Journal of Georgian Geophysical Society,
Issue (A), Physics of Solid Earth, v.17a, 2014, pp. 102-108

Result of numerical modelling of groundwater resource in the Shiraki catchment

[1]George Melikadze, [1]Natalia Jukova, [1]Mariam Todadze, [1]Sopio Vepkhvadze
[2]Tomas Vitvar

[1]Iv. Javakhishvili Tbilisi State University, M. Nodia Institute of Geophysics
[2]Czech Technical University in Prague, Faculty of Civil Engineering

Abstract

In order to assessment water resource, a numerical model of groundwater was elaborated for Shiraki area. It is consists of 3 layers. Each layer represents a porous material with different infiltration properties. The model was calibrated in transient transport mode to tritium concentration measured in boreholes and springs located in Shiraki area. Tritium was assigned as a single mobile species, not reacting with chemical elements and concentrated in water, what allowed determining the residence time of groundwater flow. The model estimated discharge and recharge zones, groundwater flow directions and velocities as well as groundwater age for Shiraki area. It is recommended to enhance the use of waters from the karstic formations as alternative drinking water sources.

Introduction

Eastern Georgia encounters, due to its semiarid climate, a big deficit of 1040 million cubic meters of water for irrigation and domestic use. One of the most important examples is the agricultural area of Shiraki Plain, which occupies over 80.000 km^2 on a large, partly artesian aquifer of the Alazani basin and on the upland synclines between the rivers Alazani and Iori (1). In order to assessment water resource, numerical model of groundwater hydrodynamics was elaborated for this area based on the conceptual model, which based on the provisional data (geological, geophysical, hydrogeological, hydrological, etc). Model of the aquifer have been processed by special software Visual Modflow Package.

Geological and hydrogeological settings

In geo-tectonic point of view the region is part of the tectonic zone of the river Mtkvari (2), and forms slanting and wide (up to 20km) syncline of considerable extension (up to 50km). The core and wings of the crease lie in the form of sediments of Krasnokolodski suite with the power of 1000m, which belongs to the akchagil-Apsheronian layer. Lythologically this uniform width of the crumby drift-pebbly layers belong to argillaceous sands, also loamy sands containing pressure waters (3,4). On the whole area of the Shiraki Plain basic rocks are covered with proluvial -deluvial and lake gypsiferous argil sands with sub-layers of loamy sands and gravel. The fourth cover is, on the whole, characterized with great diversity of the lythogenic composition of the soil of different genetic types and variable power, ranging from 5-10 to 40-50.

The dynamics of the ground waters are greatly affected with the peculiar composition of Shiraki Massif, which is the component of the Iori Plateau dividing the basins of the rivers Iori and Alazani in the lower current. To the north the Shiraki Massif is distinctly divided from the Alazani valley with the eroded tectonic batter of 400m of height. Within the plain the modern relief is characterized with considerable sloping towards the axial part. Besides, bending can be observed along the axis of the syncline as well, thus, in spite of the general regional sloping in the south- east direction, the plain is contoured as a locked depression.

In conditions of the entire lack of the hydrographic network in the area the ground water supply takes place at the expense of atmospheric precipitation, which is proved by the given regime observations. Besides we suppose the possibility of some injection of the ground waters from below by the downstream waters. The horizon of the ground waters is dated for the fourth sediments and is mapped quite sharply by the given measurements of the boreholes. The horizon is, on the whole, weakly aquifer and is characterized by the low filtration values. The average value of the filtration quotient equals K=0,1-1,2 m per 24 hours. On the map hydroisogyps the picture of water movement from the relatively raised peripheral parts of depression towards the lower and locked central part where ground waters are closer to the ground surface is quite distinctly depicted (6m at the middle sedimentary depth of 25m) and on the whole are spent on evapotranspiration. A great width of the crumby continental layers krasnokolodski suite (Akchagil- afsheron), lain in a large syncline, is a main aquifer, and contains pressure ground waters.

