SOME CONSIDERATIONS ON SEAWATER-FRESHWATER RELATIONSHIP IN ALBANIAN COASTAL AREA

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ABSTRACT

In Albanian coastal area there are developed mainly two important aquifers; gravelly alluvial and karst aquifer. In the alluvial aquifer the sea water intrusion is developed either by natural conditions or by water extraction. About 15 to 55 % of the surface of different coastal gravelly aquifers is affected by seawater intrusion. Most coastal karst area is affected by seawater intrusion. In some places where the carbonate structures overthrow to impermeable clayey formation fresh water karst springs issue. As a case studies the seawater intrusion in the alluvial basin of Mat River is described as well as the intake structure of the Uji Ftohte karst springs.

INRODUCTION

Albania is situated in the southwestern part of Balkan Peninsula on the eastern coasts of Adriatic and Ionian Seas. Otranto Channel width about 80 km separates Albania by Italy. The Albanian coastline has a total length of 476 km, of which two thirds border Adriatic Sea and one third the Ionian Sea, (figure 1). The Adriatic and Ionian coasts have different orientations and morphologies which reflect their geological diversity.

The northernmost part of the Adriatic coastline could be considered the continuation of the Dalmatian coastline. From Shengjin (near Lezha) to the Gulf of Vlore the coast is characterized by lowlands and wide coastal plains, created in part by sediments of Mat, Erzen, Shkumbin, Seman and Vjosa rivers. Some sandstone, clayey and conglomerate hills separate wide bays. Some large lagoons are located along the Adriatic coastline. The morphology of the coastline in the Gulf of Vlore marks the boundary between the Adriatic lowlands and Ionian coastline of high relief.

The Ionian coast is mainly rocky and coastal alluvium occurs only at the small valleys, like in Dukat, Qeparo and within Butrinti Lagoon. Most of Ionian coastline is characterized by cliffs cut in limestones backed steep slopes that, within a few kilometers, reach heights of over 1500 m above sea level.

At Holocene transgressive maximum, some 5000 years ago, the sea level is believed to have reached many of the uplands which today form the landward limit of the coastal plain. The Adriatic Sea line at that time has been about 15 to 20 km east to the existing one. From the time of transgressive maximum, under what became largely stable sea level conditions, it was the input of sediments from the rivers rather than a rise in sea level that dominated the coastal morphody-namic regime (BGR 1995).

The population and economic activities of Adriatic and Ionian coastal areas are very different. The Adriatic coastal area is densely populated. Including Tirana City, the capital of Albania which is located about 30 km far from the coast, the population of Adriatic coastal area is more then 1,5 million persons, equal to more than 50 % of country’s population. In the Adriatic coastal area is concentrated also more then 80 % of the industry and more then 70 % of agriculture. A massive tourism is under fast development in this area. In the Ionian coastal area there are only small traditional villages or towns. This area represents most valuable tourist resource for Albania, especially because of the many places of unspoilt natural beauty.

The groundwater resources of Albania have been found to be abundant, with an uneven geographical and to a lesser extend to a seasonal distribution. Traditionally in Albania appears a clear separation between irrigation, which rely on surface water, and drinking and industrial water, taken from groundwater. This tradition based on a controlled and centralized management is not popular any more. The farmers more and more like to have the "own" water well for irrigation. So the gravelly aquifers, the most important aquifers in the Adriatic coastal area, are threatening by the saline intrusion.

In most of Ionian coastal area the salt-water head exceed that of karst fresh water and seawater flow into aquifer. Most of karst springs are brackish or salty and only in restricted areas and at certain geological conditions some karst fresh water springs issuer.

GEOLOGICAL CONTEXT

The geology of Adriatic coast area differs essentially from that of Ionian coast area. The northernmost sector of Adriatic coast area is a part of Dalmatian tectonic Zone, which in Albanian territory is represented by Renci anticline. This structure is overthrown on west and consists of Cretaceous and Paleogene carbonate rocks. The biggest part of Adriatic coastal area geologically belongs to the Periadriatic foredeep Basin, (Meco & Aliaj 2000). It extends from Lezha to Vlora and consists of a number of anticlines and

Figure 1. Location of main coastal aquifers of Albania and case study areas. 1. Porous gravelly aquifer; 2. Carbonate fissured and karstified aquifer; 3. Karsr spring average discharge more then 100 l/s.

synclines formed by two marine molasse cycles, namely one during Middle to Upper Miocene and the other in the Pliocene. The Miocene molasse are represented mainly of clayey sediments, massive sandstone, gypsiferous clays, sandstone and siltstone. The Pliocene sediments are divisible into two formations; the Helmesi clayey Formation and the Rrogozhina sandstone-conglomerate Formation. The Quaternary, mainly alluvial deposits usually fill the river valleys and some Periadriatic lowland plain synclines (Eftimi 1966, 1975, Eftimi & Tafilaj 1979, Eftimi *et al.* 1985, Eftimi *et al.* 1999).

