The challenge of installing an Outfall in the surf zone. Mar del Plata case

J. C. Cardini*

* Serman & associates s.a., Blanco Encalada 2387 17 E, Ciudad Autónoma de Buenos Aires, C1428DDK , Argentina (E-mail: cardini@serman.com.ar)

Abstract
The installation of an Outfall in an open coastal zone with high wave energy, involves facing significant challenges. If the incoming swell is significant in height and angle not only generate important actions on any exposed area of the pipeline, but also generates a strong littoral transport if the bed is sandy, Such condition makes the installation works very difficult, as occurs in Mar del Plata, where the coastal dynamics is very intense, with maximum significant wave heights close to 10 meters and coastal transport net worth several hundred thousand cubic meters of sand per year.
The classical method of installation into a dredged trench was the only feasible alternative to be applied. Such trench should be excavated by mechanical or hydraulic dredge and keep it clean with the bottom at a given design elevation until the time of placement of each section along the pipe.
However, the intensity of the coastal transport is so high that during a storm, much of the excavation work may be covered by sand. Techniques to mitigate such situation can hardly include a significant compensatory overdredging, and in fact was not feasible in this case, as it may alter the design parameters of the trench slope, mainly due to the weak local bottom slope.
Previous deep trenching experience showed construction process failed in 2001. The intensity of trench sedimentation exceed values from one to three meters per month. Further, such sedimentation rates may happen in few days under high wave energy events.
Following a compilation of background information on waves and longshore transport in the Mar del Plata marine coast, this paper focus on the potential impact assessment on an excavated trench, its implications for the proper site construction, and conceptually explores the efficiency of mitigation measures, like sand traps on the trench sides.

Keywords
Outfall installation; trench sedimentation; sand traps.

THE MAR DEL PLATA OUTFALL

In the North area of the Mar del Plata city, the “Ente Nacional de Obras Hídricas de Saneamiento” – ENOHSA, is building an outfall - diffuser for disposal at sea of sewage, by contracting with the Contractor Group SUPERCEMENTO S.A.I.C. – DYOPSA S.A.

An outfall of total length 3,284 meters followed by a diffuser of minimum length 526 meters is under construction, with a path perpendicular to the coast, completing a total length of 3804 meters. The basic pipeline project requires implementation based on high-density polyethylene (HDPE) with 2,000 mm of nominal diameter.

There are already installed 11 PRFV pipe stretches, from the pumping elevation station until the progressive point PK 87 m, introduced from the coast in the surf zone. They have a protective cover of concrete. Subsection will be maintained and should be continued with the laying of new pipe, after demolition and removal of the remaining part. The stretch of the existing system installed in 2000/2001, failed partially due to the high rate of sedimentation in the trench.

The outfall must be installed in a trench. A previous proposal to install it over piles was not accepted by the Sanitation Authority. A trench was former excavated previously in hard soil, being filled by sediment mainly composed of fine to very fine sand. The section between the progressive PK 87m to PK 487m has a variable width between 12 and 14 meters, while in the rest of the trench the width is about 5 meters. The trench depth ranges from 3 to 4 meters.

From the coast to the progressive PK 700m the slope of the seabed is around 1%, reaching a depth of about 8 meters. Going offshore to the final progressive (PK 3820m) the bottom slope reduce to about 2 ‰, the average depth in the diffuser being of 13.50 m.

SEDIMENTATION BACKGROUND IN THE TRENCH

The installation zone of the outfall is a marine area characterized by a high energy wave climate that generates a severe coastal transport. When the trench was originally built, it was subject to a sedimentation of fine to very fine sand, with an estimated average rate about 5 to 10 cm per day, and sedimentation peaks during storms and bad weather.

At the beginning the trench sections between PK 80m and PK 500m had silted up to 3 meters of sand in 35 days, with a decreasing gradient from the coast to offshore. The trench close to the coast completely filled with sediment, and progressively to PK 500m section, siltation reached 1 meter height. The dredging continued in the rest of the trench alignment until stopped once reached between 50 and 100% of the required depth. Between PK 500m and PK 1500m reached an average depth of 2 meters. In only 45 days later on, the trench excavated was completely filled. Then, it was dredged again the section between PK 500m and PK 2000m. After 20 days, of calm and moderate swell without storm events, working on the front around PK 700m, it was found the accumulation of a sand layer over a meter height. Afterwards, during 15 days the contractor tried to install pipes, making permanent sand extraction tasks in the trench. In the following 20 days occurred winds, waves, a storm and swell. Thus the height of the sand layer deposited in the trench reached 2.5 to 3 meters. Subsequently, in the following 75 days without dredging from PK 500m to PK 2000m, the trench was filled with 3 to 4 meters of sand all along the alignment.

