ACCRETION AND EROSION WAVES ON BEACHES

Douglas L. Inman
Coastal Morphology Group
Integrative Oceanography Division
Scripps Institution of Oceanography
dinman@ucsd.edu

Scott A. Jenkins
Coastal Morphology Group
Integrative Oceanography Division
Scripps Institution of Oceanography
sjenkins@ucsd.edu

20 June 2003

Preprint from *Encyclopedia of Coastal Science* (M. Schwartz, editor),
The Earth Sciences Encyclopedia Online <www.eseo.com>,
with permission from Kluwer Academic Publishers, Dordrecht, The Netherlands.

ACCRETION AND EROSION WAVES ON BEACHES

An accretion/erosion wave is a local irregularity in beach form that moves along the shore in the direction of net littoral drift. The initial irregularity may be caused by a wide variety of events such as the bulge from an ephemeral stream delta, the material from the collapse of a sea cliff, erosion or accretion associated with convergence and divergence of wave energy over an offshore bar, erosion downdrift of a structure such as a groin, sudden loss of sand by slumping at the head of a submarine canyon, or rapid accretion due to beach nourishment as when dredge spoil is placed on a beach. Given the wide variety of causes leading to local beach irregularities, accretion/erosion waves are common transport modes along beaches.

The wave-like form of an accretion/erosion wave is related to the change in sediment transport rate along the beach (divergence of the drift). Specifically, an irregularity in beach topography along an otherwise straight beach produces wave refraction and diffraction that locally modifies the littoral drift system. Wave convergence at an accretionary bulge reduces the littoral drift passing the bulge, causing downcoast erosion. Consequently, the accretionary bulge moves downdrift with an erosional depression preceding it. An initial erosional depression in beach form, as in the lee of a groin, moves downdrift as a traveling sand deficit because the transport potential of the downdrift side of the depression is always greater.

Accretion and erosion waves are best observed from the air or by comparison of beach profiles with time and distance along the beach. The associated change may be several hundred meters in beach width, but more typically is about 10-20 m over a distance of about 1-2 km and may be masked locally by cusps and other small scale beach features.

Background

The concept of an accretion/erosion wave was developed to account for the downdrift movement of a sand delta deposited across the beach by an ephemeral stream (Inman and Bagnold, 1963). It was observed that the downdrift movement occurred as an accretionary bulge preceded by an erosional depression (Figure 1). The net littoral drift perturbs deltaic accretion through a series of spit extensions (t_2). Over time, the cumulative spit extensions will progressively displace the accretionary bulge in the downdrift direction while local wave refraction and refraction-induced divergence of the littoral drift cause erosion downdrift of the bulge (t_3). The areas of accretion and erosion migrate downdrift together in a phase-locked arrangement referred to as an accretion/erosion wave. The movement of the accretion/erosion form was quantified by surveys of the flood delta of the San Lorenzo River in central California (Hicks and Inman, 1987) and further evaluated from the sudden release of sand at the San Onofre power plant in southern California (Inman, 1987).

The propagation rate of the accretion/erosion wave form is slow initially because the on-offshore dimensions and volume of sand to be moved are at a maximum, and a significant fraction of that volume remains outside the region of rapid transport by waves (Figure 1; t_1). Once the material enters the surf zone, the longshore transport rates are much higher and the entire accretion/erosion form moves faster, spreads out along the beach, and decreases in cross-shore amplitude. Measurements near the sand release at San Onofre, California, showed that the

