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The Coastal Interceptor Waterway

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FOREWARD

The Sea Grant Coastal Zone Management Bulletin Series is being offered as a method of acquainting the public with advances in the fields of coastal zone engineering and research.

Further expansion of human population into the coastal zone is assured. As this happens, conflict over the uses of this limited area's natural resources will increase inasmuch as all uses are not compatible.

The purpose of the Coastal Zone Management Bulletin Series is to summarize new research results in the management context and to stimulate discussion of new management techniques which appear to offer possible solutions to complicated socio-environmental problems.

A further aim of this Series is to present sometimes complex thoughts and concepts in a semi-technical publication which can be used by planners, developers and persons in public office.

This Bulletin is published by the University of Miami Sea Grant Program in the belief that its contents will be helpful to those concerned with the problems of the coastal zone.

THE COASTAL INTERCEPTOR WATERWAY

Introduction

A recent report (Barada and Partington, 1972) discussed water quality in conventional development canals and concluded that "This investigation shows that the water in most of Florida's canals cannot meet federal and state water quality standards, and canal characteristics may make it impossible for these waterways ever to achieve these minimum legal standards."

They also state "The almost universal characteristic of these deep, narrow box-cut canals and dead-end configurations is sluggish circulation and a lack of flushing action, compounded by insufficient tidal exchange or a lack of adequate gravity flow due to flat terrain."

Further, "Eutrophication of limited-circulation canals is greatly accelerated by a heavy pollution load due to the increased population density in relation to shoreline length. The sources of pollution include urban runoff, septic tanks, sewage effluent and live-aboard houseboats."

We agree with these statements. Because we do agree, we have attempted to conceptualize some form of receiving water body which would eliminate most of the evils ascribed to conventional development canals, serve as a buffer between developed uplands and the coastal bays, and moderate the negative effects of massive flood control canal systems which pour large quantities of inferior water directly into coastal bays at highly localized sites. We have chosen to call our alternative a coastal interceptor waterway.

Justification

We believe that further massive coastal development is inevitable in the flat coastal plane of the southeastern U.S., at least in the forseeable future, and that landward of a generally acceptable coastal setback line Florida will undergo urbanization far more dramatic than anything yet experienced. It does not seem possible that unlimited purchase of "buffer zone" can be counted on to protect the desirable characteristics of coastal waters. Somewhere along the line such purchase becomes economically impossible. If the vast size of Everglades National Park cannot guarantee the ecological integrity of its enclosed ecosystem we think it unlikely that purchase of buffer land can be the sole means of saving coastal waters and their living resources anywhere in Florida.

The solution seems to lie in including some ecologically essential features in a coastal buffer zone by direct purchase as well as providing sound management of flood runoff, urban and agricultural pollution, rigorous treatment of sewage, and formulation of legal and engineering safeguards to protect against the otherwise inevitable overloading of management systems. Additional environmental safeguards will be costly, but developers and the buying public must be made to understand that the cost generated by inadequate safeguards will be even greater if we continue to develop as we have in the past. Safeguards will also be called for which require science and engineering that do not yet exist or, if they do, are not yet "fool proof" (e.g. many sewage treatment plants cease to function at optimum levels during heavy rains because of overload).

New technological tools are desperately needed which, when coupled with the best existing environmental engineering techniques, can advance the state of coastal resource management. The interceptor waterway, first described in principle by Tabb, (Idyll et al., 1965) is one such management tool.

Description

It will become apparent that the interceptor waterway would be unlike traditional coastal development canals. It is not a canal, except that it is man-made. It runs approximately parallel to coastal contours instead of directly into coastal bays (Figure 1). It is designed to intercept and "digest" upland nutrients irrespective of tide using sunlight, photosynthesis by plants and wind action to eliminate severe eutrophication, stratification, and oxygen depletion. Tidal exchange should not be considered an important facet of the system envisioned here. The waterway should have a relatively large surface-to-depth ratio, averaging 5' or less in depth and not exceeding 7'. Its seaward shore should be completely natural with a few easily hidden structural safeguards built to preserve uniform height of the seaward edge or sill. Its upland shore would not be bulkheaded with vertical concrete walls. We visualize riprapped banks (Figure 2) having approximately a 3:1 slope down to the mean tide line. Below mean tide line, on landward and seaward aspects, the bottom should be sloped no more steeply than 6:1. The more gradual the slope, the greater will be the effective surface area acting as substrate for benthic algae and possibly for seagrasses. Figure 3 is a diagrammatic representation of the waterway in cross section. The seaward edge of the waterway should follow natural contours and thus its shoreline would be irregular. The design should include the capacity for water level manipulation in order to increase storage capability in anticipation of heavy upland runoff. Thus, carefully constructed adjustable weirs will be called for where the ends of the interceptor waterway connects with natural waterways.

