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Technical Communication

A Determination of the Energy Flux Constant From Dredge Records

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ABSTRACT

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Simultaneous wave field measurements, dredge and bathymetric records were made in the vicinity of Mar del Plata (Province of Buenos Aires, Argentina) harbour's entrance for 13 months. These data were used to calculate the dimensionless coefficient. K in the energy flux method, the average being 0.21. Longshore littoral transport was estimated in 390,000 m^3/y.

ADDITIONAL INDEX WORDS: *Energy flux method, longshore transport, dredge records, wave measurements, Argentine coast.*

INTRODUCTION

The physical processes that affect the coastal zone are of the utmost interest for scientists, engineers and coastal managers. Knowledge of tides, currents, breakers height and local wave climate is essential not only for beach conservation but also for structure design and navigation purposes.

However, the amount of available data concerning these phenomena is far from satisfactory owing to the small number of places in which data are collected and the short periods they usually cover. This constitutes a practical limitation for computational models.

One of the physical processes for which the available data are scarce is the longshore transport rate due to wave action. Longshore transport represents perhaps one of the most important short-term factors for beach modification, and so it deserves to be carefully considered.

The relatively low and sandy coasts of the Province of Buenos Aires, Argentina, constitute an example of beach modification due to longshore transport. This is particularly important at the harbour city of Mar del Plata (Figure 1) where beach erosion and accretion result in a troublesome situation for the whole area.

In this paper a series of calculations concerning longshore transport in the coastal area of Mar del Plata were performed to get an idea of its relative magnitude. This was done by calibrating one of the well-known semiempirical formulae through field data collected at the entrance of Mar del Plata's harbour. The resulting expression will surely be an acceptable

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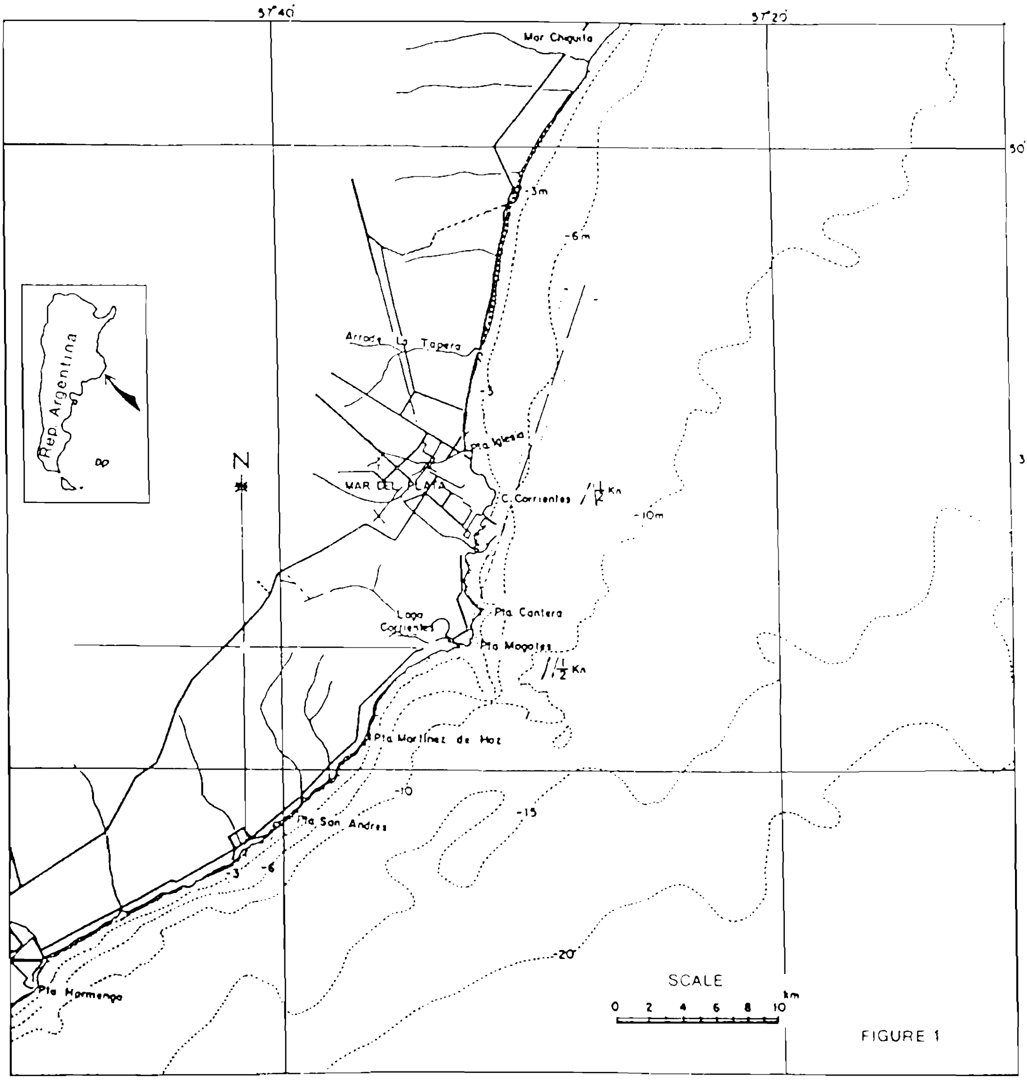

