A

PROGRESS REPORT

ON

# THE EFFECTIVENESS OF DELTOIDS AS A PRO SILTATION MEASURE IN ALLUVIAL RIVERS – AN EXPERIMNTAL INVESTIGATION

***Submitted in partial fulfillment of the requirements for the award of the***

***Degree of***

**MASTERS OF TECHNOLOGY**

**In**

**CIVIL ENGINEERING**

(With Specialization in Water Resources Engineering)

**UNDER**

**ASSAM SCIENCE AND TECHNOLOGY UNIVERSITY**


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# CANDIDATE DECLARATION

I hereby certify that the work presented in the dissertation report entitled " **THE EFFECTIVENESS OF DELTOIDS AS A PRO SILTATION MEASURE IN ALLUVIAL RIVERS – AN EXPERIMENTAL INVESTIGATION** " is accorded for the award of degree of **MASTER OF TECHNOLOGY** with specialization in water resources engineering, submitted in the department of Civil Engineering, Assam Engineering College, Guwahati, Assam has been carried out by me under the guidance of **MRS. RHITWIKA BARMAN**, Assistant Professor, Department of Civil Engineering, Assam Engineering College, Guwahati.

The content of this report has not been submitted to any other university for the award of any degree.

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# CERTIFICATE OF APPROVAL FROM GUIDE

This is to certify that the dissertation report entitled **" THE EFFECTIVENESS OF DELTOIDS AS A PRO SILTATION MEASURE IN ALLUVIAL RIVERS – AN EXPERIMENTAL INVESTIGATION "** is submitted by **BARASHA KAKOTI**, Roll No.-203620061007, a student of 3rd semester in the Department of Civil Engineering, Assam Engineering College, Guwahati in partial fulfillment for the award of degree of **MASTER OF TECHNOLOGY** in Civil Engineering with specialization in Water Resources Engineering under **ASSAM SCIENCE AND TECHNOLOGY UNIVERSITY** has been carried out under my guidance.

The content of this report has not been submitted to any other university for the award of any degree.

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# CERTIFICATE OF APPROVAL FROM HEAD OF THE DEPARTMENT

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The content of this report has not been submitted to any other university for the award of any degree.

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# ABSTRACT

As known alluvial rivers are self-made rivers in which the bed and sediments are made up of mobile sediments or soil. Alluvial rivers are very flood prone in nature due to which the channel of these rivers is shaped with the mobility of its bed sediments.

Flooding is a prominent natural disaster that cause damages to the rivers and the localities surrounding it. The most severe damage flooding cause to rivers is the scouring of the river bed and bank. To figure out the solution for mitigating this damage we have worked out a new model of porcupine in deltoid structure. This report work discusses the experiments performed with the deltoid model.

Permeable model like porcupine, jack jetty is sediment trap system that captures the sediment in the river, thereby controlling scouring. These systems have been deployed in large Indian rivers such as the Ganga, Brahmaputra, and Kosi as a cost-effective measure for river training, and has been found to produce positive results in capturing sediment. Using various dimensional parameters, trial deltoid models were prepared and laid on simulated channel with alluvial river strategies. The research aimed to investigate the sediment deposition pattern for various configurations of deltoid, with specific focus on discharge and sediment concentration of the river. The research findings provide valuable insights into the sediment trap efficiency of deltoid systems and can be used to improve the design and implementation of sediment trap systems in rivers. This can ultimately aid in reducing the impact of floods and protect both land and property.

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# ABSTRACT


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Permeable model like porcupine, jack jetty is sediment trap system that captures the sediment in the river, thereby controlling scouring. These systems have been deployed in large Indian rivers such as the Ganga, Brahmaputra, and Kosi as a cost-effective measure for river training, and has been found to produce positive results in capturing sediment. Using various dimensional parameters, trial deltoid models were prepared and laid on simulated channel with alluvial river strategies. The research aimed to investigate the sediment deposition pattern for various configurations of deltoid, with specific focus on discharge and sediment concentration of the river. The research findings provide valuable insights into the sediment trap efficiency of deltoid systems and can be used to improve the design and implementation of sediment trap systems in rivers. This can ultimately aid in reducing the impact of floods and protect both land and property.

# CHAPTER 1
# INTRODUCTION

## 1.1 GENERAL

Alluvial rivers are the most flood prone water bodies showing maximum meandering nature which cause severe erosion and scouring. Erosion and scouring causes catastrophic and uncontrollable situation if not addressed properly. During the monsoon season, when river erosion speeds up and labour and material availability becomes scarce, this is especially difficult. It is essential to be proactive in preventing this by examining the river's pattern and putting in place prompt river training procedures. These treatments may involve re-vegetation to lessen flow speed, as well as strategic bank or channel construction to stabilize and preserve the river channel. Effective river training prevents excessive meandering, minimizes stream changing, and maintains navigability. Finally, the key to successfully controlling scour is to take preventative measures and implement effective tactics that fit the river's individual needs.

River banks are typically protected by a variety of river training works such as a marginal embankment or levees, guide banks, guide bunds, groynes or spurs, submerged vanes, cut offs, bank pitching, pitched islands, sills, closing dykes, and longitudinal dykes. Some of these measures cost less than others. When using them, factors like as building cost, environmental impact, and aesthetics should be considered in addition to their performance. The least expensive structures to build are usually permeable ones. The necessity of creating affordable river training programs has come to light due to the growing demand for bank protection work in various river reaches. As a result, using framed structures has become more significant as an economical river management strategy. These low-cost techniques for river training include tetrahedral frames, board fencing, bandalling, porcupine, and jack-jetty systems.

Fig. 1- Alluvial River Example

## 1.2 SEDIMENT LOAD

The entire quantity of material carried by river water at any one time is referred to as the sediment load in a river. Particles like sand, silt, and clay that have been eroded off the landscape and carried by the river water make up sediment in rivers. A dynamic feature of river systems, the sediment load can fluctuate greatly depending on a number of variables, including geology, climate, land use, and human activity.

The structure and operation of alluvial rivers are fundamentally influenced by sediments. Even while they produce dynamic and fruitful systems, their imbalance brought on by man-made or natural sources can result in serious problems like habitat loss, flooding, and deteriorating water quality. For alluvial rivers to remain healthy and sustainable, effective sediment control is essential. Sediment is transported by rivers through different modes, including traction, saltation, suspension and solution. Sediment load affects the morphology of the river channels and beds which develops the features like bars, banks, and floodplains. Excess sedimentation can cause to aggradation, where sediment accumulation in the channel take place that eventually affect the river depth and navigation as well. High sediment accumulation can thoroughly impact aquatic life of a river negatively and can hamper human livelihood too. Excessive sedimentation can pose problems in building infrastructures such as bridges, dams, and water intakes.

