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SALT INTRUSION PHENOMENA IN THE SOUTH EAST COAST OF SARDINIA (**)

SUMMARY

Alarming phenomena of sea water intrusion have been detected in recent years in the delta plain of the rivers Flumendosa and Picocca in South East Sardinia. The coastal aquifers in the Northern part of the plain are not sufficiently recharged by the Flumendosa runoff since the river was dammed upstream for the purpose of generating hydroelectric power and supplying water to the area of Cagliari, South Central Sardinia.

Other dams have recently been planned just upstream of the deltas of the Flumendosa and Picocca in order to transfer elsewhere a considerable proportion of the local resources. Systematic research is in progress comprising hydrogeological, geophysical and hydrochemical surveys aimed at determining the characteristics of the aquifers and studying the evolution of salt intrusion.

1. INTRODUCTION

Alarming phenomena of salt intrusion have been detected in recent years in South-East Sardinia between the promontories of Porto Corallo, to the North, and Capo Ferrato to the South (Fig. 1). The effects are more marked in the Muravera area near the delta of the River Flumendosa. In fact, a few years

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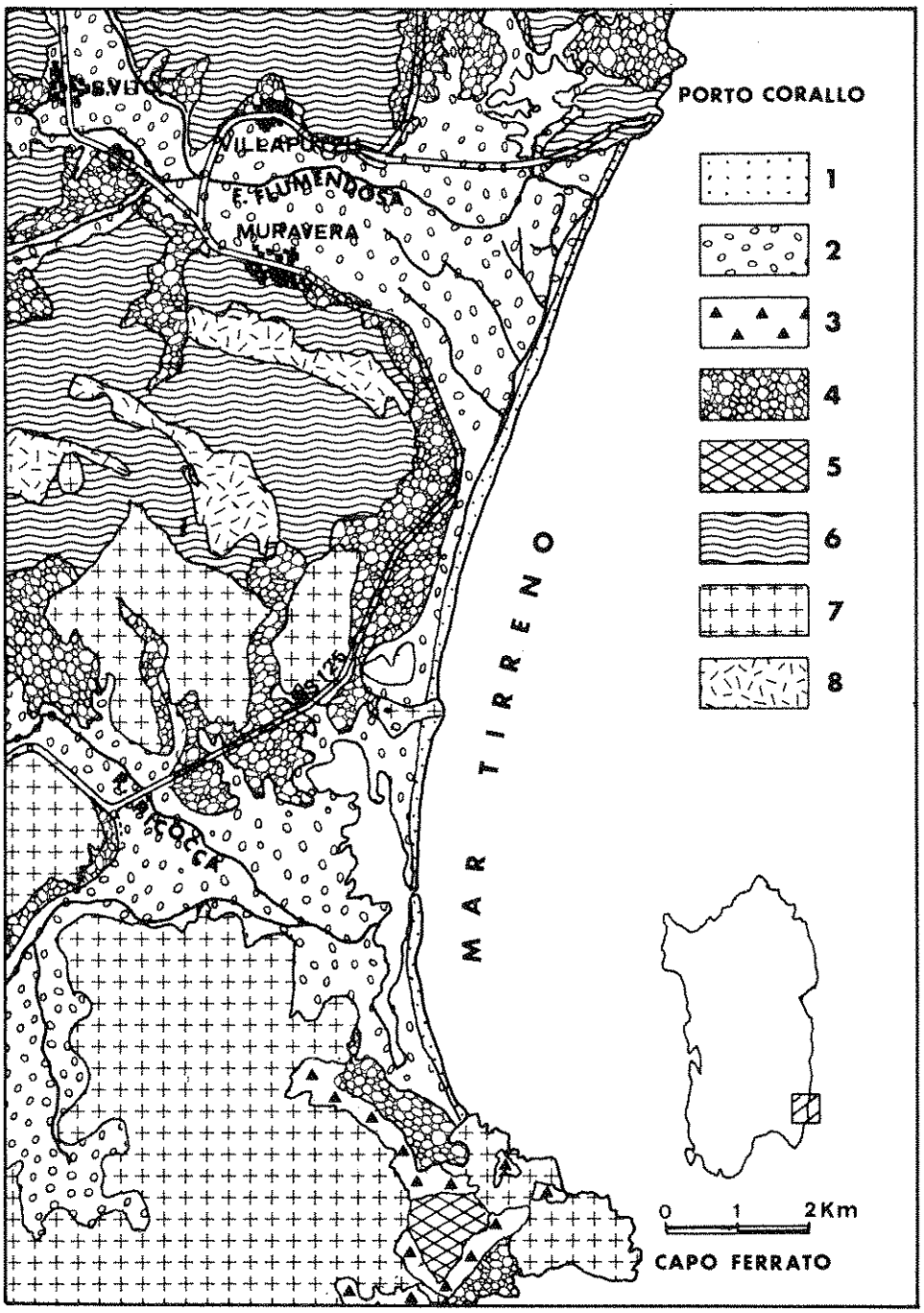

