Decadal to Millennial Impacts of LCLUC on the Nubian Aquifer System, Saharan Africa

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Objectives & Implications
PART I - Decadal LCLUC

Examine the impacts of LCLUC related to major engineering projects (e.g., Aswan High Dam) in southern Egypt on the hydrology of the Nubian aquifer

This understanding is essential for articulating futuristic water management schemes in southern Egypt

Major Engineering projects in Southern Egypt (e.g., Aswan High Dam, Tushka Canal

Specifically

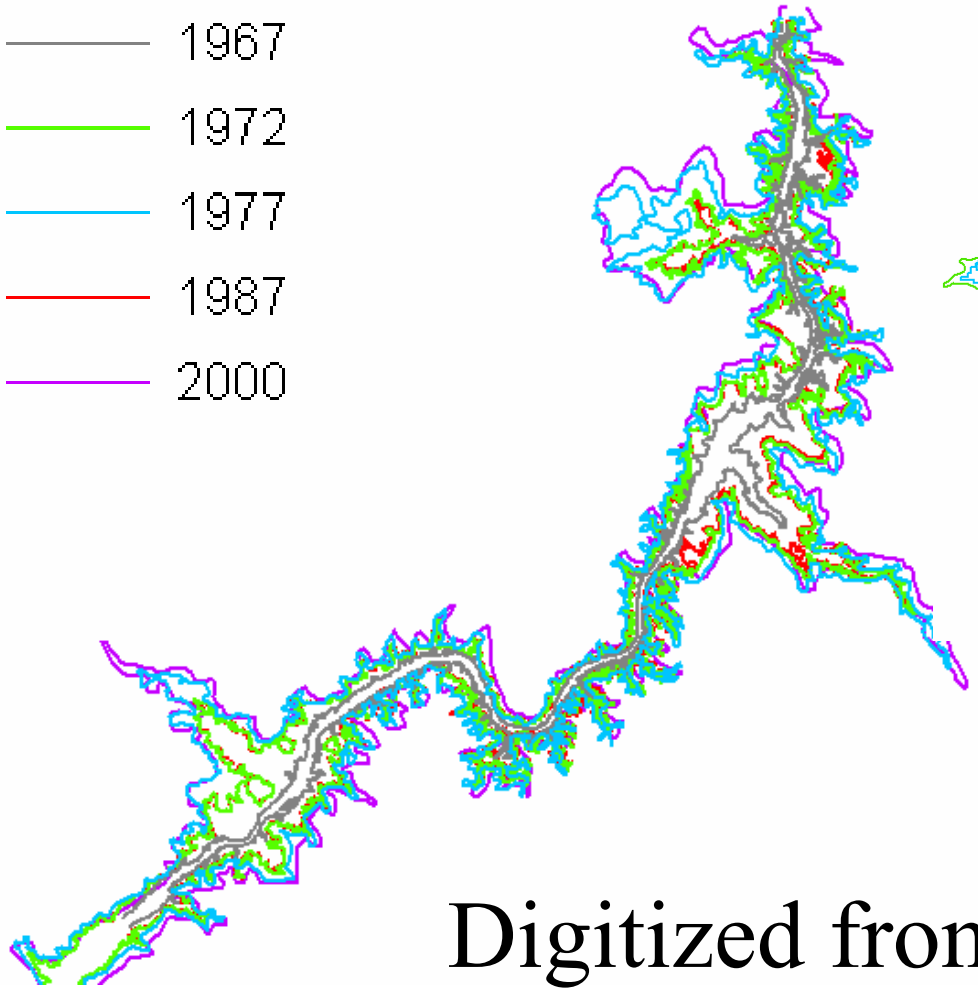
What are the impacts of the changes in Lake extent and levels on the recharge from the Lake

Is recharge changing with time (1970-2002); Decrease of recharge with time

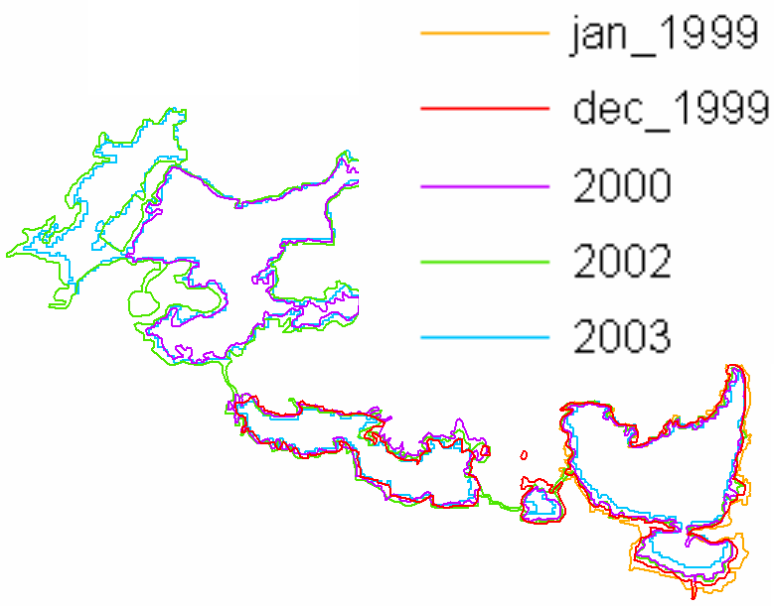
Understand the implications of the decrease in recharge on ongoing water management schemes

Lake Extents

Lake Nasser



Tushka Lakes



Digitized from Satellite Images

How?

Construct and calibrate (against head data) an Unconfined 2-Dimensional Transient Groundwater Flow Model (MODFLOW; GMS)

Elements of the Groundwater Flow Model (GIS Environment)