Finally the contractor turned to dredge the entire trench between PK 600m and PK 2000m, trying to install pipes in PK 700m. In a period of one month the sedimentation filled the trench with 2 meters of sand.

In summary, during the course of the works performed, there was the deposition of sand in the excavated trench, completely filled in time periods of 15 to 60 days, depending on trench sections and storminess. It was found that significant amounts of sand transported by littoral drift or mobilized as bedload, finding a strong disturbance in the seabed as the trench is excavated, have silted on it.

MARINE CLIMATE AND SEDIMENT TRANSPORT IN MAR DEL PLATA

The estimate of wave climate was based on 10 years of data from the National Oceanic & Atmospheric Administration (NOAA) of USA. Historical Series consists of data every 3 hours, significant wave height (Hs), wave period and incident direction, collected from WAVEWATCH model results for a point located close to the area of interest in a depth of about 14 meters referred Mean Sea Level. The joint statistical height - period (for a rose of 16 directions) is presented in Figures 1 and 2. Very few events have a significant wave height over 4 meters (the average height is 1.25 meters and the maximum 6.1 meters).

Significant wave heights frequently correspond with the directions ENE, E, SSE and S, with heights ranging between 1 and 2 meters. The highest waves are from the S and SSE sectors with heights between 3.5 and 4 meters. The period is in the range of 6 to 10 seconds. The most energetic waves (SSE and S sectors) have periods in the range of 8 to 12 seconds.

