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The Journey of Establishing Groundwater Source Protection Zones in Kosovo on the Example of Lipjan/Lipljan Municipality

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ABSTRACT
In the past decade, the Rural Water and Sanitation Support Program in Kosovo (RWSSP) funded by the Swiss Agency for Development and Cooperation (SDC) has significantly increased the access to public water supply of the rural population of Kosovo. Currently in Phase VI, the programme is supporting the regional water companies of Kosovo to protect the water resources used for public water supply. This article presents the programs phase VI output 2.5.1: improved water source protection. The programme started to support the first implementation of a ground water protection zone (locally called sanitary protection zone) in Kosovo according to laws and through a systematic process. This article describes the full process of establishing sanitary protection zones for public groundwater wells in Kosovo and reveals the technical and administrative challenges and lessons learned when doing so. The technical investigations require detailed surveys starting from geological, hydrogeological and morphological field work as well as monitoring of groundwater levels, realization of additional piezometers, calculation of hydrogeological parameters and several more. For the Lipjan well field, a hydrogeological computer model was established to understand groundwater flow and to delineate the three necessary groundwater source protection zones. The technical understanding further requires a pollution survey and water quality analysis.

Keywords: modflow, groundwater protection zones, hydrogeological modelling, processing modflow, Kosovo

INTRODUCTION

The provision of drinking water in sufficient quantity and with good quality is one of the most important and also challenging tasks of the water sector. Ensuring water quality is not only a matter of water treatment but starts with careful water resources management and the protection of the water resources themselves. Areas in which water is used for drinking need a special protection from all activities that may be harmful to the water body. This includes the protection of the source from direct contamination but may be extended to changes in agricultural practices and industrial activities to ensure that no pesticides, fertilizers or industrial contaminants can enter the groundwater. Therefore, the establishment of water source protection areas is a common water resources management tool in Europe and implemented in EU member states based on the Water Framework Directive (2000/60/EC), the Groundwater Protection Directive (2006/118/EC) and others.

Kosovo has achieved significant progress on the past decade in provision of drinking water to its citizens. With the financial contribution of the Governments of Kosovo and Switzerland implemented by the Rural Water and Sanitation Support Programme the country has increased its access to public drinking water to more than 90% in the last two decades. As the protection of water resources has gained more attention in the past years the Programme has also supported Kosovo's water sector in technically delineating protection zones and implementing them from an administrative point of view. The first water protection zone calculated by a hydrogeological computer model is located in Lipjan/Lipljan followed by another zone in the Partesh/Parteš Municipality. A new momentum for protecting water sources was created in 2017 with the new Administrative Instruction on "Criteria of Determining the Sanitary Protection Zones for Water Resources" (MESP 2017) which sets the basis for establishing water protection zones.

THE CONCEPT OF THE GROUNDWATER SOURCE PROTECTION ZONE

A water source protection zone is the catchment area of a drinking water source which is subject to specific regulations in order to protect the water from contamination (Urban & Zimmermann 2015). Thus, to protect water resources, different activities which affect water quality may be restricted or forbidden inside of the protection zone. In Kosovo the protection zones are referred to as Sanitary Protection Zones.

When groundwater is protected the protection zone is generally divided in three zones e.g. in Germany described in DVGW-Arbeitsblatt W 101 (2006-06). The methodology for dividing water source protection zones in to three zones is also the current law in Kosovo and described in detail in the Administrative Instruction (MESP 2017). A short overview of groundwater protection zones for an inter-granular aquifer such as in Lipjan/Lipljan, is given below.

Zone 1: Restriction Zone

Zone 1 is a strictly protected area designated for stringent and direct protection around the well and its installation facilities. It is closed by a fence around each well with a radius of 10 m.

It protects the water source from discharges and pollutants that can directly affect the water by human activities. No other activities than those needed for water resources operation are allowed in this zone. Only employees that are authorized by the water utility are allowed to enter the zone.