Basement elevation

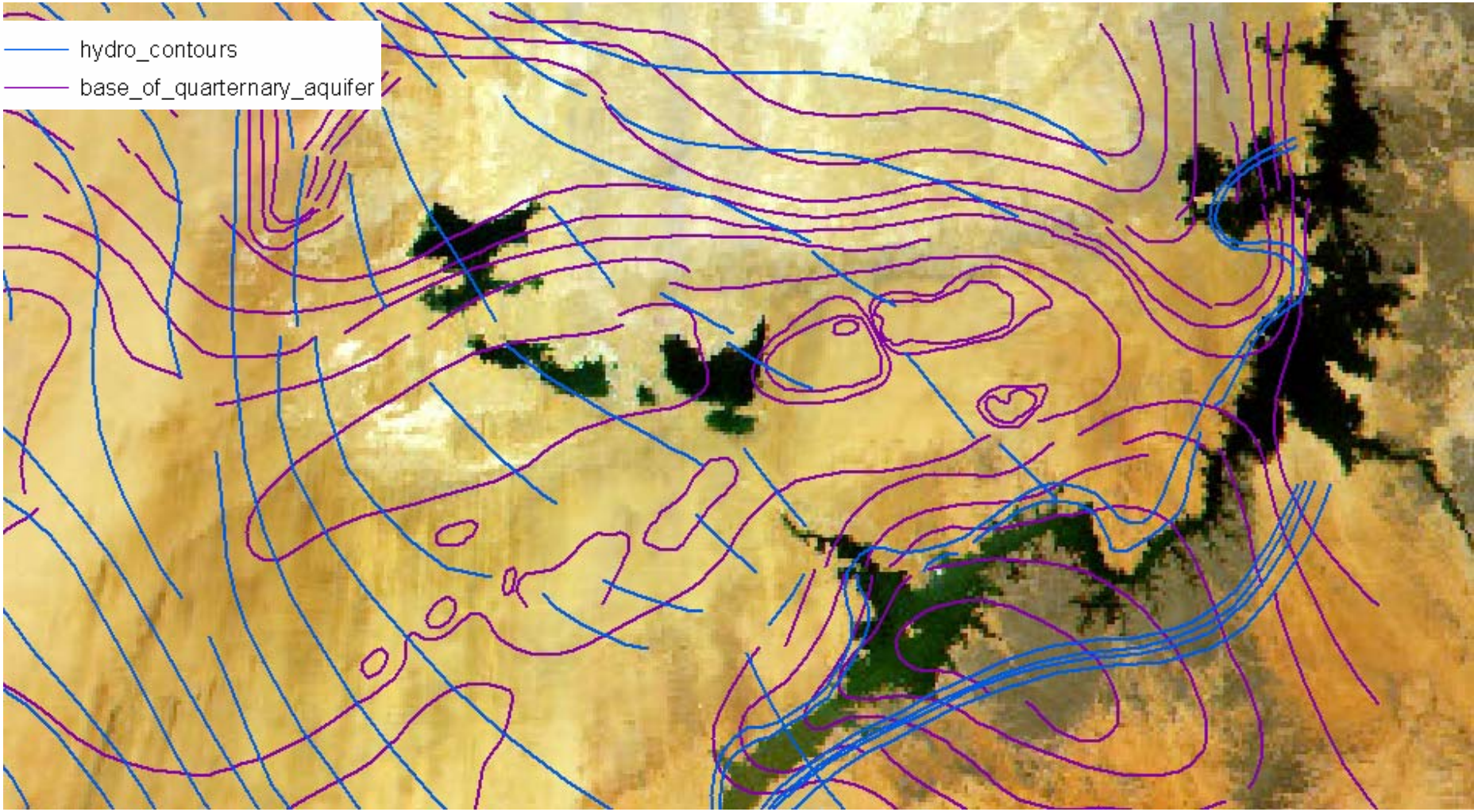
Surface elevation

Hydraulic parameters

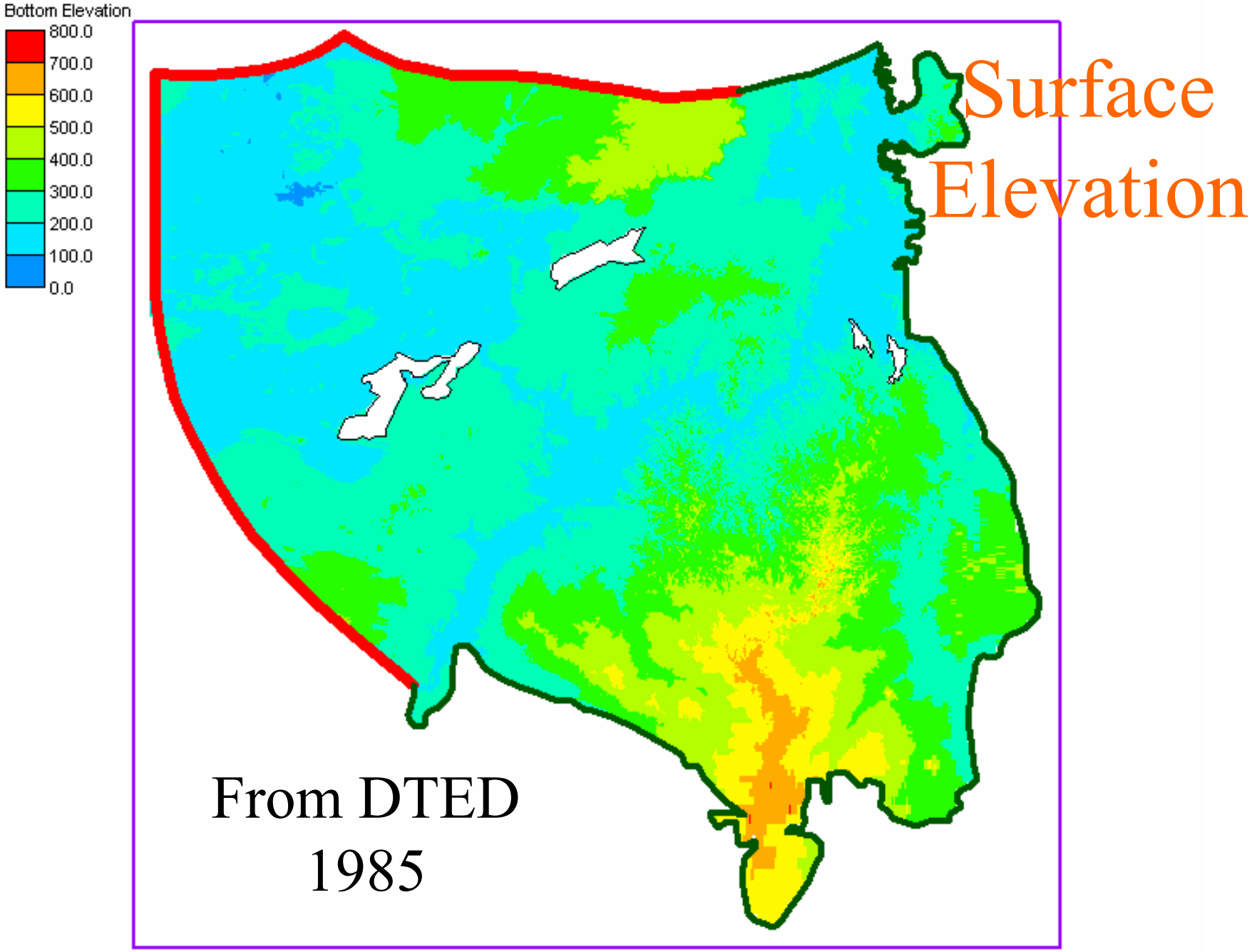
Model boundaries

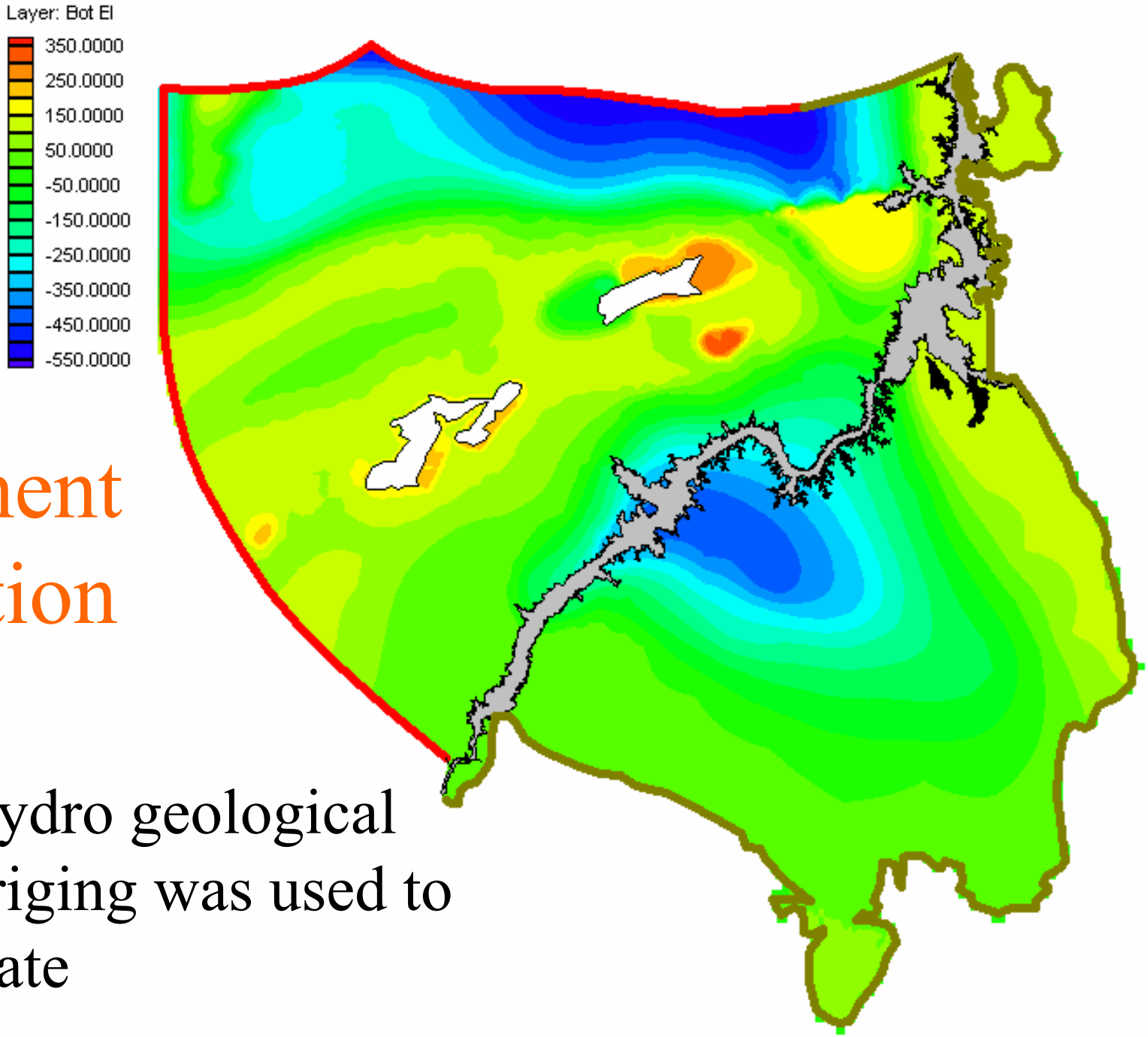
Temporal spatial variations in Lake Nasser & Tushka Lakes

Basement Elevation & Hydro Contours



Digitized from Hydro geological Map (RIGW, 1998)


Bottom Elevation
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Surface Elevation
From DTED
1985



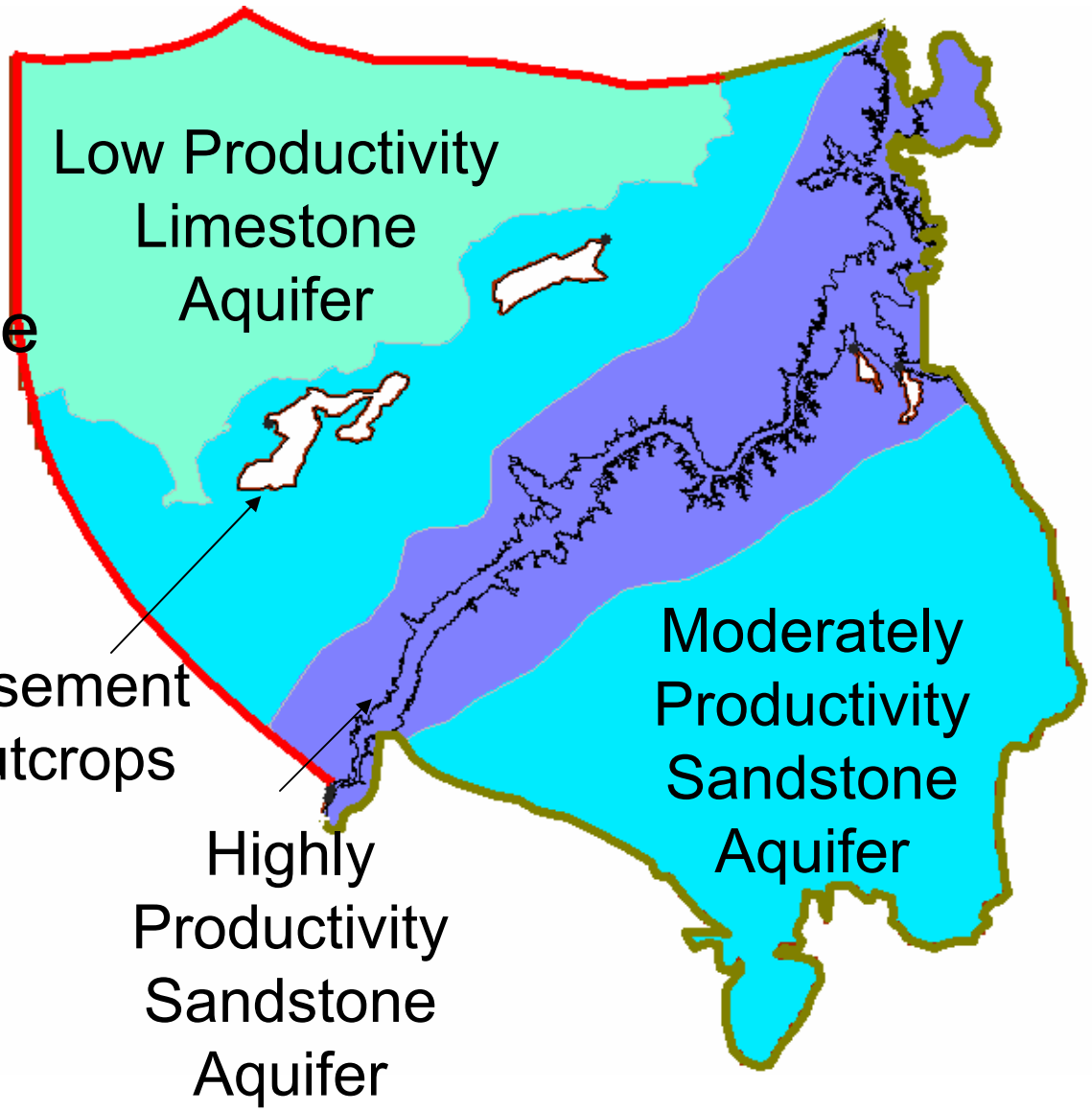
Basement Elevation

From Hydro geological map, Kriging was used to interpolate

Hydraulic Parameters

Hydraulic Conductivities:

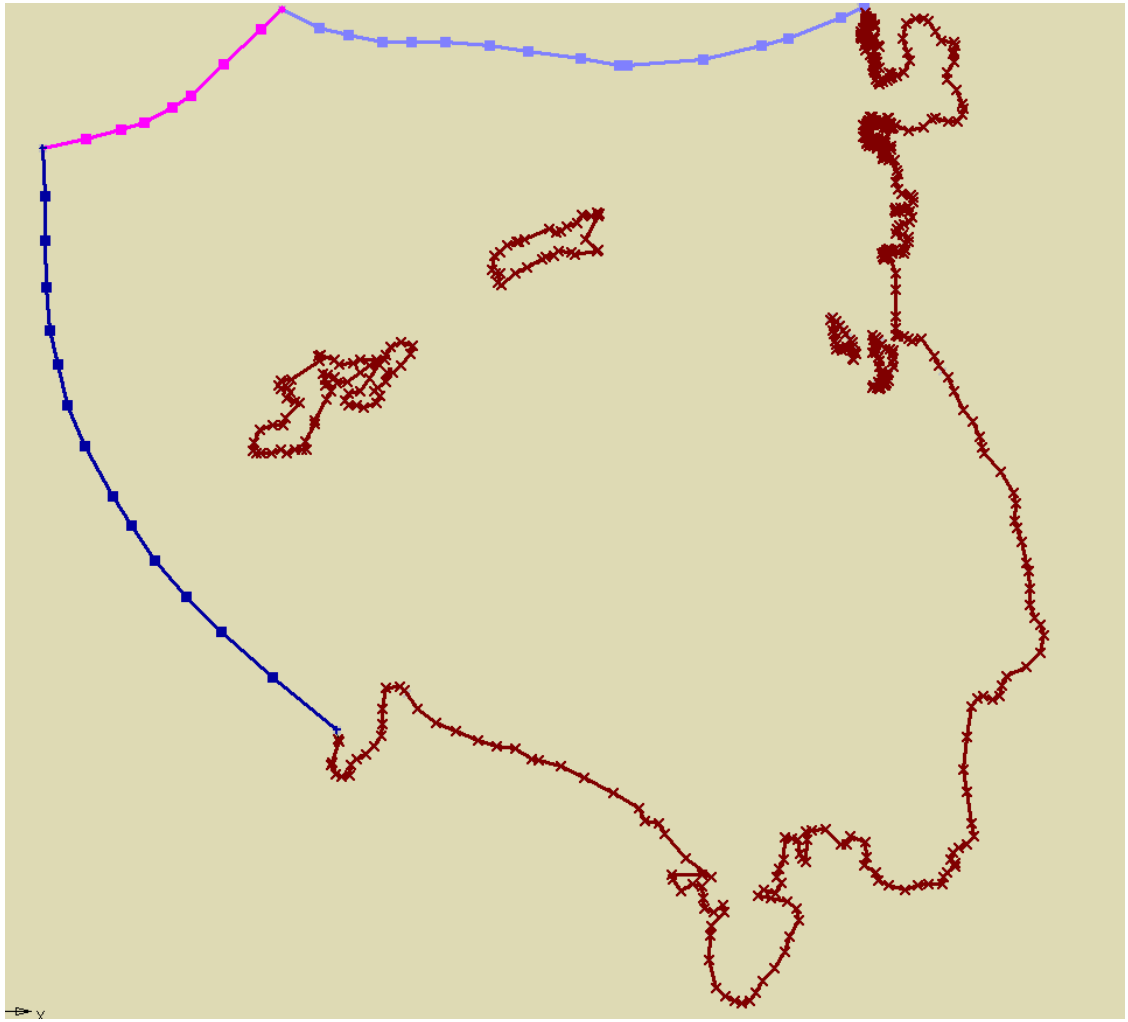
- Low Productivity Limestone Aquifer: 0.12 m/d
- Moderately Productive Aquifer : 1.2 m/d
- Highly Productive Aquifer: 4.6 m/d
- Conductivities digitized from Hydro geological Map



