

## 10 SLOVENIA: CLASSICAL KARST AQUIFER

### 10.1 Overview

The Classical Karst is a transboundary area of approx. 750 km<sup>2</sup> shared between Italy and Slovenia (Figure 32). The transboundary karst aquifer extends from Vremščica in the southeast, across Dutovlje and Komen in the east and Kostanjevica in the north, crossing the Italian border close to Doberdó and Gradisca d'Isonzo and, in the south, from Basovizza to Duino. Towns Trieste and Monfalcone are situated in the southern part of Karst area.



Figure 32: Classical Karst area (source: Geopedia)

Classical Karst area is characterized by a large variety of Karst landforms. It is the most famous karst area in the world, for which the word karst was used for the first time. The Timavo spring represents the outflow of the hypogean waters present in the Classical Karst, being fed not only by precipitation, but also by the Reka river sinking in the impressive Škocjan sinkholes (UNESCO heritage since 1986), and the Soča river flowing from Julian Alps.

### 10.2 Geology

The Classical Karst area is built primarily of intensively karstified limestones and dolomites of Cretaceous and Paleogene age (Cucchi & Zini 2002; Jurkovšek 2008).

In the north and northeast of the aquifer, carbonate rocks are in contact with layers of Eocene flysch of low permeability from the Vipava Valley to the Trstelj Hill. In the flysch sequence sandstone, siltstone, claystone and marl are found. In the southwest the aquifer is in contact with Eocene flysch beds at the Gulf of Trieste, and in the west and southwest with alluvial deposits of the Soča River.

