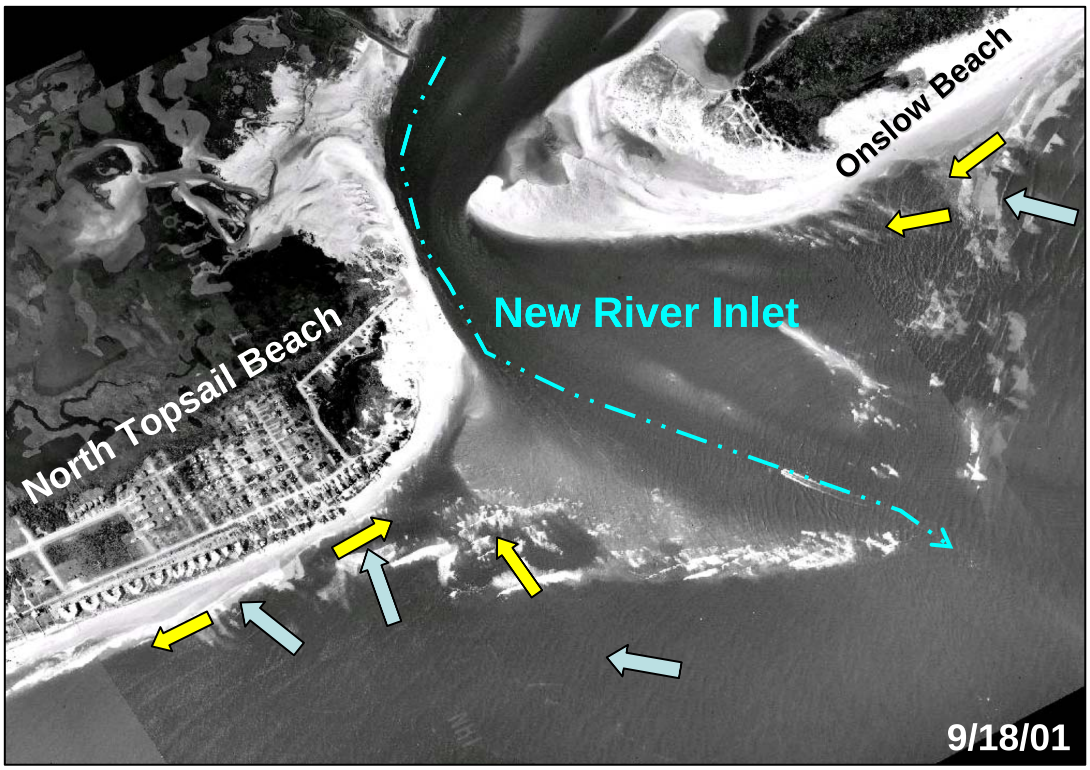
Wave Refraction, Ebb-Tidal Delta Changes and Sand By-Passing



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Pilkey and Neal (2009) in their Barrier Island Setting section of their article state that *At times, natural accretionary widening has occurred at the ends of the island a result of inlet channel dynamics, producing a bulbous drumstick shape. This accretion contributes to the local modification of the wave pattern, resulting in local long-shore transport to the north and increased erosion in the downdrift direction.* This statement is correct in the sense that North Topsail Beach prograded for a period of time between the mid-1950s and the early 1990s. This scenario is commonplace along almost all the barriers in southeastern North Carolina that border unmodified inlets. However, the statement is misleading in that it coveys to the reader that downdrift sand by-passing at the end of island ceases because a segment of the island adjacent to the inlet has accreted. The following overview describes the relationship of changes in the configuration of the ebb-tidal delta, wave refraction and the manner in which sand is by-passed to the downdrift portion of the barrier.

In wave-dominated inlet settings such as New River Inlet, the dominant manner in which sand is bypassed to the downdrift barrier is by waves breaking along the periphery of the outer bar. As waves break, they set up a wave-induced current that transports sand such as that depicted by Figure 1. Wave refraction around the ebb-tidal delta ultimately produces a zone of sediment transport reversal (nodal point), resulting in sand transport toward the inlet. Concurrently, due to the difference in the angular wave approach, sand is transported in the opposite direction away from the inlet. During the rising tide, the flood tidal current velocity increases, and, thus, enhances the wave-induced transport as the flood flow is directed toward the inlet. Figure 2 depicts this scenario at Rich Inlet in New Hanover County, NC. Along the oceanfront downdrift of the inlet, where the ebb-tidal delta merges with the barrier, the tidal flow becomes negligible and ultimately flow is directed away from the inlet. In essence, the wave-generated current is augmented by the tidal flow toward the inlet.

