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A framework for drinking water basin protection

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Abstract

Many countries have applied many measures, including preventing inappropriate activities in areas where drinking water is abstracted to protect drinking water resources. However, reaching good water quality based on human health has not been achieved in drinking water basins. Drinking-Water Protected Areas Determination has been defined as a powerful protection method to restrict inappropriate activities affecting water quality and quantity. These areas are determined based on basin properties to provide sustainable drinking water management. This study aims to present a framework for drinking water protection by giving methodological study steps. Strengths, deficiencies and inadequacies in drinking water protection practices were shown by examining the implementations of Turkey and European Union member countries. Thus, by adding new methods to these applications, a standard approach was created to be applied to each different drinking water basin.

KEYWORDS

best management practices, climate change, drinking water basin, protection zones, river basin management

1 | INTRODUCTION

Worldwide Health Organization (WHO) indicated that 91% of the world's population accessed safe drinking water in 2015 (WHO, 2017). However, reaching water quality standards of drinking water determined based on human health has not been achieved yet (Salinas, 2015). Despite a reduction in agricultural pollution, increased urban wastewater treatment and the re-naturalization of several water bodies, good status for water and ecology has not been reached (European Commission, 2019). Drinking-Water Protected Areas (DWSPAs) have been determined according to the directive (European Commission, 2019) to provide sustainable drinking water quality and quantity. Although many countries have used different management strategies to control pollution sources that affect drinking water quality, DWSPAs have been defined in many countries as powerful protection prevention to safeguard public drinking water supplies and restrict related human activities (Shen et al., 2010; Wang et al., 2021). To protect drinking water resources, EU Member States have implemented different legislation at the local and regional level that prevents inappropriate activities having adverse effects in regions where water is abstracted for drinking water supply. For instance, watershed protection in France was provided by the 1964 law, and then drinking water sources were protected by adding tools to that (ZSCE: Areas with Environmental Restrictions) in the Law on water and Environmental restrictions 2006. Drinking water abstraction areas have been protected by an action plan at defining protection zones in the law. Each drinking water basins in Germany have been protected by their special law (Land Water Act) since 2010. A working group (LAWA: the Länder-Arbeitsgemeinschaft) was generated to coordinate measurements and activities of each basin and facilitate the collaboration between basins for water resources protection.

Watershed protection areas have been applied by Spanish water law (La Ley de Aguas) since 1985 in Spain. The law was revised to transpose the WFD in 2001. The delineation of these protected areas has been prepared based on an official guide published in 1991 and updated in 2003 by IGME (Instituto Geológico y Minero de España). Drinking water basin protection is provided by the special legislation of each autonomous community as adding to the national law. The Environmental Protection Act (1990, revised in 1995), the Water Resources Act (1991) and the Water Act (2003) have an important role in the protection of water resources in the United Kingdom (Siauve & Amorsi, 2015). Netherland protects their drinking water resources by establishing regional dossiers for the area that is abstracted drinking water. Relevant data about water quality and quantity are collected and then analysed for the abstraction site to determine protection policy (Wuijts & Rijswick, 2016; Wuijts et al., 2018). In Turkey, the Regulation on Protection of Drinking and Utility Water Basins (PDUWB, 2017), have been carried out for the protection of drinking water. However, water resource managers have not ensured the protection and development of water resources in most countries due to troubles in carrying out adequate protection through a suitable strategy in this consideration (Jacobsen et al., 2017). Thus, new water protection conditions in EU policies like the Drinking Water Directive have been created (Carvalho et al., 2019). Site-specific protection areas and policies for drinking water basins must be prepared by adding new initiative approaches such as climate change impact on water resources (Garnier & Holman, 2019). Although many other ambitions have been built up at local and regional scales to further contribute to the protection of drinking water resources (Graversgaard et al., 2018; Quirin & Hoetmer, 2019), site-specific protection zone study steps have not been defined by examining gaps and determining requirements about these studies.

This article aims to contribute to drinking water protection by given a framework for determining site-specific protection zones for these resources. Thus, by this study, the holistic approach determined by examining application gaps and methods in different countries can be applied to each drinking water basin. In this paper, the practices of Turkey's site-specific protection studies were given as examples for missing aspects and which studies should be carried out during the determination of these areas.

2 | MATERIALS AND METHODS

Many studies have been enacted to determine protection zones for drinking water resources based on geological and hydrogeological factors, topology and soil type characteristics (Bytyqi et al., 2018; Kuru & Tezer, 2020; Menichini et al., 2015; Naves et al., 2017). In this study, the methodology to be followed during site-specific protection zones of drinking water resources determination is given step by step. A new framework for the protection of drinking water was proposed by examining drinking water application in Turkey as giving an example of the implementation difficulties and inadequacies.

In the first step of the proposed framework, to define protection zones and policies in the basins, general properties, settlements, population, infrastructure, transportation and plans, land use/land cover and socio-economic situation are determined. In the second step, physical properties of the basin, climate and climate change, topography, geology, hydrogeology, hydrology, hydromorphology, soil properties, biological characteristics are defined. Moreover, nonpoint and point source pollutants are defined. These study steps define the basin-specific challenges of sustainable water and land management. Thus, the environmental and ecological-economic situation has been analysed. Administrative criteria such as land use variables, water quality, quantity and ecological balance targets, constraints (ex; pasture remain as pasture, deforestation), etc. are determined. Cost analysis is necessary to show the economic benefit in determining the most appropriate land use and management pattern. Spatial and temporal distributions of water and contaminant loadings in the basin are analysed using an appropriate methodological approach based on data availability and basin properties such as hydrologic, hydrogeologic, watershed modelling, GIS, etc. Best management practices with alternative scenarios should be defined for the basin. Although to find the best management practices for basins, model-based approaches combined with scenario analysis have been used, a user-friendly integrated model linking a simulation model with an optimization algorithm that provides Pareto-optimal solutions should be adapted for supporting decision-makers identifying the most appropriate land use and management pattern. After these studies, a draft site-specific protection zones and policies are defined for the basin. The draft plan is shared with stakeholders in the basin to decide the most appropriate management plan for the basin. After that step, the relevant Institute is promulgated site-specific protection zones and policies for the basin.