The Ionian coast area belongs mostly to Ionian Zone and only Karaburun peninsula and Sazani Island belongs to Preapulian Zone. The main structural characteristic of this area is the presence of a series of carbonate anticlines in a sub-meridian orientation. Most important structures are the anticlines of Tragjasi, Karaburuni, Cika, Kudhesi, Ftera and Saranda. Generally, the anticlines are overthrown to the west; therefore the contact with neighboring syncline structures is always tectonic. The core of these structures, mostly not visible at the surface, are constructed of Permo-Triassic evaporates, which are covered by thick carbonate formation. Starting with Triassic dolomites the carbonate rocks follow with Jurassic algal limestone and bituminous schists, Cretaceous porcelain and phosphate limestones and Eocene stratified limestones.

CHARACTERIZATION OF COASTAL AQUIFERS

As shown in figure 1, the main coastal aquifers of Albania are the following:

a) Porous gravelly aquifers;
b) Carbonate fissured and karstified aquifers.

Porous gravelly aquifers

Most of the rivers in Albanian flow from east to west, to Adriatic Sea. After their debauchment into the plain area the seaward intensive sedimentation created vast deltas and low headlands of Tertiary rocks. The bigger energy rivers like Mat, Erzen, and Vjosa have created bigger deltas filled with thick and heterogeneous coarse deposits. Other rivers like Buna, Shkumbin and Seman only fine materials have deposited in the coastal area after having deposited the coarse materials inland. Some smaller rivers like Dukat (south to Vlore) and Pavlla (the southernmost river) have small but thick sediment deltas. The main parameters of the gravelly aquifers widely differ related to their geometry, hydraulic parameters and water resources. In the biggest alluvial delta, that of Mat River, the total thickness of the alluvial deposits is about 270 m and there are up to four gravelly aquifer layers. The total thickness of the alluvial deposits of the other deltas varies about 100 to 150 m and there are usually one or two gravelly aquifer layers.

Mostly, the hydraulic parameters of the coastal gravelly aquifers of Albania are high to very high as is shown in table 1.

Parameter	Mat	Erzen	Vjosa	Dukat	Pavlla
Maximal thickness, m	150	15	30	80	100
Permeabi-Lity, m/d	90-260	1 -50	50-500	50-350	10-100
Transmissi-bility, m^2/d	2000-10,000	100-700	2000-9000	1000-5000	300-3000
Capacity of wells, l/s	5-150	2-10	5-150	5-100	1-20

Table 1. Some averaging values of the hydraulic parameters of coastal gravelly aquifers of Albania (named after the rivers).

The recharge of the alluvial aquifers occurs mainly by the infiltration of the rivers in the areas of the debouchments of the rivers into the plain. The main groundwater flow direction is from the outlet areas of the rivers to the sea. Usually near the outlet areas the groundwater is unconfined but in short distances from these areas it become confined and even free flowing. The groundwater quality in the outlet areas is practically like this of respective recharging rivers. Following the flow direction the groundwater quality changes depend on the rate of the groundwater movement. It keeps a good quality in wide areas of the plains of Mat and Dukat Rivers due to the high rates of groundwater movement, but it become low mineralized and brackish in wide areas of Erzen, Vjosa and Pavlla river which have low-rate groundwater movement.

Concerning the water resources of the gravelly aquifers one can distinguish the natural water resources and the exploitable water resources. The natural water resources are identified with groundwater flow, which could be estimated using Darcy formula. The exploitable water resources are identified with the sustainable water quantity (with acceptable quality deteriorations) which can be extracted from a certain aquifer. The exploitable water resources could be even some times bigger then the natural water resources. It depends on the aquifer recharge conditions. The induced infiltration of surface water as a source of recharge is intensively developed in watercourse aquifer system areas. The water resources are extracted more intensively in the gravelly aquifers of Mat and Vjosa Rivers, table 2.

