Groundwater resources of the Kabul basin (Afghanistan)

BGR-Project

on behalf of the

Federal Foreign Office of Germany

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BGR Bundesanstalt für Geowissenschaften und Rohstoffe Hannover

History of BGR activities in Afghanistan

German Geological Mission Afghanistan (DGMA), 1959 to 1968

Geological mapping central and southern Afghanistan

1959-1966 mapping, 1966-1968 advisors at Afghan Geological Survey (AGS)

→ Geological maps 1 : 500.000

Hydrogeological Group of the DGMA, 1964-1967

Hydrogeology of the Kabul basin

→ Characterisation of aquifers by drilling, hydrochemical analyses, geophysics, pump tests

Water suppy Kabul, 1971 to 1978

→ several reports, e.g. Afshar region

Improvement of groundwater protection, AA-Project 2003 to 2005

→ quality of groundwater in the Kabul basin

→ training in the field of hydrogeology

Scheduled BGR activities 2005

Transfer of knowledge obtained in the previous project stages to decision makers and awareness rising concerning water problems for the general population

Transfer of results:

- mapping of groundwater quality
- which areas are affected by pollution?
- which immediate measures have to be taken?

Creation of fundamentals of town planning:

- data bases
- GIS
- development of Integrated Water Ressources Management (IWRM)

Set-up of a hydrochemical laboratory in Kabul (?)

Water conference Kabul 2005

August 02 – 04, 2005

German governmental support of the water sector in Afghanistan

THEMES

- **I**ntegrated **W**ater **R**esources **M**anagement (IWRM), policy making
- groundwater resources and quality
- urban water supply and sanitation
- awareness rising

Some facts on Afghanistan

Geography

Area: 647,500 km^2

Amu Darya 258 m, Nowshak 7,485 m

Agricultural area: 12.13%

Irrigated area: 23,860 km^2

Mineral resources

Gas, oil, coal, copper, chromium, talc, baryte, sulphur, lead, zinc, iron, rock salt, gems

Population (2003)

Inhabitants: 28.7 Mio. (44 pro km^2)

Population growth: 3.38 %

Life expectancy: 47 years

Child mortality: 142 / 1000

The Kabul basin

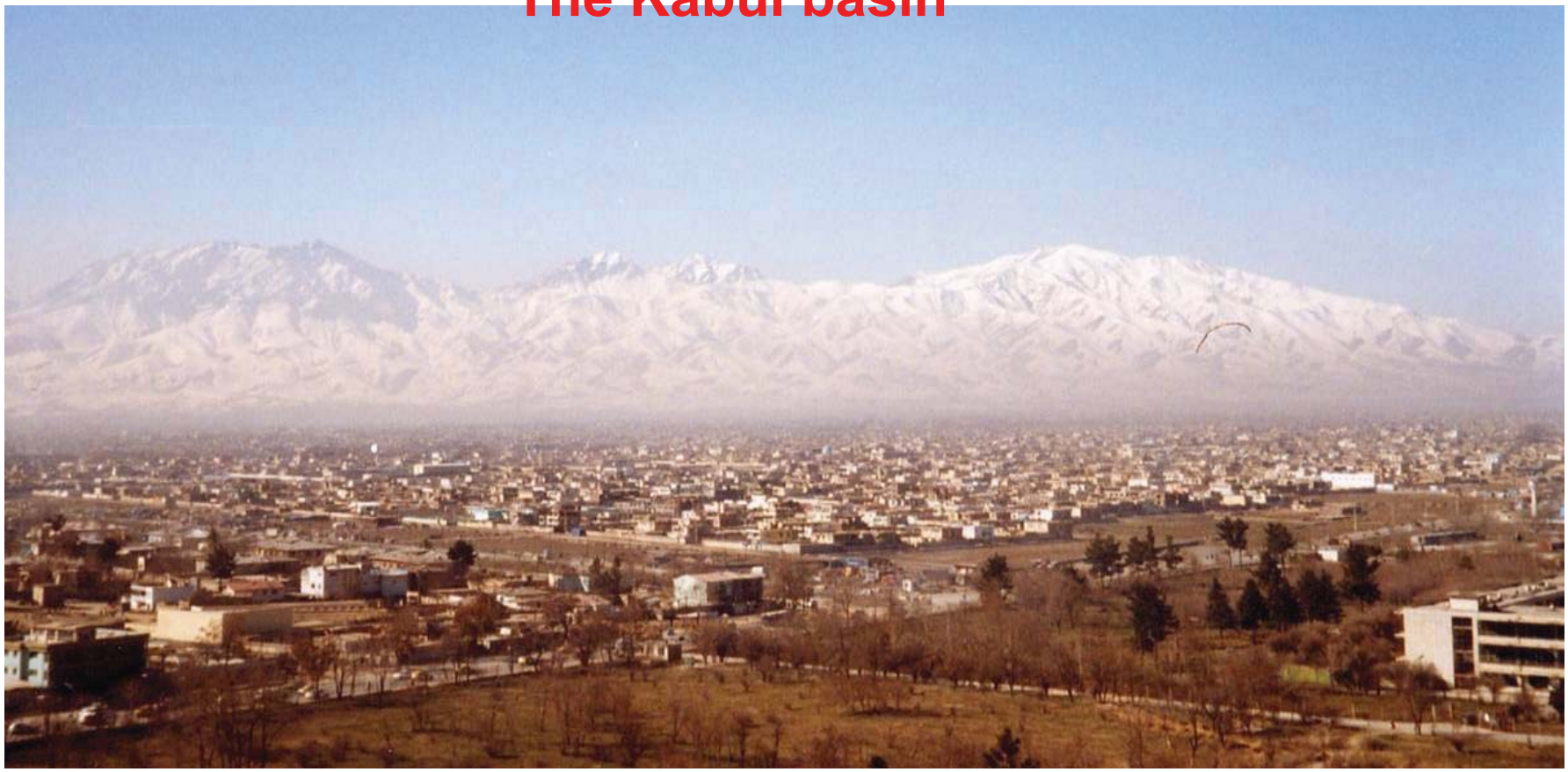


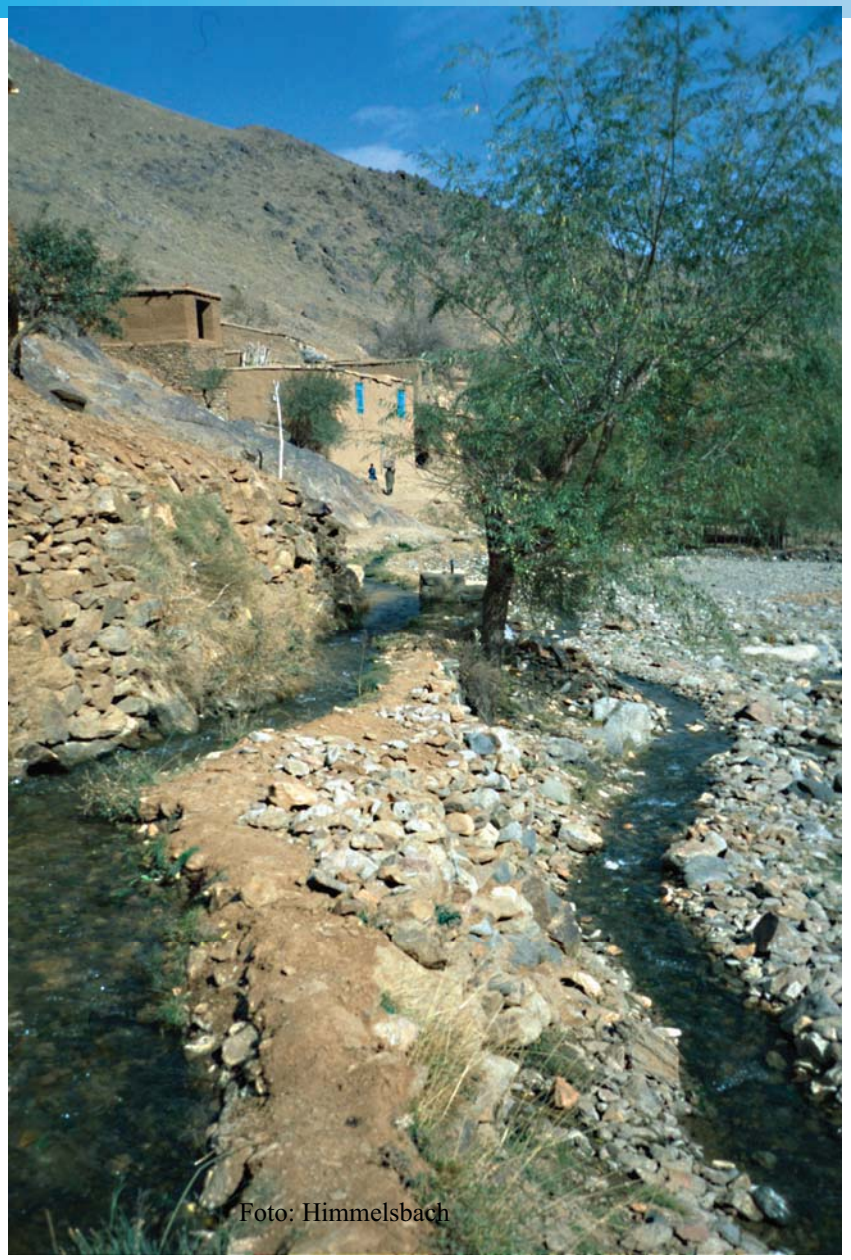
Foto: Houben

- situated south of the Hindukush, west of the Paghman range
- Tectonic subsidence basin (intra-montaineous), focus of three major fault lines
- area: ca. 1,600 km^2, ca. 3.5 Mio. inhabitants, ca. 14 % of total population

Foto: Houben

The Kabul basin from above

- Semi-arid, intra-montaneous basin
- building development reaches basin limits
- water supply predominantely from groundwater
- ground water recharge mainly during spring (snow melt)
- without sufficient snow the folllowing years will be very arid

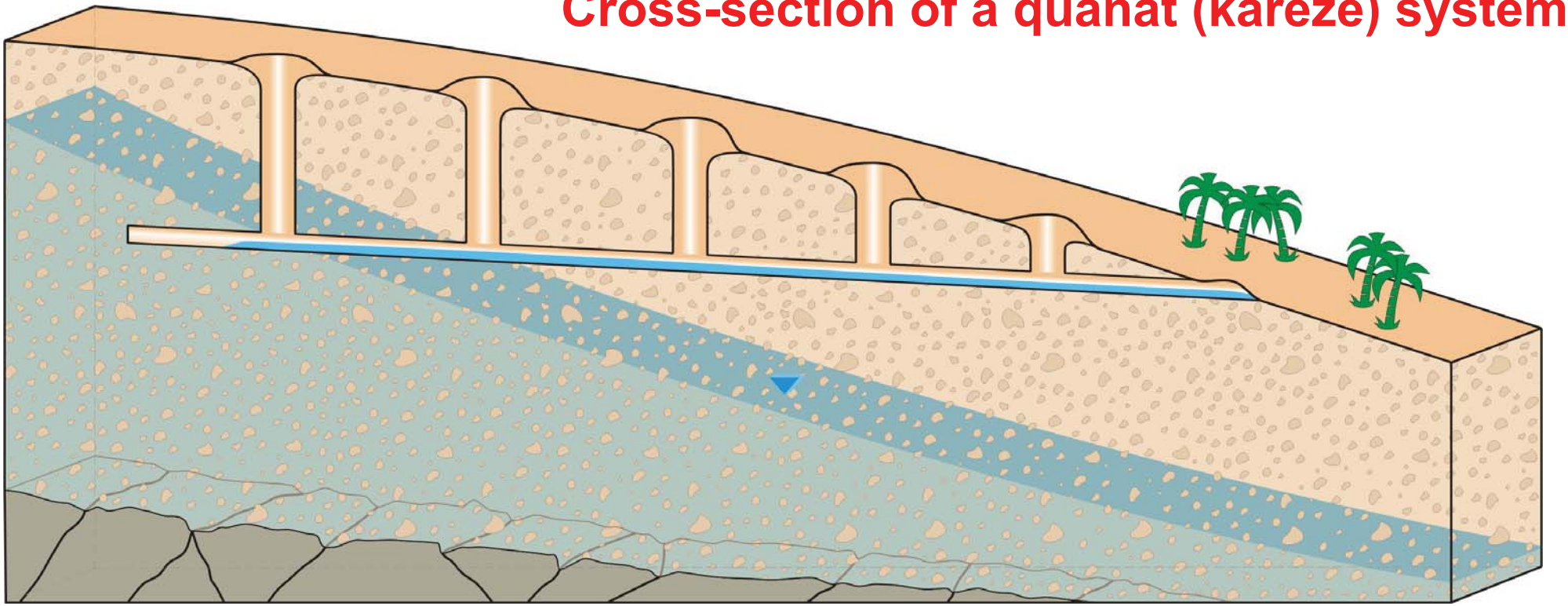


Agriculture

- irrigation
- intensive horticulture
- vegetables, potatoes, some cereals

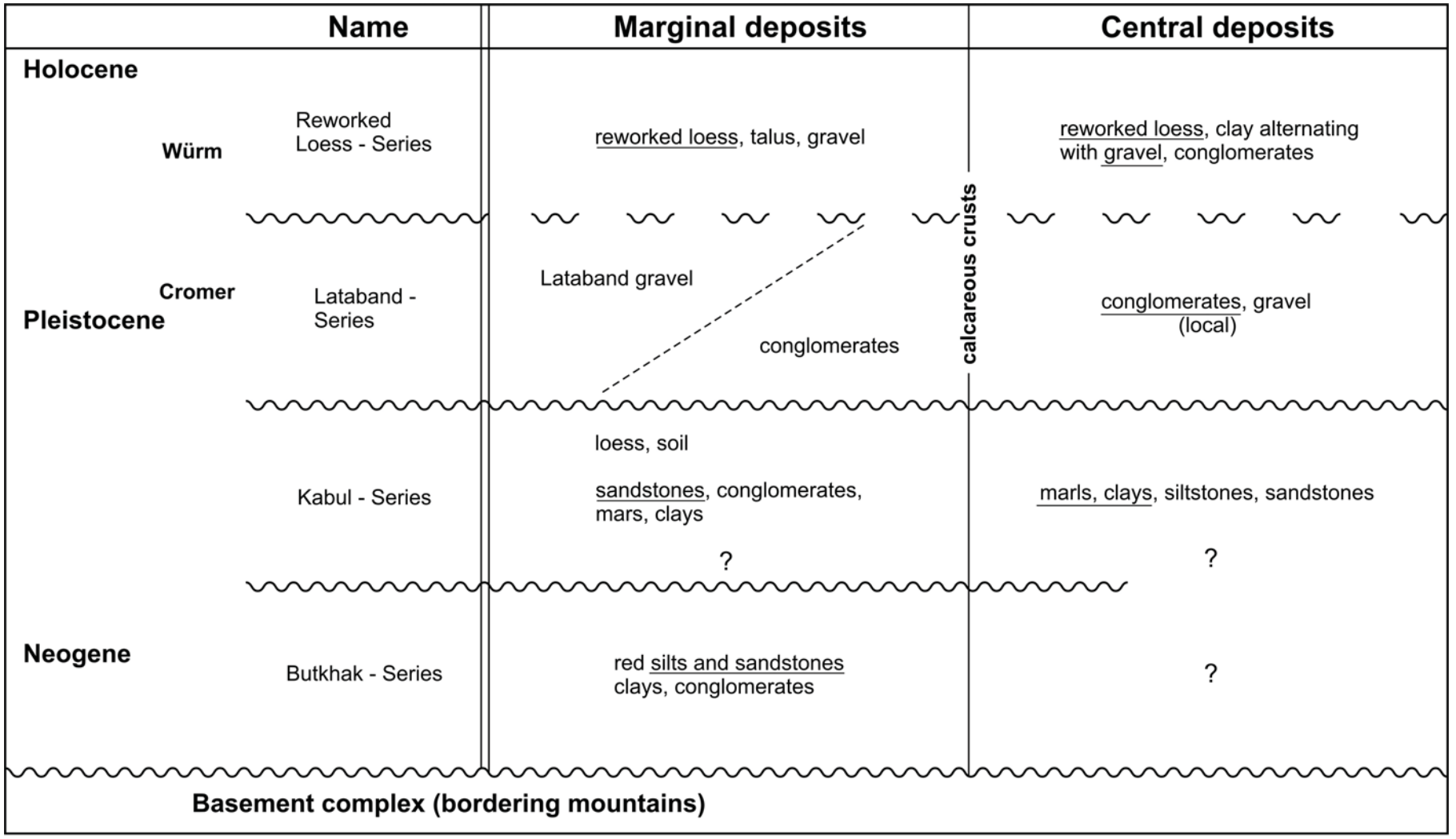

Terrace farming
irrigation using groundwater
use of old quanates (kareze)
Foto: Tünnermeier

Cross-section of a quanat (kareze) system



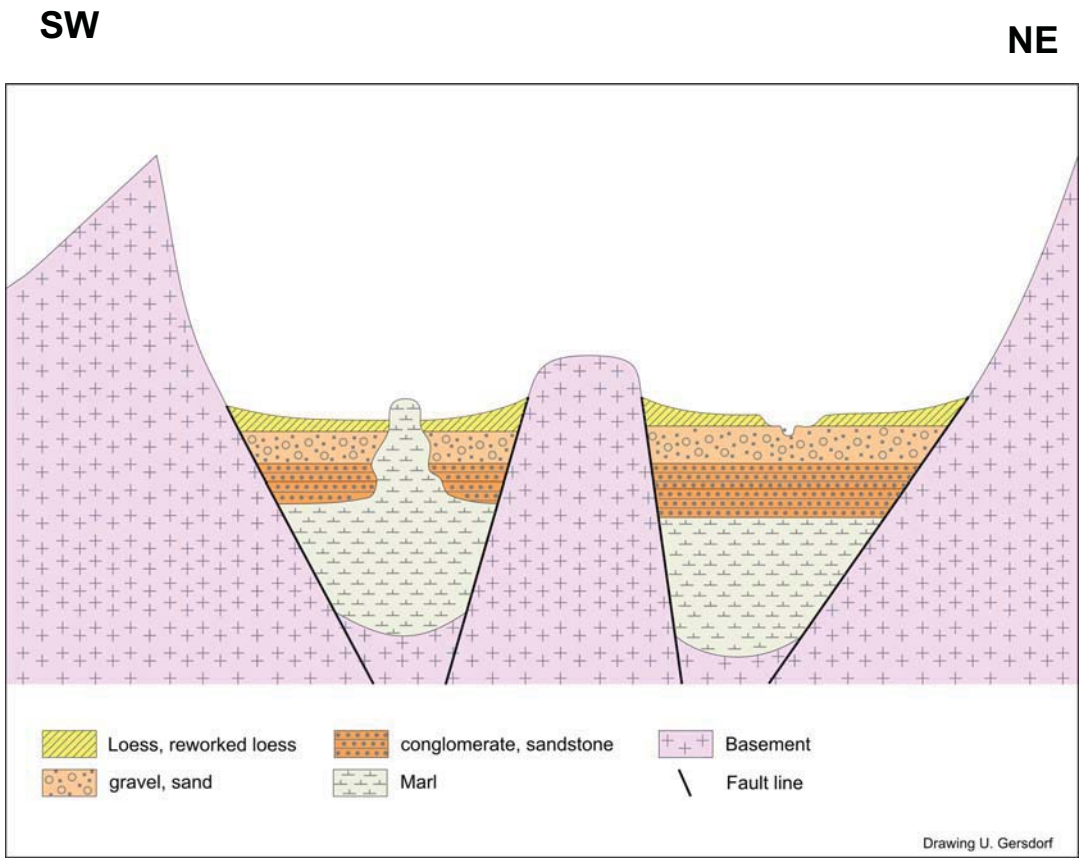
- quanat tunnel intersects water tabel at higher ground
- natural colmation prevents water losses
- less water losses due to decreased evaporation
- water transport over large distances

Stratigraphy of the Kabul basin



Basin deposits in the Kabul area
after GREBE and HOMILIUS 1968 (simplied)