2.1 | Steps in the determination of general properties of basins

First, the location and borders of the basin and sub-basins in the basin, rivers recharging reservoirs are defined in this step. Then, settlement and population, infrastructure, transportation and plans, land use and socioeconomic characteristics, and protected areas are determined to reveal the current situation in the basin (Figure 1).

2.1.1 | Settlements and population

While determining settlements in the basin, the current population set down by obtaining data from the relevant Institute. Census information of the basin from the past years gives the population growth rate character. The population growth rate is calculated based on the last census population, previous census population, the number of years between two counts. The population growth rate must be forecasted based on different methodological approaches such as Exponential, Least-Squares, Compound

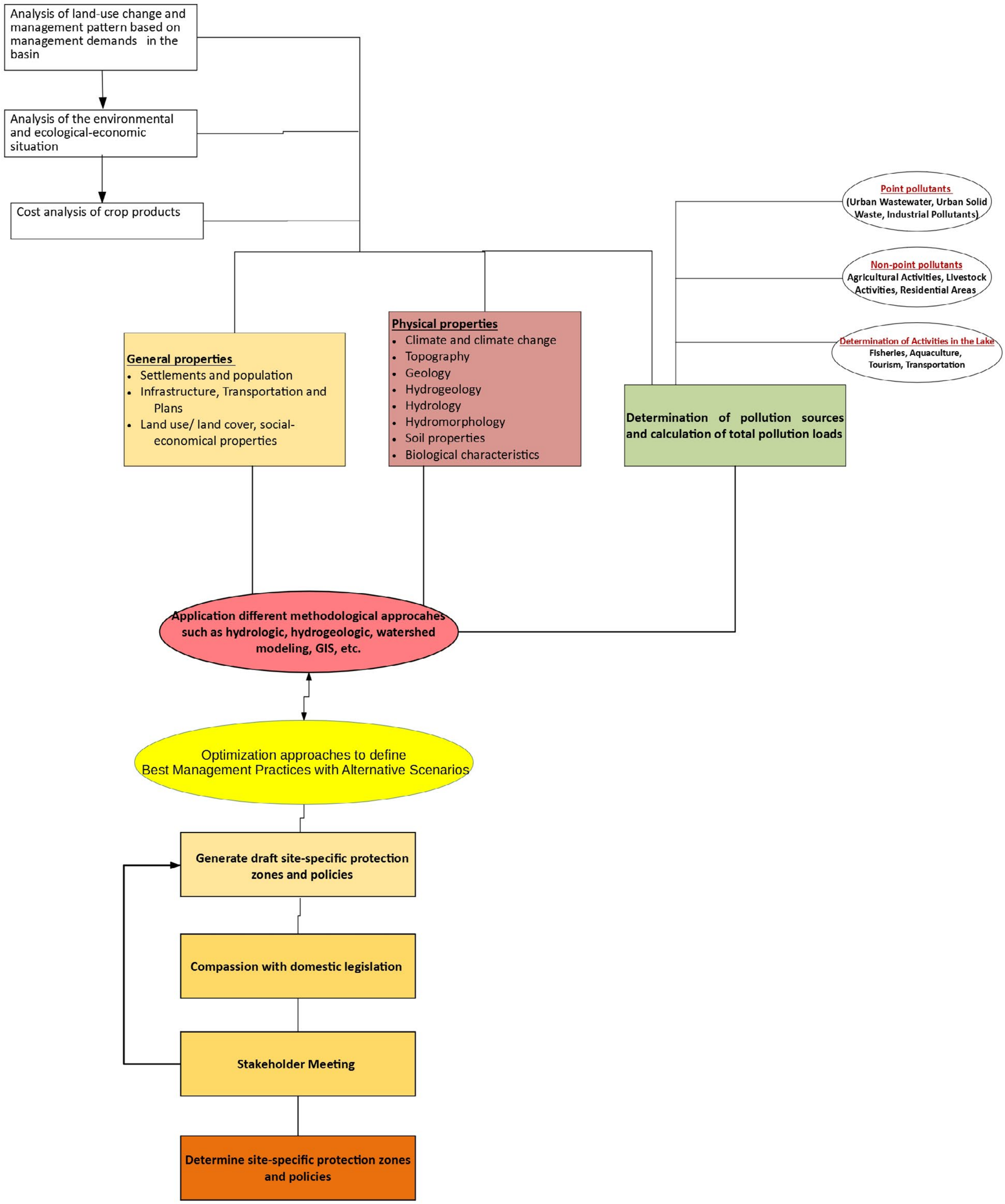

FIGURE 1 The methodological approach for the determination of site-specific protection zones

Interest and Arithmetic Average methods using the last census population, population growth rate and year parameters. These methods should be used in comparison with each other according to the basin characteristics because these methods offer different population growth rates to understand the population growth rate character in the basin. According to these methods, after calculating the future population growth rate, the most appropriate future population growth rate in the basin is determined based on the best match by comparing the graph of the census values of the past year and the population projections. Domestic pollution loads are calculated based on the population estimation assessment in the basin. According to the population projection, the water resources allocation plans can be generated based on water requirements for the present and future. Thus, water management plans with measures can be determined.

2.1.2 | Infrastructure, transportation and plans

The current infrastructure of the settlements in the basin (sewage, water, treatment plant, septic tank, solid waste storage areas, etc.) is determined to reveal pollution sources. Transportation is determined to decide the amount of pollution caused by transportation. Accurately planning in the basin is provided by knowledge of current zoning and landscaping plans. All kinds of applications and survey plans planned and carried out in the basin affecting the quality or quantity of water by institutions and organizations are specified. Human-induced activities (mining, agriculture, reconstruction, etc.) or erosion may cause material and silt transport in case of flooding into the basin. Thus, these possible events have to be prevented by protection barriers on dry stream beds that are likely to carry these materials. The surface runoff waters originating from highways may cause degrading water quality by reaching the drinking water reservoir. The surface runoff waters occurring on the highway passing through this area are collected and discharged out the basin when the land structure permits. If not provided, they passed through appropriate filtration systems. Soil erosion near roads causes sediment accumulation in the basin. Activities such as planting on roadsides are taken to prevent soil erosion that may arise from road slopes. Hazardous waste or materials may reach the lake as a result of traffic accidents. Hence, accumulation structures can be stored temporarily on the highway to prevent hazardous waste or materials from passing through the drinking water reservoir. It is obligatory to build accumulation structures by the relevant Institute. Double-story barriers should be constructed by the relevant Institute to prevent vehicles carrying hazardous waste from reaching the lake within a determined year after the specific provisions are promulgated in the drinking water basin. Regarding the pollution caused by accident situations, the emergency response plan is prepared by coordination with the relevant administrations. Maintenance and repair activities can be made on existing highways in the basin. Art structures, such as retaining walls and culverts, can be constructed to protect the infrastructure. Besides, new road construction and road widening can be carried out in line with the relevant Institute opinions. Measures and their relevant institutions to prevent pollution from transportation in Turkey are given in Table 1.