Model Boundaries

This a variable head boundary because it cuts perpendicular to head contour lines, starts at 170 and ends at 90

This constant head boundary follows the 170m head contour line



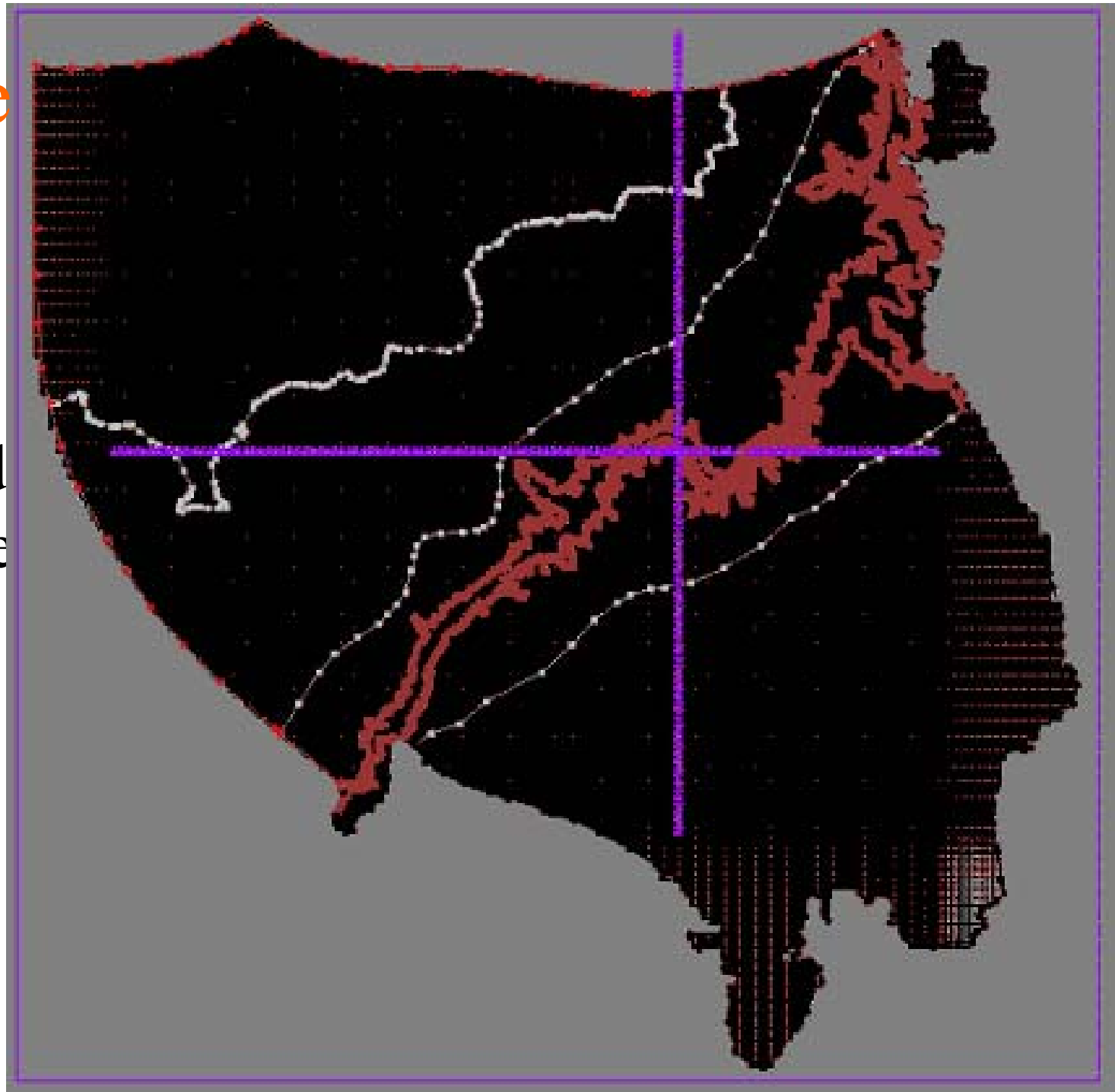
The northern boundary starts as a constant head following the 90m head contour line then begins to veer from that line and ends at the lake where head will be transient