Part of the boreholes situated on the south-western rim of the Shiraki Syncline and opening the pressure horizons within the intervals of 400-600m of depth, gives a well-spring with the maximal debit of 1,7litres per second. The rest of the wells are sub-artesian but having negative water level close to the ground surface. Besides we can observe increase in productivity of the falls of the aquifer deep horizons. Aquifer is contain paleowaters with $\delta^{18}O$ values between -11 and -13‰ V-SMOW and relatively low concentrations of tritium (0.1-1.8 TU).

The issue of the hydraulic interconnection among the pressure and ground waters of the Shiraki Plain and the possibility of surface water reserves extraction for drinking and irrigation purposes is very interesting.

Database creation and analysis

Conceptual 3D model consists of 3 layers (Q,N,J). Each layer represents a porous material with different infiltration properties. Data from geological profiles and maps where used to recreate layers. 2 layers (Q and N) are designed as unconfined.

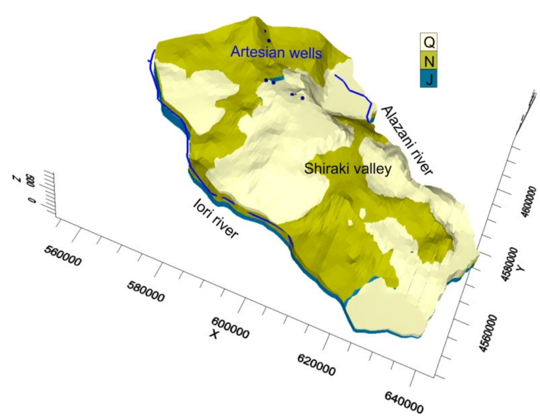

Fig. 1 (Conceptual model) Conceptual and numerical model were developed in Visual Modflow Flex 2012 and Visual Modflow Classic 2011 programs.

Each layer, as single hydro stratigraphic unit, was determined by hydraulic conductivity, specific storage, and effective porosity:

Layers	Hydraulic conductivity (m/s)	Specific storage (m^{-1})	Effective porosity
Q	$7.6042x10^{-5}$	$3x10^{-6}$	0.05
N	$1.6204x10^{-6}$	$5x10^{-5}$	0.03
J	$1.8519x10^{-6}$	$9x10^{-4}$	0.07

Rivers were used as boundaries of the model area. They were assigned as specific flow boundary conditions.

River	Riverbed thickness (m)	River width (m)	Riverbed conductivity (m/day)
Alazani	5	50	20
Iori	3	30	10

Visual Modflow Flex supports the standard Drain Boundary Package; we used it to simulate the boreholes under artesian conditions. 20 drain boundary conditions were added to the model. Next table shows parameters which were assigned to drains. Debit rate depends on the position of well screen.

Artesian boreholes screen geology	Debit rate (L/sec)
Q	Up to 165
N	Up to 60
J	Up to 10

Recharge boundary condition (800 mm/year) was assigned to upper right zone of model. Conceptual model were converted to numerical one and further development. Debits rate of artesian wells where used for to calibrate model in steady-state mode.

The model was also calibrated in transient transport mode to tritium concentration in springs and boreholes located at the Shiraki area. Tritium was specified as a single species with first-order decay of 12.32 yr. The longitudinal dispersivity was selected to be 10 m. Initial concentration was set to 10 T.U. The simulated tritium concentration for the Shiraki model is shown in the Fig. 2.

