SAND MINING FACTS

The Ojos Negros Research Group

1. IMPACTS OF SAND MINING

For thousands of years, sand and gravel have been used in the construction of roads and buildings. Today, demand for sand and gravel continues to increase. Mining operators, in conjunction with cognizant resource agencies, must work to ensure that sand mining is conducted in a responsible manner.

Excessive instream sand-and-gravel mining causes the degradation of rivers. Instream mining lowers the stream bottom, which may lead to bank erosion. Depletion of sand in the streambed and along coastal areas causes the deepening of rivers and estuaries, and the enlargement of river mouths and coastal inlets. It may also lead to saline-water intrusion from the nearby sea. The effect of mining is compounded by the effect of sea level rise. Any volume of sand exported from streambeds and coastal areas is a loss to the system.

Excessive instream sand mining is a threat to bridges, river banks and nearby structures. Sand mining also affects the adjoining groundwater system and the uses that local people make of the river.

Instream sand mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Impacts include bed degradation, bed coarsening, lowered water tables near the streambed, and channel instability. These physical impacts cause degradation of riparian and aquatic biota and may lead to the undermining of bridges and other structures.

Continued extraction may also cause the entire streambed to degrade to the depth of excavation.

Sand mining generates extra vehicle traffic, which negatively impairs the environment. Where access roads cross riparian areas, the local environment may be impacted.

1.1 Sand Budget

Determining the sand budget for a particular stream reach requires site-specific topographic, hydrologic, and hydraulic information. This information is used to determine the amount of sand that can be removed from the area without causing undue erosion or degradation, either at the site or at a nearby location, upstream or downstream.

In-channel or near-channel sand-and-gravel mining changes the sediment budget, and may result in subtantial changes in the channel hydraulics. These interventions can have variable effects on aquatic habitat, depending on the magnitude and frequency of the disturbance, mining methods, particle-size characteristics of the sediment, the characteristics of riparian vegetation, and the magnitude and frequency of hydrologic events following the disturbance.

Temporal and spatial responses of alluvial river systems are a function of geomorphic thresholds, feedbacks, lags, upstream or downstream transmission of disturbances, and geologic/physiographic controls. Minimization of the negative effects of sand-and-gravel mining requires a detailed understanding of the response of the channel to mining disturbances.

Decisions on where to mine, how much and how often require the definition of a reference state, i.e., a minimally acceptable or agreed-upon physical and biological condition of the channel. Present understanding of alluvial systems is generally not sufficient to enable the prediction of channel responses quantitatively and with confidence; therefore, reference states are difficult to determine. Still, a general knowledge of fluvial processes can provide guidelines to minimize the detrimental effects of mining. Well-documented cases and related field data are required to properly assess physical, biological, and economic tradeoffs.

1.2 Riparian Habitat, Flora and Fauna

Instream mining can have other costly effects beyond the immediate mine sites. Many hectares of fertile streamside land are lost annually, as well as valuable timber resources and wildlife habitats in the riparian areas. Degraded stream habitats result in lost of fisheries productivity, biodiversity, and recreational potential. Severely degraded channels may lower land and aesthetic values.

All species require specific habitat conditions to ensure long-term survival. Native species in streams are uniquely adapted to the habitat conditions that existed before humans began large-scale alterations. These have caused major habitat disruptions that favored some species over others and caused overall declines in biological diversity and productivity. In most streams and rivers, habitat quality is strongly linked to the stability of channel bed and banks. Unstable stream channels are inhospitable to most aquatic species.

Factors that increase or decrease sediment supply often destabilize bed and banks and result in dramatic channel readjustments. For example, human activities that accelerate stream bank erosion, such as riparian forest clearing or instream mining, cause stream banks to become net sources of sediment that often have severe consequences for aquatic species. Anthropogenic activities that artificially lower stream bed elevation cause bed instabilities that result in a net release of sediment in the local vicinity. Unstable sediments simplify and, therefore, degrade stream habitats for many aquatic species. Few species benefit from these effects.

The most important effects of instream sand mining on aquatic habitats are bed degradation and sedimentation, which can have substantial negative effects on aquatic life. The stability of sand-bed and gravel-bed streams depends on a delicate balance between streamflow, sediment supplied from the watershed, and channel form. Mining-induced changes in sediment supply and channel form disrupt channel and habitat development processes. Furthermore, movement of unstable substrates results in downstream sedimentation of habitats. The affected distance depends on the intensity of mining, particles sizes, stream flows, and channel morphology.

The complete removal of vegetation and destruction of the soil profile destroys habitat both above and below the ground as well as within the aquatic ecosystem, resulting in the reduction in faunal populations.