No flow boundary follows the basement outcrop

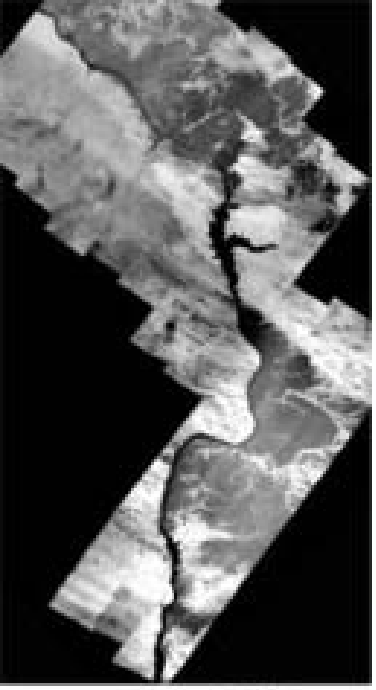
Grid Size

Grid refined around Lake Nasser

Grid size is 500-5000m



Lake Nasser Time Series

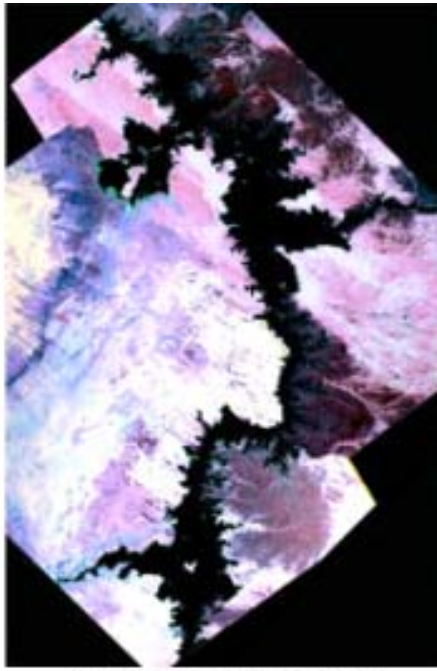


Corona 1967

Landsat MSS 1972

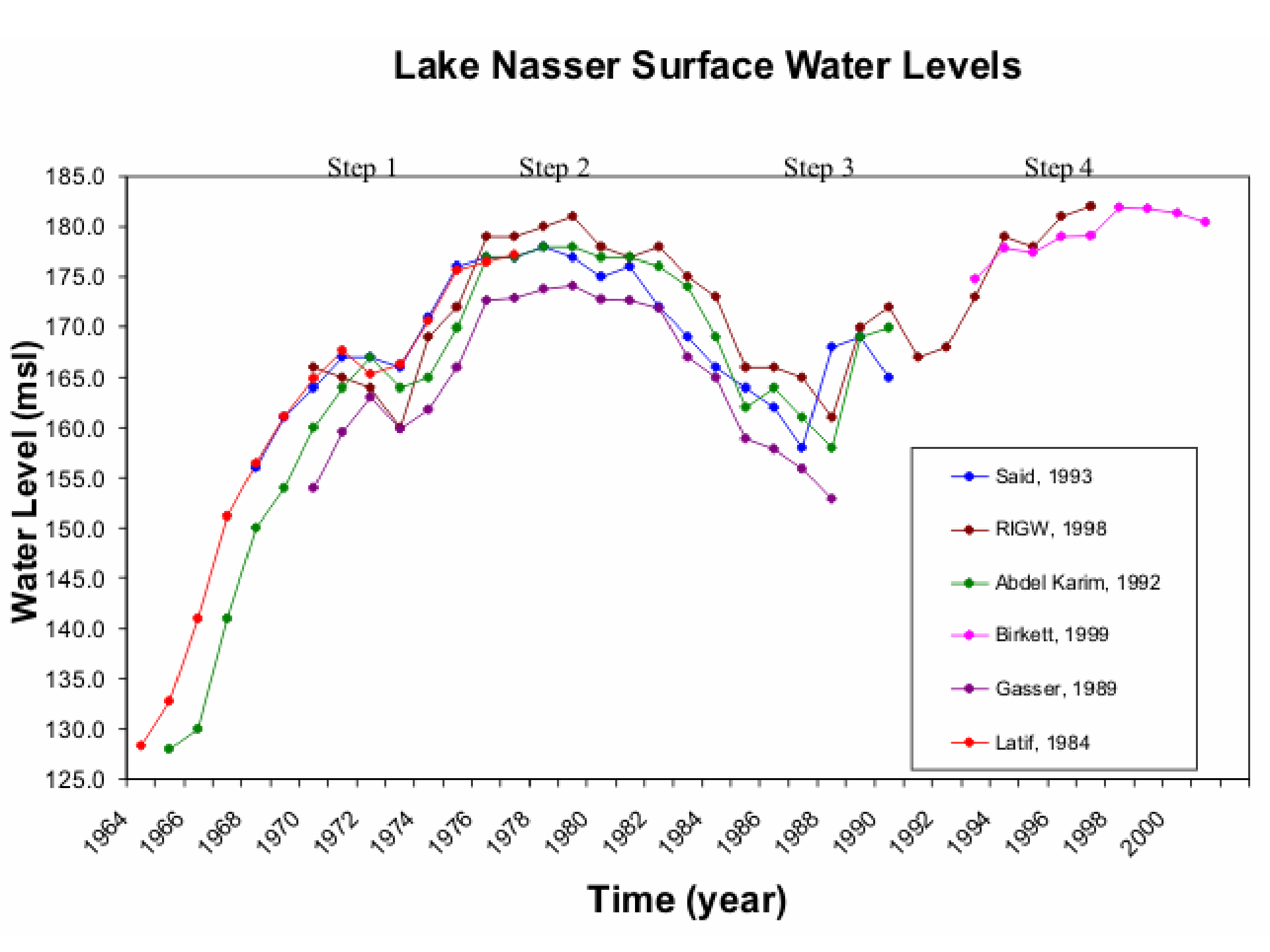
Landsat MSS 1977

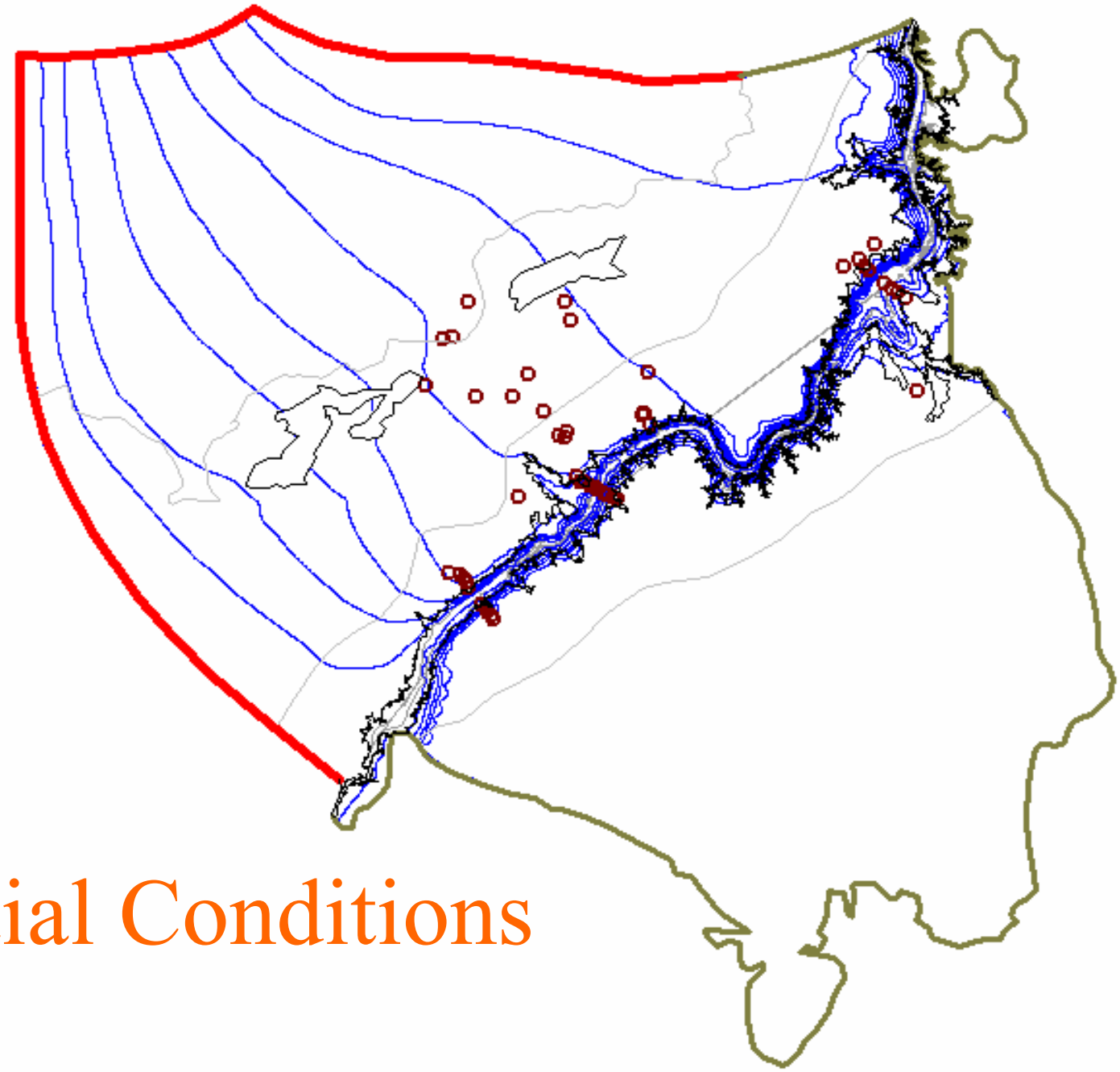
Landsat TM 1987/88



Landsat TM 2000

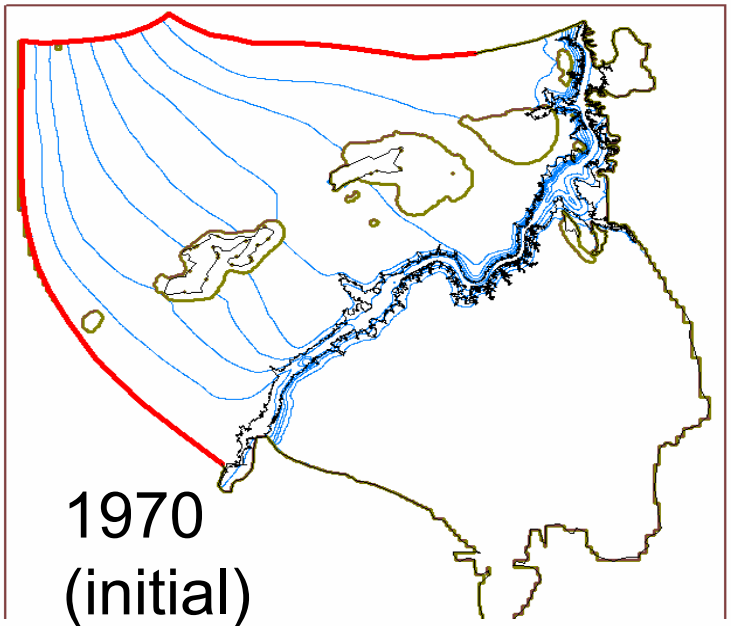
1972, 1977, 1987/88 and the 2000 images were used to map lake extent for the four time steps

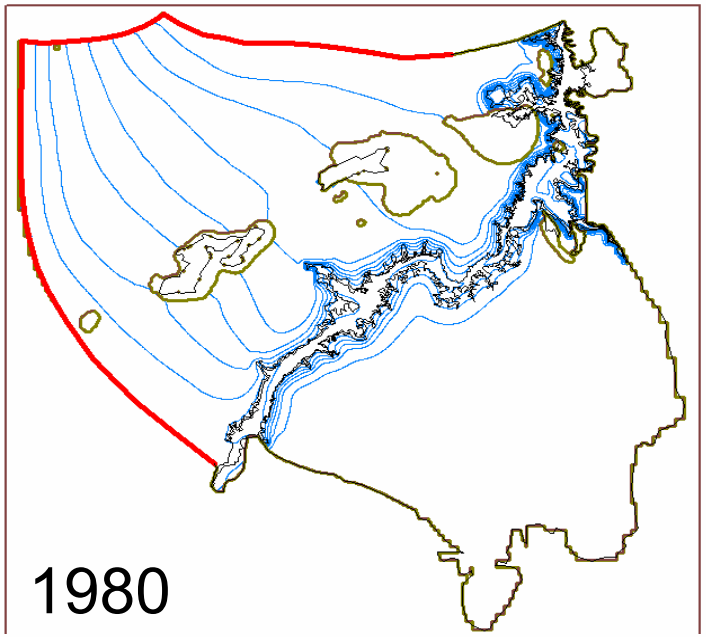

Lake Nasser Surface Water Levels
Step 1
Step 2
Step 3
Step 4
Water Level (msl)
185.0
180.0
175.0
170.0
165.0
160.0
155.0
150.0
145.0
140.0
135.0
130.0
125.0
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
Time (year)
Said, 1993
RIGW, 1998
Abdel Karim, 1992
Birkett, 1999
Gasser, 1989
Latif, 1984