Figure 3 depicts New River Inlet's ebb-tidal delta as of 3/24/86, a time when the North Topsail Beach oceanfront near the inlet was accreting. The North Topsail Beach oceanfront shoreline at this time was aligned N 60^{o} E, hence waves approaching form the N-NE quadrant to the SSW quadrant will transport sediment along the barrier. Previous work has shown that the dominant direction of longshore transport is from the northeast to the southwest. It has been estimated (Jarrett 2009) that the gross transport in vicinity of New River Inlet was ~ 819,000 cy/yr, with 522,000 cy/yr of sand transported to the southwest and 297,000 cy/yr transported to the northeast. During the months of May though July northeasterly transport is most common; approximately 64 % of the longhore transport is directed to the southwest.

Imaged in Figure 3 are two directions of wave approach which are depicted by the colored blue lines (short wave length = light blue from the SW and longer wave length = dark blue from the SE). The waves approaching form the southeast have a longer wave length, and hence are more capable of transporting material than the shorter length waves approaching form the SW. As longer waves travel toward shallower water, their direction of approach is altered; and ultimately, upon breaking, transport sand in different directions. The flood flow then augments the inlet-directed transport potential.

Figure 4 depicts different configurations of the outer bar (ebb-tidal delta) between 1984 and 2001. Inspection of Figure 4 shows that as the outer bar channel deflected toward Onslow Beach, the shape of the ebb-tidal changed. As a consequence, the zone where the ebb-tidal delta merged with the adjacent oceanfront, shifted to the northeast (New River Inlet). The location of the nodal point (zone of sand transport reversal) also changed with time as the shape of ebb-tidal delta was reconfigured in accordance with the position and alignment of the ebb channel. Figure 4C shows there is no zone of sand transport reversal due to combination of the ebb delta's shape and the direction of wave approach. The scenario similar to the above (Fig. 4C) can occur at all inlets in North Carolina, depending upon the shape of the ebb-tidal delta and the direction of wave approach.

In early 1991, the seaward most segment of the ebb channel was deflected to the northeast, and as a consequence, the nodal point shifted toward the inlet (Figs. 4 and 5). Aside from short-lived breaching episodes, the easterly deflection of the ebb channel continued, and by March 2003, the channel reached its maximum easterly deflection and alignment of 111^{o}. Since 2003, the ebb channel has been generally shifting southward, and as of mid June 2012 (Fig. 6), the alignment of the outer bar channel was 140^{o}. In January 2013, the outer bar segment of the ebb channel was relocated to a near shore-normal alignment of ~ 155^{o}.

In the process of channel relocation, a 2.85 million ft^2 segment of the southwestern ebb-tidal delta was bypassed updrift (NE of the newly relocated channel). In effect, the SW segment of the outer bar became exceedingly small in areal extent, comprising only 15% of the ebb-tidal delta's area (Fig. 6). As a consequence of the above changes, the nodal point or zone of transport reversal has shifted very close to the oceanfront reach where the flood channel impinged upon the shoreline. As a consequence, most of the sand delivered to this shoreline reach is transported along shore to the inlet or to the extending spit (Fig. 6).

