First International Conference on Saltwater Intrusion and Coastal Aquifers—
Monitoring, Modeling, and Management. Essaouira, Morocco, April 23–25, 2001

Saltwater intrusion in the Muravera plain (Italy)

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ABSTRACT

The Muravera plain is located in the South-Eastern part of Sardinia, Italy's second largest island, at the mouth of the Flumendosa river, and covers an extension of about 130 km^2. The three main centers of the plain (Muravera, Villaputzu and San Vito) comprise a population of circa 13000. The main economic activities in this area are farming, citrus fruit growing, sheep and goat grazing, and tourism. Climate is Mediterranean subtropical, characterized by a strongly variable rainfall regime with annual precipitation fluctuating between 200 and 700 mm. Saltwater encroachment in the coastal aquifer and salinization of the soils was first observed in the 1970s, attributed to a lowering of the groundwater table due to both natural (recurrent droughts, presence of salty geological formations) and anthropic factors, such as overpumping, engineering works, and fish-farming. Currently both the phreatic and confined aquifers are contaminated with saltwater. Remedial measures being considered by the Ente Autonomo del Flumendosa (EAF), one of the subjects responsable for the management of water resources in the area, include artificial groundwater recharge, creation of hydrodynamic barriers, and establishment of a district irrigation network. In order to improve the understanding of the dynamics of the degradation of the aquifer and to support these remediation strategies, a research study for the simulation of the saltwater intrusion process by means of physical-mathematical flow and transport model is necessary.

This study is being undertaken within an international cooperation project including research work from similar studies which are being (or have been) undertaken at two other sites in Tunisia and Morocco (Paniconi, 2000).

Prior to initiating the simulations, the work undertaken has consisted in an integrated overview of diverse types of data made available by EAF. The scope of this evaluation was to assess the quality and quantity of the information, with respect to the data requirements both for an integrated GIS-based characterization of the site and for the simulation model.

The available data may be classified in four distinct groups: (1) base cartography, (2) hydrometeorological data, (3) well survey and monitoring records, and (4) well information deriving from an administrative census archive.

Figure 1. Location of the study area.

The cartographic data (originally in CAD format) has been used to derive a basic set of geographic layers, such as contour lines, river network, and administrative boundaries, to be used either as a backdrop for the visualization of well data or as input to subsequent processing. An example of this is the derivation of the digital elevation model (DEM), obtained by first processing a triangulated irregular network (TIN) from the CAD point elevation data, and then resampling the TIN to a 50x50 m^2 grid. The DEM has in turn been processed via a custom-developed utility based on the ArcView package to derive the stream network for the area and the corresponding catchments (together with other relevant hydrologic coverages).

Concerning hydrometeorological data, the SISS database (EAF, 1996), which comprises time series for the 1922-1992 period, has been used to analyze the measurements recorded at four representative stations within the Flumendosa basin. The analysis of monthly average rainfall and annual distribution of precipitation, which for the stations considered was available for the 1960-1992 period) has allowed to highlight two significant periods of drought in the years 1973-1981 and 1986-1991.

The well survey and monitoring data actually includes a rather heterogeneous set of information. The core of the data set is represented by a survey performed in the summer of 1999 for 123 wells. However, time series of piezometric level and salinity have been provided for only two of these wells. Sparse additional records for these parameters can be retrieved from other archives concerning chemical analyses and borehole data, spanning a period from the late Fifties onwards. A number of charts and maps have been derived, proposing different representations of indicators related to the exploitation of the aquifer and to the degradation of its conditions. For example, Figure 2 shows a plot of well depth versus the year of its drilling, which can be reasonably related to an increase in the demand of water and/or to a deterioration in the conditions of the upper aquifer. Figure 3 displays the distribution of electric conductivity in the 123 observation wells, distinguishing the deep ones (reaching the confined aquifer) from the near-surface ones. The conductivity values have been partitioned in five classes of suitability for irrigation, according to Wilcox (1955). The classes range from values below 250 μS/cm (suitable for any type of soil and cultivation) to over 3000 μS/cm (completely unsuitable for irrigation purposes). The figure clearly highlights the different condition of the two aquifers.