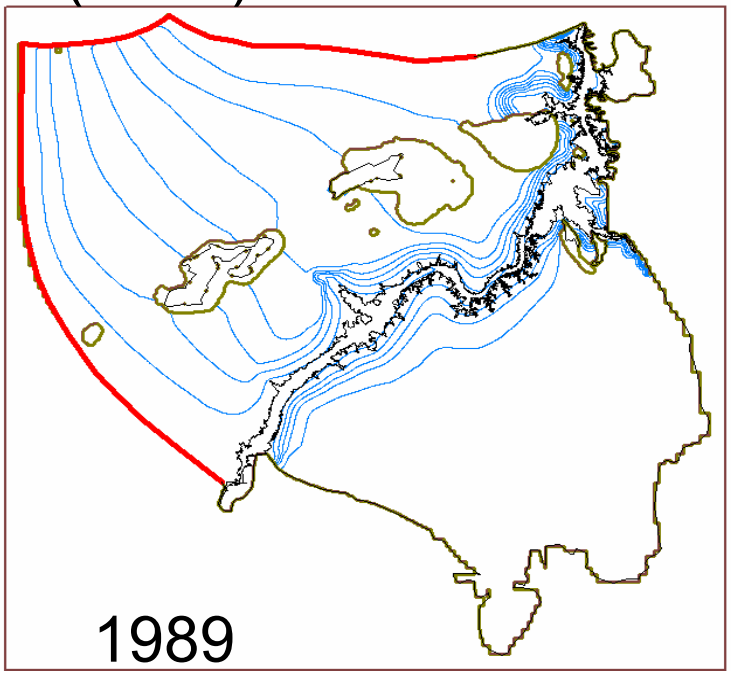


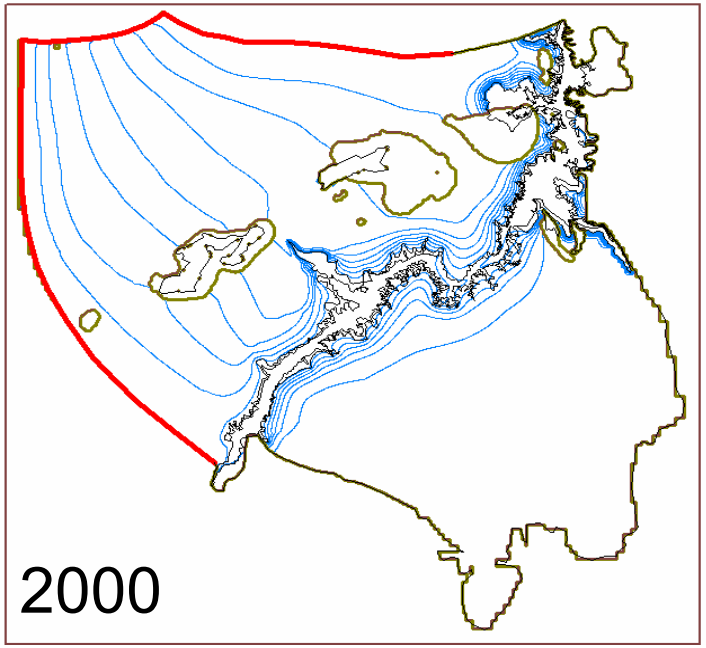
Initial Conditions

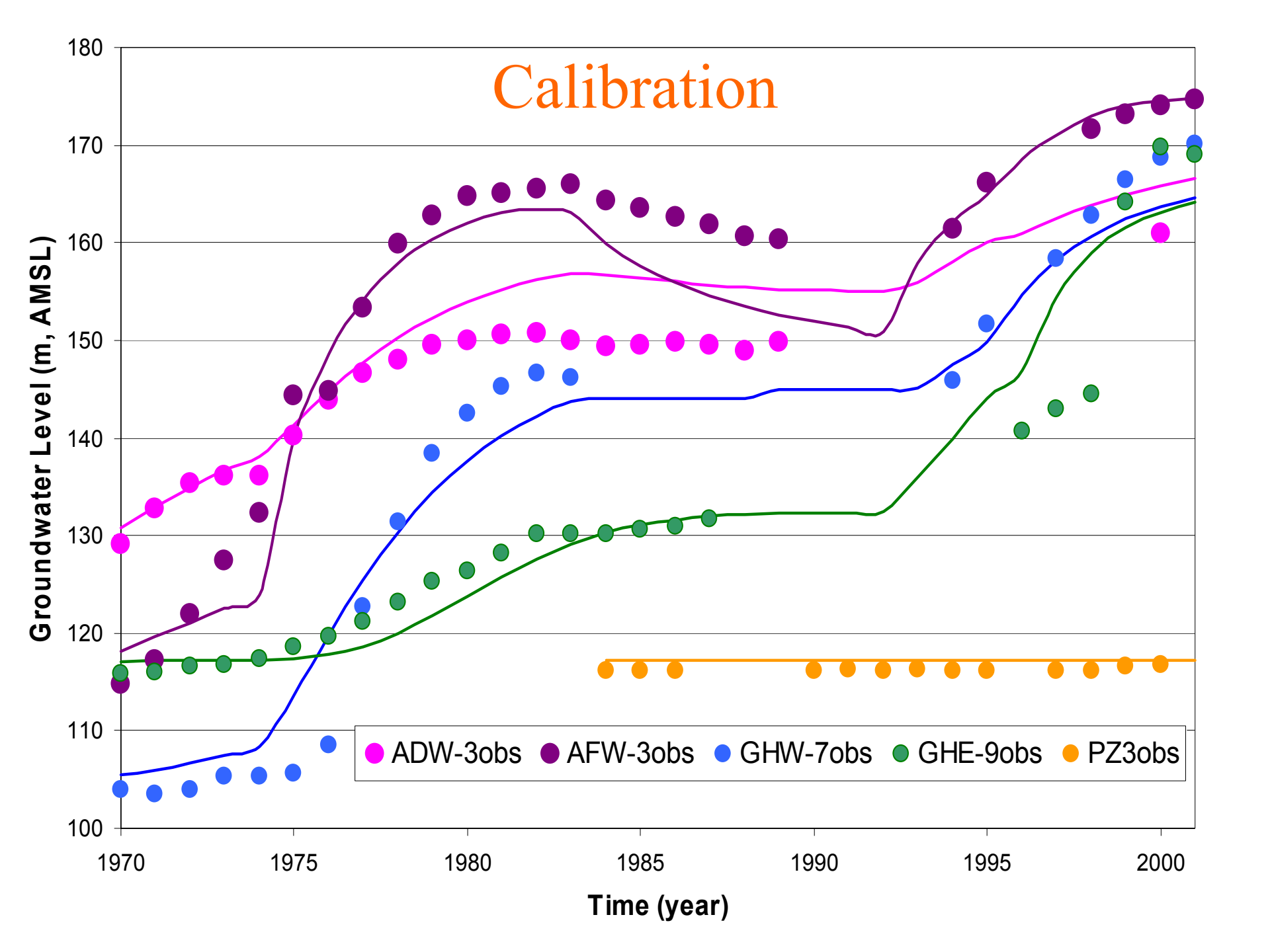
Calibrated Groundwater Head



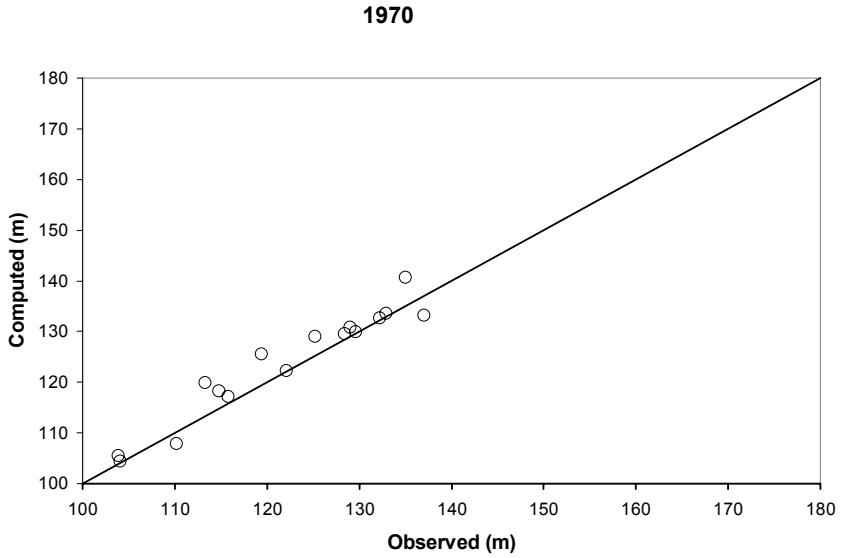


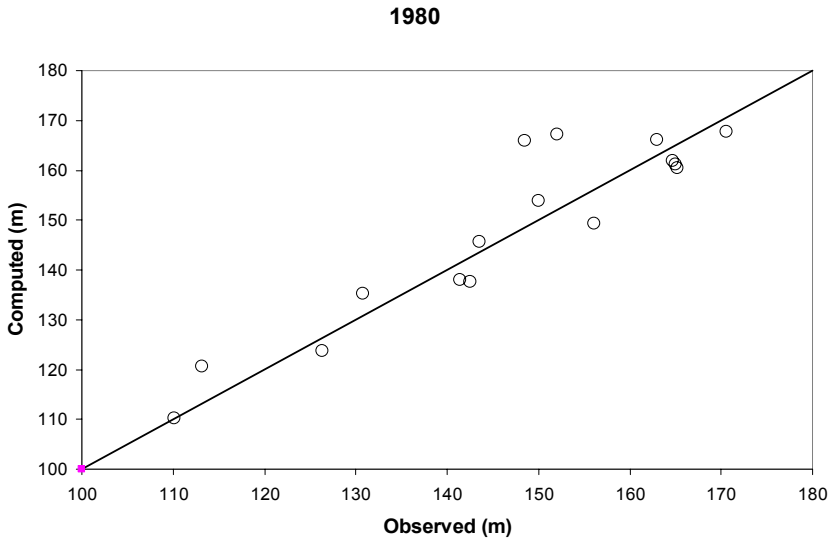


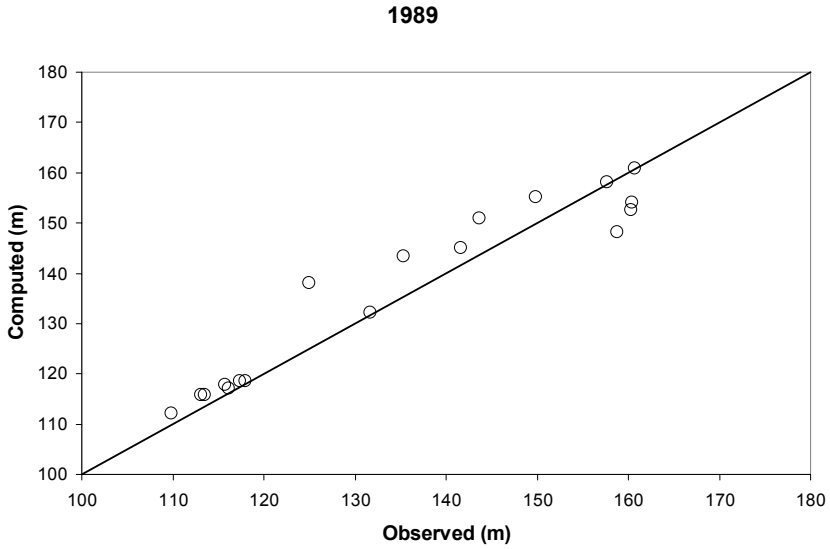


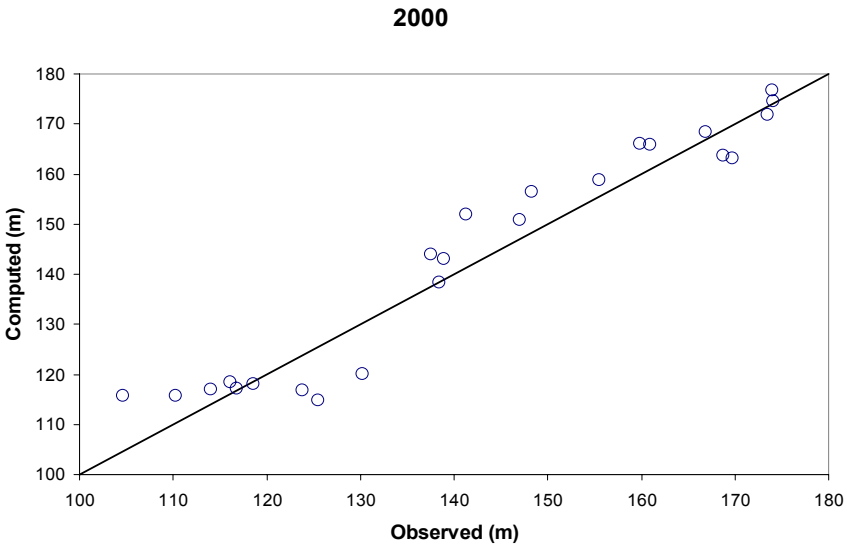

Calibration
Groundwater Level (m, AMSL)
180
170
160
150
140
130
120
110
100
1970
1975
1980
1985
1990
1995
2000
Time (year)
ADW-3obs
AFW-3obs
GHW-7obs
GHE-9obs
PZ3obs

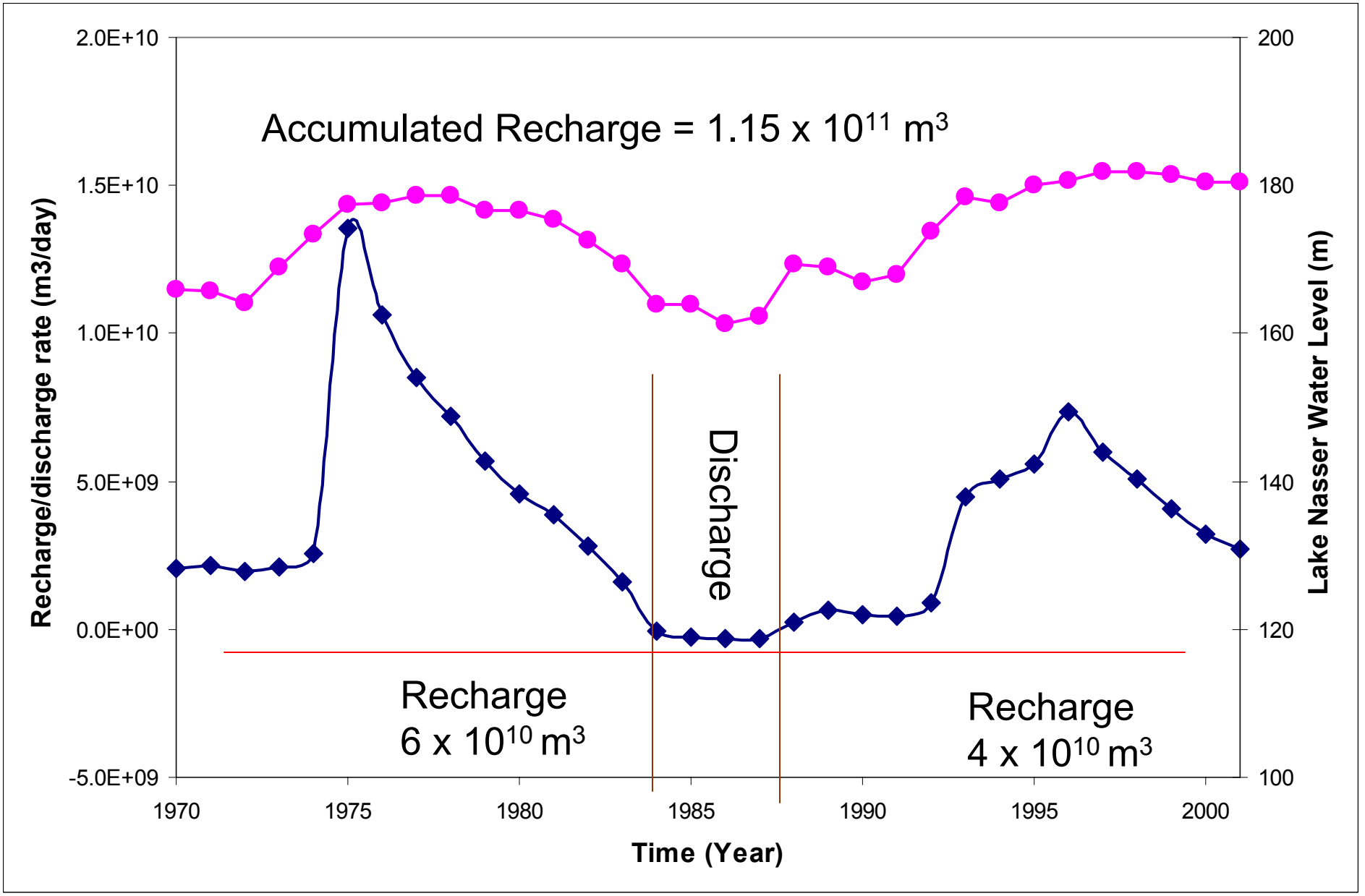
Calibration
Observed vs. Computed Head










Accumulated Recharge = 1.15 x 10^11 m^3
Recharge/discharge rate (m3/day)
Lake Nasser Water Level (m)
Time (Year)
2.0E+10
1.5E+10
1.0E+10
5.0E+09
0.0E+00
-5.0E+09
200
180
160
140
120
100
1970
1975
1980
1985
1990
1995
2000
Discharge
Recharge
6 x 10^10 m^3
Recharge
4 x 10^10 m^3

Where is all the extra water going?