Investigating sediment load is highly recommended to understand the depth of river dynamics, water resource management and implementation of effective conservation and erosion control measures. River engineers and experts including environmental scientist often use sediment transport models and monitoring techniques to assess and manage sediment load in rivers.

## 1.3 MECHANISM OF SEDIMENT TRANSPORTATION IN ALLUVIAL RIVERS

The sediment load is typically categorized into four main types based on how the sediments are transported:

**a. Suspended Load –**

Suspended load is the sediment carried by the flow in suspension, supported by the surrounding fluid, and consisting mostly of smaller particles like clay, silt, and fine sands. It settles when flow velocity decreases. It is kept in suspension by the upward motion due to the turbulence exchange which continuously exchanges fluid over a certain distance between horizontal layers, creating a balance between the settling of sediment and rising fluid from lower layers of higher concentration. Suspended load exerts additional hydrostatic pressure on the riverbed.

**b. Bed Load –**

Bed load is the sediment transported along the riverbed by sliding, rolling, and saltation. It typically makes up 5-20% of total sediment transport and consists of heavy particles such as sand, pebbles, gravels, and cobbles. Saltation is one method of bed load transport in which current lifts sediment from the bed and carries it a certain distance before it falls back to rest. This process can create a chain reaction as particles are lifted and moved, resulting in the exchange of places among similar particles on a non-moving bed.

**c. Dissolved Load –**

Dissolved load refers to the particles that are carried in solution by the stream flow. It is a much smaller component of the total sediment transport than suspended and bed load. The dissolved load consists of particles that are soluble in water and can be derived from the dissolution of rocks in the channel, as well as from tributaries entering the stream.

**d. Wash Load –**

This term is used to refer to both suspended and bed loads. It includes all the materials transported by the rivers which is not in direct contact with the river bed.

The balance between these transport mechanisms depends on factors such as the velocity of the river, the size and density of the sediment particles, the river bed slope and supply of the sediments from the watershed. Generally, high velocity rivers with steep gradient can transport larger particles as bed load, while slower rivers prone to transport finer sediments.

## 1.4 RIVER EROSION, SCOURING AND SILTATION

River erosion is the process by which soil, rock, or dissolved material is removed from one location on Earth's crust and transported to another location by the actions of surface processes such as water flow or wind. This process can be further divided into physical or mechanical erosion, in which rock or soil is broken down into elastic sediment, and chemical erosion, where soil or rock is dissolved into a solvent and then transported away. Here are the primary mechanisms of river erosion:

**1. Hydraulic Action**

- The force of moving water dislodges and removes particles from the riverbed and banks.
- The pressure of water entering cracks and crevices in the riverbank can cause materials to break apart.
- Hydraulic action is especially effective during high flow conditions, such as floods.

**2. Abrasion (Corrasion)**

- Sediments and particles carried by the river (such as sand, gravel, and pebbles) scrape against the riverbed and banks.
- This "sandpaper effect" wears away the surface, deepening and widening the river channel.
- Abrasion is more pronounced in rivers with high sediment loads.

**3. Attrition**

- Rocks and sediments transported by the river collide and break into smaller, smoother, and rounder particles.
- This process reduces the size of the materials over time.

**4. Solution (Corrosion)**

- Minerals in the riverbed and banks, such as limestone or chalk, dissolve in the water.
- The dissolution is influenced by the chemical composition of the water and the type of rock present.

**5. Cavitation**

- Occurs when air bubbles in the fast-moving water collapse and generate intense localized pressure.
- This pressure can weaken and break apart the rock surfaces in the riverbed and banks.

**6. Lateral Erosion**

- The river erodes the sides of its channel, leading to the widening of the valley.

- Common in the middle and lower courses of a river, where the flow is meandering.

**7. Vertical Erosion**

- The river cuts down into its bed, deepening the channel.
- Most prominent in the upper course of a river, where the flow is steep and fast.

**8. Headward Erosion**

- The process by which a river erodes its source area, extending its length upstream.
- Common in steep terrains and during heavy rainfall.

**Factors Influencing River Erosion:**

- **Velocity of the River**: Faster water flow increases erosive power.
- **Sediment Load**: Larger and more abrasive materials enhance abrasion.
- **Rock Type**: Softer rocks erode more quickly than harder ones.
- **Volume of Water**: Greater discharge amplifies hydraulic action.
- **Gradient**: Steeper slopes result in higher energy and more erosion.

**Factors Affecting River Erosion**

Several factors influence the rate and extent of river erosion. These include:

**1. Water Velocity**

- **Higher velocity** increases the river's kinetic energy, enhancing its ability to erode.
- Steeper gradients and narrow channels typically result in faster water flow.

**2. Volume of Water (Discharge)**

- Greater water discharge increases the river's erosive power.
- During floods, higher water levels and flows lead to more erosion.

**3. Sediment Load**

- A higher load of abrasive materials like sand, gravel, and pebbles increases erosion through abrasion.
- Conversely, rivers with minimal sediment may erode less effectively.

**4. Rock Type**

- **Soft rocks** (e.g., clay, sandstone) erode more easily than hard rocks (e.g., granite, basalt).
- Rocks with cracks or joints are more susceptible to hydraulic action and solution.

**5. Gradient (Slope)**

- Steeper slopes result in faster water flow and more energy for erosion.
- Rivers in mountainous regions typically erode more intensely than those in flat plains.

**6. Riverbed and Bank Characteristics**

- Loose, unconsolidated sediments are more prone to erosion.
- Vegetation on riverbanks helps reduce erosion by stabilizing soil.

**7. Human Activities**

- Deforestation, urbanization, and mining can increase erosion by destabilizing riverbanks and altering water flow.
- Dams and water diversion can also change erosion patterns.

**8. Climate and Weather**

- High rainfall increases river discharge, enhancing erosion.
- Freeze-thaw cycles in cold climates can weaken rocks, making them more susceptible to erosion.

**9. Channel Shape**

- Narrow and deep channels concentrate flow energy, increasing erosion.
- Wide, shallow channels dissipate energy, reducing erosive power.

