

The Tidal Bore of the Sélune River, Mont Saint Michel Bay, France

By

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Mont Saint Michel Bay (Baie du Mont Saint Michel) on the French side of the English Channel is known for Mont Saint Michel, its very large tidal range, and fast advancing flood tide. Three main rivers drain into the bay: the Couesnon, the Sélune, and the Sée (Figure 1). The strong flows of the Couesnon and Sélune rivers have strongly affected the hydrodynamics and sedimentology of the bay, as well as the access to Mont Saint Michel. Flow in the Couesnon River was controlled beginning in 1863, and has flowed west of Mont Saint Michel since. In the 1960s, the river was affected by the construction of a barrage to reduce salt intrusion in the catchment. The flow of the Sélune River was controlled only after 1879 upon completion of a dike redirecting the river northwards. The river was further affected by the completion of two dams (La Roche Qui Boit and Vezins) in 1920 and 1931 respectively.

During spring tides, the Couesnon, Sélune and Sée rivers are subjected to a tidal bore process. A tidal bore is basically a positive surge propagating upstream as the tidal flow turns to rising (Chanson 2001). Although a bore may be analysed using a quasi-steady flow analogy, its inception and development is commonly predicted using the method of characteristics and Saint-Venant equations (Chanson 2004). During the flood tide, the tail water level increases with time, and the forward characteristics converge and eventually intersect at a point where the water depth has two values at the same time: that is, the abrupt front of the tidal bore. After formation of the bore, the flow properties immediately upstream and downstream of the front must satisfy the continuity and momentum principles (Henderson 1966, Chanson 2004).

The occurrence of a bore has a significant impact on estuarine systems. Bed erosion and scour take place beneath the bore front while suspended matter is advected upstream with the bore (Donnelly and Chanson 2002). Although the tidal bore of the Couesnon River almost disappeared after construction of an upstream barrage in the 1960s, a small tidal bore is still visible during spring tides (Figure 2). The bore arrives about 1h 45 min to 1h 30 min before the high tide at Mont Saint Michel. The tidal bore of the Sée and Sélune rivers develops first in Mont Saint Michel Bay before entering both river mouths. The process spans more than 10 km and it can be quite powerful and dangerous at spring tides.

On 7 April 2004, the writer experienced the Sélune River tidal bore at Roche-Torin and Pontaubault, about 1h 30 min and 30 min respectively before the high tide at Mont Saint Michel (Figure 1). The tidal range was 13.75 m, the maximum value in Mont

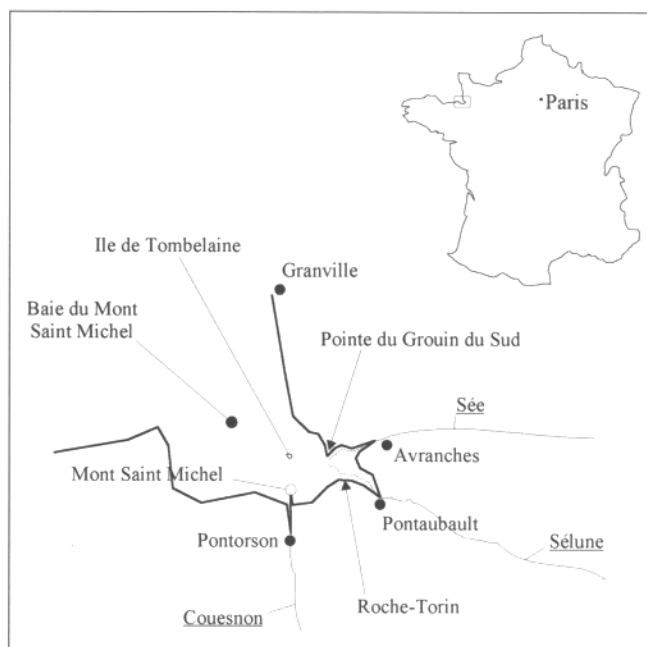


Figure 1. Map of Mont Saint Michel Bay - The names of the rivers are underlined.



Figure 2. Photograph of the Couesnon River tidal bore on 7 March 2004 at sunset (low tide: 1.40 m, high tide: 13.65 m). Looking at the undular tidal bore (mascaret) and whelps (éteules) from Tour Gabriel, bore direction from top right to bottom left.

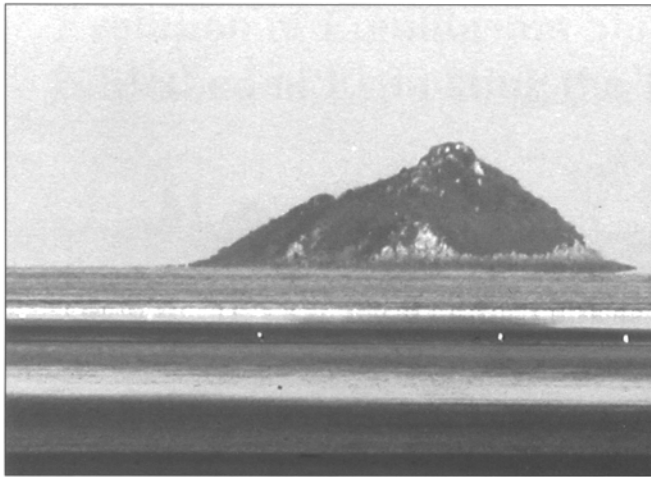


Figure 3. Photograph of the Sélune River tidal bore on 7 April 2004 at sunrise (low tide: 0.90 m, high tide: 14.55 m). Looking at the advancing tidal bore (mascaret) from Roche-Torin, with Ile de Tombelaine in the background. The tidal bore was more than 1 km wide.



