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The State of Understanding on Groundwater Recharge for the Sustainable Management of Transboundary Aquifer in the Lake Chad Basin

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Objectif of the Presentation

- **This presentation provide critical data for hydrogeologists and engineers who are concerned with transboundary groundwater management and also indicate the need for improved techniques to conserve and augment natural groundwater recharge.**

Presentation of the Lake Chad Bassin

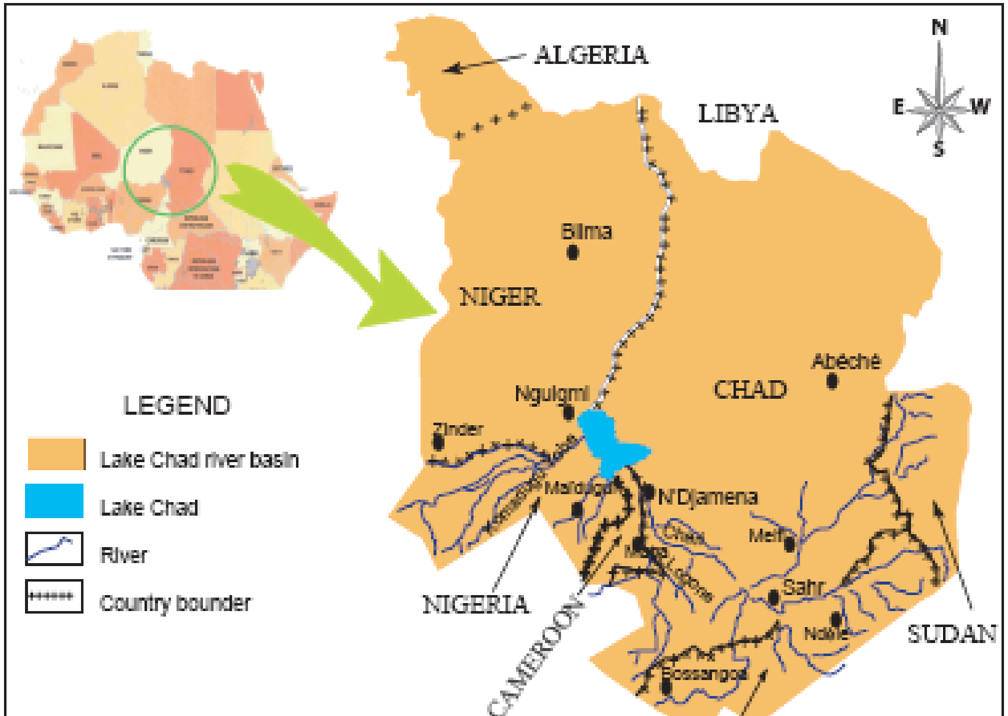
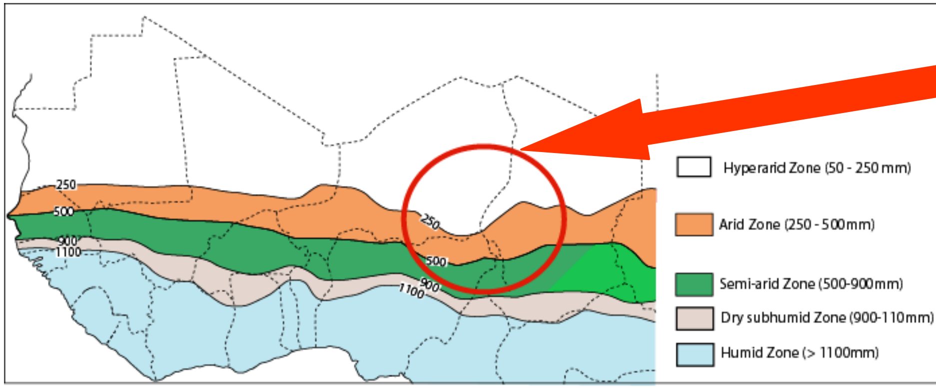


Fig. 1 Lake Chad watershed

- The Lake Chad Basin covers a large part of central Africa with an area of about 950,000 square miles.
- Lake Chad is a vitally important wetland.
- About 95% of the total surface flow into the lake comes from the Chari-Logone Rivers systems.
- The Komadugu Yobe, the Yedseram and the El Beïd Rivers are relatively large streams that discharge into lake Chad during the wet season

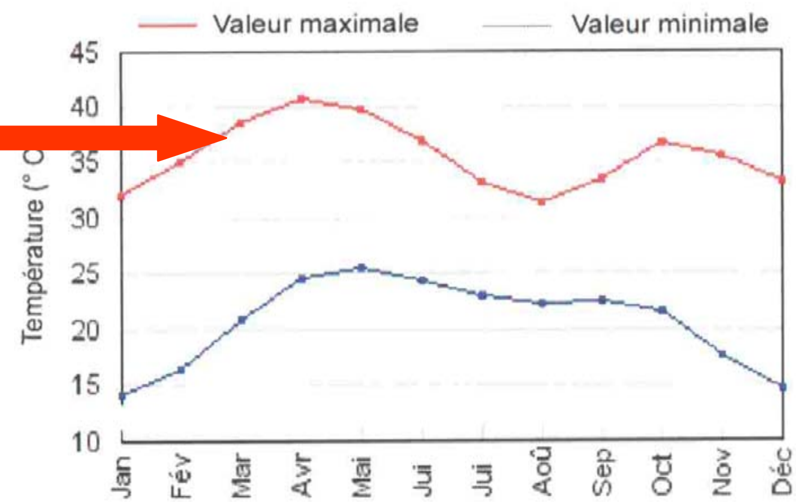
➢ The Lake Chad basin is a transboundary river basin and groundwater shared by Cameroon, Chad, Niger, Nigeria, Sudan and CAR. * In this basin, water is highly valued due to its scarcity, fragility, unequal distribution and wide exploition.

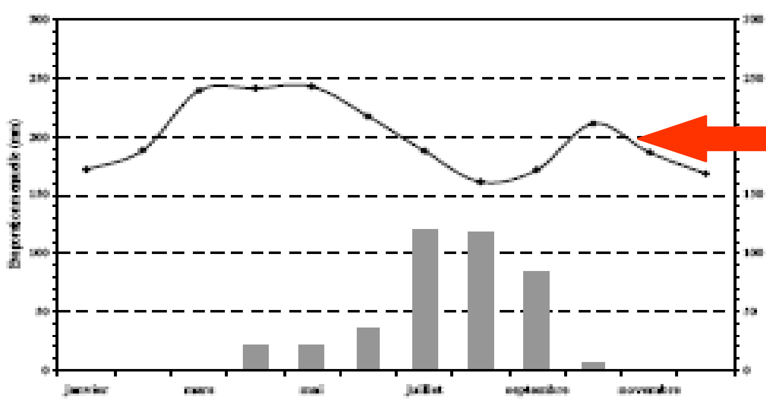
Presentation of the Lake Chad Bassin



- A great variation exists in the distribution of annual rainful from north to south.