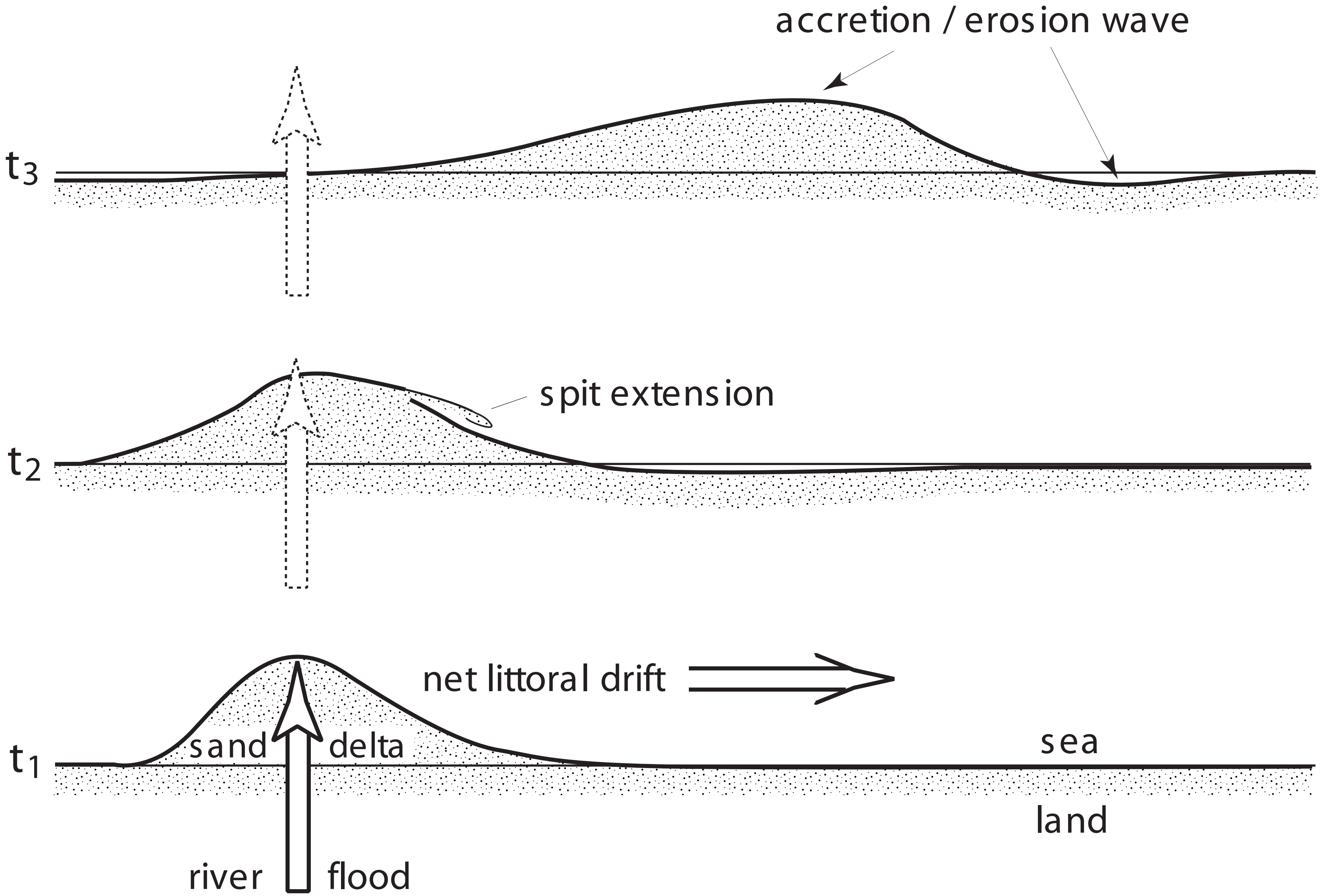

Figure 1. Formation of accretion / erosion wave downdrift from an episodically formed sand delta at time t_1, where $t_1 < t_2 \ll t_3$ [modified from Inman & Bagnold, 1963].

01.8-1b

form of the accretional wave initially traveled with a speed of about 0.6-1.1 km/yr in the 1.8 km near the release point (nearfield) and much faster farther from the release (farfield). The delta from the Santa Cruz River floods of 1982/83 was large (800,000 m^3) and extended offshore to depths of over 10 m, and that material moved about 0.5-1.5 km/yr during the first year (Hicks and Inman, 1987). Subsequently, the downdrift erosion and accretion waves from the delta moved with speeds of 2.2-2.8 km/yr (Table 1).

