# EVOLUTION OF GROUNDWATER COMPOSITION IN THE DEPRESSION CONE OF RIGA REGION

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## Introduction

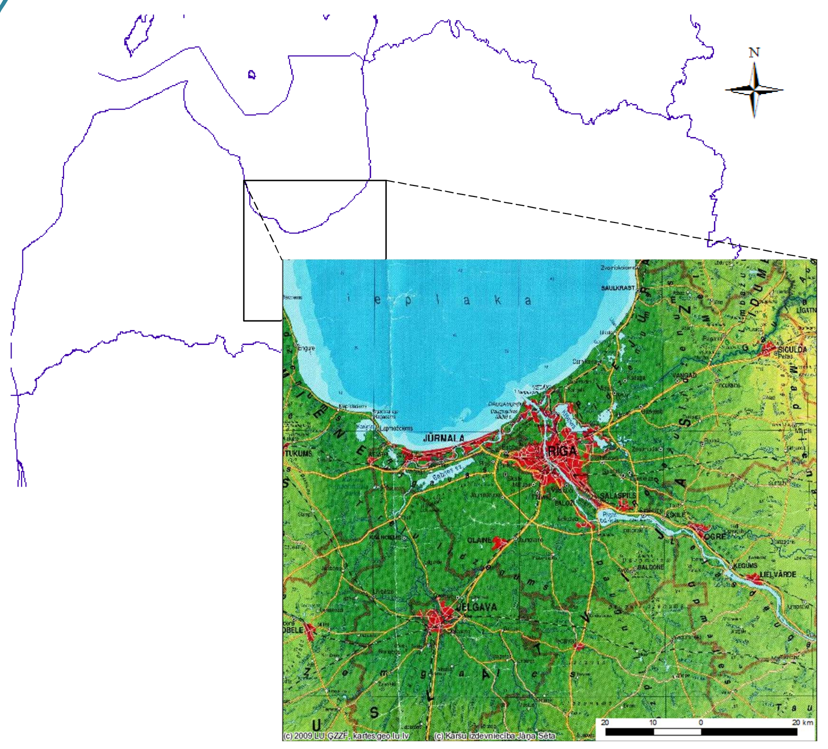

*Figure 1.* **Map of study area**

Riga is the capital of Latvia with around 0.9 million inhabitants. There the main water supply is centralised and decentralised, mostly from groundwater sources, that is from the the ***Arukilas – Amatas multi-aquifer system.*** This multi – aquifer system consists of sandstones and siltstone and belong to the middle and upper Devonian. These rocks have good properties for groundwater extraction: they have high permeability and are widely spread.

In the southern and western part of Riga this system covers the upper Devonian Salaspils formation which consists of marl and gypsum. In table 1. is showed hydrogeological cross section of active water exchange zone in Latvia.

The problems regarding the groundwater reserves for the needs of centralised water supply exists in the places where are excessive water extraction. An example of ineffective groundwater usage has been observable from 1950 to 1990 in Riga, where intensive groundwater extraction from the Arukilas – Amatas multi aquifer system has caused a sharp and significant lowering of piezometric surfaces. The groundwater composition changes are observed in Salaspils, Pļaviņu, Amatas and Gauja aquifers.

*Table 1.*

**Stratification of hydrogeological cross – section** (Levins et.al. 1998 )

| Hydrogeological zone | Multi - aquifer system | Main aquifers | Prevailing sediments |
|---|---|---|---|
| Active water exchange | Q | | Sand, till, etc. |
| | $P_2$ | | Limestone, dolomite |
| | $C_1$ | | Sandstone, dolomite |
| | Famena $D_3$fm | Mūru - Ketleru $D_3$mr-ktl | |
| | | Jonišķu - Akmenes $D_3$jn-ak | Dolomite, sandstone |
| | Eleja aquitard $D_3$ el | | Marl, clay |
| | Pļaviņu - Amulas $D_3$pl - aml | Amula $D_3$ aml | Sandstone, siltstone |
| | | Stipinu $D_3$ st | Dolomite, marl |
| | | Katlešu - Ogre $D_3$kt-og | Sandstone, marl |
| | | Daugava $D_3$ dg | Dolomite |
| | | Salaspils $D_3$slp | Marl, gypsum |
| | | Pļaviņas $D_3$pl | Dolomite |
| | Arukila - Amata $D_{2-3}$ ar-am | Amata $D_3$am | Sandstone, siltstone |
| | | Gauja $D_3$gj | |
| | | Burtnieki $D_2$ br | |
| | | Arukila $D_2$ ar | |