**Scouring** is the process of removing sediment, soil, or rock from the surface of the earth, particularly around structures or within channels, by the action of moving water. It often occurs when the velocity or turbulence of water increases, causing the detachment and transportation of particles from the bed or banks of rivers, streams, or other water bodies.

**Types of Scouring**

1. **General Scouring**
   - Refers to the removal of material from the riverbed or channel floor caused by the overall flow of water.
   - Commonly observed during high-flow conditions such as floods.
2. **Local Scouring**
   - Occurs around obstacles in the water, such as bridge piers, abutments, or culverts.
   - Turbulence and vortices created by the obstruction intensify erosion at the base of the structure.
3. **Contraction Scouring**
   - Happens when the flow of water is constricted or narrowed, increasing the velocity and erosive force of the water.
   - Typically seen in narrowed river channels or beneath bridges.
4. **Bed Scouring**
   - Refers to the deepening of the riverbed due to the consistent removal of sediment over time.

**Mechanism of Scouring**

1. **Increased Flow Velocity**: As water velocity increases, the shear stress exerted on the riverbed or structure foundation surpasses the critical threshold needed to dislodge particles.
2. **Sediment Detachment**: Loose particles are detached and lifted by the force of the flowing water.

3. **Transportation**: Dislodged particles are carried downstream, leaving behind scoured areas.
4. **Vortex Formation**: Around structures, vortex action can intensify erosion by concentrating energy on specific locations.

**Factors Influencing Scouring**

1. **Flow Velocity**: Higher velocities increase the erosive potential of water.
2. **Sediment Characteristics**: Fine particles like silt are more easily eroded than coarse gravel or bedrock.
3. **Obstructions**: Structures in the flow path create turbulence and localized erosion.
4. **Water Depth and Gradient**: Steeper gradients and deeper flows generate more energy for scouring.
5. **Duration of Flow**: Prolonged high-flow conditions exacerbate scouring effects.

**Siltation** is the process by which fine sediment particles, primarily silt and clay, are transported by water and deposited in rivers, lakes, reservoirs, or other water bodies. Over time, this accumulation of sediments can reduce the capacity, depth, and flow efficiency of water systems.

**Types of Siltation**

Siltation can be categorized based on its causes, locations, and the processes through which sedimentation occurs. Here are the main types of siltation:

**1. Natural Siltation**: Occurs naturally over time due to normal geological and hydrological processes. For Example, deposition of sediments in river deltas, estuaries, or floodplains during regular river flows. Seasonal sedimentation in lakes or ponds from natural erosion upstream.

**2. Anthropogenic (Human-Induced) Siltation:** Results from human activities that accelerate the transport of sediments into water bodies.

- **Causes**:
    - **Deforestation**: Leads to soil erosion due to the lack of vegetation cover.
    - **Agriculture**: Plowing and irrigation can wash soil into nearby water bodies.

- **Construction Activities**: Exposed soil from construction sites increases sediment runoff.
- **Mining and Quarrying**: Creates loose sediments that are easily washed into rivers and lakes.

**3. Riverine Siltation:** The accumulation of sediments within river channels.

- **Causes**:
  - Erosion of riverbanks or upstream areas.
  - High sediment load during floods or monsoons.
- **Impacts**:
  - Reduces the depth of the river channel.
  - Increases flood risks by raising the riverbed level.

**4. Reservoir and Dam Siltation:** The deposition of sediments in reservoirs and dams.

- **Causes**:
  - Trapping of sediments carried by rivers upstream of the dam.
  - Lack of sediment bypass systems in dam design.
- **Impacts**:
  - Reduces storage capacity.
  - Decreases the efficiency of hydropower generation.
- **Prevention**:
  - Desilting and dredging.
  - Sediment bypass systems.

**5. Coastal and Marine Siltation:** The accumulation of sediments in coastal or marine environments.

- **Causes**:
  - Sediment transport by rivers to coastal areas.

    - Erosion of coastlines due to wave action and storms.
- **Impacts**:
    - Smothering of coral reefs and seagrass beds.
    - Changes in coastal ecosystems.

**6. Canal and Drainage Siltation**: The deposition of sediments in irrigation canals, drainage systems, or other man-made waterways.

- **Causes**:
    - Sediments carried by water during irrigation or drainage.
    - Poor maintenance of water channels.
- **Impacts**:
    - Reduces water flow efficiency.
    - Increases the cost of maintenance and dredging.

**7. Urban Siltation**: Siltation caused by urban activities and runoff.

- **Causes**:
    - Construction sites producing loose sediments.
    - Poorly managed stormwater systems carrying sediments into water bodies.
- **Impacts**:
    - Sedimentation in urban lakes and ponds.
    - Flooding in urban areas due to clogged drains.

**8. Agricultural Siltation**: Sediment deposition in water bodies due to agricultural practices.

- **Causes**:
    - Soil erosion from ploughed fields, overgrazed lands, and poorly managed irrigation systems.

- **Impacts**:
    - Fertile topsoil loss.
    - Sedimentation in nearby rivers and reservoirs.

**9. Sediment Replenishment Siltation**: Occurs when sediments replenish areas naturally eroded by water or human activity.

- **Examples**:
    - Natural filling of eroded areas like river meanders.
- **Impacts**:
    - Can stabilize ecosystems in some cases but may also create blockages in water systems.

**Mechanism of Siltation**

The mechanism involves three main stages: **erosion**, **transport**, and **deposition**. Below is a detailed breakdown of these stages:

**1. Erosion (Source of Sediment)**

Siltation begins with the detachment of soil particles from the land surface due to natural or anthropogenic activities. The primary causes of erosion include:

- **Rainfall and Surface Runoff**: Raindrops dislodge soil particles, which are then carried away by runoff.
- **Wind Erosion**: In arid areas, wind lifts and transports fine particles that can later settle in water bodies.
- **Riverbank Erosion**: Flowing water erodes the banks and bed of rivers, contributing sediments.
- **Human Activities**:
    - Deforestation exposes soil to erosion.
    - Agricultural practices like overgrazing or plowing disturb the soil.
    - Construction and mining generate loose sediments.

**2. Transport (Movement of Sediment)**

Eroded particles are carried by natural agents such as water, wind, or gravity to their deposition site. The transport mechanism varies based on the agent:

**a. Water Transport**

- **Suspension**: Fine particles (silt and clay) are suspended in water and carried over long distances.
- **Saltation**: Medium-sized particles like sand bounce along the riverbed.
- **Traction**: Larger sediments roll or slide along the bottom of the river channel.
- **Solution**: Soluble minerals dissolve in water and are transported chemically.