Zone 2: Controlling Zone

Zone 2 is a limited protective area. This area must be calculated based on the travel time of the groundwater. Zone 2 is therefore the line from which water flows through the aquifer to reach the well within 50 days. The boundary shall however be at least 100 m around the well (MESP 2017).

The surface of this area shall be sufficient to provide protection from movements of microbial and chemical contaminants, and other types of pollutants. All limitations of Zone 3 - Supervision Zone do apply. Further it is prohibited to use chemical fertilizers, pesticides, etc.; to operate wells, poultry or animal farms; to operate industrial facilities, pipelines for transporting chemicals, fuels, oils and other hazardous materials; to transport radioactive materials, chemicals, liquid fuels, oils and other hazardous materials; to exploit gravel and sand. All activities which may damage the water supply infrastructure and pollute water sources are prohibited.

Zone 3: Supervision Zone

Zone 3 is the entire catchment of the well. It thus represents the recharge area on land surface. In this area it is prohibited the construction work of buildings and the development of activities that can contaminate water sources, e.g. discharge the untreated wastewater; industrial and handicraft units with unclean technologies (nuclear reactors, petrochemical and chemical industry, metal processing workshops, leather industry etc.); waste disposal; storage or manipulation of chemicals, fuels, oils, hazardous waste etc.; construction of highways, airports, parking lots without controlling disposal and treatment of atmospheric water.

Protection zones are generally not a circle around the well but are formed as an ellipse in the direction from where water is flowing towards the well. Understanding the dimensions of protection zone 2 and 3 requires detailed hydrogeological investigations and groundwater modelling as the next chapter shows.

TECHNICAL INVESTIGATION

The purpose of the technical investigations is to study the hydrogeology of the respective well field, model the groundwater behaviour and delineate the water source protection Zones 2 and 3. Modelling heavily relies on data and therefore a major task is to collect data that will both increase the hydrogeologists understanding of the study area and serve as input for the model itself. The technical investigations can be split into three major parts, i) Desk Study, ii) Field Work, iii) Modelling.

Data collection through desk study

At first, data will be collected in a desk study from all relevant stakeholders. This includes general conditions such as location of the study area, topographic maps, climatic information and land use. Understanding groundwater requires an idea of water flows above ground. Thus, hydrological data mainly on rainfall as well as location and characteristics of rivers in the study area are necessary. The water supply system for which the water source protection will be established must be understood. Is the water coming from a borehole, a spring or another source and how much is abstracted? Projections of future population data help to understand the future water demand and water abstraction for a well field.

Also, geological and hydrogeological information can be gathered through a desk study. Information on lithology and aquifer characteristics should always be included from literature in addition to field work. Especially maps, cross-sections and borehole-logs contain important information and save costly and timely investigations.

Desk study in the Lipjan/Lipljan case

The well field is located 15 km south of Pristina. Its topography is characterized by a large plain directed northwest-south, ranging from Mitrovica to Kaçanik/Kačanik with a height of 550–570 m asl. formed by fluvial processes. The climate is humid continental with precipitations of 600–700 mm per year. It was estimated that about 30% of the precipitation infiltrates into the aquifer on flat plains of the study area, and around 20% in more hilly areas.