Figure 4. Photograph of the Sélune River tidal bore on 7 April 2004 at sunrise (low tide: 0.90 m, high tide: 14.55 m). Looking at the tidal bore (mascaret) at Roche-Torin, bore direction from left to right.

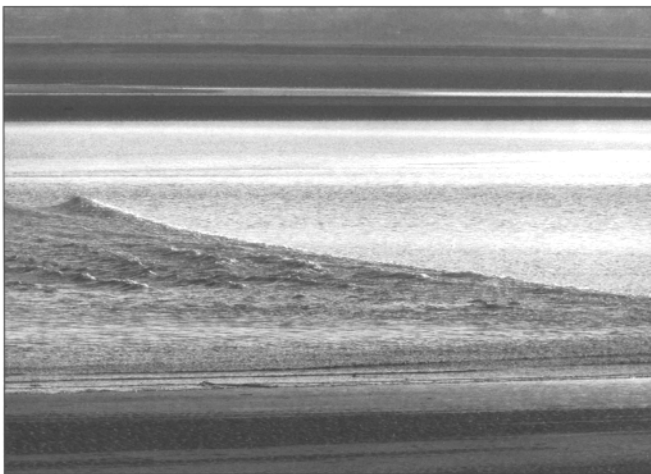


Figure 5. Photograph of the Sélune River tidal bore on 7 April 2004 at sunrise (low tide: 0.90 m, high tide: 14.55 m). Looking at the tidal bore (mascaret) just upstream of Roche-Torin, bore direction from bottom left to top right.



Figure 6. Photograph of the Sélune River tidal bore on 7 April 2004 at Pontaubault (low tide: 0.90 m, high tide: 14.55 m). Looking at the advancing tidal bore (mascaret) downstream of Pont Aubaud with some kayakers.

Saint Michel Bay for 2004. At Roche-Torin, the writer heard the rumble of the tidal bore about 25-30 min before the bore front reached Roche-Torin. The bore was first visible between Ile de Tombelaine¹ and Pointe du Grouin du Sud (Figure 3). The bore front was more than 1 km wide and it had not yet divided between the Sée and Sélune river channels. Later, the advancing front entered the Sélune River mouth with a celerity of about 2.5 to 2.7 m/s (Figures 4 and 5). In front of Roche-Torin, the middle section of the bore was undular in the deep water channel, while a breaking bore was observed in the shallower waters. At one stage, the undular bore disappeared briefly on the channel centerline, possibly because of a hole in deeper water, although the breaking bore was clearly seen elsewhere moving upstream of Roche-Torin.

About 50 min later, the writer observed the Sélune River tidal bore at Pontaubault, about 8 km upstream of Roche-Torin (Figures 6 and 7). A group of kayakers followed the bore, and one person is seen riding the bore front in Figure 6. The bore then flowed beneath the Pont Aubaud. Pont Aubaud is a 15th

century stone bridge used by the troops of General Patton during the "breakthrough of Avranches" on 31 July 1944 about 60 years ago (Figure 7). In 1944, the Pont Aubaud was the only available bridge across the Sélune River, and 7 divisions of Patton's army crossed the bridge in 72 hours! Note the bridge pier is shaped to cut the tidal bore flow (Figure 7).

Figure 2 presents a photograph of the Couesnon River tidal bore at sunset on 7 March 2004. Figures 3 to 7 present photographs of the Sélune River tidal bore on 7 April 2004, while Figure 8 shows a photograph of the plaque on the Pont Aubaud commemorating the liberation of France by the American Army.

It is the writer's opinion and experience that tidal bores have a significant impact on river mouths and estuarine systems, including in Mont Saint Michel Bay before the bore enters the Sée and Sélune river channels. Bed erosion and scour take place beneath the tidal bore front, while suspended matter is carried upwards in the ensuing wave motion. The process contributes to significant sediment transport with deposition in upstream intertidal areas. Tidal bores induce strong mixing and dispersion in these

¹ The Ile de Tombelaine is about 4.5 km west of Pointe du Grouin du Sud, and 2.5 km north of Mont Saint Michel. It is said that Queen Guenièvre, wife of King Arthur, is buried at Ile de Tombelaine. Another story says that a young princess, Elaine, was buried on the island.



Figure 7. Photograph of the Sélune River tidal bore on 7 April 2004 at Pontaubault (low tide: 0.90 m, high tide: 14.55 m). Looking at the advancing tidal bore (mascaret) passing below the 15th century Pont Aubaud. Note the bridge piers are shaped to cut the bore front.

river estuaries which are not accounted for by classical mixing theories. They also significantly impact local ecosystems. The existence of tidal bores is based upon a fragile hydrodynamic balance, which may be easily disturbed by changes in boundary conditions and freshwater inflow.

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INTERNET LINKS

Photographs of tidal bores
http://www.uq.edu.au/~e2hchans/photo.html#Tidal_bores

Tidal bores, Mascaret, Pororoca, myths, fables and reality
http://www.uq.edu.au/~e2hchans/tid_bore.html

Tidal bore of the Seine River
<http://www.uq.edu.au/~e2hchans/mascaret.html>

Tidal bore hydraulics
<http://www.uq.edu.au/~e2hchans/civ3140.html#Surges>

² Battle between the partisans of the King ("Chouans"), and the Republican Armies ("Bleus") during the French Revolution.



Figure 8. Stone plaque on the Pont Aubaud across the Sélune River at Pontaubault - The text reads :

"Pont Aubaud - Road to Freedom
 15th Century: Construction of the bridge
 1793: Battle between the "Chouans" and the "Bleus"²
 31-7-1944: Battle between German and American soldiers
 Crossing in 72 hours of 7 divisions of Patton's Army for the
 liberation of France
 'The outcome of the war depended upon one bridge' (P. Carell)"