It has been observed that any structure that interrupts the littoral drift of sand along a beach results in an erosional chain reaction traveling downdrift from the structure (Inman and Brush, 1973). The propagation rates of the downdrift erosion wave was evaluated from beach surveys following the construction of the harbor jetties at Santa Barbara, California (Inman, 1987), and the enlargement of the harbor at Oceanside, California (Inman and Jenkins, 1985). Once in the farfield of the structure, the erosion wave, followed by the accretion wave moved downdrift at 2.5-2.8 km/yr at Santa Barbara and 2.2-4.0 km/yr at Oceanside (Table 1).

Accretion/erosion waves also occur along beaches and barriers downdrift of tidal inlets (e.g., Inman and Dolan, 1989). The erosion wave from the jetties at Ocean City, Maryland, is a well known example. The inlet between Fenwick and Assateague barrier islands was stabilized by jetties in 1935. The jetties trapped the littoral drift and caused an erosion wave to travel downdrift along Assateague Island, resulting in a landward recession of the entire barrier island of 460 m in 20 years (Shepard and Wanless, 1971).

The Nile Delta experiences accretion/erosion waves driven by the currents of the east Mediterranean gyre that sweep across the shallow shelf with speeds up to

Table 1. Propagation speeds of Accretion/Erosion Waves.

Location	Type/Cause	Reference	Net Downdrift Transport Rate 10^3 m^3/yr	Speed of Accretion/Erosion Wave, km/yr Nearfield [a]	Farfield
Santa Cruz, CA	accretion from San Lorenzo River Delta	Hicks & Inman, 1987	268	0.5 - 1.5	
Santa Cruz, CA	erosion and bypass accretion from Santa Cruz Harbor	Hicks & Inman, 1987	268		2.2 - 2.8
Santa Barbara, CA	erosion from harbor and bypass accretion	Inman, 1987	214		2.5 - 2.8
San Onofre, CA	accretion from sand release	Inman, 1987	200	0.6 - 1.1	
Oceanside, CA	erosion from harbor	Inman & Jenkins, 1985	200		2.2 - 4.0
Assateague Island, MD	erosion from jetties at Ocean City Inlet	Leatherman *et al.*, 1987	153	~0.3	
Outer Banks, NC	migration of Oregon Inlet	Inman & Dolan, 1989	590	0.023	
Nile Delta, Egypt	accretion wave from onshore migration of sand blanket	Inman *et al.*, 1992	1,000		0.5 - 1.0

[a] Nearfield is within 1-2 lengths of the perturbing feature such as a sand delta.

1 m/s. Divergence of the current downdrift of the Rosetta and Burullus promontories entrains blankets of sand that episodically impinge on the beach. These sand blankets cause shoreline irregularities with average amplitudes of 100 m and wavelengths of about 8 km that travel along the shore at rates of 0.5 to 1 km/yr as accretion/erosion waves (Inman *et al.*, 1992). (see entry on *Littoral Cells*)

A related example of a traveling accretion/erosion feature occurs when the littoral drift impinges on an inlet causing it to migrate downdrift (Figure 2). The migration proceeds as an accretion of the updrift bank in response to positive fluxes of sediment delivered by the net littoral drift Q_ℓ, while the downdrift bank of the inlet erodes due to a negative divergence of drift across the inlet, $\partial Q_\ell/\partial \ell < 0$. The negative divergence of the drift across the inlet is caused by wave refraction over the ebb-tide bar and by a loss of a portion of the drift to flood-tide entrainment at the inlet, ΔQ_t. Also the offshore tidal bar, maintained by the ebb-tide flow, moves downdrift with the inlet migration. Although the migration rates of the up and downdrift banks of the inlet and the tidal bar are phase-locked, they are out of phase with the local net sediment changes in the shorezone bordering the inlet. The inlet banks and channel form an accretion/erosion sequence that travels along the beach and surf zone while the ebb tide bar forms an accretion wave that moves along the shore in deeper water. Their relative on/offshore positions depend on the inlet tidal velocities that are functions of the size of the inlet and the volume of tidal flow through it (Inman and Dolan, 1989; Jenkins and Inman, 1999).