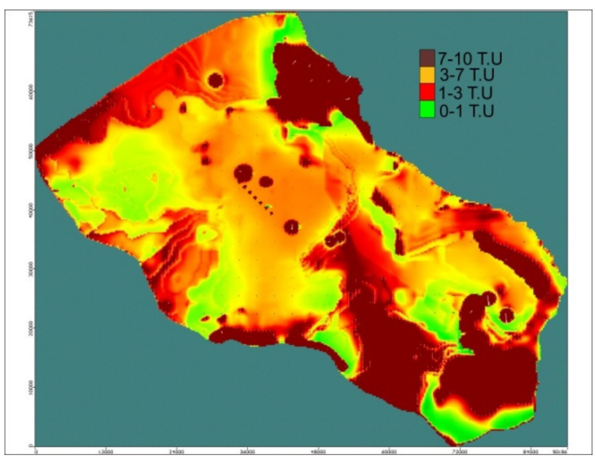

Fig. 2 Distribution of tritium concentration

Simulated water table is shown on Fig. 3

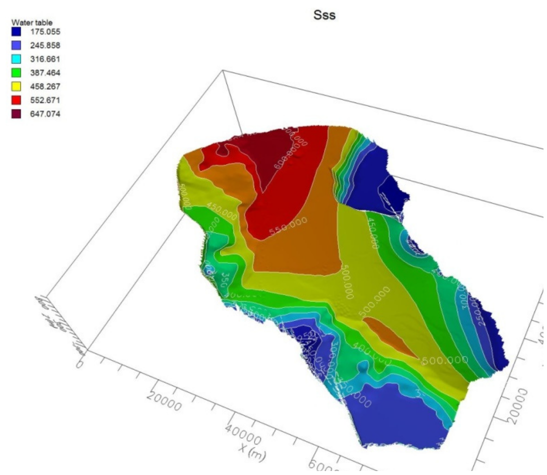

Fig. 3 Water table

In the model was fixed water level in absolute elevation (Fix 3) and was simulated Flow velocities for Shiraki area (Fig. 4).

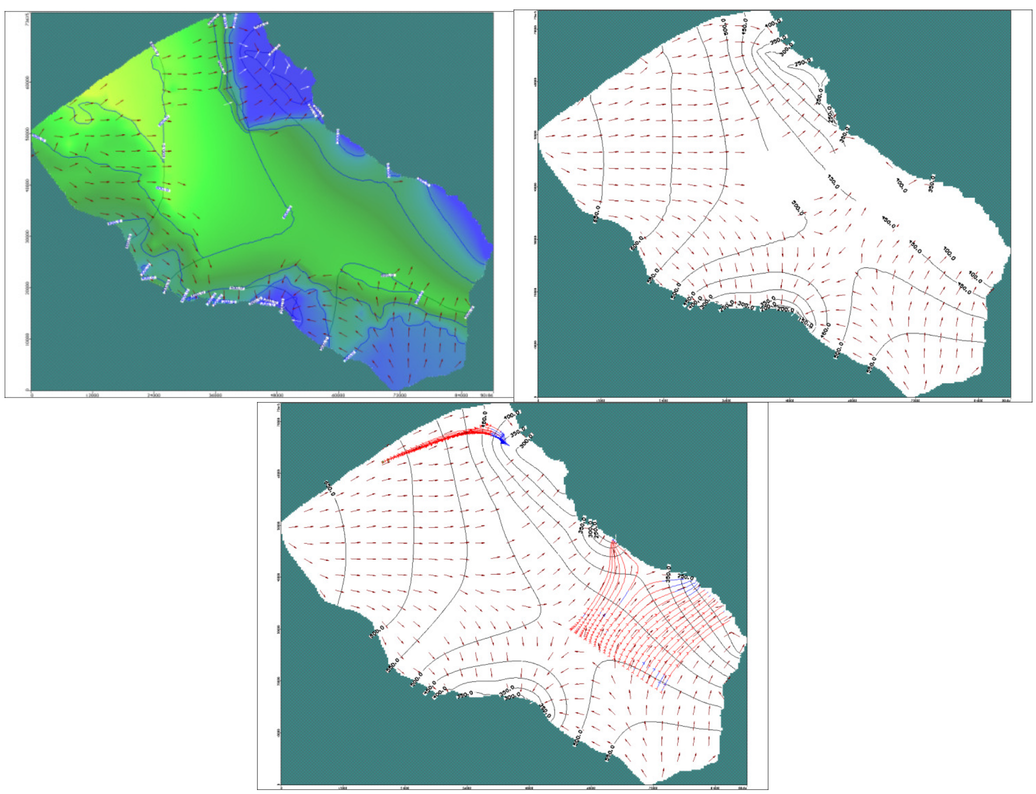

Fig. 4 Flow velocities of a) 1st layer; b) 2nd layer; c) 3rd layer

Fig. 4 shows us flow velocities intensity and direction of simulated water system. As we can see water does not enter the system in upper horizon. 1sthorizon is weakly water-bearing and does not infiltrate water down. In the middle zone water is discharged in the rivers. Middle horizon is recharged by groundwater flows. Intense of flow is increasing in the 3rd layer.