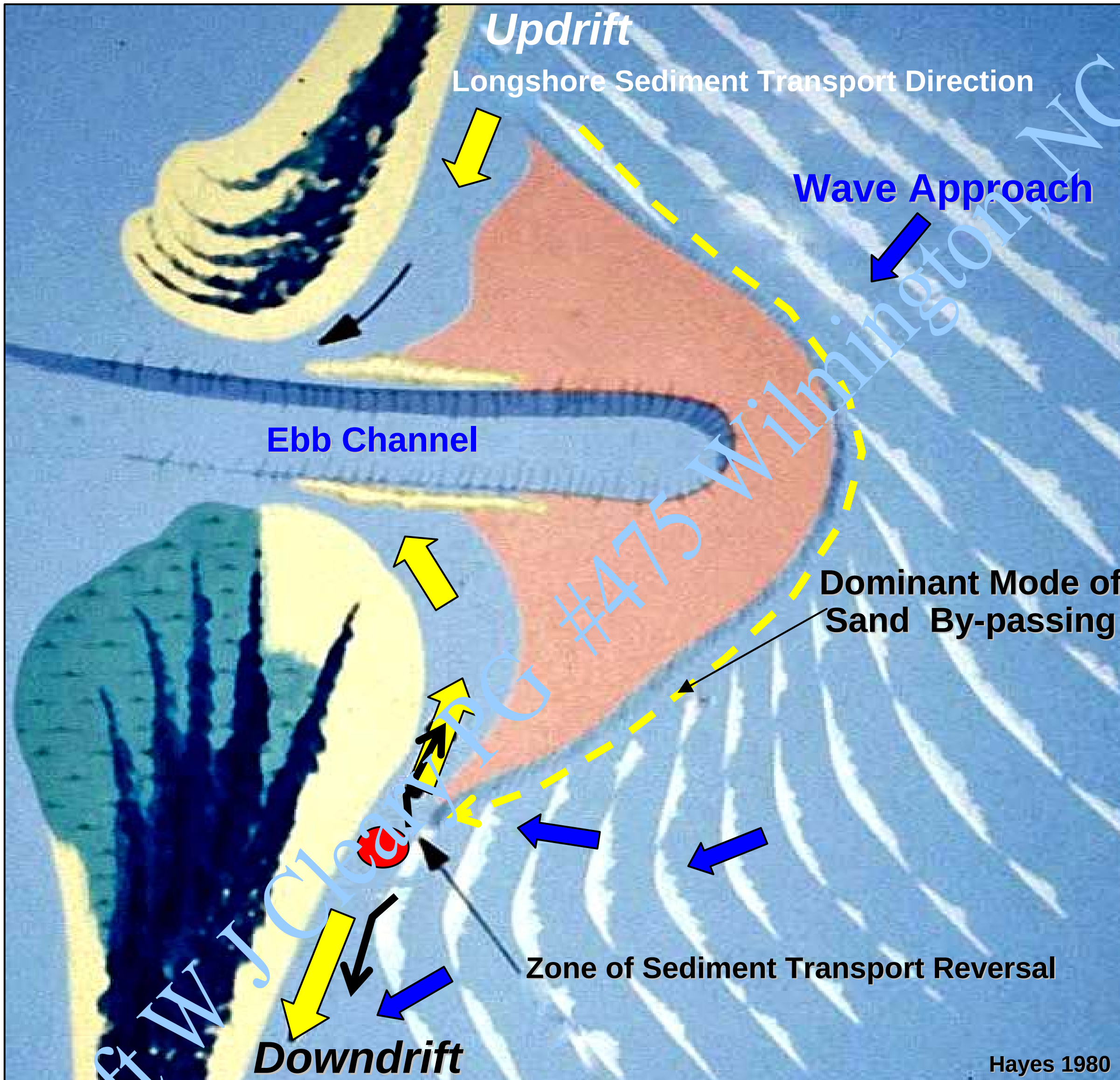

Figure 1. Cartoon depicting wave refraction around the ebb-tidal delta and development of a zone of sediment transport reversal (nodal point) resulting in build up of shoreline near inlet (courtesy of Miles Hayes). Note the direction of wave approach is from the top right and as refraction occurs the transport of sand on the downdrift shoreline (bottom) is both toward the inlet and toward the bottom of the image. In wave-dominated inlet settings such NRI, sand is by=passed along the periphery of the ebb-tidal delta.