Accretion/erosion waves associated with river deltas and migrating inlets are common site specific cases that induce net changes in the littoral budget of

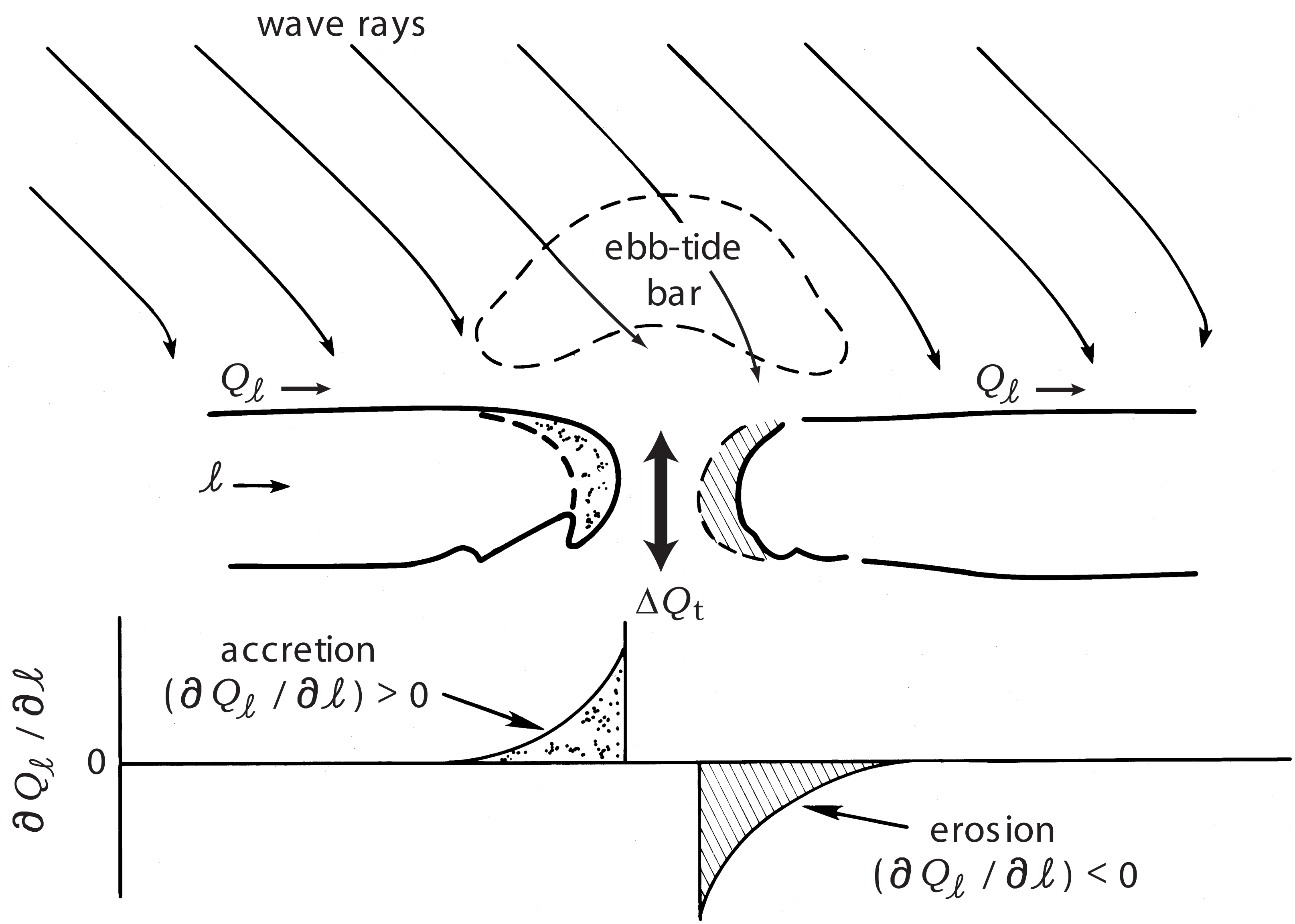

Figure 2. Schematic diagram of the divergence of drift ($\partial Q_\ell / \partial \ell$) at a migrating tidal inlet with net tidal flux of sediment, Q_t [modified from Inman and Dolan, 1989].