**b. Wind Transport**

- Wind carries fine particles from exposed surfaces, depositing them in nearby water bodies.

**c. Gravity Transport**

- Landslides or soil creep cause sediment to move downslope into rivers or lakes.

**3. Deposition (Accumulation of Sediment)**

Sediment is deposited when the energy of the transporting medium (water, wind, or gravity) decreases, and it can no longer carry the particles. Deposition occurs in various scenarios:

- **In Rivers**:
    - Sediment settles in low-energy areas like bends or riverbeds.
    - During floods, silt is deposited on floodplains.
- **In Reservoirs and Dams**: As the flow velocity decreases, sediments settle at the bottom, reducing storage capacity.
- **In Lakes and Wetlands**: Fine particles settle as water slows down.
- **In Coastal Areas**: Sediments transported by rivers settle near deltas or estuaries due to reduced flow energy.

**Factors Affecting Siltation Mechanism**

1. **Particle Size**: Finer particles (like silt and clay) remain suspended longer, traveling further before settling.
2. **Water Velocity**: Faster flows can carry larger particles and more sediment. Slower flows encourage deposition.
3. **Gradient and Topography**: Steeper slopes cause faster transport, while flatter areas promote deposition.
4. **Vegetation Cover**: Reduces soil erosion, limiting sediment availability.
5. **Rainfall Intensity**: Heavy rainfall increases erosion and runoff, accelerating siltation.
6. **Human Activities**: Deforestation, urbanization, and poor land management practices exacerbate erosion and transport.

Fig. 2- River Bank Erosion of River Brahmaputra in Majuli Island

## 1.5 RIVER BANK PROTECTION MEASURES

Riverbank protection refers to the measures and techniques used to stabilize and safeguard the banks of rivers from erosion, collapse, or degradation. These interventions aim to protect the riverbank from the forces of flowing water, rainfall, human activity, and natural processes that can weaken the soil or destabilize the bank. Riverbank protection is vital for maintaining ecological balance, protecting nearby infrastructure, and ensuring sustainable land and water management. Below are detailed measures for protecting riverbanks:

**1. Structural Measures**

These involve engineered solutions designed to physically stabilize riverbanks.

a. **Riprap: -** Rocks or concrete chunks are placed along the riverbank to absorb and deflect the energy of flowing water. Durable, cost-effective, and allows some vegetation to grow between rocks. Used in high-flow areas prone to significant erosion.
b. **Gabion Walls: -** Wire mesh cages filled with rocks or stones stacked along the riverbank. Flexible, permeable, and aesthetically adaptable. Effective for steep slopes and areas with moderate to high erosion risk.
c. **Retaining Walls: -** Vertical or near-vertical structures (concrete, wood, or masonry) built along riverbanks. Provides a high level of erosion control. Combined with vegetation or riprap for added support.
d. **Porcupines: -** Porcupines are permeable, modular, and spiny structures made of materials such as concrete, steel, or wood. They are strategically placed along riverbanks or riverbeds to slow water flow, trap sediment, and reduce the erosive force of the river. Their design allows water to pass through while dissipating energy and encouraging sediment deposition.

**2. Vegetative Measures**

Using plants to stabilize riverbanks is an environmentally friendly approach that enhances biodiversity.

a. **Grass Seeding: -** Fast-growing grasses provide ground cover and root stabilization.
b. **Tree Planting: -** Deep-rooted trees bind the soil, reducing erosion. Provide shade and enhance biodiversity.
c. **Live Staking: -** Planting cuttings of woody plants directly into the soil.
d. **Fascines: -** Bundles of branches placed along slopes to trap sediment and encourage plant growth.

**3.** Other riverbank protection measures include bioengineering techniques such as coir logs, brush layers; river training works such as channelization and flood embankments.

Fig. 3 – Rip-Rap

Fig. 4- Porcupines

Fig.5 - Gabions

## 1.6 OBJECTIVE OF THE PROJECT

The main objectives behind the project we have taken into consideration is defined through the following points:

- To introduce the deltoid structure of porcupine as a new pro-siltation measure.
- To check the effectiveness of the new model of porcupine in a simulated channel in the laboratory in terms of sediment trap and depth of flow as compared to actual porcupine structure.
- To check the efficiency of the system for various configuration of the deltoid system which are described by different non-dimensional numbers.

## 1.7 CHAPTER ORIENTATION

CHAPTER 1 – Contains the overview of the alluvial rivers, sediment load and its types, detail concept of riverbank erosion, scouring and siltation, including the mitigation measures of riverbank erosion.

CHAPTER 2 – This chapter emphasis the study of journals about the previously performed works and researches on pro siltation measures and river bank protection measures. The summaries of each journal studied are included in this chapter.

CHAPTER 3 – It contains the overview of the model used in the project, detailing about its structure, the description about the bed and bank material, description of experimental constructed channel, brief description about Acoustic Doppler Velocimeter (ADV) and the experimental setup.

CHAPTER 4 – This chapter is basically about the experiments performed showing proper procedures and set up

CHAPTER 5 – This chapter is about the conclusion drawn out from the experiments performed so far.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 GENERAL

A literature review is a fundamental component of academic research, representing a systematic aspect of creative scholarship on a certain topic. This is a systematic method of searching, choosing, and synthesizing all relevant research, journals, and books to uncover trends, gaps, and essential insights. The literature review is an important aspect of a research article since it not only contextualizes the current study but also throws light on the contributions and limits of prior efforts. The significance of carrying out this process is twofold: it informs the methodology of earlier research in the topic, which helps build the foundations of credibility for both the study itself and the process in which the research questions and methodologies are developed in order to perform a thorough and comprehensive investigation. Here we have studied several journals related to riverbank protection measures related to porcupines.