## Methods and input data

In this research work long – term monitoring data is used. These data comes from **«Latvian Environment, Geology and Meteorology Centre»** database, collected during end of 20th century 50's until 2010.

Data include information about major ions ($Ca^{2+}$, $Mg^{2+}$, $K^{+}$, $Na^{+}$, $SO_4^{2-}$, $HCO_3^{-}$, Cl) and piezometric surface from 45 monitoring wells.

In this research work these following methods is used:

- **Statistical methods to exclude «outlier» values**

  Values that was in range of two standard deviation from regression curve was accepted as believable. Regression curve characterizes changes of concentration of major ions in time.
- **Piper plots are made using software *«R»***

  Shows water composition changes in well, during observation period

  Define water type
- **Piezometric surface maps of Gauja aquifer are made using software *Surfer 9***

  Based on these maps and earlier studies territory is dived in 3 zones: central, intermediate and periphery.
- **Hydrogeolocial cross – sections are made using hydrogeological model of Baltic Artesian Basin and calculated scenarios of groundwater abstraction** (Seņņikovs 2011; Klints et.al. 2012).

  Groundwater flow and hydraulic connection of aquifer in the three years - 1950., 1980 and 2000. year was analyzed. Results are visualized using program *HiFiGeo.*
- **Mixing curves of different water types**

***References***

- Klints I., Virbulis J., Dēliņa A. 2012. Influence of water abstraction on groundwater flow in the BAB. Groundwater in Sedimentary Basins Abstract book. Riga. 48 p.
- Seņņikovs, J. 2011. Baltijas artēziskā baseina matemātiskais modelis. *Latvijas Universitātes 69. zinātniskā konference. Ģeoloģijas sekcijas apakšsekcija "Baltijas artēziskā baseina pazemes ūdeņi." Referātu tēzes.* Rīga, Latvijas Universitāte, 7.-9.
- Levins I., Levina N., Gavena I. 1998. *Latvijas pazemes ūdeņu resursi.* Valsts ģeoloģijas dienests, Rīga. 24 lpp.

## Results

### 1. Groundwater flow in active water exchange zone

The study area was divided in three zones: central, where groundwater table decline was greater than 10m, intermediate where water table lowering is in range from 5 to 10 m and pheriphery, where groundwater table decline was less than 5 m . (Fig. 2).

There are 3 differents cenarios of groundwater abstraction trends in the region of Baltic Artesian Basin starting with year 1950 until nowadays In hydrogeological cross-section is showed *g*roundwater flow directions and distribution of piezometric head in these periods (Fig.3.)

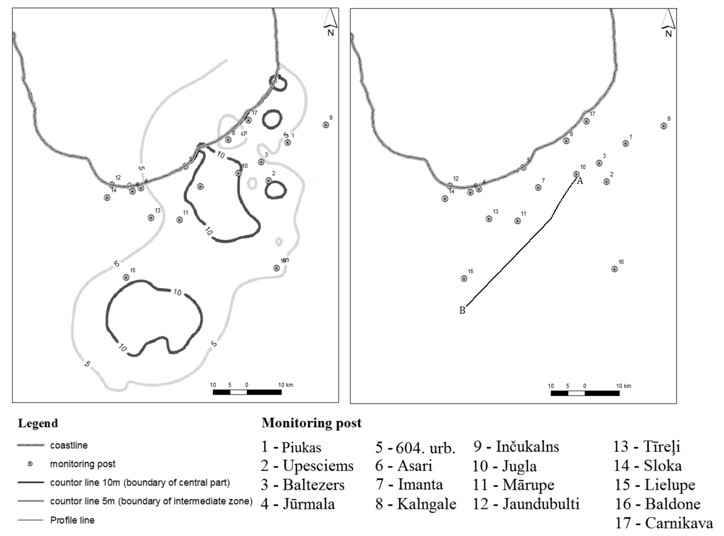


*Figure 2.* **Territory of the study a) zones of the depression cone; b) profile line of the hydrogeological cross - section**