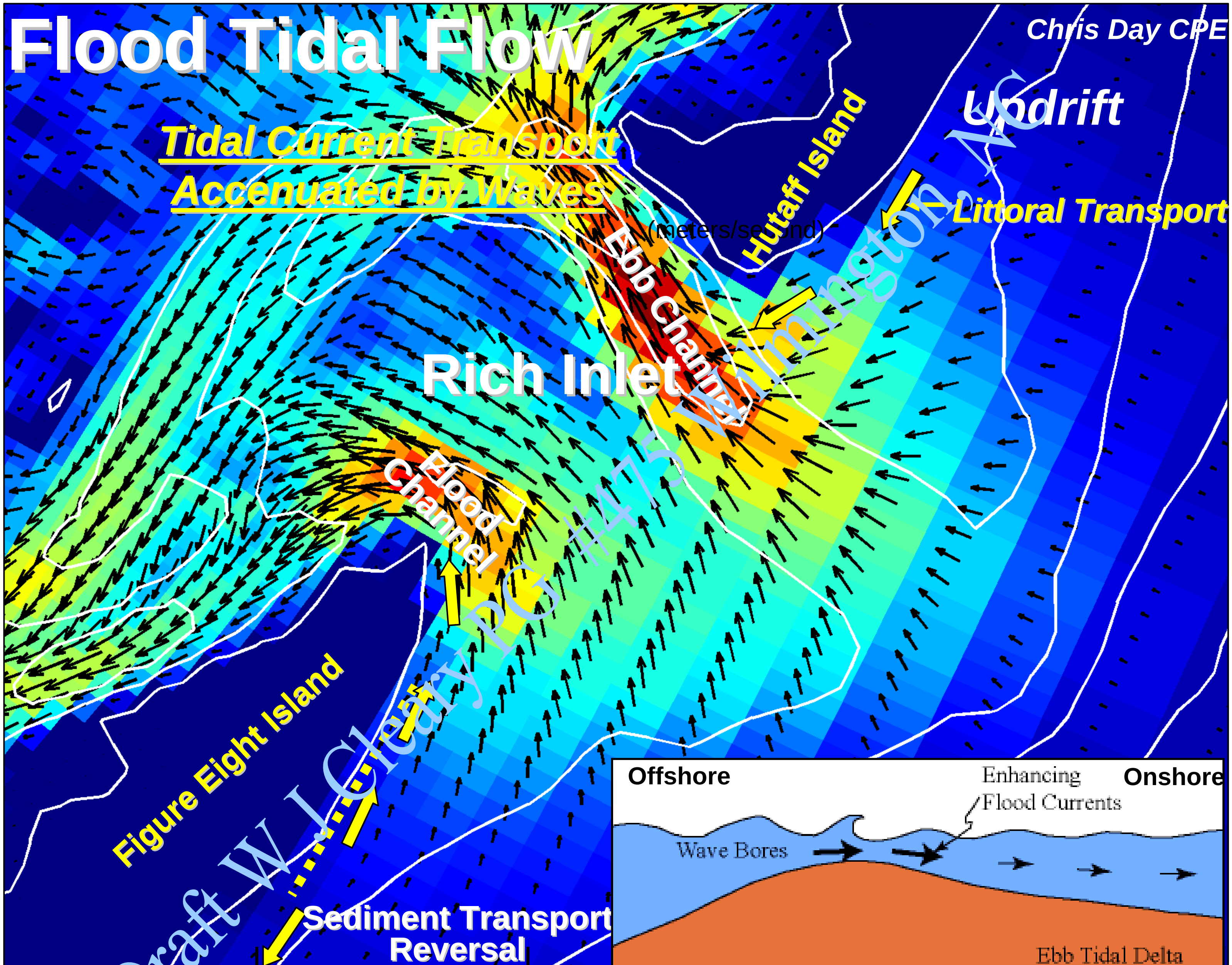

Figure 2. Map depicting the flood-tidal flow at Rich Inlet (2005) modified after C. Day CPE. Note that along the F8I oceanfront downdrift of the inlet (bottom left) the tidal flow becomes negligible and ultimately flow is directed away from the inlet. As waves approach the ebb delta from the upper right of the image refraction occurs, ultimately setting up a zone of sediment transport reversal. In essence, the wave- generated current set up by breaking waves augments the tidal flow (Insert). On the F8I oceanfront sand is transported toward (NE) the inlet along a portion of the shoreline fronted by the ebb delta while along the remaining shoreline incident waves transport sand to the southwest.