Parameters	Mat	Vjosa
Natural ground-water flow, m^3/s	About 4.5	About 1.3
Groundwater Extraction	2.45	0.95
Main use	Water supply and irrigation	Water supply

Table 2. Natural groundwater resources and groundwater extraction in the gravelly aquifers of Mat and Vjosa Rivers.

Most of the extraction wells are used for drinking and industrial water supply and mostly are located far from the sea coastline and in areas with high hydraulic parameters (table 2). There is not a good evidence about the so called "private wells" drilled mainly during the last years. They scatter over the entire aquifers surface and usually tap the top of the first aquifer layer.

The affected by the intrusion surface of gravelly aquifers of Albania constitute the following percentages of the total aquifer surface: Mati Plain – about 15 % (for the first aquifer layer); Erzen Plain – about 55 %; Vjosa Plain – about 45-50%; Dukat Plain – about 10 % and Pavlla Plain – 35 %. However the affected by the intrusion areas are those periphery ones with smaller permeability and smaller water resources. The ratio affected volume/resources stays in much lower percentages.

Carbonate fissured and karstified aquifers

The Ionian Sea coastal area is practically totally constructed of carbonate aquifers, while in the Adriatic Sea coastal line only Renci carbonate structure is located (near Lezha town). Renci carbonate structure is constructed mainly of Upper Cretaceous limestones and dolomites. The carbonate rocks of Renci structure are intensively fissured and karstified. It is calculated that the average yearly infiltration of precipitation in this area is about 800 mm, equal to about 50 % of precipitation amount. The central part of the structure border the Adriatic Sea and the fresh karst water mixes with the sea water. This results in the formation of some important free flowing brackish water springs with highly variable discharges. Some of the springs are very short life, only some days during heavy rains. In the northern part of Renci structure, which is distant to sea, the groundwater is low mineralized good quality drinking water. In the central and southern part of this structure the total mineralization of springs is about 4 to 7 gr/l.

In the Ionian Sea coastal area from Karaburun peninsula in the north, to Albanian – Greek border in the south only the karst aquifers are developed. These aquifers are related to already mentioned carbonate structures of Tragjasi, Karaburuni, Cika, Kudhesi, Ftera and Saranda. While the Karaburun structure is constructed of Cretaceous thick bedded limestone, the remaining structures are constructed of different type of carbonate rocks ranging from Upper Triassic to Eocene. Main characteristics of the karst structures of Ionian Sea area determining their hydrogeological behavior are the following: a) Overthrast of the structures to the west and the presence there or not of impermeable barriers of Paleogene formations; b) Intensive fissuring and well developed karstifikation; c) High effective infiltration and formation of big karst water resource; d) Formation of different type of springs concerning their hydraulics or their water quality.

The Paleogene formations, on which the carbonate structures overthrow, usually are constituted of impermeable clayey and flysch rocks. There are cases like in Tragjasi structure (near Vlora) where this impermeable barrier is developed along the coastal line or like in Ftera structure (in the central Ionian Sea coastal area) where this barrier is developed some distance to the sea. Along the impermeable barriers usually issue big overflow fresh water springs. The case of the overflow springs of Uji Ftohte should be further explained in detail as a case study. Where the impermeable barrier is missing most of springs are brackish or salty.

The intensive fissuring and high karstification create provide high permeability in the carbonate rocks for the moving water to the sea. It seems that as Stringfield & LeGrand (1971) have noticed the high permeability of coastal carbonate rocks terrains may result in a low water table and thin fresh-water zone overlying salty water. This is the case of Karaburun peninsula and of Saranda structure. On both mentioned structures the fast infiltrated precipitations uniformly and intensively discharge to the sea without forming perennial springs. Some tentative made in Karaburun peninsula to catch fresh water with dug wells at distances 100 to 300 m far from the sea shore have failed; the water resulted salty.

The effective infiltration in the carbonate structures of Ionian Sea coastal area estimated by the method of Kessler (1963) results to be about 800 to 1000 mm/year. The karst water resources estimated for the total area of the Ionian Sea coastal carbonate aquifers could be in average about 15 to 20 m^3/s.

