CHAPTER 215

RIA DE FOZ: SOLUTION FOR A HARBOUR AND COASTAL PROBLEM

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SITUATION.-

The ría of Foz is located in the Northwestern part of the Ibérica - Península, inside the Rías Altas group, in the Eastern extrem of Lugo/ province. It is placed on the natural form known as Golfo of Masma, - topographical accident that takes its name from the river that flows - into the ría.

From the point of view of the materials that constitute the environ ment, they are mainly composed by slaters and quarzites, with some levels of carbonates from the Low Paleozoical period. To the West, the - granitic materials are predominant.

The ría is limited in its margens by some little slope and relative ly low cliffs. Its bounds have a little depth, due to the filling process, natural in the Rías Altas. The materials that refill the ría, - come from the sea erosion of the cliffs (1), and the refilling is due/ to the sea waves action that produces in the tidal flow and ebb an - - asymetrical capacity of erosion and transport (2). That is a natural - situation, but the human action, building some channeling constructions has accelerated this refilling process.

The traditional economic development on this zone, has been based - on some principal activities: fishing and agriculture, but nowadays - turistic use rounds off the others. This situation and the evolution - of sailing neccesities on the ría, has been a conflict reason, which - is a consequence of the competition between these uses.

In these terms, the first problem to the possible feasibility of - Foz harbour was its accesibility, and that depended on the stability - of the main tidal channel. Therefore, the harbour authorities developped a planning design to fix the position of the entry channel, by the - - construction of a couple of jetties; however only one of them was built up to the date. In a certain phase of the construction, when the inlet gorge was affected, the sandy barrier was destroyed. Since then, several erosion problems have affected to the neighbour littoral and beaches. And the aim of this study is to regenerate the coast without - - decreasing the harbour availability. We might not forget that the natu ral tendence of the ría is to refill itself; and that means a hight - variability of channel, trying to adapt themselves to the new condi - tions and distribution of materials that refill the ría.

The light was built because of the risks derived of the existence -

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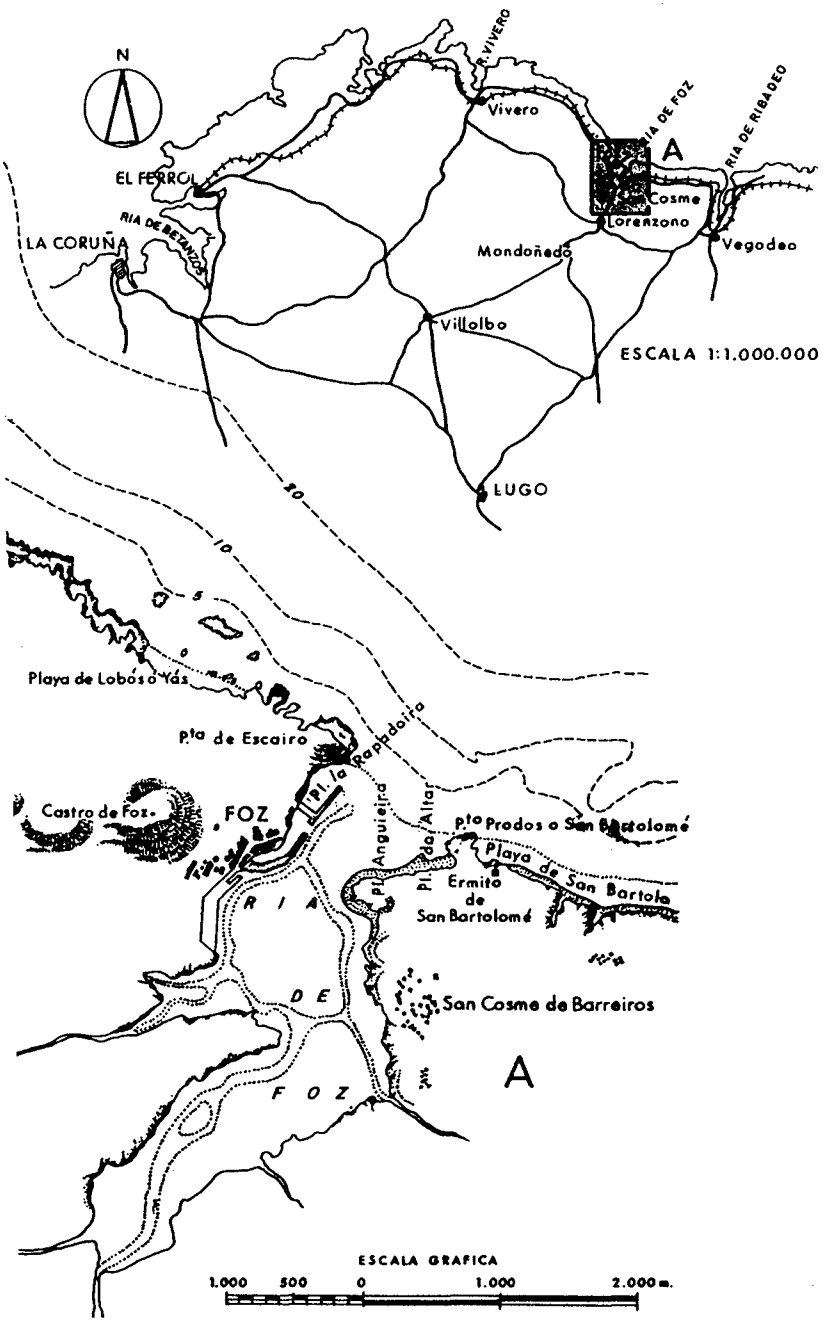