From the tritium-calibrated MT3DMS model, the groundwater age was assigned as a single mobile species that allowed determining the residence time of groundwater flows. From the Shiraki valley groundwater moves to the Azalani site, average water age between 2 locations is about 35 years. From the Shiraki hills water moves to Iori site's artesian wells (Kasritskali and others), water age between 2 locations is about 9 years (Fig.5).

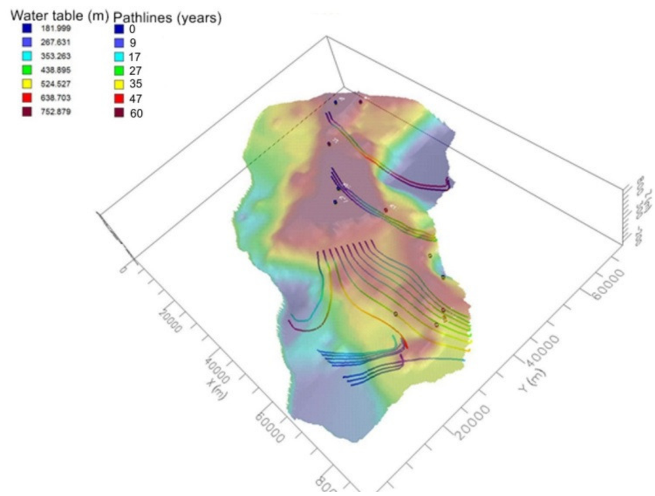

Fig. 5 Groundwater flow pathlinesand residence time

We specified two zones to investigate flow budget in the model. Zones are marked by dark regions in the Fig. 6.

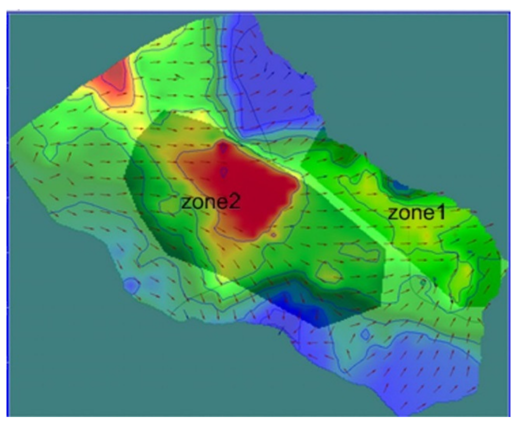

Fig. 6Water table depth and specified zones

Fig.6 shows us total flow budget of the model. As we can see, zone1 is recharged more intense than zone#2, but water discharged in general in the zone#1. Drains in the Fig.7 represent artesian wells. Groundwater discharge of drains is rather slight compared to rivers.

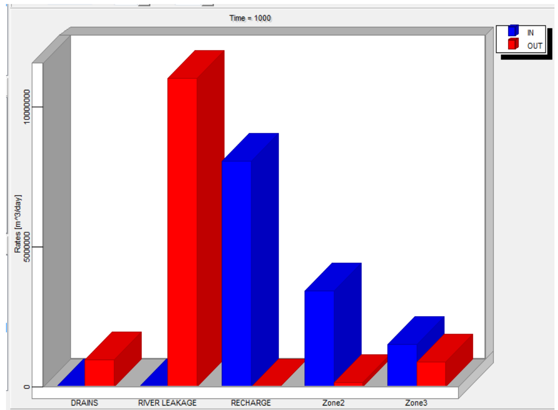

Fig. 7 (Flow Budget), Blue is discharge, Red is recharge

Conclusions

Complex geological, hydrogeological, hydrogeochemical and isotope investigations were carried out and created thenumerical model of the ShirakiArtesian Basin.

Ggroundwater belong to different hydrochemical and isotopic groups and must be considered with respect to local stratigraphy. Grounwater has confirmed the evolution in mineralization from Northwest to Southeast, with major increase in the Shiraki syncline area. Therefore, are observed changes of total mineralization in the vertical cross section of the boreholes.

Model fixed water path lines. From the tritium-calibrated model, the groundwater age was assigned as a single mobile species that allowed determining the residence time of groundwater flows from the Shiraki valley groundwater moves to the Azalani site, average water age between 2 locations is about 35 years.

