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Weir Jetties at Coastal Inlets: Part 1, Functional Design Considerations

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PURPOSE: The Coastal and Hydraulics Engineering Technical Note (CHETN) herein provides information on the function and experience of weir jetty systems and discusses introductory design considerations. A companion CHETN, "Weir Jetties at Coastal Inlets, Part 2: Case Studies," summarizes selected weir jetty systems.

BACKGROUND: A weir jetty system is one of several methods for bypassing sediment at coastal inlets. The weir section, typically less than 304.8 m (1,000 ft) long, is a depressed region of the jetty that permits waves and the longshore current generated by wind, waves, and tide to transport sediments moving along the coast to enter a deposition basin located in the lee of the weir, thereby reducing the amount of sediment entering the navigation channel. A weir also acts as a breakwater and provides a semiprotected area for dredging the deposition basin. Another benefit is to allow flood currents to enter the inlet over the weir and through the channel during flood flow with subsequent channeling of ebb flows out the navigation channel between the jetties. The flood currents are weaker in the navigation channel, relative to the channel ebb currents, promoting net seaward sediment flushing. Thus less sediment enters the bay channels, where it is lost to the beach system if it settles in flood shoals in the bay or contributes additional volume in bay channels that require dredging. A potential benefit for new jetty systems is that the outer tips of the jetties may not need to extend seaward as far as a system without a weir jetty, because seaward sediment transport from the beach along the outside of the jetty is minimized (Seabergh and Lane 1977).

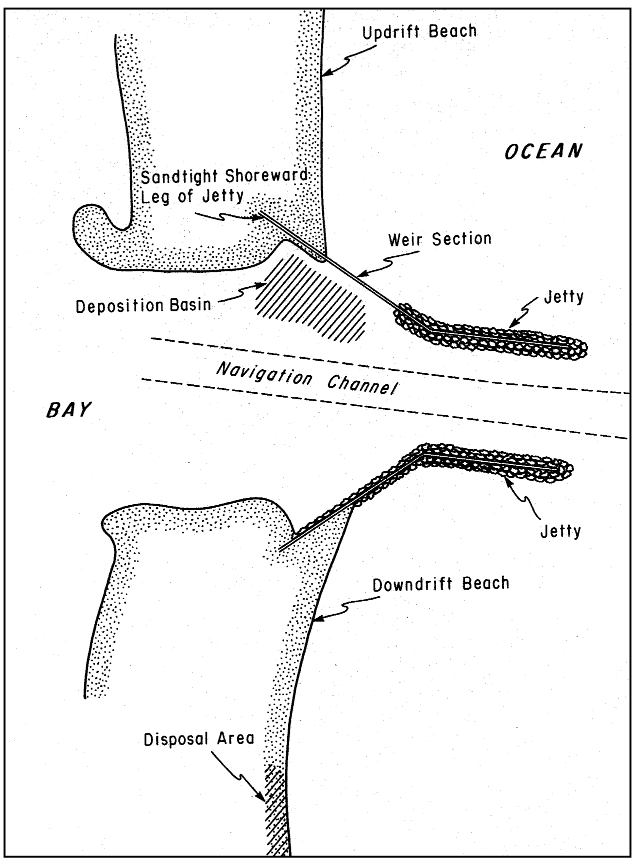

Figure 1. Typical elements of a weir jetty system

Figure 1 shows typical elements of a weir jetty system. The key elements of a weir jetty system are: (a) the navigation channel, (b) the jetty structures, (c) the weir section, (d) the deposition basin, (e) the updrift beach, (f) the downdrift beach, and (g) disposal area. Many variations of this example (Figure 1) are possible, depending on structure orientation, bathymetry, and presence of bottom features such as shoals and rock reefs.

WEIR JETTY DESIGN: This CHETN summarizes lessons learned from prototype and model studies of weir jetties. Discussion focuses on location of the deposition basin with respect to the shoreline, interior channel alignment, jetty orientation and typical sediment pathways; weir elevation and its controls on wave transmission and flow; weir length; composition of the weir; and weir function with respect to longshore sediment transport.