Geology of the Kabul basin



Strongly simplified section through the Kabul basin

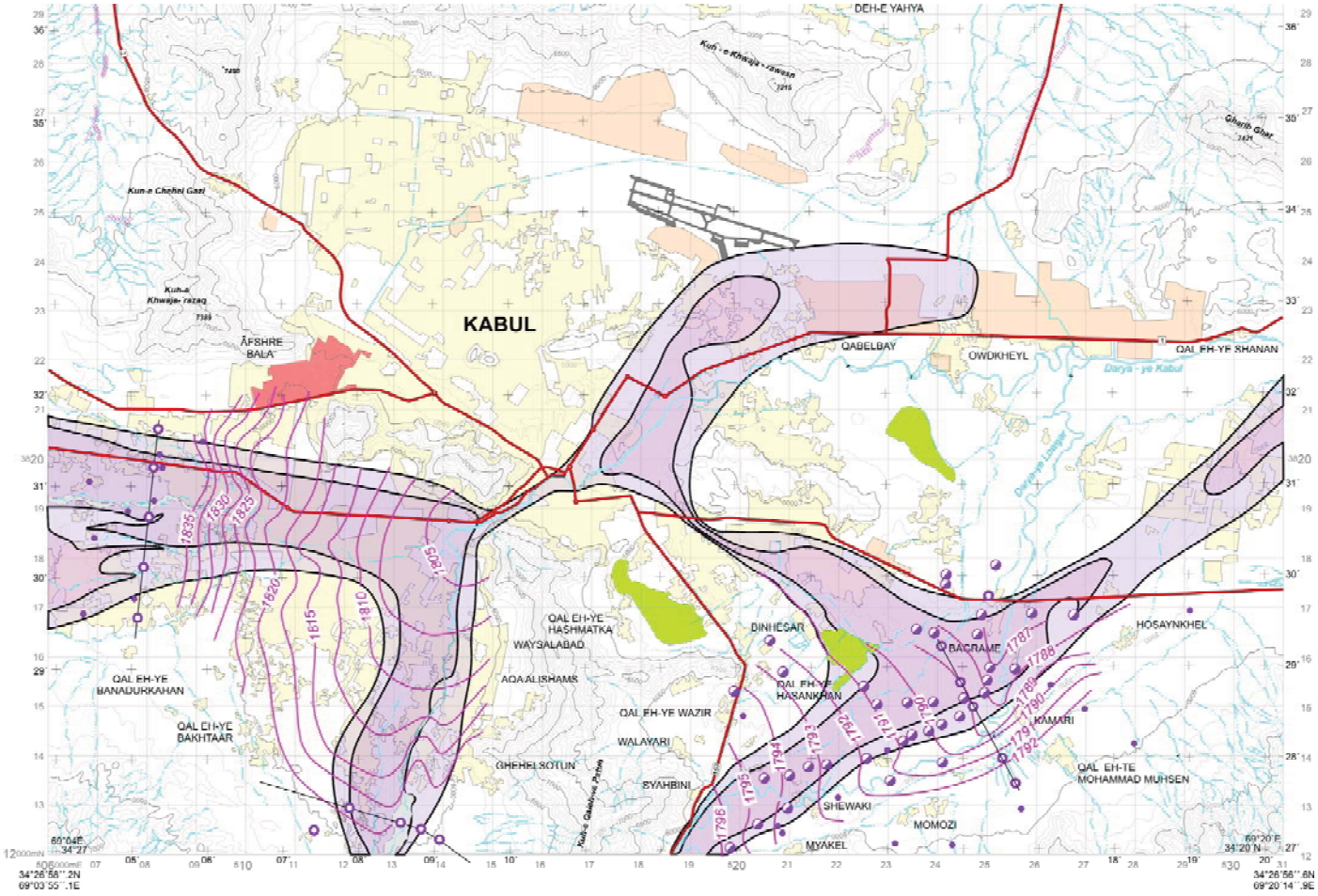
Simplified after Lang (1971)

Deposition of loess and loess loam during holocene

Fast rising of basin flanks, deposition of poorly-sorted sands and gravels (Lataband series) during pleistocene, base gravels cemented

Neogene: beginning basin formation deposition of red gravels and marine marls (Butkhak & Kabul formation)

Upper proterozoicum, metamorphics, (volcanics, carbonates and clastites)



Main aquifers in the city

Aquifers follow old river beds

Main source of water supply for Kabul

Some well fields:

- Afshar
- Bagrame
- Logar Wellfields

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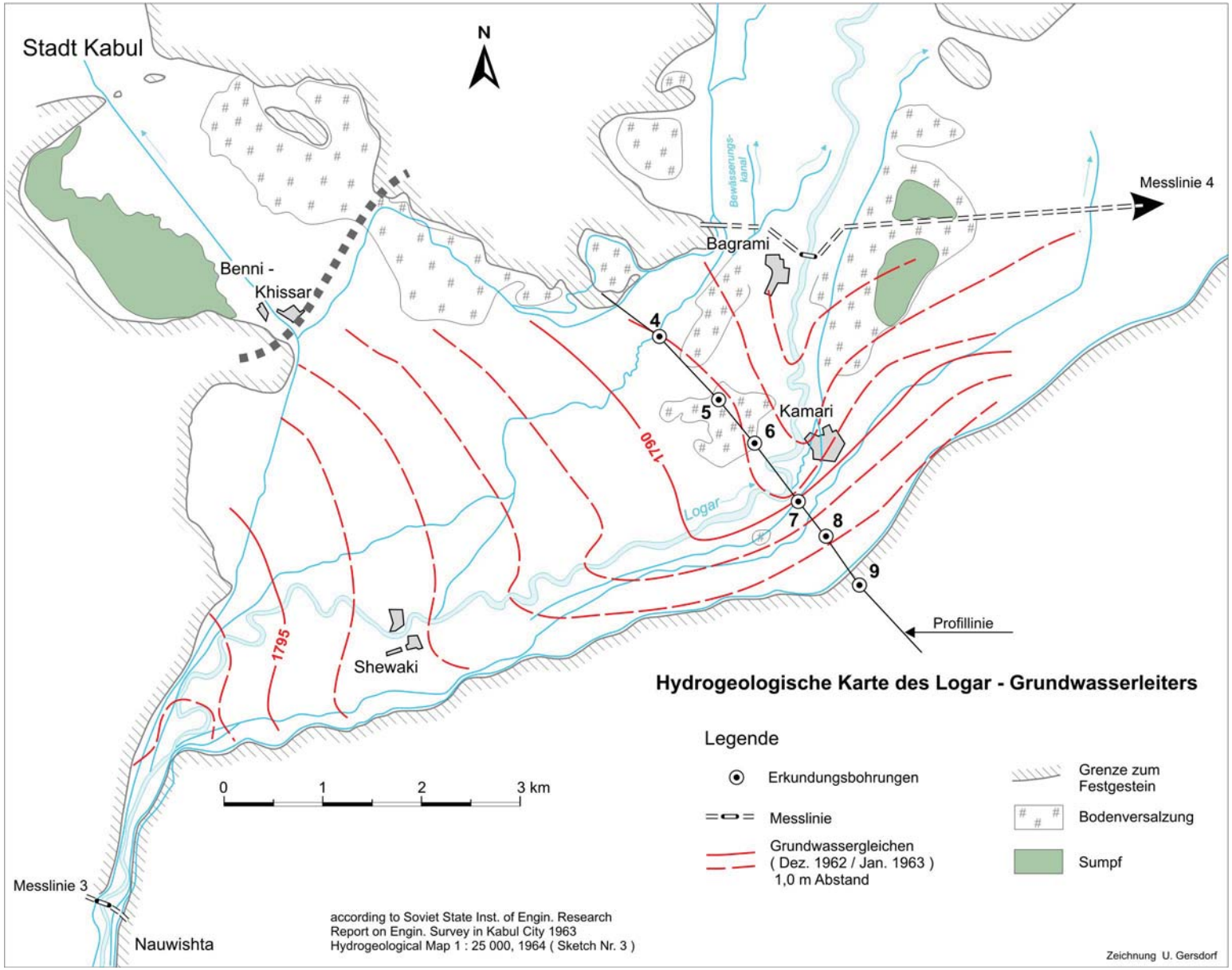
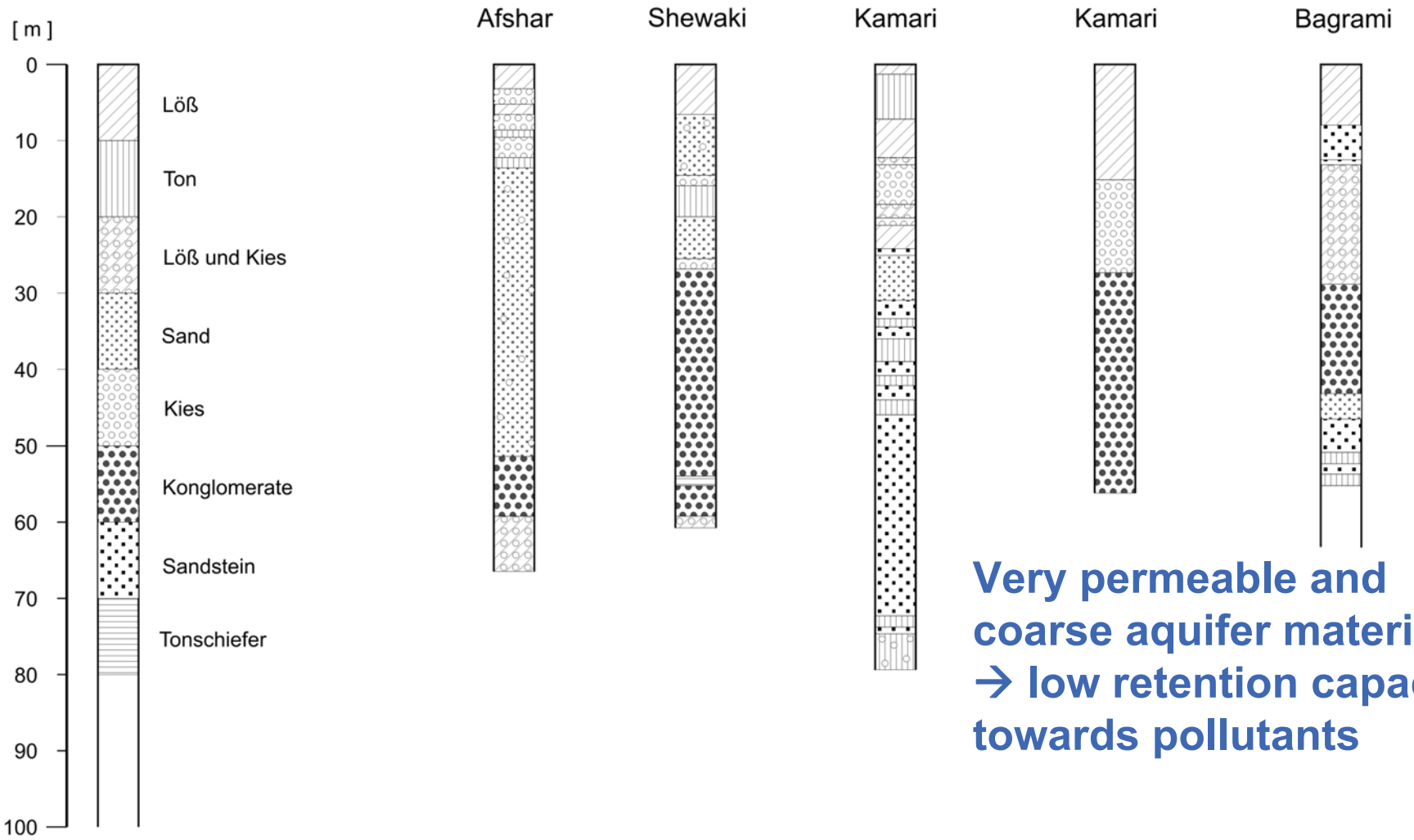

Stadt Kabul
N
Messlinie 4
Bewässerungs-kanal
Bagrami
Benni -
Khissar
4
5
6
Kamari
1790
Logar
7
8
9
Profillinie
1795
Shewaki
Hydrogeologische Karte des Logar - Grundwasserleiters
Legende
Erkundungsbohrungen
Messlinie
Grundwassergleichen
(Dez. 1962 / Jan. 1963)
1,0 m Abstand
Grenze zum Festgestein
Bodenversalzung
Sumpf
0
1
2
3 km
Messlinie 3
Nauwishta
according to Soviet State Inst. of Engin. Research
Report on Engin. Survey in Kabul City 1963
Hydrogeological Map 1 : 25 000, 1964 (Sketch Nr. 3)
Zeichnung U. Gersdorf

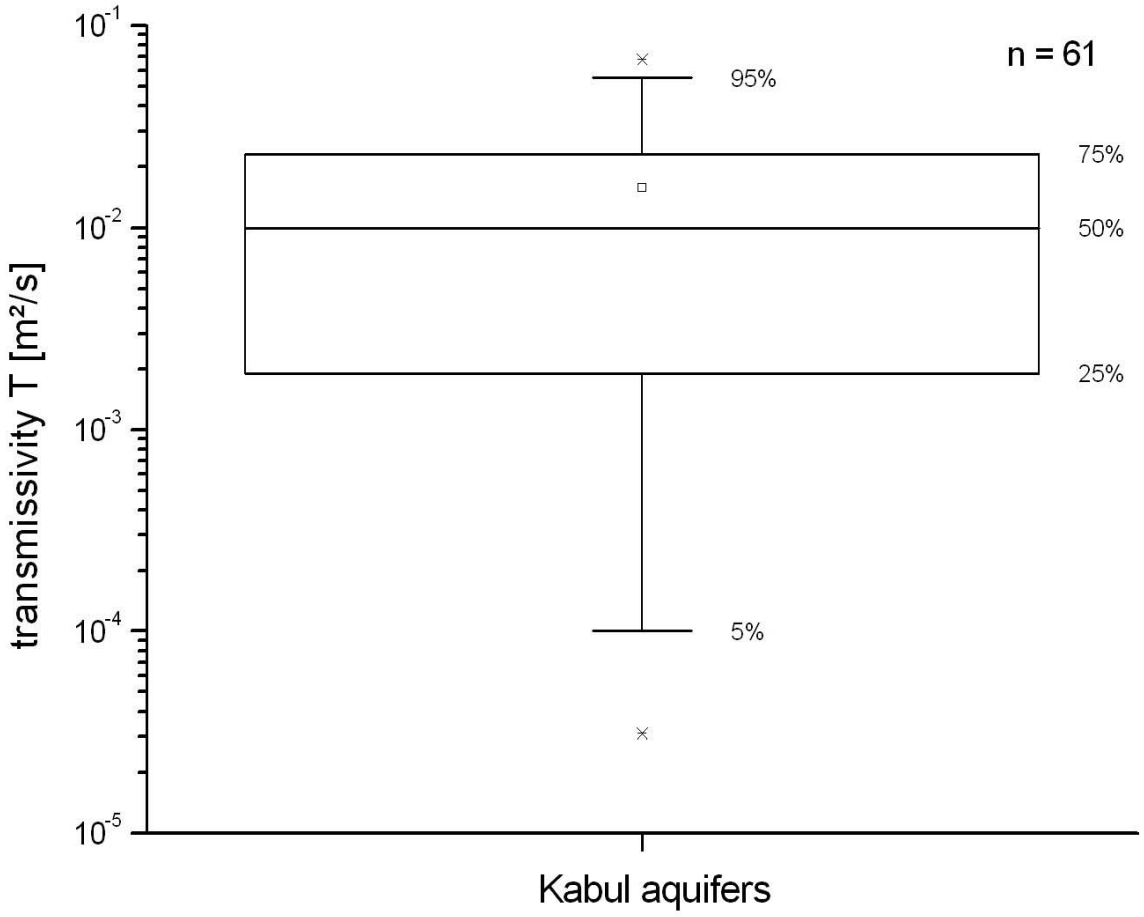
Some geologic profiles of water wells



Very permeable and coarse aquifer material → low retention capacity towards pollutants

von unveröffentlichen Berichten der Geologischen Mission in Afghanistan 1966

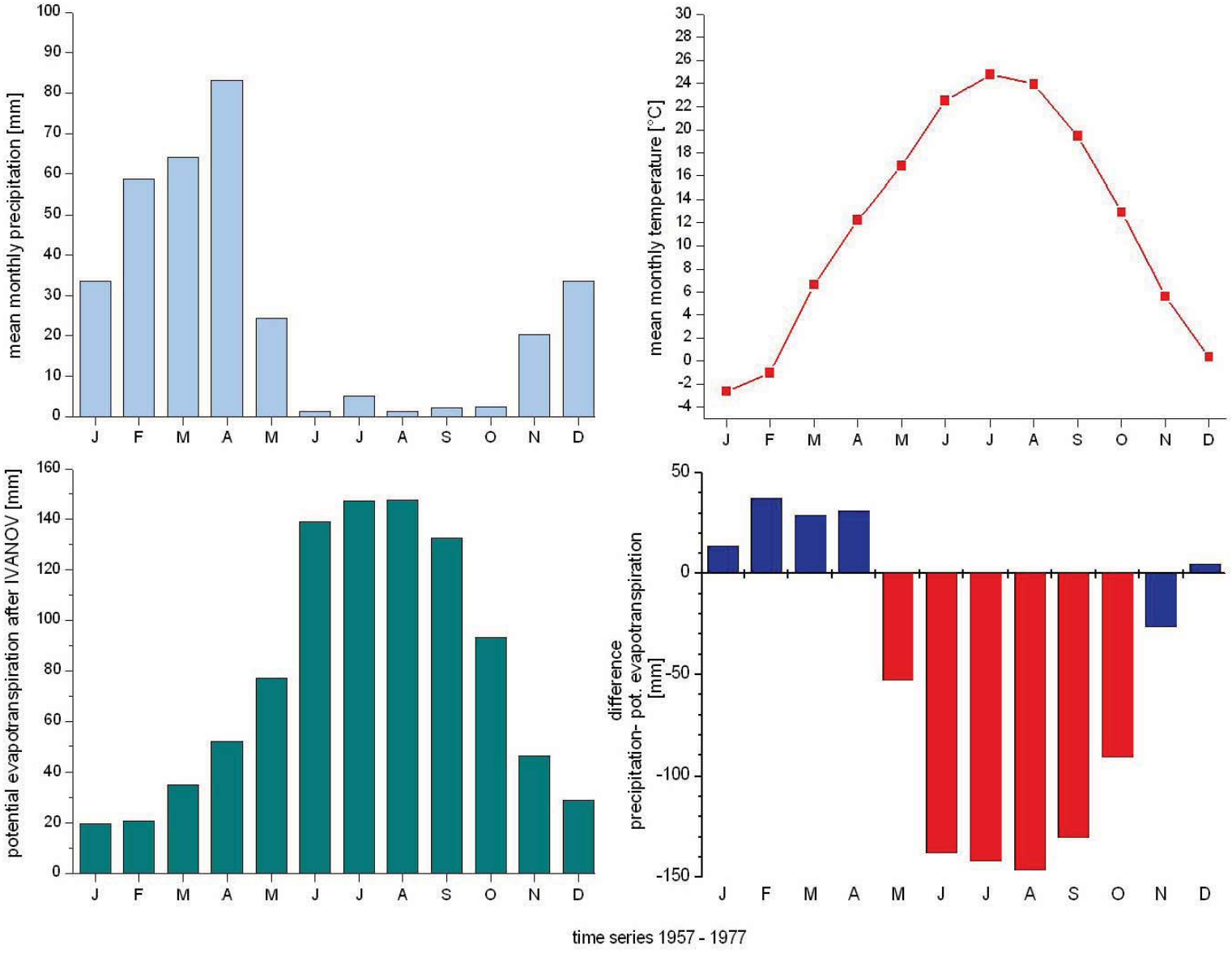
Transmissivity



High transmissivity due to coarse aquifer material (gravel)