The actual sea water level represents the absolute karst basis. This is the reason that most of the springs in the coastal areas emerge near the sea. On the other hand the karstification of the carbonate rocks is effected by eustatic changes of sea level during the Pleistocene time which are responsible for the formation of submarine spring. Two are the spring sites in Ionian Sea coast of Albania: Uji Ftohte site situated in the northernmost sector of carbonate rocks coast line, and in the central area of the coast line. In the central area of the rocky coast line there are different kinds of springs and their main data are summarized in table 3.

Springs	Type of springs	Discharge min - max mean m^3/s	Conductivity µS/cm	Cl Mg/l
Potami, Spille	Free flowing	0.1– 0.5 0.18	1700–2300	450–660
Lera Pass, Dhermi	Sub-marine	about 1.5	-	-
Mulliri, Qeparo	Free flowing	0.3	8400	2840
Hoston, Qeparo	Free flowing	about 2.0	3000-10,000	-
Borshi	Over-flowing	0.15–0.63 0.25	295	7.1
Sasaj	Over-flowing	- about 0.2	438	14.2
Bufi*	Free Flowing	1.5–4.7 2.5	9000–13,000	3000-4900

* Bufi Spring issues in the southern part of the Ionian Sea coastal area, on the south-eastern coast line of Butrinti Lagoon.

Table 3. Main data of karst springs of the central part of Ionian Sea coastal area.

The importance of the coastal aquifers

The coastal aquifers of Albania are of first importance for Albania, in some places there are the only water supply source. The gravelly aquifer of Mat River plain is actually used for the water supply of an population of about 600,000 inhabitants; including Durres City, the second biggest city of Albania and some other smaller cities and towns like Lezha, Milot, Laç and Mamurras and as well as of more then 50 villages. The gravelly aquifer of Vjosa River plain is used for the water supply of a population of about 400,000 people including the important cities like Fier and Vlora. Dukati River plain gravelly aquifer represents the most trustful resource for the water supply of the future tourist center planed to be developed in Karaburun peninsula. The remaining coastal gravelly aquifers related to rivers Erzen and Pavlla beside that have small groundwater resources in vast areas the sea water intrusion is developed. The outlet areas of the respective rivers are the only sites to develop their restricted ground water resources.

The Ionian Sea coastal area considered as Albanian Riviera is the most important area for the future planed tourism development. However the shortage of the drinking water resources is one of the biggest problems of the infrastructure modernization of this area to be resolved. The water supply of existing rural centers and of the future tourist centers seems to be a priority for the near future. By no means to resolve the water supply problem of Ionian Sea coastal area a detailed investigation of the karst aquifers of the region should be performed.

The problem of seawater intrusion in Albanian coastal area is not jet specially treated from the scientific institutions of the country at least during the last decade. Most of the data presented in this paper are related to regional hydrogeological and water supply investigations performed before 1990 and presented in the Hydrogeological Map of Albania, scale 1:200,000 published in 1985. During the last decade some hydrochemical data are collected by for Mat River plain (Eftimi, 1996, 1998 and 2000).

CURRENT STATE OF SEAWATER INTRUSION AND THE MANAGEMENT

On both coastal aquifers of Albania, gravelly and karstic ones mostly the seawater intrusion results due to natural hydrodynamic conditions. The head of fresh water in most of aquifer is not large enough to push the salt water back to the submarine outcrop of the aquifer. The natural seawater intrusion is very active along the coastal karst aquifers. It is also active in the gravelly aquifers of the rivers Erzen, Vjosa and Pavlla where the fresh water head is smaller or the aquifer permeability is generallylower. In alluvial plains of rivers Mat and Dukat where the fresh water head is large enough to push beck the seawater the intrusion is only locally developed. Some episodic observations envisage the advancing seawater intrusion in Mati River plain due to the increase of the groundwater extraction

In Albania appears a clear separation between irrigation, which rely on surface water, and drinking and industrial water, taken from groundwater. The climatic features of the coastal areas, where most of the highly productive lands are located, make irrigation a necessity to reach good yields. Yet the irrigation networks suffered as much as the industrial plant at the fall of the state farms system, either by direct destruction or by lack of maintenance. Programs are under way to rehabilitate the networks and bring them back to the original conveyance capacity. By the time the farmers more and more like to have "own" water well for irrigation and the gravelly aquifers of Adriatic coastal area, are threatening by the potential saline intrusion.