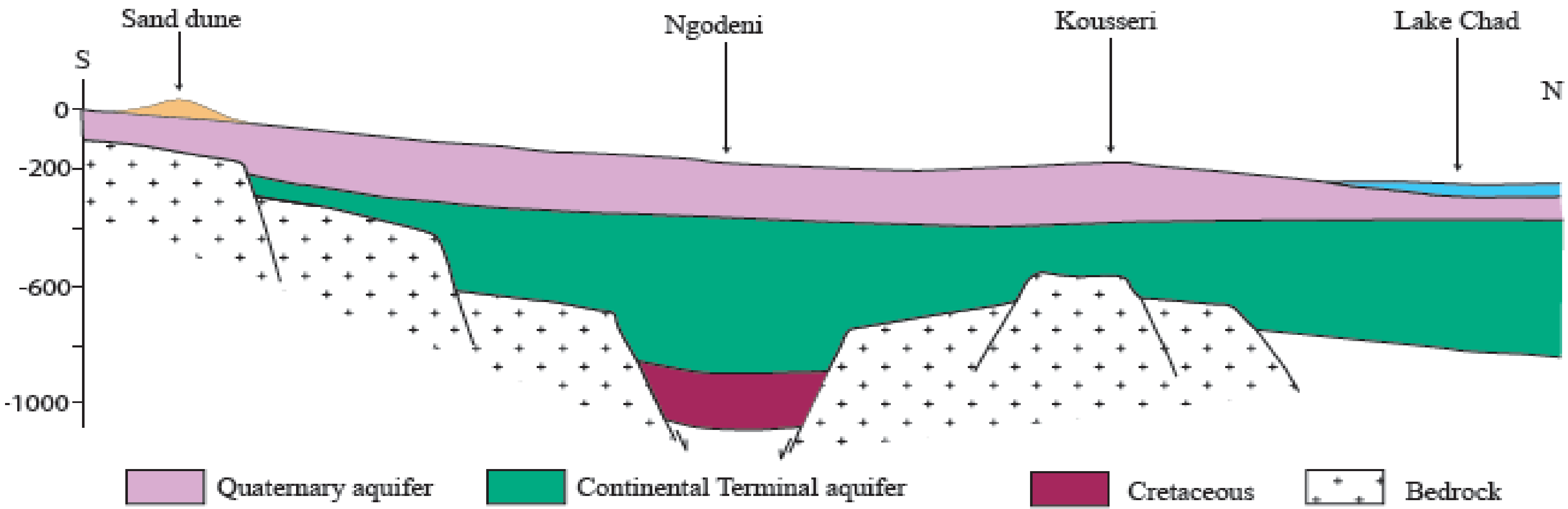
- The maximum daily temperature is often 40°C, and in some places it is as high as 50°C in April and May. During the rainy season temperature range from 13°C to 20°C.





- Evaporation rates are very high, particularly during the dry, hot season from March to June. The total annual evaporation is about 80 inches from free water surfaces.

Presentation of the Lake Chad Bassin



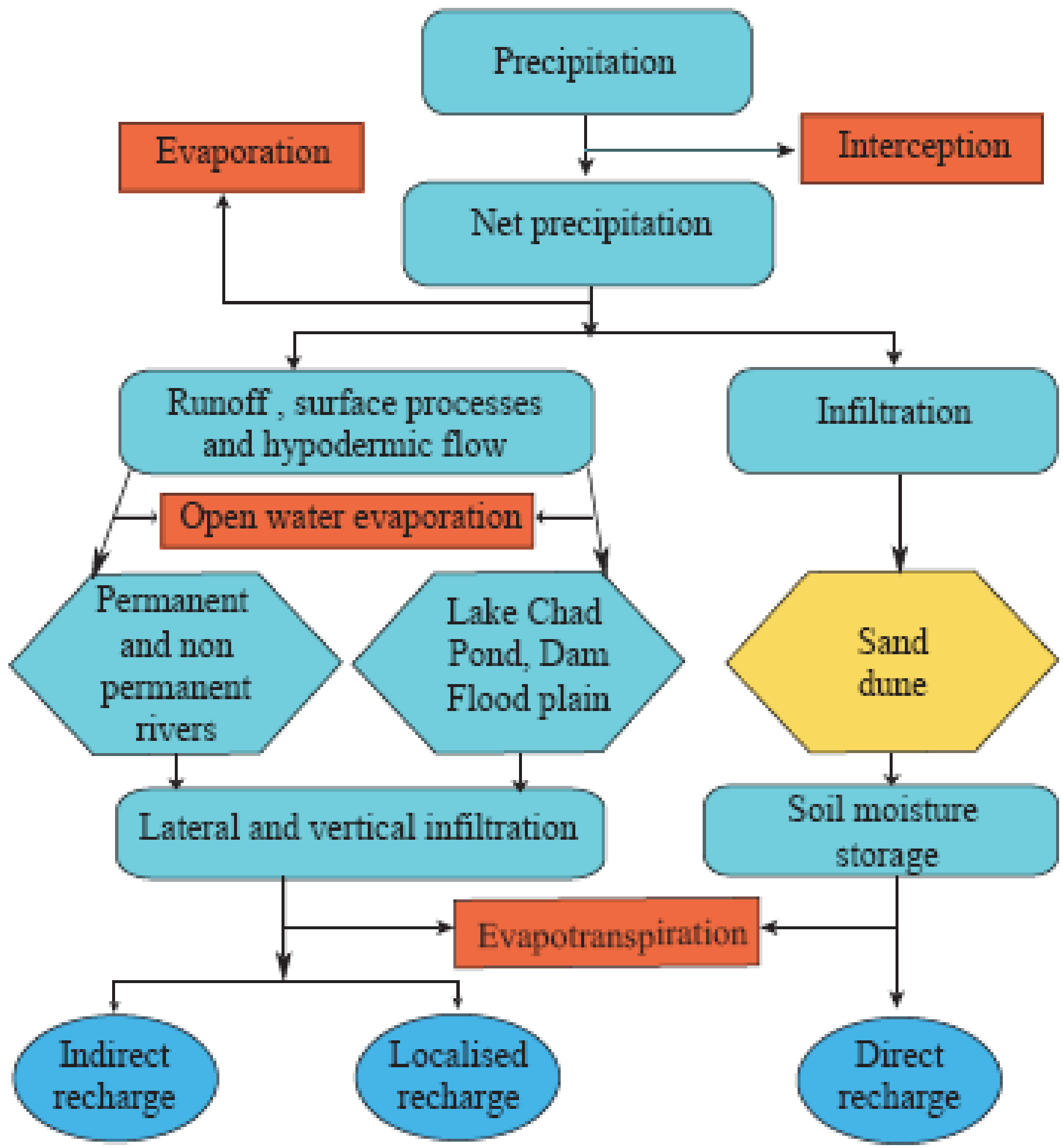
- The Lake Chad basin is a sedimentary basin formed in the Mesozoic era.
- According to the geological classification, two aquifers may be distinguished, the Quaternary and the Continental Terminal aquifers.
- The Quaternary deposits contains the principal identified aquifers. Deep to this unit is extremely variable ranging from 10 to 70 m.
- Groundwater occurs under both unconfined and confined conditions.

Sources of Recharge in the Lake Chad Bassin

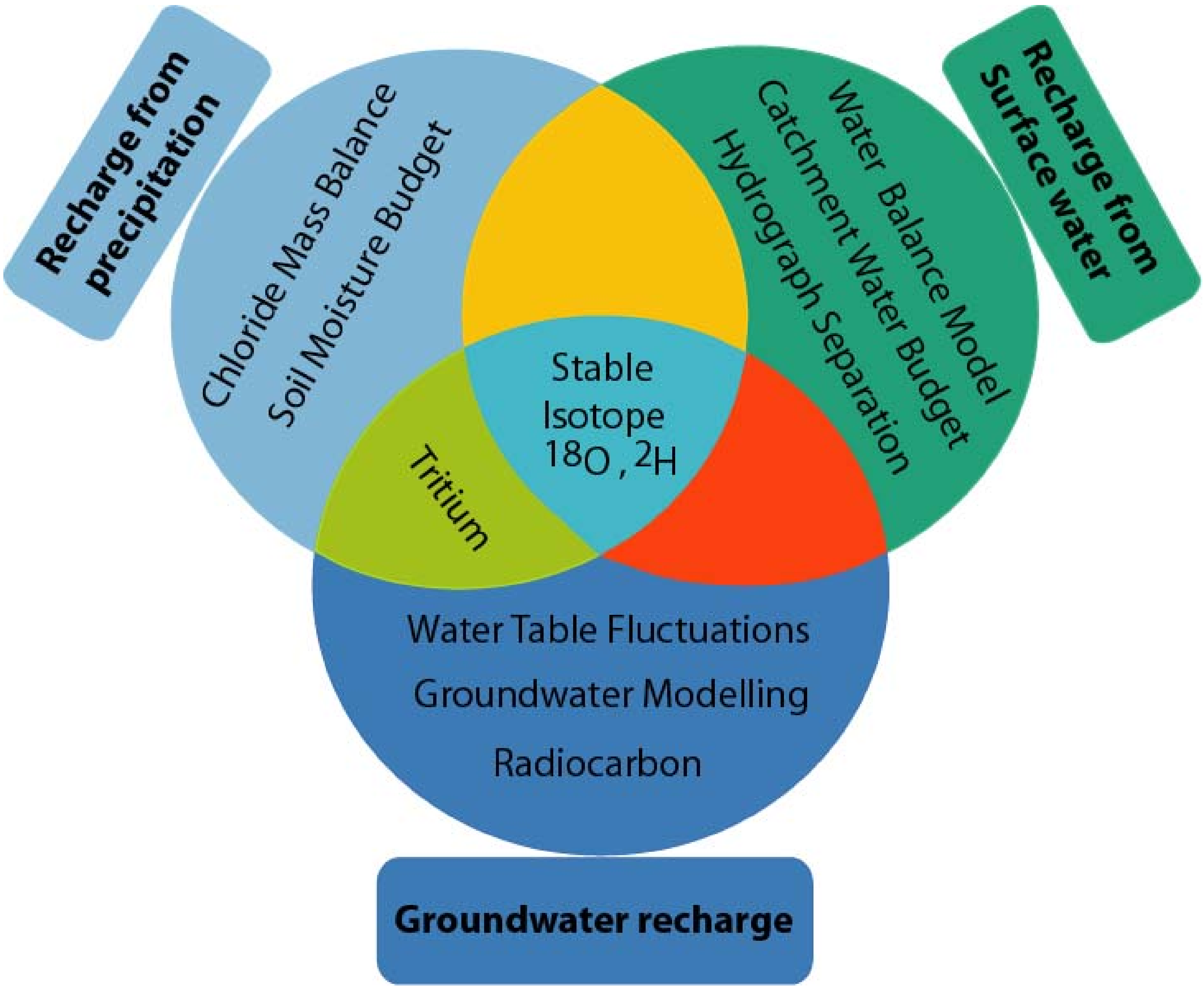
- Since the 1960's, considerable effort has gone into the estimation of natural recharge rates in various hydrogeologic environment of the Chad basin.