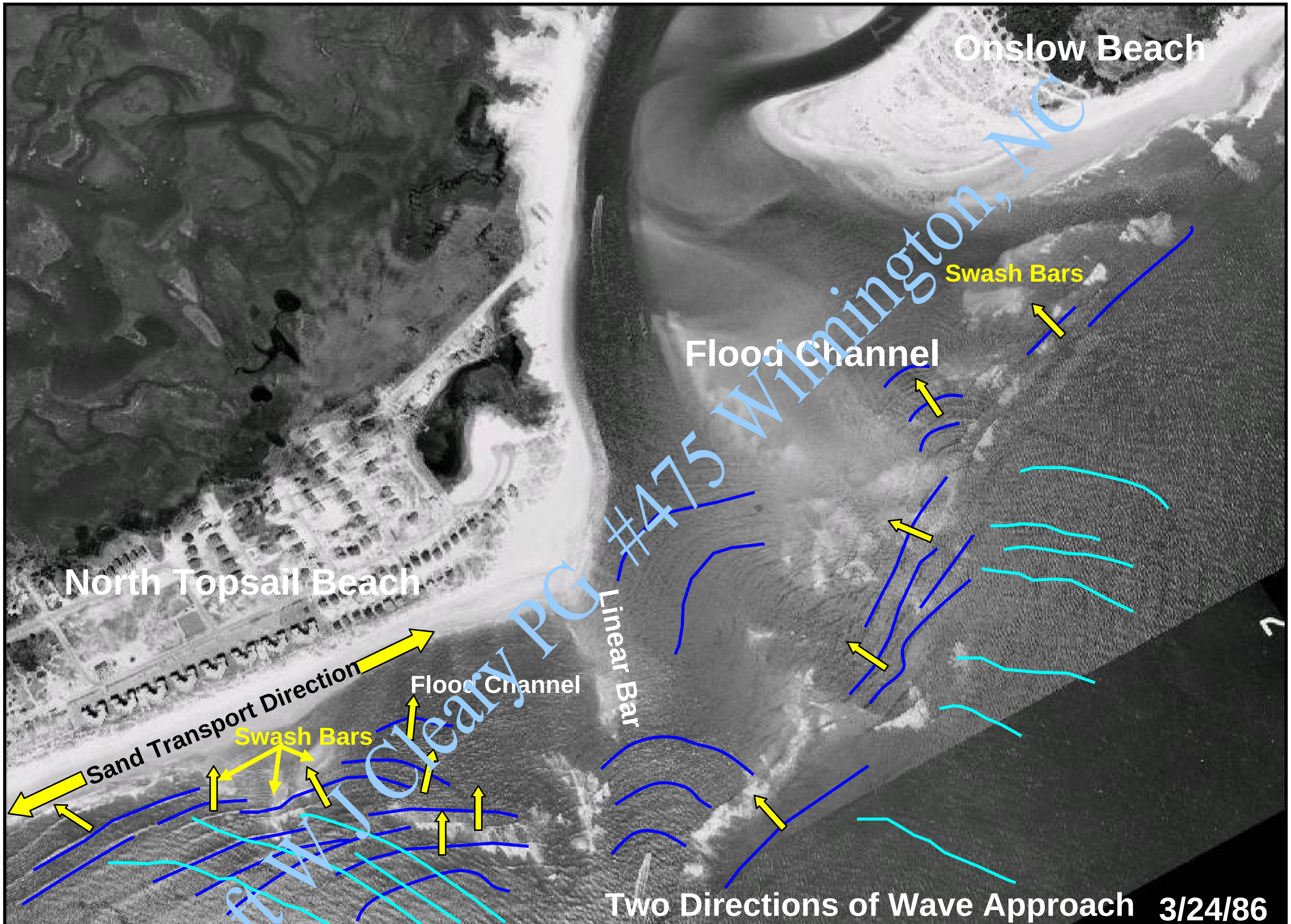

Figure 3. Photograph of New River Inlet depicting refraction of incident waves. Several directions of wave approach are depicted by the colored blue lines (short wave length = light blue from SW and longer wave length = dark blue from the SE). Note the locations where the loner waves have a different angular approach and hence transport sand in different directions (yellow arrows).

