Applicability of Porcupine as Pro-Siltation Measure and Determination of Most Efficient Pattern Adopted in Alluvial Rivers

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Fulfilment of the Requirement for the Award of the Degree of

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In
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DECLARATION

I hereby declare that the work presented in the dissertation "**Applicability of Porcupine as Pro-Siltation Measure and Determination of Most Efficient Pattern Adopted in Alluvial Rivers**" in partial fulfilment of the requirement for the award of the degree of "MASTER OF TECHNOLOGY" in Civil Engineering (with specialization in Water Resources Engineering), submitted in the Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13 under Assam Science & Technology University, is a real record of my work carried out in the said college under the supervision of Dr. Bipul Talukdar, Professor, Department of Civil Engineering, Assam Engineering College, Jalukbari, Guwahati – 13.

Whatever I have presented in this report has not been submitted by me for the award of any other Degree or Diploma.

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ABSTRACT

Flooding is a major natural disaster that can cause significant damage to both land and property. One of the most significant problems that occur during floods is the scouring of the river bed and bank, which can lead to a change in the course of the river. To mitigate this problem, a preventive measure called Porcupine has been developed.

Porcupine is a sediment trap system that captures the sediment in the river, thereby controlling scouring. The system has 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.

In this thesis, an in-depth study of the sediment trap efficiency of porcupine systems was conducted using laboratory experiments. Using various dimensional parameters, trial porcupine field models were prepared and laid on the channel with the simulated river bed. The research aimed to investigate the sediment deposition pattern for various configurations of porcupine systems, with specific focus on discharge and sediment concentration of the river.

The research findings provide valuable insights into the sediment trap efficiency of porcupine 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

Rivers with a meandering nature are prone to severe erosion, which can lead to a catastrophic and uncontrollable situation if not properly addressed. This is particularly problematic during the monsoon season, when river erosion accelerates and access to materials and labour becomes limited. To prevent this, it is crucial to take a proactive approach by studying the river's pattern and implementing timely river training measures. These measures can include re-vegetation to reduce flow speed and strategic bank or channel works to stabilize the river channel and protect its banks. By effectively training the river, excessive meandering can be prevented, shifting in its course can be minimized, and navigability can be maintained. Ultimately, the key to successfully combating scour is to act preventatively and make use of effective strategies that address the specific needs of the river.

Protection to the river banks is normally accomplished by a variety of river training works including a marginal embankment or levees, guide banks, guide bunds, groynes or spurs, submerged vanes, cut offs, pitching of banks, pitched islands, sills, closing dykes, and longitudinal dykes. Some of these measures are less expensive than others. Considerations in their use, besides effectiveness, include the cost of construction, environmental impact and aesthetics. Permeable structures tend to be the least expensive to construct. The increasing demand of bank protection work in many reaches of rivers has focused attention on an imperative need to develop cost-effective river training measures. Therefore, application of framed structures has gained importance as a cost effective measure for river management. Bandalling, board fencing, jack-jetty systems and tetrahedral frames are some of these cost-effective methods used for river training.

1.2 Open Channel Flow (OCF)

An open channel is a passage through which liquid flows with a free surface exposed to the atmosphere. This type of flow, known as open channel flow or free surface flow, is driven by the component of gravity and is characterized by a hydrostatic pressure distribution. The free surface of the flow is the boundary between the liquid and the air, which can be either stationary or moving. The pressure within the liquid is always hydrostatic, meaning that it is constant throughout the fluid and is determined by the fluid's density and the force of gravity. An example of open channel flow is depicted in Figure 1.1. This type of flow is essential in many natural and man-made systems, such as rivers, canals, and irrigation channels.

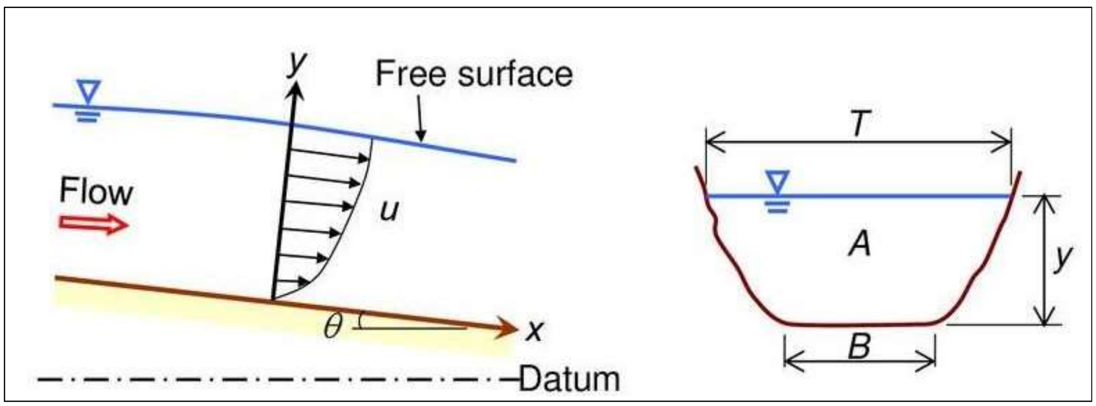


Figure 1.1: Open channel flow.

1.3 Mechanism of Sediment Transport in Open Channel Flow

Rivers transport sediments in various modes, such as bed load, suspended load, and wash or dissolved load. Bed load sediments move close to the riverbed through rolling, sliding, and hopping, while suspended load sediments move at a large fraction of the mean flow velocity in the stream. Dissolved load, on the other hand, is carried within the water column. The amount of sediments entering the channel greatly influences the channel flow, cross-section and regime. The traditional channel design theory ignored the significance of sediment transport, but it is now acknowledged that a comprehensive study of sediment transport is crucial for successful channel design. Different types of sediment flowing in a channel (figure 1.2) are broadly discussed below.

1. **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.

2. **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.

3. **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.

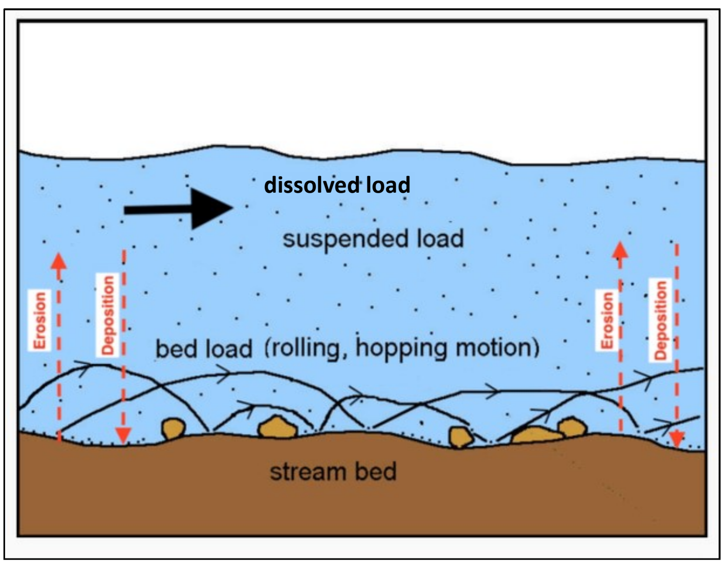


Fig. 1.2: Sediment transport process

1.4 Incipient Motion Condition

The condition of incipient motion of sediment particles refers to the point at which individual particles of a given material begin to move within a fluid flow in an open channel. Determining the exact hydraulic conditions at which this occurs can be challenging, as different criteria can be used to define the point of incipient motion. For example, it could be defined as the point when a single particle starts moving, a few particles start moving, general motion occurs on the bed, or when the rate of sediment transport approaches zero. Despite the difficulty in defining this condition, it is important to understand, as it can have significant implications for the stability of the channel and the behaviour of the sediment particles within the flow.

1.5 Brief Introduction to Related Terminology

1.5.1 Erosion

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. The transported material can range from a few millimeters to thousands of kilometers away.

River Erosion is that in which the river erodes away the bed and banks of its channel vertically and laterally. Vertical erosion is the downward erosion which deepens the river channel. Lateral erosion is sideward erosion which widens the river channel. There are four ways in how the river erode the bed and the bank (EROSIONAL PROCESS)-

(i) **Hydraulic Action-** The force of river flow helps to break the rock and dragging them away from the bed and the banks of the river.