Channel widening causes shallowing of the streambed, producing braided flow or subsurface intergravel flow in riffle areas, hindering movement of fishes between pools. Channel reaches become more uniformly shallow as deep pools fill with gravel and other sediments, reducing habitat complexity, riffle-pool structure, and numbers of large predatory fishes.

1.3 Stability of Structures

Sand-and-gravel mining in stream channels can damage public and private property. Channel incision caused by gravel mining can undermine bridge piers and expose buried pipelines and other infrastructure.

Several studies have documented the bed degradation caused by the two general forms of instream mining: (1) pit excavation and (2) bar skimming. Bed degradation, also known as channel incision, occurs through two primary processes: (1) headcutting, and (2)"hungry" water. In headcutting, excavation of a mining pit in the active channel lowers the stream bed, creating a nick point that locally steepens channel slope and increases flow energy. During high flows, a nick point becomes a location of bed erosion that gradually moves upstream (Fig. 1).

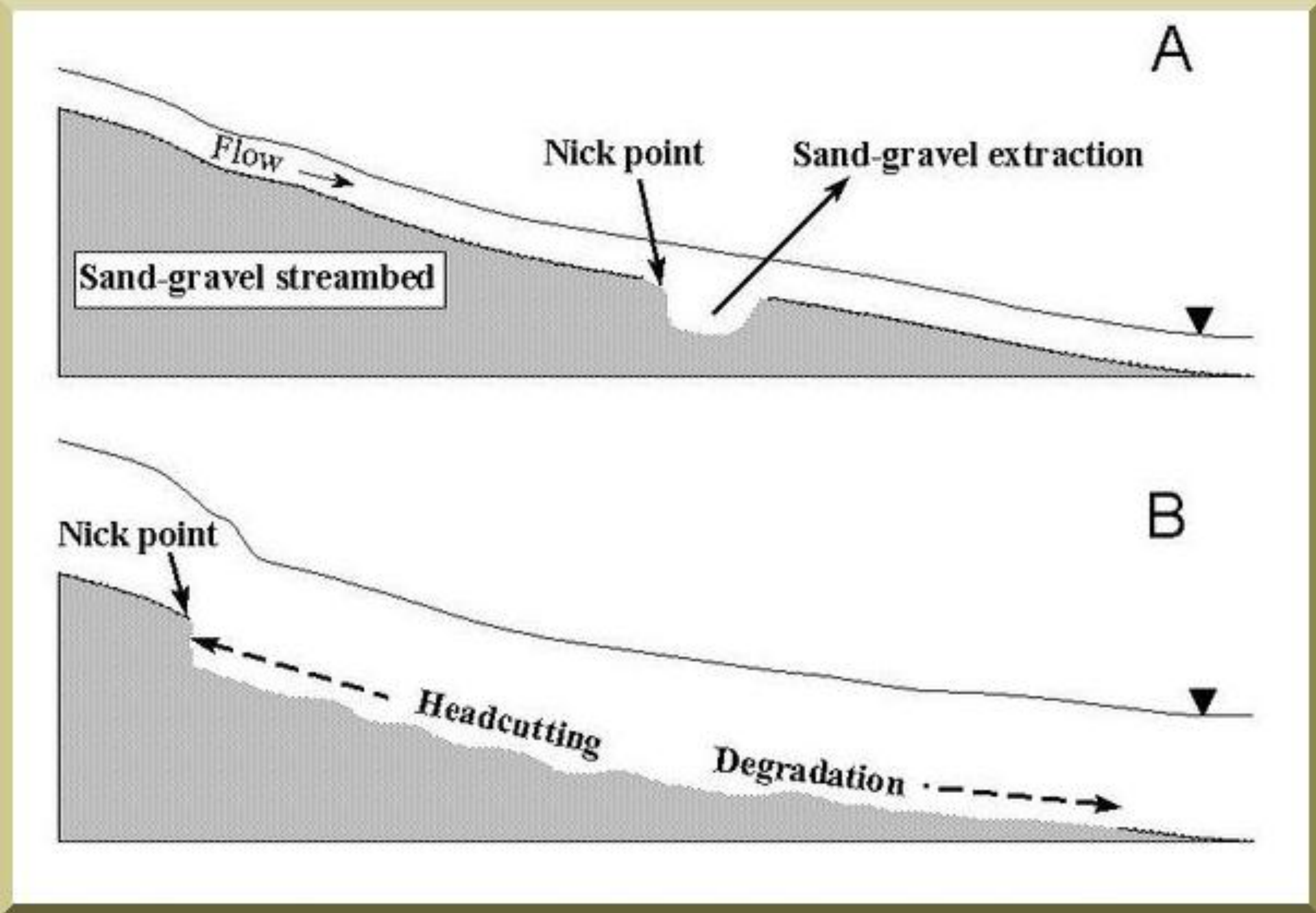

Fig. 1 Diagram of sand-and-gravel stream bed showing (A) the nick point that develops with a pit excavation, and (B) the upstream head cutting and downstream bed degradation that develop during high flows.