01.8-2a

sediment. However it appears that accretion/erosion waves in some form are common along all beaches subject to longshore transport of sediment. This is because coastline curvature and bathymetric variability (e.g., shelf geometry and offshore bars) introduce local variability in the longshore transport rate.

Mechanics of migration

An accretion/erosion wave is a wave and current generated movement of the shoreline in response to changing sources and sinks in the local balance of sediment flux along a beach. The downdrift propagation of the wave form is driven by advective and diffusive fluxes of sediment mass (Figure 3a). For convenience, these processes are usually expressed in terms of the longshore flux of sediment volume Q_ℓ into and out of a control cell (Q_{in}, Q_{out}; Figure 3b). By convention, fluxes of sediment into the cell are positive and fluxes out are negative. The net change of the volume fluxes between the updrift and downdrift boundaries of the control cell ($Q_{in} - Q_{out}$ = divergence of drift) will result in a net rate of change in the position of the shoreline $\partial x/\partial t$. Shifts in shoreline position will in turn cause the beach profile within the control cell to adjust to new equilibrium positions (Figure 3b). The new profile positions alter local wave refraction causing adjustments in the flux of sediment leaving the control cell (Q_{out}). The variation in Q_{out} will alternately accrete and erode the beach downdrift of the control cell. As a consequence, propagation of the accretion/erosion wave involves a chain reaction in the local sediment flux balances. The reaction is set off by a disturbance on the updrift side of the control cell that yields a shoreline response on the downdrift side.

At a tidal inlet, these dynamics are impacted by additional fluxes of sediment into or out of a control cell centered at the inlet. When the tidal transport of