(ii) **Abrasion-** The grinding of the rock fragments carried by the river against the banks and bed of the channel. This grinding action will widen and deepen the channel.

(iii) **Attrition-** The knocking of rock fragments in the water against each other. The fragments are broken into smaller and become smoother pebbles.

(iv) **Corrosion-** The process in which the water reacts chemically with soluble minerals in the rocks and dissolves them.

1.5.2 Alluvial River

An alluvial river is a type of river characterized by its mobile bed and banks made of sediment and/or soil. These rivers are shaped by the nature and frequency of floods they experience, which shape the channel through erosion, Deposition and sediment transportation. As such, alluvial rivers can take various forms depending on factors such as the properties of the banks, flow patterns, riparian ecology and sediment characteristics.

1.5.3 Properties of Alluvial Rivers.

1. Alluvial channels are characterized by their tendency to follow the path of least resistance, resulting in meandering and winding flow patterns.
2. These channels are dynamic, as the loose sedimentary materials can be transported and deposited by water flow, leading to changes in the channel shape and course over time through erosion and sedimentation.

1.6 Porcupine as River Training Work

Protection of river banks is a part and parcel of river training works. 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.

Functions: Permeable structures in form of RCC porcupines serve one or more of the following functions:
(a) Training the river along the desired course.
(b) Reducing the intensity of flow at the point of river attack.
(c) Creating a slack flow to induce siltation in the vicinity of the permeable structures and in the downstream reach.
(d) Providing protection to the bank by dampening the velocity of flow along the bank.

Use of porcupines: Subject only to silt availability in the flow, porcupines:
(a) Can make the river deposit its silt in and around the porcupine.
(b) Can slow down the velocity of flow of the river.
(c) Can stop riverbank erosion.
(d) Can reclaim land i.e., build up scoured or a low area to utilizable level.
(e) Can stop bed scour.
(f) Can maintain bed level.
(g) In case there is no silt in a river (or in lean season), and silt is artificially placed inside porcupines influence zone, the silt will get retained instead of getting washed out.

1.6.1 Porcupine Systems

RCC porcupine is a permeable structure, consisting of six prismatic members made of reinforced cement concrete (RCC), which are joined together with the help of iron nuts and bolts. Figure 1.3 illustrates a 3D sketch of a typical RCC porcupine. The length of each member ranges from 2 to 3 meters, with a cross-section of 15cm x 15cm. Reinforcement is provided using 4 numbers of 6mm diameter MS bars, with stirrups placed at 15cm intervals. These porcupines can be placed both along and across the flow to create gradual obstruction, reducing velocity locally and promoting sedimentation. Figure 1.5 depicts a typical RCC porcupine screen. RCC porcupines are a cost-effective measure to control erosion and facilitate channelization in rivers.

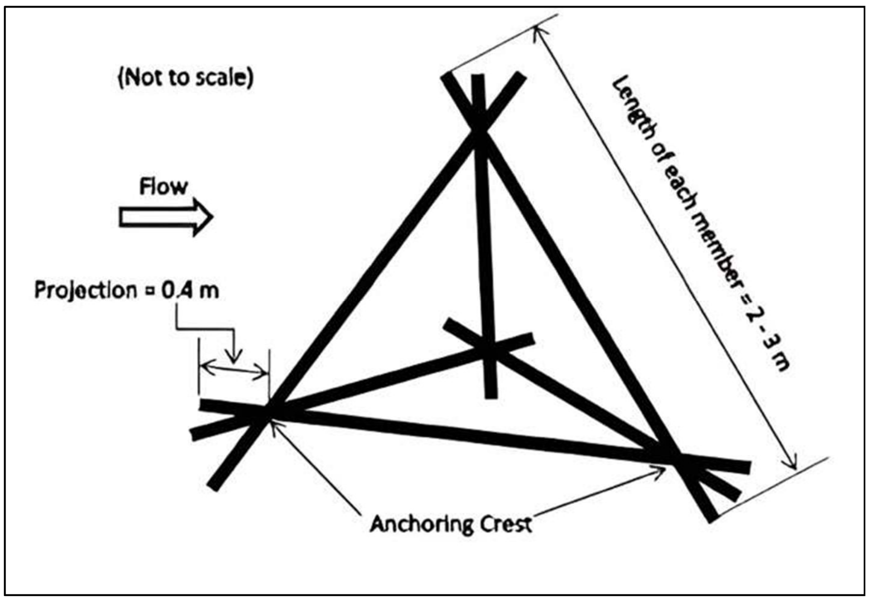


Figure 1.3: Three dimensional sketch of a typical RCC Porcupine unit
(Source: Aamir and Sharma, 2014)

Figure 1.4: RCC porcupine

(Source: http://sgov.stlindia.com/website/brahmaputraboard/)

Figure 1.5: RCC porcupine

(Source: http://sgov.stlindia.com/website/brahmaputraboard/)

1.7 Objective

1. To investigate the impact of different porcupine field configurations on sediment deposition
2. To evaluate the effectiveness of various porcupine field models in terms of their sediment trapping efficiency.
3. To make critical comparisons between the performances of the different models, which will be defined using specific dimensionless parameters and different sediments.

1.8 Chapter Wise Planning

1. Chapter 1: general introduction of the report, related terminology that supports the research is stated and the objectives are clearly presented.

2. Chapter 2: literature review, where some past works done in the same field are discussed very briefly.

3. Chapter 3: Details about the Materials used.

4. Chapter 4: Detailed description of the Experimental Works.

5. Chapter 5: Results and Discussions.

6. Chapter 6: Conclusions And Further Scope of the Study

Chapter 2

LITERATURE REVIEW

In recent years, there has been a significant amount of research and investigation on measures to combat siltation and erosion in alluvial rivers such as Ganga, Brahmaputra in India and Jamuna in Bangladesh, using various techniques such as RCC porcupines (both triangular and prismatic), RCC Jack Jetty, submerged vanes, geo bags, and revetments. A comprehensive review of the literature on open channel flow, incipient motion condition, sediment trap efficiency of porcupines, development of a rational design methodology, cost-effective river training structures, and protection of the Majuli island from flood and river bank erosion has been conducted and will be presented in the following paragraphs.

2.1 General

Garde and Rangaraju (1977) comprehensively compiled and synthesized the extensive information on sediment transport and alluvial stream-related issues found in various research publications, journals and monographs. The book covers a wide range of topics related to sediment transport, including the properties of sediments, incipient motion conditions, flow regimes, resistance to flow, bed load transport, suspended load transport, and total load transport. Additionally, it delves into applied problems such as sediment sampling and samplers, stable channels, variations in stream bed elevation and plan forms, sediment control, river training, and other miscellaneous issues such as model studies, mud flows, density currents and sediment transport through pipes.

Rijn (1984) proposed a method for calculating the suspended load in alluvial rivers by integrating the product of local concentration and flow velocity over the depth of the water column. This method is based on determining the reference concentration from bed-load transport measurements, and uses concentration profiles for calibration. Rijn also introduced new relationships to account for the size gradation of bed materials and the effect of sediment particles on turbulence. The method was verified using 800 data sets, with 76% of the predicted values falling within a range of 0.5 to 2 times the measured values.

Nicholas (2003) in a study conducted by Nicholas, the potential for understanding the mechanisms of flow and suspended sediment transport on lowland flood plains was explored by using a combination of three-dimensional numerical modelling and acoustic DopplerVelocimeter. The study found that, contrary to the commonly held belief that suspended sedimenttransport is primarily driven by turbulent mixing processes, a significant portion of the sedimentmovement is caused by advection along topographically determined flow lines. The research alsoshowed that vegetative roughness has a significant impact on flow velocity and turbulent kineticenergy, resulting in profiles that differ from the logarithmic "law of the wall." Furthermore, the study revealed that while horizontal sediment transport is primarily driven by advection, the

Vertical sediment concentration profile in the lower half of the flow is strongly influenced by a balance between turbulent ejection and sweep events.

