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Jetty Spurs at Coastal Inlets for Reduction of Navigation Channel Shoaling

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PURPOSE: The Coastal and Hydraulics Engineering Technical Note (CHETN) herein provides information on the effect of a jetty spur on the beachside circulation near a coastal inlet jetty and discusses introductory design considerations relating to alteration of water and sediment circulation near the beach side of jetties. Examples are presented from field and laboratory studies.

BACKGROUND: A jetty spur may be defined as a short structure added to a jetty that flanks a navigation channel through an inlet. The spur will typically be nearly perpendicular to the jetty, but may be oriented at some angle with respect to the jetty in the range of 45 to 90 deg. The spur may be added on the beach side of a jetty to prevent sediment from entering the inlet or may be placed on the channel side to divert the tidal current away from the jetty to reduce scour and possible jetty instability. This CHETN discusses spurs placed on the beach or sea side of a jetty as shown in Figure 1.

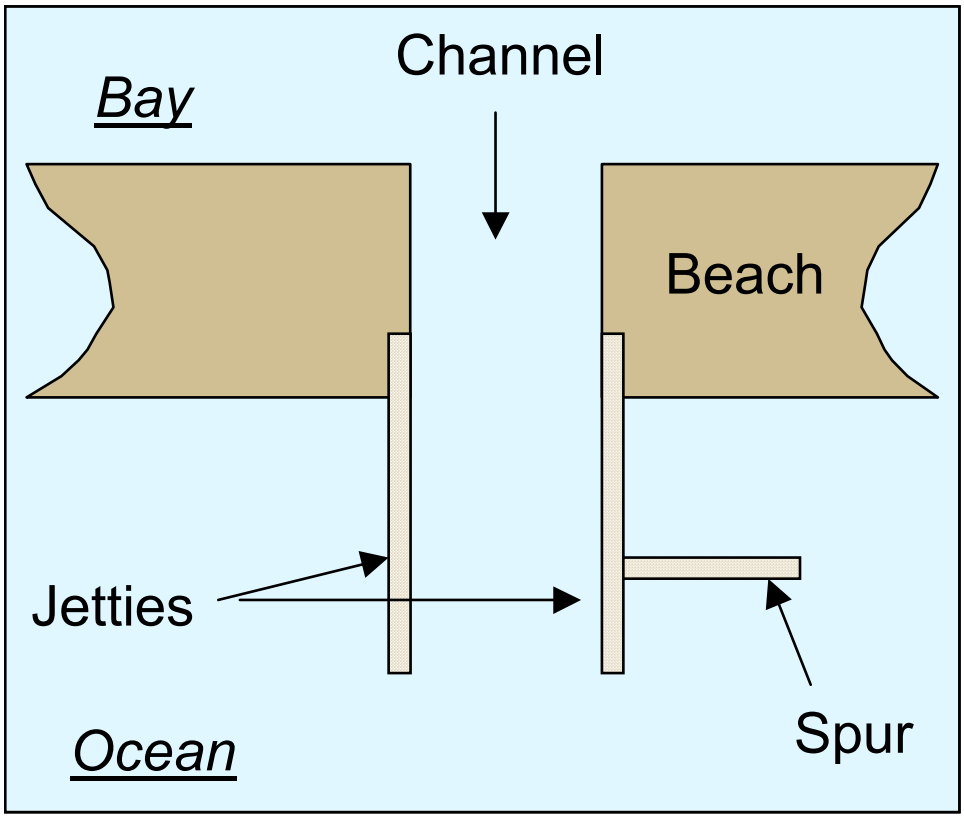


Figure 1. Example of a jetty spur

A jetty spur can be used to reduce sediment from shoaling navigation channels at coastal inlets. The spur acts as a deflector of sediment-laden longshore currents developed from breaking waves, wind and tidal current. Spurs are usually constructed of rock rubble similar to the jetty it is connected to (Figure 2). The spur's basic function is to alter the path of the sediment-laden longshore current and contain the sediment, keeping it away from the navigation channel and possibly aiding its return to the beach system through rediversion of the longshore current from going around the ends of the jetties to a 180-deg rotation of the current vector.

Figure 2. Example of spur construction at Siuslaw River, OR

Typically, longshore and tidal currents are turned seaward as they approach a coastal inlet jetty. Flow is usually seaward along the side of the jetty and typically is drawn into the channel region during flood flow. The region on the sea side of the jetty is normally shallow because sand accumulates against the jetty. This sediment moves around the jetty tip and may encroach on the navigation channel. Figure 3 shows the flood tide entering Grays Harbor, WA. Estimated sediment transport coming into the inlet from this region is 370,000 cu m/year (Kraus and Arden 2003). Figure 3 also indicates that there is some current movement towards the jetty during ebb flow (yellow arrows). A submerged 500-m-long jetty spur (Figure 4) has been proposed as one alternative to limit this large volume from entering the channel and also to protect the beach behind it.

Spurs also act as a breakwater and provide wave height reduction along the local shoreline. If added to a weir-jetty system (for information about weir-jetties see Seabergh 2002), it may provide wave reduction for dredging operations in the deposition basin. Another possible benefit for a new jetty system with spurs 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 transport along the jetty is minimized (Bottin 1981).

A spur jetty may also be included as part of a beach nourishment plan to aid in maintaining the sediments in the beach area (Walther and Dombrowski 1999). A spur could be placed on a downdrift jetty as well as on the more typical updrift jetty if it was thought that the nourished downdrift beach might have a tendency to locally feed back along the downcoast jetty towards the navigation channel.