short transport distance from mountain ranges

Climate data of the Kabul basin



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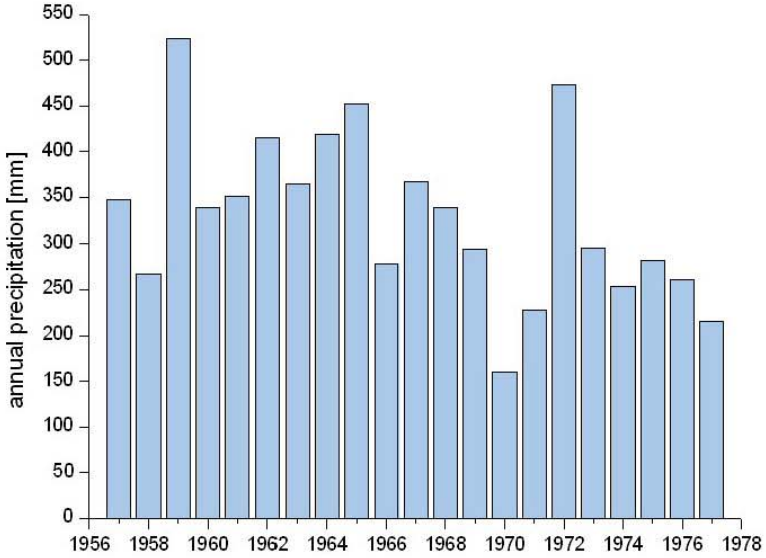
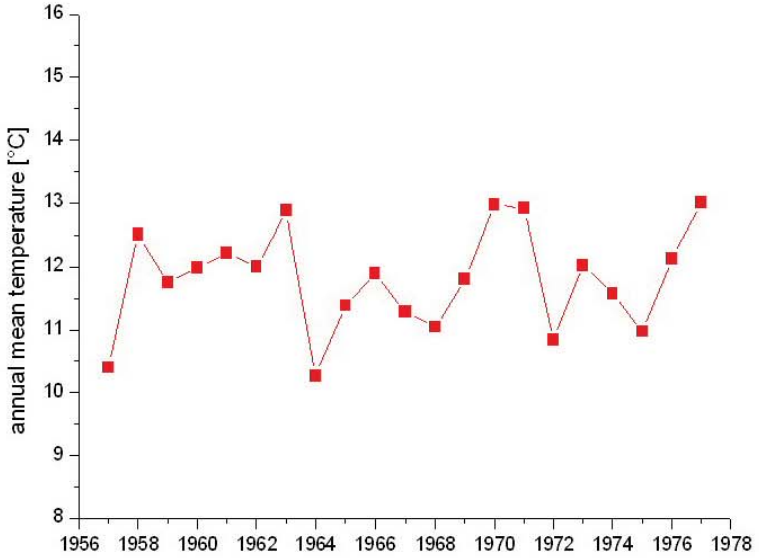
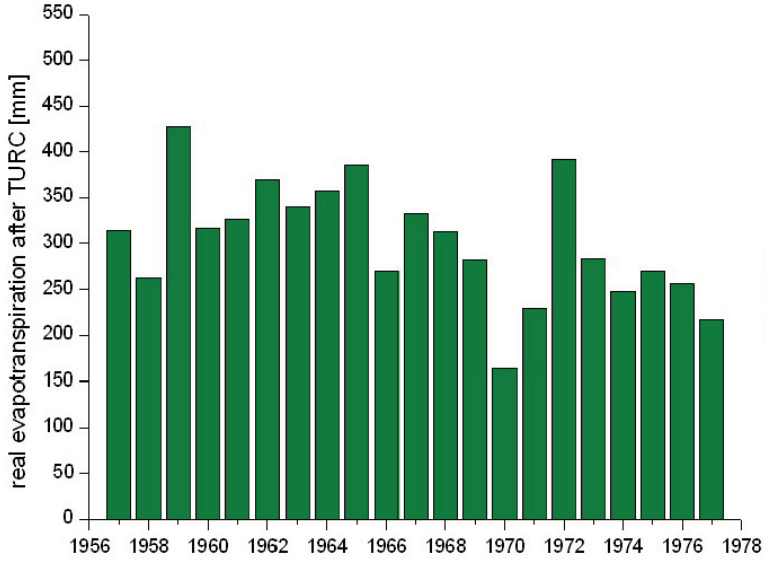
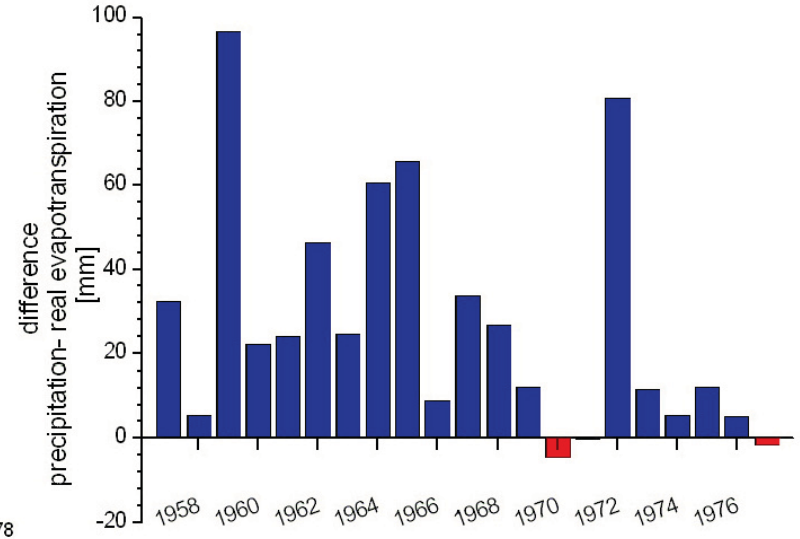
Climate data of the Kabul basin



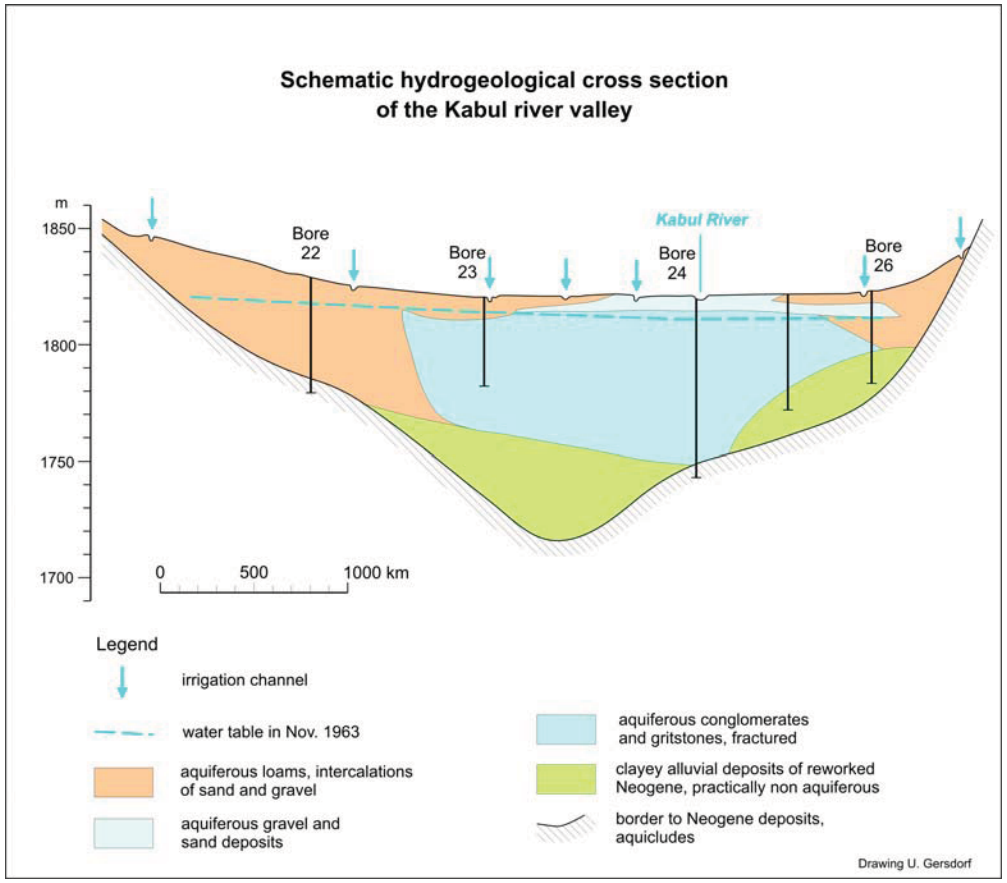


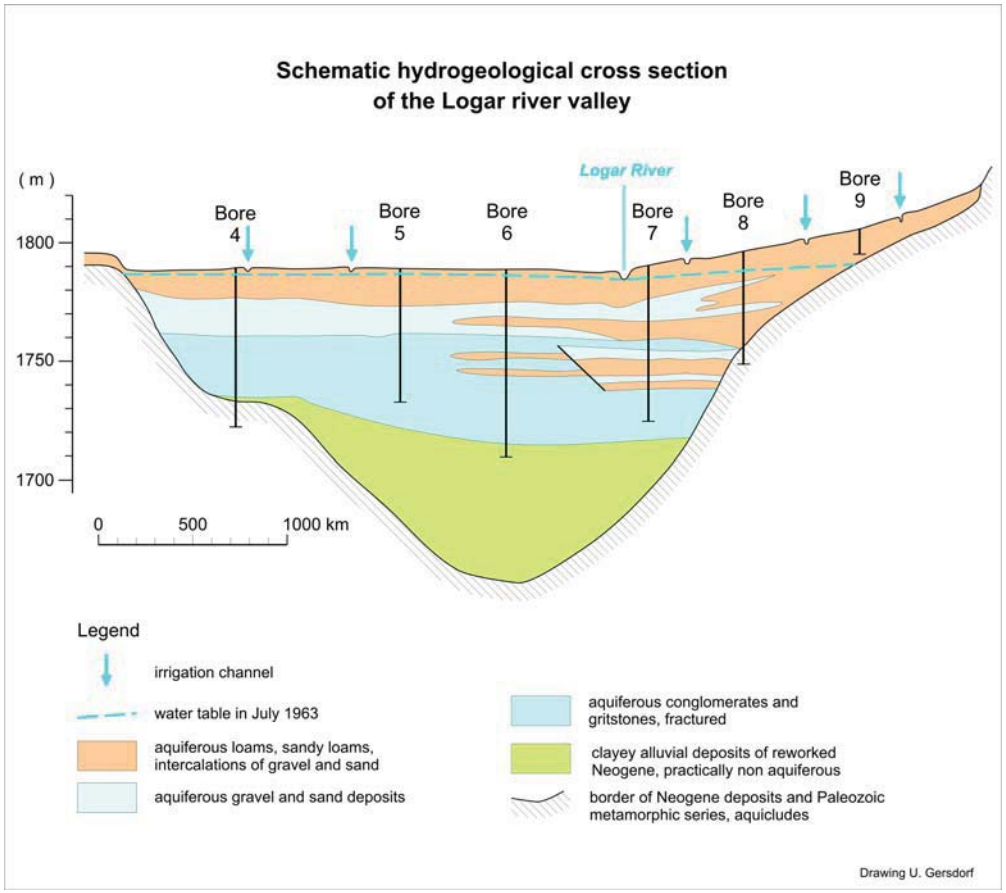




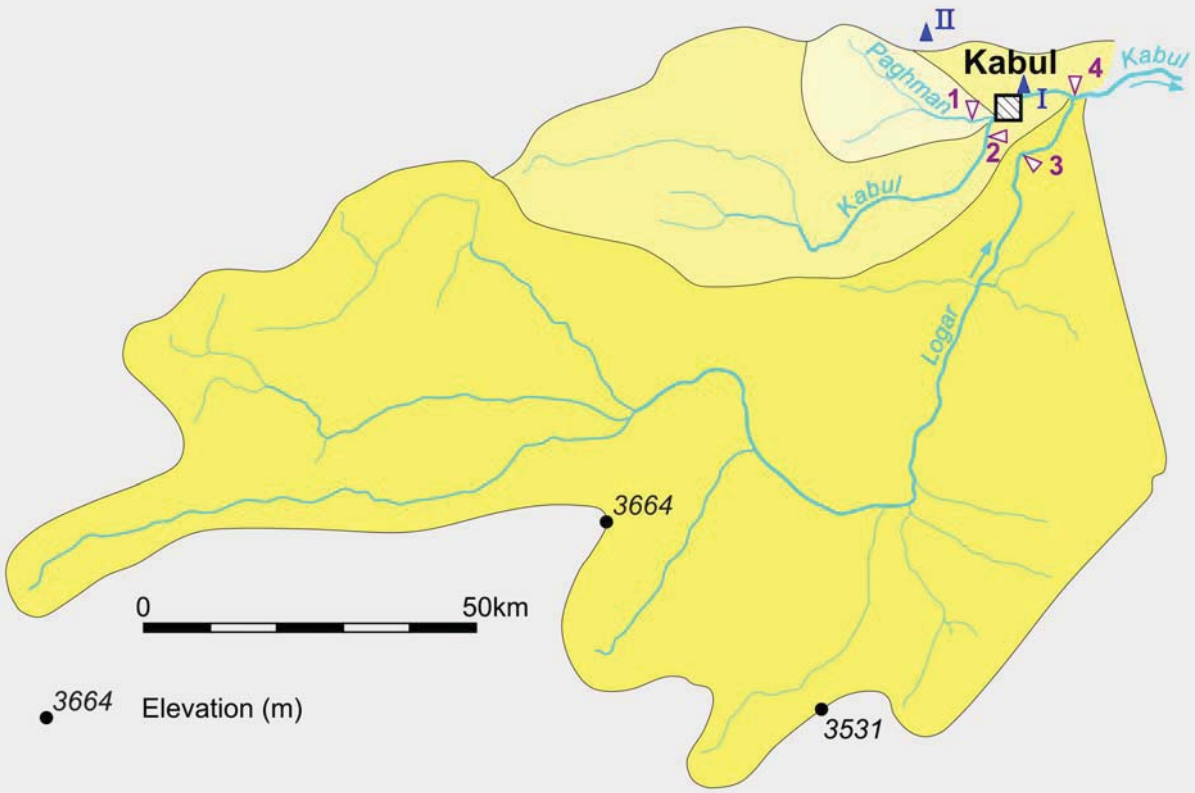
Aquifer cross sections

- loess sometimes not present
- natural (river erosion) and anthropogenic causes (excavation, brick production)





Catchment Areas of the Kabul Basins, River Gauges, Weather Stations



River Gauges (▽)

N°	River	Name	Elevation (m)	Drainage area (km²)
1	Paghman	Pule Sokhta	1805	387
2	Kabul	Tangi Saydan	1850	1646
3	Logar	Sange Nawesta	1805	9772
4	Kabul	Tangi Gharu	1770	12888

Weather Stations (▲)

N°	Name	Elevation (m)
I	Kabul - Airport	1803
II	Karizimir	1860

Zeichnung U. Gersdorf

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"May Kabul be without gold but not without snow"

Foto: Himmelsbach

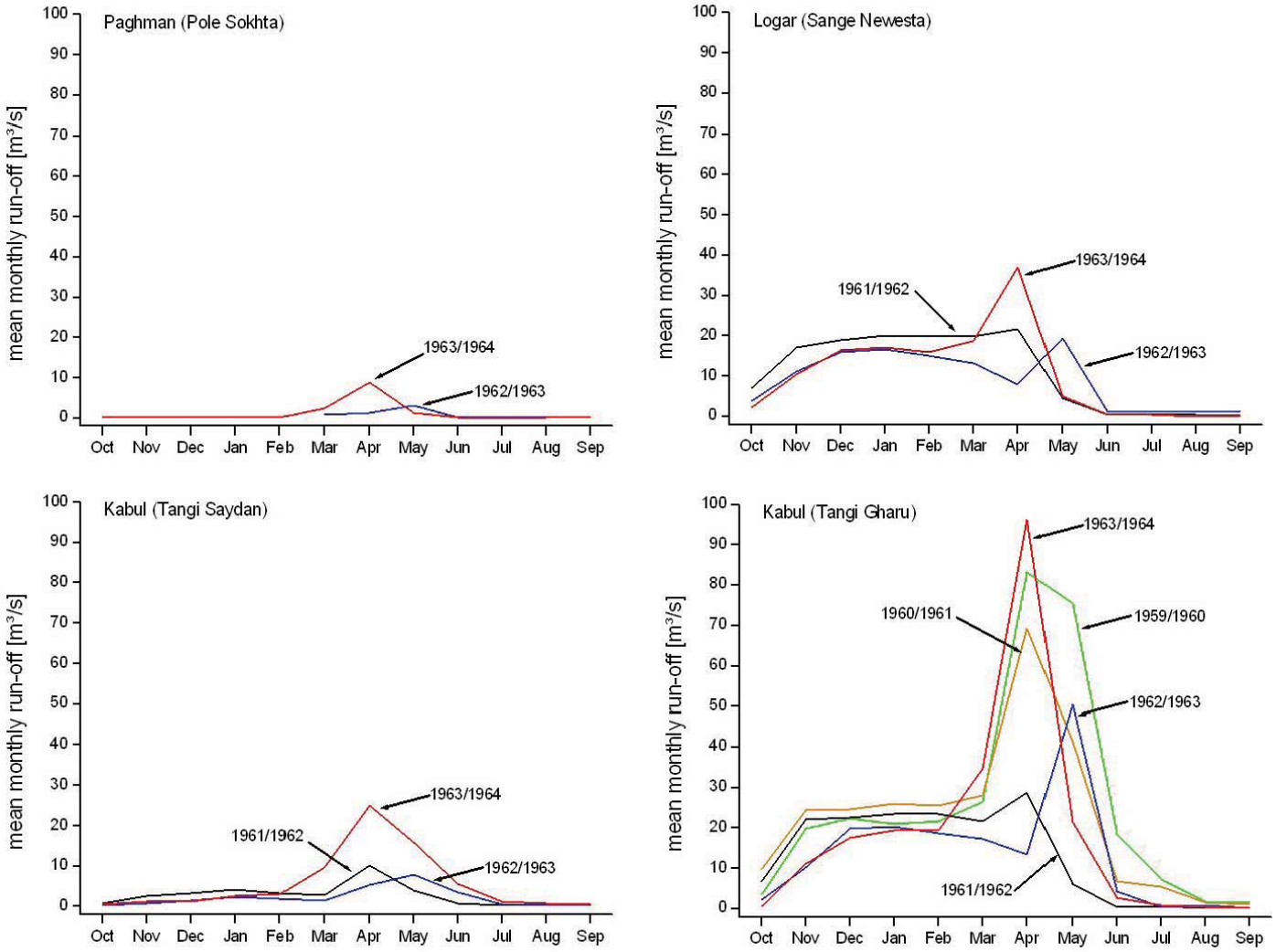
The Kabul river

Shortly after snow melt river runs dry

River water infiltrates almost completely into the subsurface
→ main source of groundwater recharge

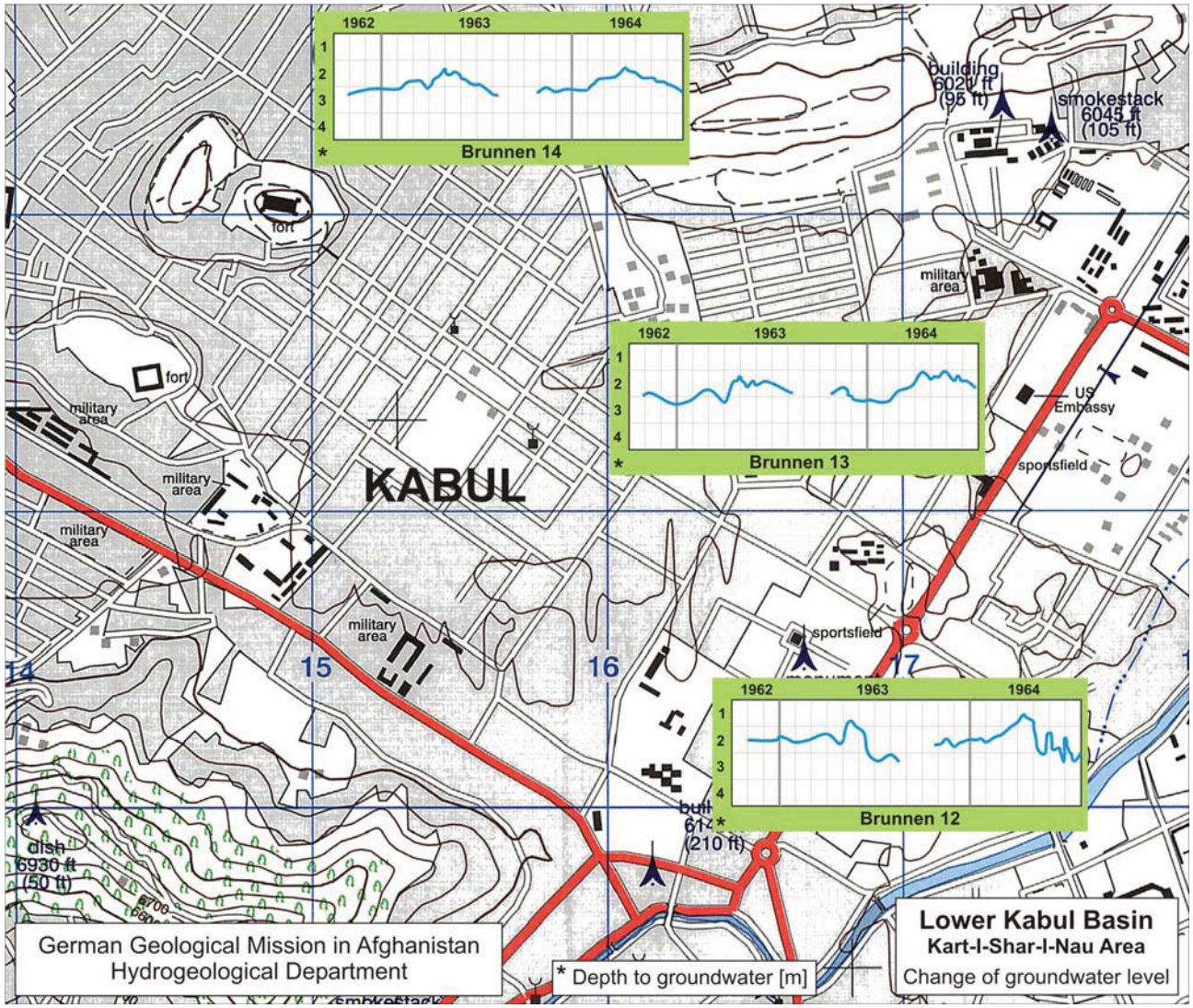
Groundwater is main supply for human water consumption