Singh and Goswami (2012) conducted a study that investigated the impacts of human activities on the flow and sediment regime as well as on the biogeochemical flux of nutrients in the Brahmaputra River Basin. The study found that human activities, such as land-use change and development practices, have a significant impact on the erosion and sediment discharge of the river, and pose a potential threat to the biogeochemical fluxes of nutrients. Additionally, demographic and socio-economic factors were found to play a role in these impacts, and the study suggests that if current practices continue, these activities will have a significant impact on the biogeochemical cycles and emissions of key elements in the basin. Furthermore, the study noted that the ecosystems in the Brahmaputra River Basin are largely shaped by the monsoon climate, and the adverse changes in the local ecological climate are likely linked to ongoing deforestation and increasing land denudation.

2.2 Porcupine

Brahmaputra Board, Guwahati (2012) -The Brahmaputra Board, based in Guwahati, conducted a study in 2012 that revealed the detrimental impact of erosion on Majuli Island due to the powerful Brahmaputra River. To address this issue, the Board developed a scheme in November 1999 for the protection of the island from floods and erosion, with an estimated cost of 86.56 crores. The scheme was executed in three phases, with Phase 1 starting in March 2005 and being completed in April 2011. Phases 2 and 3 were ongoing as of 2012.
During Phase 1, the use of permeable RCC porcupine screens, spurs, and dampeners were implemented at various locations, leading to a substantial arrest of erosion in affected areas. In Phases 2 and 3, the casting and laying of 1,27,396 porcupines encouraged heavy siltation, resulting in an increase in the island's area from 502.21 sq. km (2004) to 520.21 sq. km (2011). Additionally, the remaining protection works, including the completion of 5 spurs, river bank revetment, and the laying of porcupines at vulnerable locations, were targeted for completion by March 2014. Overall, the efforts of the Brahmaputra Board have proven to be successful in protecting and preserving the landmass of Majuli Island.

Aamir and Sharma (2014) conducted a study on the effectiveness of porcupine systems as a cost-effective measure for river training. The study was conducted in the Outdoor River Engineering laboratory of the Department of Water Resources Development and Management at IIT Roorkee, near the Toda Kalyanpur village.
The research results showed that porcupine systems have a good ability in capturing sediment, with graphs indicating that trap efficiency is inversely proportional to submergence, and directly proportional to sediment concentration when keeping the

Porcupine Field Density Index (PDFI) and Porcupine Field Submergence Index (PFSI) fixed. The results also demonstrated that densely configured porcupines have greater efficiency in capturing sediment, but a compromise between density and cost-effectiveness has to be made. The study also highlights that porcupine systems are very effective in low submergence and high sediment concentration scenarios.

Aamir and Sharma (2015) conducted a study to compare the performance of triangular and prismatic porcupines for erosion control. The experiments were carried out in the Outdoor River Engineering laboratory of the Department of Water Resources Development and Management at IIT Roorkee, near the Toda Kalyanpur village.

The results of the study showed that, for a given sediment concentration, the trap efficiency of triangular porcupines was higher than that of prismatic porcupines. The research was supported by the graphs, which plotted the relationship between trap efficiency and the Porcupine Field Density Index (PDFI) and Porcupine Field Submergence Index (PFSI). These graphs indicated that trap efficiency is inversely proportional to submergence and directly proportional to sediment concentration. The results were compared between triangular and prismatic porcupines. The study concluded that triangular porcupines have a better performance in capturing sediment as compared to prismatic porcupines. However, it is worth noting that the use of prismatic porcupines may be more economically advantageous and can be safer for trimmed bank slopes of rivers.

Aamir and Sharma (2015) logically studied the pattern of deposition caused by various configurations of porcupine field layout and hence to propose a preliminary design methodology. 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 in two phases. In phase 1, the effect of porcupines on the fluvial parameters was studied. In phase 2, the effect of various layout combinations of porcupines on the sediment laden flow of water was investigated to come up with the optimum layout combination of porcupine field to meet with the required objective of erosion control, moderate reclaim or high reclaim. Results showed that a second tier of porcupines can be placed over the outer to improve their performance in the cases of high submergence. Preliminary design template is developed which can provide the designer with the range of values of PDFI for different sediment concentration and PFSI, to achieve the desired objective of erosion control, moderate reclaim and heavy reclaim in the reach.

Kalita (2017) made critical comparisons between the performances of various models of vegetation fields (defined on the basis of some dimensionless parameters), in terms of their sediment trapping efficiency and finally compared the results with the trap efficiency of porcupine model. Results showed that sediment trap efficiency depends on the quantity of sediment that is laden in the flow, i.e., more the sediment inflow with the Clear water, more will be its trapping efficiency. Trap efficiency also depends on the type of vegetation used as the model and its dimensional characteristics. As a whole, aquatic vegetation traps more sediment than riparian vegetation. Trap efficiency also depends on the surface spread of the vegetation i.e.; more the vegetation coverage area at surface (both laterally and linearly), more is its sediment trapping efficiency. The reason behind the observation of model fields of vegetation acting solo, exhibiting more trap efficiency as compared to its performance in association with a porcupine field model; may be attributed to two facts. First, the channel bed might get scoured in presence of vegetation model trapped inside porcupine member model; as the arrangement adopted in the present study. Secondly, the pattern of laying of the vegetation field models in conjunction with the porcupine field model in the present study; might not be proper and practical and will need further exploration. It has also been found that sediment trap efficiency also depends on root diameter. Bushier root system traps more sediment than that of less bushy root system.

Sinha (2017) made critical comparisons between the performance of various models of porcupine fields (defined on the basis of some dimensionless parameters), in terms of their sediment trapping efficiency. Results showed that that more the transverse extend of the porcupine field for a given spacing between successive retards, more will be its sediment trapping efficiency. For a given value of length of single compartment, the increase of sediment trapping efficiency of porcupine fields with increasing density of retards (represented by the ratio PFDI) gets more and more enhanced as the porcupine field gets longitudinally expanded. More the ratio between the lateral and linear extends of the porcupine field; more is its sediment trapping efficiency. For a given value of length of single compartment, the increase of sediment trapping efficiency of porcupine fields with increasing ratio of its lateral to linear spread (represented by the ratio PCDI) gets more and more enhanced as the porcupine field gets longitudinallyexpanded.

Chapter 3
MATERIALS USED AND THE METHODOLOGY ADOPTED

3.1 Materials Description

3.1.1 Model

- The porcupine models used in this study were created by scaling down to match the dimensions of the laboratory channel.
- The models were constructed using MS Rods, which were 10mm in thickness and 20.32cm in length, and were welded together.
- An additional 4cm length was added to each member of the model to allow for embedding them into the simulated riverbed in the experimental channel.
- Figure 3.4 provides visual representation of such typical models. These models were used as a representation of the actual size porcupines to study their performance in the laboratory setting, providing a cost-effective and efficient method to study the efficacy of porcupine systems in controlling erosion and facilitating channelization in rivers.

Fig. 3.1: Model of porcupine made of MS Rod

3.1.2 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.

3.1.3 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.

3.2 Experimental Channel Description

- All the experiments for this study were conducted in the Hydraulics Laboratory Channel of Assam Engineering College in Guwahati (Figure 3.4).
- The channel measures 35 meters in length, 1.8 meters in width and 1.275 meters in depth, with a 0.49 meter thickness of sand bed.

