CURRENT CIRCULATION AND VELOCITY FIELDS OFFSHORE TARANTO: A COMPARISON BETWEEN FIELD DATA AND LOGARITHMIC LAW

M. Ben Meftah[1], *F. De Serio*[2], *M. Mossa*[3], *A. Petrillo*[4] & *A. Pollio*[5]
[1]Department of Water Engineering and Chemistry, Technical University of Bari, Italy, Via Orabona 4, 70125 Bari
mbenme@poliba.it
[2] Department of Water Engineering and Chemistry , Technical University of Bari, Italy, Via Orabona 4, 70125 Bari
f.deserio@poliba.it
3 Department of Environmental Engineering and Sustainable Development, Technical University of Bari, Italy, Via Orabona 4, 70125 Bari
m.mossa@poliba.it
[4] Department of Water Engineering and Chemistry, Technical University of Bari, Italy, Via Orabona 4, 70125 Bari
petrillo@poliba.it
[5] Department of Water Engineering and Chemistry, Technical University of Bari, Italy, Via Orabona 4, 70125 Bari
a.pollio@poliba.it

Abstract. In this work field measurements of current circulation and velocity vertical distribution are compared with logarithmic-law profiles. The data were collected from a series of surveys carried out offshore the coast of Taranto, South Italy, during which a Nortek AWAC vessel mounted acoustic velocity profiler was used in order to acquire all the necessary information to describe the current field and the velocity vertical profiles in various points in the investigated area. Velocity profiles and current circulation patterns are presented and discussed in this work. It is clear from the acquired data, under present empirical laws, that describing the vertical distribution of the velocity in a such complex bathymetry may be misleading because the zone itself is affected by vortex structures which develop along a relatively small scale. This is due to the fact that such laws are generally obtained experimentally from simple channel configurations in which uniform flows are imposed. However, an important aspect must be highlighted as a principal feature of the site. It is certain that at the seabed, the presence of coating surface vegetation with different characteristics in terms of flexibility, length, roughness and other parameters are present. The velocity profiles are thus also affected by these factors and as a result, describing a velocity field in these conditions may be somewhat difficult.

INTRODUCTION

The present work deals with the field measurements and analysis of the sea current and velocity profiles assessed offshore Taranto at the open north-eastern area of the Ionian Sea in Southern Italy (Figure 1). The data were acquired between 9:30 and 13:00 (GMT) on 29 December 2006. The analysis of the local current patterns is a very interesting topic due to the highly extensive pollutant discharge in this zone because of the presence of extensive industrial activity in the area. The advective processes caused by the current pattern may easily carry undesirable chemical and biological components throughout the area, thus endangering the nearby coastal areas and hence the entire ecological habitat typical of the zone.