FIG. 1 Situation

of a dangerous rocky system (shoals and rocks of the Rapadoira). This/ light caused degeneration of a little beach on the left hand of the - mouth and stabilized in a certain way the barrier on the inlet. Nevertheless, in this brief note, we have explained the situation we - have to face up, which is derived from the general development of the/ fishing activity that requests every day bigger depths and safety.

So the objective was to define the neccesary works to protect the - coast considering the natural conditions of littoral dynamics, in such a way that the conditions of the harbour entrance and explotation do - not suffer additional problems.

ELEMENTS OF LITTORAL DYNAMICS.-

Relating to the processes that affect to the mouth, the determinant elements are tides and sea waves, and, in a minor order, winds and - - fluvial contribution.

Tides: They introduce some flow and ebb currents that carry the - - solid materials. The net component of this transport is to the basin./ The main high water appears in equinox (but it is little out of phase). The M.H.W. has an amplitude of 4'50 m. aproximately. The tidal prism - considerated in the project is between 1'7 and 7 hm^3.

Waves: Due to the special morphology and topography of the exterior part of the ría, the littoral currents induced by wind waves have a - quasy permanent sense from E. to W. in Anguieira and Altar beaches; on the opposite, out of the ría mouth and along all Masma Gulf, currents/ have a variable direction, related to the wind wave direction, but the dominant currents and littoral transport are there from W. to E..

The special direction of currents and drifts in the beaches is the/ most important reason of the shaping of the lock barrier as a spit, - what may be checked by observing the distribution of materials in the/ tombolos produced by the Peña do Altar.

Winds: They are responsible of the formation of dunes on the lock - barrier before it were demolished. They are also responsible of the - filling of some marginal zones. Winds effect can be considered as a - second order action.

Fluvial waters: Their effect can be compared to the tides only in - extraordinary floods. But they are not so important in normal condi -- tions. In the project it is considered a flow between 10 and 110 $m^3/s.$ and 170 $m^3/s.$ in extraordinary floods.

MATERIALS.-

From the point of view of the materials, Masma Gulf can be considered as a morphodynamic unity, with some located differences, but the - materials are generally very similar.

Several samples have been obtained and analized in their grain size distribution and mineralogy. A group of the samples were obtained from the different sandy formations of the ría, but other group corresponds to different beaches along Masma Gulf. The analysis of sediments shows that the anterior afirmation is all right, and that is proved with a - high certainty between Foz and Ribadeo.

On the other hand, the mineralogical analysis show that in broad - outline, materials in this zone proceed from the erosion of the cliffs principally, and that the sands from the beaches around ría mouth and/ from the ría sandbanks are completely similar.

The similarity of the sediments showing in the analysis of sands - from Anguieira and Altar beaches and from the sandbanks in the interior of the ría allows the use of the last for refilling of beaches with - them.

PRELIMINARY CONCLUSIONS.-

Some historic and recent cartographic and topographic documentation has been analized and it is possible to propose some reflexions that - can help to puzzle out the present situation of the inlet-outlet system:

-Based on the available documentation before the building of the - channeling jetty, the location of the exterior tidal channel was very/ variable. This situation was foreseen to reappear (2) and is now - - reappearing, but in the extrem of the jetty; therefore the entry pro-- blems have not been definitively solved.