Figure 1. Mar del Plata and surroundings.

measure for most coastal areas in the Province of Buenos Aires.

BASIC ASPECTS

As regards longshore transport, investigations carried out by the U.S. Army Corps of Engineers (CERC) have shown that the best way of predicting longshore transport at a specific location is to adopt reliable data from a nearby site, or, if these data were lacking, to estimate them from surveyed changes in sand volumes at suitable places along the shore.

If none of the aforementioned possibilities is at hand, it will be necessary to adopt an alternative way of tackling the problem, such as the well-known energy flux method (GALVIN and VITALE, 1976).

This method empirically links the longshore transport rate, Q (volume per unit time), with the longshore component of wave energy flux in the surf zone, P_{ls} (power per unit length of shoreline), as follows

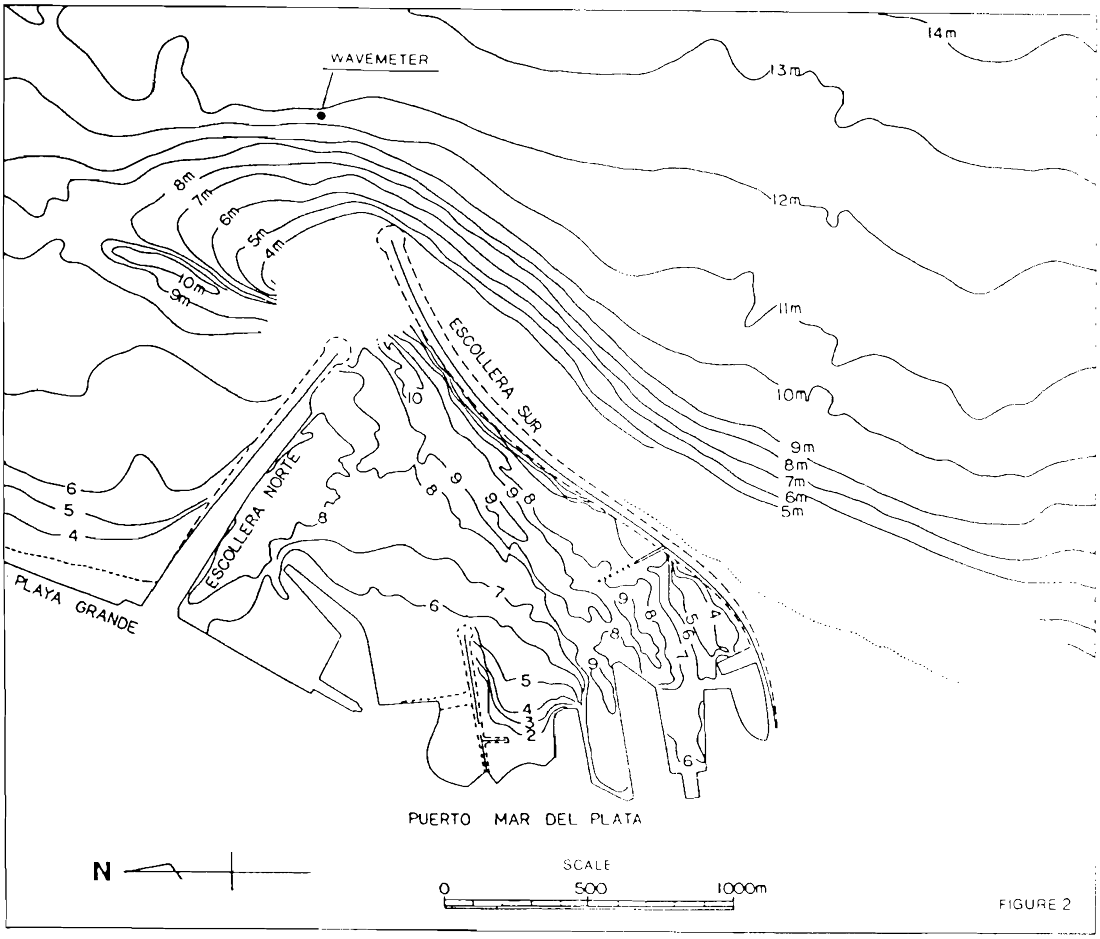

Figure 2. Mar del Plata's harbour and wave meter location.

$$Q = K^1 P_{ls} \tag{1}$$

K^1 being a constant with suitable units.

According to linear theory, P_{ls} can be shown to be

$$P_{ls} = (EC_n)_b sin\alpha_b cos\alpha_b \tag{2}$$

where E is the wave energy density, C_n is the wave group velocity, and α is the angle the wave front makes with respect to the shoreline. The subscript b indicates that all evaluations are to be made at the breaker point.

However, a number of workers (BAGNOLD, 1963; KOMAR and INMAN, 1970) have recommended using the immersed weight rate of transport, I_l (force per unit time), rather than Q because the immersed weight rate leads to a dimensionally homogeneous equation. I_l is related to Q by

$$I_l = (\rho_s - \rho)ga'Q \tag{3}$$

where ρ_s (ρ) is the sand (water) density, a' is the sand porosity, and g is the acceleration due to gravity.

From Eq. (3)

