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Prediction of Sediment Transport in Irrigation Canals

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ABSTRACT

Sediment transport in irrigation canals is a critical issue in irrigation system design and operation. Clogging of turnouts and reduction of canal conveyance capacity due to siltation are common irrigation system problems, as is instability of side slopes and structures due to erosion. Large investments are required each year to maintain or rehabilitate these systems and keep them in usable condition for irrigation purposes. Irrigation canals are typically designed with the assumption of a consistent and uniform flow of water and sediments. However, because of time-dependent discharges and constant water levels at regulation and division points, the flow is predominantly non-uniform. Sediment transport and flow conditions have a strong relationship.

KEYWORDS: *Canals, MRLC, Numerical Model, Silt ejector, Sedimentation, Simulation*

INTRODUCTION

Canals are natural or man-made waterways that connect to major navigable waterways. Tidal canals and non-tidal canals are the two types of canals. Tidal canals are those in coastal areas that are directly adjacent to the ocean or connect the sea to a water body with facilities. Non-tidal canals are those with ends that connect natural river channels, most often with oil-related field facilities or small port facilities and jetties.

Canals silt up at an alarming rate as a result of poor or non-existent maintenance. [1]Canal maintenance is both costly and necessary in order to make the facilities and ports to which they are connected accessible. The government and industries spend large sums of money each year dredging these canals, resulting in the loss of aquatic life due to excessive biological oxygen demand of the biodegradable portion of the sediments, which results in a loss of dissolved oxygen in the receiving water bodies where the dredging spoils are discharged. This necessitates an understanding of the various factors that influence sedimentation, analysing them critically in order to come up with some measures to check excessive sedimentation or, to the greatest extent possible, bring the rate of sedimentation to a minimum. [2]

Sediment transport (ST) is a significant geological factor that is associated with the mechanisms of sediment load production, transport, and deposition. It is frequently associated with the effects of a moving fluid (air or water) on cohesive or non-cohesive sediments and the resulting fluxes of particles from sources to sinks. Sediments cover the majority of the earth's surface and their long-term movement influences landscapes [1,2], making them an important interface between humans and the environment. The transport of sediment in irrigation canals has a significant impact on the sustainability of an irrigation system. Unwanted erosion or deposition not only raises maintenance costs, but it may also result in an unfair, unreliable, and unequitable distribution of irrigation water to end users. [3] Proper knowledge of sediment characteristics, including behaviour and transport, will aid in the design of irrigation systems, the planning of efficient and reliable water delivery schedules, the controlled deposition of sediments, the estimation and planning of maintenance activities, and so on.

ST happens when the flow is fast enough to erode and move the surface sediments. In practice, the process is extremely complex, and once movement begins, the fluid's properties are altered by the presence of the irregularly shaped solid particles that make up the bedform. When the particle size range is broad,

different ways of characterising ST phenomena emerge. There are two basic modes of transport: bedload transport, in which particles roll or slide along the bed of a river or sea (which is difficult to quantify), and suspension transport, in which particles are entrained by the flow and move in suspension with the water mass. [4] Rating curves based on empirical relationships between sediment concentrations and discharge are commonly used to estimate suspended sediment concentrations, as are nonlinear approaches such as artificial neural networks. The fluxes transported will vary significantly over time and space due to factors such as particle size, shape, and density.

Irrigation Canal

A canal transports water from its source to agricultural fields. Navigation canals are canals used for the transportation of goods. Power canals transport water for hydroelectric power generation. A feeder canal supplies water to one or more canals. A link canal connects the two canals so that water from one canal can be diverted to the other canal if necessary. [5] A canal can serve more than one purpose. A canal can be either permanent or inundation depending on the nature of the source of supply. A permanent canal has a constant supply of water. Perennial canals are another name for such canals.

Waterlogging

One of the major disadvantages of canal irrigation is waterlogging. An agricultural land is said to be water logged when its productivity is hampered by a high water table, and productivity is hampered when the root zone of a plant is flooded with water. Salinization and waterlogging affect more than 33% of the world's irrigated land. Soil salinity and alkalinity affect 8.4 million hectares in India alone, with approximately 5.5 million hectares waterlogged. Waterlogging is primarily caused by an increased water table, which occurs as a result of excessive or intensive irrigation in poorly drained soil where water cannot penetrate deeply and enters the soil faster than it drains away. It is exacerbated by subsoil layer compaction, where water quickly enters the topsoil but is then blocked by a water-resistant clay layer, which can occur naturally or be induced by excessive use of agricultural machinery. [6] Water from canals may seep through canal beds and sides, reservoirs, etc., or seepage of water from adjoining high lands into subsoil of affected land, or inadequate drainage system soil with less permeable substratum below topsoil will not be able to drain water deep into ground causes high water table. Water drains quickly in steep terrain, but poorly in flat terrain, raising the water table. When the water table rises, it fills the air spaces in the soil, causing plant roots to suffocate from a lack of oxygen and thus limiting plant growth in those areas. Waterlogging affects approximately 10% of all irrigated lands. It is most common on flat floodplains or gently sloping landforms with heavy rainfall and red duplex or heavy clay soils.