-Though the spit seemed to be stabilized, its morphology was adap-- ting itself to the new hydrodynamic situation, changing its orientation Northwestward and modifying its relative dimensions, its anterior - - cyclic evolution, however seems to have been broken, after the cons -- truction of the light and before the building of the channeling jetty, dunes and vegetables colonization grew up; this situation went down - during the construction of the channeling jetty, but in 1.978 the lock barrier disappeared, just when the interior stretch of the jetty was - constructed.

-The accretion in Rapadoira beach was following on the growing of - the jetty.

-After destruction of the barrier, the erosion on the right hand - beaches began to occur and with some little delay the erosion of the - beaches Eastern towards Ribadeo began too.

-Since then, the inner channel suffers quicker changes in a dialec- tic relationship with the cyclic regeneration and demolishing of the - lock barrier. The successive growths of the spit has been permited by/ the erosion of Anguieira and Altar beaches and by the mentioned perma- nent Western littoral drift along them. Finally the successive destruc tions of the spit became quicker. These variations depends on the sea- sonal changes of the conditions of the sea dynamics; it will mean that the variations of the channel are now very quick in this zone.

-The monthly variations of the tidal prism (due to the tide compo-- nents in this area) produce a very high mutability of the channel - - depths and breadths. And the increased filling process of the ría - - after the first demolishing of the spit increases the sailing difficul ties.

SOLID TRANSPORT ON THE OUTLET.-

The valües of the littoral transport contained in a first numeri-- cal study based on hindcasting methodology are very important, for the net as for the gross transports. However these values correspond to a/

potential transport and do not mean the same importance in the litto-- ral drift, which is limited by the existence of materials. In any case, the littoral drift is important enough to impose a very high variabili ty of the tidal channel, even seasonally, following the motions of the transported solids.

In the exterior mouth of the ría, like in other cases, the natural/ mechanism of by-passing of materials is stablished. In this way, the - bars that exist in front of the ría, with their net movements to the - SE., catch up their aim of solid transport when they arrive to the - - sandbanks next to the Punta de St. Bartolomé; in this moment the - - channel opens again suddenly in the Northwest end. The changes of the/ position of the outlet are so progressive towards the East up to the - sudden openings.

In terms of the transport of solids to the inner basin, it becomes/ smaller when the effect of the lock barrier is efficient; in this way, before 1.978, when the lock barrier was demolished, the net transport/ was less than it is possible to observe nowadays.

In the exterior beaches, the transport has a special direction, due to the intrinsic characteristics of this zone. The bay which is open - between Escairo and St. Bartolomé headlands, stays widely emerged in - low tide; therefore the transport only occurs in mid and high tide - - there.

If we observe the materials in the shelter formed in the Peña do Al tar, and we accept that the disposition of materials should respect - the orientation of predominant waves in term of their main annual - - resultant (recognizing the seasonal variations), we can conclude that - the disposition and growth of the lock barrier is logical, in spite of the fact that out of the mouth of the ría the transport has frequently the opposite direction. We should not forget that in the bay of the - ría it is neccesary to wait for high water to observe solid transport/ and in this moment the refraction, the diffraction in the Escairo - - headland and even the reflexion on the St. Bartolomé headland and Al-- tar Rock are important. The tide currents help this current direction/ too. We have proved that the solid transport is from E. to W. along - the bay beaches; so the genesis and orientation of the lock barrier - may be perfectly explained as a spit.

CONSTRUCTIONS: EVOLUTION.-

The morphologic changes, as an evolution of the materials distribu tion in relationship with the construction wich are made along the - time, are analized as follows:

-Between 1.931-1.953 it is built a little transversal jetty, for - giving access to the light in the Rapadoira Rocky shoals. Leaned and/ supported on this jetty a little beach was formed; that system seems/ to have operated as a stabilizer of the lock barrier which moved - - innerward and became wider allowing an increasing colonization of - - dunes.

-In 1.969 it began the construction of the jetty which starting - from the light and parallel to the left margen, tried to stabilize - the position of the main tidal channel. The response of the lock - - barrier materials was fast; the spit began to take a progressive - - orientation Northward with evident lengthening and lost of thickness/

in its extrem head due to the following processes:
. The stabilization of the tidal channel caused a reduction of its curvature in the interior zone, and so, it began to erode the lock barrier from the internal side.
. In the area extended between the jetty and the original shoreline the Rapadoira beach became progressively wider what supposed a bleeding of a part of the materials that constituted the feed of the spit, Altar beach and beaches further to the East.