Climate and hydrology: runoff



On average (18 m³/s) total runoff of ca. 570 Million m³/a

Fluctuations of groundwater levels



Shar-i-Nau

1962-1964

depth to groundwater:
1-3 meter

low fluctuations

levels follow discharge
levels of river

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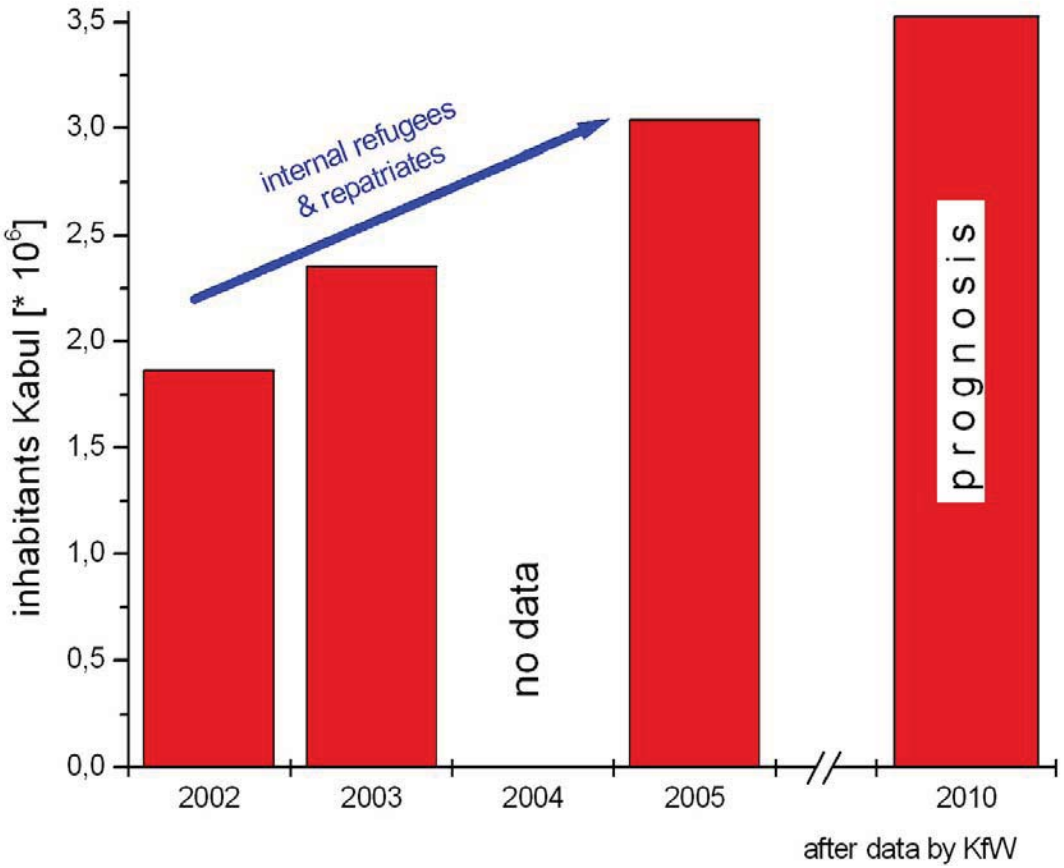
Static groundwater storage

		aquifer		
		Logar	**Kabul**	**Paghman**
Mean length	km	**10**	**9**	**6**
Mean width	km	**3**	**2,5**	**4**
Mean porosity gravel, sand	%	**7,5**	**7,5**	**7,5**
Mean thickness gravel , sand	m	**28**	**5**	**50**
Mean porosity conglomerates	%	**2,5**	**2,5**	**-**
Mean thickness congolmerates	m	**22**	**40**	**-**
Stored volume	Mio. m³	**80**	**31**	**90**
Sum	Mio. m³	**ca. 200**		

Estimates of population growth in Kabul



Dramatic increase of population numbers
In a few years *("post Taliban")*

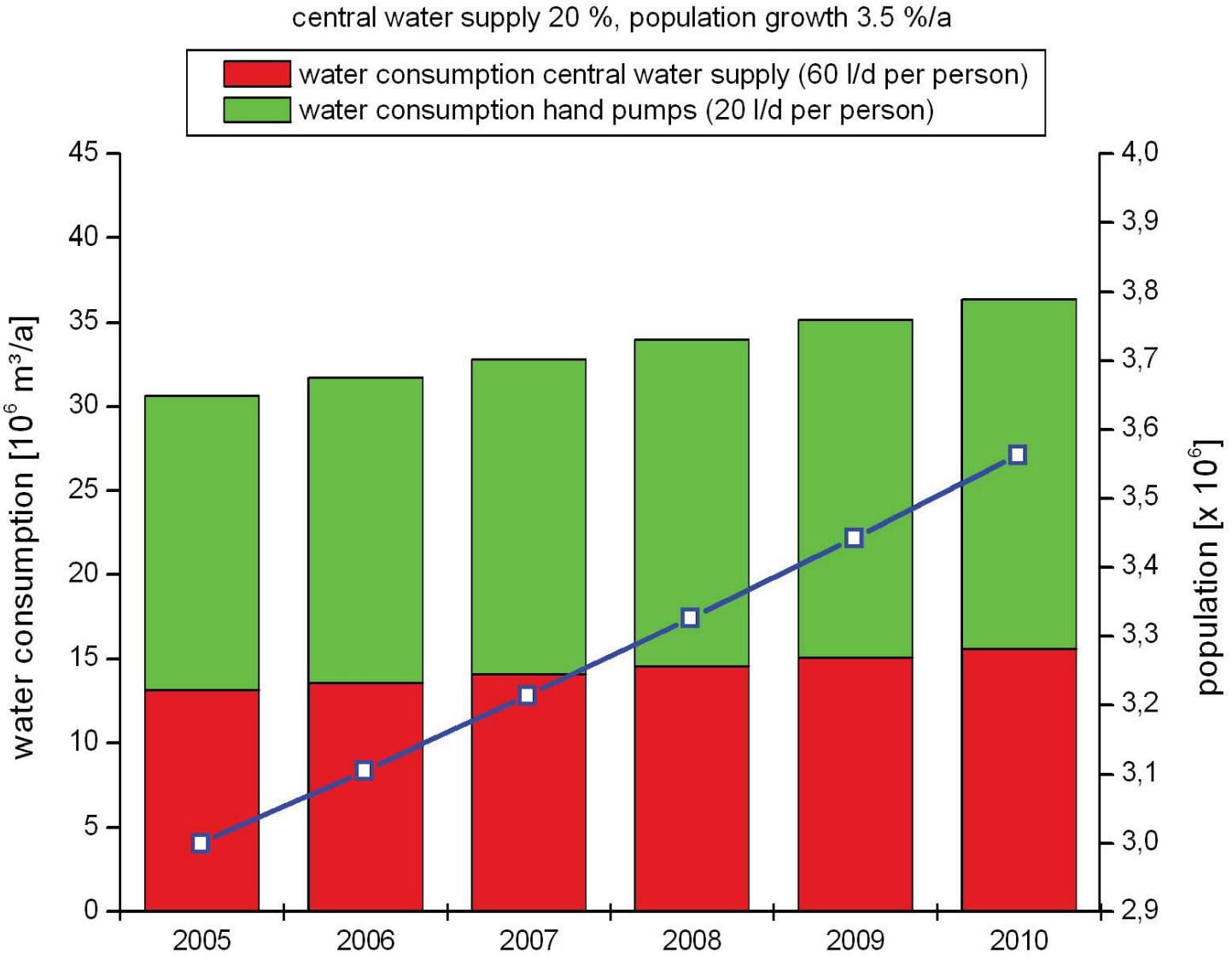
Only about 30.000 to 45.000 households
(at 16 persons each) with about
500,000 to 720,00 persons
(20% of total poulation of Kabul)
have access to piped water.

Estimated consumption: 50-75 l/d
per inhabitant

80 % use shallow wells with hand pumps:

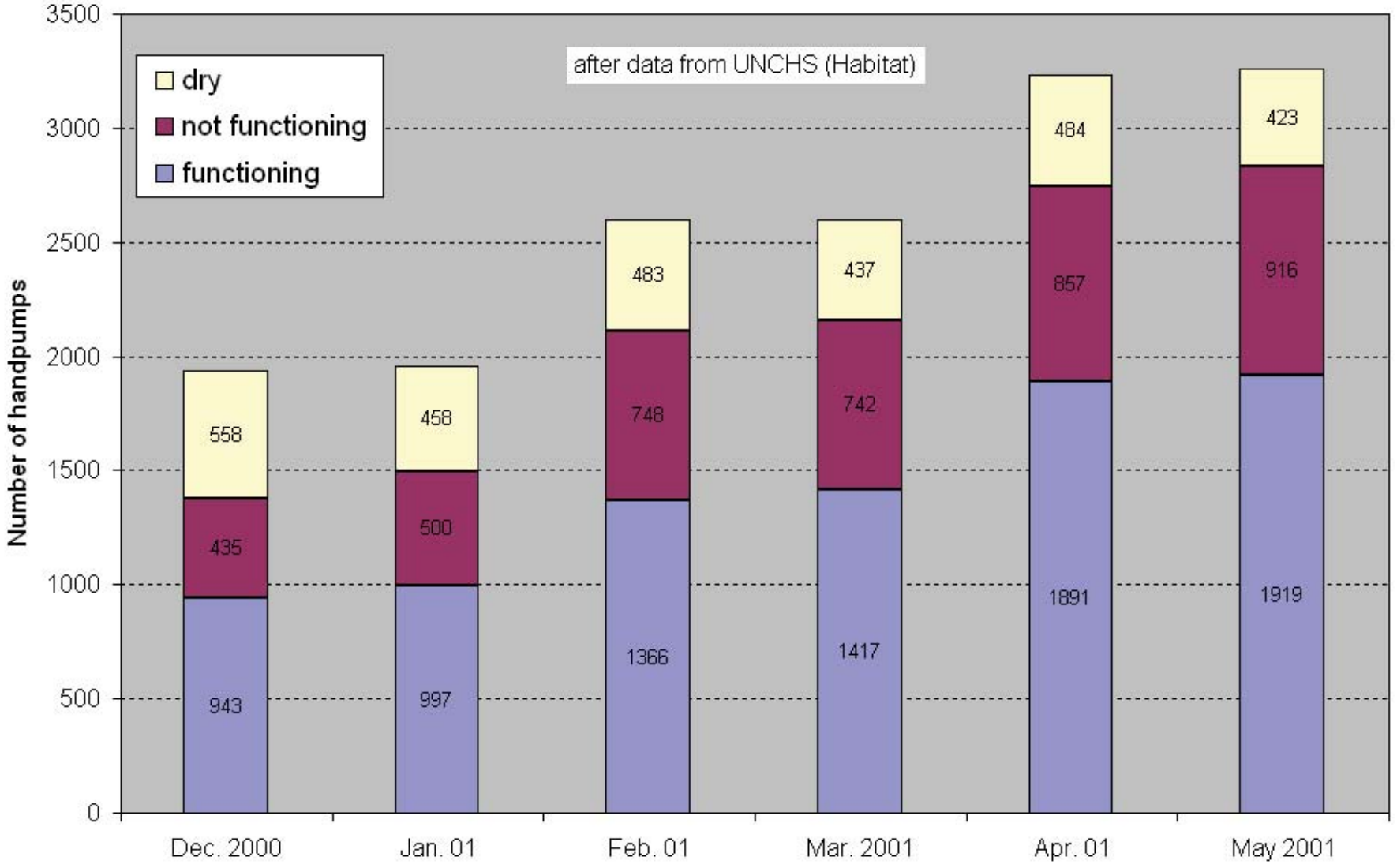
Estimated consumption : 20-30 l/d
per inhabitant

Rough estimates of water demand



Typical supply well in Kabul

Well construction in Kabul



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Waste and sewage disposal close to water wells

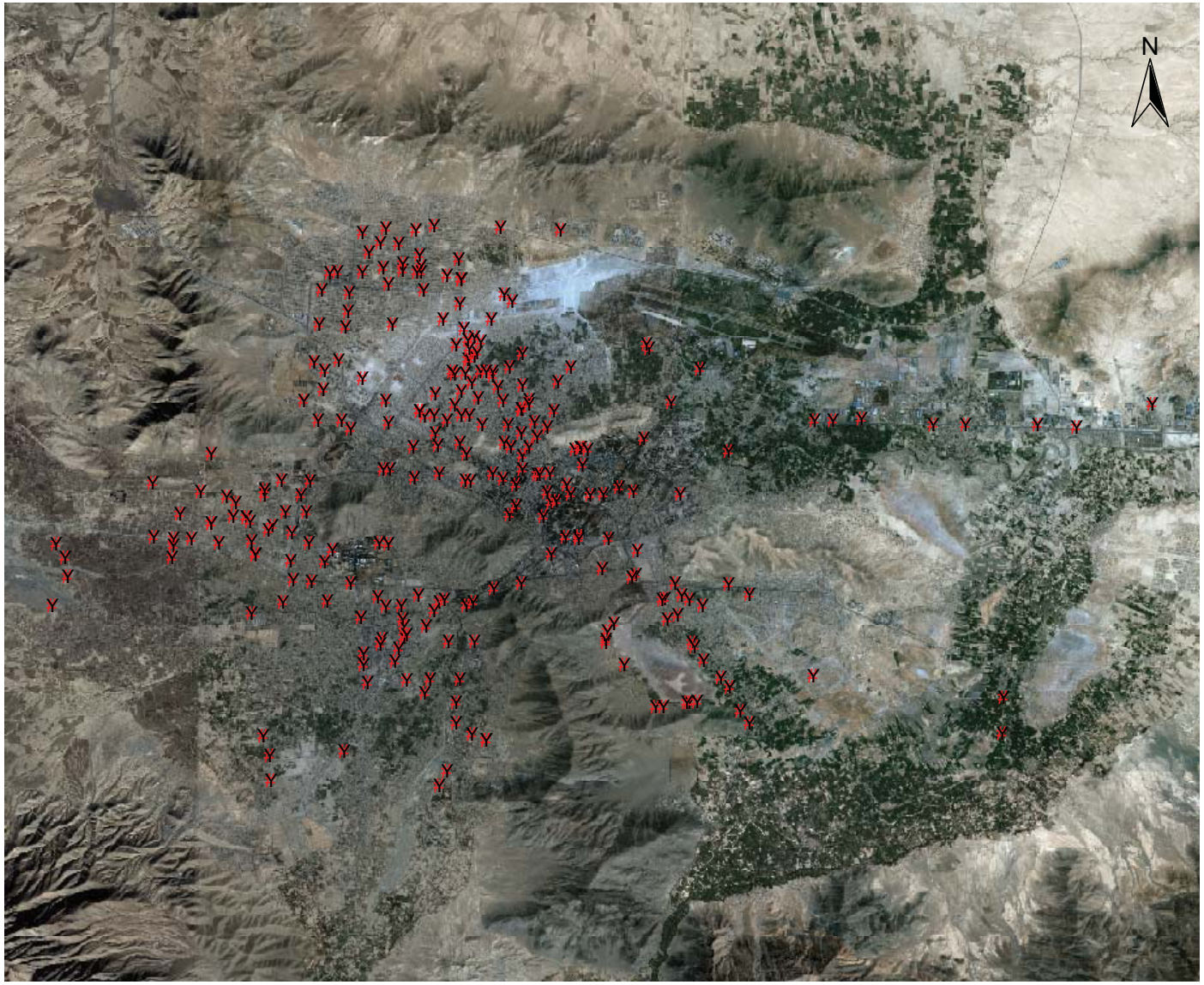
Waste and sewage disposal close to water wells

Foto: Tünnermeier

Hydrochemical screening of urban wells

- 290 well sites visited, 188 water samples analysed (65%)
- Parameters measured in-situ: pH, Eh, EC, O_2, T, nitrate (test kit), HCO_3^- (titration)
- GPS-coordinates, site description, some geological logs, depth, diameter, pump types

Foto: Tünnermeier



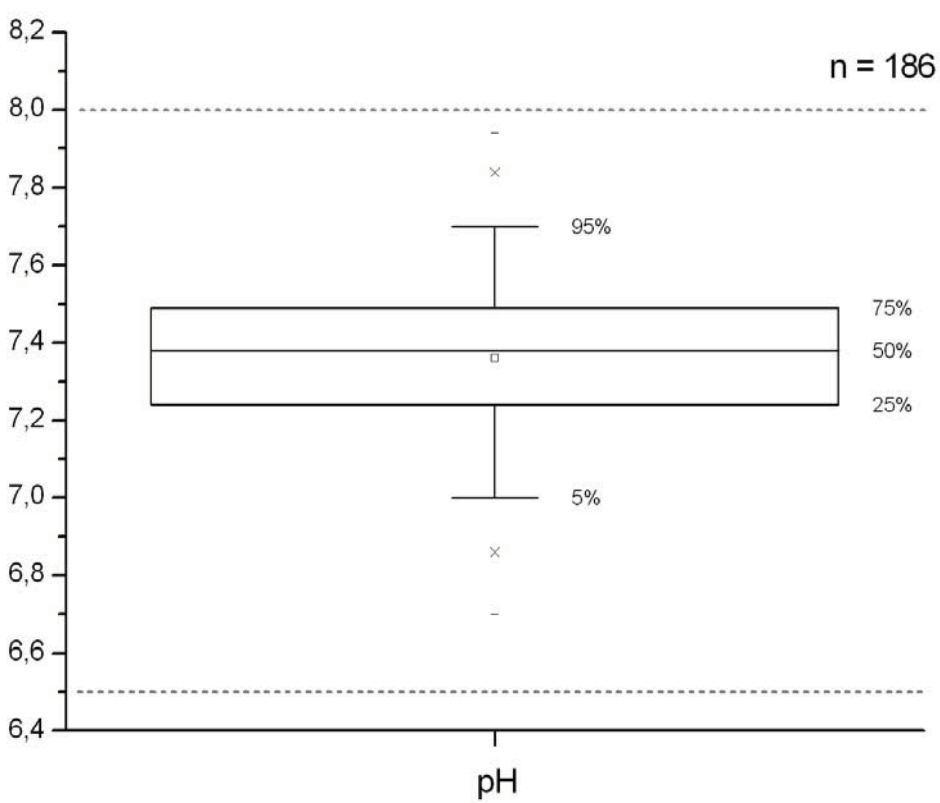
Locations of sampled wells (2004)

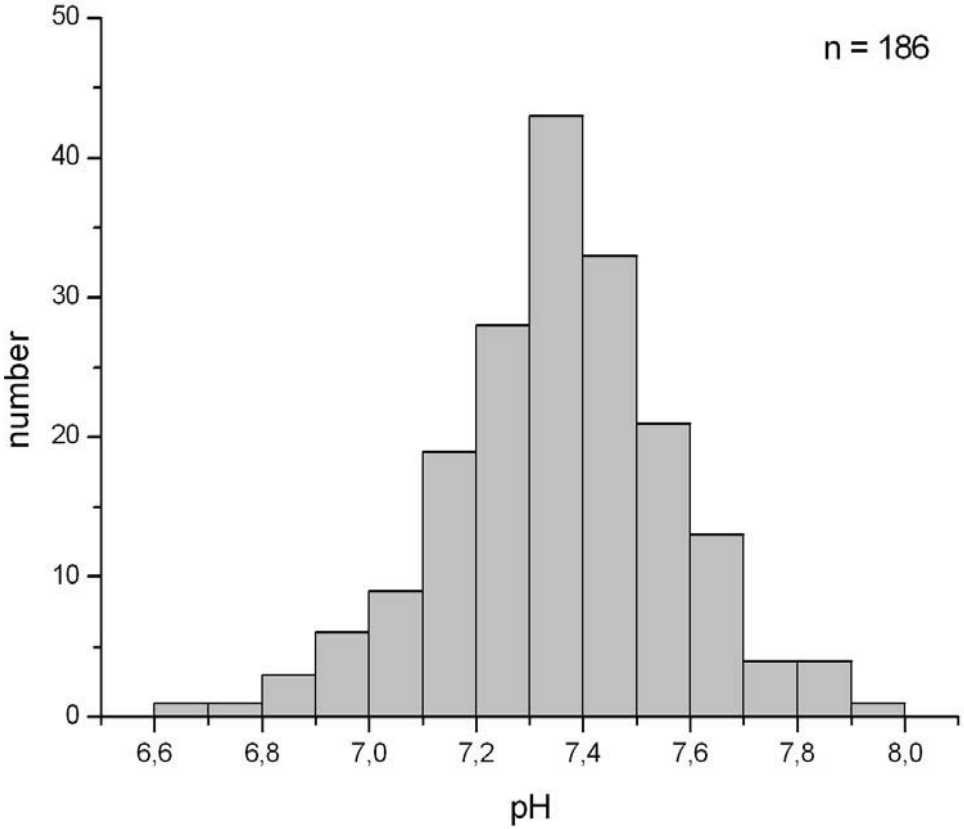
188 wells sampled:

- full chemical analyses
- microbiology
- trace elements

Good coverage of urban area but not of basin

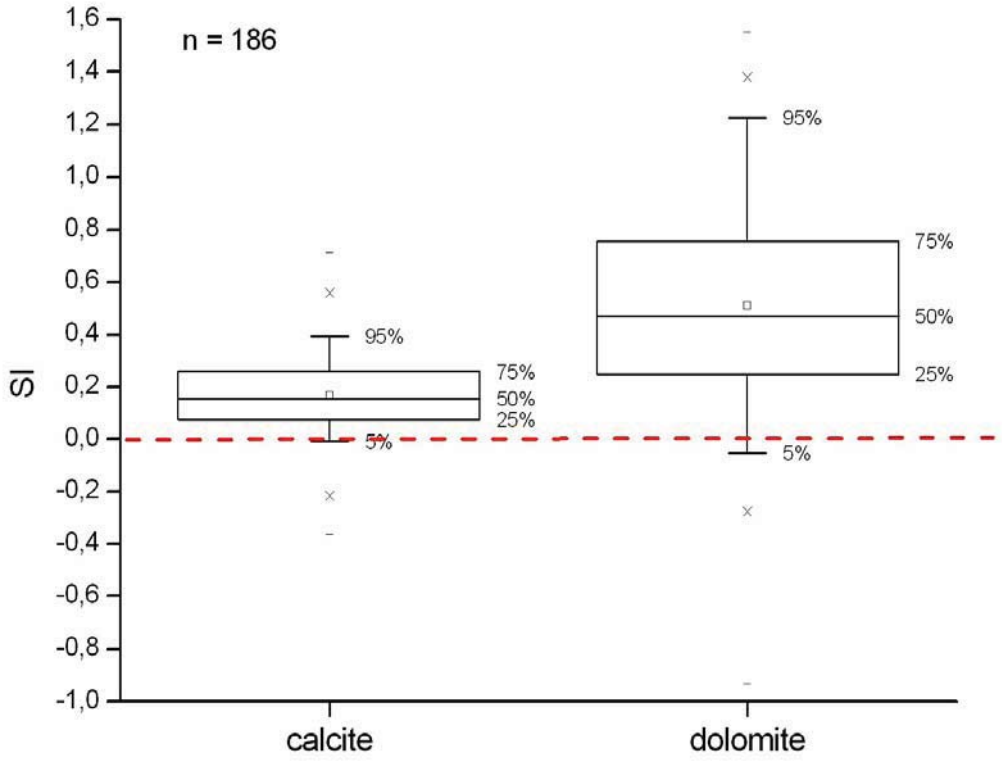
pH

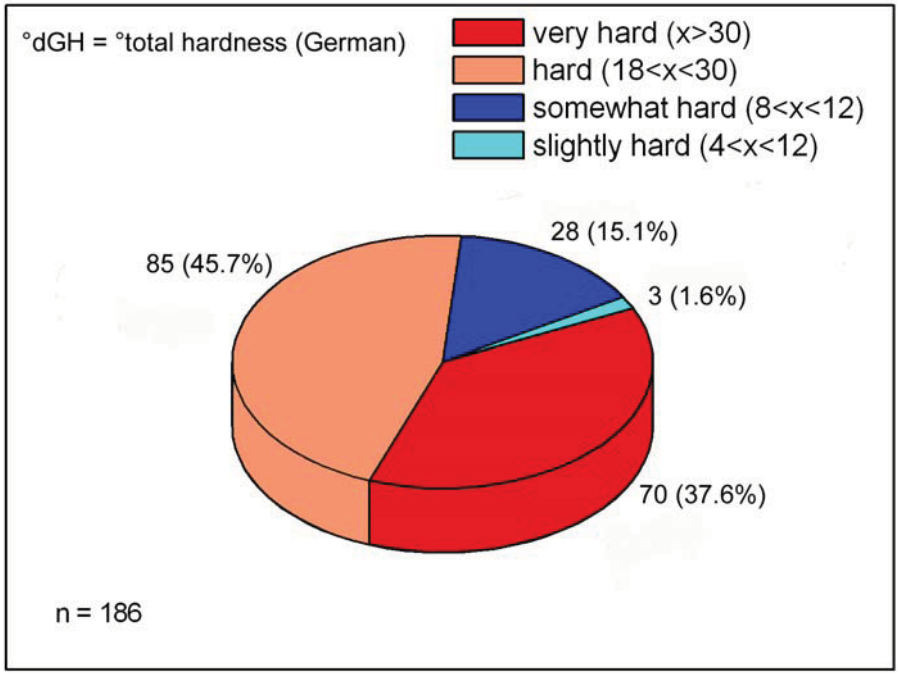




near neutral, very narrow distribution

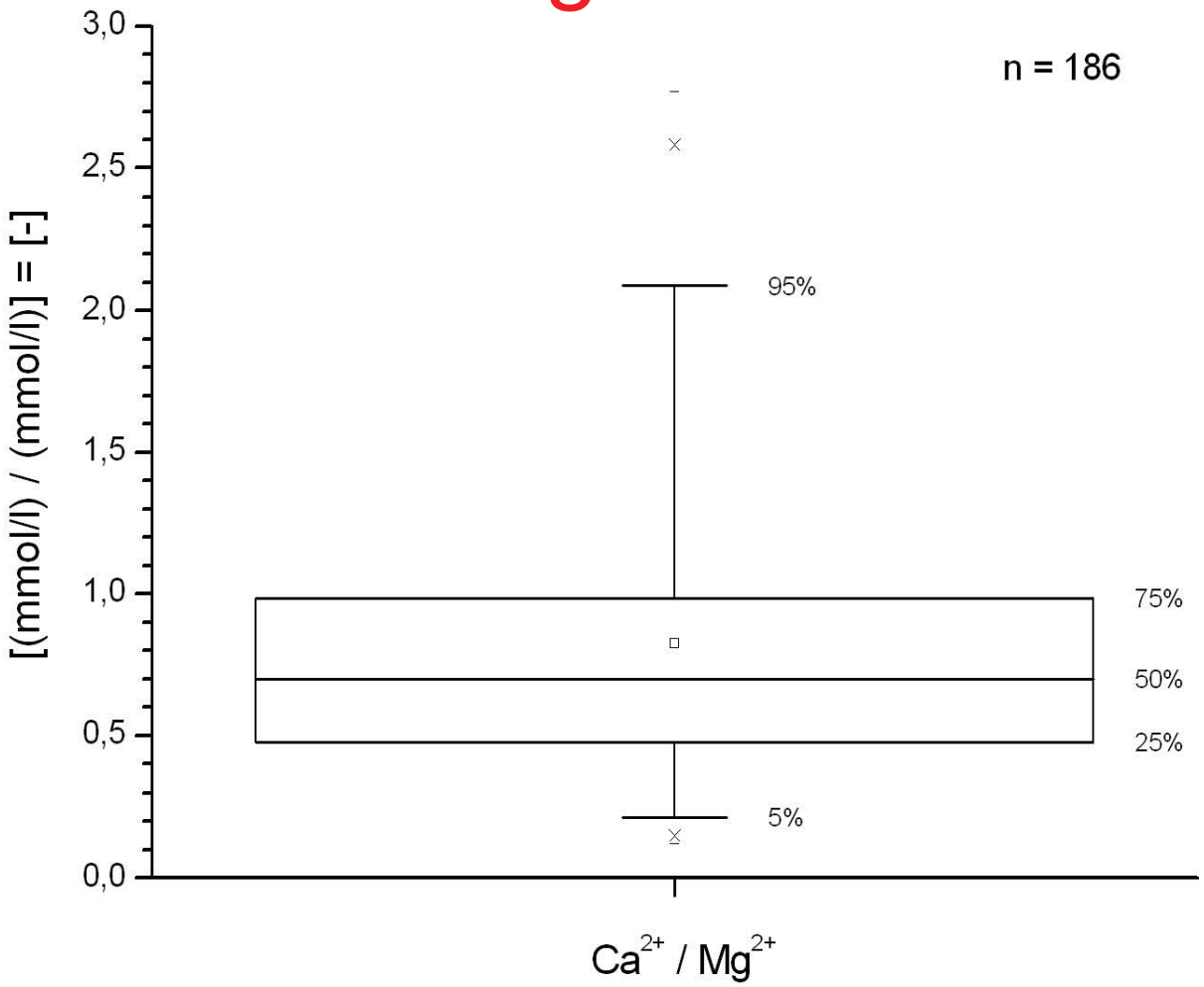
Hardness





very hard waters
carbonate buffering
(over-)saturated for carbonates
high scaling potential

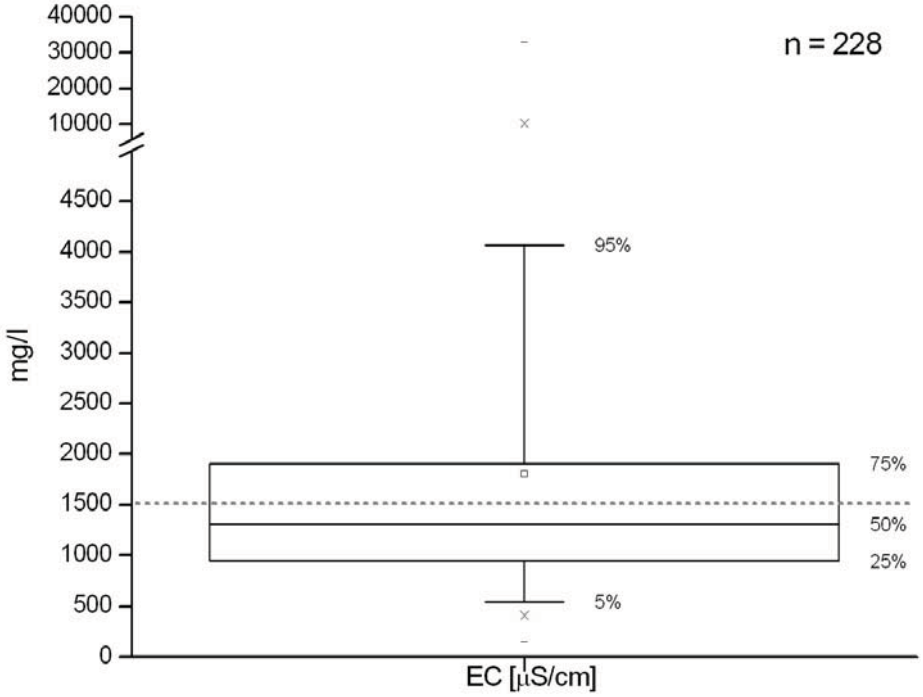
Ca/Mg ratio

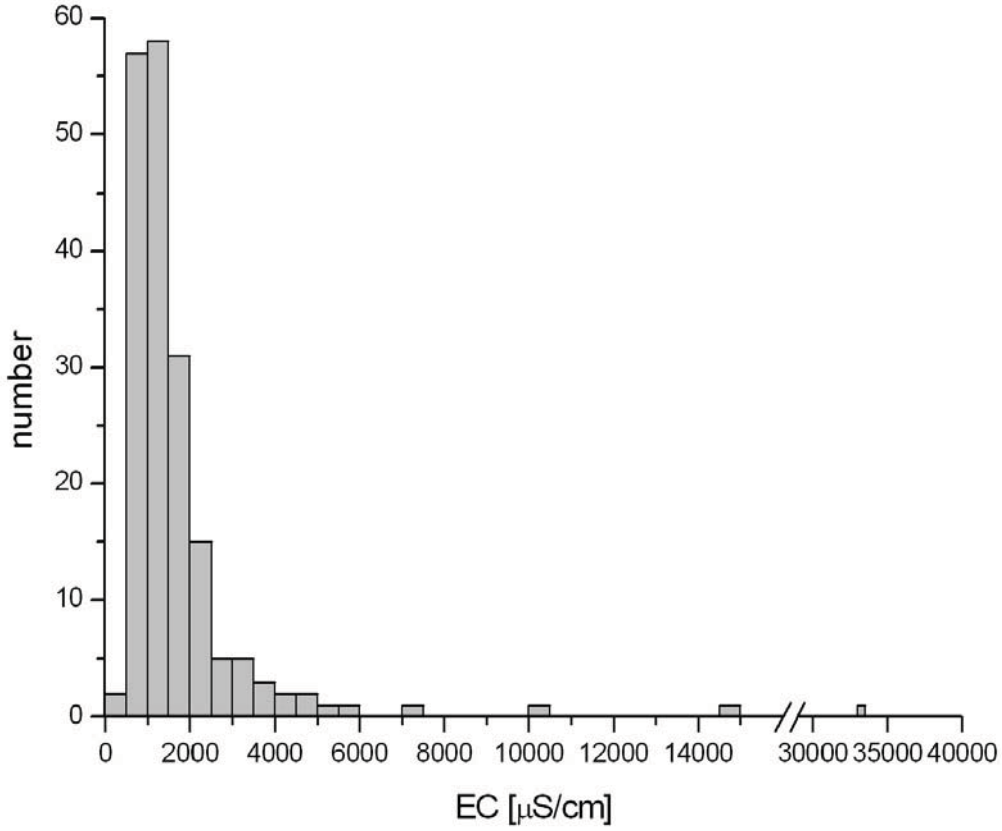


realtively high Mg content, higher than for dolomite stoichiometry, additional Mg source?

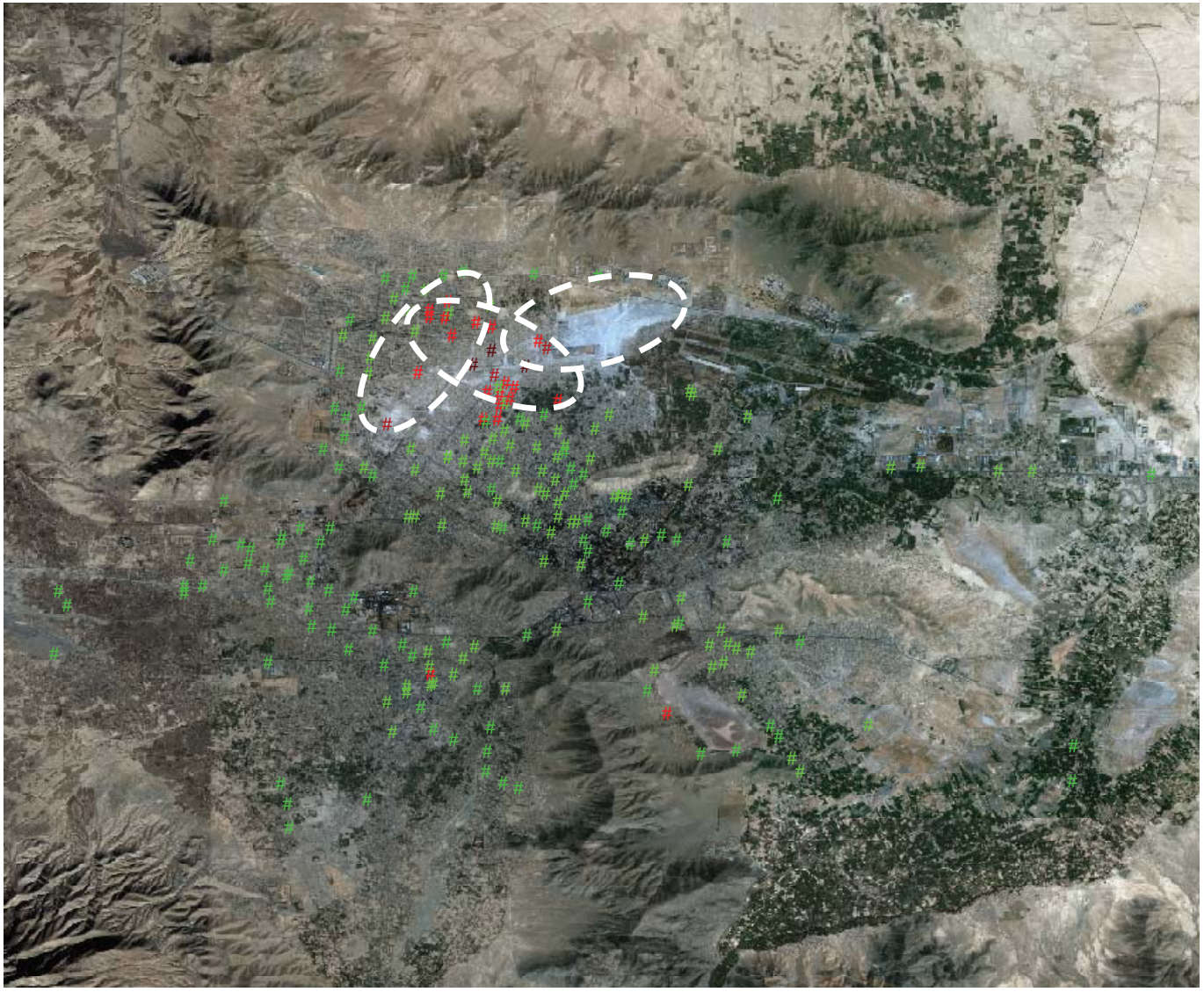
Specific electrical conductivity

- most waters show elevated to high mineralisation
- some waters are unsuitable for human consumption