Headcutting mobilizes substantial quantities of streambed sediments which are then transported downstream to deposit in the excavated area and locations further downstream. In gravel-rich streams, effects downstream of mining sites may be short-lived when mining ends, because the balance between sediment input and transport at a site can reestablish itself relatively quickly. Effects in gravel-poor streams may develop rapidly and persist for many years after mining has finished. Regardless of downstream effects, headcutting in both gravel-rich and gravel-poor streams remains a major concern. Headcuts often move long distances upstream and into tributaries, in some watersheds moving as far as the headwaters or until halted by geologic controls or man-made structures.

A second form of bed degradation occurs when mineral extraction increases the flow capacity of the channel. A pit excavation locally increases flow depth (Fig. 1) and a barskimming operation increases flow width (Fig. 2). Both conditions produce slower streamflow velocities and lower flow energies, causing sediments arriving from upstream to deposit at the mining site. As streamflow moves beyond the site and flow energies increase in response to the "normal" channel form downstream, the amount of transported sediment leaving the site is now less than the sediment carrying capacity of the flow. This sediment-deficient flow or "hungry" water picks up more sediment from the stream reach below the mining site, furthering the bed degradation process (Fig. 1). This condition continues until the equilibrium between input and output of sediments at the site is reestablished.

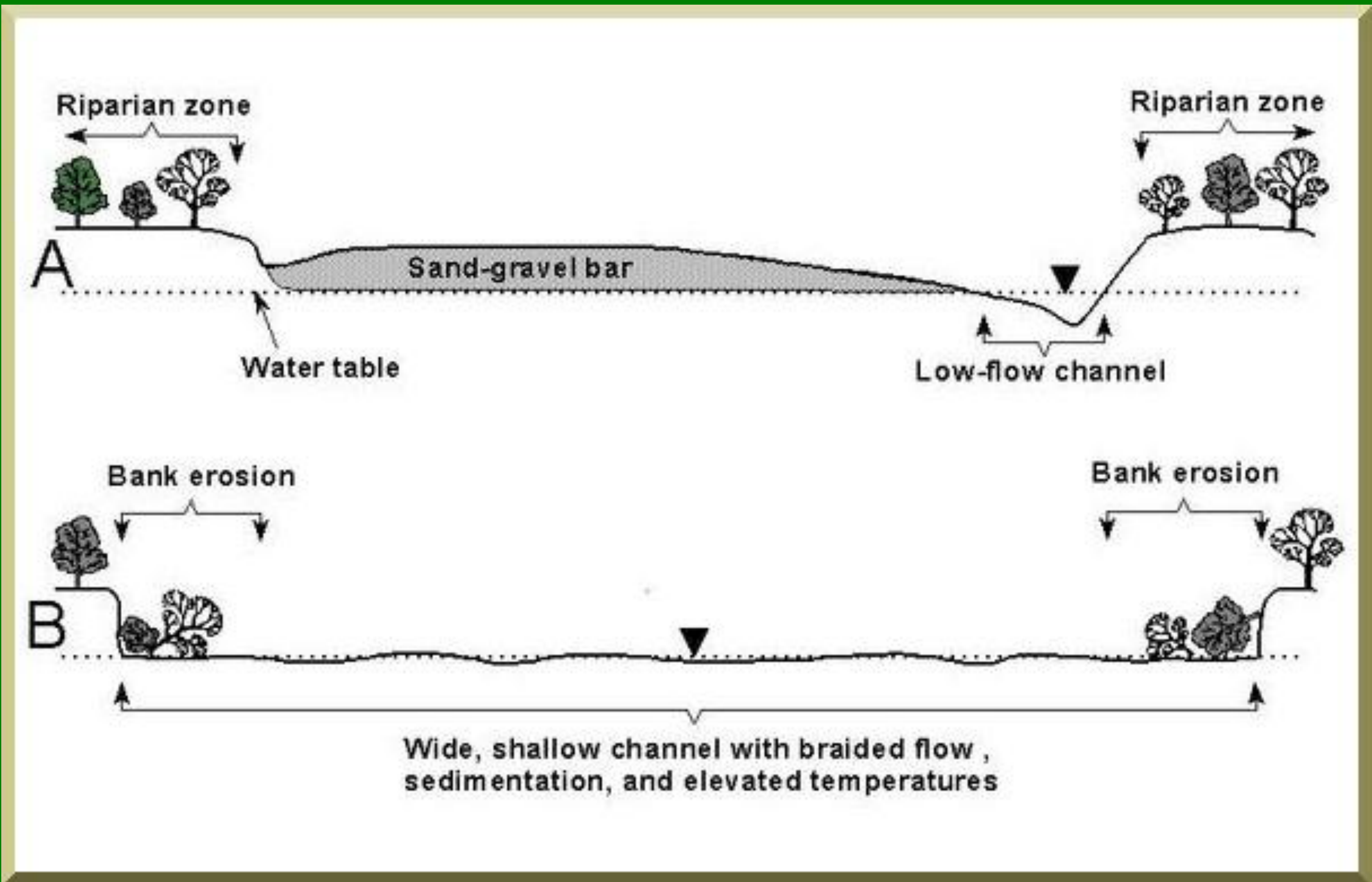

Fig. 2 Diagram of channel cross sections showing (A) a typical sand-gravel bar in relation to the low-flow channel, riparian zone and water table, and (B) the wide shallow channel that results from unrestricted mining and that is characterized by bank erosion, braided flow, sedimentation, and increased water temperatures.

A similar effect occurs below dams, which trap sediment and release "hungry" water downstream, where channel incision usually ensues. Instream mineral excavation downstream of dams compounds this problem. Although other factors such as levees, bank protection, and altered flow regimes also promote channel incision, mineral extraction rates in many streams are often orders-of-magnitude in excess of sediment supply from the watershed, suggesting that extraction is largely responsible for observed channel changes. Susceptibility to hungry-water effects would depend on the rate of extraction relative to the rate of replenishment. Gravel-poor streams would be most susceptible to disturbance.

Channel incision not only causes vertical instability in the channel bed, but also causes lateral instability in the form of accelerated stream bank erosion and channel widening. Incision increases stream bank heights, resulting in bank failure when the mechanical properties of the bank material cannot sustain the material weight. Channel widening causes shallowing of the streambed (Fig. 2) as deep pools fill with gravel and other sediments. Shallowing and widening of the channel also increases stream temperature extremes, and channel instability increases transport of sediments downstream. Mining-induced bed degradation and other channel changes may not develop for several years until major channel-adjustment flows occur, and adjustments may continue long after extraction has ended.