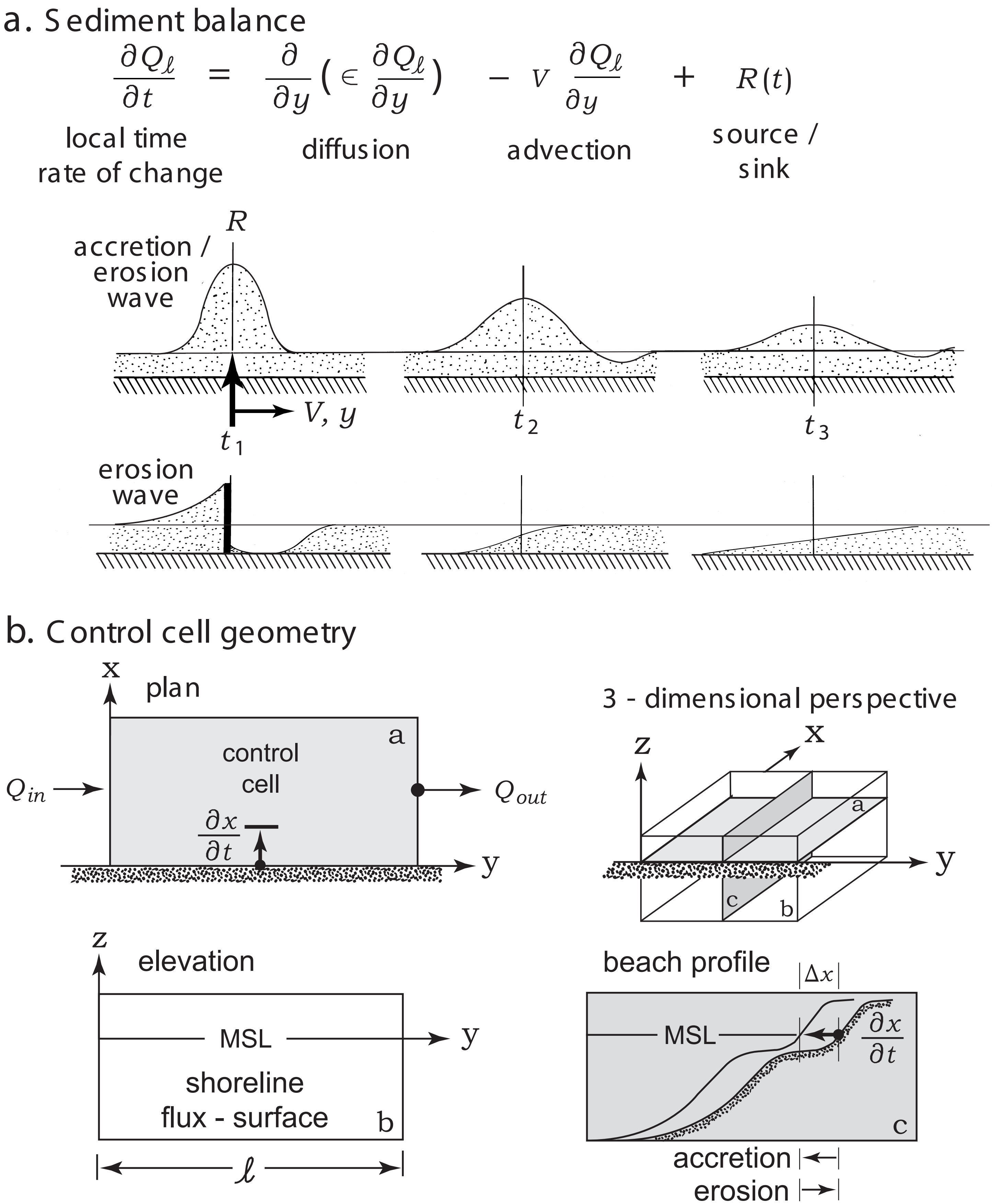

Figure 3. The balance of sediment for a propagating accretion / erosion wave [modified from Inman and Dolan, 1989].

sediment is ebb-dominated ($\Delta Q_t > 0$), the sediment flux into the control cell builds the ebb-tide bar and increases the rate of sediment that passes over the bar to the downdrift side of the inlet (Figure 2). This stabilizes the inlet position by decreasing deposition on the updrift side and erosion on the downdrift side. Flood-dominated tidal transport ($\Delta Q_t < 0$) has the opposite effect and will cause the inlet to migrate faster (Jenkins and Inman, 1999).

Douglas L. Inman and Scott A. Jenkins

Bibliography

Hicks, D. M., and Inman, D. L., 1987. Sand Dispersion from an Ephemeral River Delta on the Central California Coast. *Marine Geology*, **77**, 305-318.

Inman, D. L., 1987. Accretion and Erosion Waves on Beaches. *Shore & Beach*, **55**, 61-66.

Inman, D. L., and Bagnold, R. A., 1963. Littoral Processes. In Hill, M. N. (ed.), *The Sea, Volume 3, The Earth Beneath The Sea.* New York, London: John Wiley and Sons, pp. 529-553.

Inman, D. L., and Brush, B. M., 1973. The Coastal Challenge. *Science*, **181**, 20-32.

Inman, D. L., and Dolan, R., 1989. The Outer Banks of North Carolina: Budget of Sediment and Inlet Dynamics along a Migrating Barrier System. *Journal of Coastal Research*, **5**, 193-237.

Inman, D. L., and Jenkins, S. A., 1985. Erosion and accretion waves from Oceanside Harbor. In *Oceans 85: Ocean Engineering and the Environment.* Marine Technological Society & IEEE, **1**, pp. 591-593.

Inman, D. L., Elwany, M. H. S., Khafagy, A. A., and Golik, A., 1992. Nile Delta profiles and migrating sand blankets. *Proc. 23rd Coastal Engineering Conference*, American Society of Civil Engineers, pp. 3273-84.

Jenkins, S. A., and Inman, D. L., 1999. Sand Transport Mechanics for Equilibrium in Tidal Inlets. *Shore & Beach,* **67**, 53-58.

Leatherman, S. P., Dean, R. G., Everts, C. E., and Fulford, E., 1987. Shoreline and sediment budget analysis of North Assateague Island, Maryland," *Proceedings, Coastal Sediments '87*, ASCE, p. 1460-71.

Shepard, F. P., and Wanless, H. R., 1971. *Our Changing Coastlines*. McGraw-Hill Book Co.

Cross-references

Beach Processes
Energy and Sediment Budgets of the Global Coastal Zone
Littoral Cells
Longshore Sediment Transport
Sediment Budget