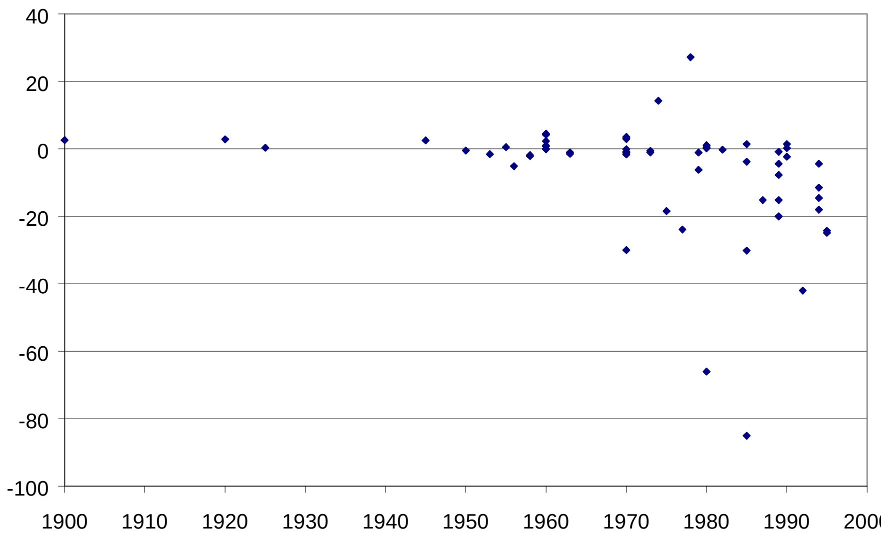

Figure 2. Plot of the depth of the observation wells surveyed in 1999 (in m a.s.l.) versus year of drilling.

Given the strong uncertainty in the distribution of pumping wells and estimation of aquifer exploitation rates reported by EAF, the well census archive - collected by the local government for administrative purposes and requiring the declaration by well owners of its location and usage- was proposed as a source of information to be considered in the study. Of the three districts covering the plain, Villaputzu was chosen in order to evaluate the actual content of the archive. While the well files provide an exhaustive list of the owners, the extraction of other information (such as piezometric level, pumping rates or type of usage) from this source needs to be addressed with extreme caution. For instance, well depth information is provided in 96% of the well files examined, but pumping rates are appear in only 50% of the sample. Another substantial problem with the well census files is the lack of accurate positioning information on the wells in terms of geographic coordinates (even though this information is actually required in a well file). To bypass this problem, alternative geocoding schemes have been tested. These include the positioning of the wells by reference to the "place name" of the site where they are located, which is *de facto* the most used geographic attribute in the archive, following an approach typically used for indirect geospatial referencing through gazetteer data (Hill et al., 1999). Another alternative which has been tested is the reference to cadastral sheet codes. While it is clear that these approaches to geocoding well data incorporate a degree of spatial uncertainty which may not be deemed suitable for a detailed mapping of these resources, the availability of a complete and validated place name coverage and/or a cadastral base map linked to the full well census archive could provide an extremely fast data integration strategy. The estimates and indications thus derived would surely be of interest to the modellers for an improved description of boundary conditions, and should provide an interesting reference also for the water resource managers.

The work undertaken so far has allowed to perform an extensive quality assessment of the data, and to provide a first set of reports on the characterization of the area. From the point of view of data requirements for the simulation models, the current data sets will be used to setup a preliminary set of one-dimensional simulations. At the same time, additional data are gradually being added to the initial core and will further enrich the description of the site.

Finally, it should be mentioned that the framework provided by the international cooperation project has also stimulated the development of tools to facilitate the comparison of the analyses performed by the different study groups, in the form of a web site enabling an integrated access to information dynamically provided by different members of the working groups.

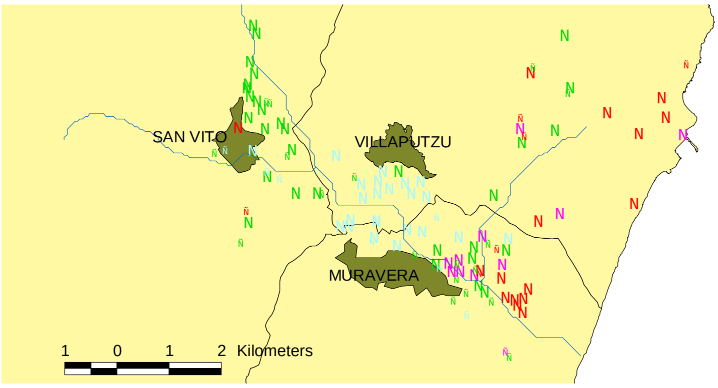

Figure 3. Map displaying distribution of electric conductivity (in µS/cm) in the 123 observation wells, sampled in the 1999 survey, and classified according to Wilcox (1955).

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Acknowledgements: The study is financed by the Sardinian Regional Authorities (L.R. 19/96, International cooperation for development).

Keywords: GIS, data assessment.

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