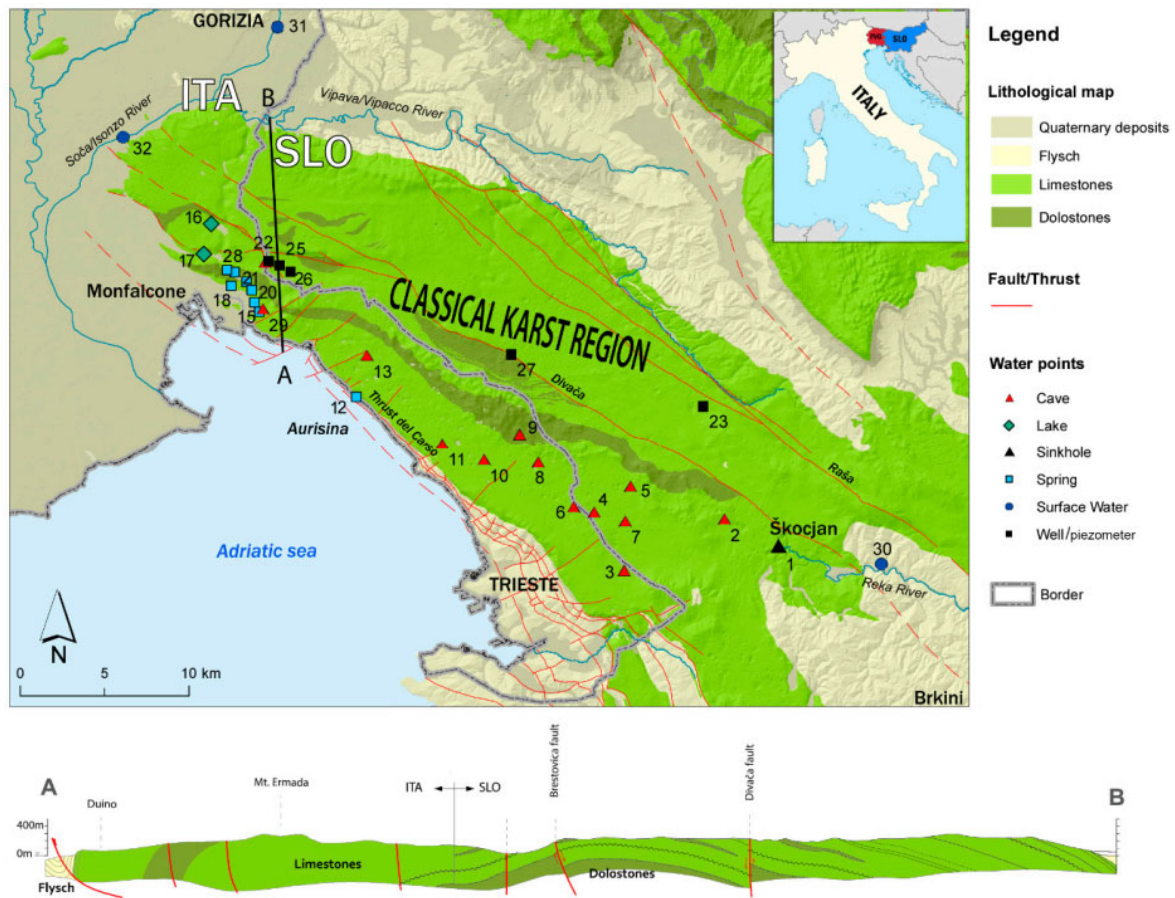


Figure 33: Lithological map of karst area

From the geotectonic point of view, the Classical karst aquifer belongs to External Dinarides as the southwestern part of the Trieste–Komen anticlinorium which is built from larger and smaller folds. The Brestovica anticlinorium is cored with dolomite near the east–west trending Brestovica fault, which is the most important structure in this research area. Important faults having a typical Dinaric orientation (northwest–southeast) in this region are the Raša and Divača faults (Jurkovšek 2008), and the Palmanova–Črni Kal line (Carulli 2011).

### 10.3 Geomorphology

Due to the dissolution of carbonate rocks that constitute the aquifer, various karst phenomena have developed (barren karst areas, dolinas, caves, deep shafts, etc.). The surface is formed by hills with gentle elevations reaching an average elevation of 250 – 300 m a.s.l. with the top at Trstelj Hill (643 m).

The analyses conducted by Cucchi and Zini (2002) recognize in the structures one of the main controlling factors in the evolution of karst features: a trend in the discontinuities controlled by the Alpine and Dinaric stresses gave rise to a network of fractures from which the main conduits and alignments of dolines formed. The maximum dip of the strata and the main sub-vertical discontinuities represent in fact the preferential directions for conduits and shafts development. The long-lasting exposure of the plateau shaped it into a mature karst.

From a speleogenetical viewpoint, the plateau emerged at least ten million years ago, during one of the phases of the alpine-dinaric orogeny. The genesis of the karst is marked with different phases. According to the nature of voids, the water was primarily stored and transmitted

through the matrix. During the Messinian crisis, the circulating groundwaters enlarged the fissures, developing defined pathways as pipes (conduits or caves).