The interceptor waterway is not a "small development" tool. Its successful use will depend on large-area planning. It is designed to preserve, as closely as possible, the surface or "sheet" flow of upland runoff across coastal marshes. This flow moves vital marsh plant detritus to the waiting bay consumers as well as prolonging the brackish water period of the estuarine system. The waterway would serve best in coastal areas having very low relief and should function equally well in salt-tolerant grass marshes of the south Atlantic and Gulf states or mangrove marshes of Florida.

Ideally the buffer zone between the coastal bays and the interceptor waterway should include the entire mangrove forest or salt grass marsh to the extreme heads of tidal creeks within those marsh zones. Generally speaking the upland limits of the mangrove forest association in south Florida (i.e. red, black and white mangroves) extends to about +2.0' mean sea level. Thus the undisturbed seaward edge of such a waterway might be at +2.0; and seaward flow along a broad front would occur at higher water levels. Exact placement of the seaward edge of the interceptor waterway must be decided on the basis of observed tidal conditions in natural waterways of each separate system. Mean level of actual water surface in these waterways is often higher than mean sea level in the adjacent ocean because of their constricted nature. Thus MWS, not MSL becomes the engineering control. To function as conceived a positive head is vital to

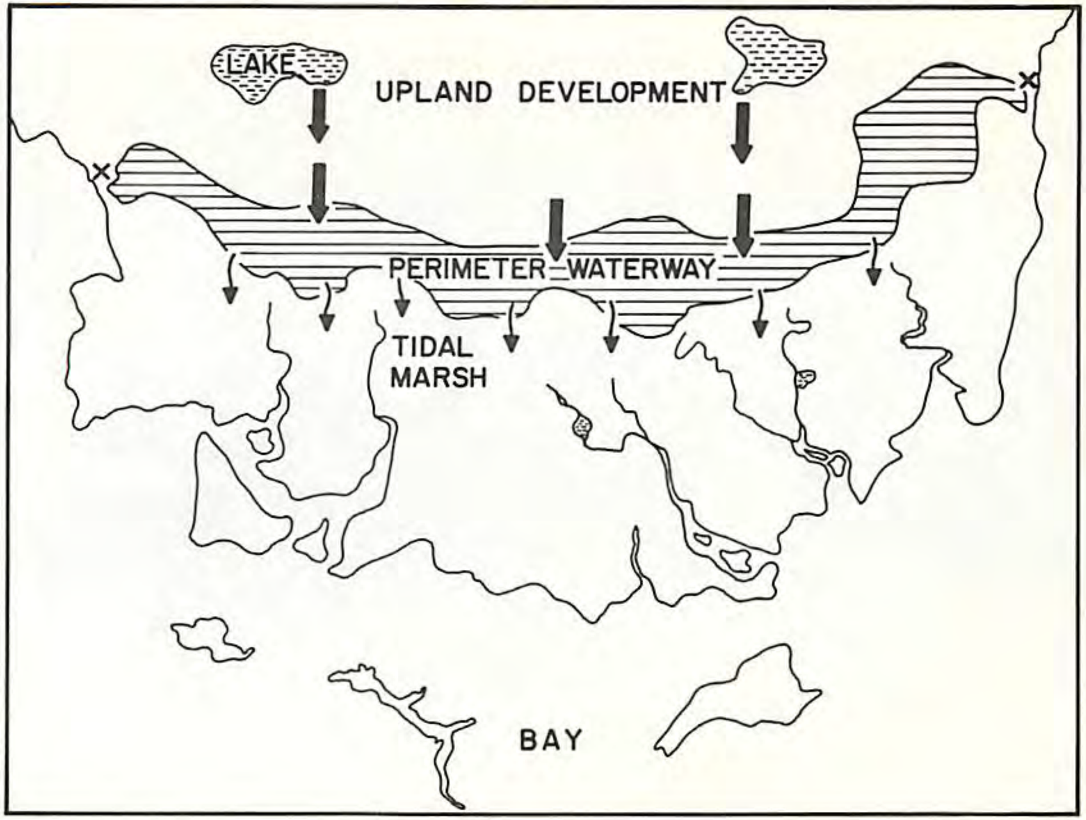

FIGURE 1. The lateral distribution of runoff water by a perimeter waterway. Points of controlled boat access to waterway are marked X.