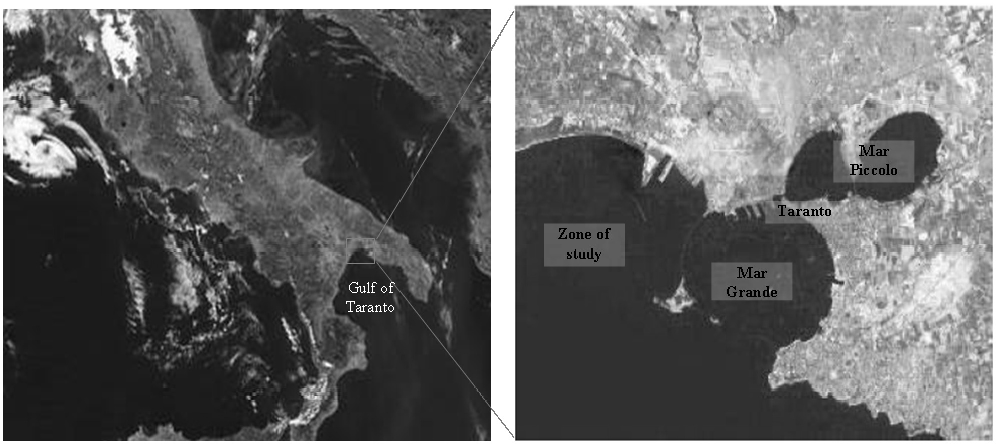

Figure 1. Location of the experimental survey offshore the city of Taranto

A series of measurements of the three current-velocity components were taken using a Nortek AWAC vessel mounted acoustic Doppler velocity profiler. Salinity and temperature vertical profiles were also measured by means of a CTD recorder. The survey was conducted in order to obtain further understanding of current circulation and to analyze flow velocity distributions in the region mentioned above. Discussion in this paper focuses specifically on the latter features.
All the measurements were carried out in shallow coastal areas, with respect to the typical wave length of the tidal phenomena in comparison with the water depth of the zone investigated. The complex geometry of the seabed together with tidal variations (leaving aside the effects of temperature and salinity) lead to the development of an unsteady flow with a strong impact on the turbulence generation (Anwar, 1996).
However in certain points under investigation, it was quite clear that for periods of some hours the flow approached a quasi-steady state, and that the current pattern variations occurred very slowly over time.
The wind intensity and direction data together with the tidal seawater elevations were obtained from the measurements available. Numerical simulations presented by Ben Meftah et al. (2006) also demonstrated that the variability of the current was not particularly high for wind conditions during the study.

INVESTIGATED AREA AND MEASUREMENT FACILITIES

As mentioned above, a Nortek AWAC vessel acoustic Doppler velocity profiler was used to measure the sea three-current-velocity components. The AWAC was connected to a gyro and a DGPS in order to take into account the vessel velocity and thus to acquire the current velocity with respect to the seabed. The measurements of the flow carried out with the Nortek AWAC were assessed with an acquisition frequency of 0.5 Hz, and thus the obtained data were not useful for turbulence analysis. Hence, in this work only the measured mean velocities are presented. The stationing point displacements and the measured mean velocity values at selected depths are reported in Figure 2.
The vertical distributions of salinity and temperature were also measured by means of a CTD recorder.