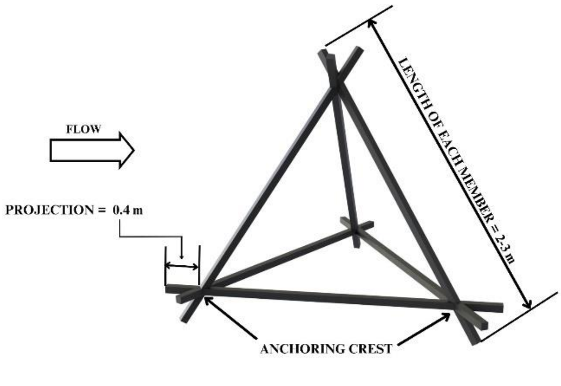


Fig.6 – Structure of a general Porcupine

The studies have addressed the following: -

## 2.2 REVIEW OF THE JOURNALS STUDIED

**Suresh Maurya *et.al* (2018)** have taken Ranganadi River into consideration because of its lower plain reach which is exposed to flood and erosion resulting in gradual rise in river bed. To mitigate the siltation of the river they have used the mechanically twisted zinc coated wire mesh gabion box ensured the stability of the geotextile bags. For better protection of the banks, they have used the RCC porcupines as a pro siltation measure.

**Mukesh Raj Kafle (2021)** in his paper investigates the performance of river protection works constructed over decades in the rivers of Nepal- Narayani, Koshi, West Rapti, Karnali and Mahakali. The study recommends initiating a bank protection pilot project to identify the cause of failure of the bank protection works and to test remedial measures for the sustainability enhancement of river protection works in future. They introduced new protection measures like porcupines as a remedy.

**S.K. Mazumder (2021)** basically discusses the effectiveness of porcupines as a river bank protection measure. The author had tried to compare the efficiency of impermeable groynes made of earth and boulders to permeable spur made of porcupines, wooden or bamboo piles, tetra hadrons, trees, etc. permit water to flow through their bodies and are helpful in bank protection due to flow dampening and energy dissipation due to production of microturbulence behind the spurs.

**Sarker *et al.* (2011)** studied that during the last few decades, the Jamuna River has increased its braiding intensity and width. The annual rate of river bank erosion is very high- several thousand hectares per year, which causes millions of people to suffer every year. Satellite images were mainly analyzed to understand the natural bank erosion processes along the right and left sides of the river. Guide bunds, revetment, groynes/spurs were constructed. After that it is seen that the river bank erosion rate continues till date. One part of the reduction is attributed to natural processes while the other is attributed to the bank protection structures, quantification of which is not possible at this moment. The revetment type structures are found to be more stable in the Jamuna River than groyne type structures.

**Mohd. Aamir Mumtaz *et.al* (2014)** investigated the efficiency of sediment traps in porcupine systems through laboratory studies. Various permutations of porcupine architecture were studied to get understanding into the sediment deposition patterns that vary depending on river discharge, depth and concentration. Porcupines with dense configurations capture sediment more efficiently, but economic limits require balancing density and cost effectiveness. A densely packed porcupine field can cause siltation and restrict flow.

**Das (2011)** in his book dealt with the concept of open channel flow, analysis of uniform flow, specific energy, force and critical depth computation, hydraulics of alluvial channels, design of channels, steady gradually varied flow, hydraulic jump, rapidly varied flow, spatially varied flow, unsteady flow and dam-break problem.

**Punmia *et.al* (2011)** intended to present the currently accepted theories, design principles and practices of soil mechanics and foundation engineering. The book dealt with the elementary properties, soil hydraulics, elasticity applied to soils, compressibility, strength and stability, foundation engineering, pavement design and miscellaneous problems. In addition, twenty-one more common laboratory experiments have been included to illustrate the practice of soil testing.

**Ashok Kharya *et.al* (2012)** gave us an overview of the permeable structures in the form of RCC porcupines for bank protection and their successful implementation in the banks of Majuli Island. Permeable structures in the form of RCC porcupine screens/spurs/dampeners are a cost-effective alternative to the impermeable bank protection works for the rivers carrying considerable amount of silt. RCC porcupine is a prismatic type permeable structure, comprises of six members of made of RCC, which are joined with the help of iron nuts and bolts.

**Mohd. Aamir Mumtaz *et.al* (2015)** considered Porcupines as the most effective bank protection measure. Here the researchers have investigated experimentally the effect of the porcupine in the velocity of flow and their capability to hold sediment. An attempt has been made to logically study the pattern of deposition caused by various configurations of Porcupine field layout and hence to propose a preliminary design methodology. Results show that there is a considerable reduction in the flow velocity resulting in the deposition of sediment with porcupines offering resistance to flow.

**Garde and Rangaraju (1977)** summarized and synthesized the vast amount of information on sediment transport and problems related to alluvial streams scattered in numerous journals, monographs and other research publications. He dealt with the theory of sediment transport and includes and includes such aspects as properties of sediments, incipient motion condition, flow regimes, resistance to flow, bed load transport, suspended load transport and total load transport. He also dealt with applied problems such as sediment samplers and sampling, stable channels, alluvial streams, variations in stream bed elevation and plan forms, sediment control, river training, and miscellaneous problems such as model studies, mud flows, density currents and sediment transport through pipes.

**Saswati Ghatak (2021)** in his journal defines that as Banoori river is highly prone to siltation, based on inputs such as HFL, Maximum Rainfall Intensity, Manning's Coefficient, the reduced levels for the proposed site a one-dimensional mathematical model was developed using HEC-RAS Software and was compare with the observed data. A new detailed design of bank protection measures was made based on hydraulic parameters obtained from the study. The result completely indicated the dependence of Manning's coefficient on the flow discharge of the river Banoori.

**Brahmaputra Board (2012)** studied that Majuli Island has been under serious attack by the mighty Brahmaputra. Loss of land mass on account of erosion of Brahmaputra River right bank has been regular feature for Majuli Island. Brahmaputra Board prepared a scheme in November 1999 for "Protection of Majuli Island from floods and erosion" at the estimated cost of Rs. 86.56 crores. The work was carried out in three phases- Phase 1 started in March 2005 and was completed in April 2011. Phase 2 and Phase 3 were on progress till 2012. During Phase 1, casting and laying of permeable RCC porcupine screen/spurs/dampeners at various locations were done due to which erosion got arrested substantially in the severely affected reaches. During Phase 2 and 3, casting and laying of 1,27,396 porcupines were done which encouraged heavy siltation. Area of Majuli Island increased from 502.21 sq. km (2004) to 520.21 sq. km (2011). Further remaining protection works, such as completion of 5 spurs, river bank revetment, laying porcupines at vulnerable locations, contemplated under Phase 2 and Phase 3 were targeted to be completed by March 2014.