Now Albania is applying the National Water Strategy comprising the legal, regulatory and technical framework as well as commissioning the co-coordinating agencies. The top water body is National Water Counsel which has a Technical Secretariat as an executive body. The Albanian territory is divided in six water basins and a Water Basin Agency (WBA) should manage the water problems of the respective basins. For the moment only two WBA are acting. The new Water Law and several other laws and regulations have tried to put order in the water sector, but their implementation has not been completed until now and the institutional situation should be by no means improved in a short period. Another strategic task is the strengthening of modernization of the hydrochemical laboratories. Albanian Geological Service the only state organization responsible for groundwater investigation should re-establish and improve the routine practice for groundwater quality monitoring especially of those related to seawater intrusion. Now for the first time efforts are being done to organize the farmers into Water Users associations which will be able to take in hands the operation and maintenance of the downstream parts of irrigation systems.

CASE STUDIES

The selected and described below case studies concerns two aquifers, one gravelly aquifer and one limestone aquifer.

Case study 1 - Mat River plain

Mat River plain surface is about 200 km^2 and it is located in the northernmost part of the Adriatic Sea coastal area of (figure 1). This plain is filled mainly by the alluvial deposits of Mat River and less by the deposits of other smaller rivers like Drini in the north and Droja in the south (figure 2). Deep well records show that the thickness of quaternary deposits at most of the Mat plain generally is more then 150 m, while the maximal thickness is about 280 m. Gravelly sediments outcrop along the Mat River course and in the remaining part of the plain, only silt to clay deposits outcrop. However, it appears that gravelly sediments form some layers separated by clayey sediments and are widely distributed at depth overall Mat River plain. On hydrogeological point of view Mat Plain represents a multilayered artesian aquifer system. The maximal cumulative thickness of the gravel aquifer layers in the central part of the Mat plain is about 150-180 m. Along the Mat River the aquifer seems to be continuous, whereas at distances 1.5 -2 km from the river two to four or more aquifer layers appear (figure 3).

The transmissibility of gravel aquifer is generally high; in the central part of the aquifer on both sides of Mat River it is about 4000 to 8000 m^2/d, and gradu-ally decreases to about 500 to 1000 m^2/d at the northern and at the southern

Figure 2.

The first hydrogeological wells of Mat River plain are drilled in the period 1960-1964 (Eftimi, 1966). During the decade 70-80 of the last century are drilled most of extraction wells used for drinking and industrial water supply, as well as for irrigation. The most important central pumping stations actually working in Mat River plain are shown in figure 2. Water resources of Mat basin are used for the water supply (drinking and industrial) of cities and towns of Durres, Lezha, Milot and Laç, as well as for the water supply of about 50 villages and for irrigation. In table 4 is summarized the situation of groundwater resources exploitation of Mat River plain.

As is described by Eftimi (1966), when Mat River basin was still at natural conditions, the seawater in-trusion has been present in the restricted areas in northern and in the southern sectors of the basin.

Area	Public WS l/s	Irrigation l/s	Private wells l/s
North to Mat River, Rilla plain	300	500	1100
South to Mat River, Fushe Kuqe plain	1150	-	200
Total	1450	500	500

Table 4. Groundwater use of Mat River plain.
Grand total = 2450 l/s

periphery of the aquifer (Eftimi, 1983). The main recharge into the aquifer system comes by the infiltration of the surface water of Mat River. Natural discharge from the system occurs toward the Adriatic Sea and as artificial discharge through pumping water supply wells, as well as through free flowing irrigation or private wells. Maximal free flow of the big diameter wells, drilled at sixties and seventies of last century, was about 100 l/s. At most of the area the groundwater pizometric surface raised up to 4-5 m above the ground surface. At present all the wells suffered a general piezometric level decline ranging about 1.5 to 3.5 m.

During the last three decades of groundwater exploitation of Mati River basin only sporadic measurements of the groundwater chemical composition are performed. Based on such limited data in the following some consideration about the actual seawater intrusion situation of this basin should be described.

In figure 2 is shown the groundwater chloride content mainly for the first aquifer layer (down to depth of about 100 m. The chloride content in groundwater increases from 10 mg/l near aquifer recharge area up to more than 500 mg/l in the northern and in the southern sectors of the aquifer. It could be considered that chloride concentrations from 50 to 100 mg/l could be considered a result of groundwater hydrochemical transformations which happen in the direction of groundwater flow. Chloride concentrations at about 100 mg/l or more could be considered as a result of the seawater intrusion. The facts which documenting the chloride concentration increase as a result of groundwater extraction increase are very limited, but nevertheless very significant. In Lezha city water supply well 1C depth 64 m the chloride concentration from 35 mg/l in 1968 is increased up to 191.5 mg/l in 1996 (Eftimi, 1996).

