Rip Current Science

Where and Why Rip Currents Form

Coastal scientists have been investigating rip currents for more than 75 years. This research has been conducted through field observations and measurements, laboratory measurements and wave tank experiments, and computer and numerical modeling. The mechanics of rip current development are complex and involve interactions between waves and currents, waves and water levels, waves and the shape of the nearshore bottom (bathymetry), as well as wave-wave interaction.

Rip currents can occur along any coastline that features breaking waves. Scientific investigations of wave and current interactions along the coast have shown that rip currents are likely present on most beaches every day as a component of the complex pattern of nearshore circulation.

Photo courtesy University of Delaware Sea Grant College Program

As waves travel from deep to shallow water, they eventually break near the shoreline. As waves break, they generate currents that flow in both the offshore (away from the coast) and the alongshore directions. Currents flowing away from the coast are called rip currents.

Rip currents are a result of complex interactions between waves, currents, water levels and nearshore bathymetry. These current systems form an integral part of nearshore circulation patterns such as alongshore and cross-shore (onshore/offshore) water motion. Along all coastlines, nearshore circulation cells may develop when waves break strongly in some locations and weakly in others. These weaker and stronger wave breaking patterns are most often seen on beaches with a sand bar and channel system in the nearshore zone. A rip current forms as the narrow, fast-moving section of water travels in an offshore direction. Rip currents can also result from a wave's natural variability or when a current traveling along the shoreline encounters a structure such as a groin or jetty and is forced offshore.

Rip current strength and speed varies. This variability makes rip currents especially dangerous to uninformed beachgoers. Rapid fluctuations or pulses in wave groups can quickly generate rip currents with velocities measured up to 8 feet per second.

Waves, Currents and Water Level Variations

As waves break along a shoreline or over a sandbar, an increase in water level occurs. This increase in water level is known as set-up. The increase in water level is especially evident as waves break over a sandbar, resulting in an increased set-up of water on the landward side of the bar. Thus, waves breaking over a sandbar can result in mass transport of water between the bar and the shoreline. There is usually a difference in set-up (water heights) between the bar, where the waves are breaking strongly, and the channel between bars, where little or no wave breaking occurs.

One of the ways this water returns seaward is through rip currents, which flow seaward against the incoming waves. This seaward flow of water typically occurs through a break in the sandbar, where water is channelized into a narrow current known as a rip current.

Brian Sapp, a graduate student at the Georgia-Tech Savannah, has provided the following explanation of how a rip current develops over a sand bar. The accompanying graphic is provided courtesy of NOAA-National Weather Service:

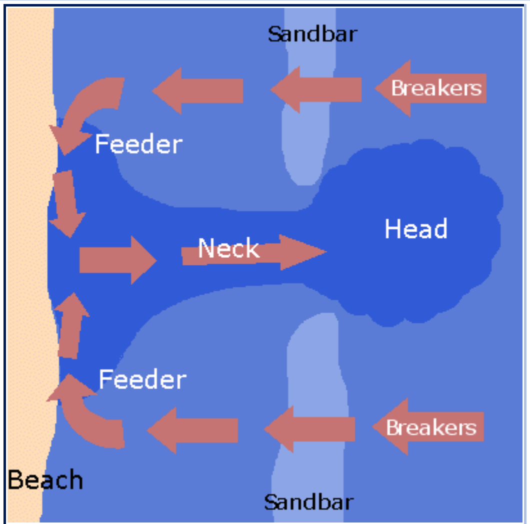

Diagram courtesy NOAA's National Weather Service

Basic Rip Current Mechanics

- Waves break on the sand bars before they break in the channel area.
- Wave breaking causes an increase in water level over the bars relative to the channel level.
- A pressure gradient is created due to the higher water level over the bars.
- This pressure gradient drives a current alongshore (the feeder current).
- The longshore currents converge and turn seaward, flowing through the low area or channel between the sand bars.

Nearshore Bottom: Bathymetry

The shape of the shoreline and nearshore bottom (bathymetry) may influence rip current development. In regions where the coastline is characterized by cuspate features (i.e. the shoreline is “scalloped”), rip current may be found between the cusps. Examples of this type of shoreline can be found in some portions of the Florida coast (e.g. Perdido Key), and in some locations along the California coast (Monterey Bay).


View from the ground and taken at low tide; this channel has formed at a break in the sand bar. *Photo courtesy University of Delaware Sea Grant College Program*


Viewed from the air, rip currents can be seen flowing past the line of breaking waves. Rip current spacing along an open coast may be dependent on many factors, including the shape of the nearshore bottom. *Photo courtesy University of Delaware Sea Grant College Program .*

The presence of longshore bars can also have an impact on rip current development and location. In some geographic locations, the nearshore bottom may be characterized by fixed structures such as reefs. In other areas, nearshore bathymetry is more ephemeral, with offshore sand bars constantly changing their shape and location. Along shorelines where sand is deposited in an offshore bar, the rip current often flows through a low spot or channel cut through the sandbar.

Man-Made Structures: Groins, Jetties and Piers

Rip currents may occur at fixed locations such as groins, jetties, piers, or other man-made structures where water can be funneled out to sea in a narrow channel. In coastal areas with structures, rip current may result when currents running parallel to the shore are deflected offshore by the structure.