Prelake Development 1998

January 1999

December 1999

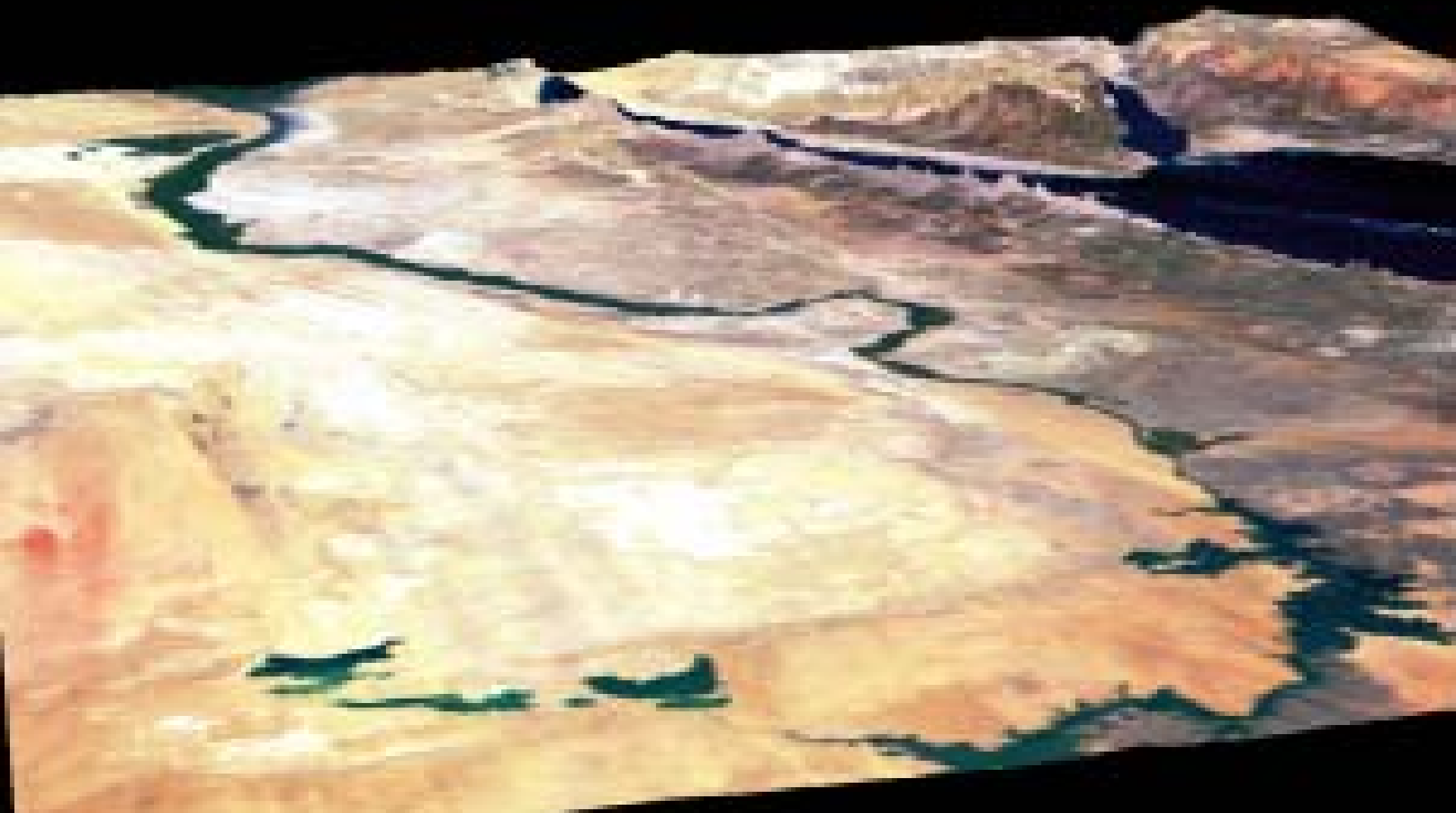
October 2000

March 2002

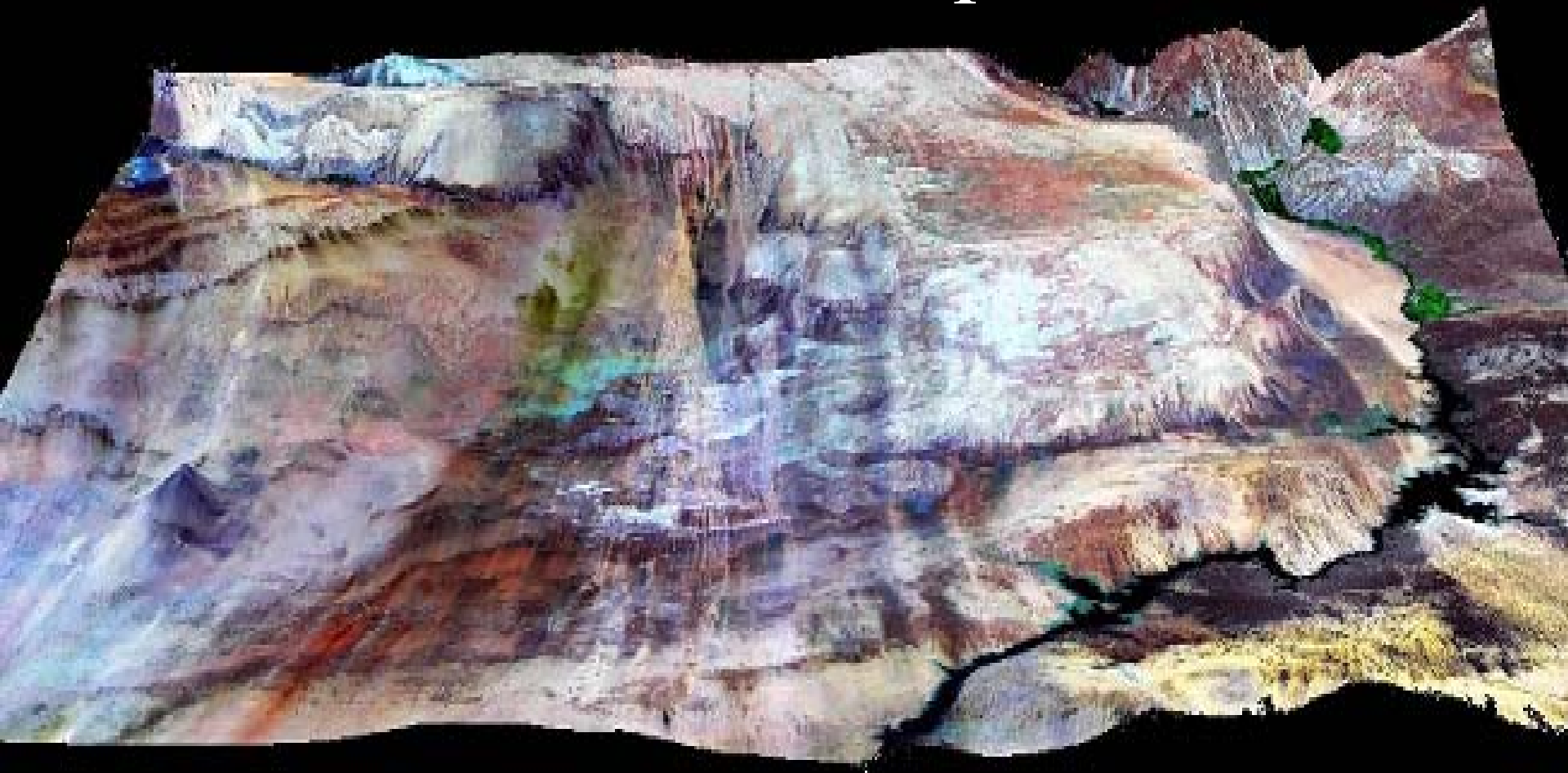
January 2003

As recharge decreases, more water becomes available…late 1998 water overflowed into the Tushka spillway & adjacent depressions

Answer the question where do we want the excess water to go?



Can we replenish the fossil water of the Nubian Aquifer?



Next Steps…

How much excess water will be available (from historic River Nile inflow)?

Futuristic simulation: Surface runoff models based on: (a) output of groundwater flow models, (b) predicted lake elevations from historical River Nile flow records, and (c) good DEMs from ASTER

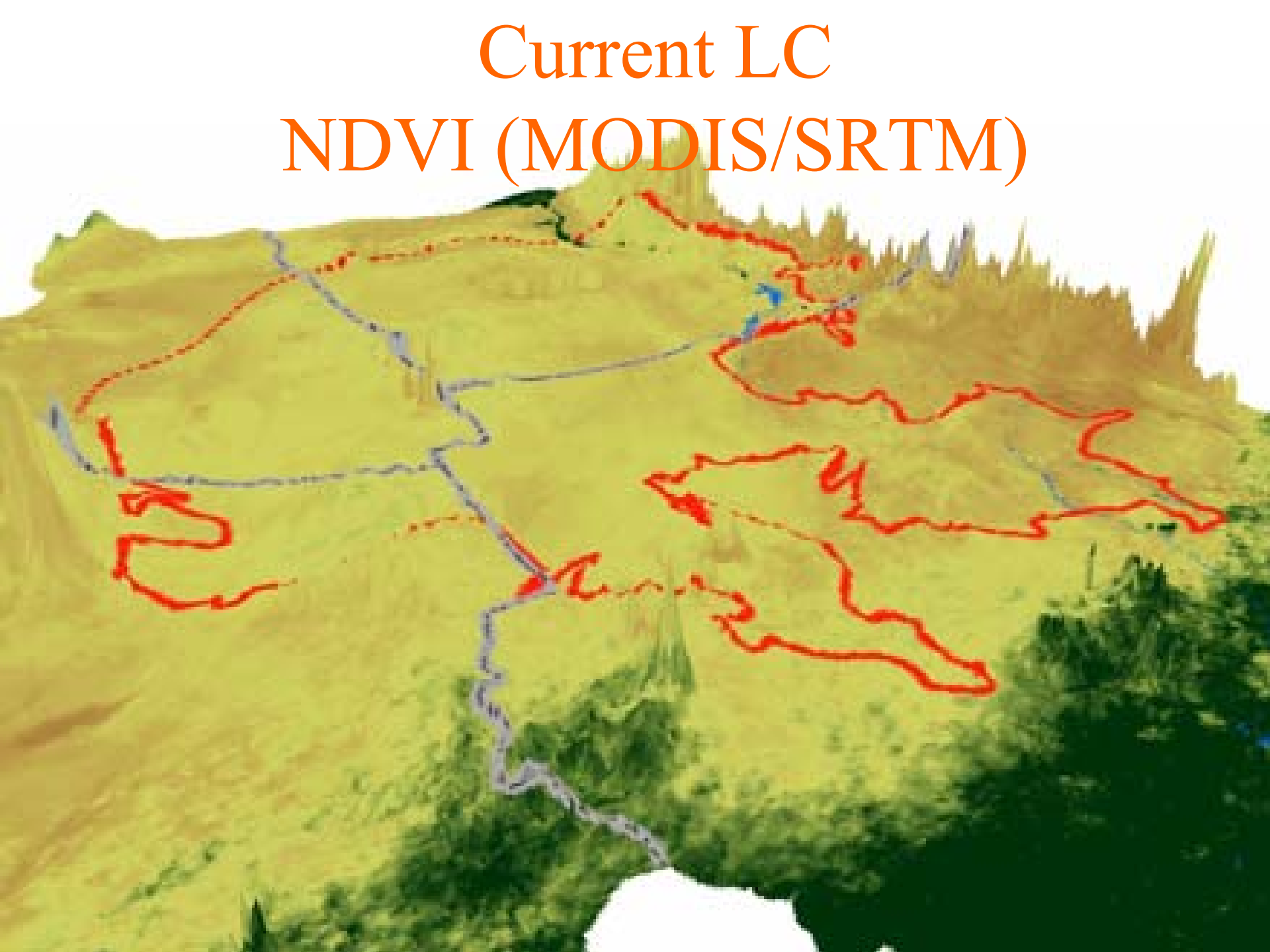
Objectives & Implications
PART II - Millennial LCC

Define millennial LCC using inferences from various RS data sets

Understand the impacts of millennial (related to paleo- climatic changes) LCC on the Nubian aquifer System

Results will assist in the development of proper water management schemes for sharing the "international waters" of the Nubian Aquifer.