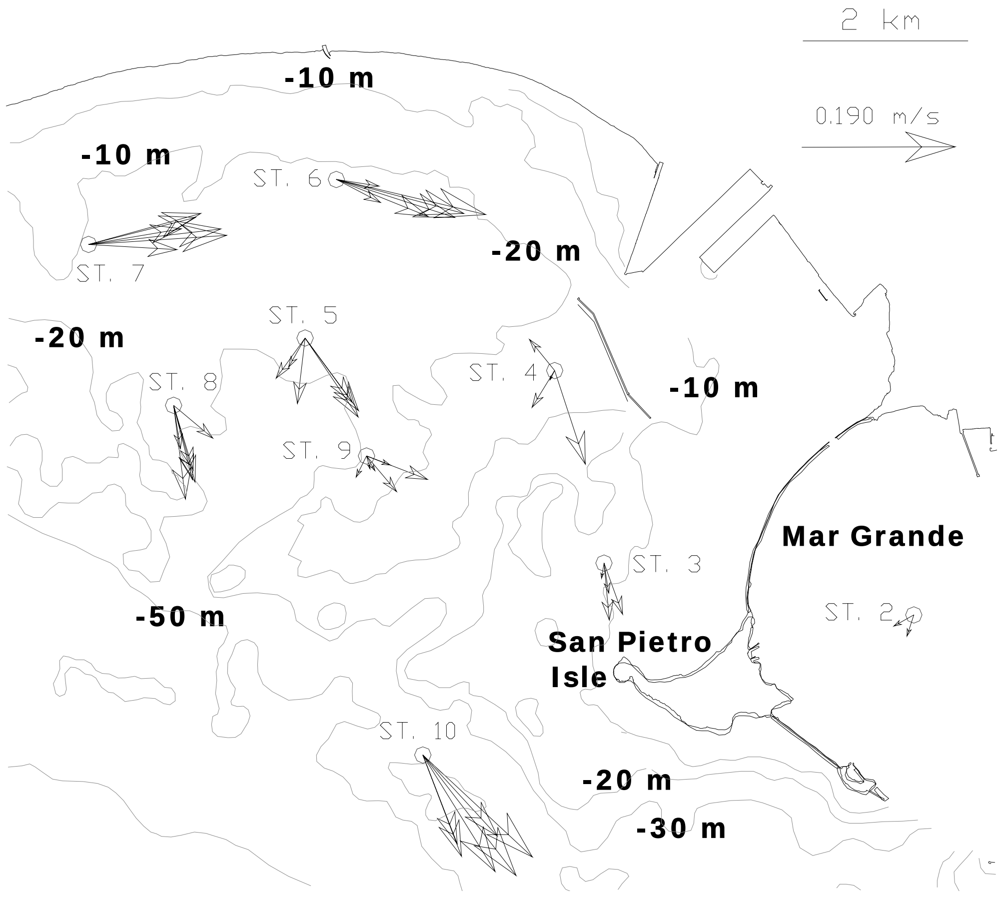

Figure 3. Stationing point displacements and measured mean velocities at selected depths

METHODOLOGY

In literature up to the present time (e.g. Cheng, 2007), velocity profile analysis has demonstrated that the velocity distributions near a rigid boundary seem to follow two kind of laws. In particular, it has been found that either logarithmic or power laws fit the velocity profiles very well, the latter being an approximation to the log law that may be extended to the entire outer flow including the outer region.
In this section the evaluation of the parameters of the logarithmic law is described, supposing that it may fit the observed data for the investigated stationing points starting from the water depth of -4 m to the sea bed or the maximum depth range of the currentmeter. It is clear that the logarithmic law fits the velocity profiles well in the so-called overlap region, a zone of transition between the inner viscous region and the outer region, and its length extends up to 0.20 ÷ 0.25 h, where h is the total flow depth. As some researchers have highlighted (Termini and Greco, 2006), in some cases the logarithmic law seems to describe the velocity distributions almost up to the free water surface, ideally when the maximum velocity values occur close to the free surface, including the so called wake function (Coles, 1956). This appears to be the case for some of the data obtained at selected stationing points, as Figure 6 clearly shows. For all the profiles characterized by a logarithmic shape velocity distribution, the following classical fitting law was assumed:

$$\frac{u}{u_*} = \frac{1}{k}\ln\left(\frac{y u_*}{\nu}\right) + B \tag{1}$$

where u is the time-averaged velocity value at the distance y from the seabed, u_* the shear velocity, k the von-Karman's constant, ν the kinematic viscosity and B a constant depending on the roughness of the seabed. In this work, supposing k to be the typically retained values of 0.41, the authors drew out from eq. (1) the values of u_* and B at each considered station.
In eq. (1) the length scale is the ratio ν/u_*, whereas in the outer region, where the inertia effects are clearly predominant, the characteristic length scale is the total flow depth d. In this region the velocity profile is described by the so called defect-wall laws. In the present paper the velocity-defect law was also investigated in the following form:

$$\frac{u - U_{max}}{u_*} = f\left(\frac{y}{\delta}\right) \tag{2}$$

where δ, used instead of d (see Anwar, 1996), is the boundary layer thickness evaluated as the flow depth from the sea bed to -4 m below the sea's free surface. In eq. (2), U_{max} is the maximum value of the velocity at the top end of the profile. Regarding this topic, Anwar (1996) found that the data fall within a narrow band around a line with 1/k slope, when $y/\delta \geq 0.08$, a value much less than the 0.25 typical of a steady motion in two dimensional open channel flows.