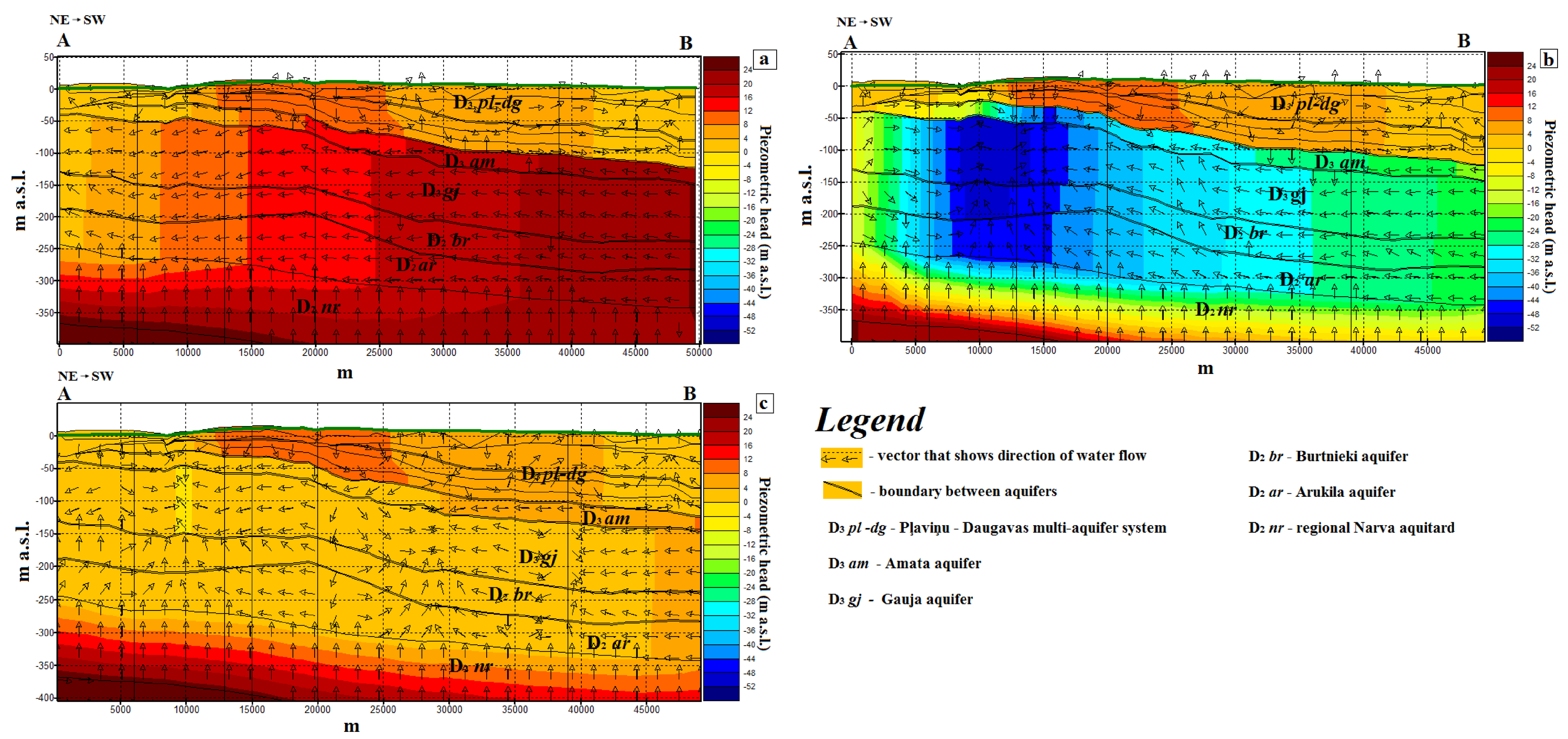


*Figure 3.* **Groundwater flow directions and distribution of piezometric head in the cross-section A-B a) in the year 1950; b) in the year 1980 ; c) in the year 2000**