2.1.3 | Land use/land cover and socio-economic characteristics

Successful integrated watershed management depends on the combination of ecological, economic, political, and social factors and natural physical processes. Multifunctionality of basins provides to meet human demands (O'Farrell & Anderson, 2010; Rallings et al., 2019). The basin-specific challenges of sustainable water and land management based on land use/landcover and socio-economic characteristics should be defined. At first, the environmental and ecological-economic situations should be analysed. Administrative criteria for land use, such as constraints (ex; pasture remain as pasture, deforestation), should be determined to generate a proper drinking water management plan for the basin during site-specific studies. The social-economic characteristics of the basin are examined by analysing historical and future statistical analysis. Based on these characteristics, demands on the basin are determined. Moreover, crop products in the basin should be defined and, cost analysis should be made to represent the economic benefit in determining the best management scenarios with alternatives. Since land use is one of the most significant factors that affect water resources in terms of water quality and quantity (Zhang et al., 2018), land-use changes in the basin should be examined.

Non-point source pollution is caused by a mixture of contaminants from a large area rather than particular detectable sources. Land use/land cover (LULC) around water sources and associated changes have degraded water quality via the transfer of non-point source (NPS) pollution (Zhang et al., 2018). Thus, the determination

TABLE 1 Measurements and its relevant institutions to prevent pollution from transportation

Accumulation structures	The General Directorate of Highways
Preventive embankment walls	The General Directorate of Highways, Metropolitan Municipalities, State Hydraulic Works (DSI)
Erosion measurements	The General Directorate of Highways, Metropolitan Municipalities, State Hydraulic Works (DSI), General Directorate of Combating Desertification and Erosion
Filtration strips	The General Directorate of Highways, Metropolitan Municipalities
Maintenance and repair on current highways	The General Directorate of Highways
The emergency response plan	The administration that uses the water in one year in coordination with the relevant administrations

of land use and land cover and associated changes in the basin is necessary for calculating NPS pollution. Using a different methodological approach, such as the Soil and Water Assessment Tool (SWAT) model (Xing et al., 2018) for NPS pollution calculation, the site-specific policy is prepared to control pollution sources.

2.2 | Steps in the determination of physical properties of basins

Since each basin has its own physical properties, climate, geology, topography, hydrogeology, hydrology, hydromorphology, soil properties and biological characteristics in the basin are studied. These properties are evaluated based on vulnerability to pollution, and then the appropriate methodological approach based on these properties and data availability is determined to delineate site-specific protection zones (Figure 1).

2.2.1 | Climate and climate change

Climate characteristics such as precipitation, temperature, evaporation and wind in the basin are examined in the basin. These data are obtained from the General Directorate of Meteorology (MGM), State Hydraulic Works (DSI) and Metropolitan Municipalities in Turkey. The spatial distribution of the climate data is generated by different methodological approaches such as spatial statistical methods. This distribution of the climate data is used to understand the local climate change distribution of the basin. It is predicted to increase global warming by 1.5°C by 2050s compared with the present situation (IPCC, 2018). Global warming has an impact on the hydrological cycle as well as water quality (Anand et al., 2018). Direct and indirect effects of climate change should be examined on drinking water resources with interdisciplinary approaches and modelling studies (Qiu et al., 2019) to generate appropriate water management plans. Direct effects are considered temperature increases and/or changes in precipitation regimen on water resources. However, indirect effects are considered the results of distinct socio-economic scenarios on water demand in response to climate change (Rodriguez & Delpla, 2017). Water management strategies for drinking water basins must be developed based on climate change's effect on water quality and quantity (Garnier & Holman, 2019).

2.2.2 | Geology

Fault zones, permeable formations, unstable areas, potential groundwater availability areas, fractured zones, areas susceptible to erosion, etc., are determined in geological studies. High permeable geological formations are determined by examining the basin geology since permeability is a significant factor in the rate of pollution transport to water sources.

2.2.3 | Topography

Basin topological properties affect geomorphological characteristics of the basin, such as area, slope, or shape. The hydrograph shape and the flow rate observed at the outlet of the basin are impacted by the shape and area of the basin. The time needed for runoff to reach the hydraulically most distant point in the watershed to the outlet is defined as the time of concentration (Tc). It varies based on the area, slope, flow path and shape of the basin (Usul, 2001). The geomorphological feature of the basin should be carefully studied to understand the hydrological character. Thus, the spatial distribution of water quality and quantity can be shown. The pollutants can run off the surface or seep through the surface based on the slope degree in the basin (Aller et al., 1987). The high degree of slopes in the basin shows high flow and erosion rates. Therefore, potential pollution risk increase in the surface water is determined based on the degree of slopes. In contrast to surface water, the high slope in the areas is less vulnerable to groundwater recharge and pollutants. Since the flow rate will be slower in areas having a low degree of slopes, the amount of water seeping into the groundwater will be higher. Therefore, these areas are more sensitive to pollution. Using sediment traps by grass filter strips at different slopes helps protect water resources from sediment particles, nutrients and other chemicals accompanying the stormwater runoff (Fulazzaky et al., 2013). A littoral zone of lakes is necessary to save wildlife habitat, water quality and provide erosion control (Dąbrowska et al., 2016). A topographic map is used for defining the littoral zone.

2.2.4 | Hydrogeology

The hydrogeologic map of the basin is prepared based on the available data. Important springs, wells, karst structures, aquifer boundaries and type is determined and displayed on at least a 1/25.000 scale hydrogeology map. Groundwater potential, aquifer properties, aquifer capacity, an annual amount of safe withdrawal water from the aquifer, a flow direction of groundwater are determined. Furthermore, the relationship between surface water and groundwater is shown.

