)



CONCLUSION

- ✓ **Integrated SW-GW analysis in Jeju island is performed**
- ✓ **Annual groundwater recharge rate in the Pyoseon basin is about 53%**
- ✓ **Impact analysis due to increasing Q scenarios**
  - **Recorvery tests show that 10Q / 20Q**
- ✓ **Sustainable additional GW resources in Jeju island could be secured**

: Thank you :

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