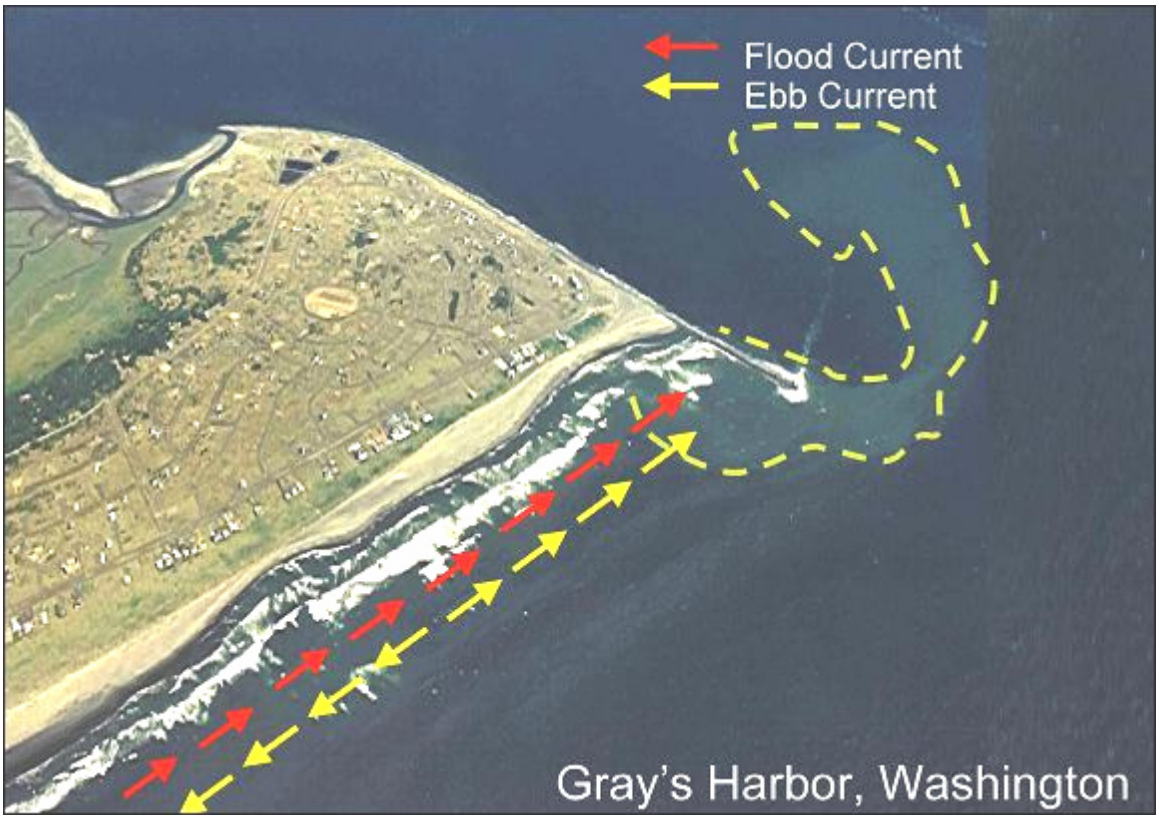


Figure 3. Sediment-laden longshore currents moving around Gray's Harbor north jetty

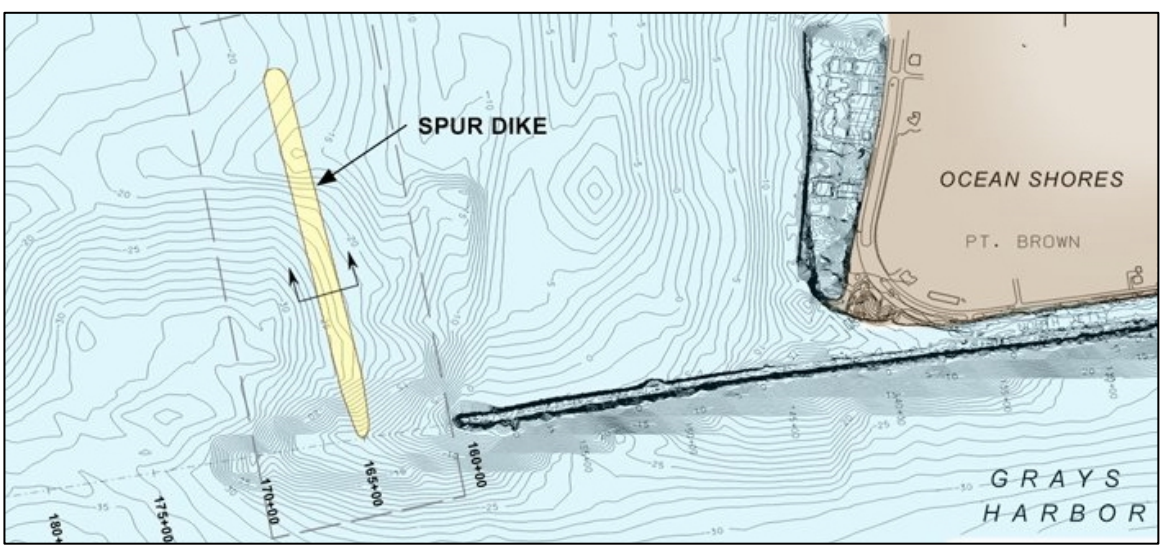


Figure 4. Possible spur design for Grays Harbor. The crest elevation for this spur was proposed to be -10 ft relative to mean lower low water datum