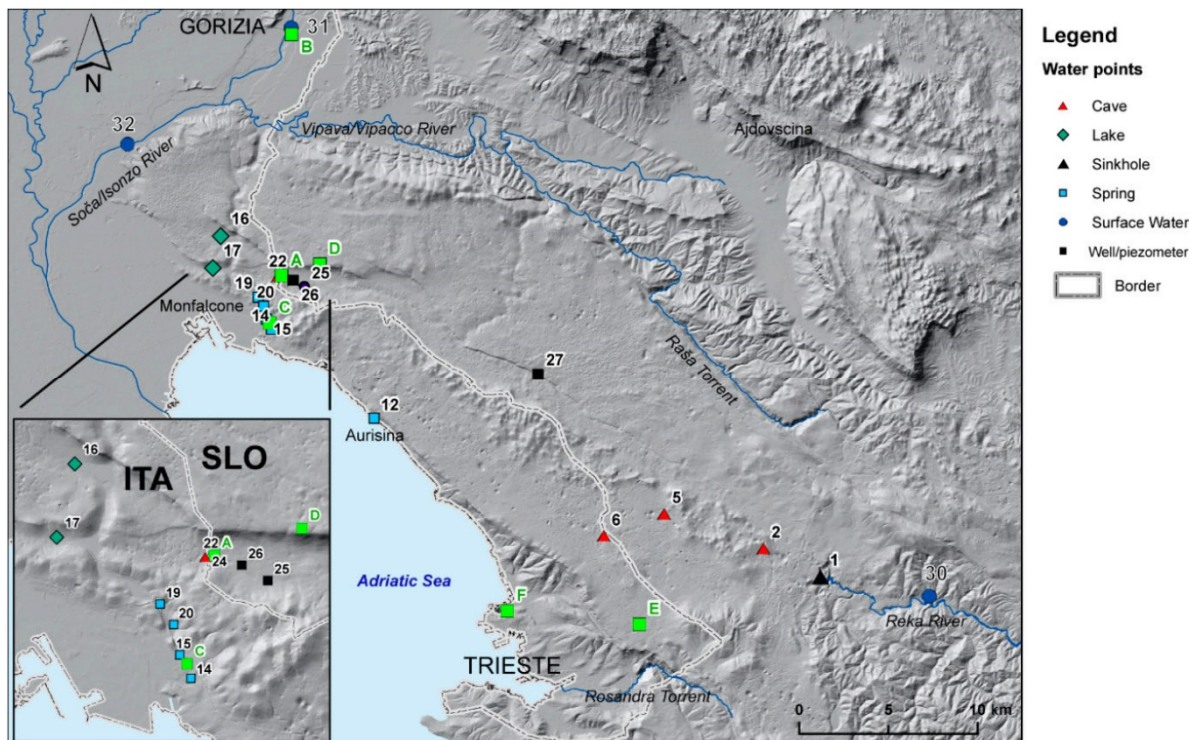


Figure 34: Digital elevation model of the Classical Karst area (Calligaris et al., 2018)

Speleological explorations over the last two centuries have supplied a lot of cave surveys (2000 in Italy and even more in Slovenia). Some caves have been studied in detail from the geological, geomorphological and sedimentological point of view: Lazzaro Jerko Cave, Trebiciano Abyss, Padriciano Cave - in Italy -, Postojna Cave, Kacna Jama Cave, Skocjanske Cave – in Slovenia.

## 10.4 Climate

The Classical Karst area lies slightly higher than the neighbouring areas. Its edges are hilly and this is the main cause for the climatic isolation and specific climatic conditions of the area. Its proximity to the sea has influence on the climate and the mild sea influences reach the interior part of the area mostly by Brestoviški Dol dry valley.

Partial isolation is the main reason that Karst climate also has some continental characteristics that are mostly featured in cold winters caused by cold air from the northeast. The consequence is strong wind, called "burja". This wind can sometimes bring snow in the area as soon as October and as late as April. Melik mentions that the temperatures are under 0 °C in average 40 days/year (Melik, 1960).

The close to sea position influences the precipitation amount (1,570 mm/year) which differs towards north and northeast. The precipitation is quite equally disposed throughout the year which is typical of continental climate. The Mediterranean climate characteristics can be noticed in October and December precipitation climax. As a continental climate characteristic there is the precipitation climax in May and June. January and February are the driest months, as well as August (Melik, 1960).

Overall Classical Karst area has typical sub Mediterranean climate with some continental characteristics. Typical are quite high summer temperatures (mean monthly July temperature is

21 °C) and cold winters (mean monthly January temperature is 2.5 °C) that are often characterized by the bora cold winds.