The hydraulic conductivity parameter controls the rate of groundwater movement in the saturated zone. Aquifer vulnerability raises by an increase in hydraulic conductivity because the speed at the transportation of pollutants increases by that parameter. High values of hydraulic conductivity indicate higher vulnerable areas to pollution (Özdemir, 2019). Aquifer media indicates the movement speeds of pollutants. Grain sizes, fractures, void ratios and consolidation of the aquifer media indicate pollution potential and rate. Permeability and attenuation capacity of the aquifer having large grain sizes, more fractures or voids are high. Thus, the pollution potential of the aquifer is high (Aller et al., 1987).

Groundwater in karst aquifers has a higher pollution risk than non-karst aquifers since travel time between the infiltration site and springs in karst aquifers is low due to the rapid flow (Kresic

& Stevanovic, 2010). Hence the protection of karstic areas is significant to preserve the quality and quantity of groundwater. The thickness of rocks or deposits overlying on non-karst aquifers allows protecting against pollutions since shallow regions are more vulnerable to the pollutants that reach the groundwater in shallow areas (Witkowski et al., 2007). Aquifers that are permeable, porous, fractured and cracked are assigned more vulnerable to pollution. Karstic structures are determined and mapped in the basin since pollutants reach groundwater rapidly in karst structures such as doline, sinkhole, swallow hole, etc. (du Preez et al., 2016). The definition of protection zones for karst aquifers is not easy since understanding hydrological processes in karst regions includes difficulties due to limited data. The combination of hydrogeochemical and isotope parameters, ^{18}O, ^{2}H and ^{3}H, has been used to help determine the protection zones for karstic aquifers (Özdemir, 2019). The protection zones for pumping wells must be determined to protect the groundwater resource against persistent pollutants from industry and agriculture (Bytyqi et al., 2018). The Environmental Protection Agency (EPA, 1993) has suggested several methods containing analytical, numerical and hydrogeological mapping, to determine wellhead protection zones. Detailed knowledge about the aquifer characteristics such as porosity, hydraulic gradient, transmissivity and saturated depth is required to apply these methods (Staboultzidis et al., 2016). When there is no detailed knowledge, wellhead protection zones can be defined based on a 50-metre radius from the well, which is the natural attenuation of pathogenic microorganisms (Taylor et al., 2004).

2.2.5 | Hydrology

In this step, the flow rate of rivers in the basin, drainage area surface area, average depth and maximum water level characteristics of the reservoir is determined. The water budget of the basin (recharge: groundwater, surface runoff, precipitation, etc.; discharge: irrigation, drinking and utility water, evapotranspiration, evaporation, etc.) is estimated. Water allocation for irrigation, electricity generation, industry, drinking and utility in the current situation is stated. Moreover, the planned water usage amounts by the relevant institutions and organizations in the basin will be specified.

2.2.6 | Hydromorphology

The flood structures, dams, hydroelectric power plants, ponds, drainage channels, etc., in the basins, are determined and displayed on the digital map in the GIS environment.

2.2.7 | Soil properties

One of the significant parameters to determine the amount of water infiltrating into the ground is also soil. The rate of pollution transport is determined as quick or slow based on the soil environment being fine-grained or coarse-grained. The soil permeability of fine-grained soil media such as silt or clay is low. The transportation of pollutants decreases in the fine-grained soil. Therefore, soil types and their properties are defined in the basins. Moreover, suitable areas for agriculture and product patterns based on soil types are determined.

2.2.8 | Biological properties of basins

Flora and fauna features are identified in the basin to decide ecological-based site-specific management plans. Protection of natural vegetation and animal diversity is vital for sustainable water management in the drinking water basin. In situ conservation of the species can be in the extent of the continuity of habitats that provide the basic requirements of the species. Any activity that may cause habitat change in the basin may cause positive or negative consequences as it affects at least one of the main factors. For this reason, it is significant to consider all the necessary activities based on ecology. Thus, while preparing site-specific protection plans, the ecological management activities should be included in site-specific protection plans in cooperation with the relevant Institute.

2.3 | Steps in the determination of pollution sources and calculation of total pollution loads

Point pollutants, non-point pollutants and pollutants from activities, such as fisheries, aquaculture, tourism, transportation in the lake are determined to calculate total pollution loads in the basin (Figure 1).

2.3.1 | Point pollution sources

Considering the condition of the basin, important point pollution sources that discharge to the receiving environment and their current infrastructure conditions are defined. The pollution loads of each settlement located within the basin boundaries are determined. The discharge points, a sewage system, or a treatment plant of settlement locations are shown on the digital map in the GIS environment. The current infrastructure status of the settlements (sewerage and connection status, rainwater condition and wastewater treatment plant conditions, treatment type, capacity, treatment efficiency, etc.) are specified.

Irregular storage areas are defined, and the amount of leachate from these areas is determined. Whether or not there are industrial facilities in the basin is determined. If industrial facilities are located in the basin, the name, address, location, sector, amount of wastewater, discharge permit and sewerage connection states of industrial facilities are defined. The coordinates of the discharge points of each industrial facility are determined and displayed on the digital map in the GIS environment. Industrial facilities that create hazardous waste due to their production and/or dangerous materials in wastewater are identified separately. The pollution load from each industrial facility is calculated.

Furthermore, the reserve area, coordinates, production and enrichment method of the existing and abandoned mines and natural materials quarries, the waste dam of the quarries, the state of the passage site are determined. The pollution loads from mine and material quarries are estimated. Besides, restored areas to nature and the abandoned mining sites and the coordinates of these areas are determined and displayed on the digital map in the GIS environment.

2.3.2 | Non-point pollution sources

Non-point pollution loads from agricultural activities, forestry, pasture and plains, residential areas, etc., are determined. Agricultural areas and approximate pollution load from these areas based on fertilizer, pesticide types and amounts used in agricultural activities in the basin are specified. The amount of pollution coming from livestock and fattening are determined. The amount of pollution carried by surface runoff from residential areas is assigned. Heating, traffic and industrial activities causing air pollutants affecting the potable water source are defined. In the reservoir, activities, fuel-powered watercraft, swimming, aquaculture and hunting, etc., are determined.