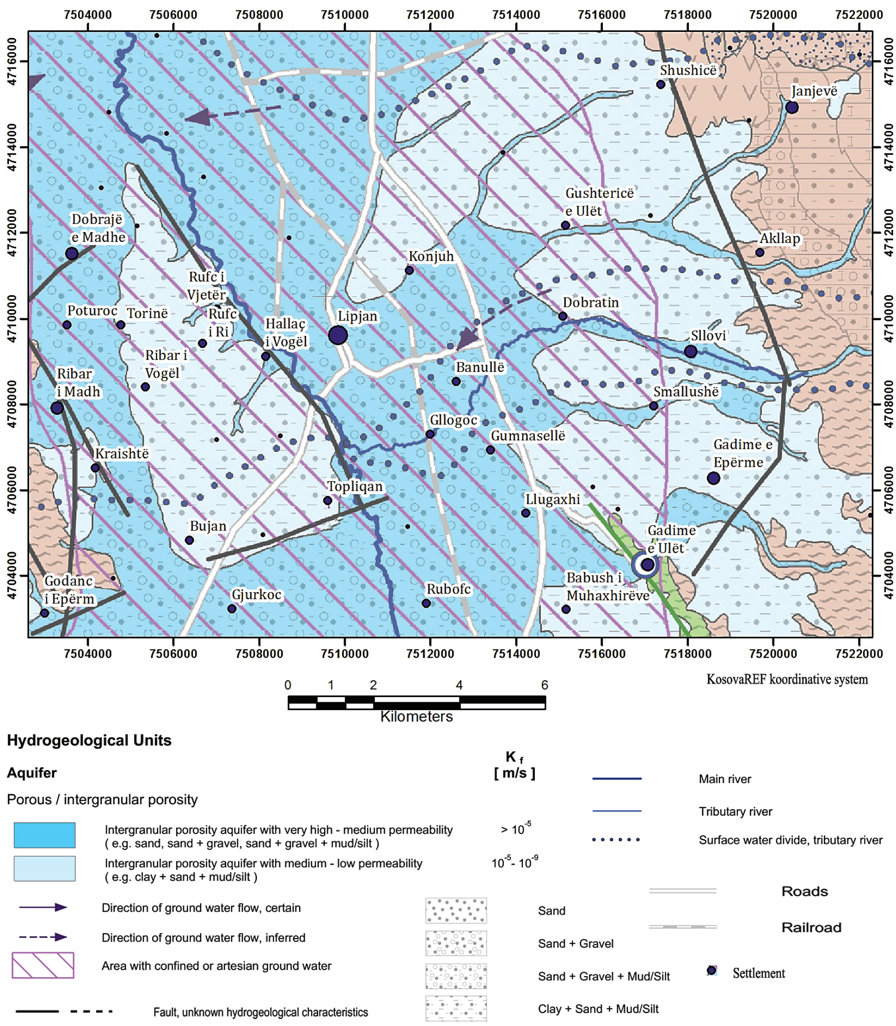

Figure 1. The hydrogeological map of the study area shows how the well field is located on an intergranular aquifer with high porosities. The general groundwater flow direction is from northeast to southwest. The hydrogeological map was obtained from ICMM (2006) through the desk study

The surroundings of the well field are agriculturally used yet domestic and commercial buildings are located in the vicinity. The highway from Pristina to Skopje is located 300 m from the well field. The study area is part of the Sitnica catchment area, and two smaller rivers cross the well field. The well field comprises of a total of 8 wells from which the city of Lipjan/Lipljan and five additional villages are supplied. A total sustainable yield from the well field of Q = 84 l/s was estimated. The well field is located on Cenozoic basin sediments below quaternary alluvial, Proluvial and Pliocene sediments. The wells are filtered in the Proluvial sediments with favourable aquifer characteristics (see Figure 1). A study area of 12 km² around the well field was investigated.

Data collection field work

No water source protection zone can be modelled without understanding the situation in the field. It gives the modeller a general understanding of how the model area will look like and helps to put desk study information into perspective. Several field visits are needed to combine desk study knowledge with the situation on the ground. Field work, however, is often necessary to gather information that could not be obtained through the desk study.

The extent of the field work depends on the quality and quantity of the desk study information. Some information such as hydro-meteorological or general geology must mainly be obtained through existing data from geological institutes and meteorological agencies, since obtaining such information from the field would exceed the scope of the study.

Other information such as borehole logs, pumping test results, water supply data, hydrogeological characteristics etc. are often available in the respective institutions and if not must be obtained in the field. Here, a careful desk study is relevant to ensure full utilisation of existing data.