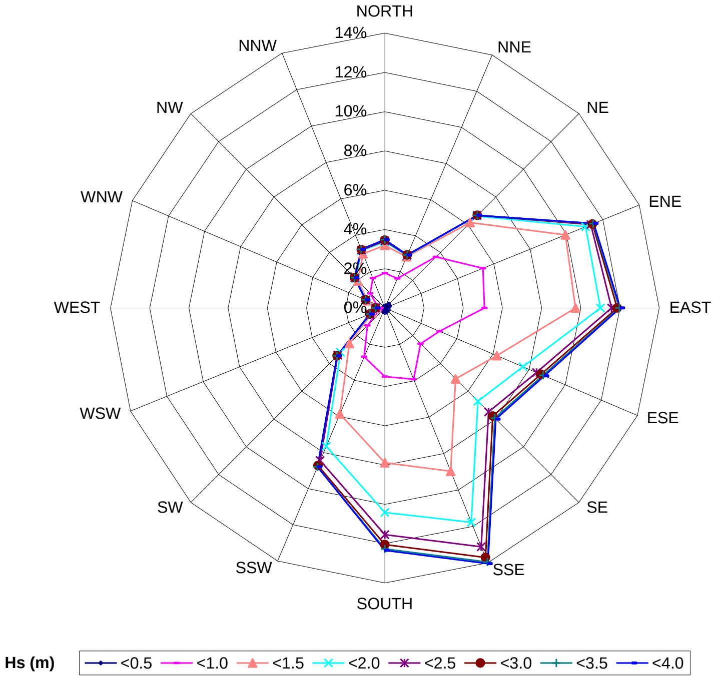

Figure 1. Significant Wave Height distribution

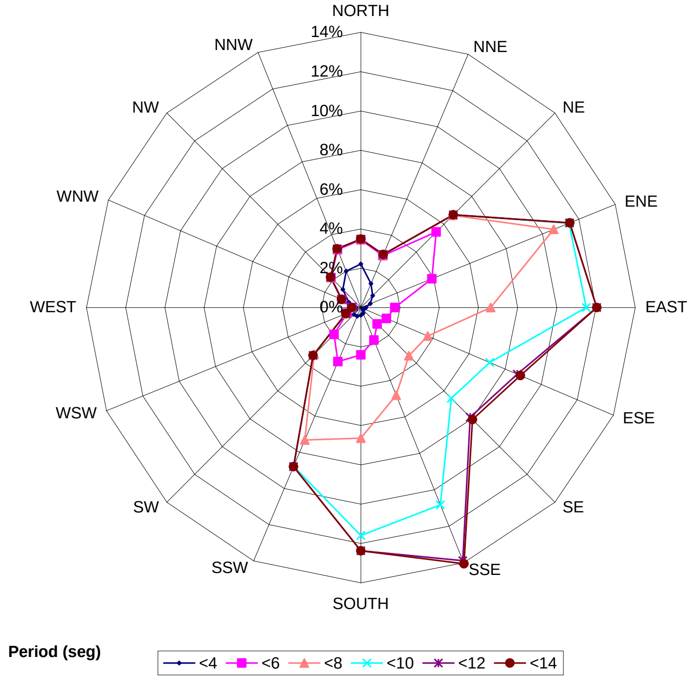

Figure 2 Wave Period distribution

The design significant wave height in deep water for a recurrence of 100 years was established in the tender documents; Hs: 9 meters using breaking criterion due to the low depth..

Table 1 Significant Wave Height Frequency

>0.5	>1.0	>1.5	>2.0	>2.5	>3.0	>3.5	>4.0	>4.5	>5.0	>5.5	>6.0
2.24%	35.99%	37.18%	14.47%	6.12%	2.43%	1.01%	0.394%	0.149%	0.017%	0.007%	0.003%

The action of waves oblique to the beach generates a longshore sediment transport, so called “Littoral Transport”. The breaking waves transfer a momentum to the water in the surf zone.

The component parallel to the coast of the transmitted momentum is responsible for the movement of water parallel to the coast called littoral current. If this longshore current is intense enough, it can also move the bottom sediments placed in suspension by the waves breaking, generating transport. The longshore transport direction is determined by the direction of swell, which varies according to the incident wave and in the study area can go both north and south, at different times. However, due to the predominance of waves arriving from the South quadrant, the average annual net transport is directed northward. The net littoral drift in the Atlantic area of Buenos Aires Province, ranges from 100,000 to 500,000 m^3/year, according most of the available data sources.

Potential longshore transport caused by waves, assuming an unlimited amount of sand, has been estimated using a model that applies the formulation recommended by the Coastal Engineering Manual (USACE, 2006). The average diameter of the sediment varies from 0.11 mm out of the surf zone to 0.09 mm inside. Longshore transport results are presented below in Figure 3 and Table 2.

Table 2 Longshore Transport classified by direction of incident waves (positive values indicate North travel direction)

Direction	Transport [thousands m^3/year]	Wave Frequency
NE	-40	7%
ENE	-140	11%
E	-90	12%
ESE	70	9%
SE	190	8%
SSE	310	14%
S	100	12%
NET	400	74%

The average monthly transport equivalent is then the order of 33,000 m^3 consisting of some 56,000 m^3 to the north and about 23,000 m^3 to the south. Figure 3 and Table 3 shows that most transport is generated by waves with significant heights Hs ranging from 2.0 to 2.5 meters.

Table 3 Longshore Transport classified by wave height

Hs [m]		Transport [thousands m^3/year]			
Range	Mean	To North	To South	Net	Accumulated
0-0.5	0.25	0	0	0	0
0.5-1.0	0.75	30	-36	-6	-6
1.0-1.5	1.25	125	-107	18	12
1.5-2.0	1.75	158	-59	99	111
2.0-2.5	2.25	139	-31	108	219
2.5-3.0	2.75	92	-18	74	293
3.0-3.5	3.25	63	-11	52	345
3.5-4.0	3.75	37	-9	28	373
4.0-4.5	4.25	22	-4	18	391
4.5-5.0	4.75	5		5	396
5.0-6.5	5.75	4		4	400