Fig. 1 – Geological sketch map of the delta plain of the rivers Flumendosa and Picocca. QUATERNARY: 1. Aeolic sands and coastal dunes; 2. recent alluvium; 3. screes; 4. terraced cemented alluvium; 5. trachyte and trachyandesitic complex of Monte Ferru. PALEOZOIC: 6. Sandstones and schists; 7. granites; 8. quartz-porphyries.

ago the river was dammed upstream for generating electric power and impounding water to subsequently supply the area of Cagliari (Southern Sardinia), the result being that now the coastal aquifers are no longer adequately recharged.

Other dams have been planned in the lower part of the Rivers Flumendosa and Picocca which means that a large proportion of local water resources will be diverted to other catchment areas. Consequently sea water could intrude further inland and the phenomenon could affect a large area in the delta of the River Picocca where the aquifers are not yet contaminated by salt.

Furthermore, phreatic aquifers have been overexploited to irrigate orange groves and rice fields and to supply tourist resorts, developed, up to now, without rational planning of local resources.

This paper reports on the first results of a systematic study in progress on salt intrusion phenomena in coastal areas of Sardinia.

2. GEOLOGY

As indicated in the geological map of Italy (F° 227 Muravera – 1: 100.000) sketched in Fig. 1, and the relative explanatory notes, the coastal plain consists of quaternary alluvial deposits overlaying a paleozoic granite and schist bedrock. An older formation of terraced alluvial deposits, well cemented with paleozoic silty sandy gravels of Pliocene-Pleistocene age, continue the ancient alluvial fans, now inactive, that border the slopes of the paleozoic schist and granite hills to the West of the plain.

The deltas of the rivers Flumendosa and Picocca, once swampy and now reclaimed, are composed of recent alluvium, mostly sandy with layers of gravel, silt and clay. The coastal area is bordered by aeolic deposits and dunes that bar lagoons (Saline, Colostrai and Feraxi).

The alluvial plain is dominated to the West by the paleozoic reliefs; near Capo Ferrato a recent trachyandesitic volcanic dome protrudes therefrom.

The thickness of the alluvial deposits and the morphology of the bedrock is not as yet well-defined. Only a few bore-holes in the northern part have reached the bedrock at a maximum depth of 50 m. Geophysical investigations conducted in the framework of the present study and still in progress, indicate that in the bed of the river Flumendosa the alluvium is thicker than 100 m. Vertical electric soundings with induced polarization measurements revealed several evident discontinuities in the stratigraphy.

3. HYDROGEOLOGY

Owing to the stratigraphical variations, the different aquifers are not easily identified in the Flumendosa delta, in the upper part of the coastal plain.

Numerous wells have been dug or drilled throughout the area and the data collected point to a highly productive phreatic aquifer, mostly developed with wells of considerable diameter, generally excavated without any geologist control. Near the coast this aquifer, now representing the sole water resource, is contaminated by salt intrusion, which is gradually creeping inland with the increasing exploitation of ground water for drinking water and irrigation purposes. Locally the salt content in soils is more pronounced, due to the fact that on account of its embankments and damming upstream, the Flumendosa no longer flushes them out with its floods and sedimentation is now minimum [1].

In the delta of the River Picocca, in the southern part of the plain, there is a phreatic aquifer, up to 5 m thick, mainly supplied by the river itself. Reclamation works carried out to prevent the river from flooding have lowered the water table [8]. Hence, the exploitation of the underlying aquifer has recently started. The water bearing formation is represented by a bed of pebbles and gravel between the granite bedrock and an overlying layer of illitic clay rich in organic matter.