EXISTING SPUR JETTIES: Spur jetties have been constructed at Bakers Haulover Inlet, FL (Figure 5a), Ft. Pierce Inlet, FL (Figure 5b), at Siuslaw River Inlet, OR (Figure 5c), and Shark River, NJ (Figure 5d). The north jetty at Bakers Haulover Inlet (Figure 5a) shows a spur placed at the end of the jetty. The south jetty at Bakers Haulover (Figure 5a) also appears to be a form of spur due to its outward flare. The shoreline response on both sides of this inlet is similar. Note that the spur at Ft. Pierce (Figure 5b) is on the downcoast side of the inlet where the shoreline is offset landward from that of the shoreline at the top of this figure. Its construction was associated with a beach-fill project placed on the south beach (bottom portion of the photo) and prevents beach fill from moving into the navigation channel.

a. Bakers Haulover, FL

b. Fort Pierce, FL

c. Siuslaw River, OR

d. Shark River, NJ

Figure 5. Examples of jetty spurs

The spurs at the Siuslaw River were designed to divert sediment back to the beach on both sides of the jetty system. A monitoring study of this project by Pollock et al. (1995) indicated that spur implementation onto the existing jetties was successful in reducing channel maintenance significantly. The Shark River spur is associated with a beach fill on the downcoast side of the inlet. The beach extends to the spurs' connection with the jetty.

Table 1 summarizes the characteristics of these spurs with regard to length, angle with the jetty, and location along the length of the jetty. Typically spurs are located about 75 percent of the jetty length from the local shoreline. The Bakers Haulover jetty spur is at the end of the jetty.

Table 1
Existing Spur Jetty Installations in United States

Location	Spur Length, m	1) Spur Distance from Local Average Shoreline, m 2) Length from Jetty Tip to Local Average Shoreline, m	Ratio of Spur Distance from Average Shoreline to Length from Jetty Tip to Average Shoreline	Ratio of Spur Length to Spur Distance to Average Shoreline	Angle (deg) of Spur Relative to Jetty (opening seaward)
Siuslaw River, OR	North jetty spur - 122 or 86 m perpendicular to jetty	1) 480 2) 650	0.74	0.18	45
	South jetty spur - 122 or 86 m perpendicular to jetty	1) 640 2) 800	0.80	0.13	45
Shark River, NJ	North jetty spur - 50	1) 120 2) 160	0.75	0.42	90
Ft. Pierce Inlet, FL	South jetty spur - 60	1) 220 2) 350	0.63	0.27	90
Bakers Haulover Inlet, FL	North jetty spur - 35	1) 60 2) 60	1.00	0.58	90

CHARACTERIZATION OF REGION ADJACENT TO JETTY: The sea side of a jetty is usually shallower than the adjacent natural beach due to accumulation of sand along the structure. This shallow fillet region provides a platform for sediment movement toward the jetty tip. Figure 6 shows a sampling of slopes adjacent to the jetty and at a 45-deg angle away from the structure. Slopes are typically in the range of 0.1 to 1.0 percent on the East and Gulf coasts and a slightly greater range band of 0.3 to 2.0 percent slope on the West and Great Lakes coasts, for this limited sample. Typical natural beach slopes are in the range of 2.5 to 10 percent slopes. The slopes at an angle that bisects the shoreline and the structure are similar, for the most part, to the slopes along the structure, indicating a degree of spatial extent of this fillet form. The shallower water depths will place breaker lines farther seaward along the jetty, so these smaller depths require spurs to be farther seaward, and, as shown in Table 1, spurs have typically been located seaward at least 75 percent of the jetty length.