U.S. Army Corps of Engineers documents, in particular Weggel (1981), provide detailed design guidance. Another useful reference with observations from a general physical model study of weir jetties is Seabergh (1983b). Other summarizing references are in Weggel (1983) and Seabergh (1983a). The *Coastal Engineering Manual* (Headquarters, U.S. Army Corps of Engineers, 2002) also provides information.

DEPOSITION BASIN LOCATION AND SIZE: At many weir jetty sites, the shoreward edge of the deposition basin was placed at about the location of the low-water line of the adjacent beach. Murrells Inlet, SC, is an example of this. Under normal conditions, sediment transport is along the shoreline at the landward end of the weir, and sediment moves along the shoreline landward of the basin creating a spit that elongates toward the interior channel or into the main navigation channel. Flood flow, together with waves and wave-generated longshore currents over the weir, develop the spit feature and curve it around the inlet shoulder. Ebb currents shear off the sediment from the wrapping spit, and sediment moves into the channel side of the basin (early ebb flow was aligned with the basin while currents exited over the weir, which shut off once the midtide level of the weir was reached); then, some sediment is carried seaward along the navigation channel to the ebb shoal (Figure 2). The interior spit was formed during construction of the jetties before the south jetty was built, and stronger wave energy wrapped the spit tighter into the interior channel.

Ebb currents directed toward the deposition basin are expected to decrease as the tide level falls. Because the weir elevation at Murrells Inlet is at mean tide level, ebb flows are concentrated in the navigation channel during the later stages of ebb flow. To prevent sediment from passing over the weir and bypassing the deposition basin on the shoreward side once inside the weir, a possible solution would be to move the deposition basin landward relative to the weir, or in the case of an existing weir, cover a portion of the landward edge of the weir with stone, creating an offset with respect to the basin. Figure 3 illustrates this setback of the basin. Also shown in Figure 3 is that for more energetic wave conditions, suspended sediment could pass over the more seaward portion of the weir and settle in the deposition basin. The location of maximum sediment transport over the weir is at the location of wave breaking on the seaward side of the weir. This figure was derived from laboratory studies (Seabergh 1983b). For small or typical waves, sediment would wrap landward into the basin. Because of greater basin depth, the sediment will be constrained to the basin. As the deposition basin fills and becomes shallower, there will be a tendency to develop a sediment pathway that will extend to the rear of the basin and out toward the bay and interior channels. This potential problem can be alleviated by regular basin dredging. If the dredging schedule is irregular or the transport episodic, a revetment wall can be constructed at the back of the basin for confinement. Problems with a confining wall may relate to potential scour if a wall terminates adjacent to the navigation channel, and it also could be a hazard to navigation.