Review of Literature

When water flows through a channel or a reservoir, the velocity of the water is reduced due to suspended sediments being deposited. High water velocity causes more sediment to be picked up. When water velocity is reduced, the heaviest sediments settle (Haun et al., 2012[7], Lysne et al., 2003[8]).

Jaan Hui Pu et al. (2014)[9] investigated the numerical and numerical computation of abutment scour development. However, work on three-dimensional modelling of sediment flows in canals continues. There has never been a single example of three-dimensional modelling being used to investigate sediment transport in canals in Pakistan.

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Sediments are generally defined as solid particles that are being or have been moved by a fluid. Sediment is generally classified based on its size, specific weight, shape, mineralogical composition, colour, and other characteristics. The grain size is the most important factor in its movement by water because it causes the greatest range of mobility. Sediment can be classified as deposited or suspended for the purposes of aquatic monitoring (Ongley, 1996). [10]

Objectives

- To investigate the sketch of sediment transport in open water;
- To investigate the sediment size relationship with sediment concentration;
- To investigate the sediment size relationship with fall velocity; and
- To investigate sedimentation processes.

Research Methodology

A research methodology is a method for solving a research problem in a systematic manner. It can be thought of as a science that studies how scientific research is conducted. In it, we look at the various steps that a researcher takes when studying a research problem, as well as the logic behind them. The researcher must understand not only the research methods/techniques but also the methodology. The current study is descriptive in nature and is based on secondary data gathered from a variety of sources such as books, education, and development, journals, scholarly articles, government publications, and printed and online reference materials.

Result and Discussion

The sediment can be eroded by the river current acting on the movable bed, or it can be moved downstream by raindrop impact from eroding slopes (see Fig 1) and conveyed to a river or valley, or it can be moved by the actions of currents (i.e. the longshore current) and transported along the shoreline in coastal areas. [11] However, depending on the case, the processes that cause solid particle detachment can vary greatly.

Fig. 1 Examples of eroding slopes and the natural erosion/sedimentation processes

The fall velocity is proportional to the size of the sediment. Gravitational velocity increases as particle size increases. Different sediment sizes contribute differently to total deposition in the canal. [12] Figure 2a depicts the graphic relationship between sediment size and fall velocity.

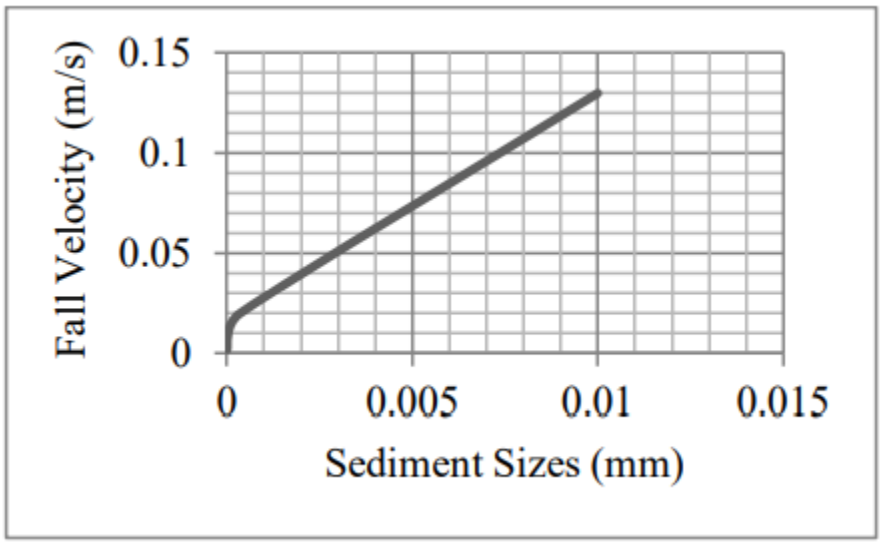

Fig.2a Sediment size relationship with Fall Velocity

Silt particles (0.02 mm) have the highest concentration, followed by sand (0.13mm) and caly Figure 2b depicts the concentration of various sediment sizes in the flows.