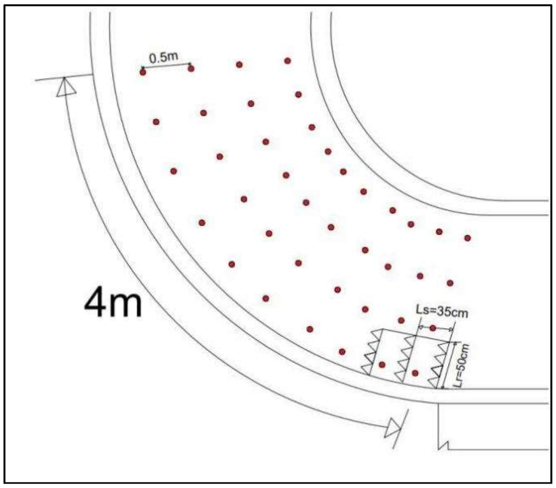


Fig. 3.2: Test points in the experimental channel

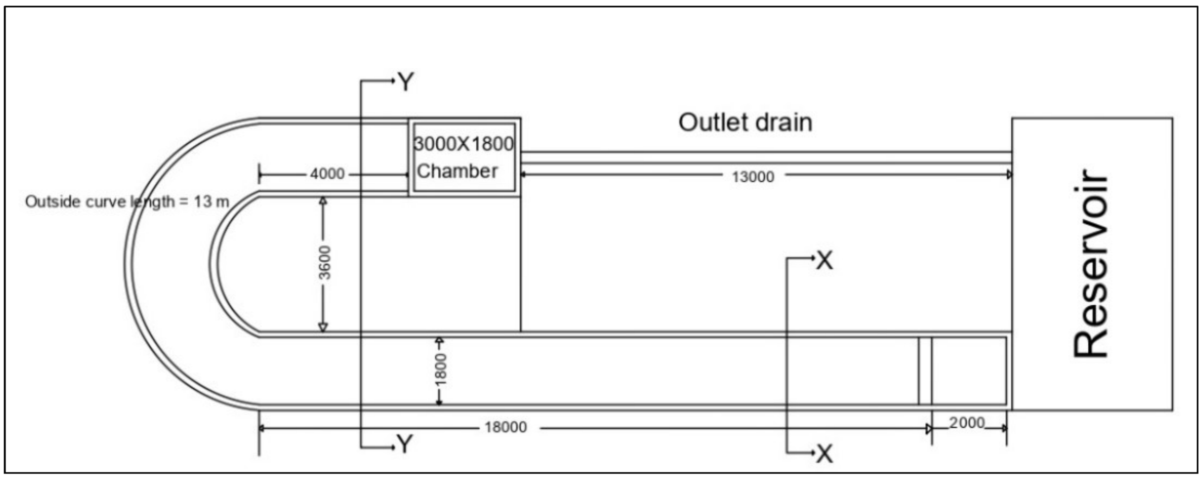


Fig.3.3: Experimental channel

- The water flow in the channel was maintained by utilizing two pumps of5 HP and 10 HP.
- Water from the pumps was collected in a tank, passed through a combined arrangement of energy dissipater and wire mesh screens to reduce turbulence, and then fed into the channel through an inlet.
- The water at the outlet was collected in a rectangular tank and the flow rate into the channel was controlled using a discharge valve at the inlet.
- The slope of the channel bed was taken 1:250 and the slope of the bank was taken as1.5H:1V. This setup provided a controlled environment to study the performance of the erosion control measures and bank stabilization techniques in the laboratory setting.

(a)

(b)

Figure 3.4: Experimental Channel of AEC, Hydraulics Lab

3.3 Experimental Procedure

- The experiments were conducted in the Hydraulics Laboratory Channel of Assam Engineering College in Guwahati (Figure 3.4a and 3.4b). The channel was first levelled and the flow was gradually introduced into it by releasing the discharge valve slowly until reaching the point at which the bed materials just tend to lift, representing incipient motion condition. The valve was then readjusted back a little to maintain a flow velocity less than the critical velocity.
- A clear water run was continued for 45 minutes before starting the experimentation with the porcupine field models. The rectangular weir was then removed to allow the water to drain out gradually from the channel without disturbing the sand bed. The position of the discharge valve was fixed and kept constant for the rest of the experiments. Sand bed levels were measured with the help of point gauge (Figure 3.7).
- After placing the first trial model of the porcupine field, the sediment bed of the channel was again levelled around the field and the flow was introduced. A fixed quantity of sediment was injected into the channel 2 meters upstream of the porcupine field for 2 hours(For 1st Ten trial) and 3 hours(For next 10 trial). The motor was then shut down and the rectangular weir removed to allow the water to drain out gradually from the channel. After the water had completely drained, the sand bed levels were again measured with the help of point gauge.
- The same procedure was followed for the rest of the model porcupine fields studied in this work. All the experiments were performed with sediments having specific gravity of 2.57(Sediment 1),2.59(Sediment 2) and 2.61(Sediment 3) and porosity of 34%(Sediment 1),34%(Sediment 2) and 35%(Sediment 3) and bed material having, specific gravity of 2.62.

Figure 3.5: Point Gauge with trolley

3.3.1 Measurement of Velocity

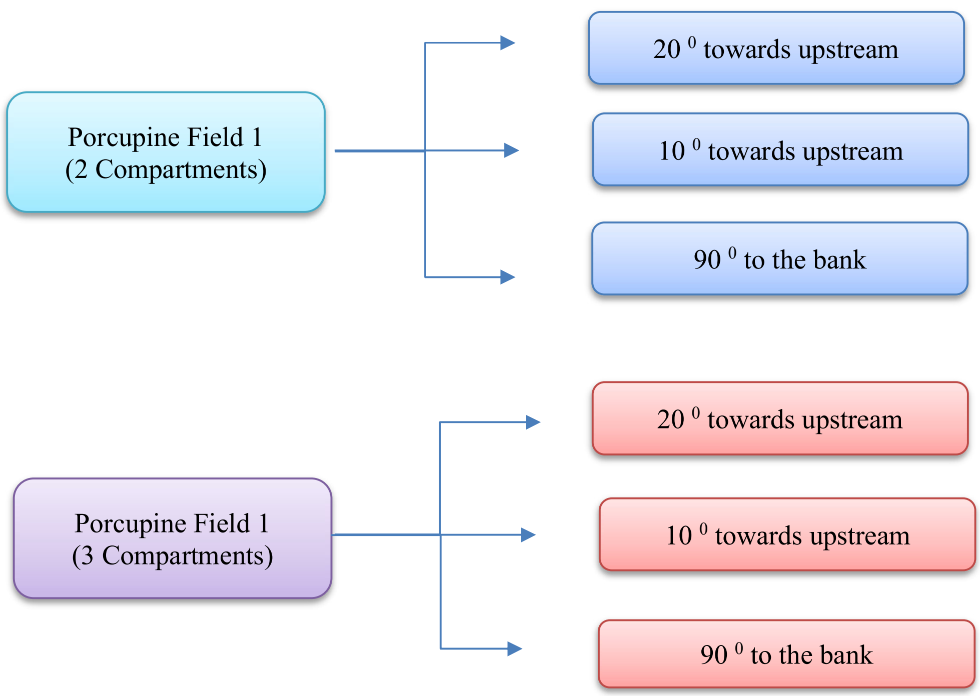
The Acoustic Doppler Velocimeter (ADV) was utilized to accurately measure the velocity of water flow. The Vectrino Velocimeter, a device that utilizes the Doppler Effect, was employed in the ADV. The device emits a short pulse of sound, captures the echo, and then calculates the change in pitch or frequency 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.

Figure 3.6: Acoustic Doppler Velocimeter (ADV)

3.4 METHODOLOGY ADOPTED

3.4.1 The scheme of the experiment has been described in fig 3.7 below. Phase 1 experiments were conducted for a single sediment size, whereas phase 2 was conducted by using 3 different sediment sizes.

<u>Phase 1</u> (Sediment Size Fixed)



<u>Phase 2</u> (porcupine inclination perpendicular to the bank)

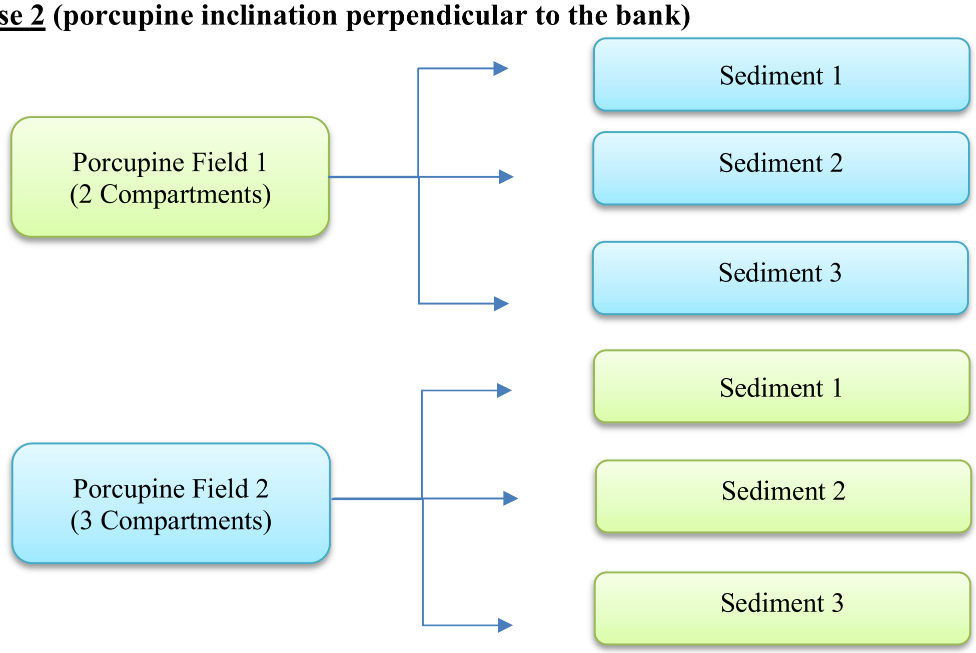


Fig 3.7: Flow chart for methodology

Chapter 4

EXPERIMETAL WORK

4.1 Sieve Analysis of Bed Material

The particle size distribution of the bed material was determined as per IS 2720: (Part 4)-1985 using dry sieve analysis.