Generally the fresh-water head of the second aquifer layer is not sufficient to prevent the seawater intrusion. At the Adriatic Sea shore about 1.4 km south to Mati River two artesian wells placed at a distance of about 50 m, tapped different aquifer layers. The shallow well depth 50 m taps the first aquifer layer, while the deeper well depth 90 m taps the second aquifer layer. According the measurements made in 2000 the chloride concentration in the first aquifer layer was 152.3 mg/l while in the second aquifer layer it was 309.9 mg/l (Eftimi 2000). It seems that both aquifer layers suffer a small seawater influence being bigger in the deeper layer. This fact is also supported by environmental isotope data (Eftimi at al. 2001). Similar is the picture also north to Mati River. According the measurements made in 1996 the chloride concentration in four wells tapping the deep aquifer layers varied from 260.6 to 804.9 mg/l while the chloride concentration in the first aquifer layer at the same area was about 50 to 87.6 mg/l (Eftimi, 1996). It should be noticed that practically impervious clayey layers separating the gravelly aquifer layers are important from the standpoint of the water supply because they prevent upward encroachment of salt water.

As described above the sea water intrusion in Mat River plain in the first aquifer layer is developed at relatively restricted areas corresponding to about 15 % of the total aquifer surface. At deeper aquifer layers the sea water intrusion is developed at about 35-40 % of the total aquifer surface. This situation imply for serious measures for prevention and control of sea water intrusion. Strategically the groundwater resources of this Mati River plain must be used only for public water supply. Urgently should be closed the uncontrolled free flowing irrigation wells of the northern part of the plain (Rilla plain) which total discharge is about 500 l/s. Supplemental river water could be available for the irrigation. As a second step a partial rearranging of pumping pattern is recommended. The Lezha city water sup-

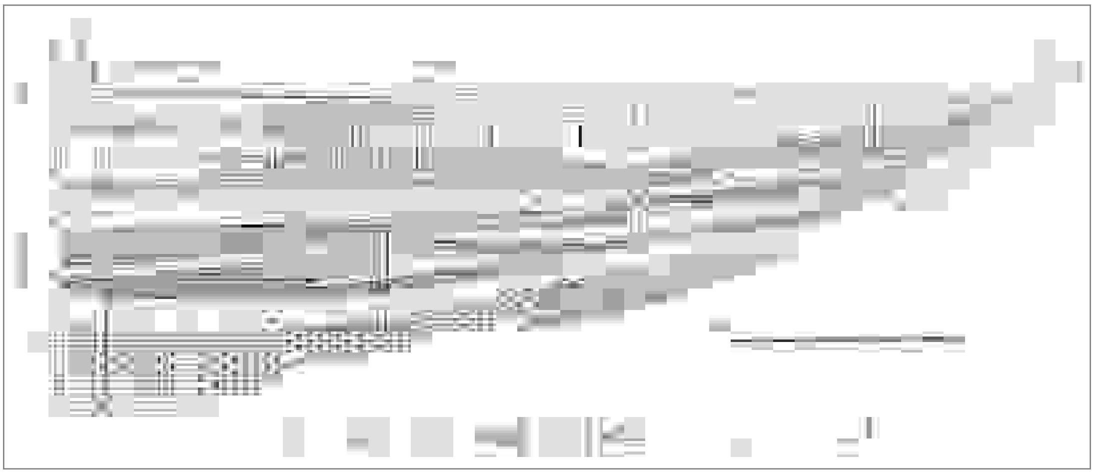

Figure 3. Cross – section A – A in the northern part of Mat River plain. 1. Sand; 2. Clay and sand; 3. Silty clay; 4. Clay; 5. Gravel; 6. Conglomerate; 7. Pizometric surface; 8. Well on the cross-section line; 9. Well projected on the cross-section line; 10. Well screen and well depth, m.

ply wells with increased chloride concentration of about 200 mg/l is recommended to be abandoned and new wells should be replaced at least about 1.5 km south to existing wells. Creation of a data base for the basin, establishment of a monitoring program for sea water intrusion and the elaboration of a basin wide model should enable the control of the sea water intrusion and the sustainable development of the groundwater resources of this basin.