Current LC
NDVI (MODIS/SRTM)

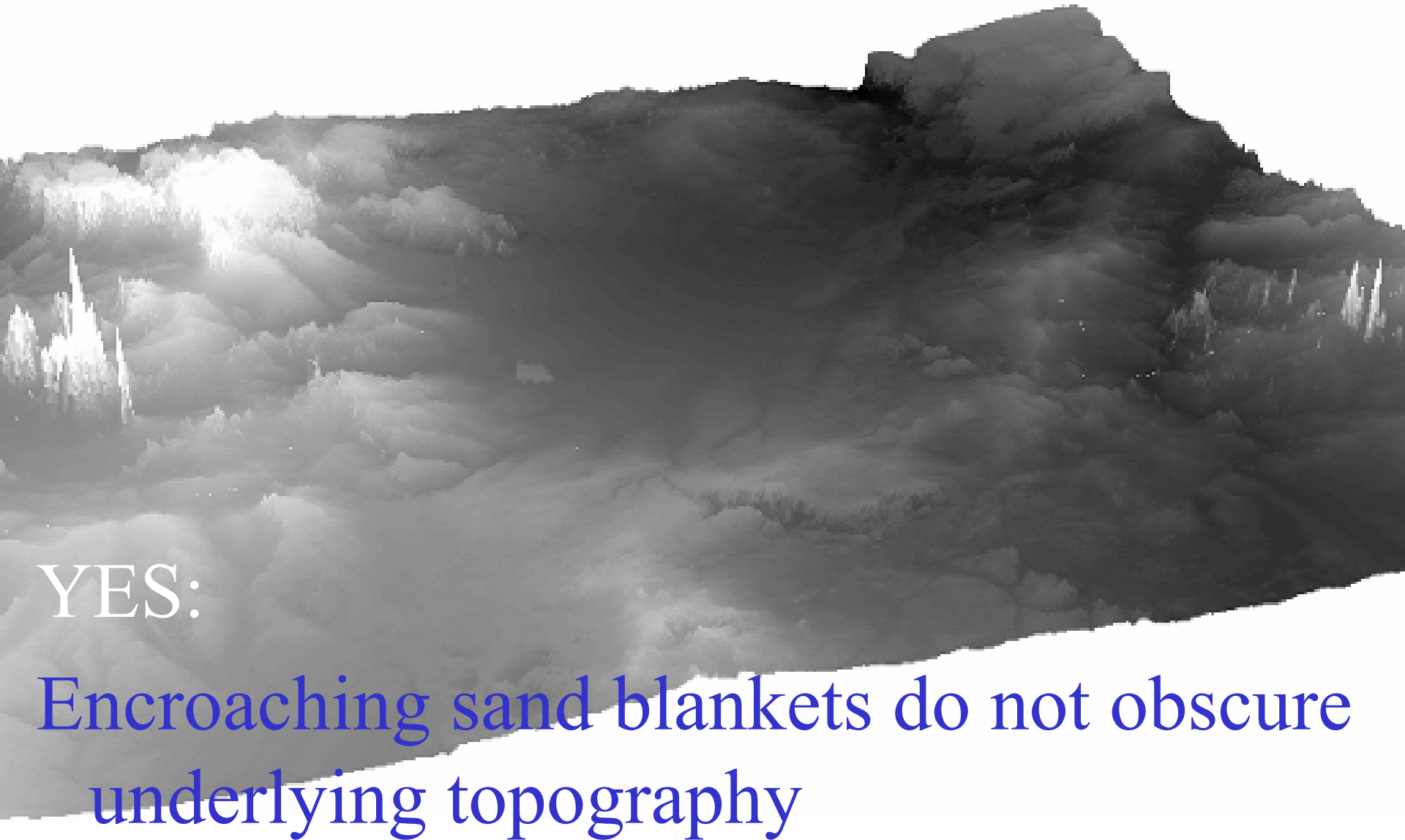


Is this the paleo- LC?


If yes, there must be paleo-watersheds;
Can we see Paleo-LC in TM data?
NO: Because of encroaching sand
TM band 7

Can we see Paleo-LC in SRTM?

3-D SRTM (vertically exaggerated)



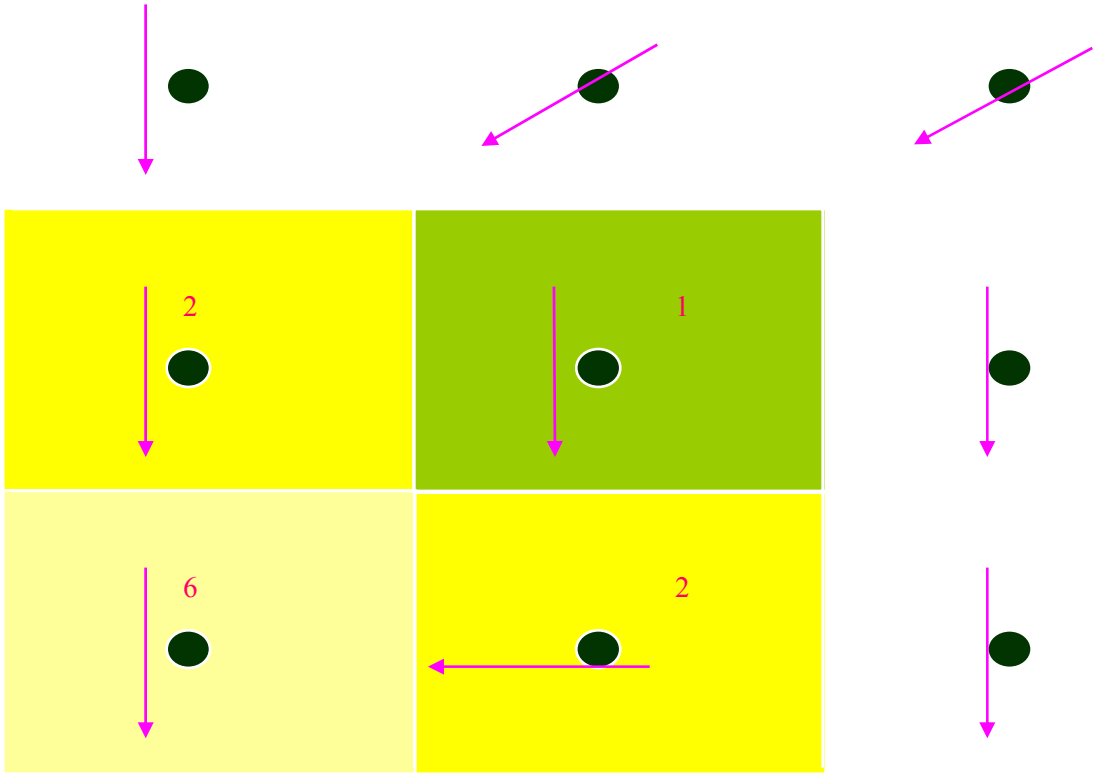
YES:

Encroaching sand blankets do not obscure underlying topography

Can we map Paleo-LC (watersheds) from SRTM?

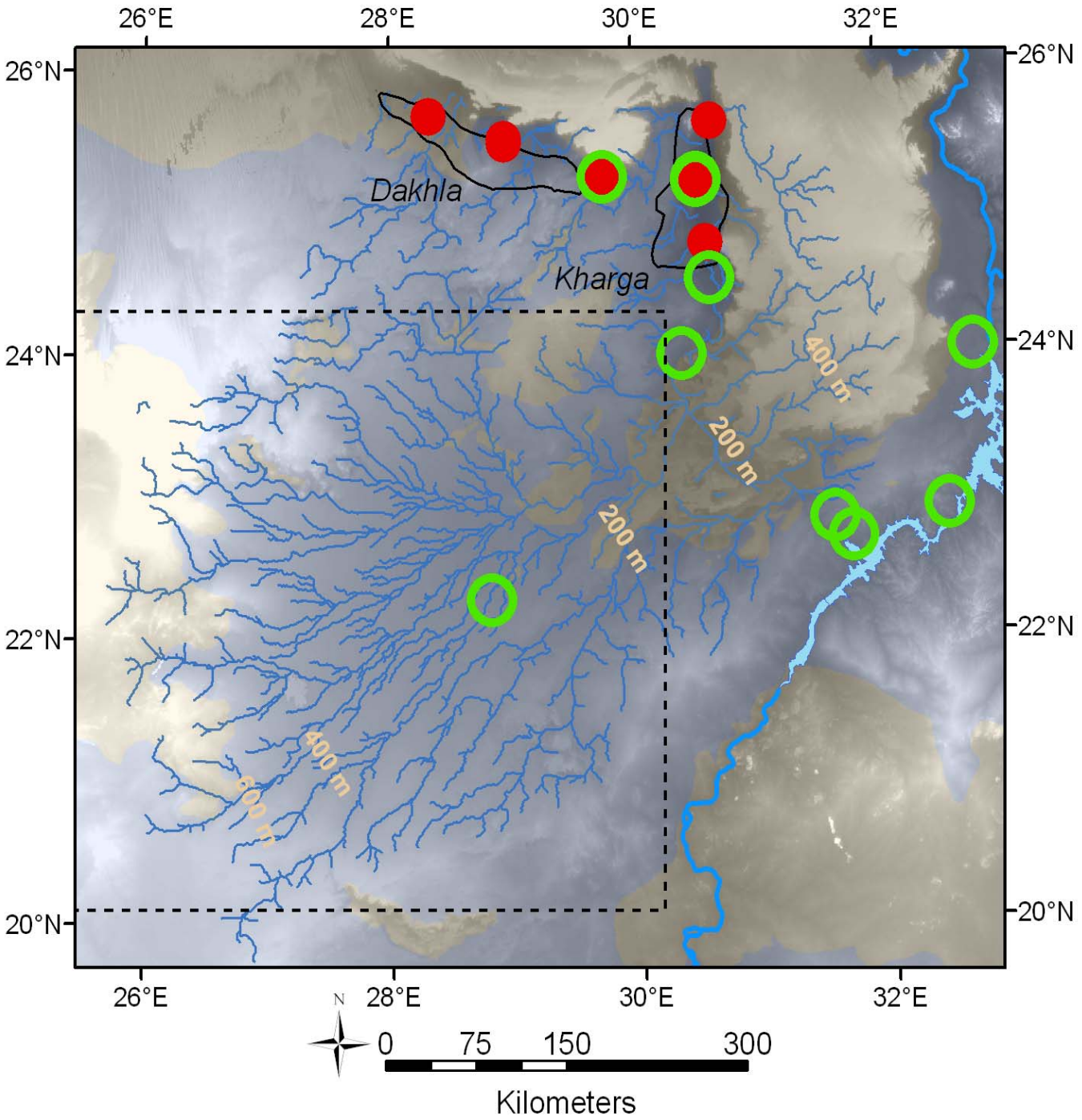
- Topaz technique

Cells draining to the same outlet point belong to the same watershed



YES:

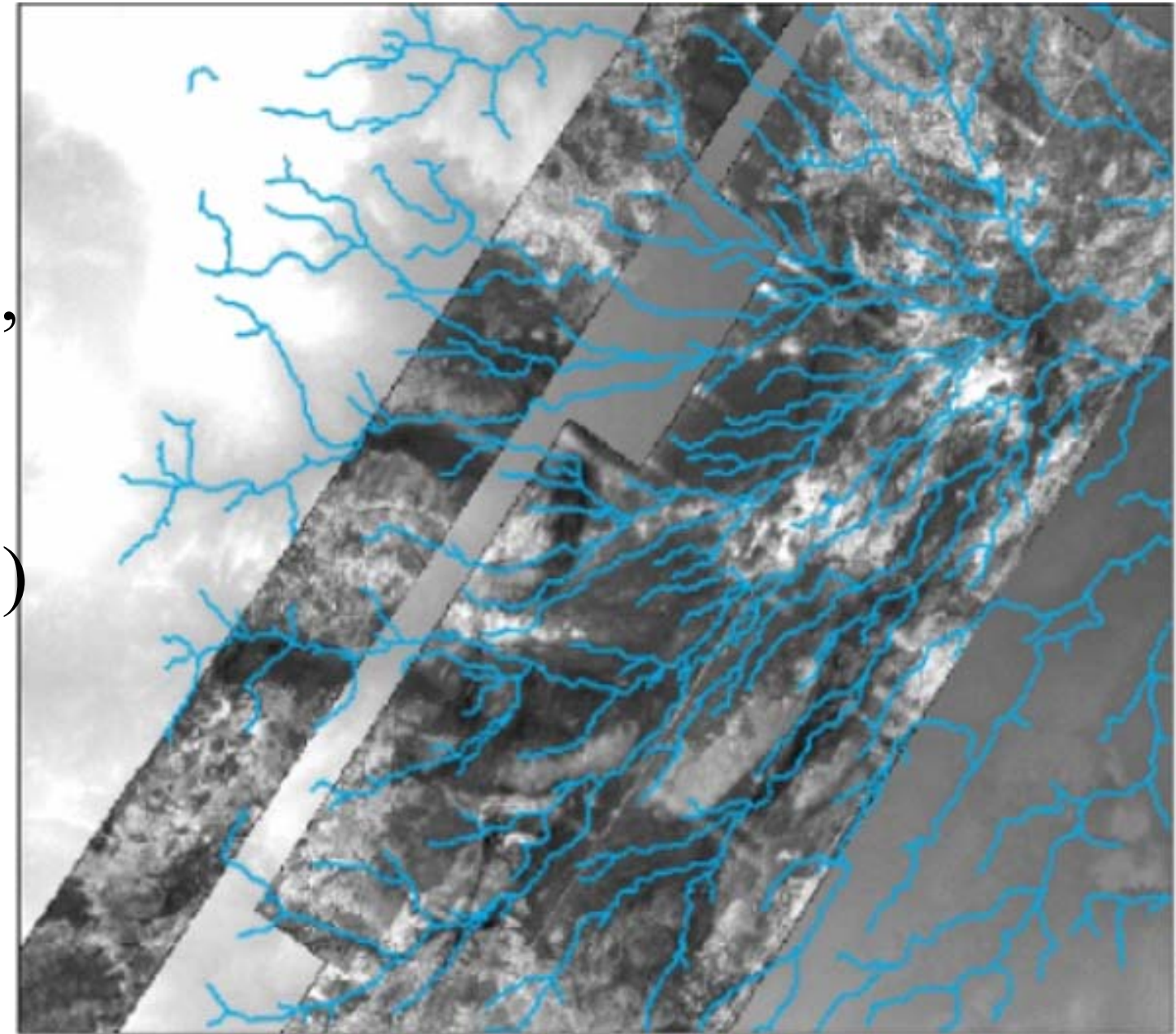
Watershed delineated using 1 km SRTM



Can we verify LCC using SIR-C?

Yes:

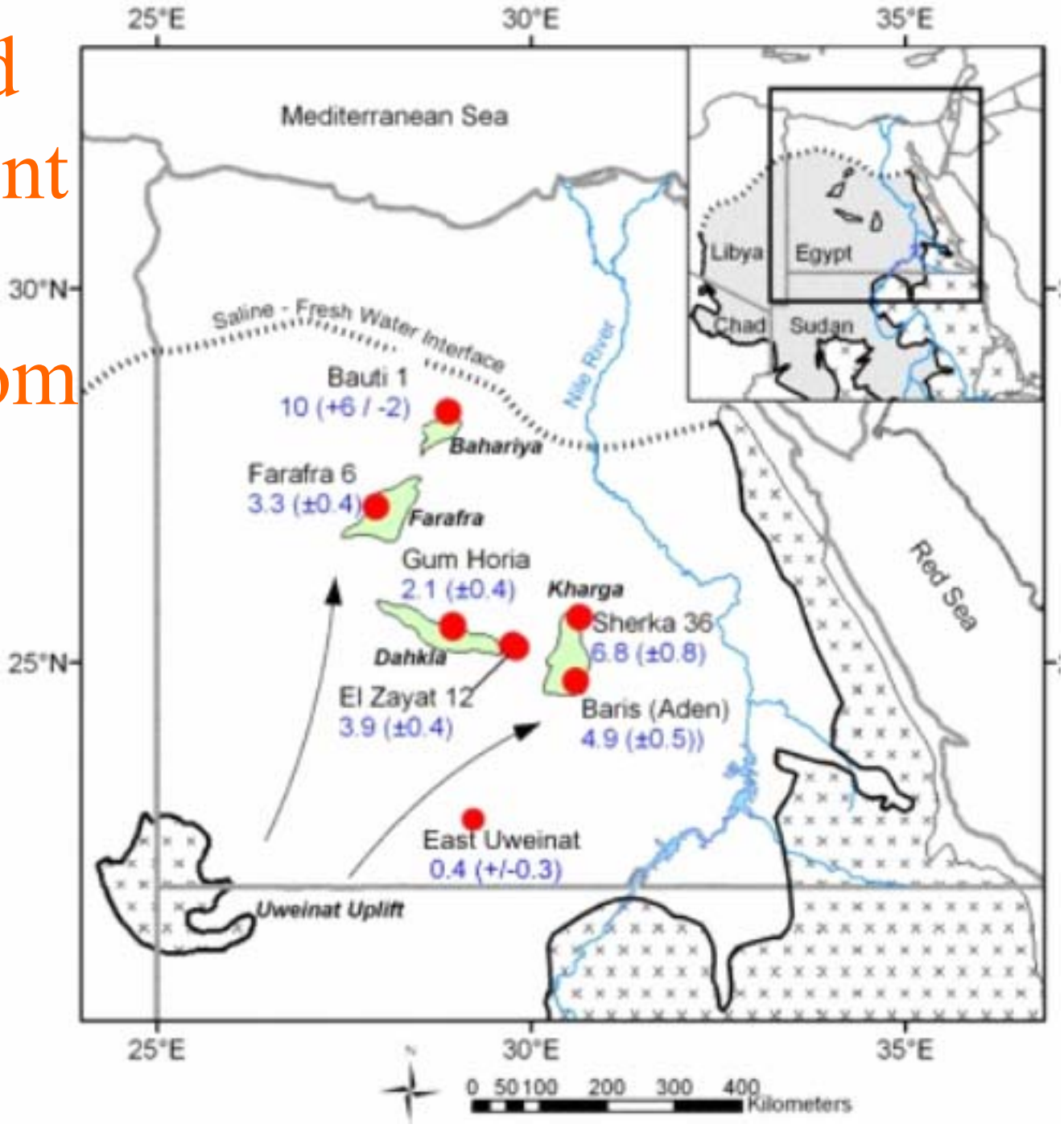
In dry areas, SIR-C can penetrate (few meters)



Is the inferred LCC consistent with inferences from groundwater ages?

YES:

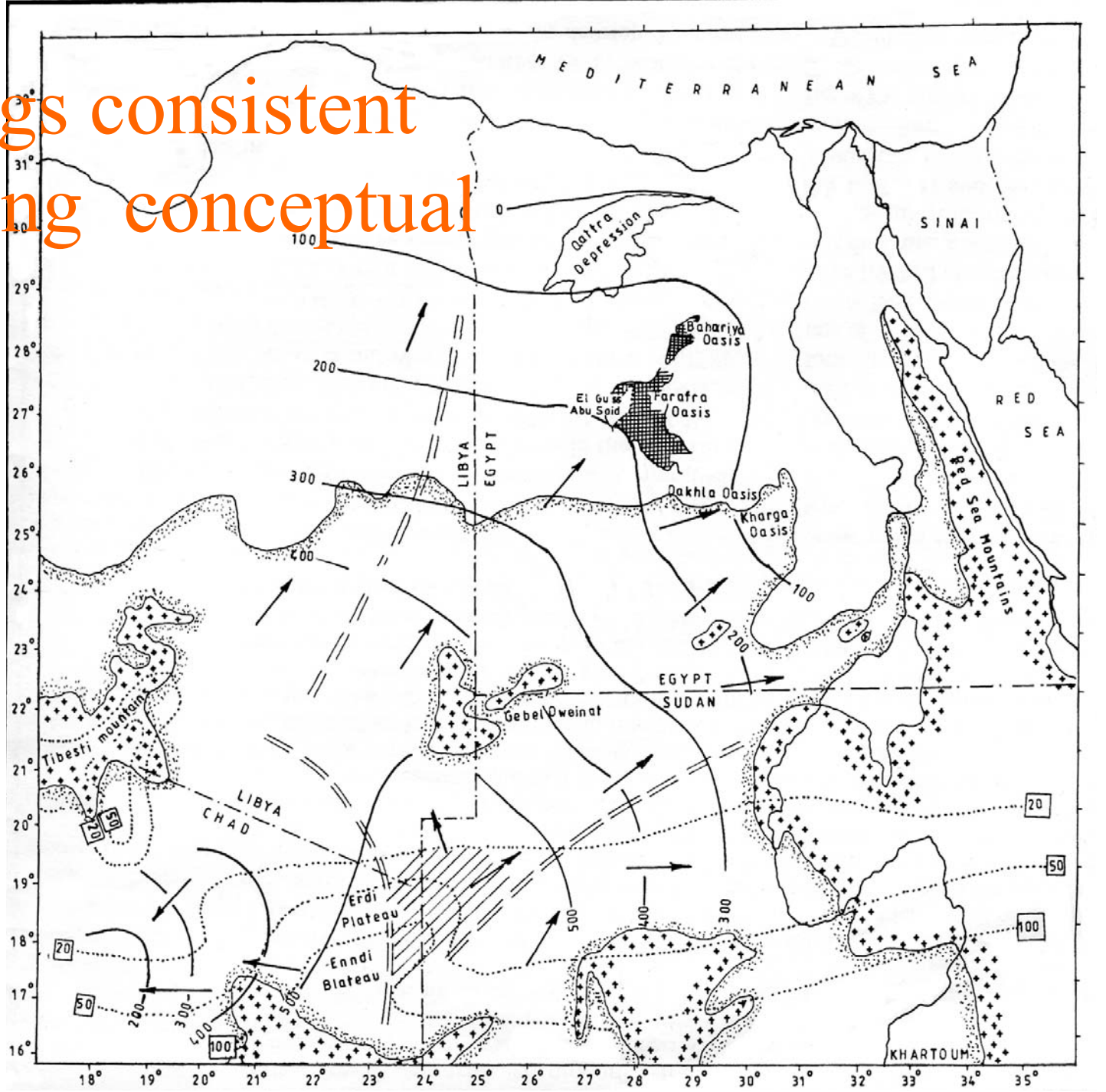
Age gradient from SW to NE in Egypt only



Are findings consistent with existing conceptual Models?

NO:

Flow does not originate in Chad



Results

LCC was inferred from Landsat TM (current) and SIR-C/SRTM data and dating techniques (paleo) in southern Egypt & northern Sudan

LCC should not necessarily be inferred from temporal remote sensing data; rather through the correlation of inferences from different RS data sets; *similar applications could be adopted by the LCLUC program*

Results

Autochtonous recharge of the Nubian aquifer in Egypt during previous wet climatic periods

An understanding of the impacts of LCC on the hydrology of the Nubian System requires similar applications across the entire Nubian Aquifer