RESULTS

Observing Figure 3, it is possible to note that the time-averaged velocity directions present slight dispersions around a mean value at each measurement point. In particular this is noticeably true for stationing points 6, 7 ,8 and 10, in which, as will be subsequently shown, logarithmic profiles are clearly observable. It should be underlined that in a previous study by the authors (Ben Meftha et al., 2006), it was shown that flows obtained by numerical simulations tend to follow a constant direction near the stationing point under study; this confirms field measurements, whereas at the other stationing points the vicinity of vortex structures and the complex features of the seabed geometry seem to affect the results. Therefore, the values of u in equation 1 below are analyzed for stationing points 6, 7 ,8 and 10. In these stationing points u is defined as the component of velocity in the mean flow direction.
The measured temperature and salinity data at the various stations (see Figures 4 and 5) show that even though greater differences are present at stations 6, 7, 8 and 10, the velocity dispersion around the mean direction there is smaller and, at the same time, the velocity values are greater. This fact does not occur at the other stationing points (a comparison can also be made observing Figure 3). Similar to stations 6, 7, 8 and 10, at station 3 the velocity dispersion is very low along the depth and the temperature and the salinity values undergo higher variations. Nevertheless, in this station the velocity values are lower and this seems to affect the shape of the velocity profile.
Profiles were not plotted for station 2 where only three points were acquired because of the low sea water depth.
Figure 6 shows an example of the velocity profile acquired at station 6, in which the logarithmic trend is clearly present. The same figure also shows that the profiles were acquired up to 4 m from the seawater surface; thus δ, the turbulent boundary layer thickness, was considered up to that depth.

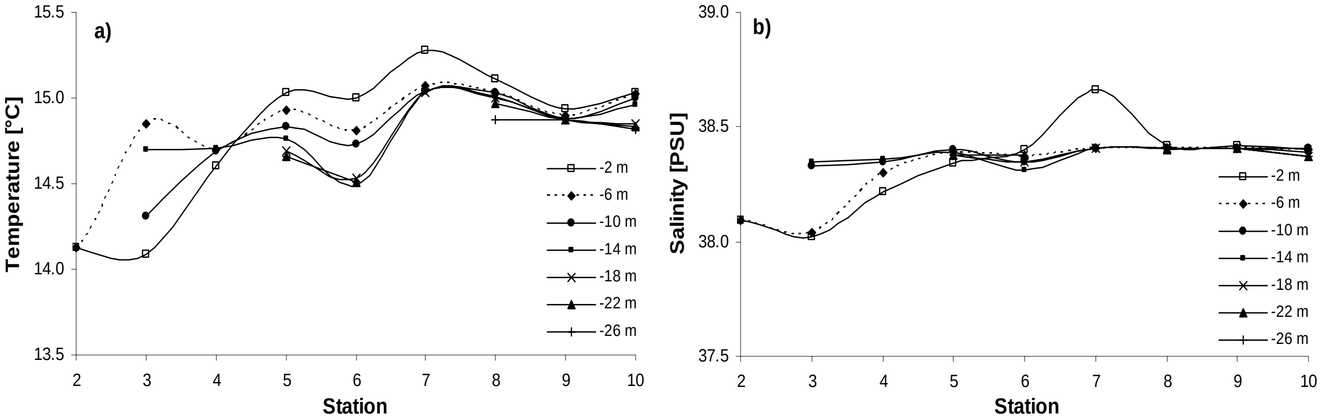

Figure 4. Temperature (a)) and salinity (b)) variations along the depth at each station.