-Between 1.975-1.977 the construction of the last exterior of the channeling jetty was ended. These buildings supposed the outer prolongation of the jetty in the left margen to the present position. Its inner prolongation began then producing a subsequent reduction of the gorge.

-The effects were inmediate and spectacular; in March 1.978 the lock barrier had disappeared. It is possible to observe a faster filling of the ría and an increasing of the exterior bars since then, and also Altar beach began to be eroded, trying the materials to feed the lock barrier that was demolished every time by the littoral dynamics. But this process was not inmediately evident in the regression of the shoreline up to three years later; initially the erosion only affected to the intertidal beach (depth erosion).

-In 1.981-1.982, we could confirm a very important backward movement of the coast-line due to the processes we have explained.

-Since 1.983, we could observe a relative important erosion (changes in the transversal profiles) of the beaches East from ría of Foz.

OBJECTIVES.-

The most adjusted solution to the problem we have exposed, might accomplish therefore the following objective:

1. Regeneration and stabilization of the shore between Anguieira and St. Bartolomé headlands. This is the principal objective; the follows are secundary and act as limitant conditions.

2. Preservation and improvement of Foz harbour facilities, so that particularly the sailing conditions in the access channel do not worsen.

3. To avoid negative impacts in the ría and its environment.

4. To respect the natural conditions of littoral drift Eastward from the ría.

Securing theses objectives it will be possible to obtain an integral solution to Foz coastal and harbour problem. And a discussion of the possible element of the solution will be done previous to the analysis and definition of the complete solution.

A. Artificial filling with sand.-

The level of the regression process of the Altar beach is so important and the risk of damages so high that it seemed neccesary an artificial refilling on this beach. But that decision planned two suplementary problems: the source of sands and their stabilization.

- In relation to the sand source the sedimentological analysis have shown that the sands from the bay and from the channel as the ones - - from the banks of the ría have the same characteristics than the sand/ of the beaches; the use of them is, in consequence, allowed. We have - also test the materials of Rapadoira beach; these sediments have not - the same characteristics but they can be used too. Nevertheless the Rapadoira beach has become too wide and now it needs a bleeding because/ the sediments are in the way to overstep the jetty, bringing some navegability problems in the exterior end of the channel.

-Nowadays, due to the natural processes that the littoraz dynamics impose in Altar and Anguieira beaches, the balance of sediments is - - negative; that means an evident erosion of them. This erosion has some inmediate consequences: the acceleration of filling speed in the ría,/ and the lost of the materials that feeded the beaches, further to the/ East from the ría. Therefore, in relation with the stabilization of - materials, it would be neccesary some kind of artificial shelter, - - barrier or protection. Taking into account both problems. Two different types of solutions may be considered:

. A continuous feeding after an adecuatelly great first reclamation - what should interrupt the actual rythm of filling in the inner basin./ The simple reclamation surely would be not enough; it is also neccesary to feed periodically with, to counteract the deficit that imposes - the natural eroding tendence.

. Construction of a kind of element that allows the stabilization of - sands, by support, shelter or protection. These elements are analized/ in the following discussion.

B. Transversal jetties.-

It is a parcial solution that should allow the defence of shore - and buildings (apartments and hotels) in the zone of Altar beach, - - where the erosion has been stronger, attacking the quaternary cliffs/ over what these constructions are located. They behave principally as barriers or supports. Nevertheless this solution has some important - disadvantages:

-On the one hand, it does not resolve all the problem because it - does not give a really solution to the accessibility to Foz harbour.

-On the other, the traspassing of materials to the beaches Eastern from Foz is not favoured and possibly, if the barrier was long enough, it would be even not allowed; so there the erosion process should - - increased.

-In addition, this kind of jetties would produce indesirable visual impacts.

C. Free jetties.-

Though they behave a shelter works, like in the previous case, it - is a parcial solution if they are not complemented with other channe-- ling constructions and by-passing disposal.

D. Channeling constructions.-

The only way to complay with the demands of Foz harbour is to sta-- blish a channeling element on the right margen that completes the old/ jetty. The old channeling project defined two parallel jetties already.