- Direct recharge results from vertical percolation of precipitation through the sand dune.

- Indirect and localised recharge results from percolation from secondary features such as ponds, lakes and other surface water bodies.

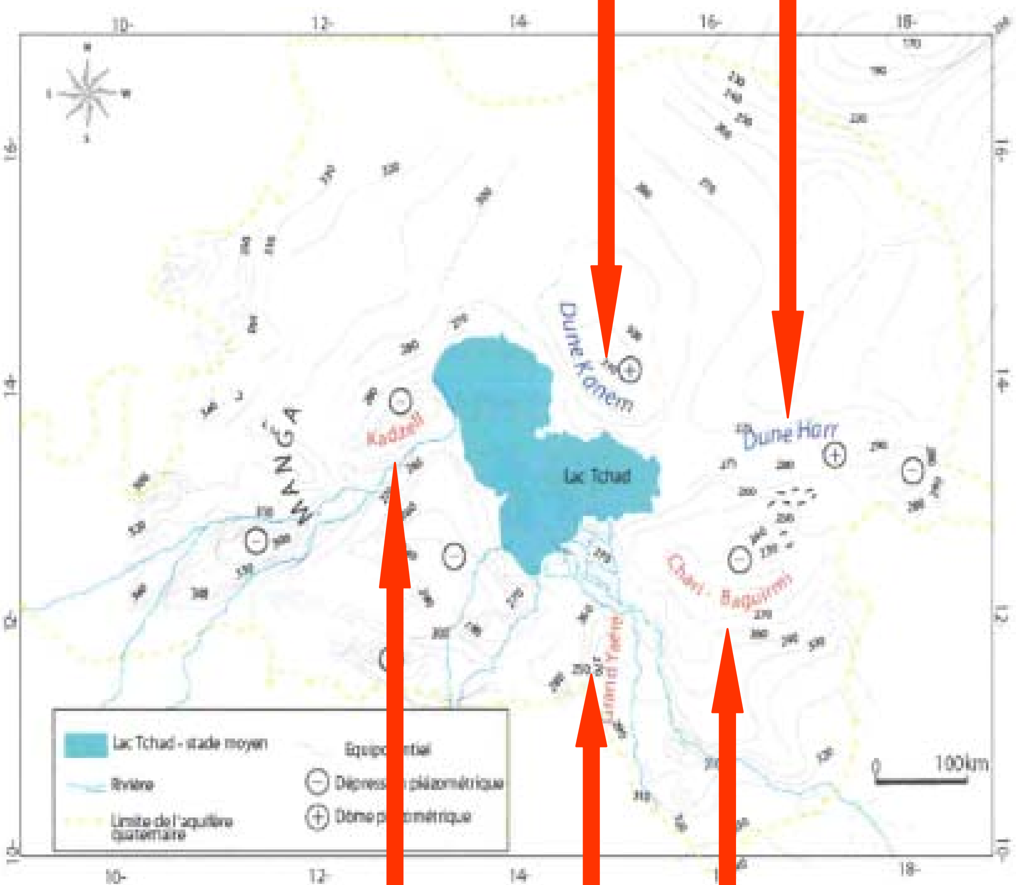


Recharge Estimation Methods Applied in the Lake Chad Bassin



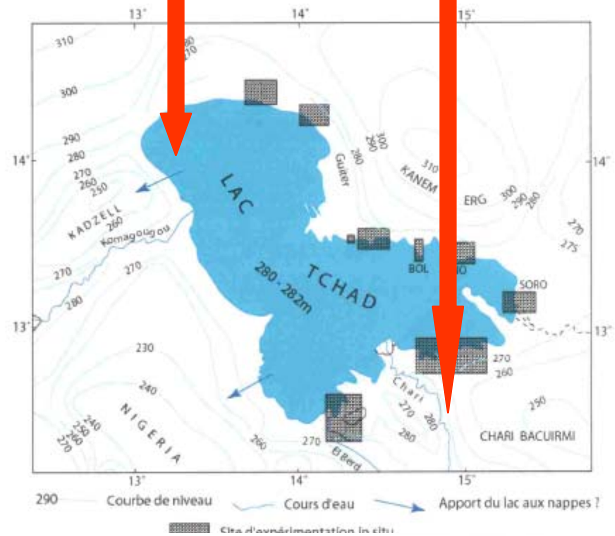
Results from Water Table Fluctuations

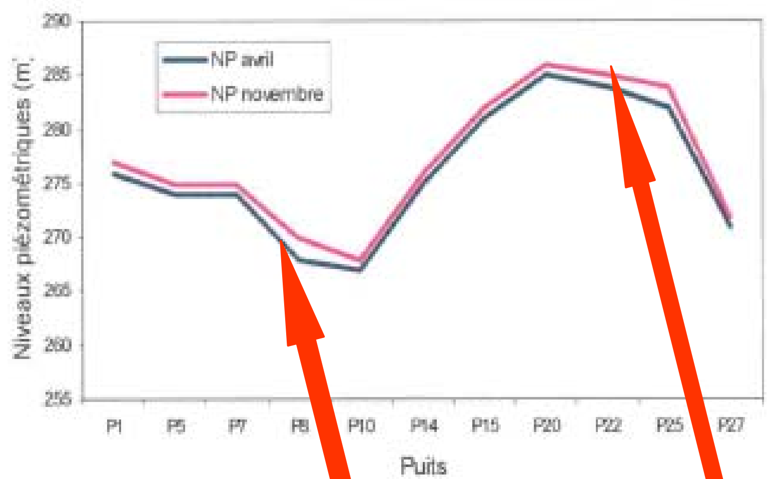
Piezometric dome near the sand dunes



Piezometric time-measurements highlight a generalized groundwater lowering (closed depression).