### 2. Piper plots: groundwater composition changes

#### Central part

Significant changes in groundwater composition were observed in central part, where the greatest lowering in the piezometric surface is found, and was sufficient to cause stronger downward flow from upper aquifers, which induced the mixing of water from different aquifers in this territory (Fig.4.).

As a result, there are great changes in water composition in this zone.

In addition, the first signs of changes in water composition show up very quickly, but return to a natural situation is relatively slow (Fig. 5.).

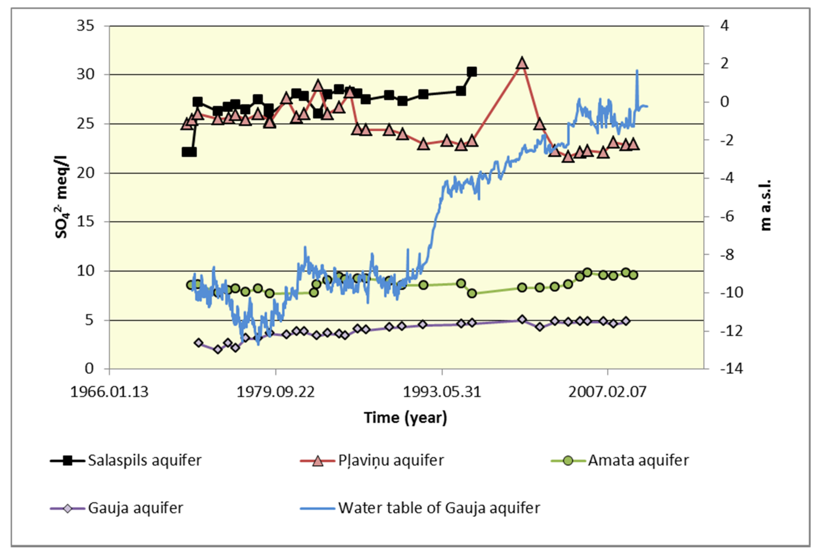


*Figure 4.* **Changes of sulphate ion concentration and piezometric level of Gauja aquifer in monitoring post „Imanta", central part of depression cone**