A significant and indispensable dataset are several borehole water level measurements. Measuring the water level gives an insight into the groundwater level and its flow direction and is a key component for setting up and calibrating the model. In Kosovo, these values are often not available and thus a major part of the field study is to measure water levels in piezometer boreholes and private wells in the entire study area. If necessary, new boreholes must be drilled to gather groundwater level data, understanding of the lithology, and aquifer characteristics through pump tests. Groundwater levels must be gathered several times per year to understand seasonal variations. Further, field work is also necessary to gather information on potential pollution sources.

Field work in the Lipjan/Lipljan well field

In Lipjan/Lipljan, borehole data from literature and additionally drilled wells provided sufficient information to draw a cross section through the study area and understand the dimensions of the aquifer. The additionally drilled wells were used to measure water levels and conduct pumping tests. Furthermore, more than 270 existing mostly private wells were used to measure groundwater levels and thus understand the groundwater surface in the study area. Figure 3 shows the hydro isolines of the study area and the general flow direction towards the wells.

Information from field and desk study were evaluated and an average hydraulic conductivity of 1.0e4 (min. 1.6e-4, max 5.0e-4) and an average transmissivity of 5.0e-3 (min. 1.6e-2, max 8.0e-4) were calculated and used in the model. A number of potential pollution sources were identified, such as agricultural activities, petrol stations and other commercial sites. This is shown in Figure 4.

Data requirements and modelling

Several computer modelling methodologies and software is available. A common model is a finite difference model which can be solved with the modflow software. Modflow was developed by USGS (Harbaugh 2005) and is available as the international standard open source groundwater modelling software. Literature such as Harbaugh (2005), Kinzelbach & Rausch (2001) and Chiang & Kinzelbach (2001) describe in detail how a conceptual groundwater model is prepared, a mathematical model is set-up, calibrated and scenarios are modelled. We aim to focus on the necessary data.

Modelling in Lipjan/Lipljan well field

The model in Lipjan/Lipljan was set up with a grid of 3 km west-east and 5 km north-south, a quadratic cell size of 20 m and three layers. Boundary conditions in this area are a fixed head boundary in the northeast and southwest corners

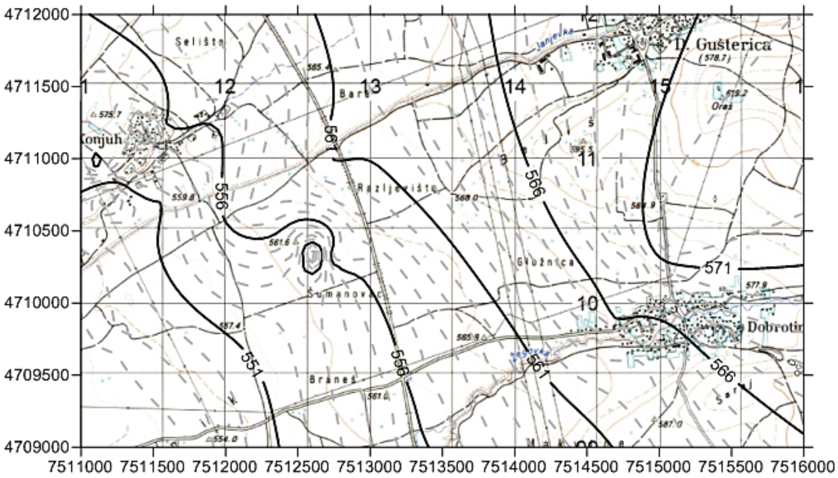

Figure 2. Ground water surface of February 2016 shown through interpolated hydro isolines. The groundwater table is decreasing from northeast towards southwest