Specific electrical conductivity

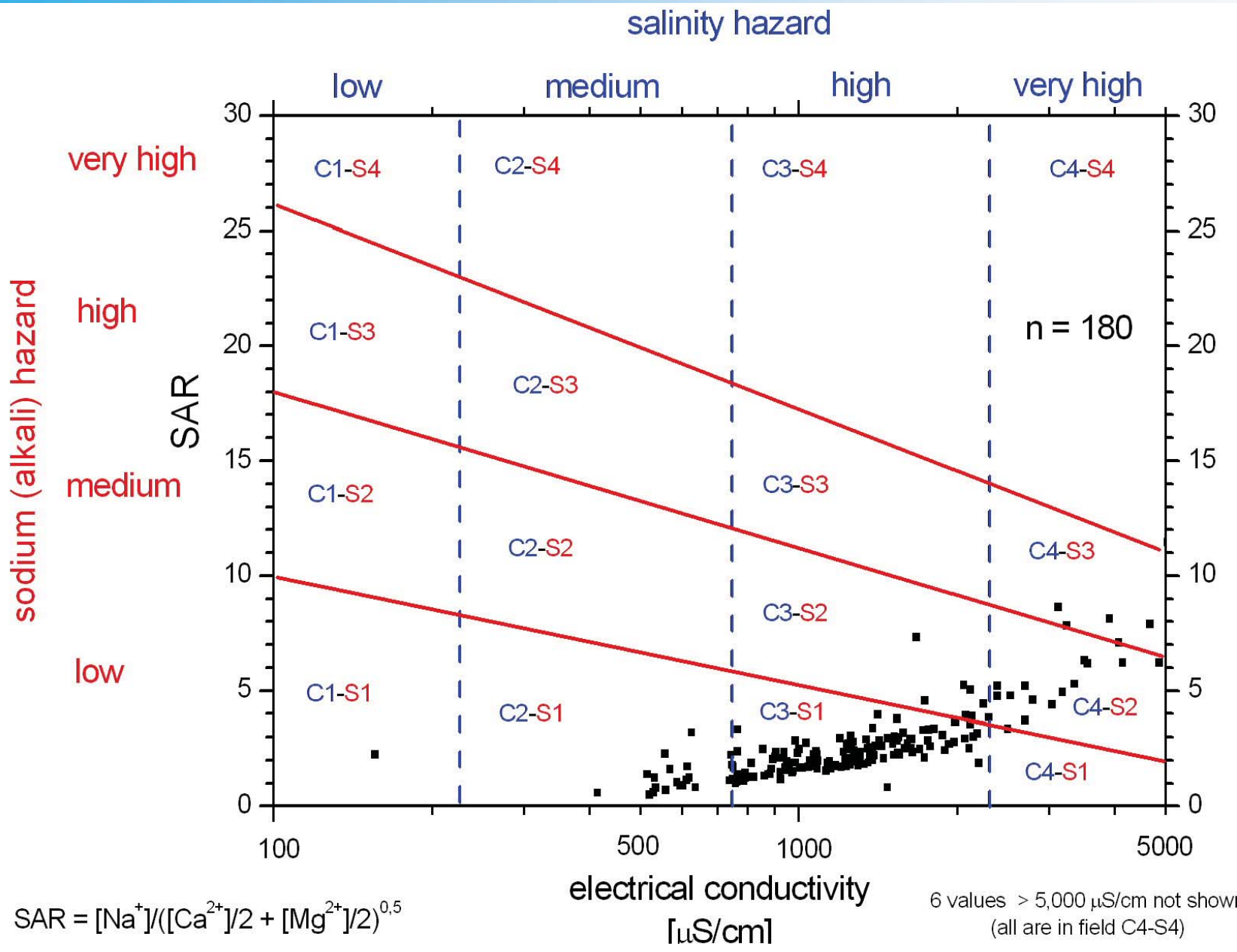


Satellite image Kabul basin

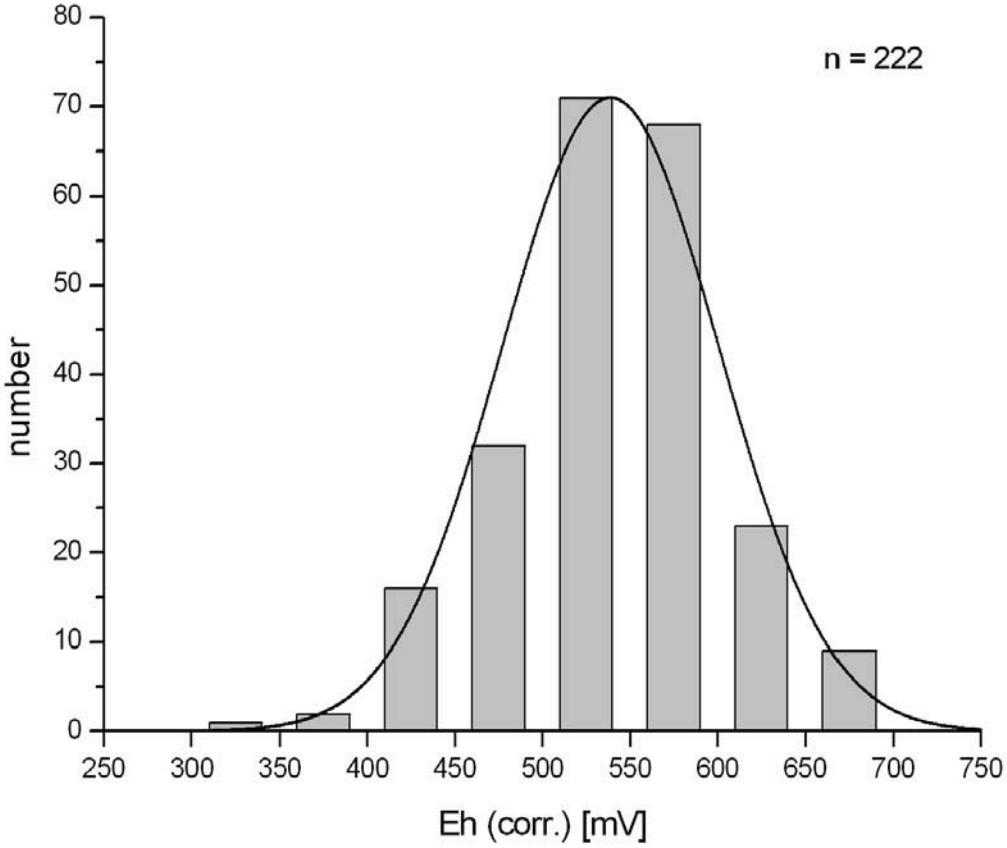
228 wells sampled

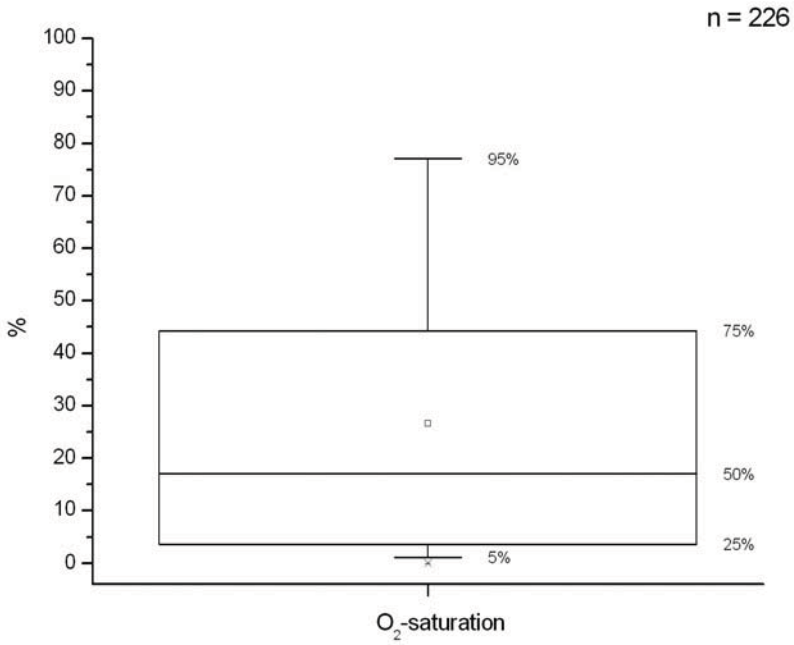
Former swamp areas dried up due to abstraction and lack in precipitation

groundwater and soil salinisation


salinity hazard
low
medium
high
very high
sodium (alkali) hazard
very high
high
medium
low
SAR
C1-S4
C2-S4
C3-S4
C4-S4
C1-S3
C2-S3
C3-S3
C4-S3
C1-S2
C2-S2
C3-S2
C4-S2
C1-S1
C2-S1
C3-S1
C4-S1
n = 180
30
25
20
15
10
5
0
100
500
1000
5000
electrical conductivity
[µS/cm]
SAR = [Na+]/([Ca2+]/2 + [Mg2+]/2)0,5
6 values > 5,000 µS/cm not shown
(all are in field C4-S4)

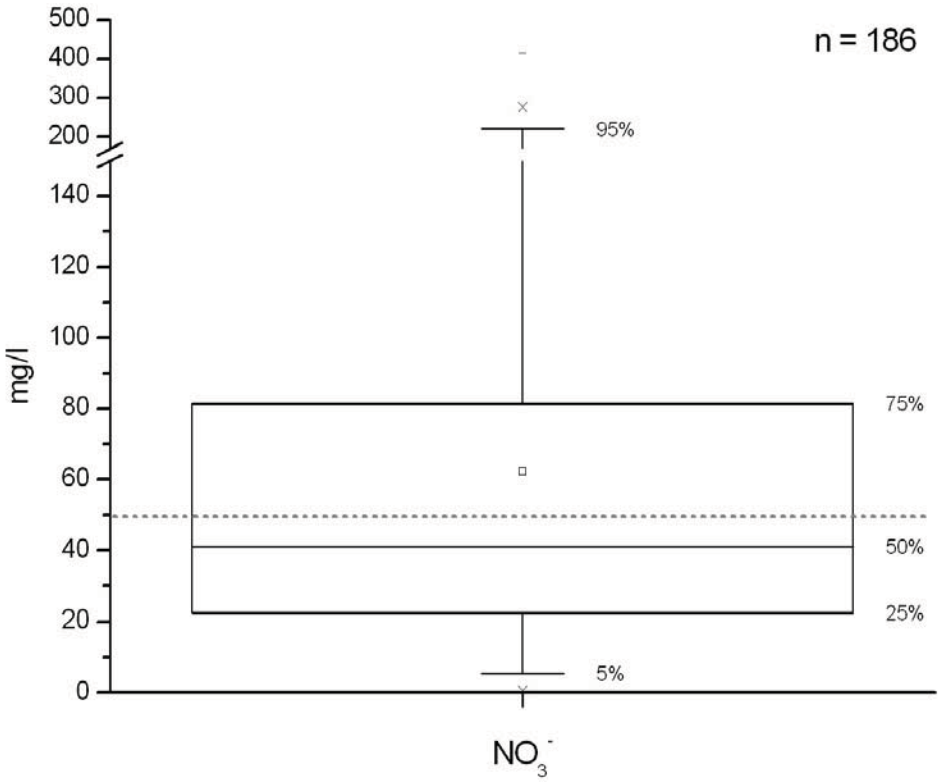
Redox condition

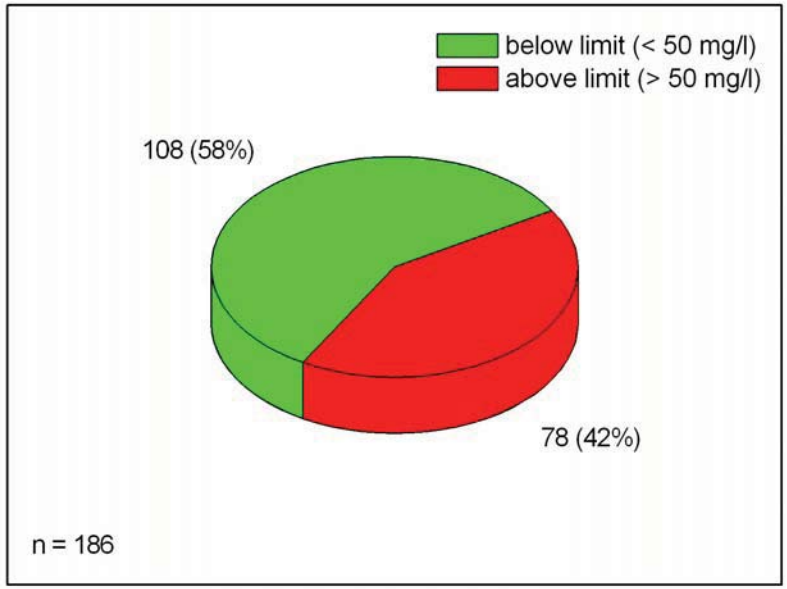




slightly oxic
- no iron, no manganese
- no ammonia, little nitrite

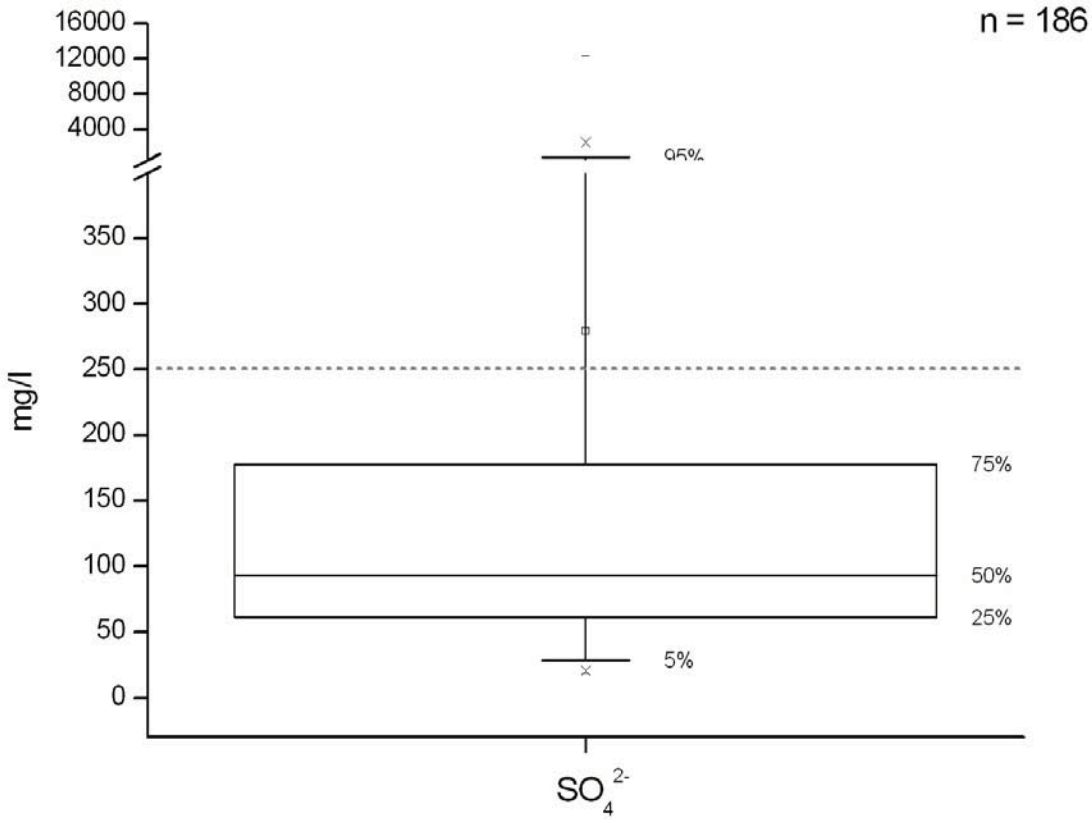
Nitrate

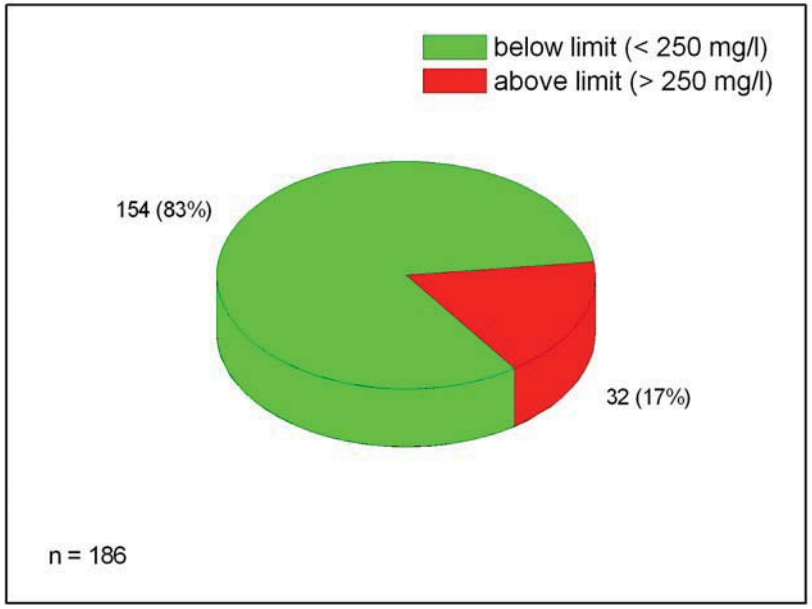




Almost half of all samples above WHO limit of 50 mg/l

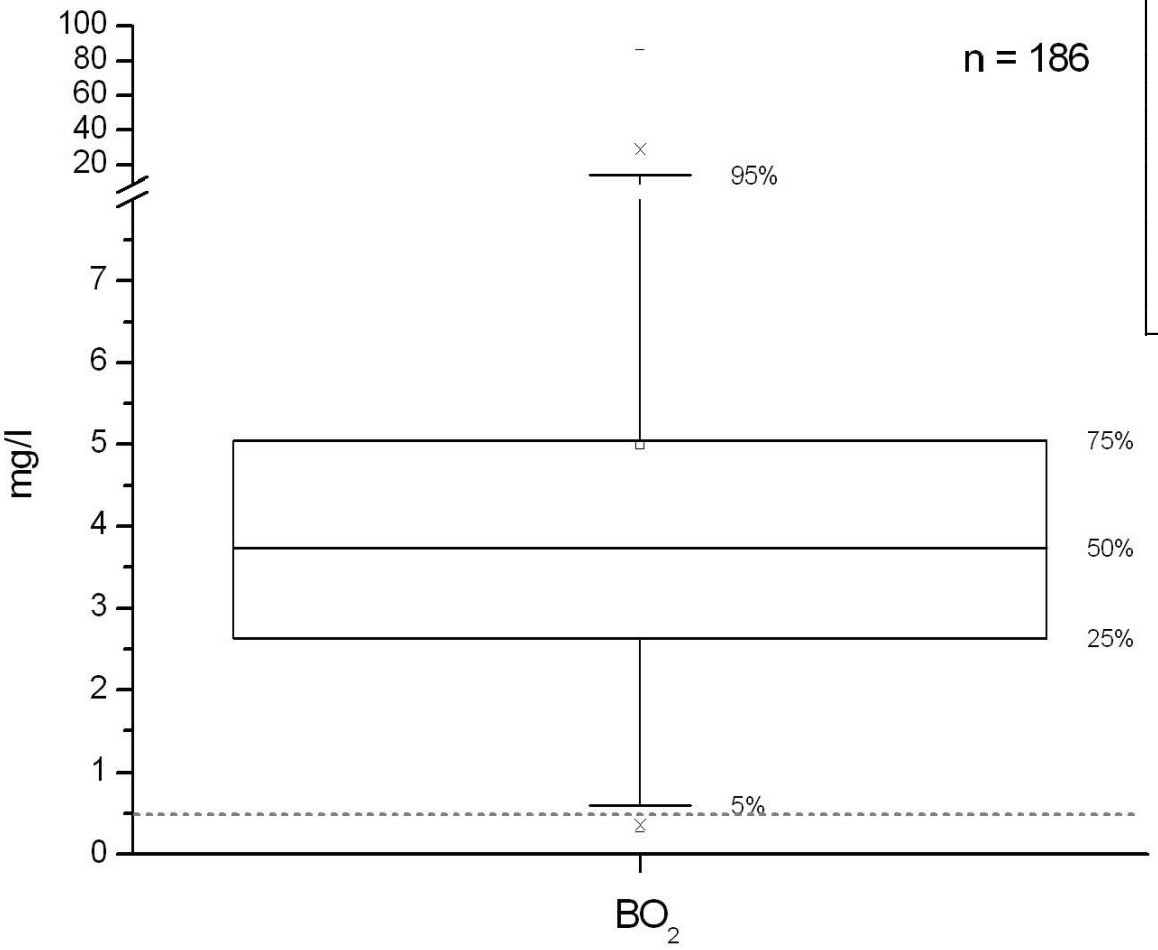
Sulphate

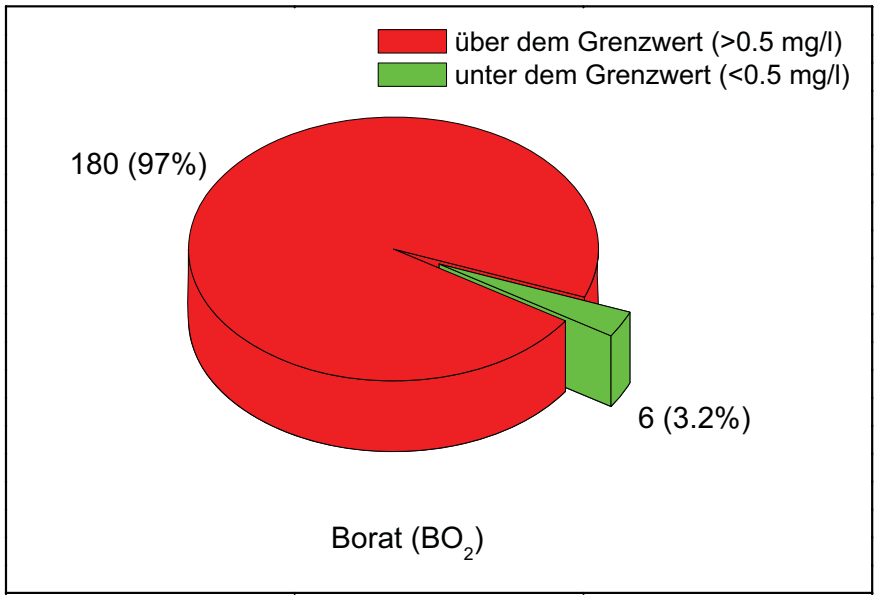




waste water influence (?)