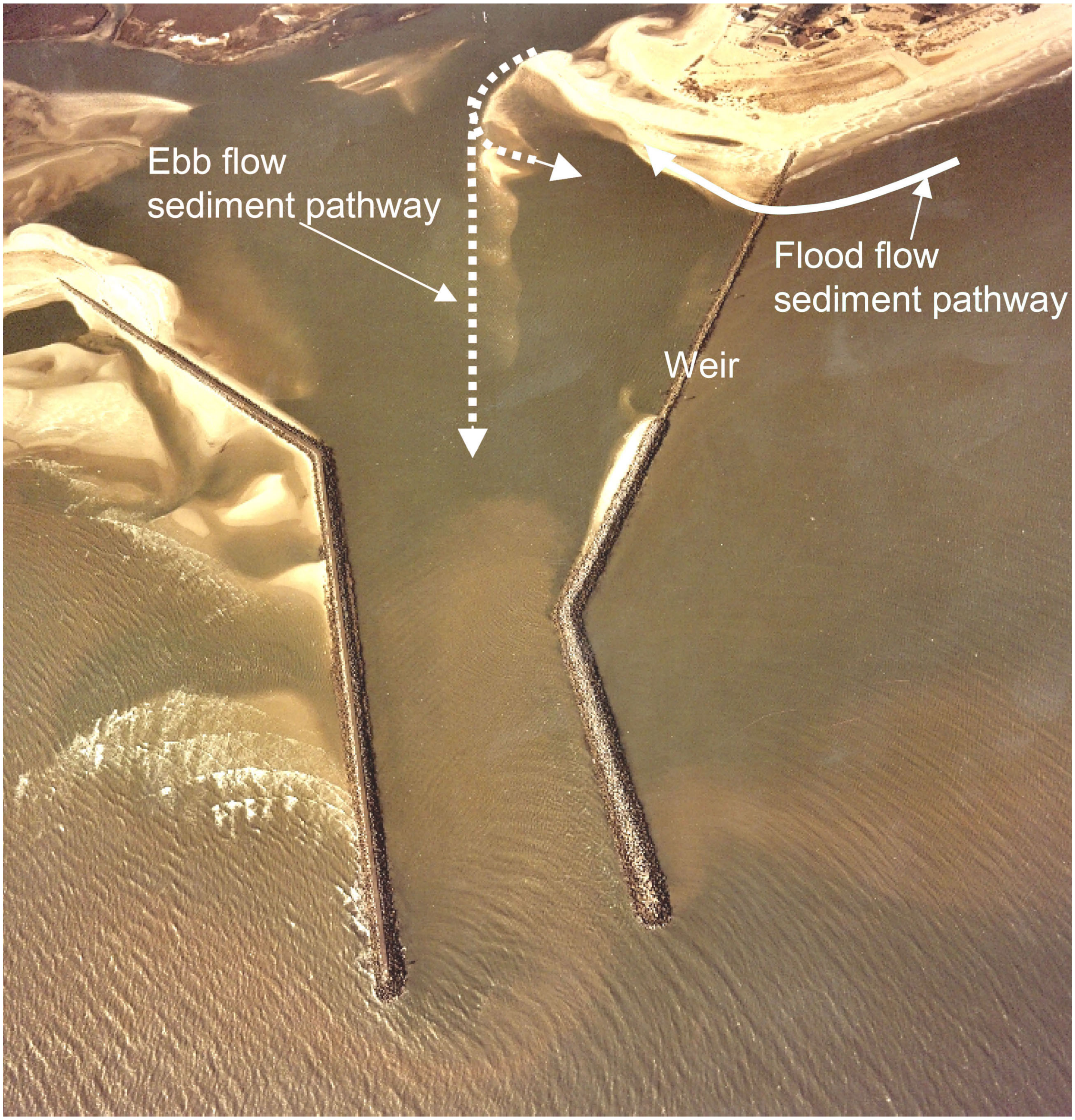

Figure 2. Sediment pathway for typical wave conditions at Murrells Inlet, SC

Deposition basin size is usually based on how often dredging can be scheduled and the estimated longshore sediment transport rate. The optimal design of a basin and associated structures is intended to capture the net longshore transport volume, as described in the next section. (Such capture of sediment assumes the basin is placed on the side of the inlet where the greater amount of longshore sediment volume originates). Capturing only the net longshore transport volume will facilitate reduced sediment handling. The recommended procedure is to design for some amount greater than the yearly net, but less than the yearly transport directed toward the basin. This value may then be doubled to provide reserve if, for some reason, a dredging cycle is missed. Ways to achieve capture of only the net transport are described in the next section.

DESIGN WITH RESPECT TO NET LONGSORE SEDIMENT TRANSPORT: Ideally, a weir jetty system should provide a deposition basin that can contain 1 to 2 years of the net longshore transport. In order to capture only the net longshore transport rather than the total right-to-left transport (use Figure 3 as a reference), the weir should be less transmissive than if the longshore transport were unidirectional (right-to-left) and in this case it is desirable to capture all the sediment in the basin. In order to accomplish this, the difference between the right-to-left sediment and net sediment volumes must be temporarily stored where it is available to be moved back during left-to-right movement. In other words, a portion of the right-to-left movement must be prevented from entering the deposition basin. Offsetting the weir seaward of the original shoreline may be beneficial with regard to the creation of a temporary fillet region that fills when the longshore sediment transport is directed from right to left in Figure 3. After the fillet has grown to the shoreward edge of the weir, sediment will begin entering the deposition basin. Capturing the net transport minimizes sediment-handling costs. If right-side jetty orientation will permit wave approach to move sediment out of the fillet region back upcoast, this is possible. If the right-side jetty creates a large shadow zone so sediment does not move left-to right out of the fillet, a possible upcoast groin may hold sediment, so it is available for transport to the right. Figure 4 illustrates this approach.