Case study 2 – Uji Ftohte karst springs

In this case study is described the experience of a successful intake structure of the karst coastal springs of Uji Ftohte. This is a group of springs situated south to Vlora city along the Adriatic Sea cost. The springs issue from the intensively fissured and karstified Upper Jurassic limestone of Tragjas anticline. Just along the sea shore at sea level an overthrust tectonic fault is developed bringing in contact the limestone formations with the clayey Neogene formations (figure 4). However the clayey formations represent a barrier for the karst water of Tragjas anticline and for the sea water intrusion. On the line of the contact of limestone with clayey formation issue about 32 springs situated in a line length about 1.5 km (Tafilaj, 1970).

The total karst water resources of Tragjas anticline are estimated to be about 5 m^3/s. The biggest springs issue in three sectors of different lengths separated by sectors with very small springs. The springs issuer usually at the foot of high vertical rocky sectors. The biggest springs issuer at sea level or about 30-40 cm below the sea level.

After detailed observations and monitoring it was concluded to capture the springs at the sea level and inside the limestone massive (Tafilaj, 1970). In figure 5 is shown the plan and the cross – section of intake structure nº 6. A tunnel length 70 m is dug perpendicular to sea shore and along a well developed tectonic fault zone. At the end of the tunnel two galleries were dug on both sides of the tunnel and parallel to sea shore, each length 60 m. The floor elevation of galleries is about 0.4 m below sea level. The water drained into the galleries flows to the tunnel and in a collection room located about 35 m from the sea is pumped. The discharge of the tunnel nº 6 vary from about 300 l/s to more then 800 l/s. The intake structure provides fresh karst water not mixed with sea water. The maximal chloride content of pumped karst water

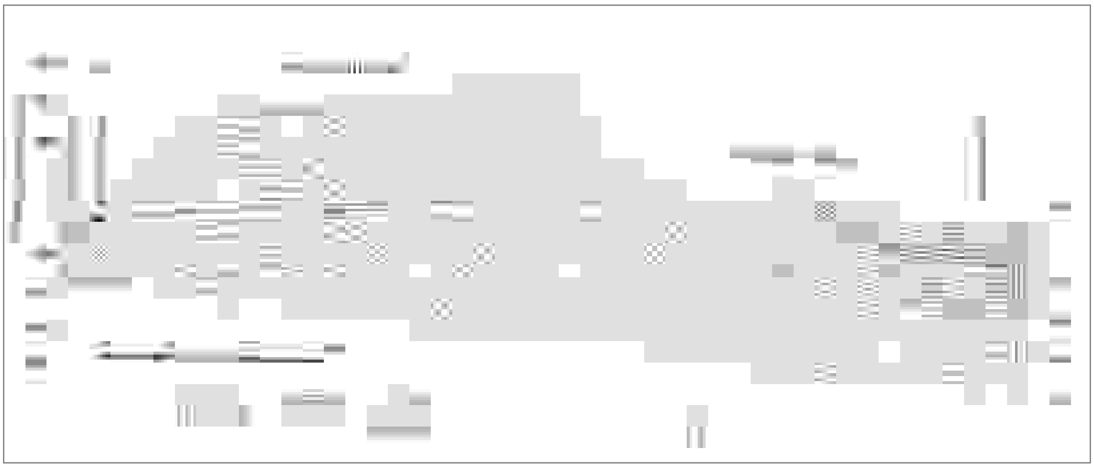

Figure 4. Cross – section of Tragjas anticline showing geological conditions of Uji Ftohte karst springs. 1. Limestone formation, Low Jurassic – Eocene; 2. Flysch, Oligocene; 3. Clay, Neogene; 4. Tectonic fault; 5. Karst water level; 6. Direction of karst water flow; 7. Artesian well.

is about 20 mg/l. Another intake structure is that known as tunnel nº 5. The length of the tunnel is only 13 m and two galleries each length 15 m are dug on both sides of the tunnel and parallel to sea shore. The pumped water quantity in this tunnel varies from 350 l/s to about 680 l/s. The water of this tunnel has a slight increased chloride concentration up to about 100 mg/l.

Figure 5. Intake tunnel nº 6 of Uji Ftohte springs. a) Plan; b) Cross – section. 1. Limestone, fissured and karstified, Upper Jurassic; 2. Clay, Neogene; 3. Tectonic fault; 4. Karst water level; 5. Intake tunnel and the collection room.

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