2.4 | The definition of the best management practices for the basin

Understanding temporal and spatial distribution of water, including recharge and contaminant loading, is necessary for generating a proper management plan to protect water resources. Thus, the development and the application of mathematical simulation models, representing all the hydrological processes at the pertinent scale, may play a key role in predicting short and long-term effects on the aquatic system for a successful river basin management plan. Water resource managers have widely used models to understand and control inappropriate activities impacts on the river basins, either natural or anthropogenic. The model to be applied should be chosen based on the physical characteristics of the basin and the sources of pollution. Model-based approaches combined with scenario analysis have been used to find best management practices for basins (Jhang et al., 2017). The modelling tools propose to achieve a targeted ecological status, considering possible land use and management scenarios. Thus, alternative land management practices are used to reduce the spread of load pollution. However, these models do not fully reveal the changes in water quality and quantity and ecological balance of the changed land use and management pattern for economic benefit in the basins since trade-offs between conflicting objectives are involved inevitable shifts (Fischer et al., 2017a, Fischer et al., 2017b). Applying the most appropriate management strategy to basins depends on understanding and balancing trade-offs between these objectives (Verhagen et al., 2018). Alternative “optimal” management strategies can be provided for decision-makers about basin management by the tools to identify the trade-off between objects (Bennett et al., 2009; Lautenbach et al., 2013; Seppelt et al., 2013; Verburg et al., 2016). Optimization algorithms have been applied to compare current management plans and generate alternative scenarios. It is possible to combine the simulation models with optimization methods to show the most suitable land use. Thus, the maximum economic benefit in land-use changes and the minimum negative impact on water quality and quantity and the ecological balance in the basin can be shown by this combination. As a result, the best management practices for the basin should be determined to meet human needs and reach environmental targets.

2.4.1 | Stakeholder meeting

WFD (2000/60/EC) indicated that the role of stakeholders in the basin is significant to reach the good quality status of the water during the integrated river water management. Stakeholders involve public authorities, water companies, farmers’ organizations, industry associations and experts, such as agricultural advisors and consultants. Many institutions have different responsibilities for implementing measures at the local level, so they have different interactions with stakeholders while implementing these measures. Farmers and local citizens have the most significant role in protecting and improving water quality and quantity in drinking water basins because they are directly affected by administrative measures, and they are practitioners (Fulazzaky, 2017). Although different applications about providing stakeholder participation in water management, legally or voluntary-based, have been implemented by countries, active participation in applying measures has not been achieved yet to provide sustainable water management in basins (Wuijts et al., 2018). Therefore, after determining draft site-specific protection areas and policies, stakeholder meetings should be organized to decide the best management plans to supply socio-economic and environmental demands in the basin. The site-specific policies are published in local newspapers to inform the public who live in the basin and take their demands and proposes. If there is no objection after determining the time based on domestic legislation, it is approved and conducted by the relevant Institute responsible for water management in the basin. A basin management delegation is formed by stakeholders involved in decision-makers to ensure sustainable water management in basins. The delegation generates a watershed protection plan for the implementation of site-specific protection policies by the relevant Institutes. Moreover, the delegation follows the implementation of the site-specific protection policies by organizing meetings with stakeholders at regular times. After each meeting, a basin report including monitoring results and the implementation programme is prepared to present to the relevant Ministry to be assessed water quality and quantity. According to the report results, site-specific studies for drinking basins are updated at least every five years to generate appropriate water management and policy.

3 | RESULTS AND DISCUSSION

The different methodological approach has been used to define drinking water protection areas by European Union countries. Based on the amount of available data, simple or complex approaches with calculations and modelling have been applied to delineate the protection areas. For instance, the protection zones of drinking water resources in the Tuscany Region, Italy, were delineated using an integrated approach involving geological, hydrogeological and hydrogeochemical studies (Figure 2). After this study, fifteen protection zones were determined. Primary and secondary areas were defined for each zone based on their relative significance in providing drinking water (Menichini et al., 2015). The absolute guardianship zone (an area of at least 10 m Radius immediately surrounding the abstraction point), respect zone (the territory identified by a travel time of 180 to 365 days surrounding the absolute guardianship zone) and protection zone are defined in Emilia Romagna Region, Italy to protect and improve drinking water (GWPA, 2013). Germany protects groundwater and surface water in watersheds by geological, hydrological, hydrogeological and modelling studies (Hölting & Coldewey, 2019). For instance, drinking water safeguard zones in the Lingen area, Germany, were established based on the hydrogeological investigation (European Communities, 2007). In Turkey, several studies about site-specific provisions are carried out by the Republic of Turkey Ministry of Agriculture and Forestry-General Directorate of Water Management or the Metropolitan Municipality Water and Sewerage Administration General Directorates under the coordination of the Ministry since 2011. Since it is not possible to explain all studies in this paper (Appendix: determination of site-specific studies), site-specific protections of Gördes and Namazgah dams are given as an example to show technical and application difficulties about drinking water management.

3.1 | Gördes dam basin

The Gördes Dam is between 39° 10′ and 38° 40′ north longitude and 28° 5′ and 28° 30′ east latitude in the Aegean region, Turkey. The area of the dam basin is 1049.93 km^2. The dam has supplied irrigation to agricultural areas around the dam and potable water to Izmir province. The active storage volume of the dam is designed to be 5.5 hm^3, and the surface area of the dam is 14.05 km^2 at the normal