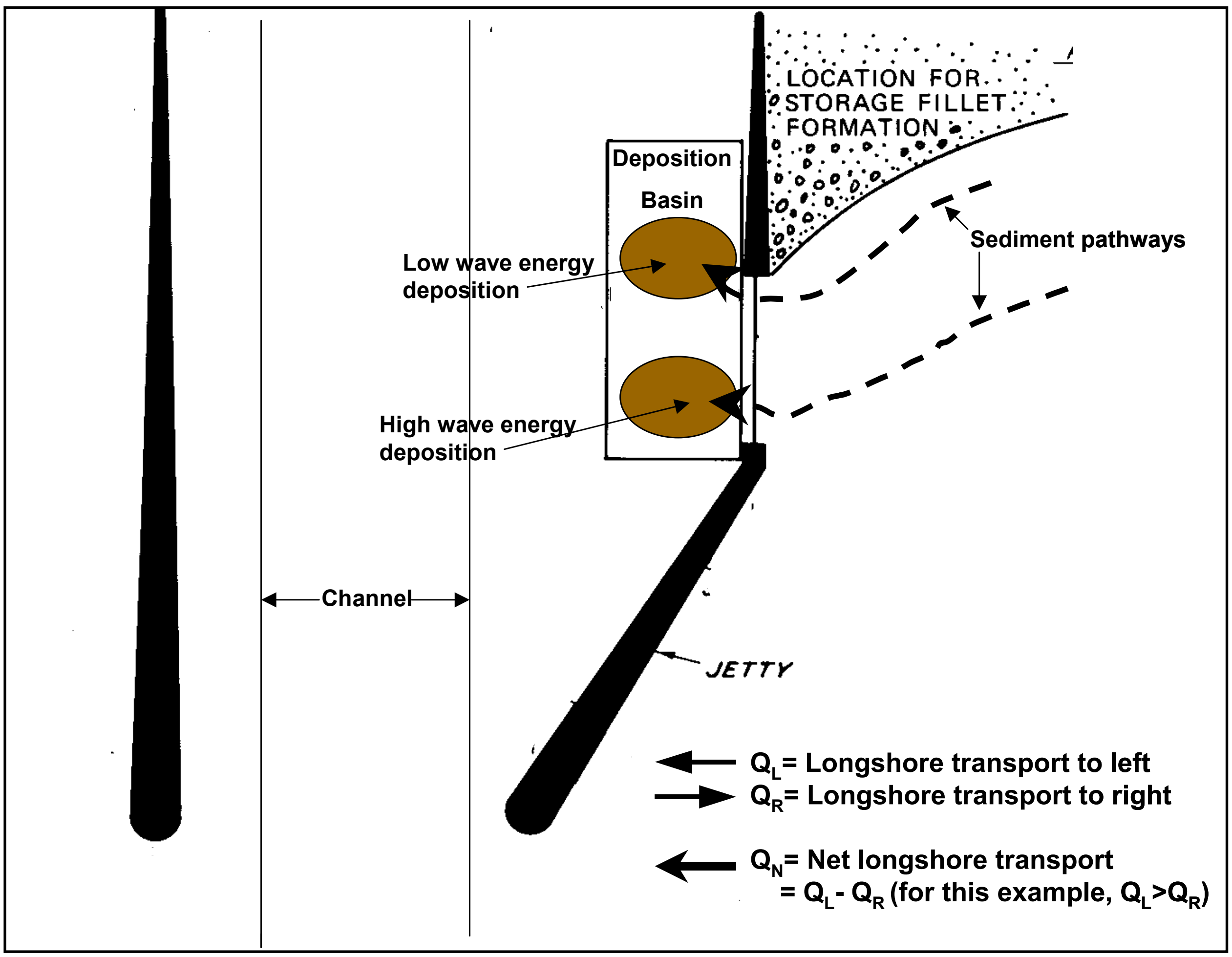

Figure 3. Sediment pathways over weir for low and high wave conditions

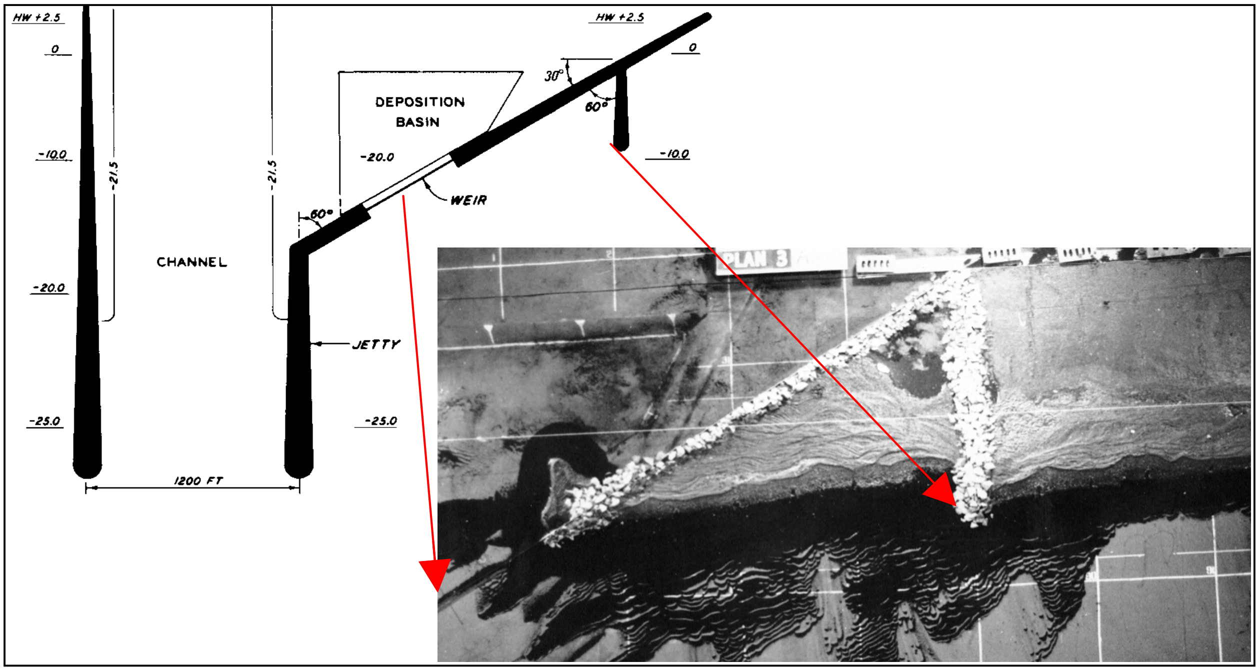

Figure 4. Placement of a groin updrift of weir jetty to aid in capturing only net sediment volume in deposition basin

In the discussion in the previous paragraph, designing weir sections to capture and bypass only the net transport is reasonable guidance if there is a relatively greater volume of sediment approaching from the predominant direction. In the case of balanced left-to-right and right-to left transport, it may not be desirable to construct a weir jetty, unless sediment is moving seaward along the jetty to the tips of the jetty. Then, to reduce sediment pathways to the jetty, a weir might be constructed. However, other methods may be employed to prevent sediment from entering the channel, such as jetty spurs on the seaward side of the jetty, or groin systems to keep sediment reaching the shadow of the jetty, so the sediment will be moved away from the jetty when wave direction changes.

Consideration of bypassing of sediment to the downdrift beaches should be part of a weir system. The regular dredging of the deposition basin can provide sediment for this bypassing. Such bypassing maintains continuity in sediment movement and integrity of the downdrift beach. There may be some natural bypassing around the jetty tip during larger storm conditions, also. Planning of weirs, spurs, and groins is done as part of a sand-sharing system approach that involves means and costs for bypassing the appropriate volume of material.

WEIR CONSTRUCTION MATERIAL: Weirs have been constructed from concrete sheet piles, wooden piles, and rubble rock. Each of these materials can be set to any required elevation after examination of the necessary considerations to determine height. The typical crest elevation range is between low water up to about midtide. Concrete and wooden piles can be set for a more precise elevation than rubble rock weirs. Murrells Inlet, SC, with a rubble rock weir, functions well. The elevation of rubble rock weirs can more easily be adjusted, if necessary, than concrete or wood pile weirs. Also, wave reflection is less for rubble rock than for the sheet pile. Wave reflection may increase undesirable wave energy in the channel and may alter sediment pathways on the sea side of the weir as it approaches the structure. Seabergh (1983a), in monochromatic wave model studies (which would tend to emphasize the effect), noted offshore movement of sediment before it reached the weir section due to the interaction of incident and reflected waves.