It is recommended to enhance the use of waters from the karstic formations such as the Dedoplitskaro Plain for alternative drinking water sources in the Shiraki region.

References

1. Bagoshvili, G.N. (1990). Report on hydrogeological survey 1:50000 on the southern slope of the Greater Caucasus. Ministry of Geology of USSR, Tbilisi, 2 volumes, 95 and 163 pp. (unpublished, in Russian)

2. Beselia, B.N. (1988). Prelimiary survey on the appearance of groundwaters Quaternary alluvial-prolluvial confined and Upper Lurassic and Lower Cretaceous aquifers between the rivers Chelti and Durudji. Ministry of Geology of USSR, Tbilisi, 3 volumes. (unpublished, in Russian)

3. Buachidze, G. 2005. Transboundary Artesian Basin of Georgia. Presentation at the conference EURO-RIOB 2005, Namur, Belgium, 29 Sept-1 Oct 2005. http://www.riob.org/IMG/pdf/Euro-RIOB_29sept2005_Buachidze.pdf

4. Buachidze, I.M., and Zedginidze, S.N. 1985. Hydrogeology and Perspectives of Groundwater Use in the Alazani-Agrichai aquifer. Tbilisi, 335pp. (in Russian).

Acknowledgments

The authors thank the Rustaveli National Scientific foundation for financial support of the project #31/27 “Environmental Isotopes Testing in Alazani-Iori Catchments (East Georgia) For Provision of Sustainable Use of Groundwater Resources”.

Результати цифрового моделирования ресурсов подземных вод Ширакского водосбора

[1]МеликадзеГ.И, [1]Жукова Н. О, [1]Тодадазе М. Ш., [1]Вефхвадзе С. Г., [2]Витвар Т. А.

РЕЗЮМЕ

[1]Тбилиский Государствений Университет им. Ив. Джавахишвили, Институт Геофизики
[2]Технический Университет Праги, Чехия, Факультет Гражданского Строительство

С целью оценки ресурсов подземных вод численная модель грунтовой воды была разработана для области Шираки. Модель состоит из 3 слоев. Слои представлют собой геологические породы с различными фильтрационными свойствами. Модель была откалибрована в переходной режиме по значениям трития, который мерился в скважинах и источниках Шираки.Тритий был использован в модели как независимое вещество, которое не вступает в реакции, но концентрируется в воде. Модель определила области питания и разгрузки грунтовых вод, пути и скорость движения подземных вод,а также время задержки воды под землей. Рекомендуется увеличить использование вод в карстовых формированиях как альтернативный источникв питьевой воды.

შირაქის წყალშემკრების ციფრული მოდელირების შედეგები

[1]გიორგი მელიქაძე, [1]ნატალია ჟუკოვა, [1]მარიამ თოდაძე, [1]სოფიო ვეფხვაძე
[2]ტომას ვიტვარ

[1]ივ. ჯავახიშვილის სახ. თბილისის სახელმწიფო უნივერსიტეტი, მ. ნოდიას გეოფიზიკის ინსტიტუტი
[2]პრაღის ტექნიკური უნივერსიტეტი, ჩეხეთი, სამოქალაქო მშენებლობის ფაკულტეტი

რეზიუმე

მიწისქვეშა წყლების რესურსების შეფასების მიზნით შემუშავდა შირაქის წყალშემკრების რეგიონის ციფრული მოდელი. ის შედგება3 ფენისგან. თითოეული ფენა შედგება სხვადასხვა გამტარებლობის ფოროვალი გარემოსაგან. მოდელში გადაადგილების ნაწილი დაკალიბრებული იქნა ტრიტიუმის მნიშვნელობებით, რომელიც გაზომილი იქნა წყალპუნქტებში. მოდელში განსაზღვრული იქნაკვებისა და განტვირთვის არეალები.ასევე დაფიქსირდა წყლის გადაადგილების გზები, სიჩქარე და მიწისქვეშ მოძრაობის პერიოდი. გაცემული იქნა რეკომენდაციები კარსტული წყლების გამოყენებისთვის როგორც სასმელი წყლის ალტერნატიული წყაროსი შირაქის რეგიონისთვის.