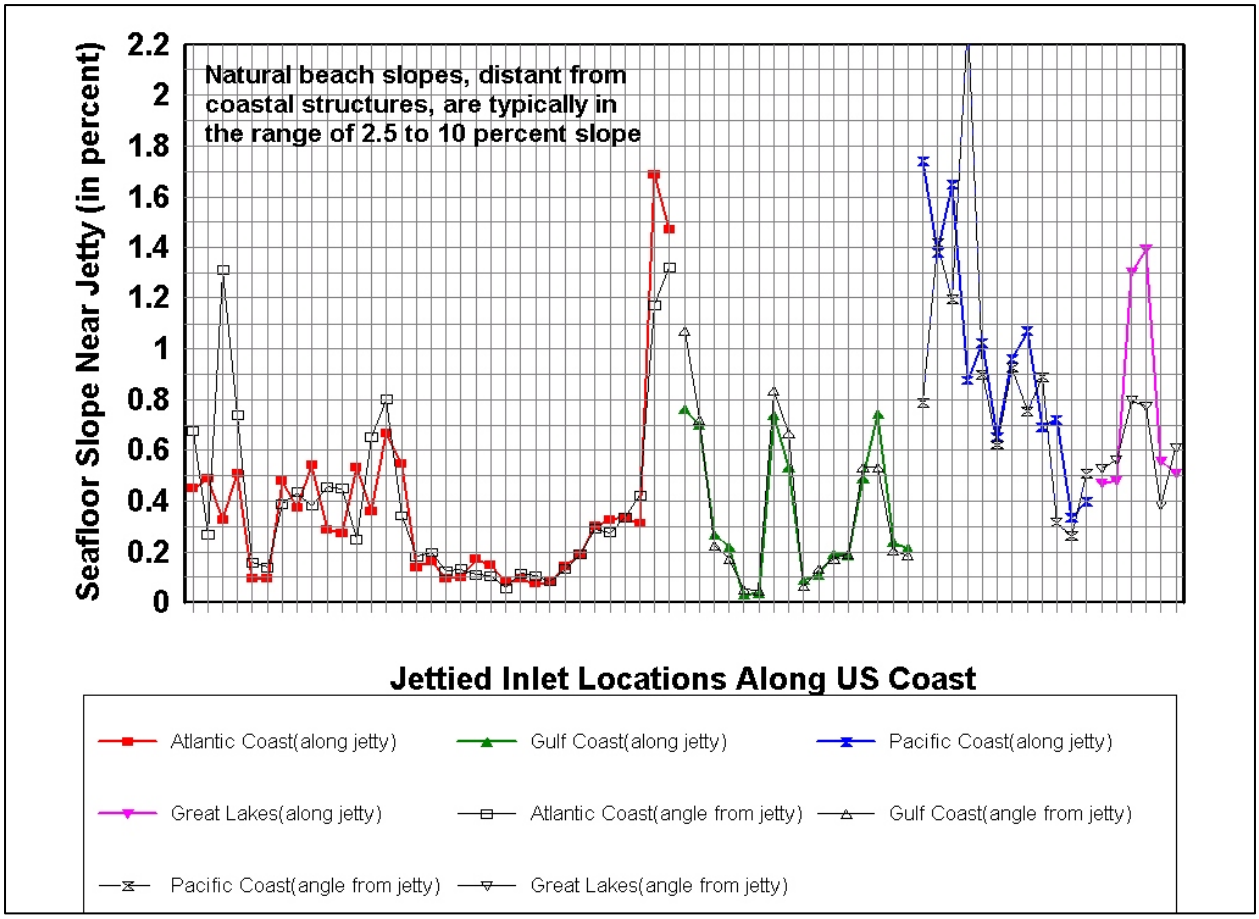


Figure 6. Seafloor slopes adjacent to jetties

Another factor in characterizing the circulation of water and sediment on the sea side of the jetty is the resultant action of seaward contours on wave approach. There may be refraction over the seaward contours that can control circulation patterns adjacent to the jetty. For example, at Ocean Shores, WA (beach region adjacent to Grays Harbor), offshore contours refracted waves such that a counterclockwise circulation cell (meaning landward flow along the jetty) exists for certain wave direction approaches (Figure 7). This complexity calls for detailed wave transformation study.

Figure 7. Bathymetric control of waves creating counterclockwise circulation near Grays Harbor north jetty

SPUR JETTY DESIGN CONSIDERATIONS: Governing factors for spur design are location along the jetty, spur elevation, spur length, distance from the shore, beach slope, water depth, length, angle with structure, crest elevation, if submerged or emergent, width of crest if submerged or overtopped, and wave climate.

Spur Location. As noted from Table 1, existing spurs have been placed from about 60 percent of the jetty length from the shoreline to 100 percent, with 75 percent typical. This location will depend on local conditions near the jetty, such as bottom slope, wave climate, and proximity of the shoreline. These will determine where waves are breaking and where sediment transport will be greatest. For short jetties or a flat bottom slope, wave breaking can occur seaward of a jetty system and sediment transport will be strongest in many cases at the location of the breaker. A spur may not be as useful if this situation is frequent, as there is small frequency to intercept/divert sediment pathways. Figure 6 shows typical bottom slopes along the U.S. coasts near inlet structures.

Spur Elevation. Spur elevation might typically be expected to be similar to the jetty it is attached to. Dependent on wave climate, the spur can serve as a fishing platform if access is provided. The Fort Pierce spur has an asphalt walkway. This may be seen at: *http://www.visitfortpierce.com/Fort_Pierce_Jetty.htm#pano*. As mentioned previously, submerged spurs have been proposed (Grays Harbor). A reef-type spur was examined in the laboratory (discussed later) and may provide similar benefits as a surface-piercing spur, yet is less costly.

Spur Length. A spur should be long enough to promote a diversion of flow from along the jetty to keep sediment in the nearshore area rather than move offshore towards the jetty tip. Some

physical model results discussed later will illustrate this. Field data from Table 1 were used to compose the plot in Figure 8. A S/L ratio (S is spur length and L is distance from spur to the local average shoreline) is plotted for each field site. A shoreline response ratio was determined from the ratio of distance from the local average shoreline (defined as the shoreline within 300 m of the jetty) to the immediate shoreline at the jetty, divided by the distance from local average shoreline to the spur. Therefore, a shoreline response of 1.0 means the shoreline has reached the spur. This is seen for Bakers Haulover and Shark River, with S/L ratios greater than 0.4. The others have S/L less than 0.4 and shoreline responses much less than 1.0. In this simplified approach that may neglect other important parameters, such as beach slope and wave height, a line was drawn at S/L = 0.4 to divide from full shoreline response and a partial shoreline response. Typically, one would not want the shoreline to reach the spur in order to keep the potential for sand transport to the sea side of the spur minimal. If the wave climate is not too energetic or if the spur is on the downcoast side of a jetty system where sediment is bypassed to, it might be acceptable. On the other hand, one needs to have a long enough spur to create a deflection of the longshore currents as seen in physical model experiments discussed later.

Spur Construction. Care must be taken in the structural design of a spur. Little design guidance is available. Issues involved would include the effect of a mach stem wave increasing wave height at the junction of the spur and the breakwater, wave focusing at the junction, the placement of stone at the transition region between jetty and spur, and the possibility of scour at the spur tip. Careful structural design would be required, especially in energetic wave climates. The site-specific nature of the local bathymetry and structure-wave interaction might require a model investigation.