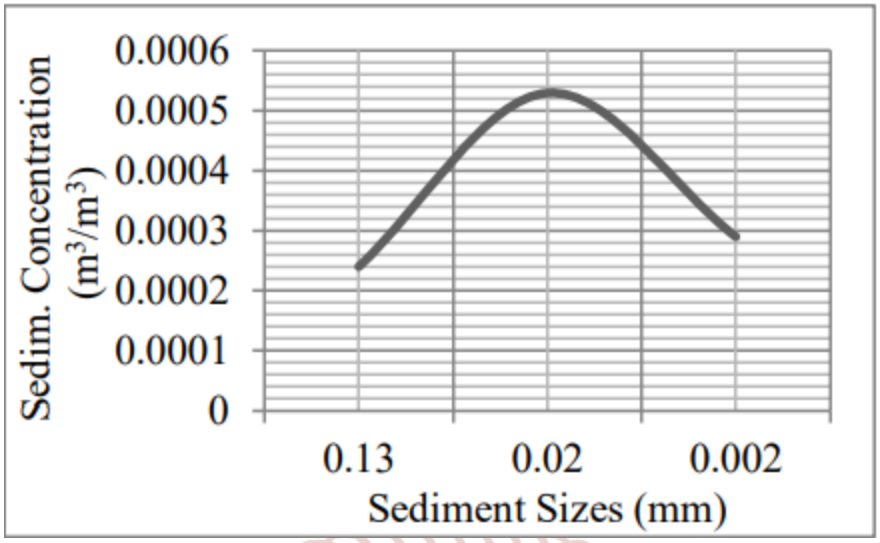

Fig. 2 b Sediment size relationship with Sediment Concentration

Sediment transport in natural waters is classified into two major modes: bed-load transport and suspended-load transport (Fig. 3). The movement of sediment grains within a thin layer just above the seabed is referred to as bed-load transport. It includes grain rolling, sliding, and saltation. Although some literature considers saltation to be a type of suspended-load transport, it appears more appropriate to treat it in numerical models as bed-load transport. This is due to a strong interaction between saltating particles and the bed surface, as well as a high settling velocity of saltating particles that is difficult to resolve numerically. Suspended-load transport is the entrainment and transport of sediment particles by a fluid flow in which sediment particles sink slowly and are carried over a long distance before settling. [13] There is no clear distinction between these two modes because the range of relocation of a sediment particle is highly dependent on the motions of the surrounding water. [14]

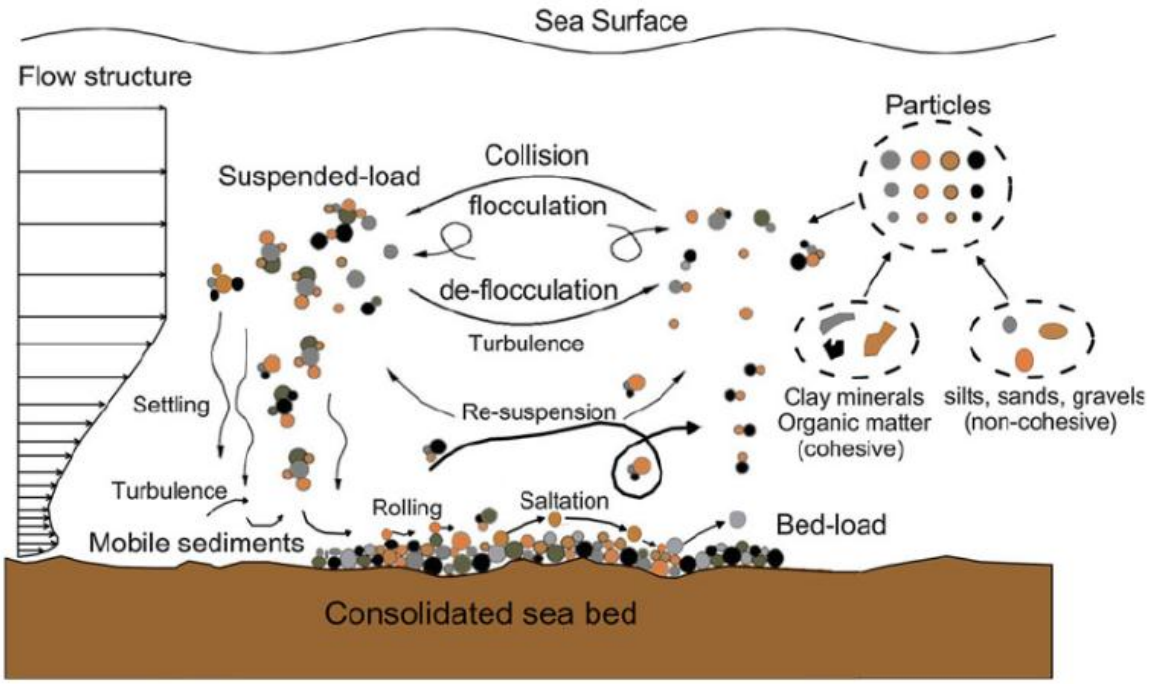

Fig. 3 Sketch of sediment transport in open water

Conclusion

Sediment transport is one of the most difficult topics in many fields (e.g. coastal, hydraulic and environmental engineering). It can be found in seas and oceans, lakes, rivers, harbours, and a variety of other natural systems. All of these aspects have historically been linked to specific research areas such as engineering, geology, geomorphology, biology, and so on, but it is difficult to find a comprehensive overview of these topics. At the moment, human activities (such as dams, railways, and bridges) have caused significant changes in sediment transport rate

behind the natural processes that cause soil erosion, sediment transport, and deposition. These changes have affected the coastal sediment budget, which has implications for shoreline dynamics, as well as the morpho dynamics and water quality of rivers. The findings of this study indicate that sedimentation can occur only when there is a decrease in water current due to constrictions and barriers to flow water in the canal. Given that the majority of the constrictions are natural occurrences caused by the process of delta formation, limiting excessive sedimentation to that which would occur under natural conditions relies on removing as many barriers or impediments to water flow as possible. This will invariably keep the water current moving in such a way that the sediments stay afloat, allowing them to be transported to areas where navigation is not affected.

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