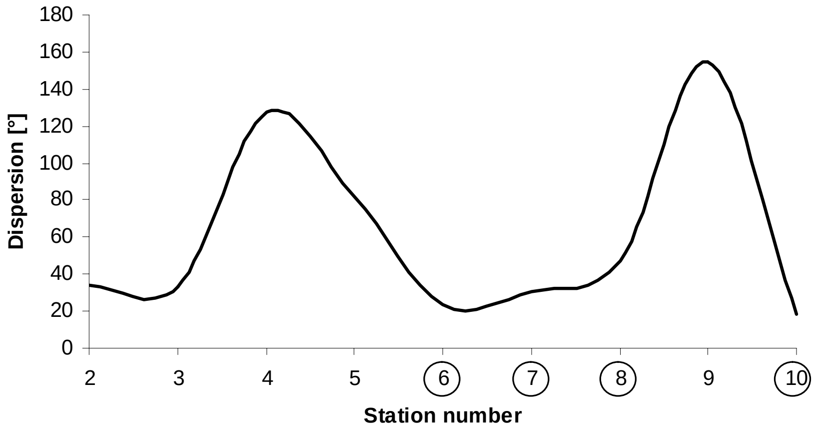

Figure 5. Maximum dispersion of the velocity direction at each station and along the depth (the circled stations were considered for logarithmic plots)

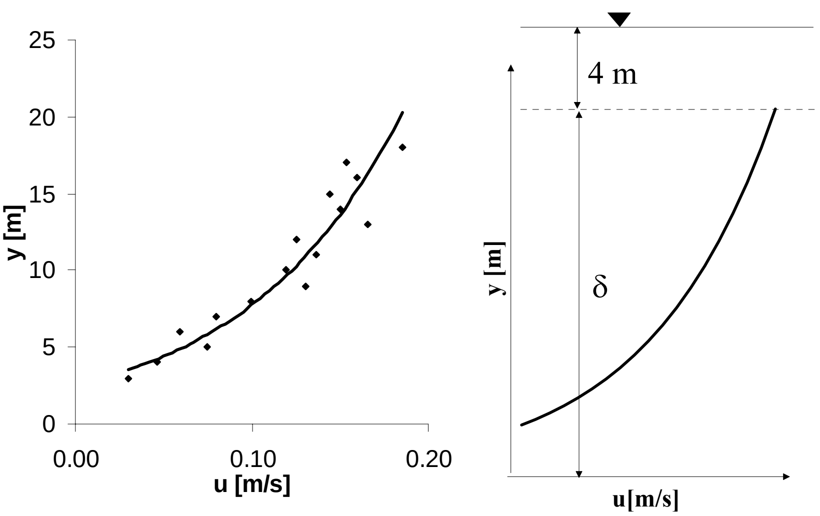

Figure 6. Typical logarithmic velocity profile (station 6)

By following the methodology mentioned previously, starting from eq.(1), the values of the shear velocity and the coefficient B were evaluated. Figure 7 reports the relationship between the mean velocity u and the natural logarithm of

the ratio y/ν for the four stations studied, from which the abovementioned quantities were calculated. It is important to note that at station 10 the measured values were only considered down to a depth of 24 m, since the AWAC profiler only allows for data to this depth, as confirmed after correspondence with the instrument's manufacturer.
Furthermore, Table 1 reports the investigated depths, the correlation coefficient R^2 of the fitting straight lines of Figure 7, the kinematic viscosity mean value ν along the depth, obtained from the depth-averaged water temperature as measured from the CTD recorder, the range of the ratio y/d and the shear velocity u_* for each of the stations under study. It is possible to note that considerations on the inner region were not possible because of the lack of available data.