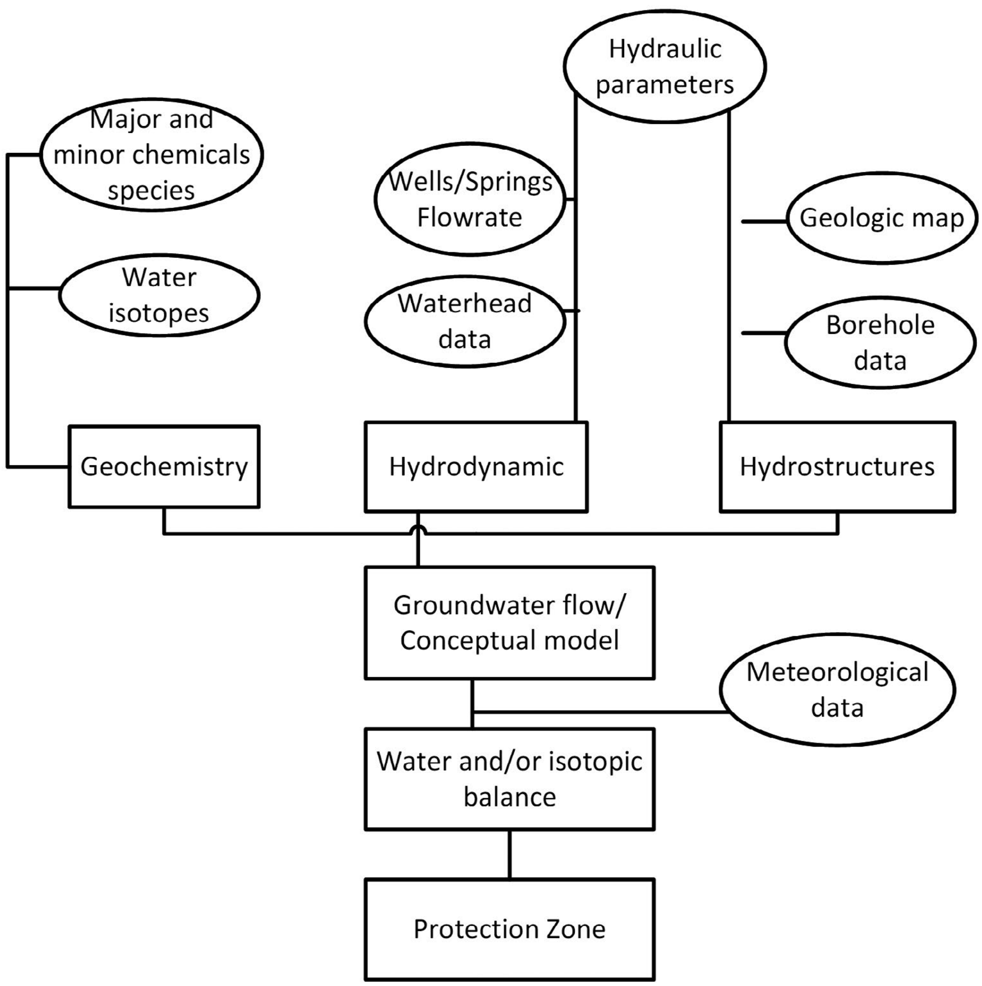

FIGURE 2 Integration of different data types into a conceptual model for delineation of protection zone in the Tuscany Region (Menichini et al., 2015)

water level conditions of the dam. Agriculture activities are the most common land use, and coniferous forests are predominantly land cover in the basin. The recorded mean annual rainfall, evaporation, maximum and minimum temperature values are 613 mm/year, 744.3 mm/year, 21.07°C and 8.42°C, respectively. The mean annual flow rate of the Gördes River is 2.64 m^3 /s. Pollution sources of the basins are agricultural activities, poultry, septic tanks and mining activities. Surveillance monitoring stations are not enough to understand all physical and chemical processes in the basin. After site-specific studies, reservoir buffer zone, reservoir protection and basin protection areas were defined to protect and improve drinking water resources in the Gördes dam basin (Figure 3). The new settlement is not allowed, and agricultural activities are forbidden in the reservoir buffer zone. However, fishing and water sports can be made in the defined pocket in the reservoir. New agricultural areas cannot be allowed to open except for the current areas where organic agriculture or good agricultural practices will be carried out to reduce the pollution load in the reservoir protection area. Since agricultural activities (irrigation, fertilization, spraying, pesticide use and all other applications) have not been recorded exactly, there will be some difficulties in transitioning to good agricultural activities. Farmers will have not willing to abandon their old agricultural practices and pass good agricultural practices. Controlled grazing in this area can be allowed to meet the personal needs of the inhabitants. Industrial facilities that do not produce and store hazardous waste and substances and do not generate industrial wastewater can be allowed in the basin protection area. Mining enterprises are allowed as long as wastewater originating from mining activities must be re-used in their process or stored in leak-proof pools in that area (Gördes, 2017). Since mining activities are a significant source of income for the basin, specific precautions should be determined for each mining activity by examining the effects of mining activities on water quality and quantity. However, the application of this issue is not easy since this requires detailed studies.

3.2 | Namazgah dam basin

Namazgah Dam is between 40°55′ and 41° 04′ north longitude and 30° 00′ and 30° 25′ east latitude in the Marmara region, Turkey. The area of the basin is 120 km^2. The recorded mean annual rainfall, evaporation, maximum temperature and minimum temperature values are 108 mm, 124.5 mm, 25°C and 5°C, respectively. The mean annual flow rate of the Namazgah River is measured as 48.88 hm^3. Agriculture, hazelnut and pasture are the most common land use in the basin. Lime-free brown forest and reddish-chestnut soil types are predominantly soil types in the basin. Site-specific protection areas for the Namazgah Dam basin were defined to protect, improve and ensure sustainable use of the water quality of the dam that provides drinking, utility and irrigation water. Green belt (maximum water level-50 m), dam protection zone (50–250 m), short-range protection zone (250–700), medium-range protection zone (700–1000), long-range (1000-watershed) protection zone, stream protection zone and geological based protection area were defined at the end of the Kandıra Namazgah Dam basin special provision studies (Figure 4). Highly permeable sinkholes, dolines, karst units located in the recharge areas of groundwater providing drinking and utility water are defined as geologically based protection areas. Agricultural and industrial activities and settlements are forbidden in the green belt zone. Mining activities and new industrial establishments are not allowed in any way in the dam protection zone. Integrated animal husbandry is not allowed in this area. However, the construction of non-residential buildings to be built to meet the needs of the settled people within the boundaries of the rural residential areas, the number of animals, their types and building sizes are permitted by the opinion of the relevant institutions and legislation. Although livestock fattening areas are allowed within the long-range protection zone, wastes of livestock fattening areas must be taken out of the basin. Within the boundaries of geologic-based protection areas, mining, blasting, excavation with construction equipment, foundation excavation, etc., are strictly prohibited. It is obligatory to start organic farming practices in the existing agricultural areas in this area. Stream protection areas cover rivers that recharge the Namazgah dam. Aquaculture is not allowed in these streams (Namazgah, 2016). The livelihood of the people is composed of agricultural activities and livestock. Therefore, people will not be willing to apply these restrictions as the limitations on these activities can cause economic difficulties for the people living in the watershed.