FIGURE 2. Riprap treatment of sloping banks

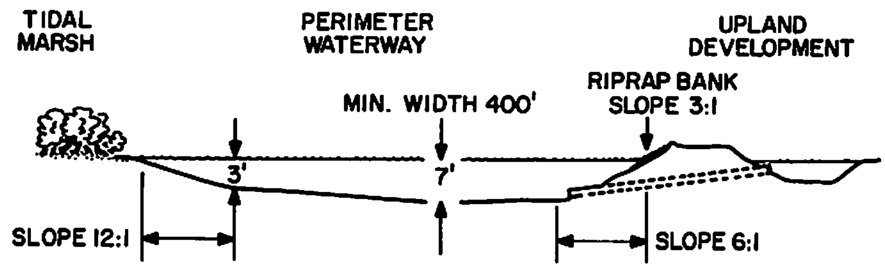

FIGURE 3. Cross-section of the perimeter waterway

the system designed to achieve sheet flow by gravity. A positive head could not be maintained by uncontrolled access of the interceptor waterway to adjacent natural waterways, hence the need to stay upland of the heads of natural tidal creeks. Furthermore, where large streams or major sloughs cross the alignment of the interceptor waterway these must be built up to the control elevation or provided with carefully designed water control structures to effect lateral spread of runoff before it flows over the seaward banks of the waterway. During drought periods, however, high evaporation and absence of fresh-water runoff may produce hypersaline conditions in the waterway unless modified by exchange with the estuary. At such time, free tidal ingress probably should be permitted and water levels in the canal may then fluctuate normally between high and low water levels for the locale.

Concern has been expressed that such a waterway would extend the salt front inland. Our experience suggests that the salt front penetrates inland (in the absence of canals or creeks) only so far as the fresh-water head permits. If, as happens in southwest Florida during drought, there is very little fresh-water head to hold back the saline front, sandy coastal lands already experience a general underground penetration of salt water far inland of the area where the interceptor waterway would be constructed. This inland penetration of salt and subsequent upward migration of salt water by capillary action causes excessive soil salting and massive mortality of plant life. Along the southwestern Florida coast this is a "normal" dry season phenomenon which results in formation of a linear white zone of bare sand, or saltern, where plants seldom grow. Under such dry conditions, the presence of flowing (ebb + flood) seawater should actually moderate salinity, while upland sand-bottom lakes containing highly treated sewage effluent should actually assist in preventing inland penetration of saltwater in the surface soils.

Operational Philosophy

The interceptor waterway can perform a number of real functions, but the single most important one from an environmental standpoint is that of nutrient removal. Since it is not designed primarily as a tidal waterway it must accomplish this by local physical and biological means rather than by dilution. The guiding operational principle lies in the fact that the biota associated with a given volume of static water can, usually in the presence of sunlight, consume and convert dissolved nutrients into tissue utilizable by the other organisms in the food web. If this conversion proceeds in an oxygenated system the most common and objectionable effects of eutrophication (i.e. stratification, H_2S formation, fish kills) will be prevented and useful by-products will be produced which can be consumed by the bay biota.

Usually the combined nutrients from cities and farms are converted in drainage or development canals where the level of enrichment is excessive for the water body. Furthermore, the "box-cut" narrow and deep configuration of such canals tends to preclude wind-induced circulation and penetration of sunlight. A coastal interceptor waterway can overcome these objections if it is designed properly and if the upland development is supplied with suitable safeguards to insure against overloading the system.

In the following discussion we have drawn heavily on experience gained in mariculture, where deliberate fertilization of static brackish-to-saline waters is practiced through feeding or by the use of inorganic nitrates and phosphates to encourage populations of microorganisms. The values proposed are preliminary estimates which must be refined further to suit local meterological conditions. To extrapolate the data it is necessary to have total water surface and depth of the water way, area of runoff surface tributary to the waterway and extremes of runoff likely to be encountered.

Operational Characteristics

Narrow and deep conventional development canals cannot be "self-maintaining" under conditions of continuous input of nutrients. Wind-induced turnover is usually insufficient to prevent bottom water from becoming de-oxygenated. In addition, there is usually insufficient fresh-water runoff during the dry season, at least in southern Florida, to dilute and cause mixing and tidal flushing is often weak or absent. Consequently the "loading capacity" (i.e. amount of nitrogen, phosphorus, etc.) which can be assimilated by such water bodies is low.

A wide, shallow waterway (e.g. minimum width of 400'; maximum depth of 7'; average depth of 4 to 5') exhibits qualities prohibited by the deeper character of conventional canals. A shallow waterway permits penetration of incident sunlight sufficient for growth of phytoplankton, benthic microalgae and attached plants including some "sea grasses" such as *Ruppia maritima*.