 Brownish-colored water can be seen flowing seaward, deflected offshore by the timber groin. *Photo courtesy University of Delaware Sea Grant College Program*	 Rip current formation adjacent to coastal structure. Currents that flow in the longshore direction are deflected offshore by structures. *Photo courtesy University of Delaware Sea Grant College Program.*

As waves approach the shoreline, they usually break at an angle, generating a longshore current that flows parallel (along) the beach. When the longshore current (moving along the shore) encounters coastal structure (such as a groin, jetty, or pier) it is deflected in an offshore direction. This offshore-directed flow of water is called a rip current.

Wave-Wave Interaction and Wave-Current Interaction: Generation of Circulation Patterns

Rip currents can develop due to interactions between waves and currents, even in the absence of nearshore sand bars and without shoreline or bathymetric influence on their formation. Breaking waves force narrow regions of offshore-directed flows, known as rip currents.

As waves break near the shore, complex wave interactions may generate circulation patterns that result in the formation of rip currents, sending water back out to sea. Along open coasts (coasts without sand bars), rip currents are caused by variations in breaking waves, with waves breaking strongly in some locations and less strongly in others. These variations generate circulation cells causing water to be deflected offshore as a rip current.

Rip Current Size and Speed

Rip currents can occur along any coastline with breaking waves. Although rip currents are often present daily on many beaches, the velocities may be too slow to be a threat to experienced swimmers. However, their inherent variability makes them especially dangerous to unwary or uninformed beachgoers. Changes in the size of the incoming waves can cause pulses in the strength of a rip current, which can be dangerous to all swimmers and anyone entering the surf.


Periodic rips: Beach face currents along the coast of Germany. *Photo courtesy of Dr. Robert A. Dalrymple.*

Wave Groups and Rip Current Pulsations

Rip currents are very unsteady and may increase in strength within a short time frame (a few minutes) because of larger incoming wave groups or current instabilities. It is extremely important to understand that changes in rip current velocity can occur very rapidly with random increases in incoming wave heights and water levels. Water depths can rapidly increase in rip current channels, catching unwary beachgoers and swimmers off-guard. If the higher waves and water levels sweep bathers off their feet, they may be transported offshore by the rip current.

Rip Current Characteristics and Velocities

Although rip currents are not caused by tides, the water level (tide elevation) at the coast may have an impact on rip current speed and strength. Generally, rip current velocities increase as water levels (tide elevation) decrease.

Rip current velocities also typically increase as wave heights increase. An increase in the height of incoming waves can result in sudden increases in water depth and rip current velocities. These sudden changes or pulses in water depth and current speed can catch bathers off-guard. Rip current pulsations are extremely dangerous to all swimmers!

While average rip current velocities of 1 to 2 feet per second do not pose serious hazards to strong swimmers, rip currents may rapidly reach or exceed velocities of 3 feet per second. Also, rapid fluctuations or pulses in wave groups can quickly generate rip currents with extreme velocities that have been measured up to 8 feet per second – this is faster than an Olympic swimmer can sprint! If a swimmer is caught in a rip current, attempting to swim directly back to shore against the seaward flowing current can result in exhaustion and possible drowning.

Rip currents are usually narrow (~ 20 to100 feet in the alongshore direction), may extend hundreds of feet offshore, and generally span the entire water column. However, offshore, or outside the surf zone, they tend to be confined near the surface.

Rip currents do not pull people under water – they pull people away from shore. Drowning deaths usually occur when people are unable to keep themselves afloat and swim back to shore. This may be due to fear, panic, exhaustion, a lack of swimming skills, or any combination of these factors.

Rip Current Duration

Some shorelines are characterized by permanent rip currents which may be found in a fixed location such as a break in a reef or other hard structure. Some rip currents are persistent, lasting for many days or months in one location. Rip currents may also migrate along a stretch of coastline. Rip currents may also be ephemeral, forming quickly and lingering for a few hours or days before dissipating and disappearing.

Miscellaneous/General Information

Rip Currents vs. Rip Tides

Rip currents are not rip tides. A specific type of current associated with tides may include both the ebb and flood tidal currents that are caused by egress and ingress of the tide through inlets and the mouths of estuaries, embayments, and harbors. These currents may cause drowning deaths, but these tidal currents or tidal jets are separate and distinct phenomena from rip currents. Recommended terms for these phenomena include *ebb jet* , *flood jet* , or *tidal jet* .

Warning sign posted adjacent to tidal inlet in South Carolina. Photo courtesy University of Delaware Sea Grant College Program

What is Undertow?

Undertow, an often misunderstood term, refers to the backwash of a wave along the sandy bottom. After a wave breaks and runs up the beach face, some of the water percolates into the sand, but much of it flows back down the beach face creating a thin layer of offshore-moving water with a relatively high velocity. This backwash can trip small children and carry them seaward. However, the next incoming wave causes higher landward velocities, pushing them back up on the beach. Undertow does not pull you under water or out to sea.

For additional science and information on rip currents, see our links and Frequently Asked Questions pages.

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