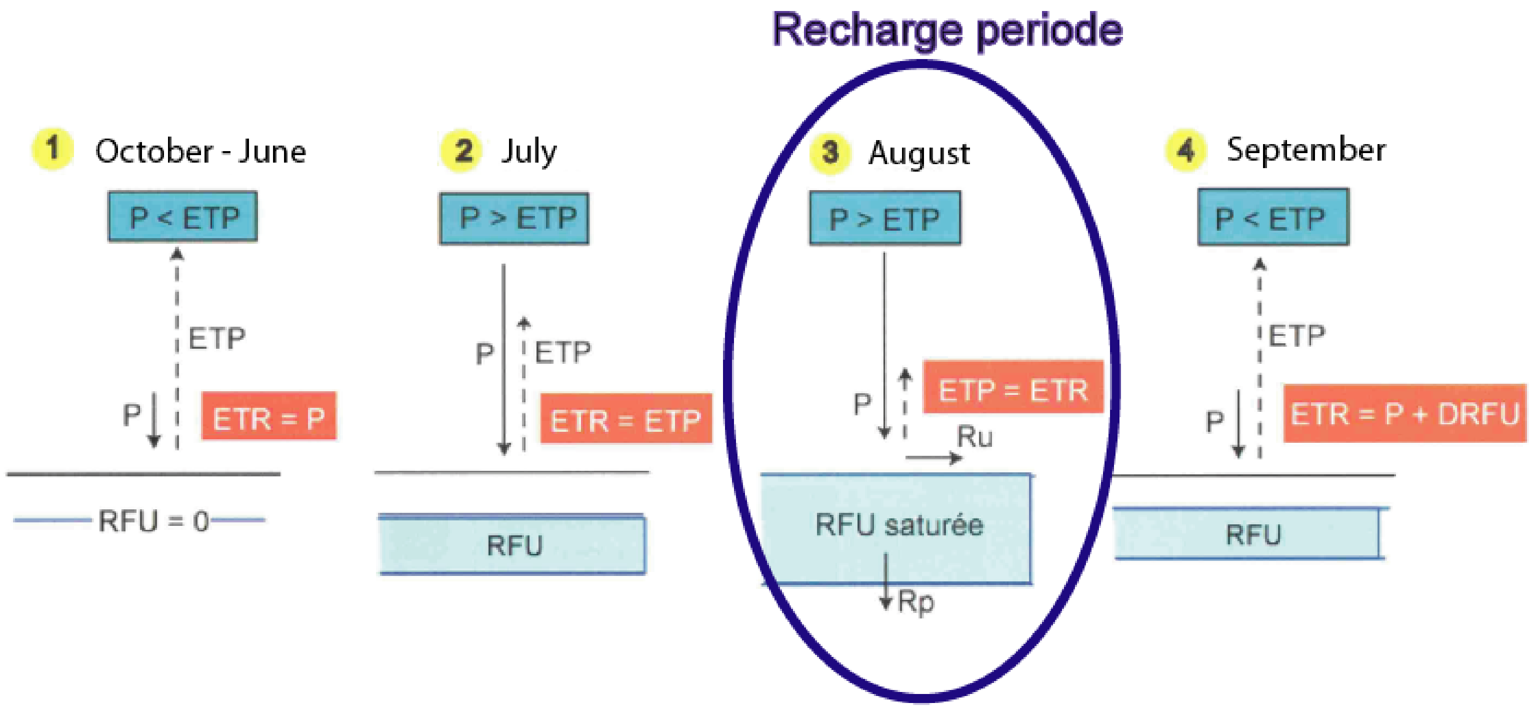
Recharge fronts coming from the Lake and rivers.





Groundwater levels during wet season are always higher than those during the dry season

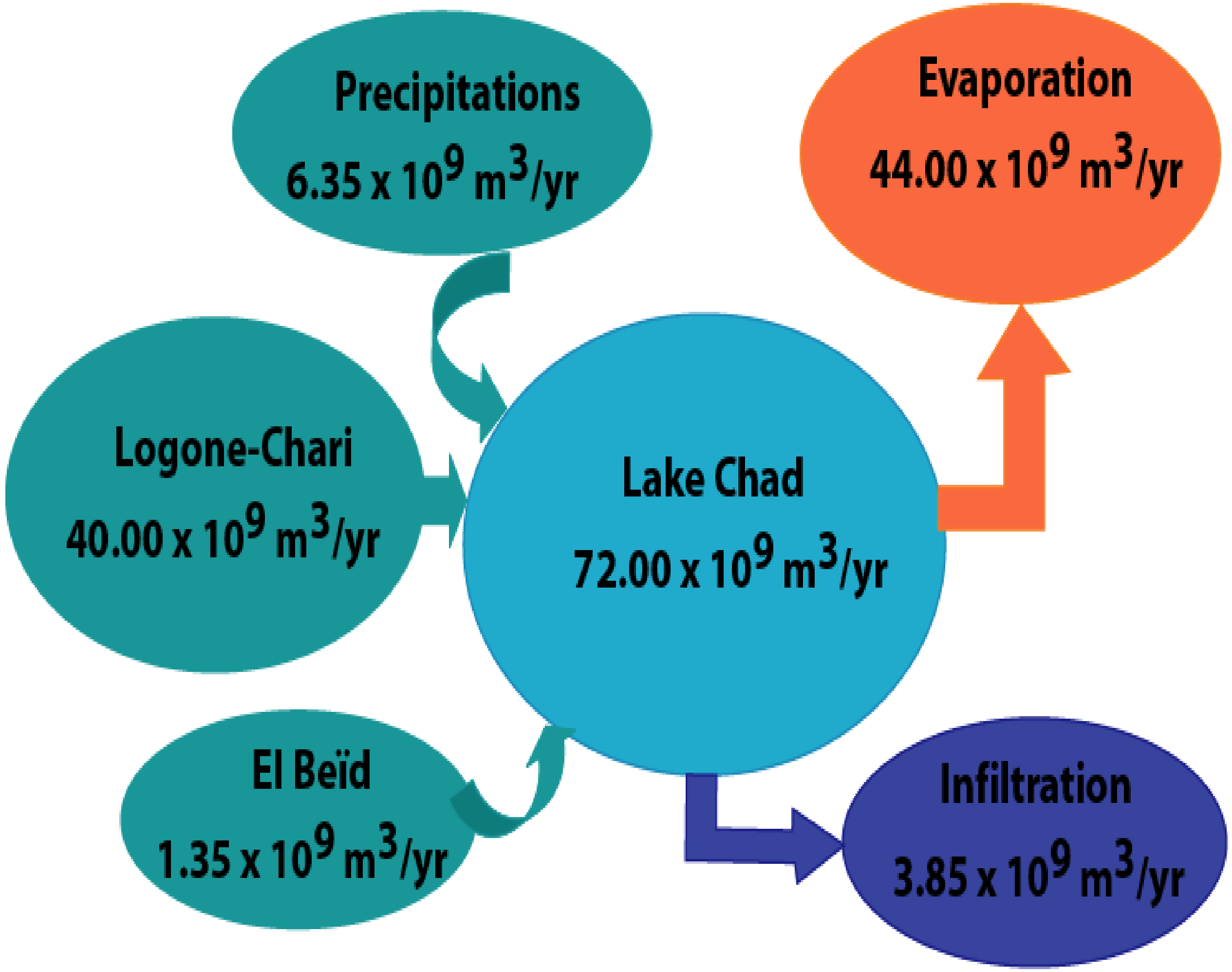
Results from Soil Moisture Budget (Thornthwaite Method)



Locality	Infiltration (mm/yr)	Period	Annual rainful(mm)	Reference
Grand Yaere (Cameroon)	50 - 200	1970-1985	600	Ngounou *et al.* 2007
Western Niger	25 - 50	?	550	Leduc *et al.* 1996
North Senegal	0 - 58	1977-1980	250	Tandia, 1990
Geneina (Sudan)	62	1971-1990	500	El Tayeb, 1993
Katchari (Burkina-Faso)	50 - 100	?	513	CIEH-BRGM, 1976
Center Mali	50	?	500	CIEH-BRGM, 1976