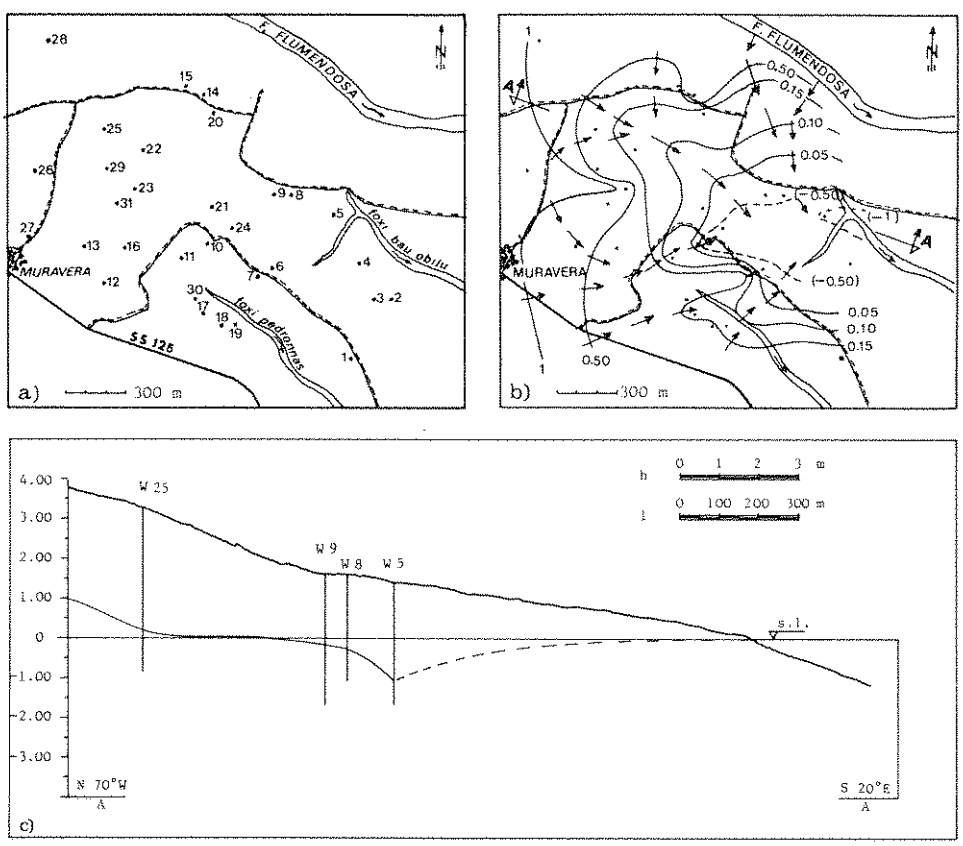

Fig. 2 – Delta of the river Flumendosa
a. site of observation wells;
b. contour and flowlines of water table;
c. longitudinal section of the aquifer (A-A in Fig. 2b).

Up to now salt water intrusion is confined to the area near the coast but it is likely to increase due to the growing demand for ground water and the reduction in recharging as a result of the damming of the River Picocca.

More than 300 wells exist in the Flumendosa delta. The hydrochemical characteristics and the elevations of groundwater were determined in observation wells sampled so as to have an average density of 16 wells/km^2 (Fig. 2a).

The contour map of Fig. 2b, representing the water table near the Flumendosa in April 1983, clearly shows that the aquifer is supplied by the river. The area of maximum exploitation is evidenced by the convergence of the flowlines and the density of the contour lines.

The cross section of Fig. 2c illustrates the piezometric head with the drawdown below sea level in the area of maximum exploitation.

Chlorinity and hardness contour lines in Figs. 3a and 3b provide a fair indication of two intrusion wedges protruding into this area with a maximum chloride content of 3112 mg/l. Induced polarization measurements in time domain detected a layer of clay and salt water with a high chargeability value (7 mV/V) between the two lobes.

As the geomorphology also suggests, this area might be a former bed of the River Flumendosa, whose present mouth is 2.5 km to the North.

In the area of the River Picocca a maximum chloride content of 255.4 mg/l was registered in more than 5 wells; i.e. below the maximum of 600 mg/l recommended by the WHO for drinking water. Nevertheless, localized salt intrusion phenomena have been observed in a few wells excavated, and in one drilled, by the sea where the groundwater chloride content attains 1600 mg/l. Investigations are in progress to study the effects of the dams planned. Pumping tests carried out in some wells of the Muravera plain tapping the phreatic aquifer gave mean yields of 3-5 l/sec in regime conditions but from a draining ditch more than 200 l/sec are continuously pumped.