Borate



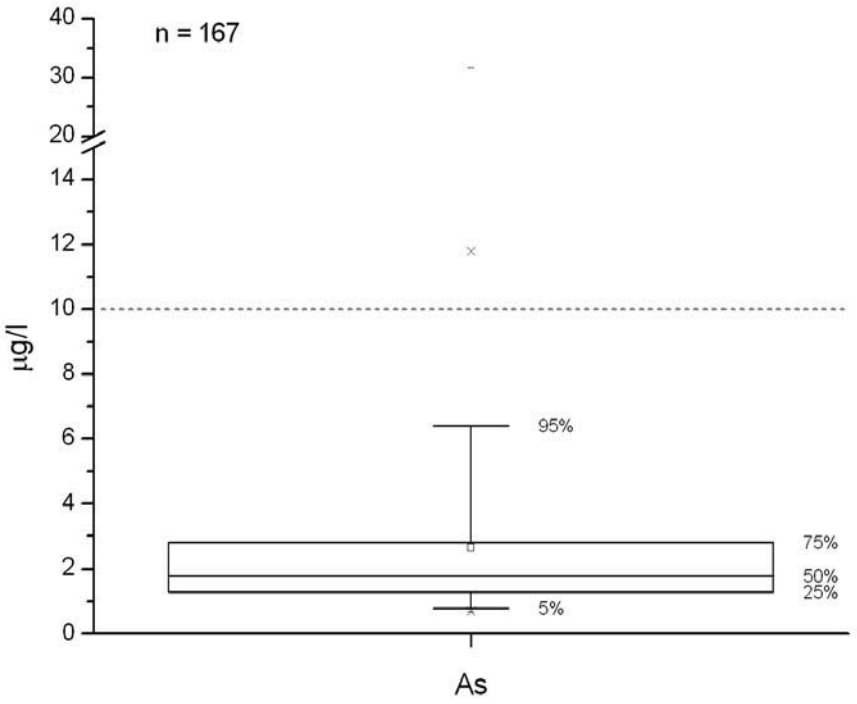


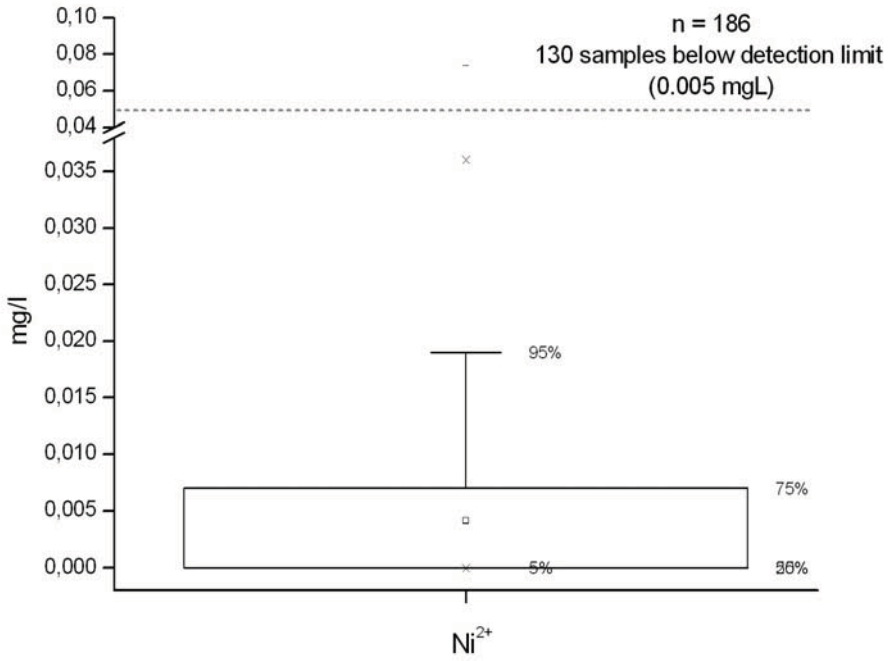
Almost all samples above WHO limit

Borate used as bleaching agent in washing powders

Natural enrichment in evaporative environments also possible

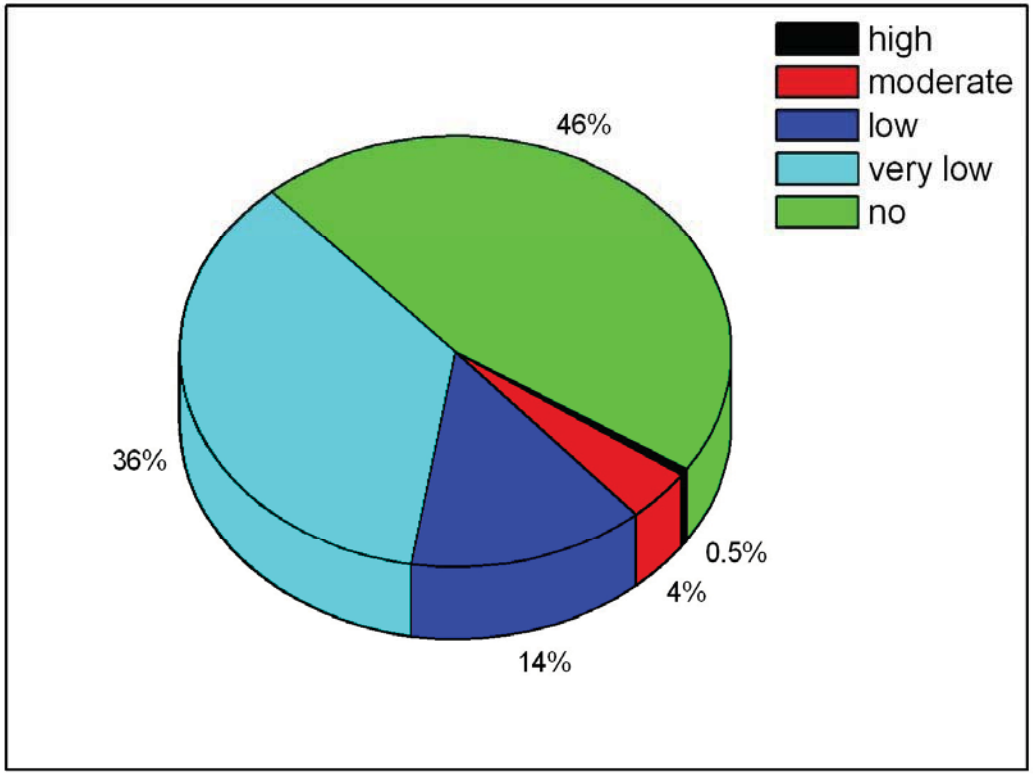
Trace metals and metaloids

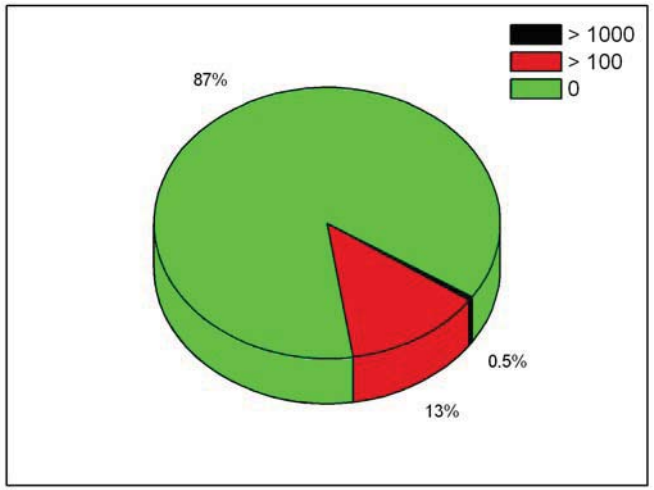




usually very low concentrations due to neutral pH and oxic redox potential

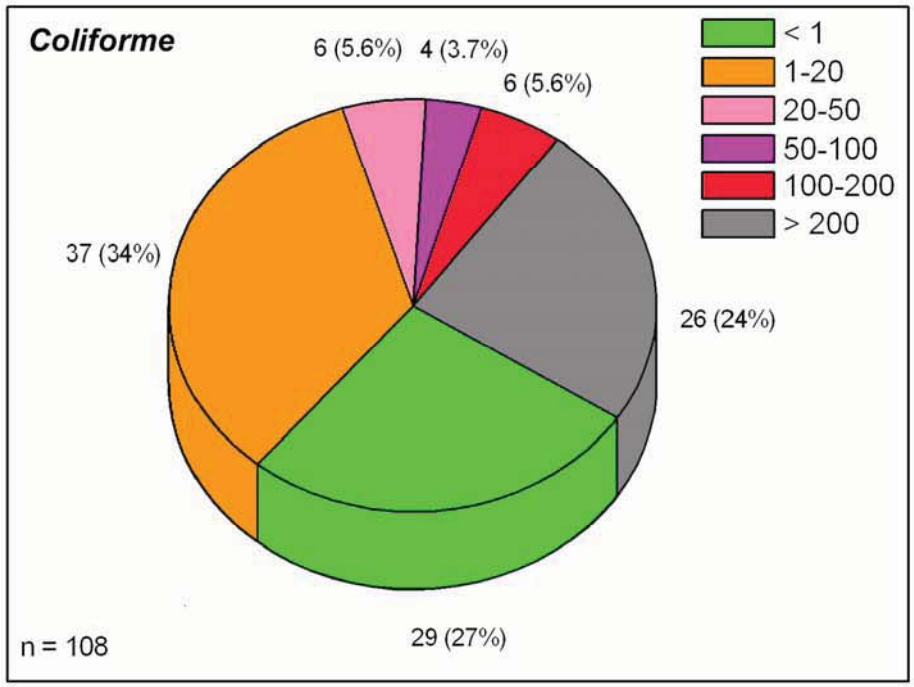
Aerobic & coliforme bacteria

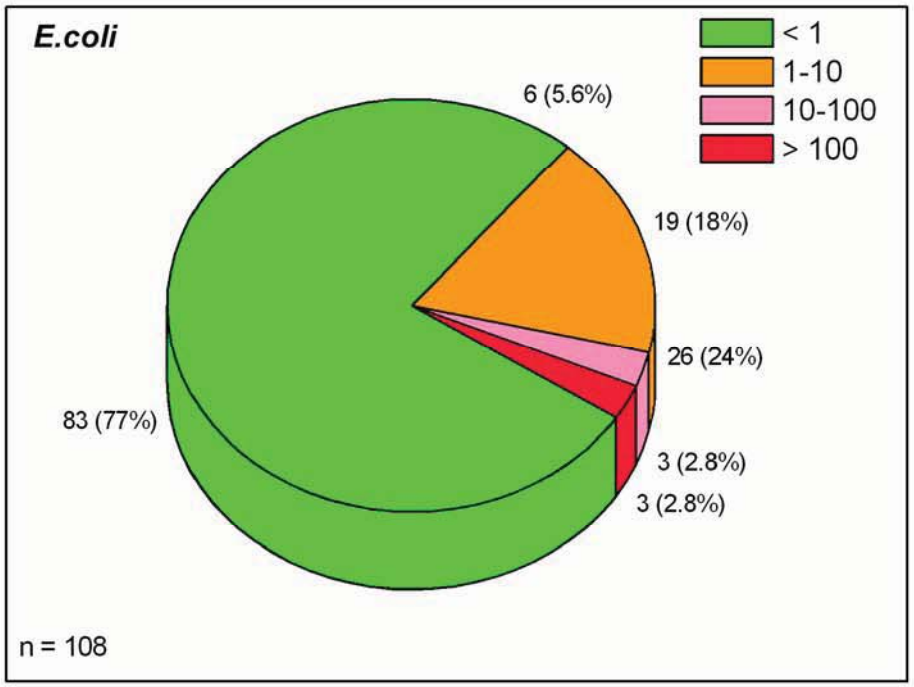




About 15-20 % of all wells are strongly polluted by bacteria

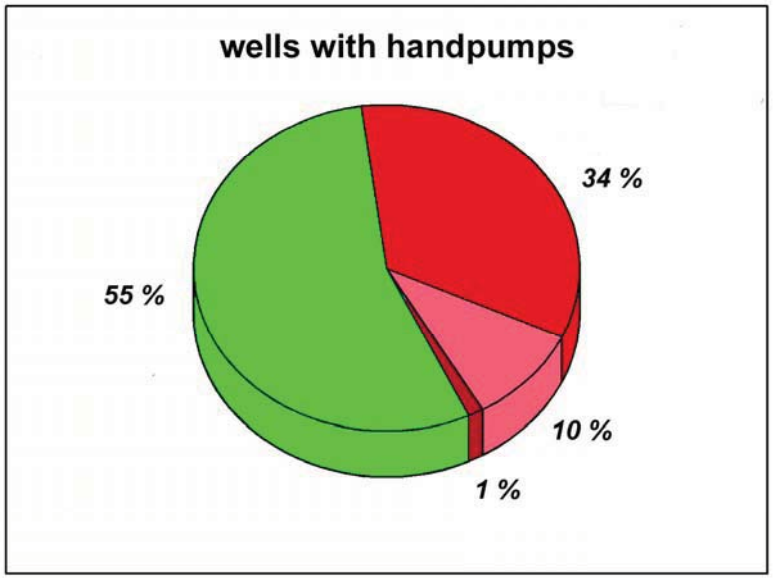
Microbiology, fecal bacteria

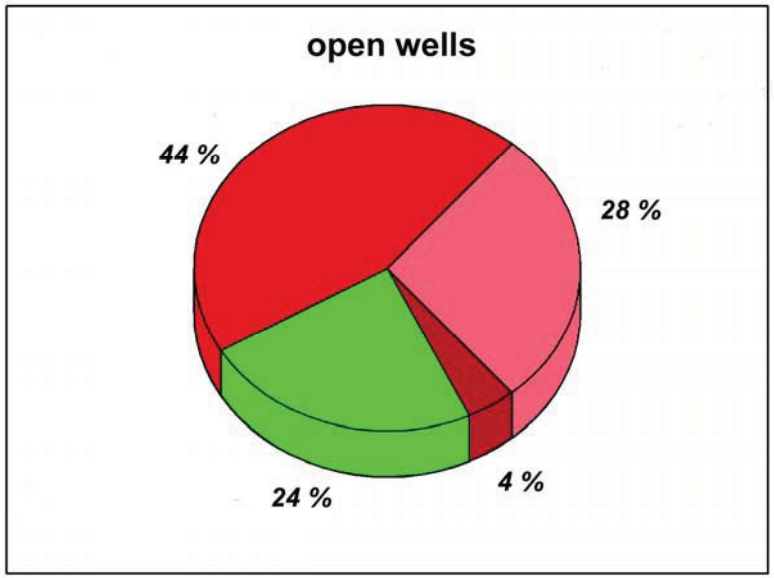


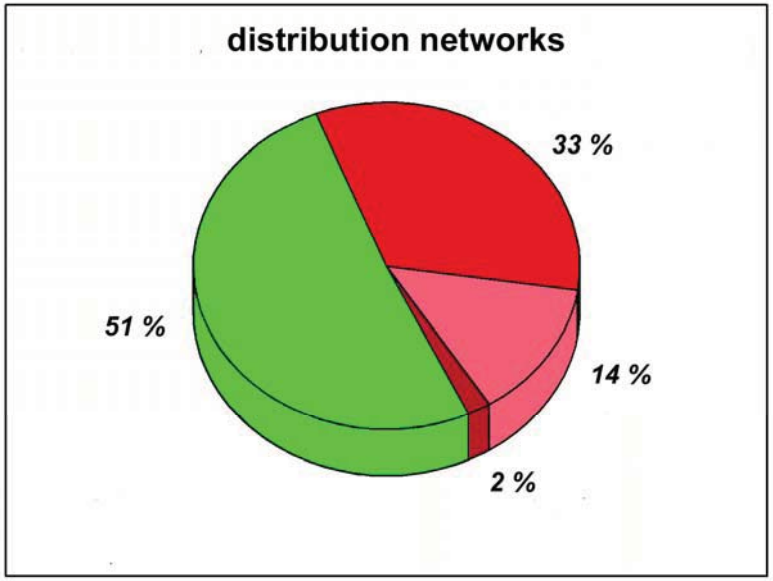


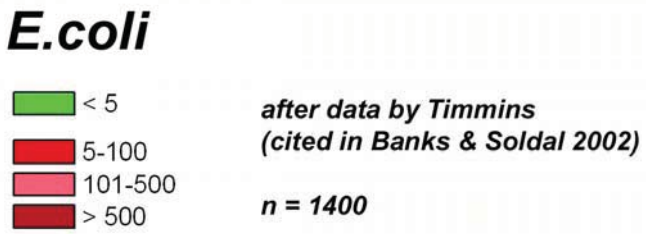
About 70 % of all wells are polluted by fecal bacteria, one quarter by *E.coli* (after data by USGS 2005)

> 85 % of all households in Kabul only have a one stage cesspit



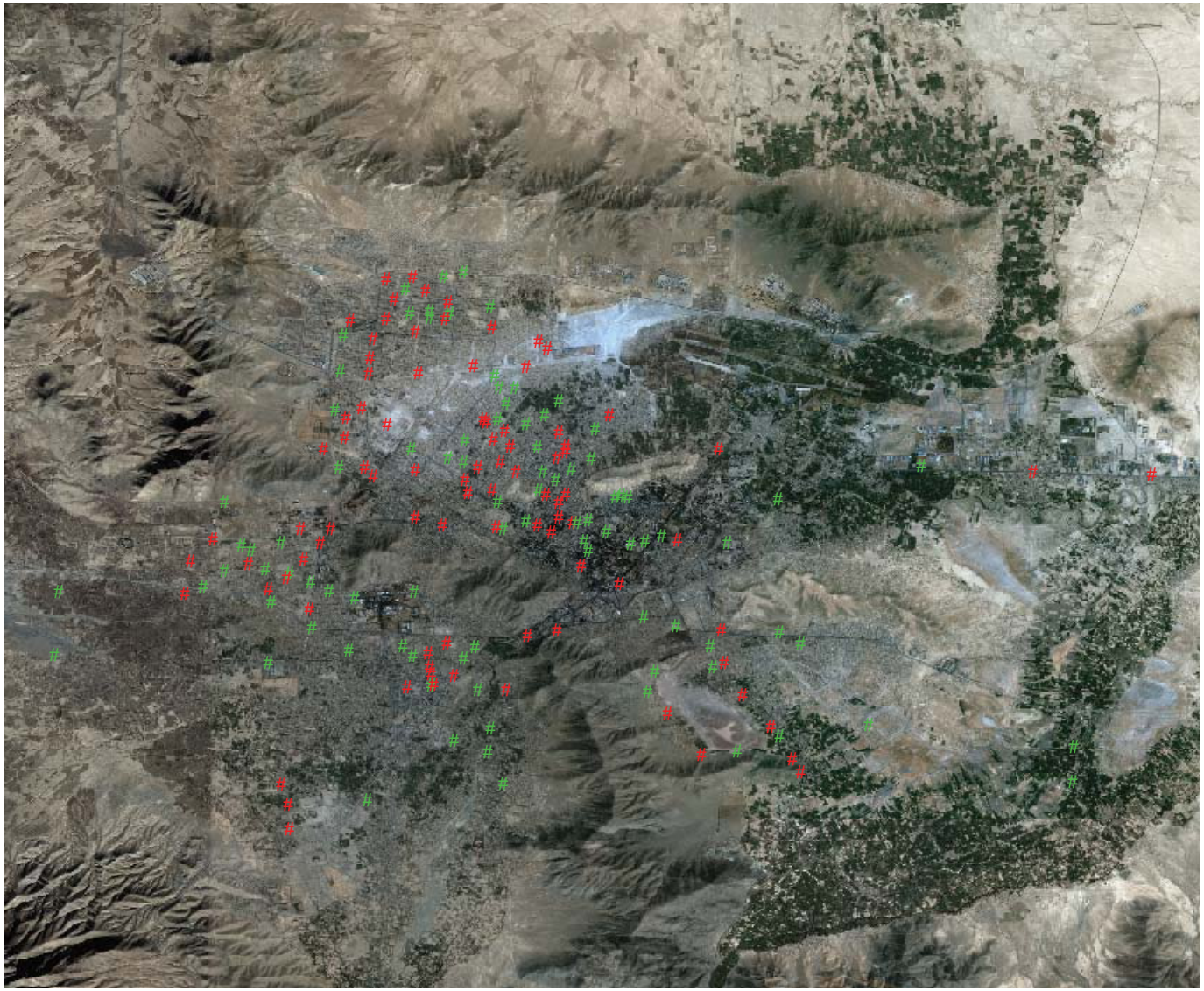






About half of all distribution networks and wells with hand pumps are polluted by fecal bacteria. Three quarters of shaft wells suffer from the same problem (data: Timmins)

Microbiology (Hach-paddle tests)