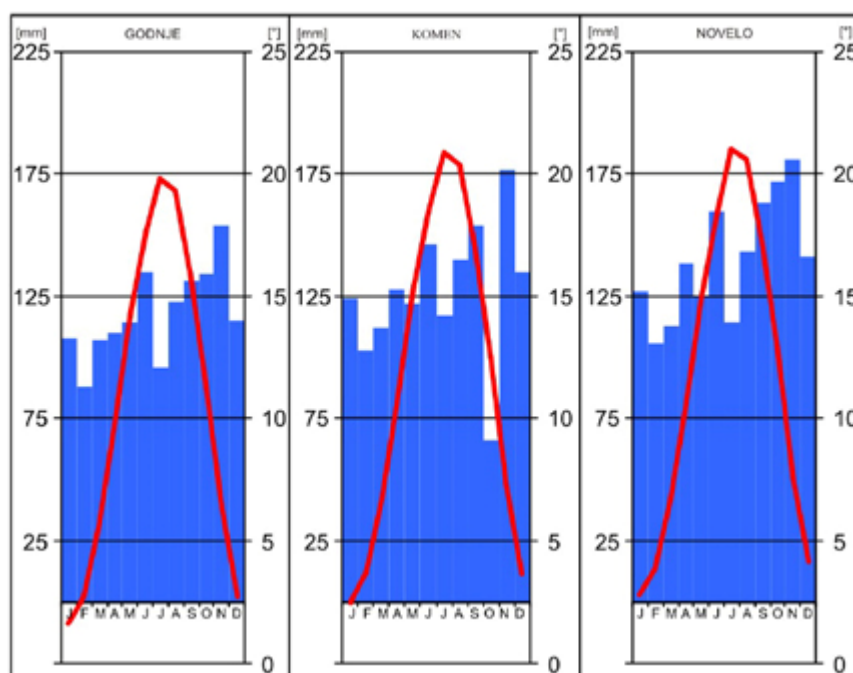


Figure 35: Climatograph of Godnje, Komen and Novelo (1961-1990). Source: *Klimatografija Slovenije 1961.-1990*.

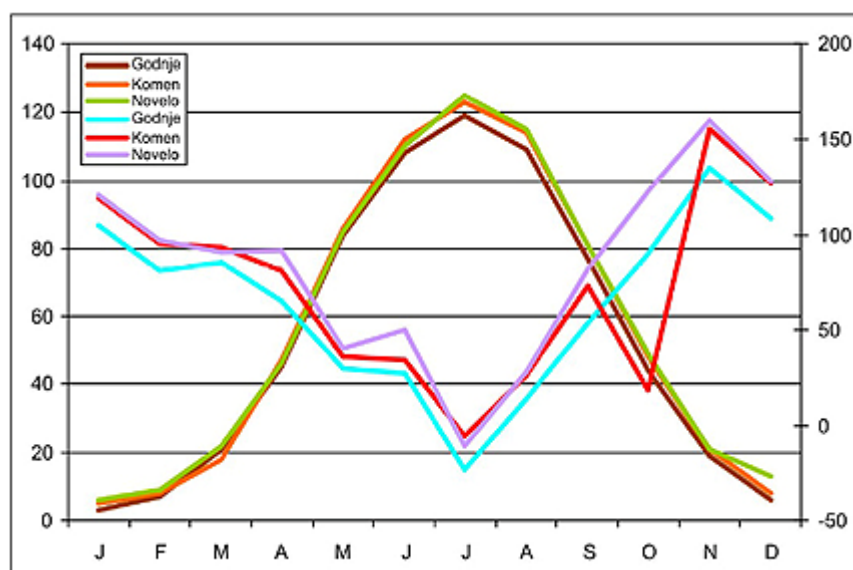


Figure 36: Potential evapotranspiration (according to Thorntwait) in water balance (in mm) Source: *Mrak, Repe, 2002*.

## 10.5 Hydrogeology

From a hydrogeological point of view, the Reka-Timavo aquifer system recharge is due to three different contributions: the autogenic recharge resulting from the precipitations on the Karst surface; the allogenic one due to the sinking of the Reka River in the Škocjanske jame sinkhole, and the input coming from the Isonzo alluvial aquifer.

In the Karst area, the first input is the average rainfall contribution considered between 1000 mm/year in the coastal area and 2600 mm/year in the Reka hydrogeologic system, with an effective infiltration of 20.6 m<sup>3</sup> /s (Civita et al. 1995).

The second input is from the Reka River. From the spring area, it flows for about 43 km on impermeable rocks in Flysch facies; for the last 7 km, it flows on limestone lithotypes developing an influent character. After 50 km from the spring area, the Reka River totally sinks into the Škocjan sinkhole. It has a mutable discharge with values within the range of 305 m<sup>3</sup> /s (in the high water conditions) – 0.18 m<sup>3</sup> /s (in low water conditions) with an average value of 8.26 m<sup>3</sup> /s (Gabrovšek and Perič, 2006).