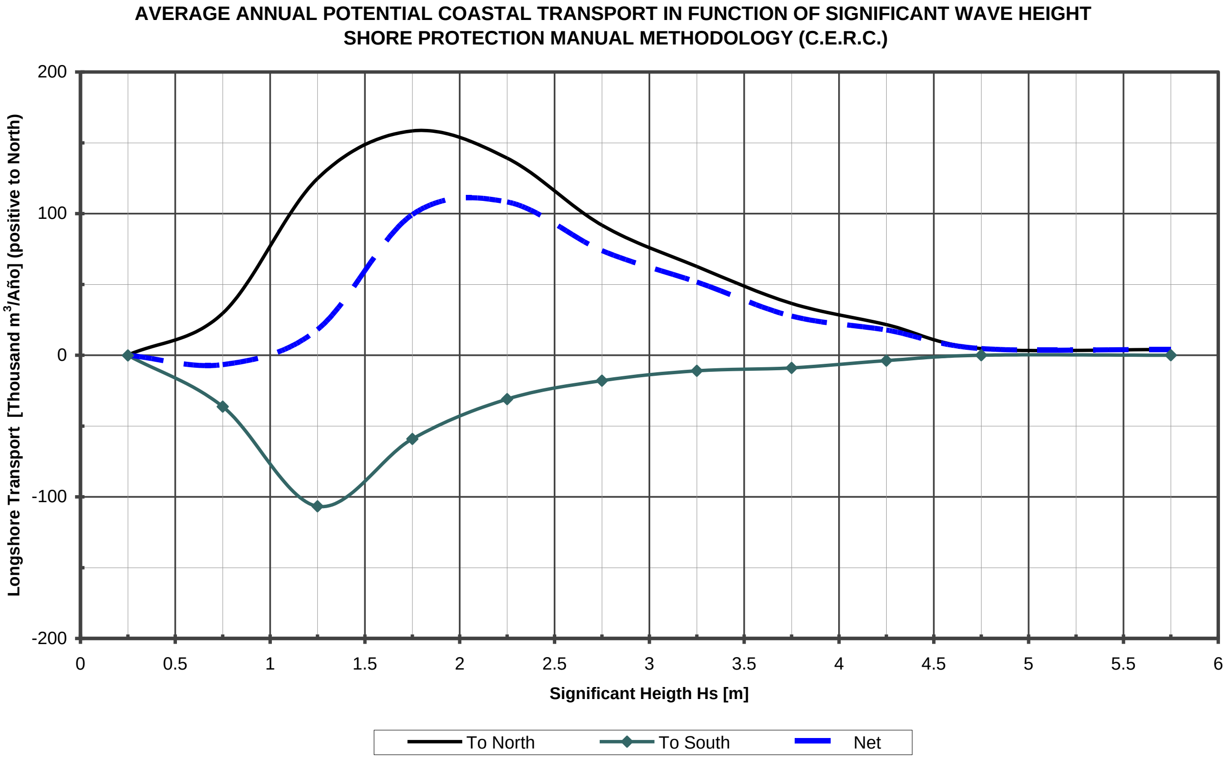

Figure 3 Longshore Transport classified by wave height

EVALUATION OF POSSIBLE SOLUTIONS: A SEDIMENT TRAP

It is conceptually analyzed under what design conditions a sediment trap could be more efficient to minimize the sand deposition on the trench. The analysis focuses in the section where normally the transport phenomena is stronger, close to the shore (from coast to PK 800m).

Considering a zone with the most active transport in each wave condition of 150 meters long perpendicular to the coastline, the average daily volume transported per unit length of the trench in that area would be around 6 m^3/m/día north (with waves of the South–SE sector) and 3 m^3/m/día south (with waves of the North-NE sector).

The "annual average" thickness calculated for a typical width of the trench dredged of 15 m, considering the assumption that all the littoral transport material is deposited in the trench, siltation would be around 40 cm a day with waves from South and 20 cm with waves from North. Considering the side slopes, the typical width of the trench in the surface would be greater than 30 m, but the mean order of magnitude of the deposit seems to be not less than 15 to 20 cm per day.

By comparing these computed values with the estimated sedimentation of sand in the bottom of the trench (about 5 to 10 cm per day) based in historical surveys, it can be concluded that most of the sediment carried over the trench by the longshore current does not settle inside and remains in suspension. Further, the order of magnitude of the process estimated theoretically is correct.

The theoretical calculation shows that, in order to build a sediment trap to mitigate the effects of sedimentation in a dredged trench in the surf zone, the following criteria should be taken into account.

Given the limited percentage of bed load in the total sediment transport, the predominant phenomenon is the deposition of sediments in suspension, which will occur progressively throughout the length of the trench (as a "rain"), being more intense near the slopes that in the middle of it, but without major differences (see Figure 4) .