One other approach that would function as a weir, but offer greater wave protection is a highly permeable jetty. Over time, permeability might be adjusted by adding additional stone or removing stone.

WEIR ELEVATION: Weir elevation is determined from a combination of leading parameters including tide range, wave height, inlet bay response (which will define timing of maximum ebb and flood flows with respect to tide elevation) and magnitude of left- and right-directed longshore sediment movement in the vicinity of the weir.

The weir elevation must allow sediment to pass over the weir into the deposition basin. A low-crest elevation would maximize this; however, wave energy would be relatively greater than if the weir were higher. Significant wave transmission would introduce wave energy into what is typically protected water for a regular jettied inlet. Multiple wave directions (incident and reflected) inside the entrance could be a hazard to navigation. Probably more significantly, the weir provides protection for dredging activity in the deposition basin and minimization of downtime. Weggel (1981) describes wave transmission formulas to estimate wave height in the deposition basin.

Weir elevation with respect to inlet hydrodynamics is a subtle but key parameter for timing of maximum flows and flow volume over the weir. Inlets with a small bay tide range with respect to the ocean tide range have maximum currents in the inlet at high and low water. Therefore, the flood current would be strongest at high water, when wave energy would be likely to be greatest. A weir at an inlet such as this should be relatively higher than for an inlet that has a bay that nearly completely fills. If the inlet bay tide range is nearly as great as the ocean range, then maximum flood and ebb currents occur at midtide level. Probably the greatest care with respect to currents would be in regard to the direction of ebb flow. Presence of a strong ebb current directed towards the weir may set up a gradual cutting of the region between the deep deposition basin and the shallower water that separates the basin and the channel. Eventually, the channel might be pulled through the basin causing dispersal of sediments coming over the weir.

WEIR LENGTH: Early weir designs called for long weir sections. This was thought necessary to prevent a storm from bringing in so much sand as to impound the weir and isolate it from the littoral system. To date, complications associated with storms have not been documented. As noted in the discussion on basin location, most of the sediment crosses over the weir at its intersection with the shoreline. For larger waves, some sediment is transported over the weir at the breaker line with the aid of flood tidal currents and longshore currents generated by breaking waves. If the breaker zone is located beyond the seaward limit of the weir, the sediment will likely be diverted along the outer portion of the jetty and enter the navigation channel as a tip shoal. Weir length is a tradeoff between wave protection in the channel and deposition basin area and the possibility of diverting significant amounts of sediment seaward. Local beach slope is also a factor in determining how far seaward the weir should extend. Flatter slopes will need longer weirs to prevent too much sediment from bypassing the weir with a potential to enter the channel.

JETTY DESIGN AND WEIR AND BASIN LOCATION: Ideally, the weir should be located at some distance from the navigation channel, though this must be tempered by the need for a dredge to access the deposition basin. If a new weir and new jetties are being designed, once the jetty system is constructed, adjustments to channel orientation may take place, because waves and currents may be redirected. Laboratory studies (Seabergh 1983b) noted that jetties with the outer legs parallel as opposed to those with flared outer sections promote milder wave conditions in the deposition basin.

CONCLUSIONS: There are multiple factors to consider in the design of a weir jetty. This document discusses weir jetty system processes and the controlling factors of weir elevation and length, together with the location and size of the associated deposition basin. A companion CHETN (Seabergh and Thomas 2002) describes several case studies involving weir jetties. In addition to design guidance as described here and in the references, physical and numerical models are available to develop alternative designs and design optimization for site-specific conditions.

ADDITIONAL INFORMATION: Questions about this technical note can be addressed to Mr. William C. Seabergh (601-634-3788; e-mail: William.C.Seabergh@erdc.usace.army.mil. For information about the Coastal Inlets Research Program, contact the Program Manager, Dr. Nicholas C. Kraus at Nicholas.C.Kraus@erdc.usace.army.mil. This technical note should be cited as follows:

> Seabergh, W. C. (2002). "Weir jetties at coastal inlets, Part 1: Functional design considerations," ERDC/CHL CHETN IV-53, U.S. Army Engineer Research and Development Center, Vicksburg, MS.
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