$$Q = \frac{I_l}{(\rho_s - \rho)ga'} \tag{4}$$

There is, however, an empirical relation between I_l and P_{ls}

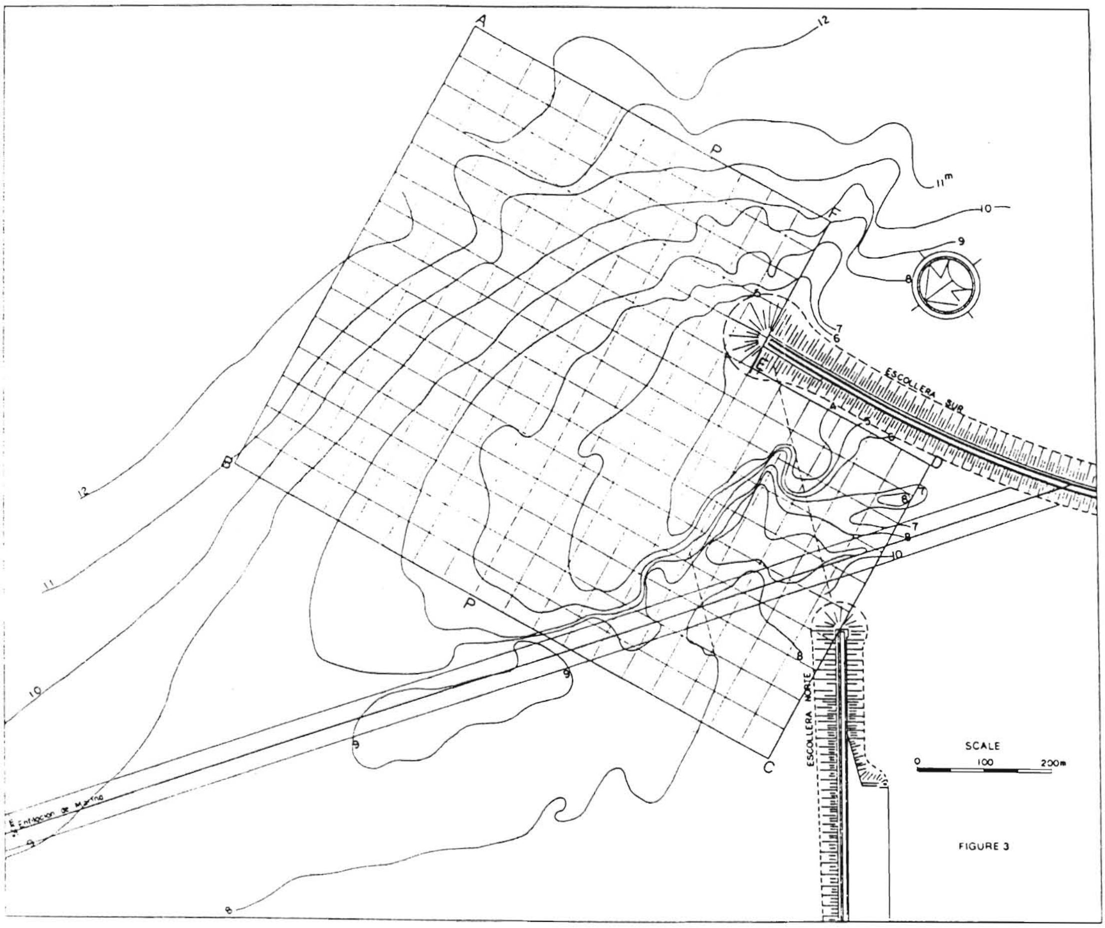

Figure 3. Control area of dredged volumes.

$$I_l = K\,P_{ls} \qquad (5)$$

K being a dimensionless constant this time since both I_l and P_{ls} have the same units (force/time). Substitution into Eq. (4), gives

$$Q = \frac{KP_{ls}}{(\rho_s - \rho)ga'} \qquad (6)$$

The main question concerning equation (6) is how to determine the dimensionless constant K, a point that has focused the attention of many workers. In this paper an average value of K is computed using available data from the harbour area of Mar del Plata. Field data consists of dredge records and wave measurements simultaneously collected.

SITE DESCRIPTION

Mar del Plata is located in a coastal area of emersion type with undulating, alluvial plains and narrow dune strips running along the shoreline without significant rocky crops. The adjacent beaches have gentle slopes (1.5° to 2°), variable widths, and consist of fine sand with low percentage of gravel and shell. To the south, between Punta San Andrés and Punta Hermengo, there are sea cliffs, of about 10 *m* in height, eroded by wave action. There are no rivers in this region that could transport significant quantities of sediment toward the beach. Tides are semidiurnal with spring and neap ranges of 0.91 *m* and 0.61 *m* respectively. Tidal currents are reversing with a dominant north-