When activities in drinking water basins to protect water quality and quantity of European Union member countries (MS) is examined, the same measures have been taken on the agricultural, industry, urban activities, spatial planning, etc. In contrast to Turkey site-specific drinking water policy, good agricultural practices are elaborated, communication to the farmers (training, exchange workshops, individual training, field demonstrations), practices are changed (land use, crop rotation, farming and grazing, manure management, rational irrigation), verification of equipment and training to good use of them, bringing up to standards facilities and equipment are made by MS. In addition to these differences from Turkey applications, citizens are trained specifically about the appropriate use of fertilizers and pesticides and raised awareness on this subject (Siauve & Amorsi, 2015). The determination of discharges, storage and pre-treatment or in situ treatment, restrictions of pesticides and nitrogen inputs (including livestock food), afforestation of susceptible regions are the same activities for drinking water basin in both Turkey and MS.

Implementation of site-specific policies involves many technical and managerial difficulties. Since many drinking water basin does not include surveillance monitoring stations, physical and chemical processes in basins could not be represented well during the site-specific studies. Since the socio-economic situation in basins has not been examined in detail, citizens in the basin face socio-economic difficulties due to measures generated after site-specific policies. For example, good agricultural practices are not determined based on making cost analysis of crop products and Pareto-optimal studies that show best management practices for maximum economic benefit and water

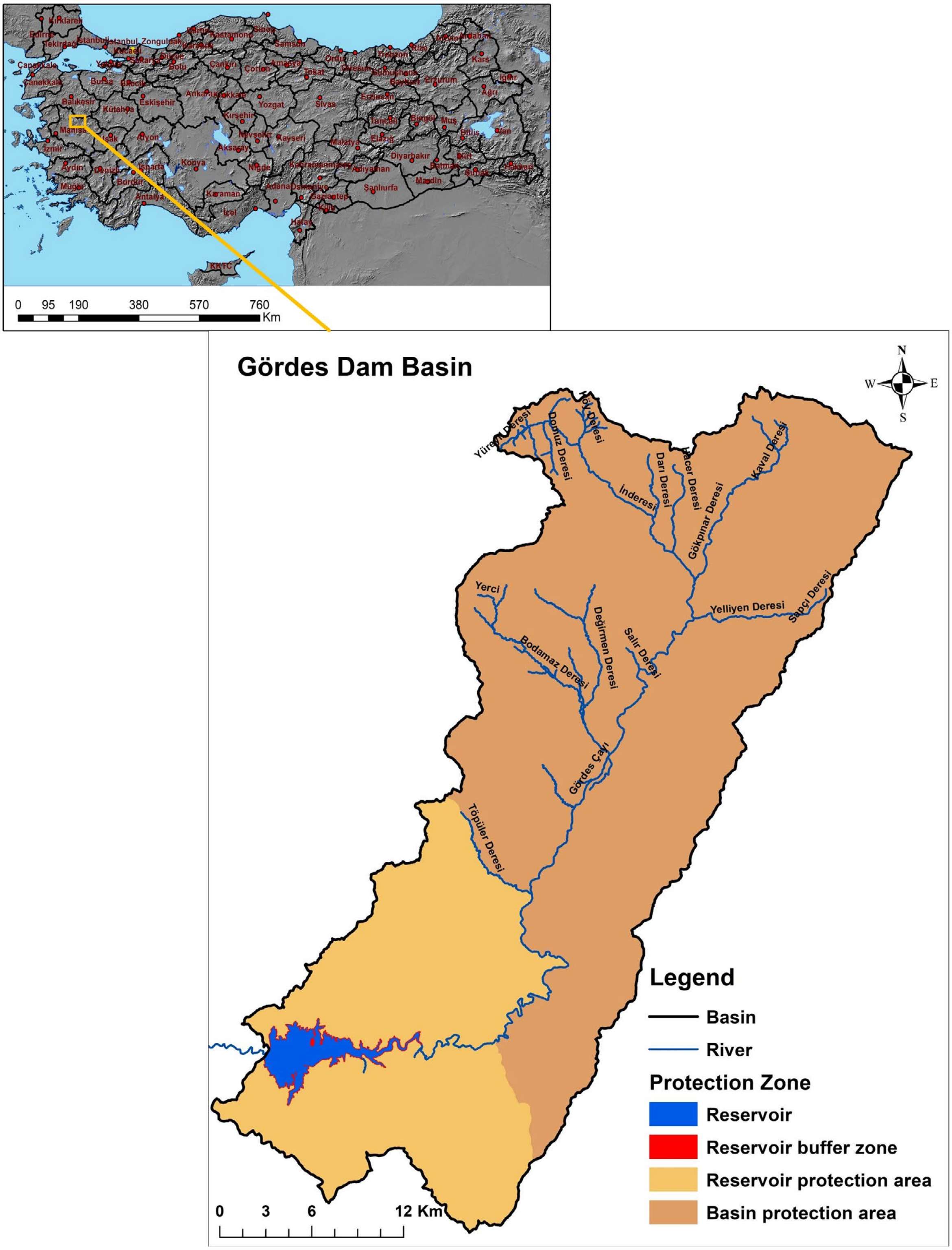

FIGURE 3 Site-specific protection zones of the Gördes Dam Basin (Gördes, 2017)

quality, and ecologic status. Climate change effects on drinking water resources have not been studied to generate future water management strategies. Based on climate change impact, best management practices with alternative scenarios should be determined. Institutions responsible for water management in basins should work with stakeholders in coordination while implementing site-specific policies in basins. Although many measures have been carried out with legal regulations, voluntary-approached should be adapted by organizing meetings and training to inform the stakeholders, especially the farmers and the people living in the basin. Thus, more effective sustainable water management for drinking water basins can be provided by reducing pollution sources and pesticide usage.