Figure 4 Sedimentation Processes

Consequently, it is necessary to have a buffer (overdredging) with enough depth to absorb this material. Regardless of the geometry of the designed trap, it should be noted that the longshore transport is bidirectional, and depending on the relative magnitudes of the estimated transport is probably convenient that the size of the trap into the south side is in the order of twice the dimensions of the north side.

It can be mentioned also that the high wave height in the breaking zone is a problem to install de pipeline. The typical height of the breaking waves in the trench area near the coast is shown in the Figure 5 for different incoming wave conditions.

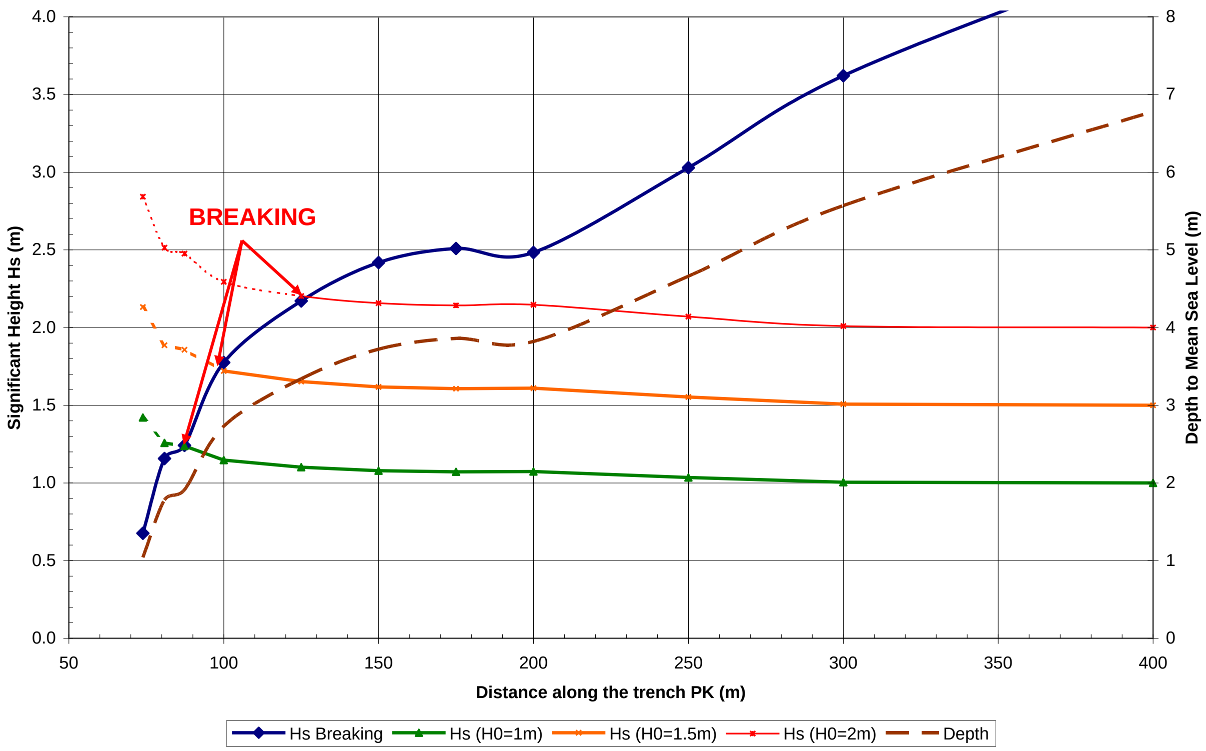

Figure 5 Variation of Wave Height along the trench

Several measures can be considered to reduce the wave energy, buy all of them modifies the littoral transport outside the trench, generating process of sedimentation and erosion.

Another possibility to modify the existing wave conditions, is by conducting in-depth dredging the seabed, because the refraction of the waves in the slopes of the dredged area reduces the wave height in the centre of the trench. The lifetime of these dredging would be very short because the deposit of longshore sediment transport, particularly from the South in the first 200 meters from the coast.

Several analyses were conducted to conclude that the best measure to mitigate the agitation caused by the waves, would be an excavation of a wideness area (with a width limited to not more than 50 meters done with only a dredge swing) to cause a deflection of the wave fronts due to the effects of wave refraction on the slopes. This type of work conceptually coincides with the sediment trap.