A mean transmissivity value $T = 2.217 \cdot 10^{-3}$ m^2/sec was determined with the Jacob and Chow method. This low value is probably to be attributed to the silty clayey component in the aquifer alluvium.

The confined aquifer underneath yields 10-20 l/sec, with transmissivity $T = 1.3 \cdot 10^{-2}$ m^2/sec and storativity $S = 4.8 \cdot 10^{-3}$. In the Picocca delta the pro-

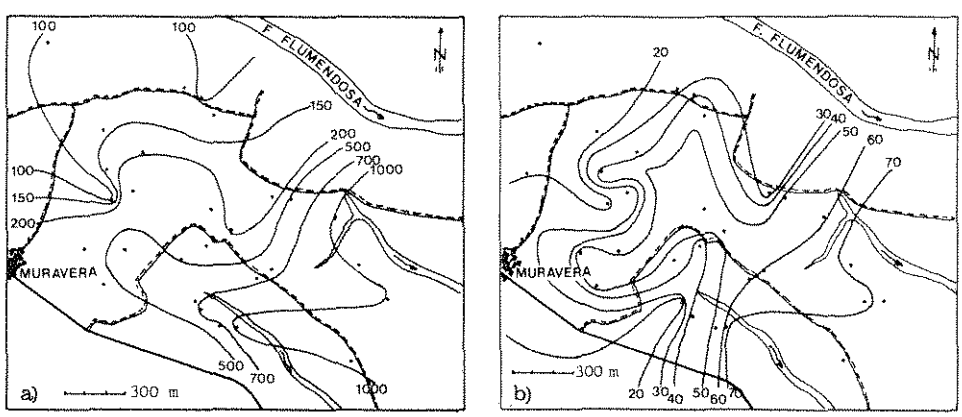

Fig. 3 – a. Contour lines of chlorinity (mg/l); b. Contour lines of total hardness (°F).

ductive wells all tap the confined aquifer, yielding on average 15-20 l/sec with transmissivity $T = 1.38 \cdot 10^{-2}$ m^2/sec. Some artesian wells have a head of a few decimeters above the surface. In Fig. 4 the characteristic curves of some of the most relevant wells are shown.

4. HYDROLOGIC BALANCE EVALUATION

The yield of the alluvial aquifers in the deltas of the Flumendosa and Picocca was estimated on the basis of present consumption. The total groundwater demand was then compared with the groundwater resources, evaluated from hydrological data collected over some 60 years and statistically treated in a recent study on the surface hydrology of Sardinia [5, 7]. In particular, the average groundwater resources available was estimated for the period May-August when consumption is at its peak.

For the aquifer supplied by the Flumendosa both the present situation and that prior to the construction of the artificial reservoirs have been considered. Since the latter have been operational the surface run-off is minimum and discontinuous with a marked effect on the recharging of aquifers downstream.

The demand is mainly represented by irrigation, with a 90% maximum for the aquifer supplied by the Flumendosa. Nevertheless, drainage only contributes to a very minor extent to recharging of groundwater because it runs off along ditches into che sea.

As illustrated by Table 1, referring to the present demand, the reservoirs built on the Flumendosa may be thought of as the cause of the serious deficit in the groundwater balance and of sea water intrusion into the aquifer.

TABLE 1 – Groundwater balance of the aquifer in the delta of the Flumendosa.

Situation	Groundwater resources (m^3)	Demand (m^3)	Groundwater balance (m^3)
Prior to damming	7.200.000	4.800.000	+ 2.400.000
After damming	3.300.000	4.800.000	– 1.500.000

According to the data of Table 2, a situation of equilibrium still exists in the delta of the Picocca. Nevertheless, development plans over the short-medium term which foresee a considerable expansion of orange groves lead to predict a critical situation in this case too. The construction of a dam planned on the Picocca will aggravate this state of affairs.