Table 1. Model Input Parameters for modflow and potential sources

Modell input parameters	Desk study	Field work	Source
Size and grid of study area		✓	Consultant
Geology	✓	(✓)	Geological institutions, (Consultant)
General aquifer characteristics	✓	(✓)	Geological institutions, (Consultant)
Boundary conditions	✓	✓	Consultant
Hydraulic conductivity and transmissivity	✓	✓	Geological institutions, (Consultant)
Groundwater levels		✓	Consultant
Hydraulic gradient		✓	Consultant
River data	✓	(✓)	Hydro-meteorological institute, Ministry of Environment and Spatial Planning, (Consultant)
Well abstraction rates	✓	(✓)	Regional water company, (Consultant)
Recharge	✓		Hydro meteorological institute, Ministry of Environment and Spatial Planning
Effective porosity	✓	(✓)	Geological institutions, Literature, (Consultant)
Chemical analysis	✓	(✓)	Public health institution, Regional water company, (Consultant)

and no flow conditions along the flow of the groundwater. The upper described parameters were included in the model and calibrated. The first result of the groundwater model is to track water particles backwards from the wells along the groundwater flow for 50 days which. This marks the 50-day line. The second result is to track the particles for an infinite amount of time. Particles will then stop at the catchment boundary of the well which depends mainly on its recharge rate. This area then marks Zone 3. Figure 3 gives an example of particle tracking for Zone 3. The final result of the study is the technical and hydro geologically defined zones. These are shown for Lipjan/Lipljan in Figure 4 which includes the identified potential polluters.

Potential sources of groundwater contamination

Both, natural (geological) and anthropogenic sources may cause groundwater contamination. The Kosovo case is focusing on contamination induced by human activities. Human groundwater contamination can be related to waste disposal (solid waste, private or municipal sewage disposal systems, municipal wastewater, sludge and brine spreading, any waste from petroleum industry, mine wastes, waste from industrial animal farming, radioactive wastes) or indirect waste disposal (accidents, agricultural activities, mining, highway de-icing, contaminated rain, improper well construction and maintenance, road salt etc.).

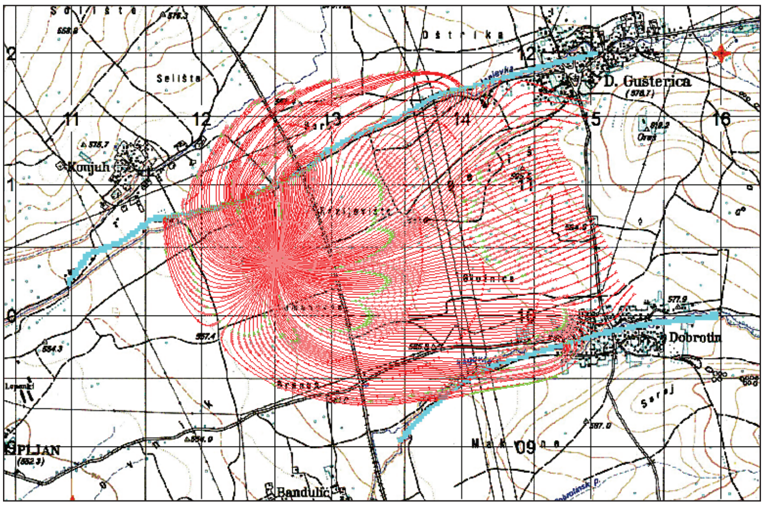

Figure 3. Particle tracking to delineate the wells catchment area

Figure 4. All three calculated protection Zones including identified potential sources of pollution

Potential groundwater contamination in Lipjan well field

The simulation of Zone 2 covered an area of approximately 14 hectares around the production wells (extension of approximately 200 m distance to well heads. This requires consequent protection against chemical and biological contamination. The area is covered by agricultural area and needs to be monitored and protected against any biological or chemical contamination. Also, some uncovered wells have been found e.g. abandoned wells and other kind of open wells which have to be inspected on a regular basis in order to monitor any upcoming risk of contamination inside Zone 2. To the south the highway touches the Zone 2. This area of around 200 m length requires specific attention, as any pollution from highway traffic may reach to the well in 50 days or less. For Zone 3 several potential pollution sources from the categories in table 3 have been identified. They are shown in figure 4. After the technical report identifies and suggests Zone 2 and Zone 3, the main focus is on the administrative processes to reach a final implementation of the suggested area.

Acknowledgments

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