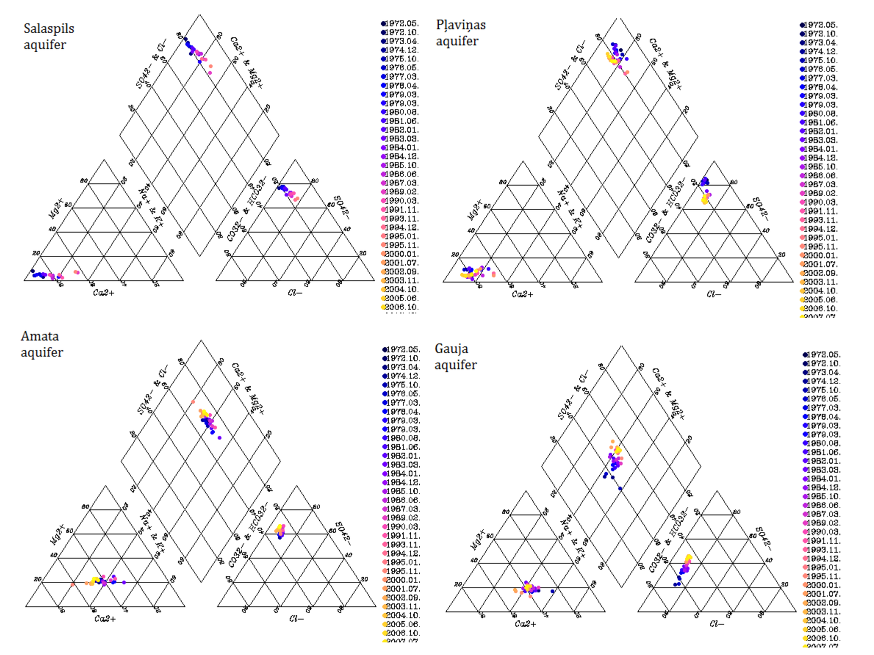


*Figure 5.* **Changes of groundwater chemical composition in the monitoring post „Imanta"**

#### Intermediate zone

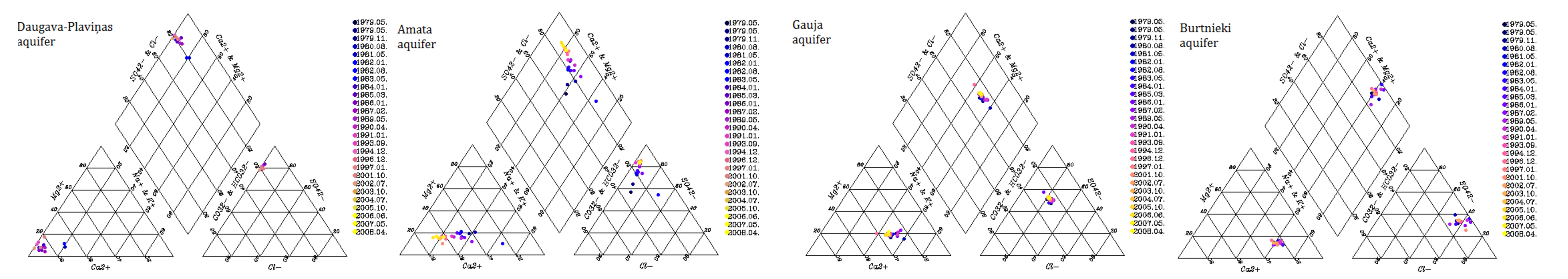


*Figure 6.* . **Changes of groundwater chemical composition in the monitoring post „Mārupe"**

In Amatas aquifer increase concentration of sulphate ion are observed. These changes marked associate with groundwater level changes in Gauja aquifer. In deeper aquifers significant groundwater composition changes are not observed (Fig. 6.). This situation are explained with bad technical quality of one of wells in monitoring post.

#### Periphery

In this part of depression cone groundwater level decline in long – term period is insignificant. In Gauja aquifer water type is almost alike: calcium – bicarbonate. Only in some monitoring post like «Sloka» are observed calcium – sulphate type of water.

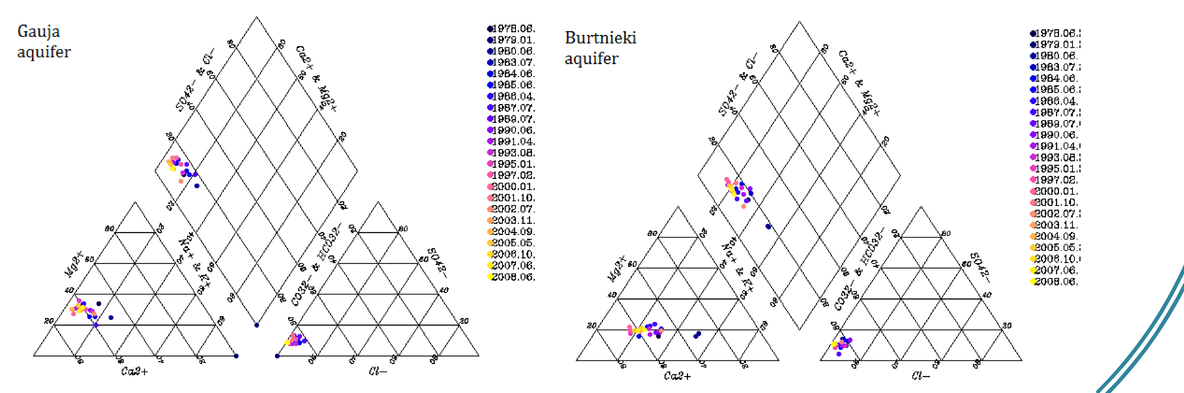


*Figure 6.* . **Changes of groundwater chemical composition in the monitoring post „Inčukalns"**