ANGLE (°)	T (s) \ WAVE HEIGHT (m)	< 0.5 NUMBER OF TIMES (%)	0.5~1.0 NUMBER OF TIMES (%)	1.0~1.5 NUMBER OF TIMES (%)	1.5~2.0 NUMBER OF TIMES (%)	2.0~2.5 NUMBER OF TIMES (%)	> 2.5 NUMBER OF TIMES (%)	SUM
20°	7.0~8.9	1		2				3
	9.0~10.9		3					3
	SUM	1 (0)	3 (0.1)	2 (0.1)				6 (0.3)
30°	< 7.0		1					1
	7.0~8.9			1				1
	9.0~10.9		1	1				2
	SUM		2 (0.1)	2 (0.1)				4 (0.2)
40°	< 7.0		1					1
	7.0~8.9		1					1
	9.0~10.9	3	8	1				12
	11.0~12.9	1		1				2
	SUM	4 (0.2)	10 (0.5)	2 (0.1)				16 (0.7)
50°	< 7.0		2					2
	7.0~8.9	1	18	2				21
	9.0~10.9	4	16					21
	11.0~12.9	2	1	2				5
	SUM	7 (0.3)	37 (1.7)	5 (0.2)				49 (2.2)
60°	< 7.0		6	1				7
	7.0~8.9	2	14	7				23
	9.0~10.9	7	12	2				21
	11.0~12.9	4						4
	13.0~14.9							
	> 15.0	1						1
	SUM	14 (0.6)	32 (1.5)	10 (0.5)				56 (2.6)
70°	< 7.0		3					3
	7.0~8.9	6	46	18	3			73
	9.0~10.9	16	35	4				55
	11.0~12.9	7	6	1				14
	13.0~14.9	7						7
	SUM	36 (1.6)	90 (4.1)	23 (1.1)	3 (0.1)			152 (6.9)
80°	< 7.0		1					1
	7.0~8.9	4	50	6	3	1		64
	9.0~10.9	12	46	10	1			69
	11.0~12.9	8	2					10
	SUM	24 (1.1)	99 (4.5)	16 (0.7)	4 (0.2)	1 (0)		144 (6.6)
90°	7.0~8.9	1	28	4	1			34
	9.0~10.9	13	37	16	2	1	1	70
	11.0~12.9	5	1	1			1	8
	SUM	19 (0.9)	66 (3.0)	21 (1.0)	3 (0.1)	1 (0)	2 (0.1)	112 (5.1)
100°	7.0~8.9	1	26	5	2			34
	9.0~10.9	6	79	22	5	1	4	117
	11.0~12.9	3	6		1	1	1	12
	13.0~14.9	1						1
	SUM	11 (0.5)	111 (5.1)	27 (1.2)	8 (1.6)	2 (0.1)	5 (0.2)	164 (7.5)
110°	< 7.0			1		1		2
	7.0~8.9	1	40	8	3	1	2	55
	9.0~10.9	13	68	21	3	1		106
	11.0~12.9	15	15	4	5	1		40
	13.0~14.9	2	1					3
	> 15.0	2						2
	SUM	33 (1.5)	124 (5.6)	34 (1.5)	11 (0.5)	4 (0.2)	2 (0.1)	208 (9.5)
120°	< 7.0		1	3				4
	7.0~8.9	3	31	4		1		40
	9.0~10.9	20	62	28	3	2		115
	11.0~12.9	20	18	11	3	1		53
	13.0~14.9	3	7	6				16
	> 15.0	1						1
	SUM	47 (2.1)	119 (5.4)	52 (2.4)	7 (0.3)	4 (0.2)		229 (10.4)