**Aamir and Sharma (2014)** studied that porcupine systems have been deployed as a cost-effective measure for river training and have produced good results in capturing sediment. The experiments for their study were carried out in the Outdoor River Engineering laboratory of the Department WRD&M, IIT Roorkee, situated near the Toda Kalyanpur village, Roorkee. The graphs between trap efficiency and PFDI (Porcupine Field Density Index), keeping sediment concentration ($q_s$) fixed and different values of PFSI (Porcupine Field Submergence Index), showed that trap efficiency is inversely proportional to submergence and between trap efficiency and PDFI, keeping PFSI fixed and different values of submergence showed that the trap efficiency is directly proportional to sediment concentration. Results showed that densely configured porcupines have greater efficiency in capturing sediment but taking into account economic constraints, a compromise has to be made in between density and cost effectiveness. Also, these are very good for low submergence and high sediment concentration.

**Nayan Sharma *et.al* (2015)** done experiment Ganga River of India at Nakhwa Site by using RCC Jack Jetty and Bamboo Submerged Vanes. The right bank of the channel of the

Ganga River near Varanasi is a concave bank and was more susceptible to bank erosion during floods thereby constantly reducing inland navigation depth. During dry weather low flow from December to June, the navigation depth was invariably insufficient. The lab and pilot field study deploying modified RCC Jack Jetty supported by bamboo submerged vanes have achieved the following – the secondary left channel was nearly choked diverting the flow to the navigation channel along right bank, and also the ongoing bank erosion along the right bank could be arrested. Evidently the above transformed channel processes resulted in developing and sustaining the desired Inland navigation waterway along the right bank as evidenced from satellite imagery as well as topographical survey. The encouraging outcome of the pilot field study on the large Ganga River warrants re-application of the modified cost-effective technology in similar other river systems of the world with required fine tuning for specific site condition.

**Abhigya Shrivastava *et.al* (2014)** done laboratory experiment on jack jetty field of different pattern and found significant reduction in flow velocity due to the presence of submerged jacks which depends on variety of situations such as, reduction in velocity with bigger jacks than smaller ones. Reduction in velocity is pronounced and is more enhanced in the initial stretch which then tapers off to minimize further downstream of the jack. Effect of submergence could be observed. The work also describes that effect is more prominent for when the arrangement of jack jetty field is for 20 degrees at angle of incidence of attack then at 30 degrees.

# CHAPTER 3
# METHODOLOGY

## 3.1 OVERVIEW

This chapter contains a brief detail of the materials used and procedures followed working over this project. The general layout of the experimental channel is described including the procedures of the placement of the deltoids in the simulated channel to get the desired outcome.

## 3.2 MATERIALS USED

### 3.2.1 MODEL

In this study we have used an advanced model of Porcupines named Deltoid to prove it as an effective pro siltation measure in alluvial soil. The proper description of the deltoid model is defined in the following points:

- The deltoid models were created by measuring down to match the dimensions of the simulated channel in the laboratory, maintaining a symmetrical structure.
- The new model is constructed by using **MS Rods** of a thickness of **10 mm** and **15cm** in length, and were welded together.
- In this new modelled structure, 4 extra members has been added into the actual porcupine tetrahedral frame to give it a new structure.
- The extra 4 members made the tetrahedral porcupine heavier so that they resist the high velocity current and don't get washed away.
- The figures given here shows the theoretical and designed model of the deltoid structure. There was total **35** models made for this project.

Fig.7 - Deltoid Structure

Fig.8 - Constructed Deltoid Model

### 3.2.2 BED MATERIAL

- The laboratory channel used in this study was filled with bed materials collected from the River Brahmaputra, specifically from the Pandu Port of Maligaon, Guwahati, Assam.
- The bed materials were collected, air-dried and then evaluated for particle size distribution, in order to determine the relative percentages of fine and medium grained sand, as well as fines present in the sample.
- Specific gravity of the sample was determined by using a pycnometer.
- To replicate the natural conditions of the river bed, the simulated river bed in the laboratory channel, which had a depth of 0.49 meters, was prepared by maintaining the same relative percentages of fine and medium sand that were present in the actual river bed material sample collected from the site.
- This ensured that the laboratory channel closely mimicked the real-world conditions, providing a more accurate representation of the porcupine system's performance in controlling erosion and facilitating channelization in rivers.

### 3.2.3 BANK MATERIAL

- The laboratory channel used in this study was lined with bank materials collected from the River Brahmaputra, specifically from the Pandu Port of Maligaon, Guwahati, Assam.
- This information was used to replicate the natural conditions of the river bank, in order to provide an accurate representation of the performance of various erosion control measures and bank stabilization techniques in the laboratory setting.

## 3.3 EXPERIMENTAL CHANNEL DESCRIPTION

- The experiments are conducted in the Hydraulics Laboratory Channel in Assam Engineering College, Guwahati.
- The channel measure 35m in length, 1.8m in width and have a depth of 1.275m and a 0.49m thickness of sand bed.
- The slope of the channel bed is taken as 1:250 and the slope of the bank as 1.5H:1V. This study setup has provided a controlled environment to study the performance of the erosion control measures and bank stabilization techniques in the laboratory.

- The water flowing in the channel was maintained by installing two pumps of 5HP and 10HP. The water pumped by them is collected in a tank, which is then passed through the arrangement of energy dissipator to reduce the turbulence; and then fed into the channel through inlet.
- The water at the outlet was collected in a rectangular tank.