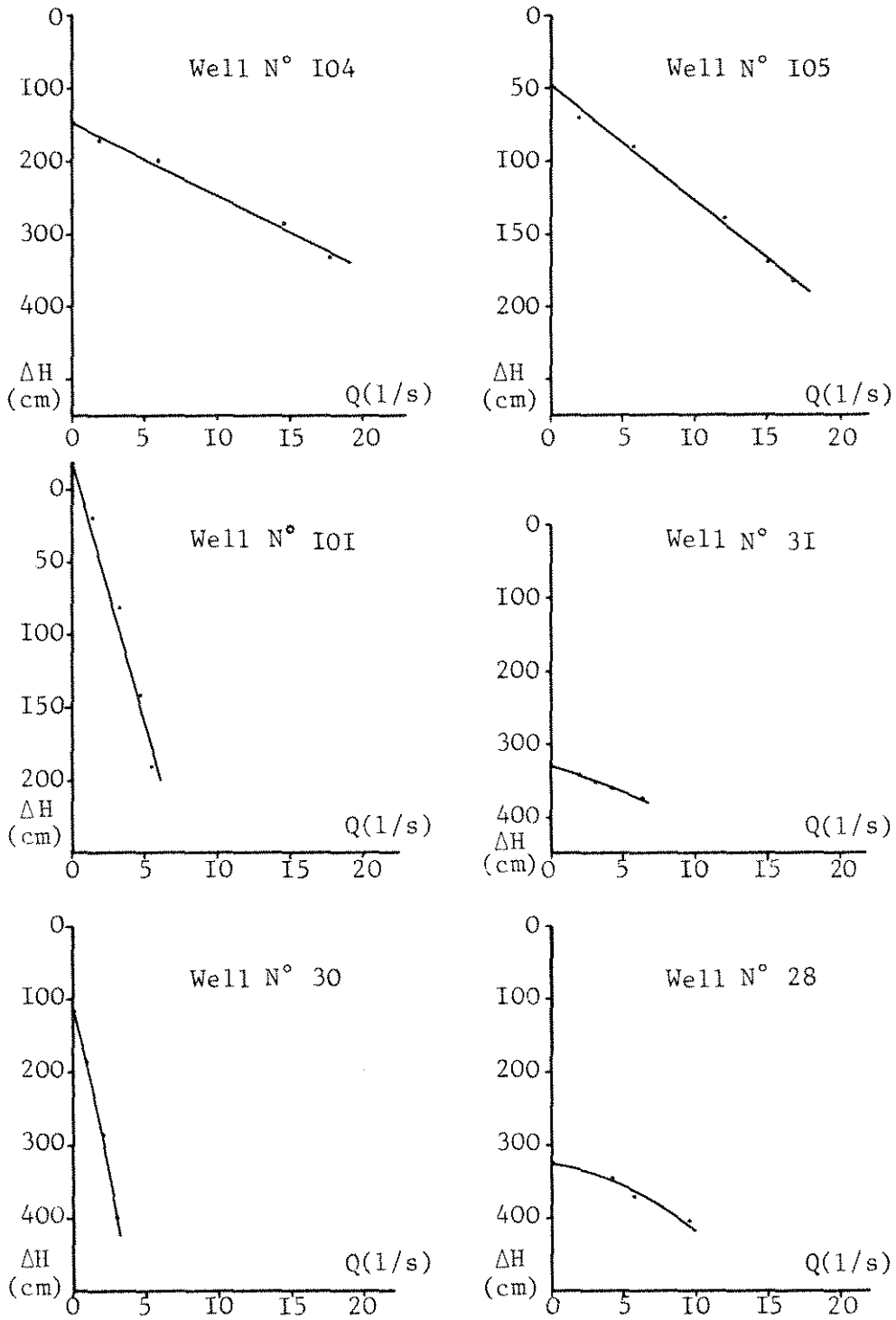

Fig. 4 – Characteristic curves with drawdown versus yield of some relevant wells in the delta of the Flumendosa (Nos. 28, 30, 31) and the Picocca (Nos. 101, 104, 105).

TABLE 2 – Groundwater balance of the aquifer in the Picocca delta.

Situation	Groundwater resources (m^3)	Demand (m^3)	Groundwater balance (m^3)
At present	1.100.000	920.000	+ 180.000
Over short-medium terms	1.100.000	1.240.000	– 140.000

5. CONCLUSIONS

The findings of the investigations confirm that salt intrusion is gradually advancing in the Flumendosa delta and sea water could begin encroaching the delta of the Picocca as well. In the specific case, the phenomenon still seems to be reversible, on the condition that:

1) the run-off from the reservoirs is adequately regulated;
2) agriculture and irrigation systems are rationalized;
3) tourist development is planned in function of local water resources.

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