The third important water input is occurring in the northwestern sector, in correspondence with the contact between limestones and the Isonzo alluvial aquifer. Its contribution, assumed since the beginning of last century (Timeus 1928), has been later estimated and verified using natural tracers (Mosetti and D'Ambrosi 1963, Gemitì and Licciardello 1977, Doctor et al. 2006) and water hydrogeological balance computation, to 10 m<sup>3</sup> /s (Zini et al. 2013).

Waters of the Reka/Timavo River were identified in several caves: B3G Brezno treh generacij, Kačna jama, Jama v Kanjaducah, Brezno v Stršinkni dolini (Slovenia), Abisso di Trebiciano and Pozzo dei Colombi (Italy).

Only during flood periods or heavy rainstorms the groundwaters of the Classical Karst Region aquifer reach the Abisso Massimo, Abisso di Rupingrande, Grotta Skilan, Grotta Lindner, Grotta meravigliosa di Lazzaro Jerko and Grotta Gigante (all in Italy).

The aquifer is also highly karstified at considerable depths: cave divers explored the conduits starting from the Timavo spring reaching more than 80 m b.s.l.; well withdrawals linked to the Slovenian aqueduct network are realized at 55–70 m b.s.l., corresponding with Karst conduits (Urbanc et al. 2012)

The vadose zone of the aquifer at Klariči pumping station is around 20 m thick. With distance from the pumping station to the northeast of the aquifer the unsaturated zone is getting thicker, reaching up to 150 m at Pliskovica (Urbanc *et al.* 2012).



*Figure 37: Drinking water pumping station Klariči*

The pumping facility Klariči (Figure 37) consists of three 70 m deep wells (VB4/79, VB4/80 and VB4/81) with diameters of 400 and 500 mm and a total capacity of 250 L/s. After many pumping tests in the period from 1976 to 1979, a potential estimated capacity of over 1,000 L/s of groundwater was estimated for the Brestovica – Klariči aquifer. Estimated apparent aquifer

transmissivity in the area around Klariči pumping station is between  $7 \times 10^2$  and  $8 \times 10^1 \text{ m}^2/\text{s}$  with an effective porosity between 3–4% (Krivic 1985).

To define the direction of groundwater flow five 50 m deep piezometers were drilled (in 1985) in a 100–120 m radius around the pumping station Klariči. During years 2006–2007 further intensive hydrogeological research took place, where three additional 150 m deep piezometers (Br6, Br7 and Br8) and a new well B10/06 with 600 mm diameter and 80 m depth were drilled (Urbanc *et al.* 2012).

The pumping station Klariči is a part of the Karst water supply system Kraški vodovod Sežana, providing drinking water to five Karst communities (Miren – Kostanjevica, Komen, Sežana, Divača, and Hrpelje – Kozina), and during summer months to the Slovenian Coastal region as well. Usually around 100 L/s are pumped for the Karst area water demand, however, when simultaneously supplying the coastal area, around 200 L/s are extracted (Kristan & Skrinjar 1998).

## 10.6 Hydrodynamic characteristics of springs

All karst groundwater is drained by the spring system enclosed in a few square kilometers along the coast from the Aurisina spring to Monfalcone town. The main spring is the Timavo, with an average discharge of  $29.3 \text{ m}^3/\text{s}$ , the second is the Sardos ( $1.9 \text{ m}^3/\text{s}$ ), and the third are all the other smaller springs as Aurisina ( $0.3 \text{ m}^3/\text{s}$ ), Moschenizze ( $0.5 \text{ m}^3/\text{s}$ ), Pietrarossa and Sablici lakes ( $1.2 \text{ m}^3/\text{s}$ ), Monfalcone ( $0.2 \text{ m}^3/\text{s}$ ), Lisert ( $1.0 \text{ m}^3/\text{s}$ ), and lastly the coastal springs arising below sea level located between Aurisina and Timavo, having an average estimated discharge of 0,5–1  $\text{m}^3/\text{s}$ . The Timavo spring is characterized by a large flow fluctuation, between 8 and  $155 \text{ m}^3/\text{s}$  (Gemiti 1984, 1995).