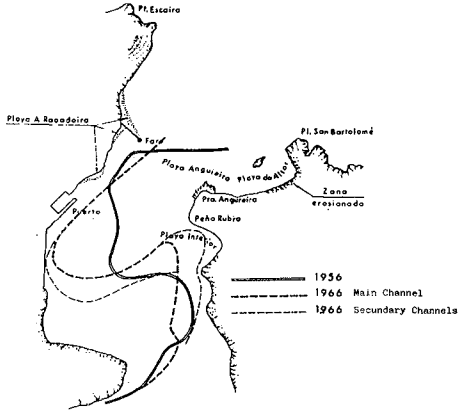

FIG. 2
Evolution of the inner channel-1956-1966

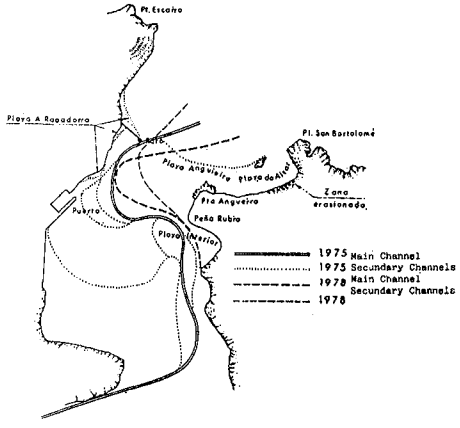

FIG. 3
Evolution of the inner channel-1975-1978

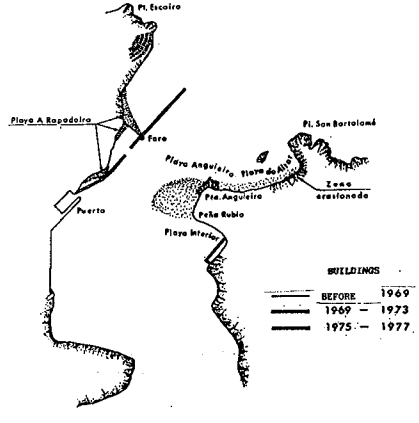

FIG. 4
Schedule of the channeling constuctions

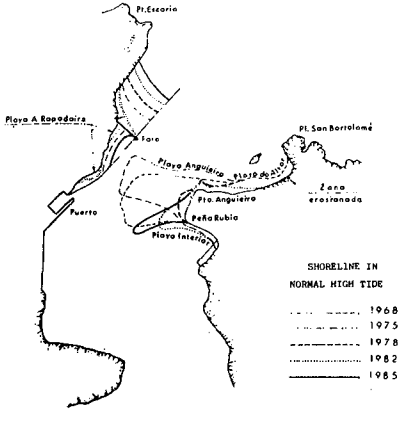

FIG. 5
Changes in shoreline

But only the one of the left margen was built. That was other reason - of the posterior erosion happened. At present the second jetty is also necessary for channeling, however nowadays it is necessary to regenera te the lock barrier too.

There is a difficulty derived from the shortage of complete studies about bathymetric and hydrodynamic conditions, and in consequence, - - there are not dates enough to assure the success of the solution, - - because the definition of the exact cross section of the tidal channel, that would be necessary to improve the accessibility conditions of Foz harbour needed a wider research.

The channeling works on the right margen made behave as bracket and protection against the waves and tidal erosion of the spit that may be regenerated in base of an artificial filling. This is, in consequence, the most complete and economic solution in relationship with all the - planned objectives. It has the advantage of beeing the less detectable visually because the jetty stays sumerged under the lock barrier, - - except on the tide channel side.

ADOPTED SOLUTION.-

The adopted solution is composed of the following elements:

1. Artificial filling with sand.

2. Extraction of sand from the ría increasing the tidal prism and - reconstituting the primitive condition. It is possible to take out the sands from Rapadoira beach too. We have explained that Rapadoira beach needs a bleeding to avoid both posterior problems of accessibility to/ Foz harbour and risks in the own beach.

3. Construction of a bracket-channeling jetty that starting from - Anguieira headland approaches enough to Foz light to allow a breadth - compatible with the final tidal prism. This jetty should stabilize the tidal channel on one hand, and avoid the breaking and eroding of the - spit due to the tidal and wave actions on the other hand. The following conditions must be observed:

-The jetty would be short enough to be sure that the distance from/ its head to the Rapadoira jetty exceeds the theoric channel breadth, - to make easier the foreseen construction of its extension as the right margen channeling jetty; but at the same time it must be as long as - possible to favour the natural inlet-outlet stability.