Table 4.1: Test results of sieve analysis of bed material

Sl. No.	IS Sieve size In mm	Weight retained in gm	% weight retained	Cumulative % Weight retained	% passing
1	10	0	0	0	100
2	4.75	5	1	1	99
3	2.36	7	1.4	2.4	97.6
4	1.18	23	4.6	7	93
5	0.60	265	53	60	40
6	0.30	160	32	92	8
7	0.15	33	6.6	98.6	1.4
8	0.075	5	1	99.6	0.4
9	pan	2	0.4	100	0

Fineness Modulus = $\frac{360.6}{100}$ =3.61

The particle size distribution graph is shown in figure 4.1.

EXPERIMENTAL WORK

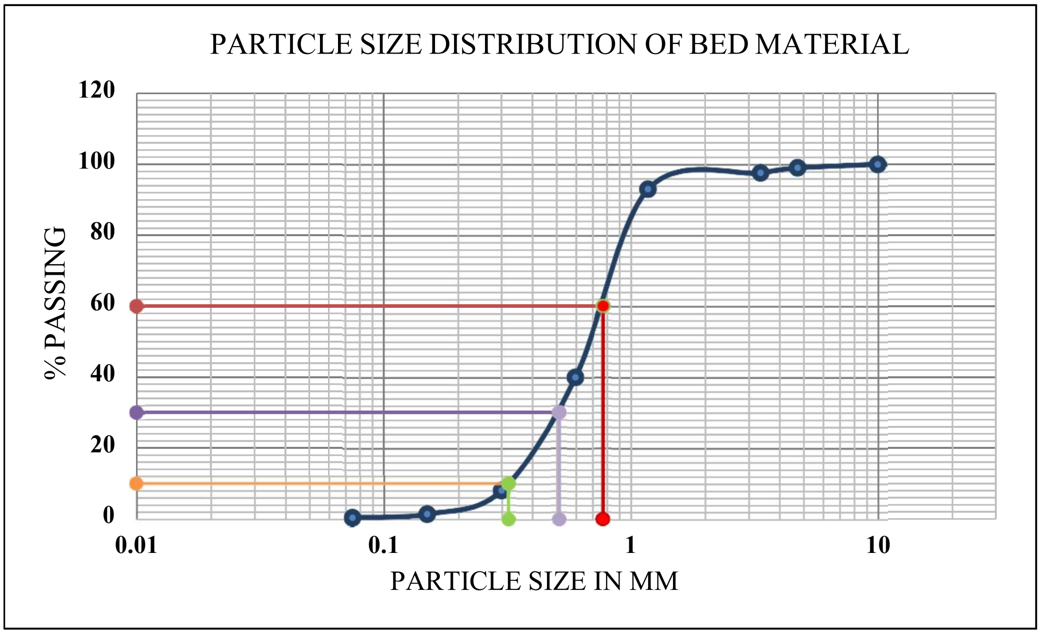


Figure 4.1: Particle size distribution of bed material

From the sieve analysis data, following results were obtained. From the above graph of percentage finer and particle size, the values of D10, D30, D50, D60, Cu and Cc were determined.

Uniformity Coefficient, Cu = D_{60} / D_{10}

Coefficient of Curvature, Cc = $(D30)^{2} / D60 \times D10$

Table 4.2: Summary of particle size distribution of the river bed material

Properties	Value
D_{10}	0.32 mm
D_{30}	0.51 mm
D_{60}	0.77 mm
Uniformity coefficient, C_u	2.4
Coefficient of Curvature, C_c	1.05
Classification (IS)	Poorly graded sand

4.2 Sieve Analysis of Sediment

Table 4.3: Test results of sieve analysis of **Sediment 1**

Sl. No.	IS Sieve size In mm	Weight retained in gm	% Weight retained	Cumulative % Weight retained	% Passing
1	10	0	0	0	100
2	4.75	3	0.6	0.6	99.4
3	2.36	2	0.4	1	99
4	1.18	1	0.2	1.2	98.8
5	0.6	0	0	1.2	98.8
6	0.3	7	1.4	2.6	97.4
7	0.15	345	69	71.6	28.4
8	0.075	115	23	94.6	5.4
9	pan	27	5.4	100	0

Fineness Modulus = $\frac{172.8}{100}$ = 1.728

From the sieve analysis data, following results were obtained. From the graph of percentage finer and particle size, the values of D_{10}, D_{30}, D_{60}, Cu and Cc were determined.

The particle size distribution graph is shown in figure 4.2

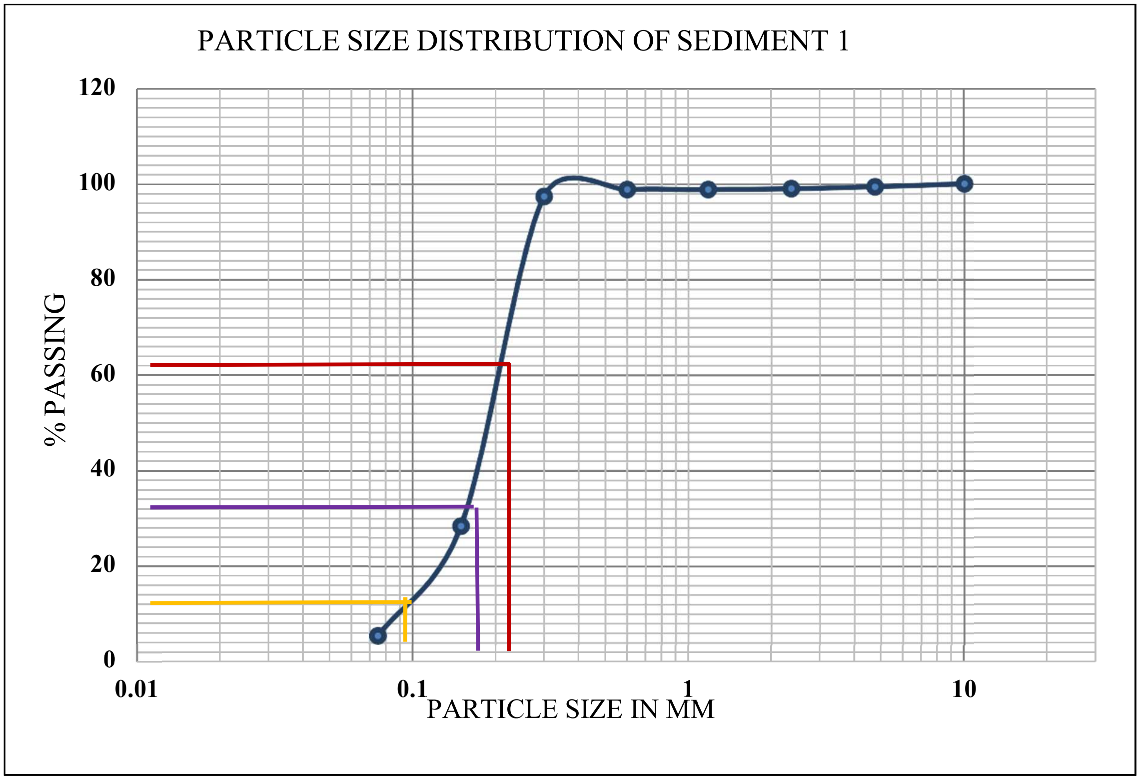


Figure 4.2: Particle size distribution of sediment 1

Table 4.4: Summary of particle size distribution of the sediment 1

Properties	Value
D_{10}	0.088 mm
D_{30}	0.15 mm
D_{60}	0.2 mm
Uniformity coefficient, C_u	2.27
Coefficient of Curvature, C_c	1.27
Classification (IS)	Poorly graded sand