PHYSICAL MODEL EXPERIMENTS OF SPURS: The field monitoring study of the Siuslaw Inlet project by Pollock et al. (1995) indicated good agreement with physical model results of Bottin (1981, 1983). The field monitoring indicated that at high water the flow patterns were circular eddies (Figure 9a) and there was a strong seaward-flowing rip current along the jetty. At lower tide stages, and dependent on wave height, there might be an “S”-shaped flow pattern (Figure 9b). The results were similar in the physical model study of Bottin. Based on this information it may be noted that wave height, tide stage, and water depth are probably significant design parameters for determining the hydraulic response of spur jetties and most likely the sediment circulation response.

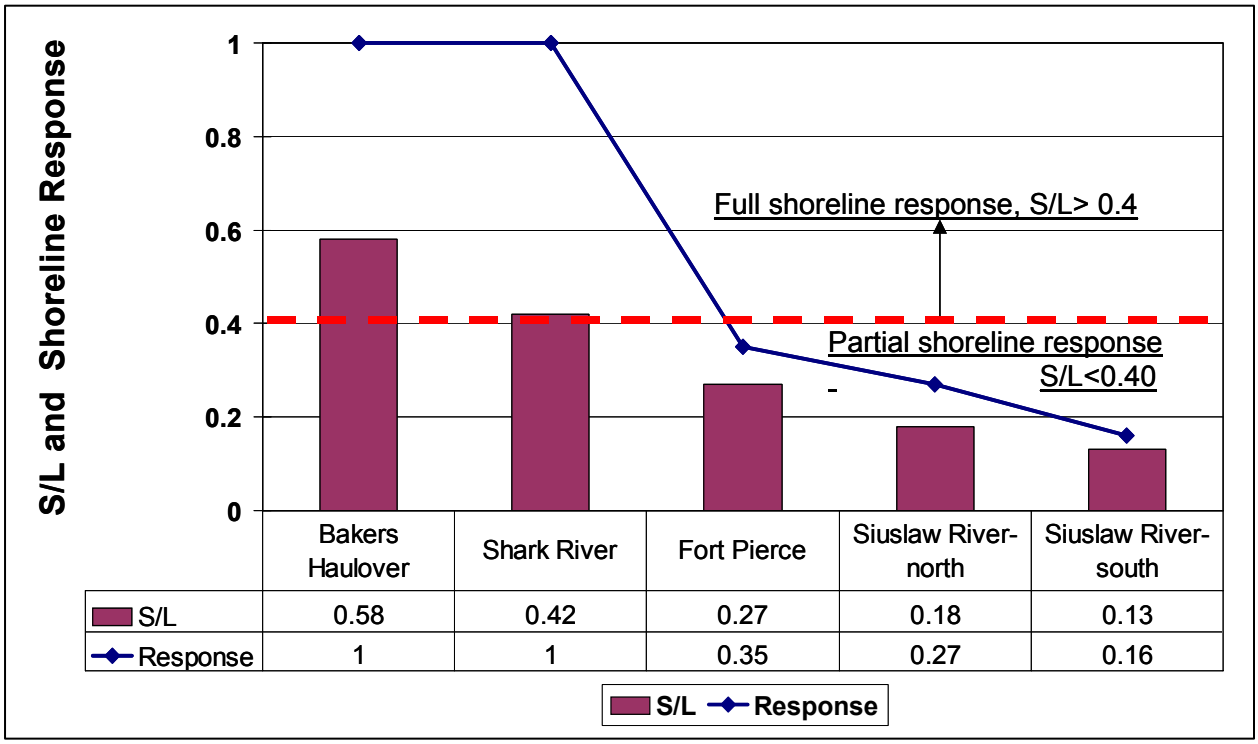
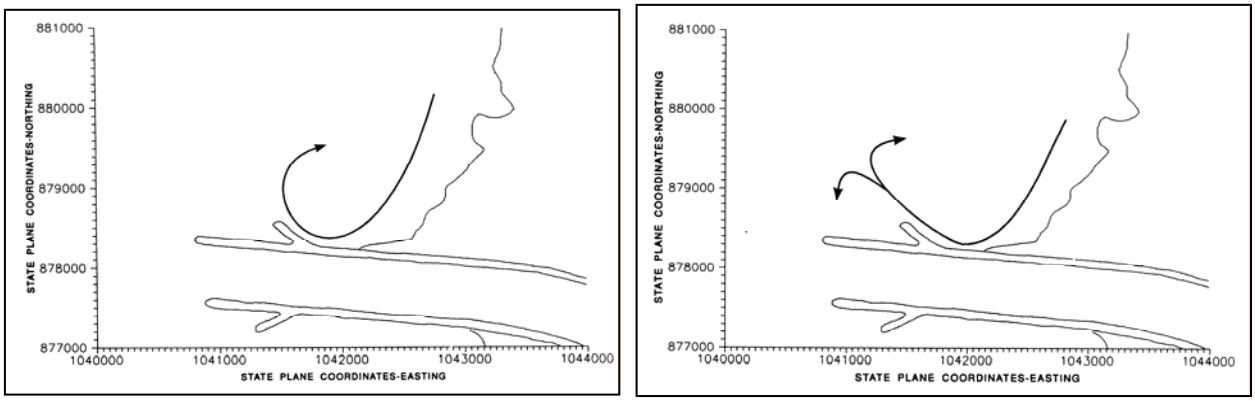


Figure 8. Spur length (S) to distance from spur to local average shoreline (L) ratio plotted with shoreline response, which is ratio of (a) distance from local average shoreline to immediate shoreline at jetty to (b) distance from local average shoreline to spur



a. High tide b. Low tide

Figure 9. Currents deflected by Siuslaw River jetty spurs (from Pollock et al. 1995)