130°	< 7.0		2					2
	7.0~8.9	1	19	7	3	1		31
	9.0~10.9	14	82	40	9	1	2	148
	11.0~12.9	30	29	6	8	1		86
	13.0~14.9	2	1	3	1			7
	SUM	47 (2.1)	133 (6.1)	66 (3.0)	21 (1.0)	3 (0.1)	2 (0.1)	274 (12.5)
140°	< 7.0			1				1
	7.0~8.9	1	16	13	1			31
	9.0~10.9	20	51	37	2		2	112
	11.0~12.9	16	23	30	8	3	1	81
	13.0~14.9	1		1	4			6
	> 15.0				1			1
	SUM	38 (1.7)	90 (4.1)	82 (3.7)	16 (0.7)	3 (0.1)	3 (0.1)	232 (10.6)
150°	< 7.0		1					2
	7.0~8.9		17	5	2			24
	9.0~10.9	6	30	31	9	1		77
	11.0~12.9	8	10	17	18	5		58
	13.0~14.9	2	1		1	1		5
	> 15.0	1						1
	SUM	17 (0.8)	60 (2.7)	53 (2.4)	30 (1.4)	7 (0.3)		167 ([illegible])
160°	< 7.0			1				1
	7.0~8.9		6	4	1			11
	9.0~10.9	8	34	36	8	1		87
	11.0~12.9	5	11	12	4			32
	13.0~14.9	1			1	2	2	6
	> 15.0							
	SUM	14 (0.6)	51 (2.3)	53 (2.4)	14 (0.6)	3 (0.1)	2 (0.1)	137 ([illegible])
170°	< 7.0							
	7.0~8.9	1	10	2	2			15
	9.0~10.9	6	33	29	8			76
	11.0~12.9	3	2	8	5			18
	13.0~14.9		1					1
	SUM	10 (0.5)	46 (2.1)	39 (1.8)	15 (0.7)			110 (5.0)
180°	< 7.0							
	7.0~8.9	1	8	2				11
	9.0~10.9	7	12	17	3			39
	11.0~12.9	1	5	8	3	2		19
	13.0~14.9			1				1
	SUM	9 (0.4)	25 (1.1)	28 (1.3)	6 (0.3)	2 (0.1)		70 (3.2)
190°	< 7.0		3					3
	7.0~8.9		3	6				9
	9.0~10.9		8	7	4	2		21
	11.0~12.9		1		2	1	1	5
	13.0~14.9	1	1					2
	SUM	1 (0)	16 (0.7)	13 (0.6)	6 (0.3)	3 (0.1)	1 (0)	40 (1.8)
200°	< 7.0							
	7.0~8.9		1	1				2
	9.0~10.9		5	2				7
	11.0~12.9		4	3				7
	SUM		10 (0.5)	6 (0.3)				16 (0.7)
210°	< 7.0							
	7.0~8.9							
	9.0~10.9		3	1				4
	11.0~12.9		1					1
	13.0~14.9	1						1
	SUM	1 (0)	4 (0.2)	1 (0)				6 (0.3)
220°	< 7.0							
	7.0~8.9							
	9.0~10.9		1					1
	SUM		1 (0)					1 (0)
230°	< 7.0							
	7.0~8.9		1					1
	9.0~10.8			1				1
	SUM		1 (0)	1 (0)				2 (0.1)
		(15.2) 333	(51.5) 1,130	(24.5) 538	(6.5) 144	(1.5) 34	(0.8) 17	(100) 2,198