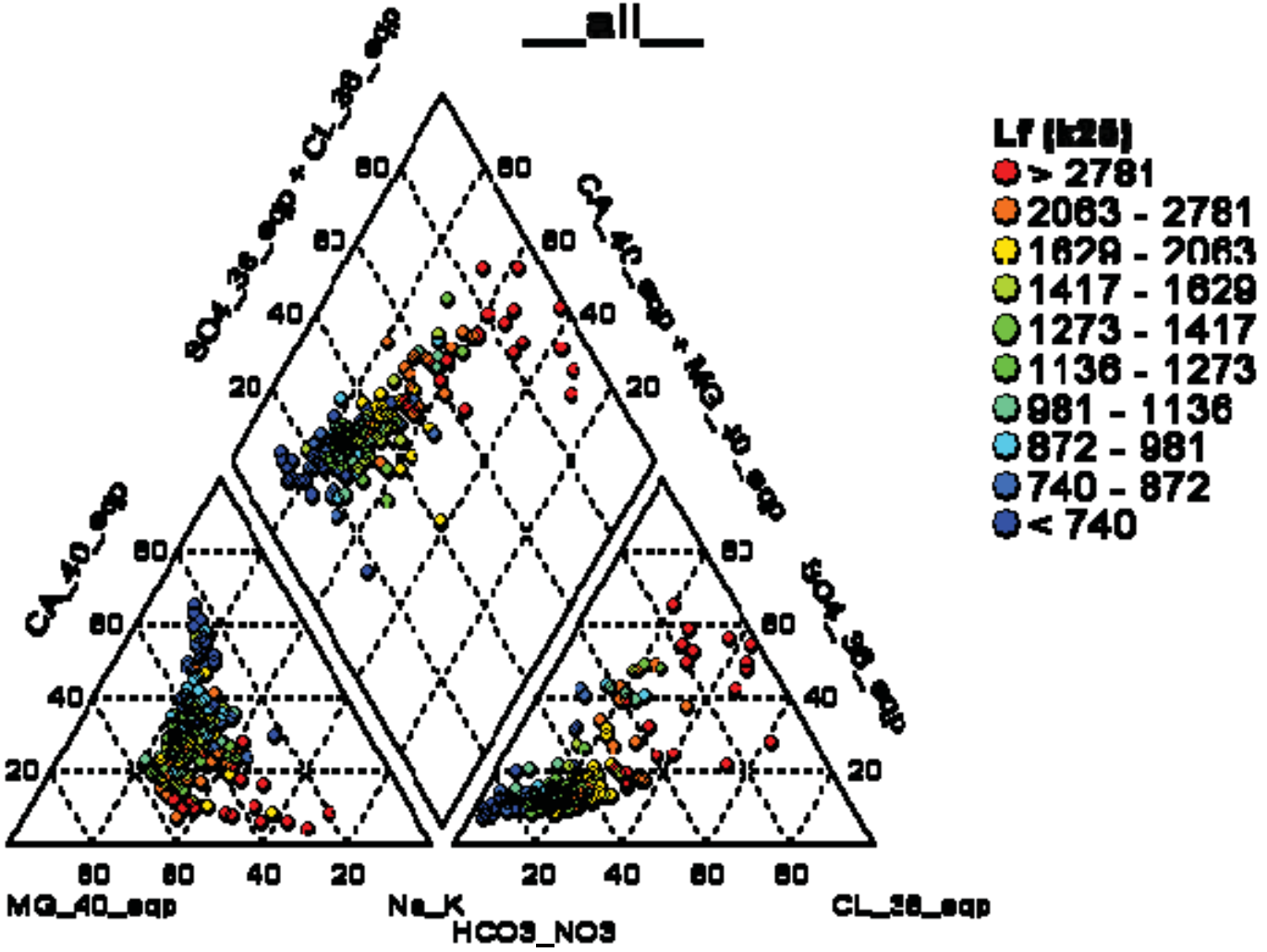


Irregular spatial distribution of microbially polluted samples

Causes?
- heterogeneity of aquifer
- heterogeneity of input

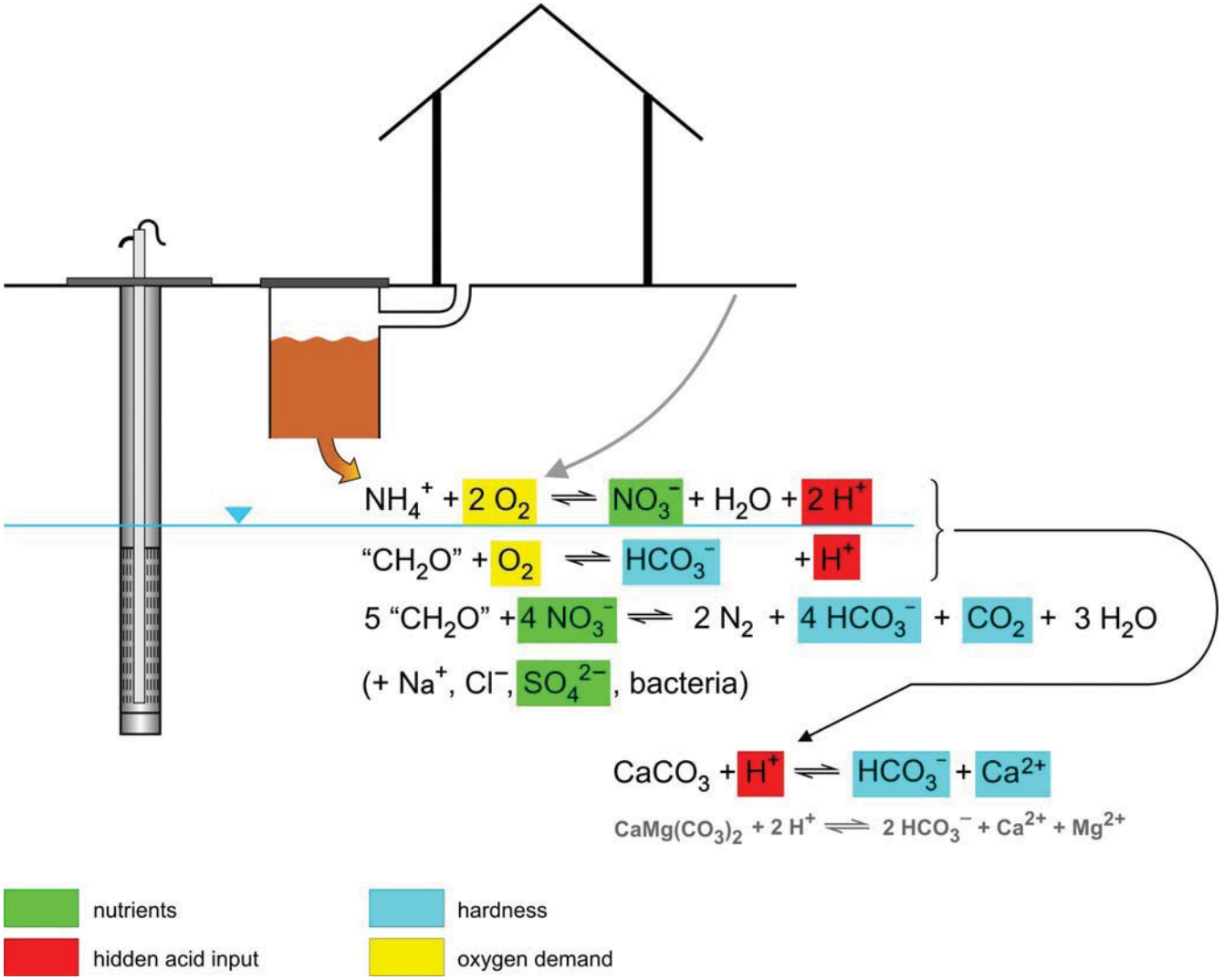
Loess layers are of utmost importance for groundwater protection !

PIPER-diagram of Kabul groundwaters

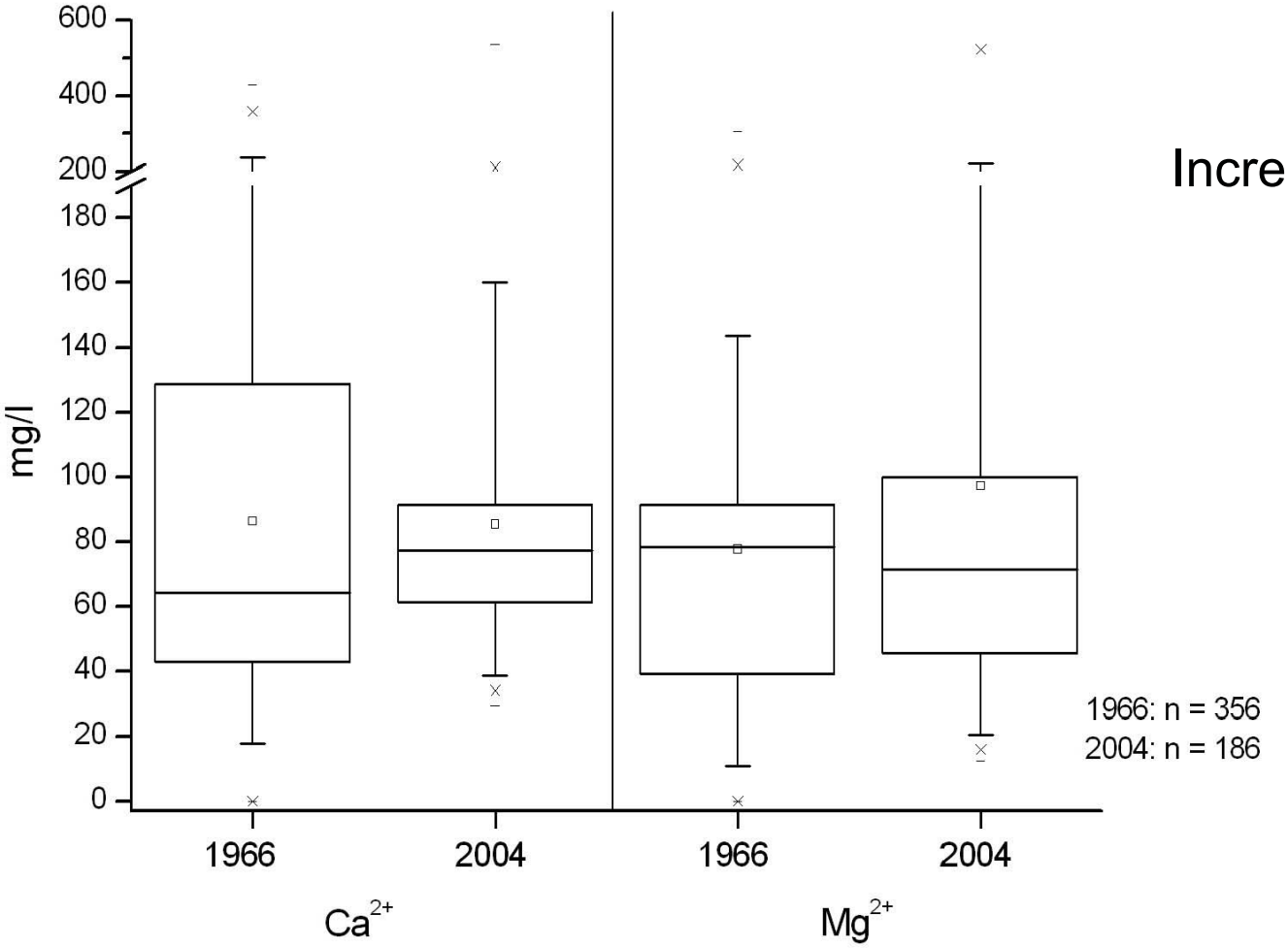


BGR Bundesanstalt für Geowissenschaften und Rohstoffe Hannover

Cess pits and their influence on shallow groundwater

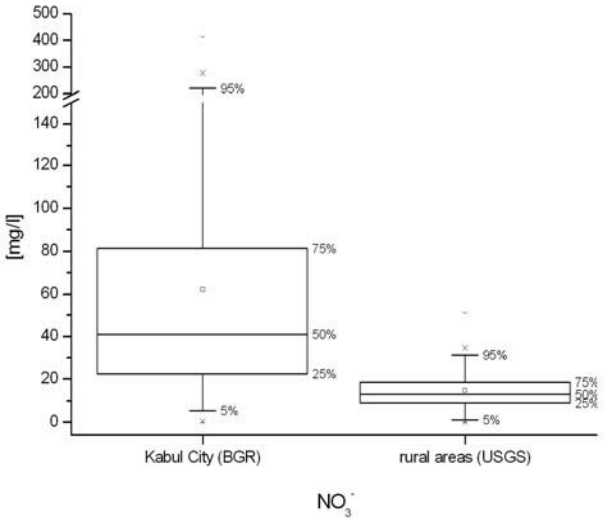


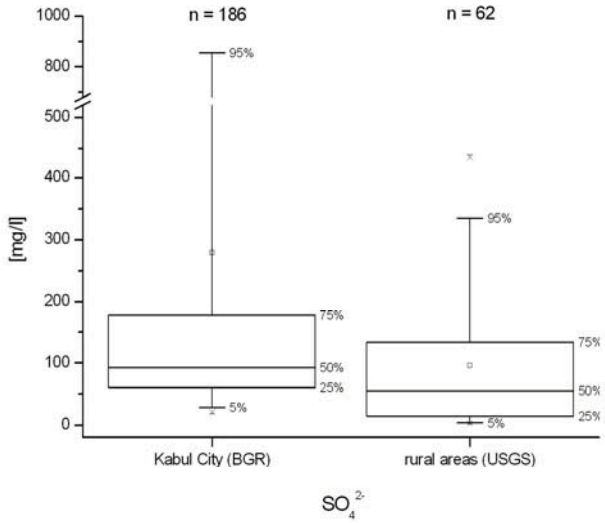
Comparison 1966 and 2004

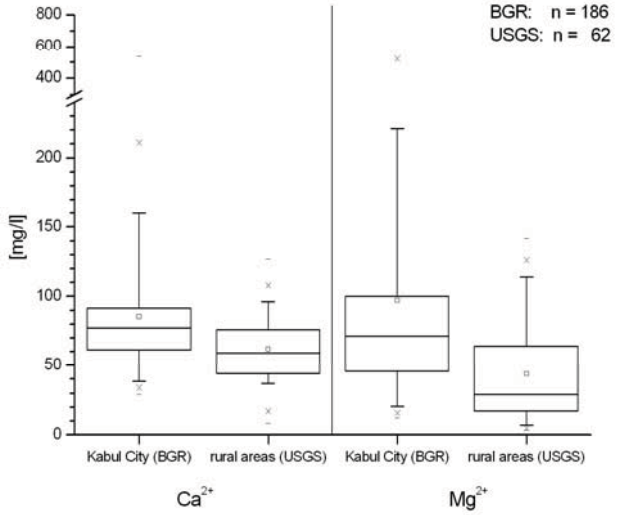


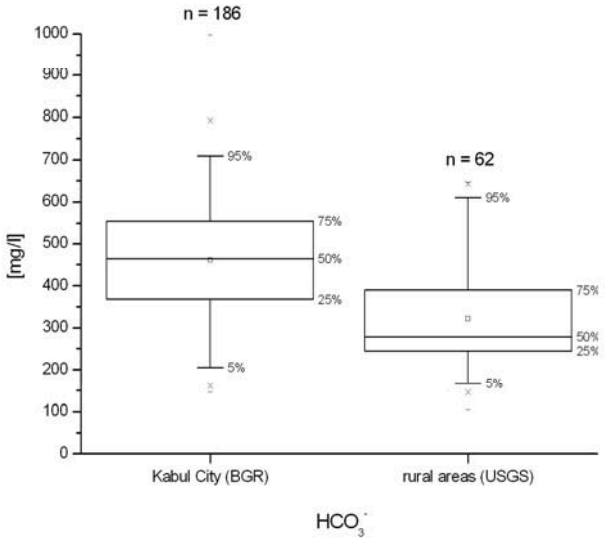
Increasing hardeness!

Comparison of Kabul City and its surroundings



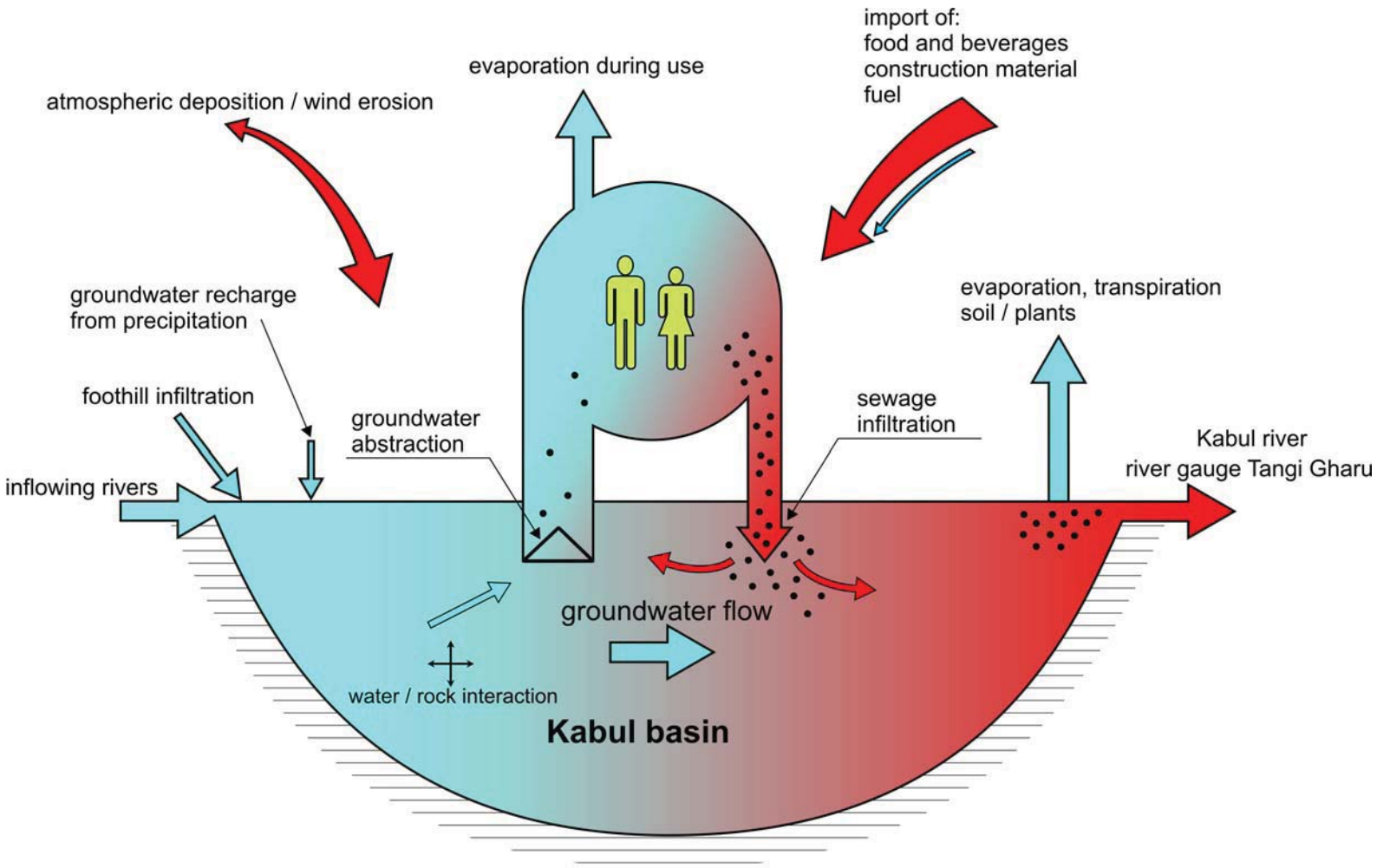






City groundwaters are much more affected by pollutants (e.g. nitrate and sulfate) and indirect pollution indicators (e.g. hardness) than the agricultural surroundings

Fluxes in the Kabul basin



enrichment of salts and nutrients through waste water input and evaporation

Summary

- highly permeable gravel aquifers in channel structures, deeper parts often cemented (conglomerates), protective loess layers
- groundwater recharge mostly from river-bed exfiltration, foothill infiltration?
- neutral pH through strong carbonate buffering (→ carbonate precipitation)
- slightly oxic redox conditions, no iron, no manganese
- elevated nitrate, borate concentrations but no heavy metals and metaloids
- mineralisation of human faeces and urine from cesspits causes oxygen consumption and massive input of hidden acid (hardness!), nitrate and salts
- accumulation of salts through constant waste water input and evaporation
- strong increase of hardness, salt and nutrients from 1966 to today

Summary

- problematic development of water resources (negative water balance)
- ground water levels have decreased by about 9-10 m compared to 1970s
- water quality deteriorates due to massive uncontrolled waste water input
- high evaporation rates amplify salt accumulation
- growing population poses threat to quantity and quality of water resources
- several wet years are needed to fill up the aquifers and flush out accumulated salts and pollutants

Outlook

better data on water demand, fluctuations of water levels, static storage (pumping rates of hand pumps, automatic water level recorders)

→ water balance
→ rough model

- re-establishment of discharge measurements of rivers
- re-establishment of climate data measurements
- comparison of hydrochemical data from Kabul city with data from surrounding agricultural areas
- chemical analysis of rain (snow) and river water, soil and aquifer material
- isotopic studies to clarify hydrochemical problems


Thank you for your attention!
…and also to:
Ines Teuteberg,
Dr. Robert Kringel
Foto: Tünnermeier