A pilot study of spurs was initiated in the Coastal Inlet Research Program physical inlet model. The physical model facility (Seabergh 1999) is a large experimental basin (46 m wide by 99 m long) with an idealized inlet and smooth offshore contours (Figure 10). Short-period waves and tidal currents can be simulated in this facility. A scale of 1:50 is applied to this generic inlet configuration. Twin parallel jetties were placed at the inlet entrance, with three spur conditions examined. Wave height, wave period, and tidal current were varied to produce different surf and alongshore-current conditions. Experiments included measurement of wave height, measurement of currents in the region on the sea side of the jetty with dye and acoustic-Doppler current meters, and examination of sediment pathways with a lightweight sediment tracer. Initial or base

experiments collected data for the parallel jetty configuration. A short spur was then constructed (46 m in length, if a 1:50 model to prototype scale is applied). A long spur of 76 m was also constructed and a submerged version of this long spur was made by reducing the crest elevation to mean low water while experiments were conducted at a +1.5-m elevation (again assuming a 1:50 model scale).

Figure 11 compares current patterns for these configurations. Red and green dye trace the current patterns created by breaking waves and a flood tide maximum current. The deflection of the wave-generated current by spurs in an upcoast direction is seen before it reverses direction seaward of the spur, as the flood current entrains it. The submerged spur also deflects the longshore current (Figure 11, bottom right). Waves break on the submerged spur, effectively deflecting the longshore current and functioning similar to the emergent spur. A submerged spur is much less costly to construct.

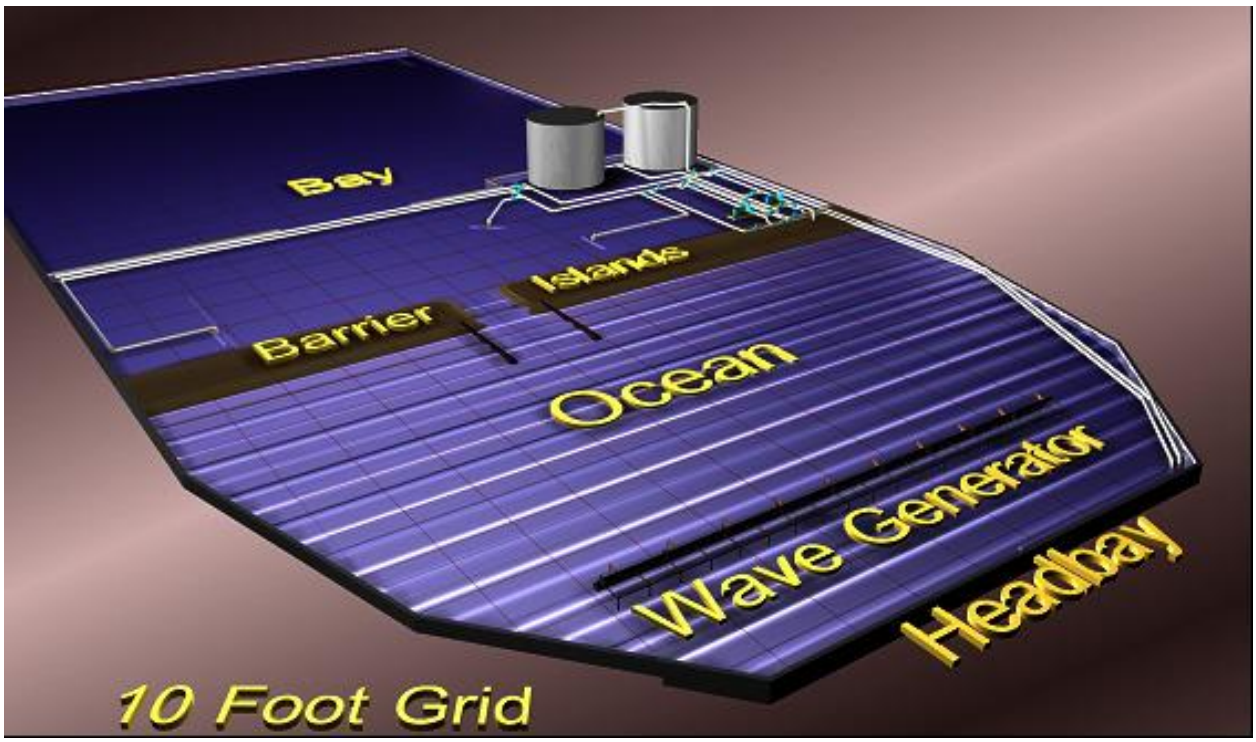


Figure 10. CIRP idealized inlet physical model

Figure 12 shows the results of sediment tracer experiments for the same wave and tidal current conditions. The no-spur arrangement permits the tracer to enter the channel region. The short spur reduces this transport somewhat and the longer spurs achieve better results, holding sediment in the region of the shoreward side of the spur.

Figure 13 shows detailed velocity fields in the region near the jetty for the four previously discussed model setups. An energetic wave (11-sec period, 3-m height) plus a maximum flood current situation in the channel exist for these plots. Interesting to note are the current deflections along the spurs and the increase in darker (slower currents) area regions, though changes are small.