Table 4.5: Test results of sieve analysis of **Sediment 2**

Sl No	IS Sieve size in mm	Weight Retained in gm	% Weight Retained	Cummulative % Weight Retained	% Passing
1	10	0	0.00	0.00	100.00
2	4.75	2	0.40	0.40	99.60
3	2.36	0	0.00	0.40	99.60
4	1.18	2	0.40	0.80	99.20
5	0.6	5	1.00	1.80	98.20
6	0.3	32	6.40	8.20	91.80
7	0.15	361	72.20	80.40	19.60
8	0.075	93	18.60	99.00	1.00
	Pan	5	1.00	100.00	0.00

Fineness Modulus = $\frac{191.00}{100}$ = 1.91

From the sieve analysis data, following results were obtained. From the graph of percentage finer and particle size, the values of D_{10}, D_{30}, D_{60}, Cu and Cc were determined.

The particle size distribution graph is shown in figure 4.3

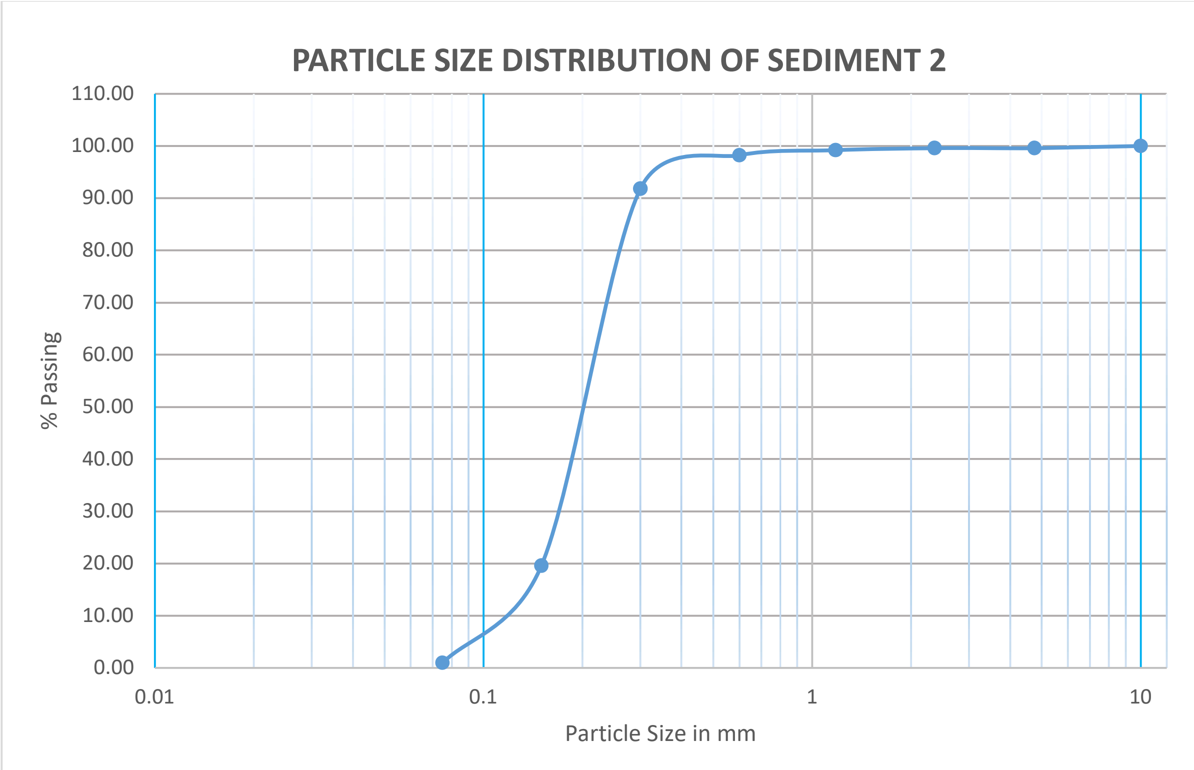


Figure 4.3: Particle size distribution of sediment 2

Table 4.6: Summary of particle size distribution of the sediment 2

Properties	Value
D_{10}	0.13
D_{30}	0.17
D_{60}	0.21
Uniformity coefficient, C_u	1.62
Coefficient of Curvature, C_c	1.06
Classification (IS)	Poorly graded sand

Table 4.7: Test results of sieve analysis of **Sediment 3**

Sl No	IS Sieve size in mm	Weight Retained in gm	% Weight Retained	Cummulative % Weight Retained	% Passing
1	10	0	0.00	0.00	100.00
2	4.75	2	0.40	0.40	99.60
3	2.36	1	0.20	0.60	99.40
4	1.18	3	0.60	1.20	98.80
5	0.6	13	2.60	3.80	96.20
6	0.3	54	10.80	14.60	85.40
7	0.15	317	63.40	78.00	22.00
8	0.075	98	19.60	97.60	2.40
	Pan	12	2.40	100.00	0.00

Fineness Modulus = $\frac{196.20}{100}$ = 1.962

From the sieve analysis data, following results were obtained. From the graph of percentage finer and particle size, the values of D_{10}, D_{30}, D_{60}, Cu and Cc were determined.