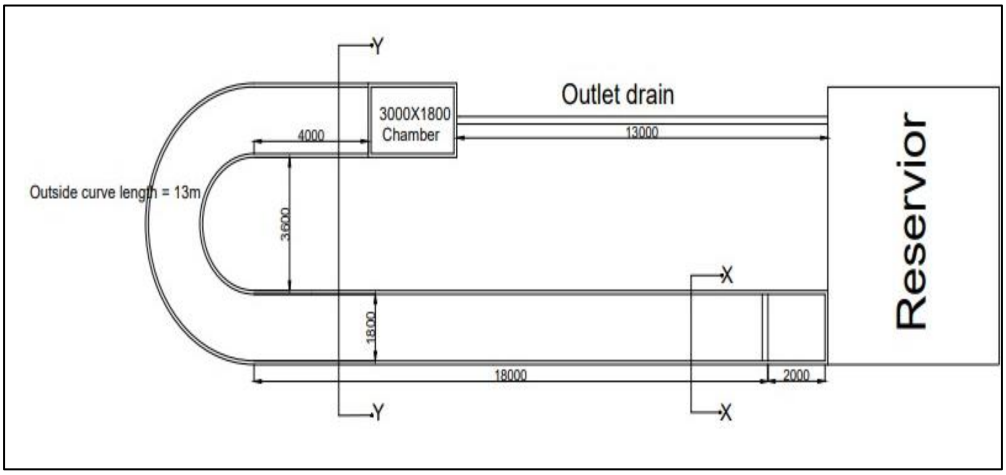


Fig.9 - Layout of the Experimental Channel


Fig.10 - Experimental Channel in the Hydraulics Lab, AEC, Guwahati

### 3.4 VELOCITY MEASUREMENTS

The Acoustic Doppler Velocimeter (ADV) was utilized to accurately measure the velocity of water flow. The Vectrino Velocimeter, a device that utilizes the Doppler Effect, was employed in the ADV. The device emits a short pulse of sound, captures the echo, and then calculates the change in pitch or frequency of the echo to determine the water speed. The Vectrino Velocimeter measures the velocity of water flow in three beam components, parallel to its three beams. The data is reported in both Beam and XYZ coordinate systems. The XYZ coordinates are relative to the probe and are not dependent on the orientation of the Vectrino. In the XYZ coordinate system, a positive velocity in the X-direction is indicated by the arrow on the X-axis. To ensure the accuracy of the measurements, velocity was recorded at three distinct points along the flow path - upstream, midstream, and downstream - for each trial.

Fig.11 - Acoustic Doppler Velocimeter (ADV)

# CHAPTER 4

# EXPERIMENTAL WORK

## 4.1 GENERAL

In this chapter we have described the procedures followed during the performance of the experiments in the channel to get the desired results.

## 4.2 EXPERIMENT METHODOLOGY

All the experiments for this project work were performed in the artificially constructed channel in the Hydraulics Laboratory, Assam Engineering College (AEC), Guwahati.

- Before starting the experiments, the banks of the channel were mended well to freshly start each experiment and arrangement on the channel bed.
- The channel sand bed was level was measured using point gauge before placing the deltoids models for the experiment.
- For the first set of experiments the deltoids model were placed in two different arrangements consecutively in two different positions in the channel bed.
- The required field measurements were taken and the channel bed was levelled.
- After levelling the discharge was finally introduced for a continuous 3 hours and a fixed quantity of sediment was injected into the channel 1 meter upstream of the deltoid field.
- The motor was then shut down and the water was allowed to drain out gradually from the channel. After the water got completely drained out gradually from the channel the sand bed levels were again measured with the help of point gauge.
- After completion of the first set of experiments the same steps were repeated for the next set of experiments as well.


Fig. 12 – Prepared Channel in the laboratory

### 4.3 EXPERIMENT ORIENTATION

For the time being we have performed only one set of experiment with two arrangements.

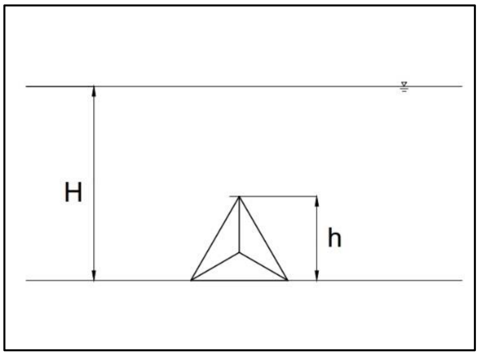


Fig. 13 – Sketch of a Deltoid submerged in water

In the present study, a new index has been introduced, known as the Submergence Depth ratio (SDR). It is a ratio between the height of the octahedron and the total depth of water in the channel i.e.

Submergence Depth Ratio (SDR)= Height of octahedron (h) /Total depth of water(H)

Since the height of an Octahedron remains constant for a particular model or set of models, SDR depends on the depth of a water flowing through the channel and are inversely related. For low depth of flow, SDR>1

For medium depth of flow, SDR<1

For high depth of flow, SDR<<1

#### 4.3.1 EXPERIMENT 1

In the first arrangement we have placed the models at 10 degrees in the direction of flow and the line of diversion of the deltoid models are kept parallel to the bank of the channel for both the arrangements.

- In the first arrangement, total 11 deltoids were placed arranging into two compartments.
- For the second arrangement in total of 15 deltoid models were placed in 3 compartments towards the downstream of the first arrangement in the opposite bank to that of the first.

Fig.14 – Exp 1; Arrangement 1 (*before the start of the experiment)*

Fig.15 - Exp 1; Arrangement 2 (*before the start of the experiment)*

After the arrangements were set up the pump was run and water with required discharge was allowed to flow for 3 hours to obtain the expected result.

Fig. 16- Water was run from the source

Fig.17- Model submerged under running water

After the running of water was complete and got drained out the measurements were taken as per requirement.

Fig.18 – Measurement taken after the water got drained out for both the arrangements

# CHAPTER 5
# RESULTS AND CONCLUSION

## 5.1 RESULTS

The performed experiment has been completed and the results for both the arrangements were measured and has been given in the below tables:

| Distance along the length of the channel(m) | Point gauge reading without Deltoid field (m) | | Point gauge reading with Deltoid field (m) | | Height of ripple of sand (m) | |
|---|---|---|---|---|---|---|
| | At A | At B | At A | At B | At A | At B |
| 0 | 0.915 | 0.92 | 0.90 | 0.91 | 0.015 | 0.01 |
| 0.5 | 0.915 | 0.92 | 0.89 | 0.90 | 0.025 | 0.02 |
| 1.00 | 0.915 | 0.92 | 0.87 | 0.895 | 0.045 | 0.025 |
| 1.5 | 0.915 | 0.92 | 0.86 | 0.88 | 0.055 | 0.04 |

Table 1 – Measurement of sand deposition for medium depth of flow (arrangement 1)

| Distance along the length of the channel(m) | Point gauge reading without Deltoid field (m) | | Point gauge reading with Deltoid field (m) | | Height of ripple of sand (m) | |
|---|---|---|---|---|---|---|
| | At A | At B | At A | At B | At A | At B |
| 0 | 0.95 | 0.955 | 0.94 | 0.943 | 0.01 | 0.012 |
| 0.5 | 0.95 | 0.955 | 0.93 | 0.944 | 0.02 | 0.011 |
| 1 | 0.95 | 0.955 | 0.913 | 0.932 | 0.037 | 0.023 |
| 1.5 | 0.95 | 0.955 | 0.894 | 0.916 | 0.056 | 0.039 |