Greater submerged surface to volume ratio affords greater substrate for attached and burrowing biota which consume the primary production, while greater water surface area allows wind-induced turnover with gentle (5-10 mph) breezes from any quarter.

Consequently, having opted for a wide, shallow water body which will have a greater nutrient "scrubbing" capability one must attempt to estimate how much nutrient input such a water mass can assimilate while maintaining an acceptable water quality.

The following is a "first-cut" attempt to draw upon marine fish and shrimp pond culture experience to arrive at tentative estimates of the "loading" capacity of a wide, shallow, non-tidal saline waterbody.

During the course of a 4 month dry season period, with no water exchange, 4 acre feet[1] of ponded seawater having salinities between 21 and 35 ppt and temperatures between 23° and 32°C can absorb the following nutrient inputs without a significant probability of deoxygenation.

(1) Inorganic nitrogen 13 pounds (5.9 kilos)
(2) Inorganic phosphorus 16 pounds (7.3 kilos)

Although the above quantities of nutrients could be more easily handled if received over an extended period, the system is capable of assimilating approximately half of these quantities in a single "application" such as might occur during a 24 hour peak storm runoff period.

(3) In addition, this same water body and its biotic elements can withstand the steady input of approximately 80 pounds of protein nitrogen[2]. This is theoretically equivalent to 2.5 - 3 tons of dead leaves and grass clippings. It should be pointed out, however, that this does not constitute an endorsement of the use of such waterways as receptacles for garden refuse.

The pond will not "fix" 80 pounds of organic nitrogen completely in 4 months, but it will withstand this amount without deoxygenation. A degree of enrichment will obviously occur; the water will not be crystal clear, but it is not likely to become stagnant and anoxic. A measure of the "self-cleansing" capabilities of such a system is afforded by the fact that culture pond water will usually become relatively clear within 30 days if no further nutrient sources are received.

Carrying capacity of phosphorus and micronutrients from organic sources is less well-known, possibly in the region of 60 pounds in a 4 month period. The maximum achievable biomass (e.g. fish, shrimp, oysters, etc.) under the above conditions of enrichment appears to be approximately 2800 pounds per surface acre.

Obviously, a completely closed water system cannot maintain itself indefinitely under the influence of continual nutrient addition. Accumulation must occur, either in the form of animal and plant biomass or as free nutrient. The end result is death, decay, and deoxygenation. Therefore, removal of some of the accumulated energy is essential. This can be effected by harvesting fish, shrimp and oysters; by allowing migratory access (over the seaward shore of the waterway or at its terminal points); or by a combination of methods.

With the above estimates as a guide it becomes possible to calculate the nutrient consuming capability of a coastal interceptor waterway.

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1 1 acre surface area, average depth 4 feet, maximum depth 5 feet.

2 If calculated from wheat bran feedings of shrimp ponds, the value is 70 lbs. N. If calculated from high-protein pellets used in shrimp feeding the value is 85 lbs. N.

One would need to know the extent of the waterway surface and acreage of different types of developed uplands contributing nutrient laden runoff.

If sewage is treated and removed from the system by some means (e.g. deep well injection) then one will deal only with pollutants in surface runoff (i.e. grass clippings, leaf litter, pesticides, animal excrement, etc.). The volume of pollution from such sources is described by Browning (1972) who, in describing the character of urban runoff made the following comment (p. 5).

"If we were to assume that a two week period had elapsed since the last rain, and if the rain fell over a two hour period, then for the Miami example, the pollution potential of the dirt and dust in the streets would be 160 per cent of the raw sanitary sewage generated by the population during the same two hour time period. The same scale-up applies to the smaller towns and cities."

"This peak effect is a much more realistic way of looking at the pollution effects of urban runoff. The runoff does occur over a short time period and we are thus faced with an accumulation of dirt and debris impacting on the environment instantaneously and most definitely not spread over a period of accumulation. These peak or shock loads can cause severe pollution problems such as dissolved oxygen depletion due to BOD present, turbidity and discoloration from the suspended solids, large amounts of the major nutrients deposited into the waterbody and as previously indicated, sufficient bacteria so as to cause the water to be unfit for body contact sports."

The above quotation shows why we would also suggest that upland developments contain as many catchment lakes as possible, preferably with storage capacity sufficient to contain urban runoff resulting from rainfall of a given intensity, and with controllable connection to the interceptor waterway. Some pollution removal is thus accomplished in the lakes, solids are caught and the shock of runoff minimized. A secondary "polishing" of runoff water then occurs during its retention in the interceptor waterway.

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