-It might adopt in the ground plane a compatible form with the - - tidal ebb channel eroding action.

In abstract, the solution can be defined as the artificial settle-- ment of a lock barrier, stabilized by a channeling and bracket jetty,/ in such a way that this may constitute the first stretch of the comple te right side channeling jetty.

THE JETTY.-

1. The ground plane will be conditioned by two kind of considera--- tions: fluent circulation and constructive facility.

They have been taking into account three different layouts which -

FIG. 6 View of the spit in 1975

FIG. 7 View of the spit in 1978

FIG. 8 General view 1975

FIG. 9 Alternatives for the jetty to tesig.

are shown in figure 3. The following discussion was carried on:

The hydrodynamical conditions improved for number 1 to number 3; - number 3 allows better the evacuation of water in the ebb, and the - - changes of direction are less than in number 1; the curvature is minor in number 3 too. At the same time, solution number 1 corresponds to - the maximum increasing of the lock barrier. Therefore, all these consi derations select layout number 3. However the easiness decreases from/ number 1 to number 3; while the number 3 layout suposes a construction through the presently flattened lock barrier sandbanks, demanding to - pump out a great quantity of sand, number 1 layout demands a minor - - previous sandy pumping. This need for pumping sandy out is imposed by/ the necessity of getting an adecuate level for jetty fundation. Never- theless on the other hand, solution number 3 has the advantage of - - beeing shorter than the others; so, the anterior disadvantages are - - parcially balanced. Therefore, solution number 3 has been selected, - taking into account other motives:

-The present changes of the tidal channel do not allow a clear defi nition of the jetty based on the present morphology and other condi -- tions in the moment of the design, which undoubtedly will be some - - different from the ones of the unforeseeable moment of the construc -- tion.

-The jetty number 3 has the advantage of starting from the rocky - massif known as Peña Rubia, what means a good stability in the star-- ting point.

-This solution guarantees the best stability of depths in the har-- bour access channel.

2. Refering to the jetty cross section, its double function as a - channeling and bracket jetty may allow the construction of an asymetri cal section. The channel zone demands bigger slopes to decrease the - roughness and in consequence to improve the evacuation of waters in - ebb tide. On the other hand, the right slope is going to be covered by the sands of the supported lock barrier.

OTHER ACTIONS.-

As it has been pointed out before in this paper, it is possible to/ observe some changes in the natural transversal profiles of the bea -- ches Eastern from the ría of Foz. These changes forseeably mean some - erosion of the shore and therefore it is recomended to refill the - - shortage of sands of those beaches. It is also proposed to carry the - sands out of the inner ría for this reclamation in order to increase - its tidal prism.

ECOLOGICAL ASPECTS.-

The proposed sandy extraction from the ría may affect the ecosystem, but this affection may be considered positive, because it is just the/ acceleration of the speed of filling of the ría and the variability in the position of the internal sandbanks (and channels), the factors - - that more ecological impact have represented in the past.

On the other hand, the bentonic fauna and flora needs a certain - - stability of bounds and this project foreseeably will favour this stabi lity, and the ecological impact for sandy extraction is not so important

as the stabilization of bounds.

SOME INTERESTING RESULTS.-

The construction of the jetty has begun on the beginning of 1.987 - and as early in summer of that year was still possible to observe as - an interesting result, the advance from the near shore of an important sandbank towards the beach all along the Altar and Anguieira beaches./ Besides it was the first summer without erosions in Altar beach since/ 1.978. By then, the artificial refilling was still scarce. It is a - - good prove of the correct behaviour of the jetty as a support for the/ lock barrier. The work will foreseeably be finished in summer of 1.988.

POST CONCLUSIONS.-

Since 1.987, based on the results of the measurements of currents - speed and tidal levels, we are working in the sense of determining the hydrodynamics of the ría. Periodically we make some bathymetrics cam-- paigns, to allow us to discern the changes of the volume of materials/ that come into the ría in relation to the volume that entered before - the construction of the jetty.

On the other hand it is foresight to make a pursuit for the project to verify the grade of adjusting of it to the foreseen behaviour.

In other term, we are measuring the relationship between the tidal/ prism and the cross section of the gorge. We have not forget that soon in the future it will be necessary to determine the breadths and the - depths to the definitive stabilization of the harbour entrance and it/ has been previously exposed.

All these works in the future can serve to elaborate some conclu -- sions about ría of Foz hydrodynamics to extrapolate them to other - - analogous outlets.

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