Results from Catchment Water Budget

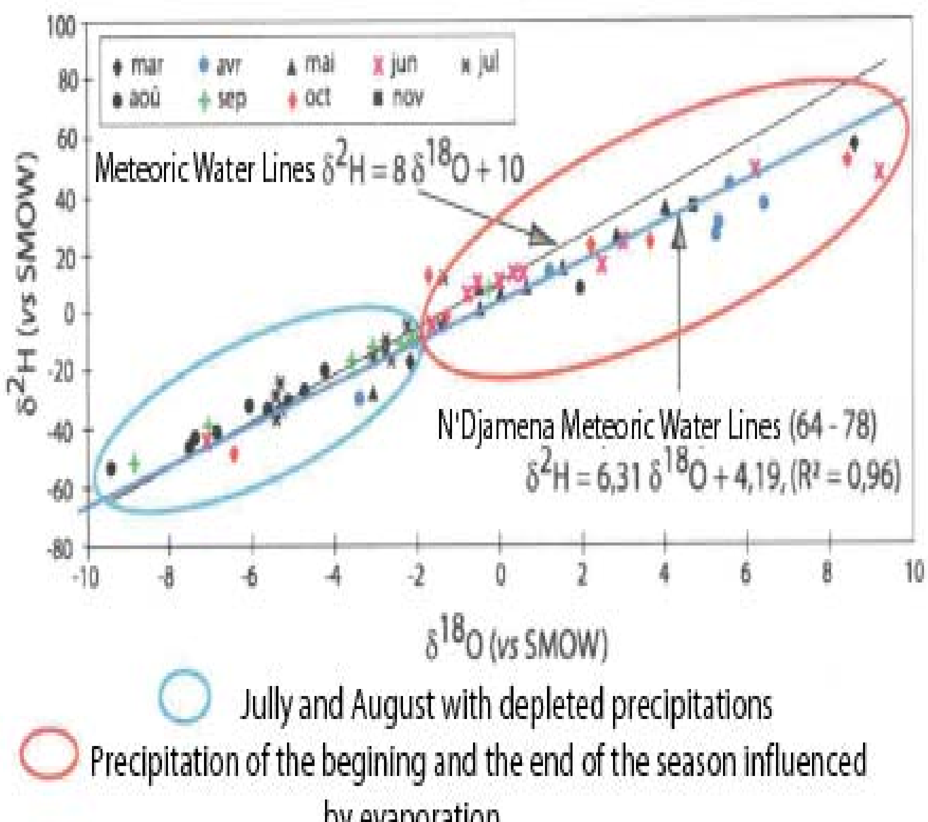
➢ Little work has been carried out to assess the total balance, and recharge and abstraction rates are poorly defined



Catchment Water Balance (Data from Carmouze, 1976)

Evaporation (91.95 %) Infiltration (8.05 %)

Results from Rainwater Stable Isotopes (^{18}O , ^{2}H)



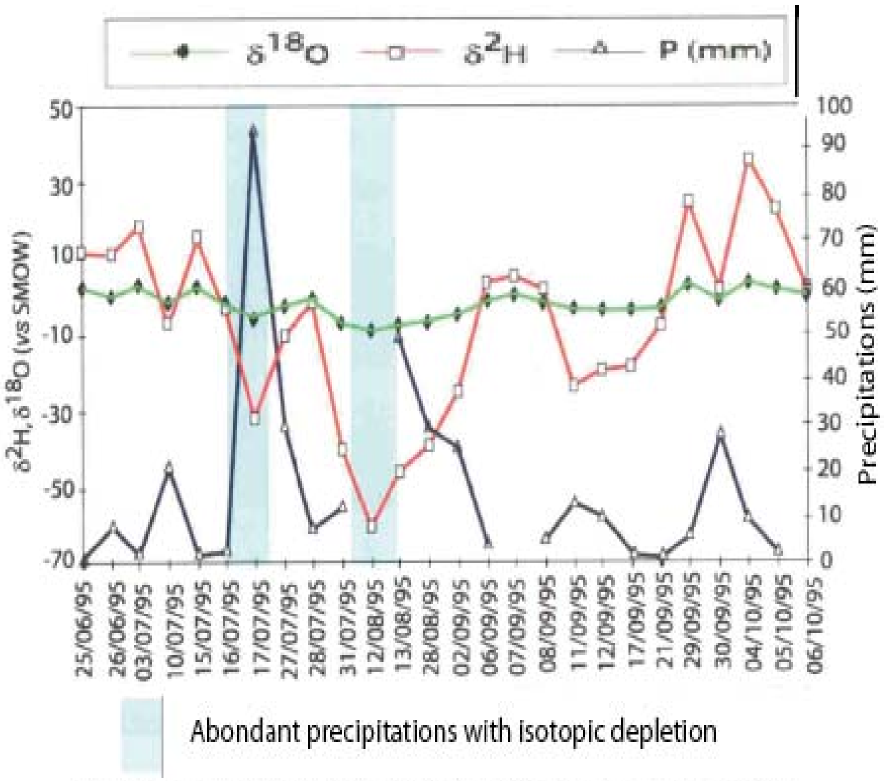
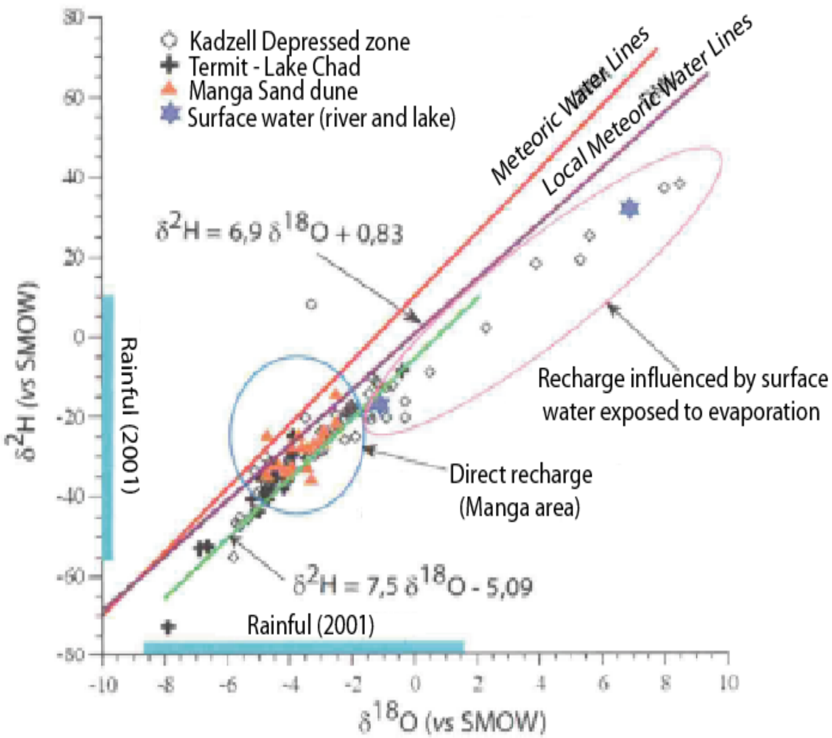
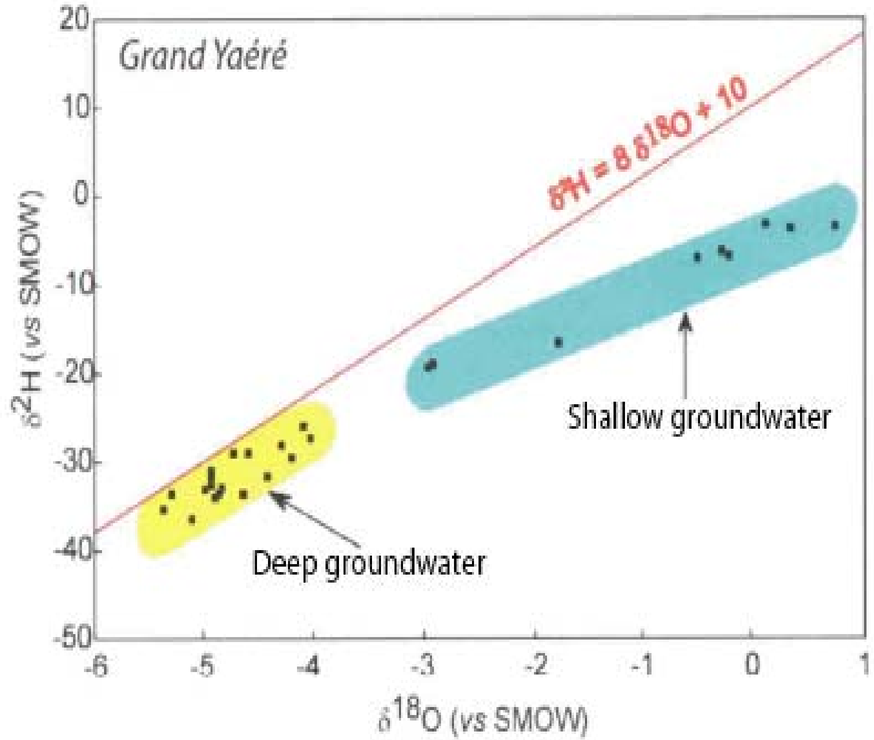


Fig. Seasonnal variations of rainfull isotopic composition at N'Djamena 1995 (after Djoret 2000)

- Rains of July and August that are usually intense are more depleted.
- Despite the strong evaporation in the Chad basin, it is possible to have present day recharged waters with isotope contents range from -4 to -6‰ ^{18}O *vs* SMOW