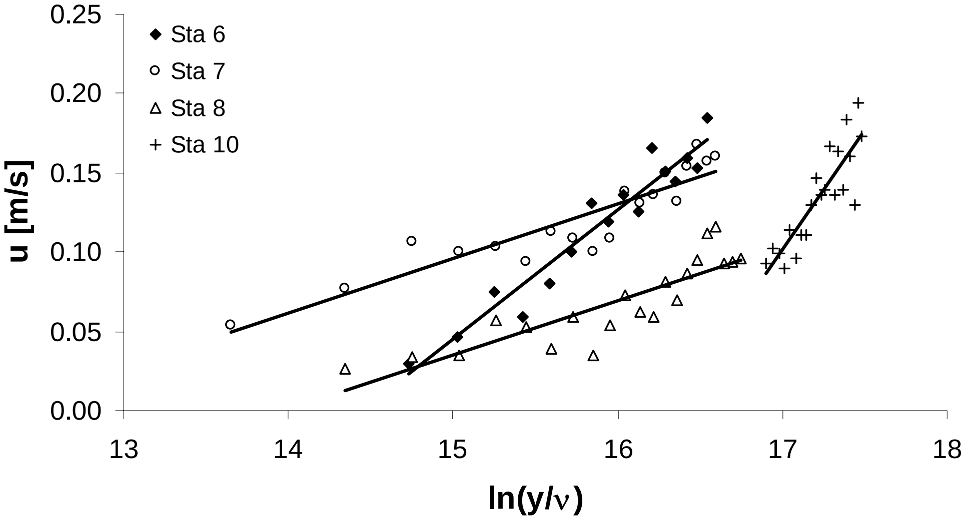

Figure 7. Fitting straight lines used to obtain the shear velocities at the investigated stations

Table 1. Main parameters obtained

Date	Station	Investigated depth [m]	R^2 [-]	ν [m^2/s]	y/d [-]	u_* [m/s]
29/12/2006	6	19	0.9320	$1.128 \cdot 10^{-6}$	0.14 ÷ 0.82	0.034
	7	22	0.8330	$1.128 \cdot 10^{-6}$	0.04 ÷ 0.83	0.014
	8	24	0.7381	$1.128 \cdot 10^{-6}$	0.08 ÷ 0.85	0.014
	10	24	0.7595	$1.131 \cdot 10^{-6}$	0.52 ÷ 0.92	0.062

Figure 8 shows the dimensionless velocity profiles, where $u^+=u/u_*$ and $y^+=yu_*/\nu$. It is possible to note that the fitting curves are characterized by different values of B of eq. (1), which is also due to the differences of the distinct seabed textures.

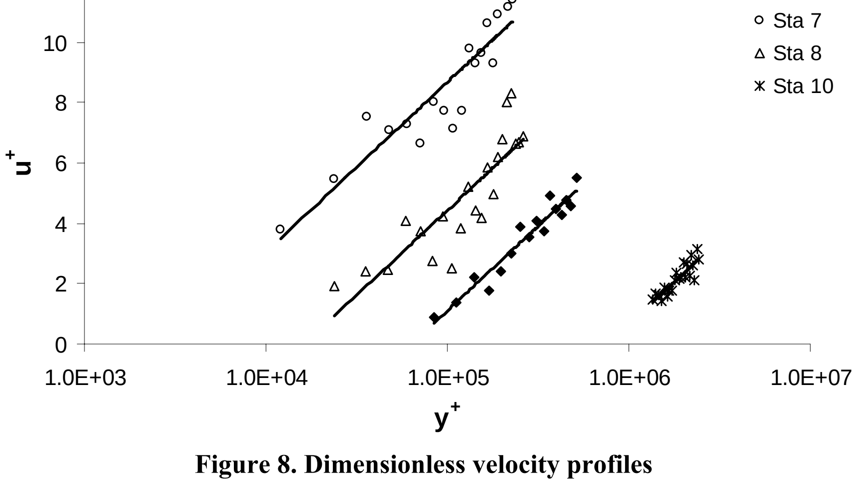

Figure 8. Dimensionless velocity profiles

By applying the defect-wall relationship expressed by eq. (2), it was possible to obtain the graph in Figure 9 in which all the measurement points for all the station were grouped. The graph shows a clear dispersion around the solid interpolating line at a lower depth. This seems to confirm that eq. (2) fits well with the experimental data in the outer region while it fits less near the bed where the logarithmic law seems to work more effectively. In this case, the data were plotted until the points where $y/\delta \approx 0.06$.