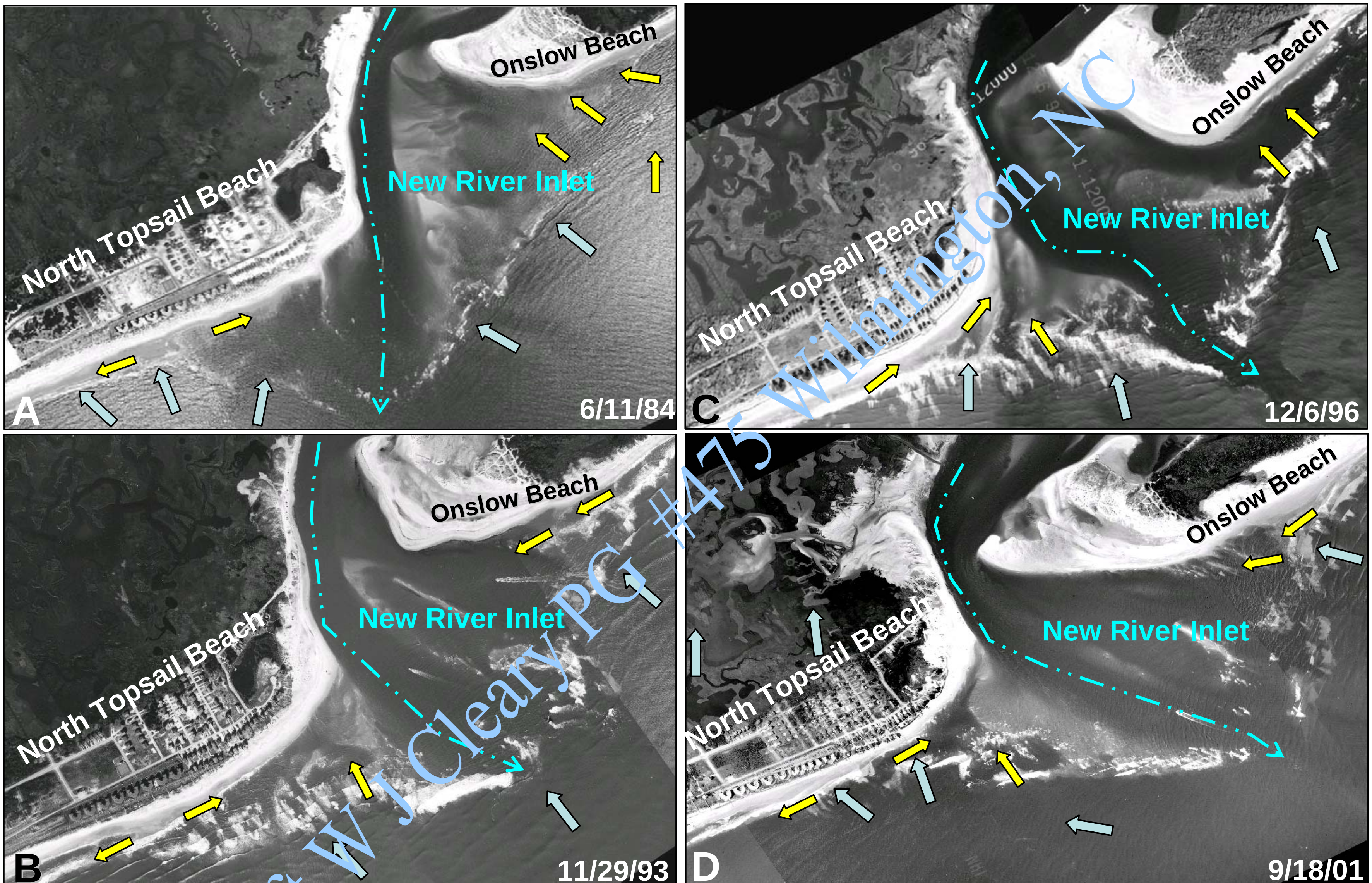

Figure 4. Historic aerial photographs of New River Inlet depicting the ebb-tidal delta and different directions of wave approach. A. Photograph (6/11/84) of NTB oceanfront progradation and fronting ebb-tidal delta. Note the wave approach (lt. blue arrows) and the direction of sediment transport (yellow arrows). B. View (11/29/93) of breaking waves along periphery of ebb-tidal delta and the resulting directions of sand transport. C. Photograph (12/6/96) of deflected ebb channel and shift of the ETDs breakwater effect toward the inlet. During certain situations of wave approach from the SE quadrant sand transport is directed toward the inlet. D. Photograph (9/18/01) of skewed ebb-tidal delta and sand transport reversal zone. The difference in “D” and “C” is the waves angular approach near the surf zone.