Results from Groundwater Stable Isotopes (^{18}O , ^{2}H)

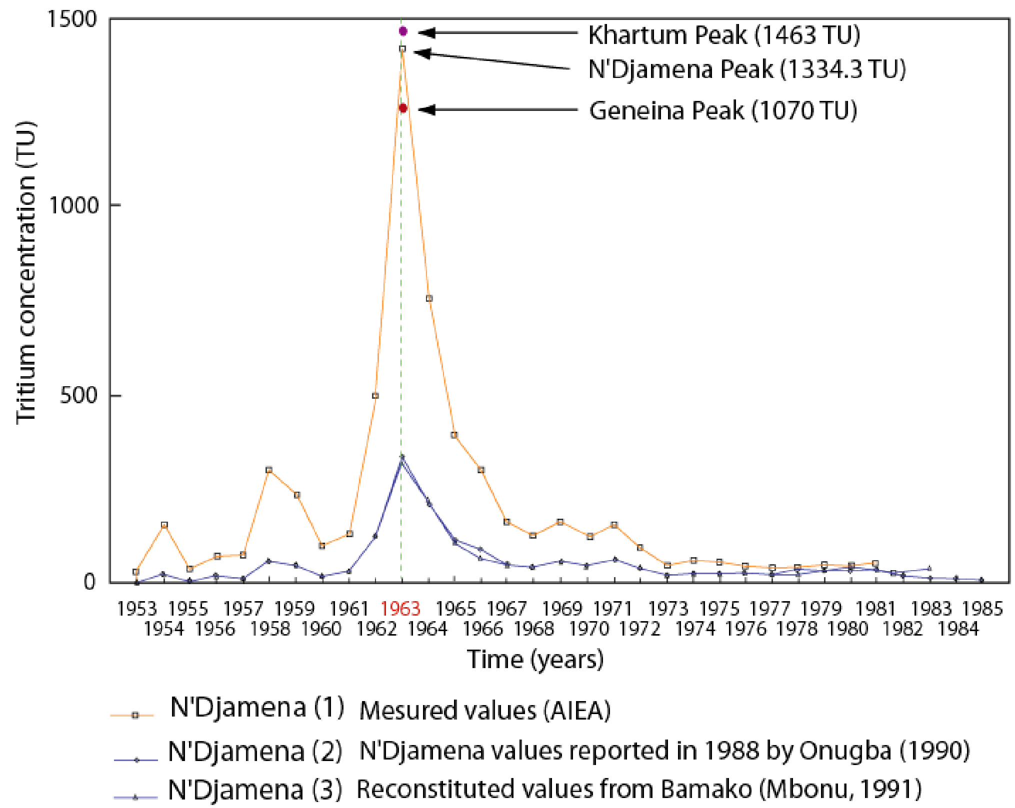




- The isotopic composition of groundwater sources is characterized by a large spread in the ^{18}O and ^{2}H amounts.
- The stable isotope data is being used in a qualitative sense to demonstrate present day recharge to the groundwater.

Results from Tritium (Rainwater and Groundwater)

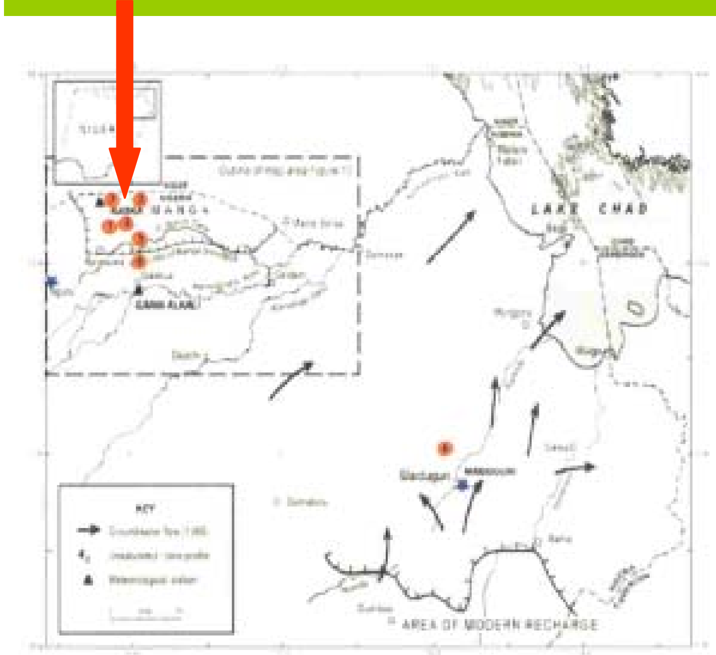
- Environmental-tritium was used in the delineation of the recharge area by comparing the total tritium present in the groundwater with the total tritium precipitated at a giving site (N'Djamena).
- Results of environmental-tritium recharge experiments of groundwater samples from the Quaternary aquifer correlated well with recharge values that were obtained using conventional methods.

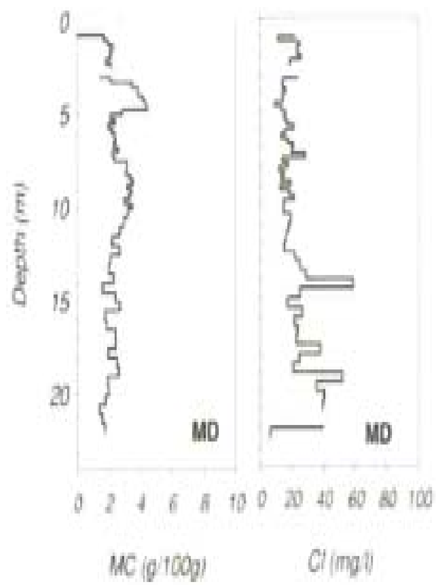


Country	N'Djamena	Nigeria	Senegal	Sudan
^3H (TU)	5 - 30	9 - 16	5 - 10	11
Reference	AIEA, 1982	Mbonu, 1991	Travi, 1988	El Tayeb, 1993

Results from Chloride Mass Balance Method

➢ Use of environmental-chloride in estimating recharge in the Lake Chad basin (Manga area) was successfully demonstrated by Edmunds *et al*. (2002).





Locality	Manga (Lake Chad Basin)	Louga (Senegal)	kalahari (Botswana)
Precipitation (mm)	320 - 400	330	350 - 400
Mean Recharge (mm/yr)	4 - 49	6.7 - 80.5	9 - 22

➢ This method is useful under certain conditions, where for exemple, surface runoff is negligible, precipation (P) is the only source of groundwater recharge and chloride.