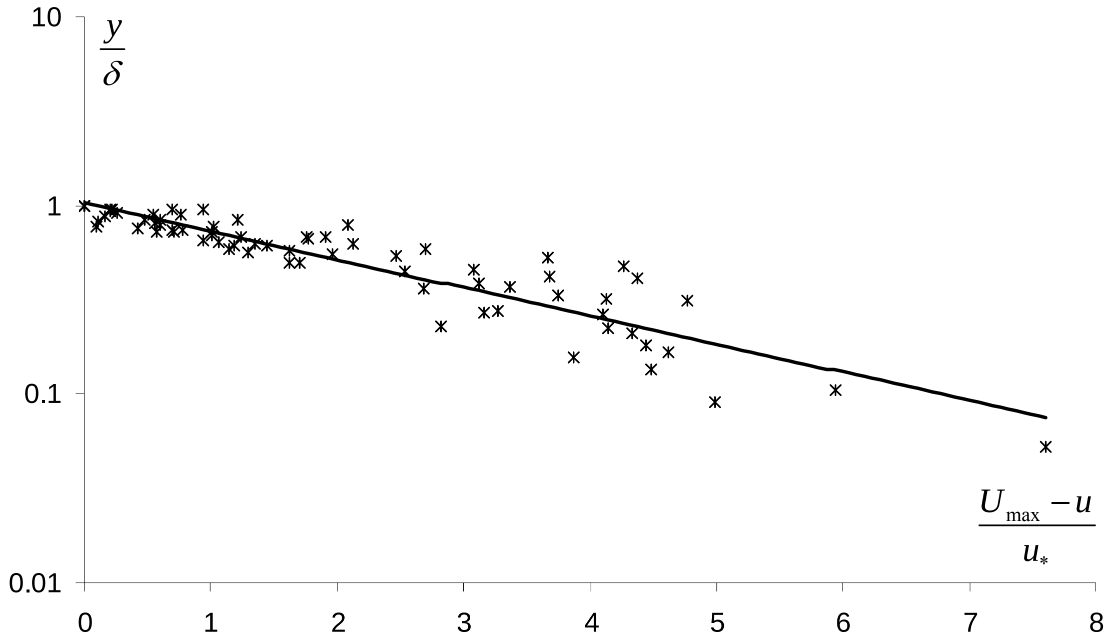

Figure 9. Defect-law relationship

CONCLUSIONS

In this work velocity profiles acquired offshore Taranto in a shallow coastal area are presented. It was observed that the profile shapes seem to follow the classical formulations related to steady two-dimensional open channel flows when the sea flow presents a quasi-steady state and the depth-averaged flow velocity is higher.

In particular, both the logarithmic law and the defect-velocity law were used to fit the acquired data for the entire investigated water heights. It was found that the logarithmic law fits well with the data up to the ratio $y/d \approx 0.90$, which is almost up until the free water surface.

As proposed by Anwar (1996), the defect-velocity law was also used to fit the experimental data for the investigated flow depth. The point dispersion remained low even though it increases at a at a lower depth.

REFERENCES

H.O. Anwar (1996), “Velocity profile in shallow coastal water”, Journal of Hydraulic Engineering, Vol. 122, No. 4, 220-223.

N.S. Cheng (2007), “Power-law index for velocity profiles in open channel flows”, Advanced in Water Resources, 30, 1775-1784.

D. Coles (1956), “The law of wake in the turbulent boundary layer”, Journal of fluid mechanics, 1, 191-226.

M. Ben Meftah, F. De Serio, M. Mossa, A.F. Petrillo and A. Pollio, “Current circulation in the gulf of Taranto: numeric simulations and experimental data analisys”, Flucome 2007, Tallahssee, Florida, accepted.

D. Termini, M. Greco (2006), “Computation of flow velocity in rough channels”, Journal of Hydraulic Research, Vol. 44, No. 6, 777-784.