Table 1. Yearly wave statistics

Table 2: *Numerical results.*

Period	*N° of days*	$V_d (m^3/day)$	$I_l (N/s)$	$P_{ls} (N/s)$	K
Mar 3 to May 15	74	1330.5	159.4	898.0	0.18
May 17 to Jul 26	72	1353.2	162.1	590.1	0.27
Jul 27 to Nov 20	117	836.7	100.2	602.2	0.17
Nov 21 to Mar 8	108	895.0	107.2	506.8	0.21

south direction and a mean velocity of about 0.5 *m/s*. Wave trains approach the shore mainly from the south and southeast, giving rise to a northward littoral drift in the whole area.

Before the harbour had been constructed (1911-1924), there were no signs of beach accretion; in 1926, however, sand deposit began to be detected on the windward side of the southern groin (Figure 2). Nearly 14 years later, a bar started to hinder the harbour's entrance. Dredging activities were first performed in 1950 with a self-propelled hooper dredge in the control area A, B, C, D, E, F shown in Figure 3 with respect to the 11-*m* contour. By 1956 it appeared as if an equilibrium condition had been reached. This was based on the fact that hydrographic surveys showed that changes in the 11-*m* contour were already very small. Consequently, it may be assumed that by the middle fifties the groin had already lost its capacity of interrupting the littoral drift. This caused the transported sediment to turn over the tip of the groin enlarging the bar at the harbour's entrance.

DATA COLLECTION

As part of a plan to remodel the harbour's entrance (SUNRISE TECHNICAL CONSULTANTS, 1968), wave measurements were performed for 13 months using a pressure sensor, moored at a depth of 11.5 *m* and located 500 *m* seaward the harbour's entrance (Figure 2). The angle of approaching wave fronts was measured with respect to the north-south direction using an engineer's transit placed at the end of the southern groin. Measurements were taken four times a day and each one of them took 20 minutes.

Table 1 presents the annual wave statistics. Significative wave height and period ranged from 0.5 *m* to 5.5 *m* and from 6 *s* to 16 *s* respectively. Wave fronts approached the harbour's entrance from ENE to S.

In order to apply the energy flux method, wave heights were previously reduced to the surf zone through the following assumptions: (a) conservation of energy flux between orthogonals and application of the energy relationship for Airy waves; (b) Snell's law; and (c) McCowan's breaking criterion (GALVIN, 1972). On the other hand, the angle between the wave fronts and the shoreline at breaking was determined assuming a straight shoreline south of the harbour.

RESULTS

A transport rate was calculated through dredge records giving 390,000 m^3/y. This value, together with wave statistics, made it possible to determine the constant K. Table 2 displays dredging data (V_d) and the results obtained. It is seen that K ranges from 0.17 to 0.27 with an average of 0.21, which is approximately half the value of 0.39 proposed by the *Shore Protection Manual* (1984).

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□ RÉSUMÉ □

On a effectué durant 13 mois des dragages, des enregistrements de bathymétrie et des mesures de la houle près du port de Mar del Plata (Province de Buenos Aires, Argentine). Ces données ont servi au calcul du coefficient sans dimension K (méthode du flux d'énergie). Il est en moyenne de 0,21. Le transport littoral parallèle à la côte a été estimé à 390 000 m^3 par an.—*Catherine Bousquet-Bressolier, Géomorphologie EPHE, Montrouge, France.*

☐ RESUMEN ☐

Durante 13 meses se realizaron mediciones simultáneas de olas, de dragados y registros batimétricos en las proximidades de la entrada al puerto de Mar del Plata, Provincia de Buenos Aires, Argentina. Estos datos se usaron para calcular el coeficiente adimensional K que aparece en el método del flujo de energía. El valor medio obtenido fue de 0.21. El transporte litoral se estimó en 390,000 m^3/año.