The particle size distribution graph is shown in figure 4.4

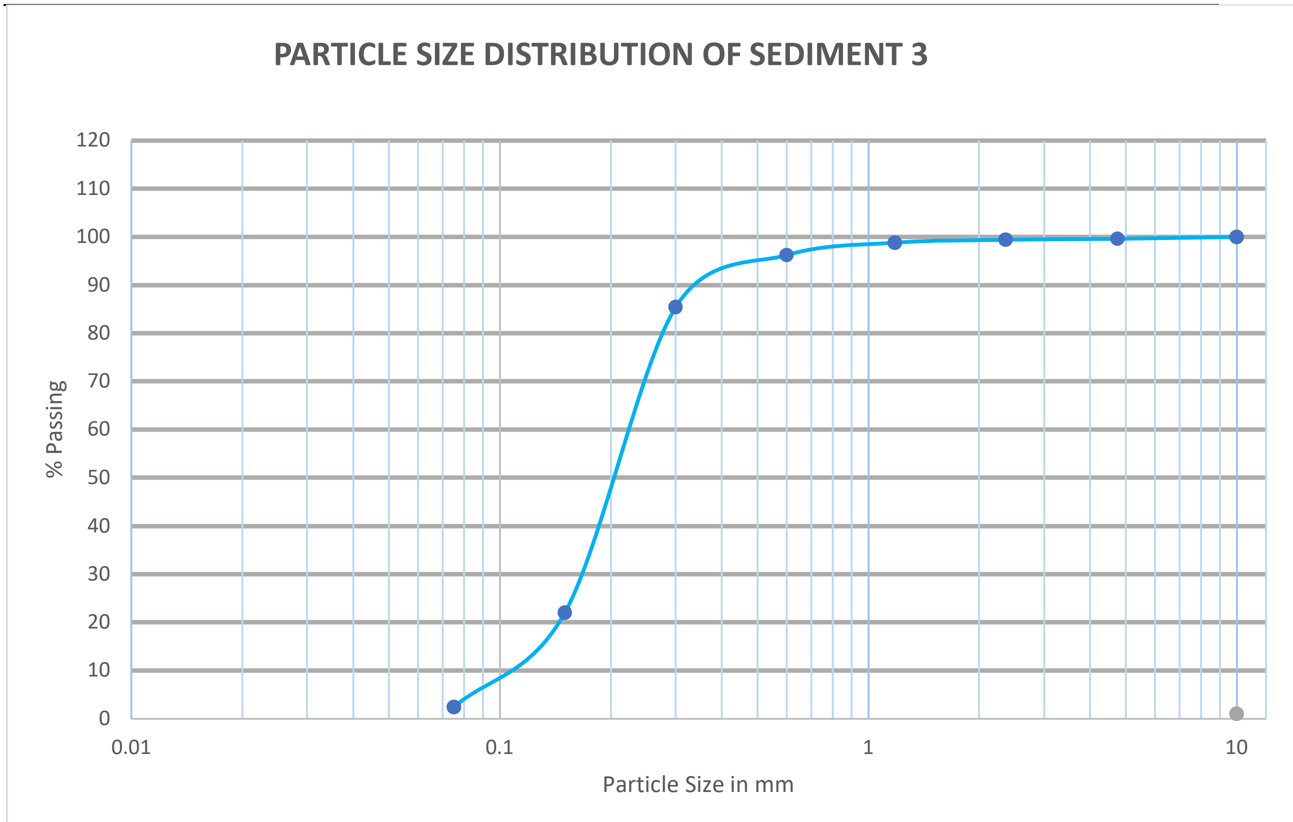


Figure 4.4: Particle size distribution of sediment 3

Table 4.8: Summary of particle size distribution of the sediment 3

Properties	Value
D_{10}	0.12
D_{30}	0.18
D_{60}	0.23
Uniformity coefficient, C_u	1.92
Coefficient of Curvature, C_c	1.97
Classification (IS)	Poorly graded sand

4.3 Specific Gravity of Sediment 1

Determination of specific gravity using pycnometer

Table 4.9: Data and observation sheet for determination of specific gravity of sediment 1

Serial no.	Specific Gravity
1	2.56
2	2.58
3	2.59

Specific Gravity = 2.57

4.4 Porosity of Sediment 1

Table 4.10: Data and observation sheet for void ratio determination of sediment 1

Serial No.	**Void ratio**
1	0.5
2	0.5
3	0.53

Average e = 0.51

Porosity, n =e/1+e =34%

4.5 Specific Gravity of Sediment 2

Determination of specific gravity using pycnometer

Table 4.11: Data and observation sheet for determination of specific gravity of sediment 2

Serial no.	Specific Gravity
1	2.56
2	2.62
3	2.60

Specific Gravity = 2.59

4.6 Porosity of Sediment 2

Table 4.12: Data and observation sheet for void ratio determination of sediment 2

Serial No.	**Void ratio**
1	0.51
2	0.53
3	0.53

Average e = 0.52

Porosity, n =e/1+e =34%

4.7 Specific Gravity of Sediment 3

Determination of specific gravity using pycnometer

Table 4.13: Data and observation sheet for determination of specific gravity of sediment 3

Serial no.	Specific Gravity
1	2.58
2	2.60
3	2.64

Specific Gravity = 2.61

4.8 Porosity of Sediment 3

Table 4.14: Data and observation sheet for void ratio determination of sediment 3

Serial No.	**Void ratio**
1	0.54
2	0.53
3	0.53

Average e = 0.53

Porosity, $n = \frac{e}{1+e} = 35\%$

4.9 Specific Gravity of Bed Material

Determination of specific gravity using pycnometer

Table 4.15: Data and observation sheet for determination of specific gravity of bed material

Serial no.	Specific Gravity
1	2.56
2	2.63
3	2.69

Specific Gravity = 2.62

4.10 Specific Gravity of Bank Material

Specific Gravity (Pycnometer)

Table 4.16: Data and observation sheet for determination of specific gravity of bank material

Serial No.	**Specific Gravity**
1	2.5
2	2.5
3	3.33

Average G = 2.78

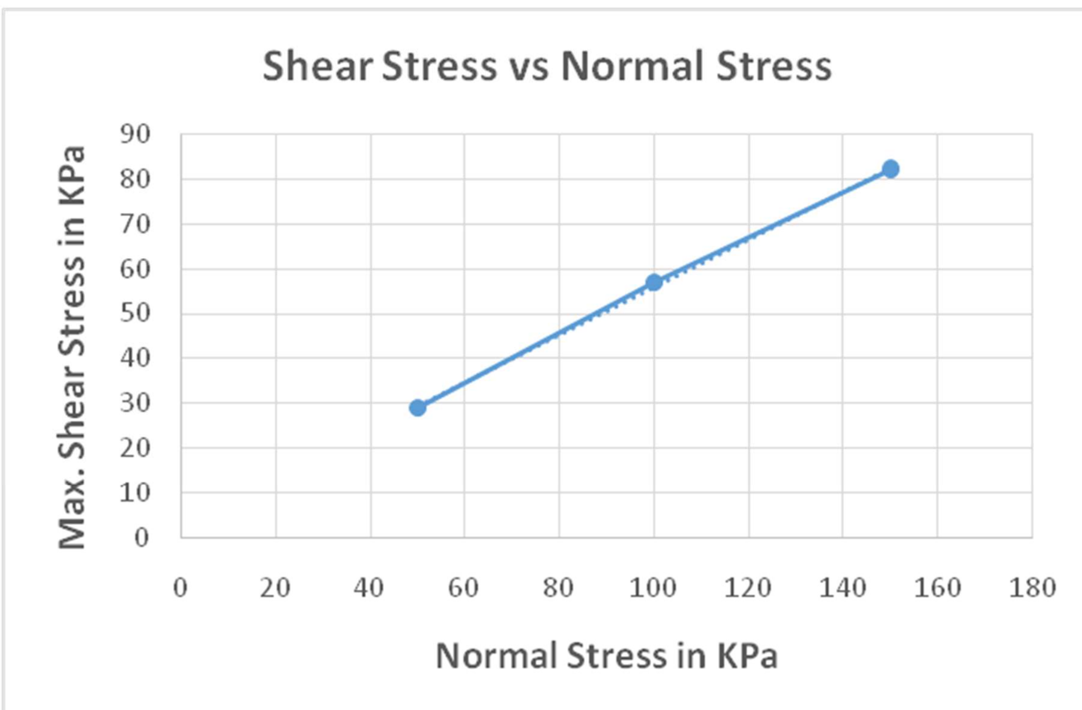
4.11 DIRECT SHEAR TEST

The shear parameters of the river bed material were determined using direct shear test. The plot of maximum shear stress versus normal stress are shown in the figure below.

Table 4.17: Maximum shear stress corresponding to each normal stress

SEDIMENT 1

Normal stress (kPa)	50	100	150
Maximum shear stress (kPa)	30	55	82



Slope= 0.55
Intercept=4.33

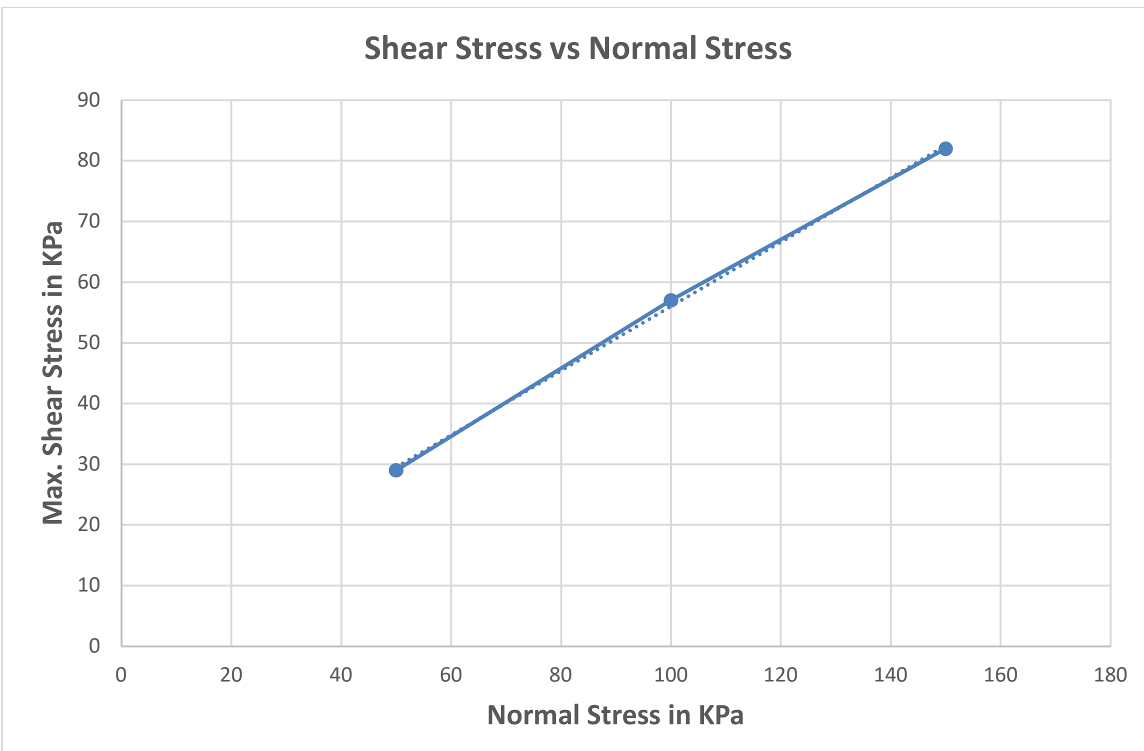
Figure 4.5: Shear stress vs. normal stress graph