1.4 Groundwater

Apart from threatening bridges, sand mining transforms the riverbeds into large and deep pits; as a result, the groundwater table drops leaving the drinking water wells on the embankments of these rivers dry. Bed degradation from instream mining lowers the elevation of streamflow and the floodplain water table which in turn can eliminate water table-dependent woody vegetation in riparian areas, and decrease wetted periods in riparian wetlands. For locations close to the sea, saline water may intrude into the fresh waterbody.

1.5 Water Quality

Instream sand mining activities will have an impact upon the river's water quality. Impacts include increased short-term turbidity at the mining site due to resuspension of sediment, sedimentation due to stockpiling and dumping of excess mining materials and organic particulate matter, and oil spills or leakage from excavation machinery and transportation vehicles.

Increased riverbed and bank erosion increases suspended solids in the water at the excavation site and downstream. Suspended solids may adversely affect water users and aquatic ecosystems. The impact is particularly significant if water users downstream of the site are abstracting water for domestic use. Suspended solids can significantly increase water treatment costs.

1.6 Summary

Impacts of sand mining can be broadly clasified into three categories:

- **Physical**

  The large-scale extraction of streambed materials, mining and dredging below the existing streambed, and the alteration of channel-bed form and shape leads to several impacts such as erosion of channel bed and banks, increase in channel slope, and change in channel morphology. These impacts may cause: (1) the undercutting and collapse of river banks, (2) the loss of adjacent land and/or structures, (3) upstream erosion as a result of an increase in channel slope and changes in flow velocity, and (4) downstream erosion due to increased carrying capacity of the stream, downstream changes in patterns of deposition, and changes in channel bed and habitat type.

- **Water Quality**

  Mining and dredging activities, poorly planned stockpiling and uncontrolled dumping of overburden, and chemical/fuel spills will cause reduced water quality for downstream users, increased cost for downstream water treatment plants and poisoning of aquatic life.

- **Ecological**

  Mining which leads to the removal of channel substrate, resuspension of streambed sediment, clearance of vegetation, and stockpiling on the streambed, will have ecological impacts. These impacts may have an effect on the direct loss of stream reserve habitat, disturbances of species attached to streambed deposits, reduced light penetration, reduced primary production, and reduced feeding opportunities.