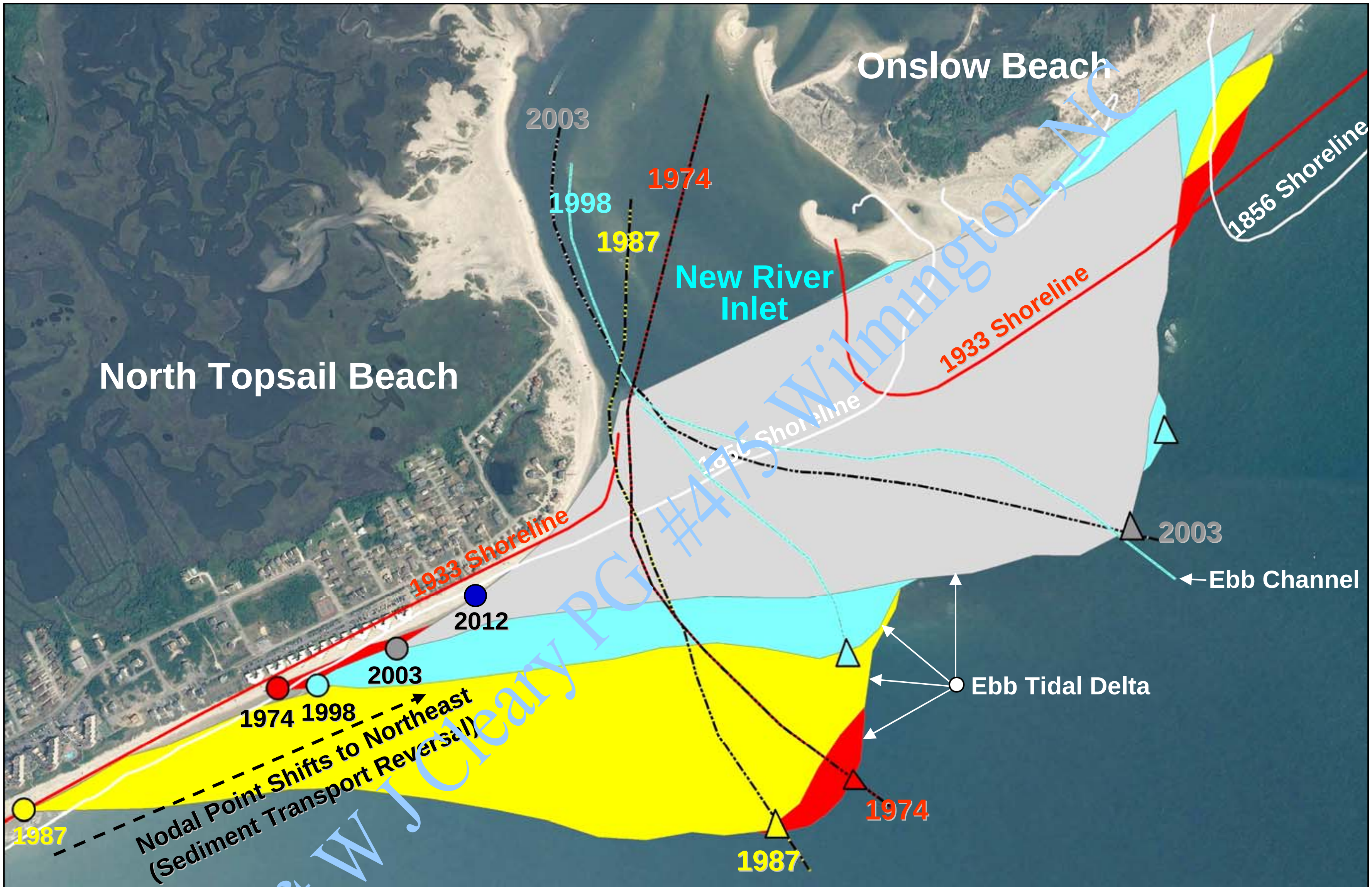

Figure 5. Map depicting New River Inlet, North Topsail Beach and Onslow Beach. The positions of the 1856 and 1933 shorelines are also depicted along with the ebb channel positions and alignments for 1974, 1987, 1998 and 2003. The colored polygons represent the ebb-tidal delta shapes for the above mentioned years. The colored dots refer to the zone of sediment transport reversal (NTB) while the colored triangles refer to the apex of the ebb-tidal delta. Note as the ebb channel deflects toward OB the breakwater effect of the shoals shift to the NE. Also note as the shifts occurred the zone of sediment transport reversal (nodal point) moves to the NE. As a consequence of the NE shift (compare 1974 & 2003) the opportunity for swash bar attachment along the NTB oceanfront decreases significantly.

Figure 6. Map depicting select ebb channel positions and alignments and the outline of the ebb-tidal delta on 29 Jan 13 (dashed yellow line). The NE and SW segment refers to the areas of the ebb-tidal delta located on opposite sides of the 1/29/13 ebb channel. When the ebb channel was relocated (Jan 2013) from its 2012 position a portion of the southwestern segment of the ebb-tidal delta was by-passed updrift. In effect, the NE segment increased in areal extent while the SW segment became exceptionally small in size.