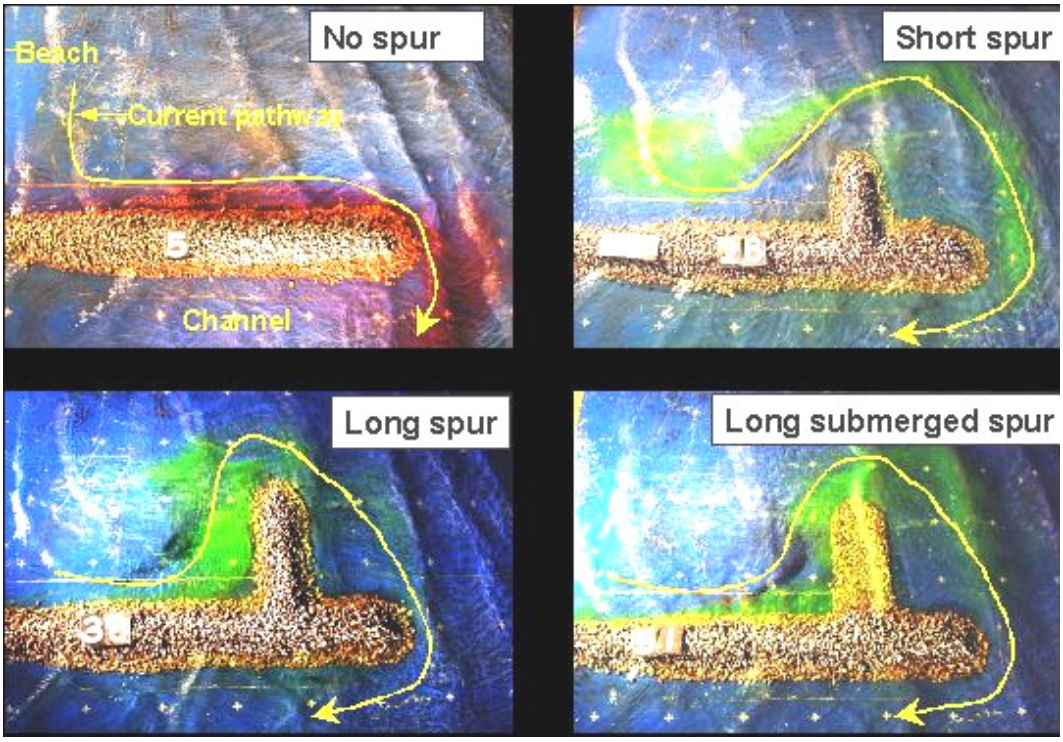


Figure 11. Dye movement of wave-generated and tidal currents approaching jetty for a 2.4-m, 10-sec wave and maximum flood current of 1.4 m/sec in channel.

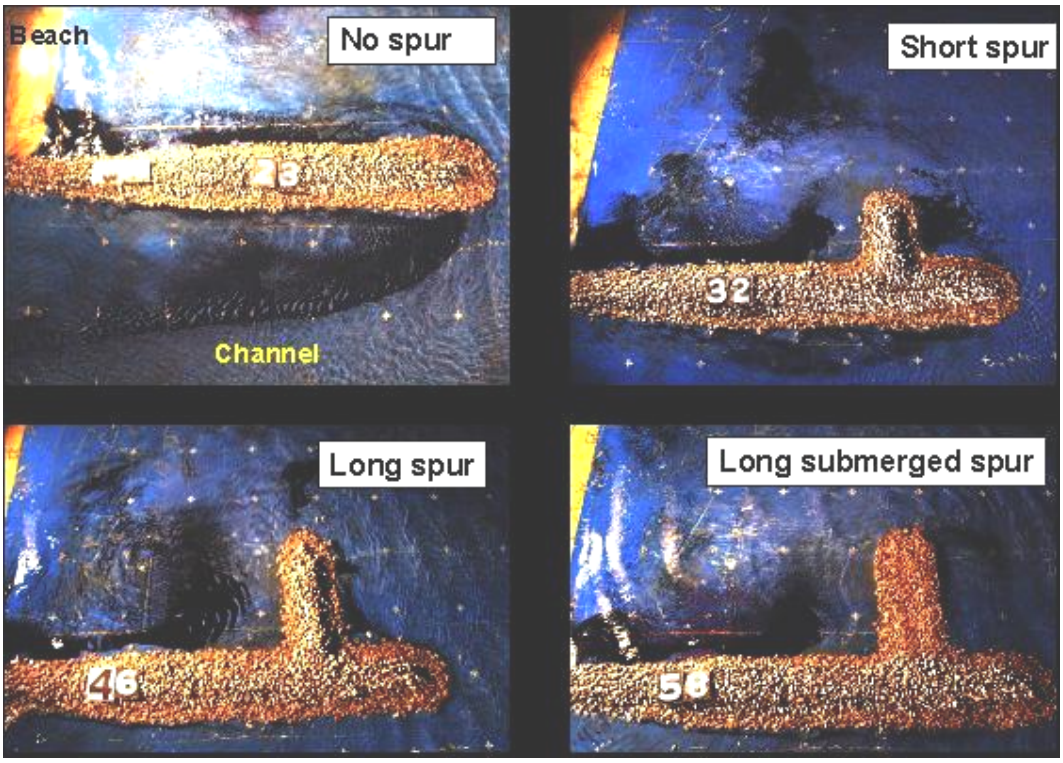


Figure 12. Sediment tracer movement due to 3-m, 15-sec waves, with maximum flood current of 1.4 m/sec in channel