## 10.7 Data available for the project

| Pumping well Klariči VB-4/79 |           |                   |             |
|------------------------------|-----------|-------------------|-------------|
| Data type                    | Time step | Monitoring period | Time period |
| GW level                     | 1 hour    | 9 years           | 2006 - 2014 |
| Temperature                  | 1 hour    | 9 years           | 2006 - 2014 |
| El. conductivity             | 1 hour    | 9 years           | 2006 - 2014 |

| Pumping well Klariči VB-4/80 |           |                   |             |
|------------------------------|-----------|-------------------|-------------|
| Data type                    | Time step | Monitoring period | Time period |
| GW level                     | 1 hour    | 9 years           | 2006 - 2014 |
| Temperature                  | 1 hour    | 9 years           | 2006 - 2014 |
| El. conductivity             | 1 hour    | 9 years           | 2006 - 2014 |

| Pumping well Klariči VB-4/81 |           |                   |             |
|------------------------------|-----------|-------------------|-------------|
| Data type                    | Time step | Monitoring period | Time period |
| GW level                     | 1 hour    | 13 years          | 2006 - 2018 |
| Temperature                  | 1 hour    | 13 years          | 2006 - 2018 |
| El. conductivity             | 1 hour    | 13 years          | 2006 - 2018 |

| Observation well Klariči B-9 |           |                   |             |
|------------------------------|-----------|-------------------|-------------|
| Data type                    | Time step | Monitoring period | Time period |
| GW level                     | 1 hour    | 13 years          | 2006 - 2018 |
| Temperature                  | 1 hour    | 13 years          | 2006 - 2018 |

|                  |        |          |             |
|------------------|--------|----------|-------------|
| El. conductivity | 1 hour | 13 years | 2006 - 2018 |
|------------------|--------|----------|-------------|

| Pumping well Klariči BR-7 |           |                   |             |
|---------------------------|-----------|-------------------|-------------|
| Data type                 | Time step | Monitoring period | Time period |
| GW level                  | 1 hour    | 11 years          | 2008 - 2018 |
| Temperature               | 1 hour    | 11 years          | 2008 - 2018 |
| El. conductivity          | 1 hour    | 11 years          | 2008 - 2018 |

## 10.8 Summary

|                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                                                                              |           |                      |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|----------------------|
| Pilot name                                                                                                                                                                                                                                                                                                                          | <b>CLASSICAL KARST AQUIFER</b>                                                                                                                                                                               |           |                      |
| Country                                                                                                                                                                                                                                                                                                                             | Slovenia / Italy                                                                                                                                                                                             | EU-region | Mountain areas       |
| Area (km <sup>2</sup> )                                                                                                                                                                                                                                                                                                             | 750                                                                                                                                                                                                          | Lithology | Limestone & dolomite |
| <p>The Classical Karst is a transboundary area of approx. 750 km<sup>2</sup> shared between Italy and Slovenia. It is the most famous karst area in the world, where the word karst was used for the first time. Classical Karst area is built primarily of intensive limestones and dolomites of Cretaceous and Paleogene age.</p> |  <p>All karst groundwater is drained by the Timavo spring system enclosed in a few square kilometers along the coast.</p> |           |                      |
| Monitored objects                                                                                                                                                                                                                                                                                                                   | Pumping and observation wells; springs                                                                                                                                                                       |           |                      |
| Monitored data                                                                                                                                                                                                                                                                                                                      | GW level, temperature, EC                                                                                                                                                                                    |           |                      |
| Contact person                                                                                                                                                                                                                                                                                                                      | Janko Urbanc (janko.urbanc@geo-zs.si)                                                                                                                                                                        |           |                      |

## 10.9 References

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