Table 2 - Measurement of sand deposition for medium depth of flow (arrangement 2)

| Distance along the length of the channel(m) | Point gauge reading without Deltoid field (m) | | Point gauge reading with Deltoid field (m) | | Height of ripple of sand (m) | |
|---|---|---|---|---|---|---|
| | At A | At B | At A | At B | At A | At B |
| 0 | 0.96 | 0.964 | 0.955 | 0.95 | 0.005 | 0.014 |
| 0.5 | 0.96 | 0.964 | 0.943 | 0.945 | 0.017 | 0.019 |
| 1 | 0.96 | 0.964 | 0.93 | 0.93 | 0.03 | 0.034 |
| 1.5 | 0.96 | 0.964 | 0.93 | 0.936 | 0.03 | 0.028 |

Table 3 - Measurement of sand deposition for high depth of flow (arrangement 1)

| Distance along the length of the channel(m) | Point gauge reading without Deltoid field (m) | | Point gauge reading with Deltoid field (m) | | Height of ripple of sand (m) | |
|---|---|---|---|---|---|---|
| | At A | At B | At A | At B | At A | At B |
| 0 | 0.966 | 0.95 | 0.94 | 0.94 | 0.026 | 0.01 |
| 0.5 | 0.966 | 0.95 | 0.945 | 0.946 | 0.021 | 0.004 |
| 1 | 0.966 | 0.95 | 0.923 | 0.93 | 0.043 | 0.02 |
| 1.5 | 0.966 | 0.95 | 0.927 | 0.93 | 0.039 | 0.02 |

Table 4 - Measurement of sand deposition for high depth of flow (arrangement 2)

| Arrangement | Distance along the length of the channel (m) | Ripple Height | Radius of Cone (r) | Total Volume of sand | Volume of sand taking porosity into consideration($m^3$) | Weight of sand trapped (kg) |
|---|---|---|---|---|---|---|
| | | 'h' (m) | in (m) r=h/tan Ø | $V= (\prod r^2 h)/3$ E=10^ | V' = V - 35% V | W= ∂ V' ∂ = 2040 Kg/$m^3$ |
| | 0 | 0.0125 | 0.014090177 | 2.59488E-07 | 1.68667E-07 | 0.000344081 |
| | 0.5 | 0.0225 | 0.025362319 | 1.51333E-06 | 9.83666E-07 | 0.002006679 |
| | 1 | 0.035 | 0.039452497 | 5.70198E-05 | 3.70628E-05 | 0.075608208 |
| 1 | 1.5 | 0.0475 | 0.053542674 | 1.42386E-05 | 9.2551E-06 | 0.018880397 |
| | 0 | 0.011 | 0.012399356 | 1.76834E-07 | 1.14942E-07 | 0.000234481 |
| | 0.5 | 0.0155 | 0.01747182 | 4.94746E-07 | 3.21585E-07 | 0.000656033 |
| | 1 | 0.06 | 0.067632851 | 2.86973E-05 | 1.86532E-05 | 0.038052575 |
| 2 | 1.5 | 0.0475 | 0.053542674 | 1.42386E-05 | 9.2551E-06 | 0.018880397 |

Table 5 – Calculation of Sediment Deposition for Arrangement 1 and 2 for medium depth of flow

| Arrangement | Distance along the length of the channel (m) | Ripple Height | Radius of Cone (r) | Total Volume of sand | Volume of sand taking porosity into consideration($m^3$) | Weight of sand trapped (kg) |
|---|---|---|---|---|---|---|
| | | 'h' (m) | in (m) r=h/tan Ø | $V= (\prod r^2 h)/3$ E=10^ | V' = V - 35% V | W= ∂ V' ∂ = 2040 Kg/$m^3$ |
| | 0 | 0.0095 | 0.010708535 | 1.13909E-07 | 7.40408E-08 | 0.000151043 |
| | 0.5 | 0.018 | 0.020289855 | 7.74826E-07 | 5.03637E-07 | 0.00102742 |
| | 1 | 0.032 | 0.036070854 | 4.35784E-05 | 2.8326E-05 | 0.05778495 |
| 1 | 1.5 | 0.029 | 0.032689211 | 3.24027E-06 | 2.10617E-06 | 0.004296594 |
| | 0 | 0.018 | 0.020289855 | 7.74826E-07 | 5.03637E-07 | 0.00102742 |
| | 0.5 | 0.0125 | 0.014090177 | 2.59488E-07 | 1.68667E-07 | 0.000344081 |
| | 1 | 0.0315 | 0.035507247 | 4.15258E-06 | 2.69918E-06 | 0.005506327 |
| 2 | 1.5 | 0.0295 | 0.033252819 | 3.41077E-06 | 2.217E-06 | 0.004522685 |

Table 6 – Calculation of Sediment Deposition for Arrangement 1 and 2 for high depth of flow

**CALCULATION OF TRAP EFFICIENCY**

| Inclination of diversion line to the bank (in degrees) | SDR | Depth of Flow | Weight of Sand Deposited (kg) | Weight of sand injected (kg) | Trap Efficiency (%) |
|---|---|---|---|---|---|
| 10 | 0.59289 | Medium | 0.0968393 | 3 | 3.2279788 |
| 10 | 0.56180 | High | 0.0632600 | 3 | 2.1086669 |

Table 7 – Trap Efficiency for arrangement 1

| Inclination of diversion line to the bank (in degrees) | SDR | Depth of Flow | Weight of Sand Deposited (kg) | Weight of sand injected (kg) | Trap Efficiency (%) |
|---|---|---|---|---|---|
| 10 | 0.59289 | Medium | 0.0578234 | 3 | 1.9274495 |
| 10 | 0.56180 | High | 0.0114005 | 3 | 0.3800171 |

Table 8 – Trap Efficiency for arrangement 2

**5.2 CONCLUSION**

As the project work is in progress state, so we cannot draw any rigid conclusion for the time being as there is other experiments needed to be performed to declare the deltoid model as an effective pro siltation measure. The results we have got so far are:

- The ripple height for medium and high depth of flow is measured from the deltoid field.
- The weight of sediment for both the arrangement of the performed experiment is calculated for medium and high depth of flow.
- The trap efficiency for both the arrangement were also calculated so far.

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