*** The measured values of annual recharge are extremely small, ranging from 4-49 mm.**

*** This method highlight the role of sand dune in controlling groundwater recharge.**

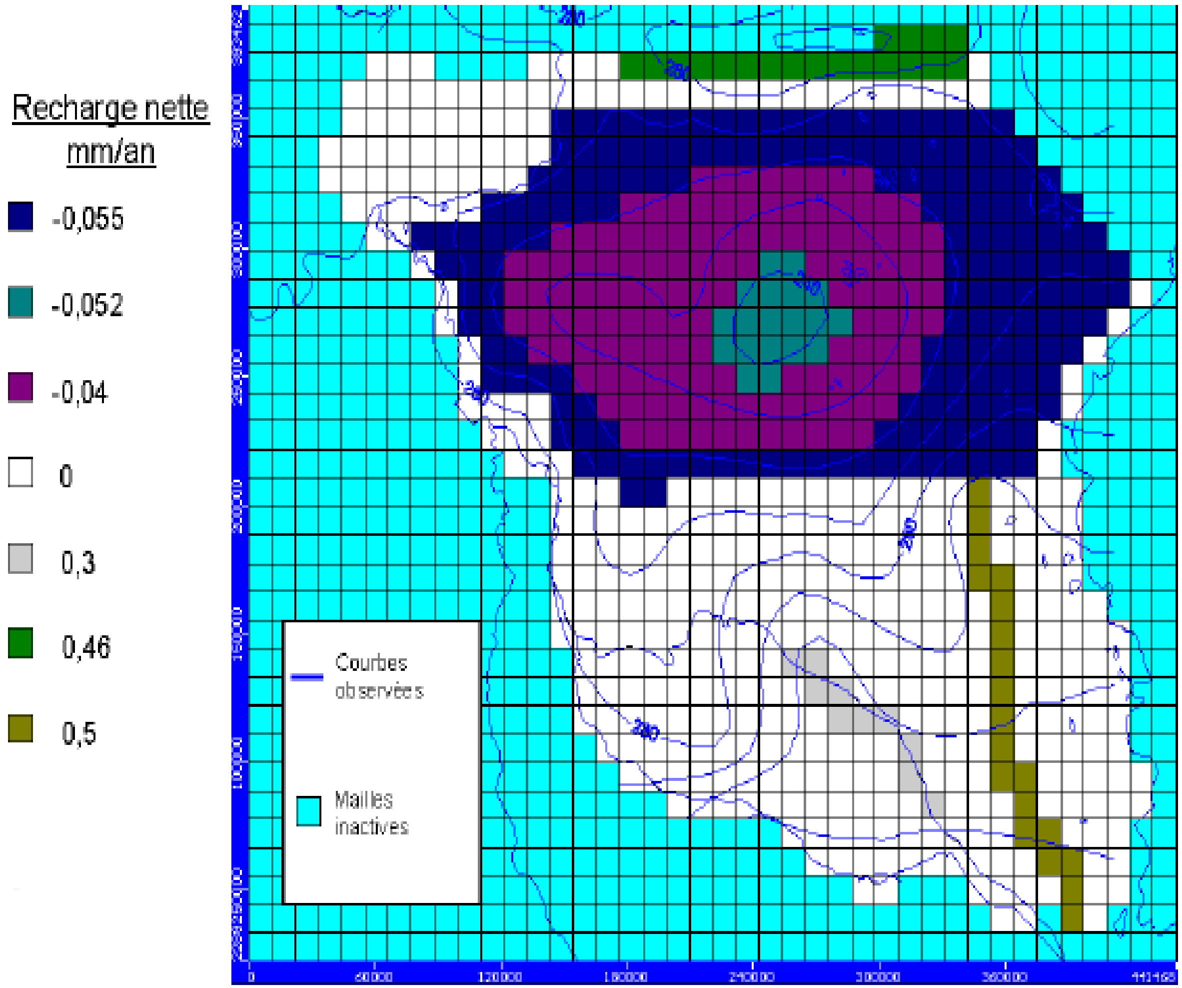
Results from Groundwater Modelling

➢ At the regional level, a model called MARTHE has been developed (Eberschweiler, 1993).

* The discretization of the systems is relatively coarse (12.5×25 km, 25×25 km and 25×50 km).

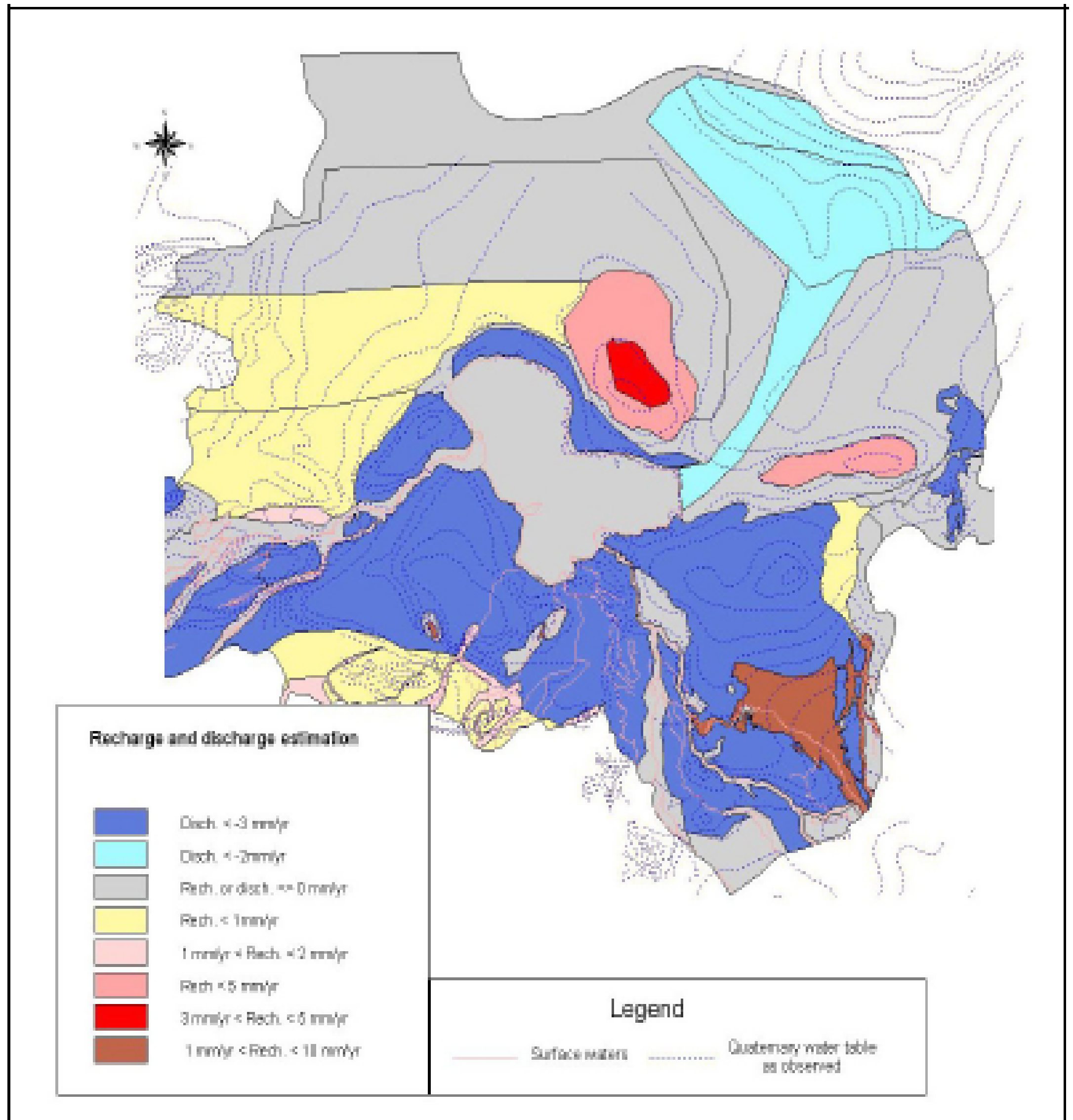
* Recharge values derived from this model are very low.

* The groundwater flow pattern in the area has been reconstructed.



Results from geographical information systems (GIS) Data

- A more recent contribution by Leblanc *et al*. (2002) showed that recharge areas in the Lake Chad basin could be readily identified using aerial photographs and Landsat (TM) colour composites.
- This result have to be verified by hydrogeological field studies.