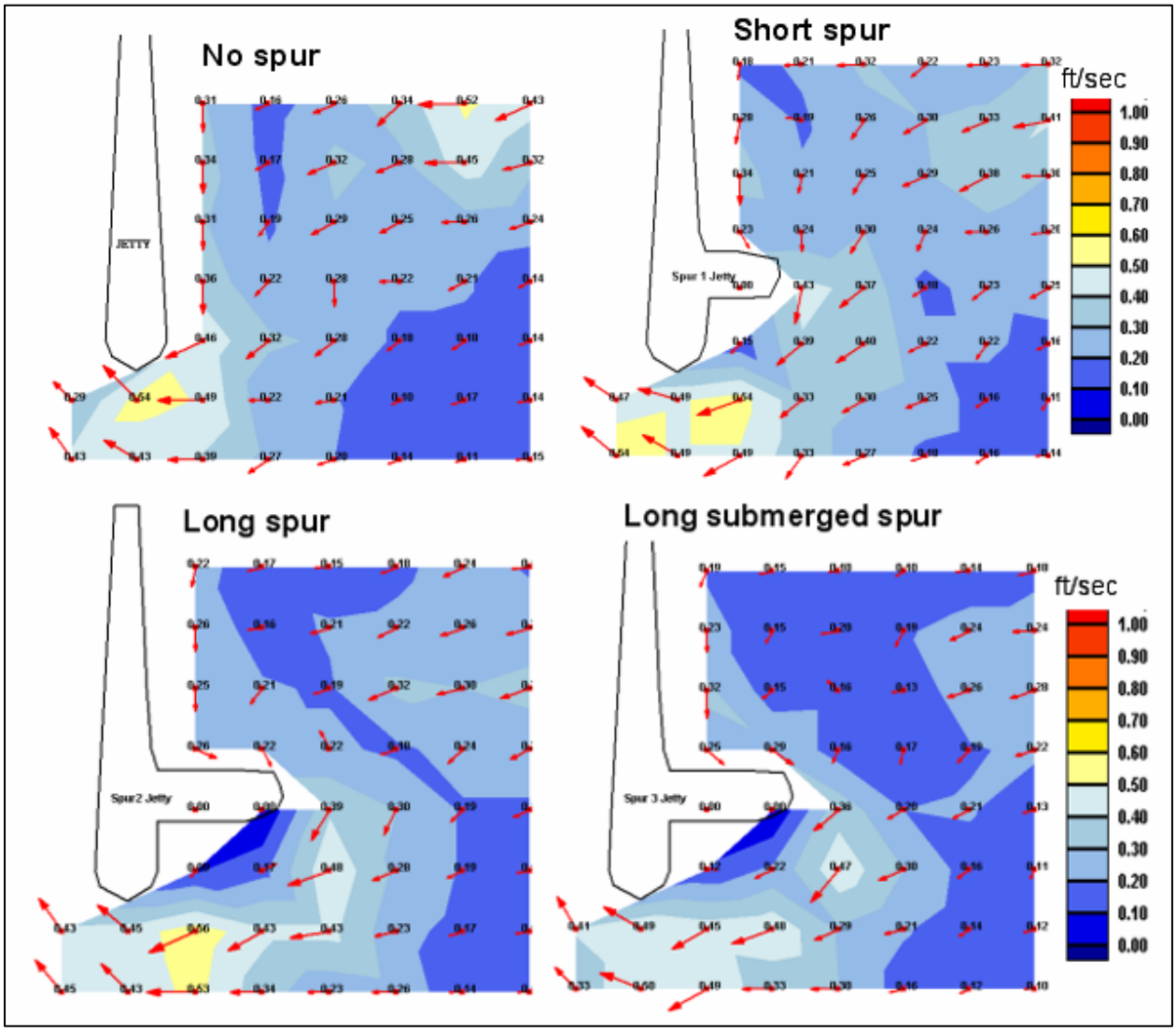


Figure 13. Detailed velocity fields upcoast of dual jetties for 11-sec, 3-m waves with maximum flood current in channel. Dark color contours are slower currents

LITTORAL DRIFT DIRECTION CONCERNS: The use of spurs would probably be considered optimal for a region of coast that has a balanced littoral drift environment. There would be little need to bypass sediment to an eroding downcoast region. The spur concept is to maintain/keep sediment on one side of a jetty, reducing its likelihood to shoal an inlet navigation channel. If bypassing were desired, the spur would not necessarily direct sediment to an easily accessible and protected location for dredging. However, spurs would probably aid in directing sediment to a location that would move back to the beach during a wave reversal. Rather than being impounded in the shadow of the jetty, the sediment would be more accessible to wave action. If there is a large net movement of longshore sediment though, spurs on each jetty might be beneficial in first, on the upcoast jetty, limiting sediment movement into the channel and second, a spur on the downcoast jetty might reduce sediment entering the channel from that side during wave direction reversals and reduce the eddy-type circulation patterns that move sediment towards the channel when waves are from the upcoast direction.

CONCLUSIONS: There are multiple factors to consider in the design of a jetty spur. This document has discussed wave and tidal current processes and a few of the controlling factors, spur elevation and length. Based on a limited set of field data for spurs, it was seen that for a S/L (spur length over distance of spur from shore) ratio of 0.4 or greater, that the shoreline reached the spur. Shoreline attachment to the spur may be acceptable if the wave climate is not too energetic so that sediment does not by-pass the spur and move towards the channel or if the spur is on the downcoast jetty and it is functioning to retain the by-passed sediment in the nearshore region. It was noted from physical model study of spurs that the structure should be long enough to significantly deflect the longshore currents away from their usual direction parallel to the jetty; so in this respect, a spur length to shoreline distance ratio of greater than 0.4 may be necessary. Physical and numerical models are available to develop and optimize spurs for site-specific conditions. Modeling is likely to be necessary to understand complex current and sediment circulation due to varying wave parameters of height, period and direction. Also the effect of offshore bathymetry may be critical in controlling current and sediment circulation in the region just upcoast of the jetty.

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