Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 162 (2016) 324 – 331

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development, 2nd EWaS 2016

Delineation of wellhead protection areas in Crete, Greece using an analytic element model

Alexandros Staboultzidis[a], Zoi Dokou[a,*], George P. Karatzas[a]

[a]*School of Environmental Engineering, Technical University of Crete, University Campus, Chania, 73100, Greece*

Abstract

Groundwater is one of the main sources of drinking water in many regions and therefore investing in its protection is of paramount importance. A very important step in ensuring water of good quality is the delineation of well head protection areas (WHPAs), which is the focus of this research. The area of interest is the basin of the Keritis River, located near the city of Chania, Crete, Greece. The main contamination threats in the area are: i) olive oil industries ii) cemeteries and iii) urban waste from the towns located near or within the basin. The delineation of WHPAs in this work is performed using a more accurate method than a simple fixed radius around the well, which is currently common practice in Greece. A decision support modeling tool called Wellhead Analytical Element Model (WhAEM) was used for this purpose. WhAEM is a groundwater flow model designed to facilitate the delineation of capture zones and mapping well head protection, using the analytic element method. The unique hydrogeology of the modeled area (location of local heterogeneities, discontinuities, rivers, recharge, no-flow boundaries) is taken into account in order to prevent potentially harmful contaminants reaching the water supply. This process can be used as a management tool by water resources managers, stakeholders and public authorities in order to impose rational measures and potential restrictions in urban, agricultural and industrial activities developed in the area.

Peer-review under responsibility of the organizing committee of the EWaS2 International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development

Keywords: well head protection areas; analytic element models; groundwater modeling; contamination; environmental protection

* Corresponding author. Tel.: +30-28210-37793; fax: +30-28210-37847.
E-mail address: zoi.dokou@enveng.tuc.gr

Peer-review under responsibility of the organizing committee of the EWaS2 International Conference on Efficient & Sustainable Water Systems Management toward Worth Living Development
doi:10.1016/j.proeng.2016.11.070

1. Introduction

As global awareness towards the significance of preserving groundwater quality rises, there have been changes in laws involving WHPA (Well Head Protection Zones) or SPZ's (Source Protection Zones) affecting the safe distance from a well where a potentially polluting activity can take place. There are three methods to determine this distance: a) the simplistic method of setting a radius around the well based on experience, which is a low cost but highly uncertain approach, b) analytic element methods, which are mathematical models used for the delineation of SPZ's mainly based on the aquifer characteristics (porosity, hydraulic gradient, transmissivity and saturated depth) and c) numerical methods, which are also based on a mathematical model, but have the ability to account for seasonal changes in temperature, precipitation etc. [1]. The basic idea of numerical methods is to divide the area of interest in a very large number of cubes (or other geometrical shapes) with unique geo-hydraulic properties and summarize them to delineate the SPZ's. This creates very low uncertainty results for the predicted zones but also has a high cost of application due to the large quantity of data required to calibrate the model as well as the need for an experienced user to produce reliable results [1]. With all the above in mind, the method used in this paper is the analytical method because it is easier to use than the numerical method and provides much more reliable results than the simplistic. The analytic element method estimates the minimum time it takes for a water particle to reach the well, otherwise known as travel-time, to create points in all directions from the well, which when unified as a polygon form the SPZ. The goal of this research is to produce zones, aiming towards the preservation of both the quality and quantity of groundwater, without over restricting areas like the simplistic method could result in. The more sophisticated the method used, the less uncertainty exists in the results of the zones shapes, leading to optimal zones which benefit the economic growth by allowing the operation of potentially polluting activities only if they are outside the protection zone (according to the level of danger that the activity poses to the aquifer).

The basic classification of SPZ's by the EPA Great Britain separates the main capture zone in three different zones. The most sensitive is the inner protection zone, which is meant to protect against pathogenic microorganisms, viruses and in general biodegradable substances by giving them the appropriate time to decay and not pose danger to the consumer. The outer protection zone has the role of providing a minimum travel-time for slow decaying pollutants, giving them time to attenuate and reach the source in a concentration that are acceptable. The third is referred as the source catchment protection zone which corresponds to the area needed to provide long term sustainability for the wells in the aquifer; this zone is rarely defined for individual wells and is a requirement mainly for aquifers with a ratio of licensed yield to recharge greater than 75% [2].

The work presented here focuses on the delineation of protection zones in the area known as Kampos Chanion, near the city of Chania, Crete. This area is divided by the Keritis river, which brings water from the Leyka Oroi mountain at a height of about 1900 m and ends in the sea after passing the region of Platanias, which together with the lake of Agia are NATURA (2000) protected areas. Nineteen communities are within the general area of Kampos Chanion. Most wells are used for agriculture purposes with three being used for drinking, two of which are very near the lake of Agia [3,4,5]. Threats or polluting activities in the area are waste from olive oil producing industries, cemeteries and urban waste water from the communities.

2. Methodology

The WhAEM model requires the following input parameters for the estimation of the SPZs: the general hydraulic gradient of the area, pumping rates of all currently operating wells, the basic elevation level of the aquifer as well as its thickness, porosity, precipitation, maximum and minimum contours of water levels and general hydraulic conductivity values. Additional model parameters include inhomogeneous regions within which the hydraulic conductivity can vary significantly. This is illustrated in Fig.1 which shows the geologic map of the area where the hydraulic conductivity varies with color as follows: green represents highly permeable formations with K=300 m/d, gray represents impermeable formations with very low hydraulic conductivity value (K=0.000086 m/d), light blue is relatively permeable with K=8.61 m/d and light green has medium permeability (K=51.86 m/d). Pumping wells in the area are represented by black circles while the pollutant sources of olive oil industries and cemeteries are shown by red and green circles, respectively (Fig. 1). There is no legally permitted area to dispose suburban waste in the area. Table 1 shows the pumping rates and other information of the 12 wells used in this study. Wells will be referred to by their number in the text.