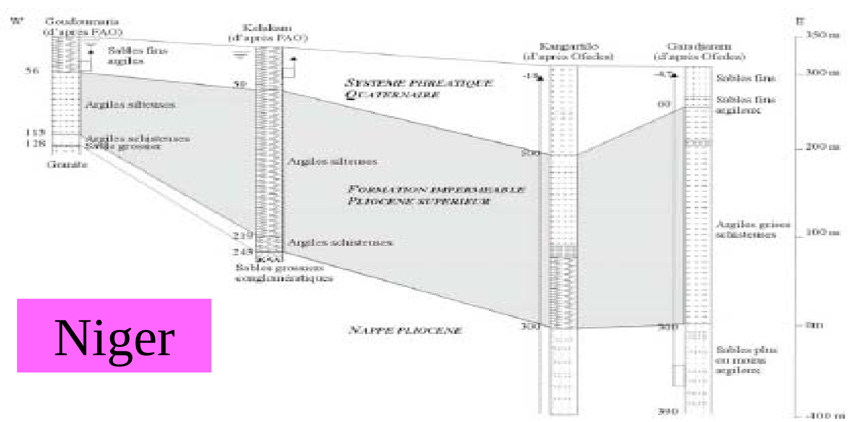


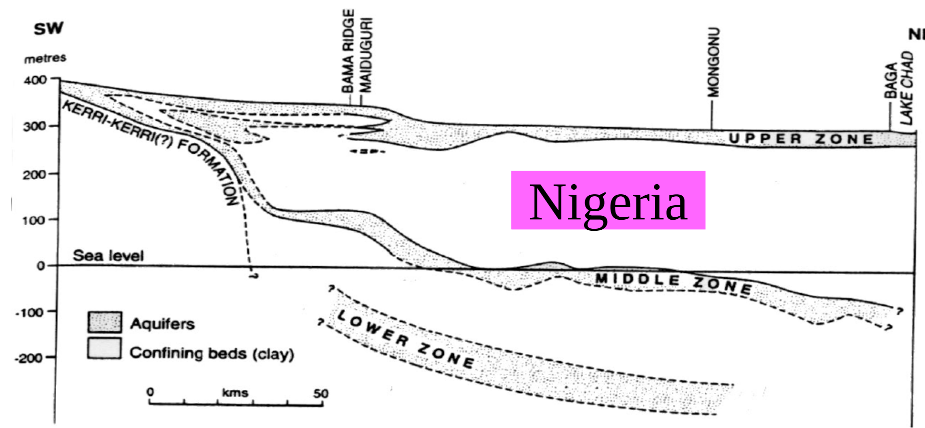
Concluding Remarks

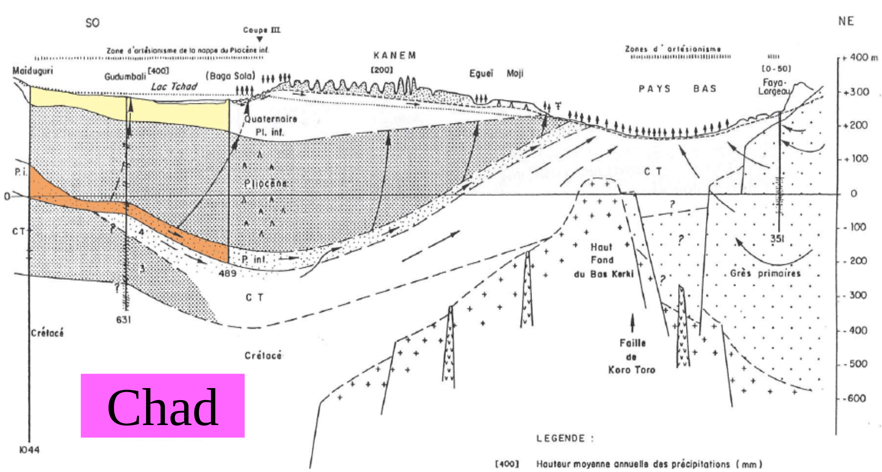
- For estimating direct recharge, geochemical and environmental isotopes approaches appear to offer the best potential for reliable results in local studies.
- Sufficient advances have been made in recent years to show that the value of water balance and Thornthwaite methods should not be understimated.
- Much more controversial are the results of radiocarbon of the various studies carried out in the Lake Chad basin.
- Although, there is an indication of modern recharge in the Lake Chad Basin, the future potential of the Chad basin as source of groundwater has not been fully evaluated.
- At general, existing data are not sufficient or reliable enough to plan regional actions for the sustainable use of groundwater.
- To develop and evaluate strategic policies for groundwater management it is a prerequisite that the monitoring and assessment of groundwater in the countries sharing the Lake Chad is performed in a comparable way.

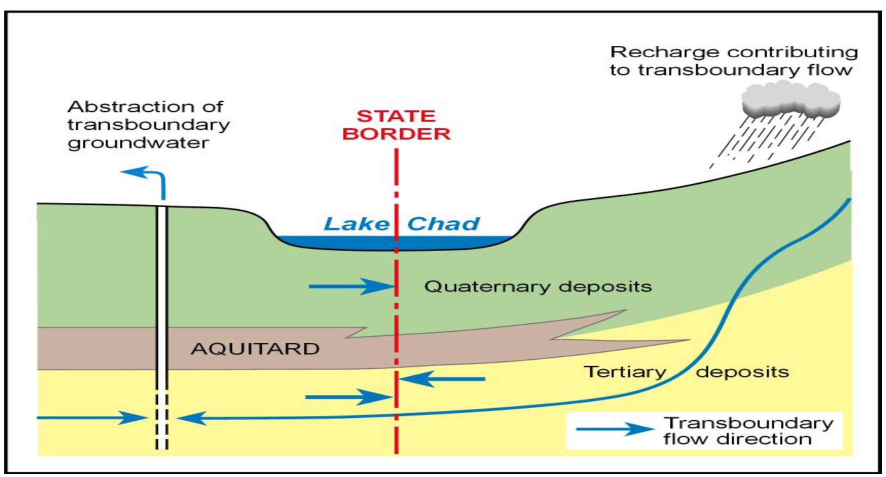
Concluding Remarks

➢ For groundwater management in the Lake Chad basin, we need more about reservoir geometry, hydraulic relations, volumes of water stored in both saturated and unsaturated zones.



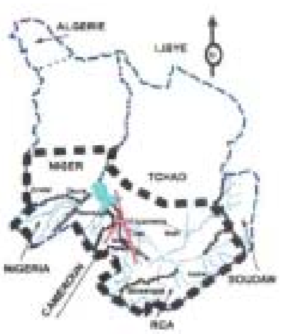


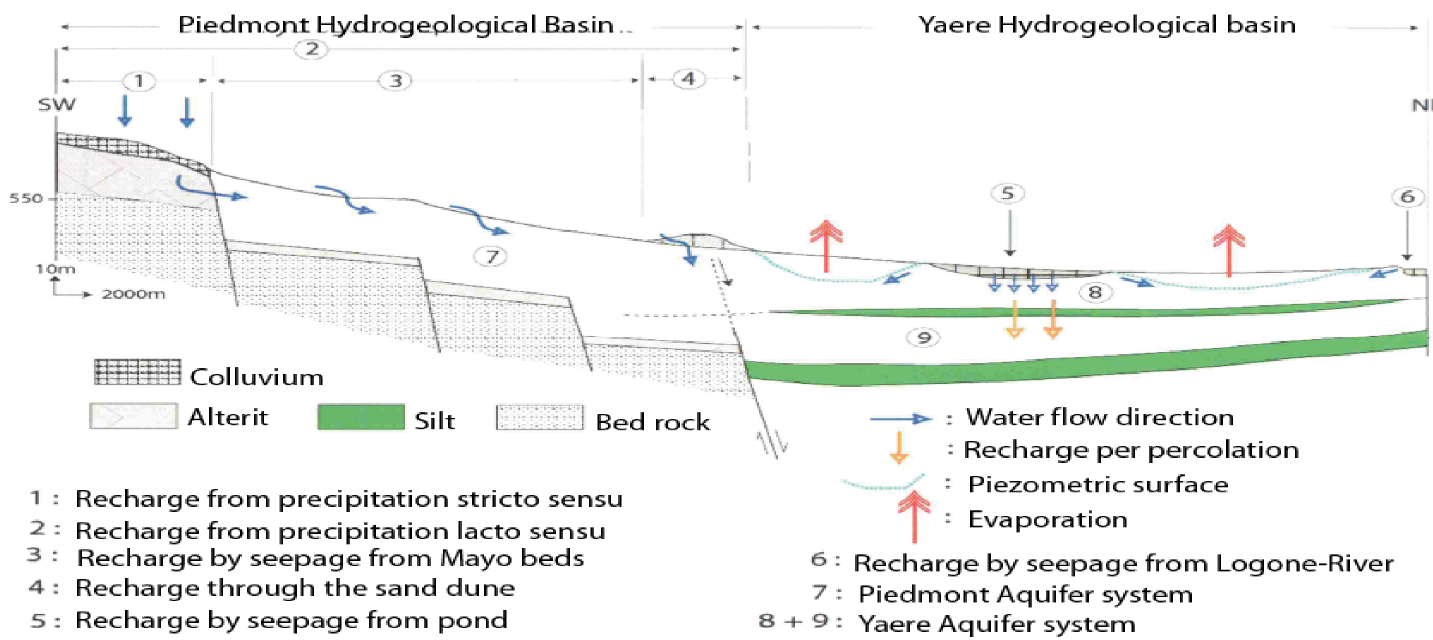




Concluding Remarks

- Efforts must be intensified to gather fundamental groundwater data for:
  - * understanding the flow system and renewal rate;
  - * quantifying inter-relationships between surface water (Lake, pond, rivers) and groundwater;
  - * determining and detecting trends in groundwater levels and quality and identifying actual and emerging problems;
  - * assessing the magnitude and impact of pressures and rate of use of the resource, especially where the regulatory system is deficient.





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