### 3. Mixing of different type of water

Mixing lines shows that in central part of depression cone, where Salaspils formation is spread, changes of water composations in Amata and Gauja aquifer were influenced by mixing with water of calcium – sulphate type (Fig.7. a). In intermediate zone of depression cone (monitoring post «Tīreļi») is observed that water from Gauja and Amata aquifer was mixing with water of calcium – bicarbonate type from Pļviņas aquifer (Fig.7.b). In monitoring post that is located in pheriphery of depression cone, significant groundwater composition changes are not observed (Fig.7.c).

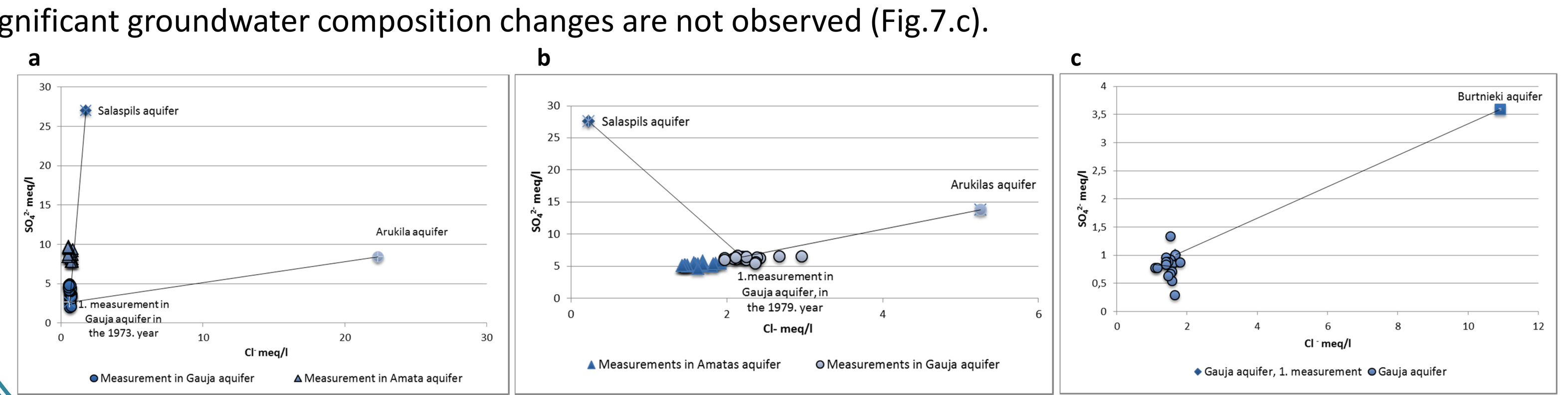


*Figure 7.* **Mixing of water of different type a) central part, monitoring station «Imanta»; b) intermediate zone, monitoring station «Tīreļi»; c) periphery, monitoring station «Kalngale» ( —— - mixing line)**

## Conclusions

- The downward oriente flows from Salaspils aquifer caused rapid water composition change in underlying Plavinas aquifer, but the water composition changes in Gaujas aquifer are very slowly and with time lag.
- The groundwater resource in Gauja aquifer was supplemented by water from adjacent aquifers. The sea water intrusion is observed only in some areas, where intrusion occurs through the bed of river Daugava
- Canges of water supply without significant time delays affect the groundwater level decline and renew.
- Supplement of Gauja aquifer in central part mainly comes from covering aquifers, but in intermediate zone from deeper ( Arukila and Burtnieki ) aquifer.

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