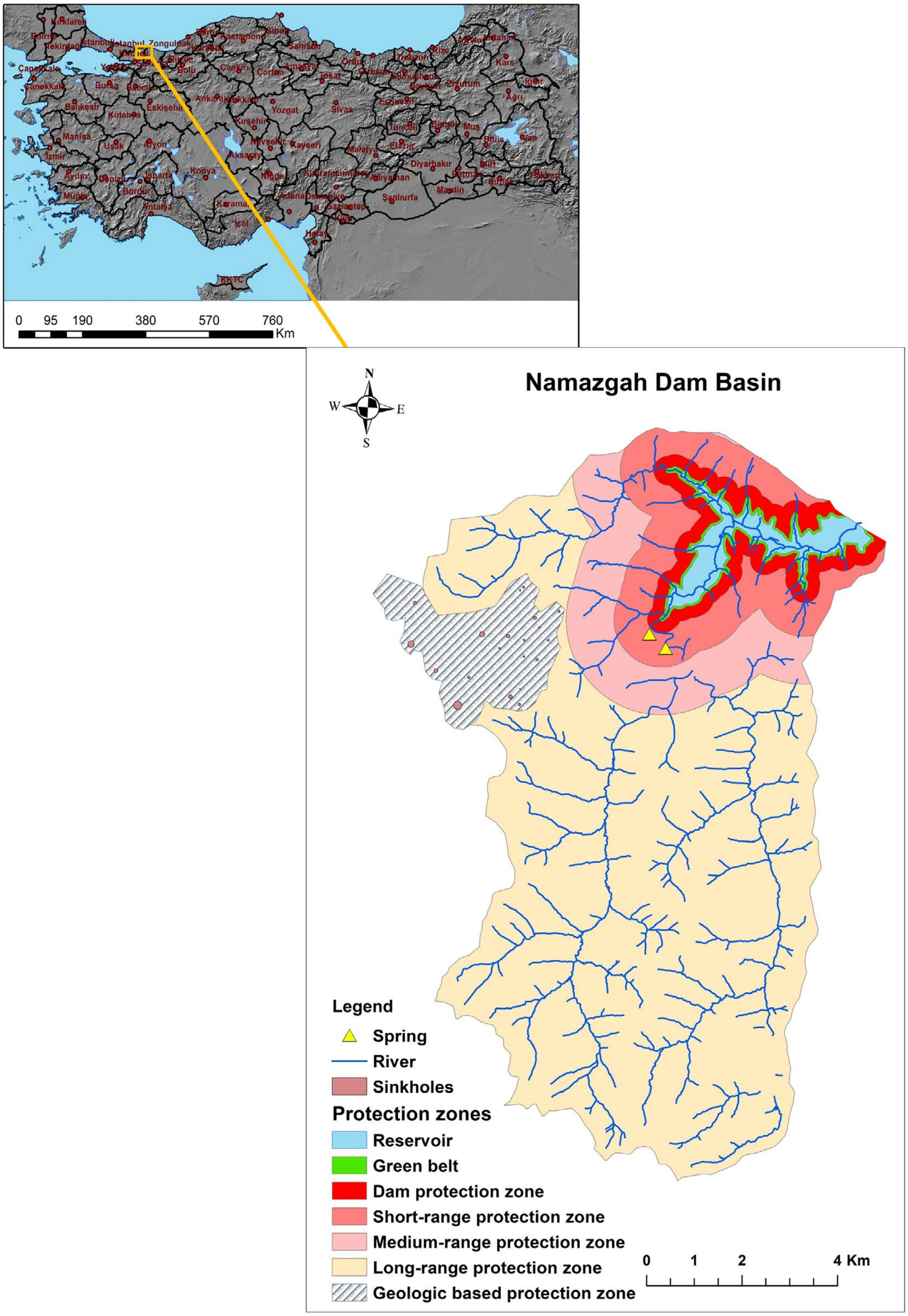

FIGURE 4 Site-specific protection zones of the Kandıra Namazgah Dam Basin (Namazgah, 2016)

4 | CONCLUSIONS

In this study, a framework for drinking water resources protection has been presented by giving a methodological approach created by examining the protection practices of drinking water resources of Turkey and European Union member countries and their deficiencies and inadequacies in these practices. As a result of this study following studies should be carried out or completed for drinking water protection studies;

- Surveillance monitoring in drinking water basins is necessary to understand all the physical and chemical processes. Decision-makers about water resources management should update site-specific protection areas and policies in drinking water basins regarding surveillance monitoring results when it is required.
- Instead of restrictive measures, protective measures should be aimed to achieve good water quality and ecological status in drinking water basins. The best management scenarios should be planned with alternative scenarios, using tools such as the Pareto-optimal approaches that show maximum water quality, quantity with economic benefit to achieve that.
- Although many countries take measures in basins using legal approaches, a voluntary-based approach should be taken over to apply obligations efficiently to reach good water quality and ecological status in drinking water basins. As farmers and citizens living in the watershed play significant roles, they should be educated about water protection. Based on surveillance monitoring results, site-specific protection areas and policies should be updated. Site-specific protection areas for drinking water basin provides to protect water quality and quantity.
- Climate change and land-use effects on drinking water resources should be studied. Drinking water management plans should be generated considering these changes.

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APPENDIX

Atatürk Dam Basin Protection Plan and Special Provisions

Eğirdir Lake Basin Protection Basin and Special Provisions

Beyşehir Lake Protection Basin and Special Provisions

Gördes Dam Protection Basin and Special Provisions

Karacaören 1 and 2 Dam Basins Protection and Special Provisions

Kartalkaya Dam Basin Protection Plan and Special Provisions

Kazandere and Pabuçdere Basins Protection Plan and Special Provisions

Mamasın Dam Basin Protection Plan and Special Provisions

Porsuk Dam Basin Protection Plan and Special Provisions

Büyükçekmece Dam Basin Protection Plan and Special Provisions

Elmalı 1-2 Dams Basin Protection Plan and Special Provisions

Gökçe Dam Basin and Kurtdere Diversion Protection Plan and Special Provisions

Special Provisions and Protection Plan for Çamlıdere Dam Basin and Gerede Işıklı Regulator

Gönen Dam Basin and Kumköy Regulator Protection Plan and Special Provisions

Kandıra Namazgah Dam Basin Protection Plan and Special Provisions

Yuvacık Dam Basin Protection Plan and Special Provisions