$\Phi = 29^o$

Table 4.18: Maximum shear stress corresponding to each normal stress

SEDIMENT 2

Normal stress (kPa)	50	100	150
Maximum shear stress (kPa)	29	57	82



Slope= 0.53
Intercept=3.00

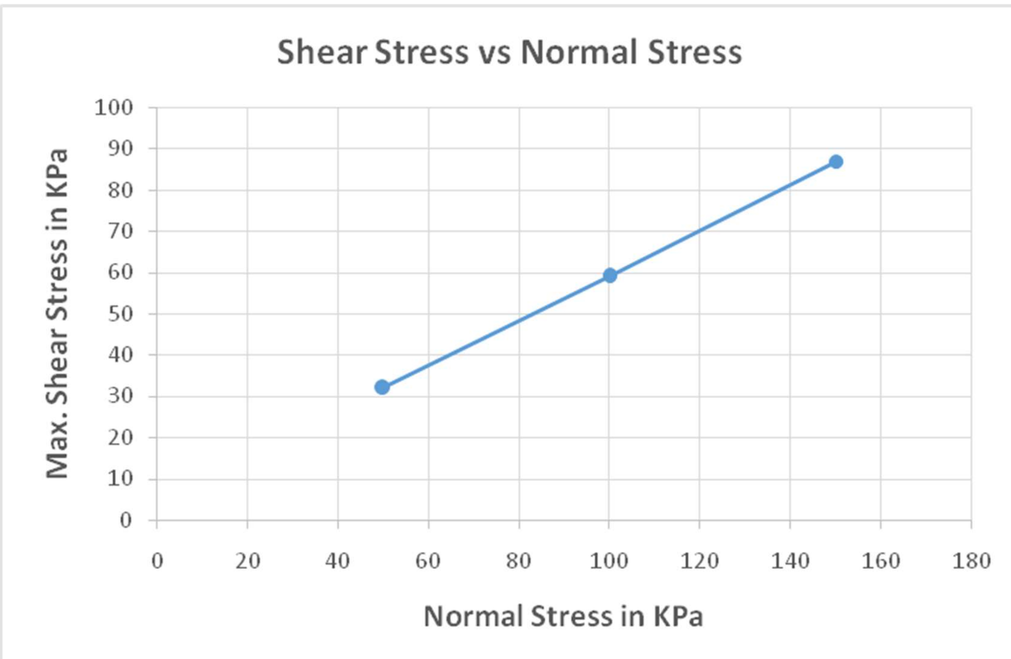
Figure 4.6: Shear stress vs. normal stress graph

$\Phi = 28^{o}$

Table 4.19: Maximum shear stress corresponding to each normal stress

SEDIMENT 3

Normal stress (kPa)	50	100	150
Maximum shear stress (kPa)	32	59	87



Slope= 0.52
Intercept=3.67

Figure 4.7: Shear stress vs. normal stress graph

$\Phi = 27^{o}$

4.12 Results of Experiments Done with Different Porcupine Layouts.

Using the dimensional parameters as listed in Table 4.9, trial porcupine field models were prepared and laid on the channel with the simulated river bed. Relevant observations were made to study the sediment deposition of these trial field models as per the methodology laid down and described in the third chapter of this report. Length of each porcupine field was started from a distance of 18 m from the upstream end of the simulated bed in the channel and the width started from the bank of the channel. After each experimental run, the bed profiles were measured in the form of 0.50 m x 0.50 m grid with point gauge along three imaginary lines (A, B & C) on the channel bed along the flow, as shown in figure 4.5. Figure 4.6 shows typical layout of porcupine field.

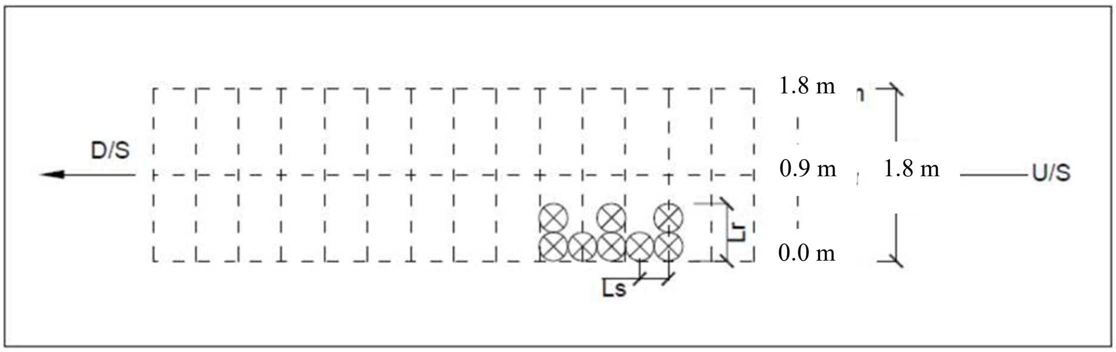


Figure 4.8: Line diagram of channel grid

4.13 Indices

Some indices were coined in this study in order to differentiate between various porcupine field models in their terms. These indices are defined as under:

A) Porcupine Field Density Index (PFDI) = Length of one retard / Spacing between the two retards = L_r/L_s

B) Porcupine Compartment Density Index (PCDI) = Length of retard / Total length of compartment = L_r/L_c

C) Porcupine Field Length Factor (PFLF) = Length of one compartment of porcupine field / Total length of compartments = L_s/L_c

D) PFVI (Porcupine Field Velocity Index) = (Upstream velocity – Mid velocity)/ (Mid velocity – Downstream velocity)

E) PFVI (Porcupine Field Velocity Index) = (Upstream velocity – Mid velocity)/ (Mid velocity – Downstream velocity)

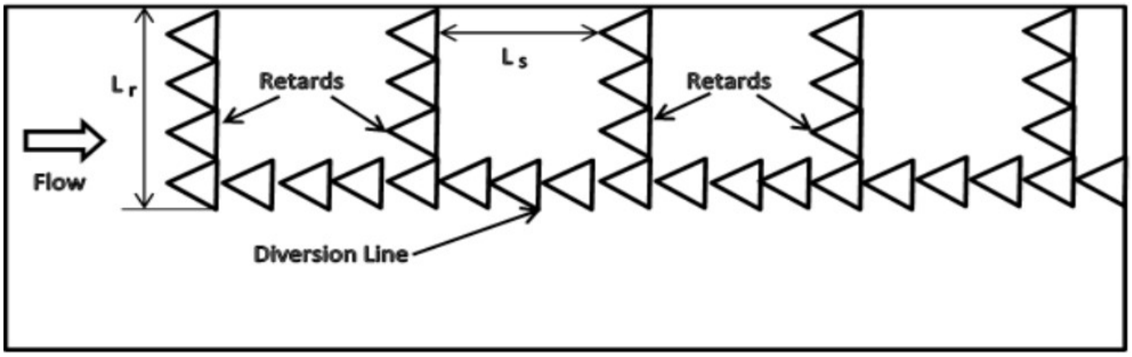


Figure 4.9: Typical layout of porcupine field

(Source: Aamir and Sharma, 2014)

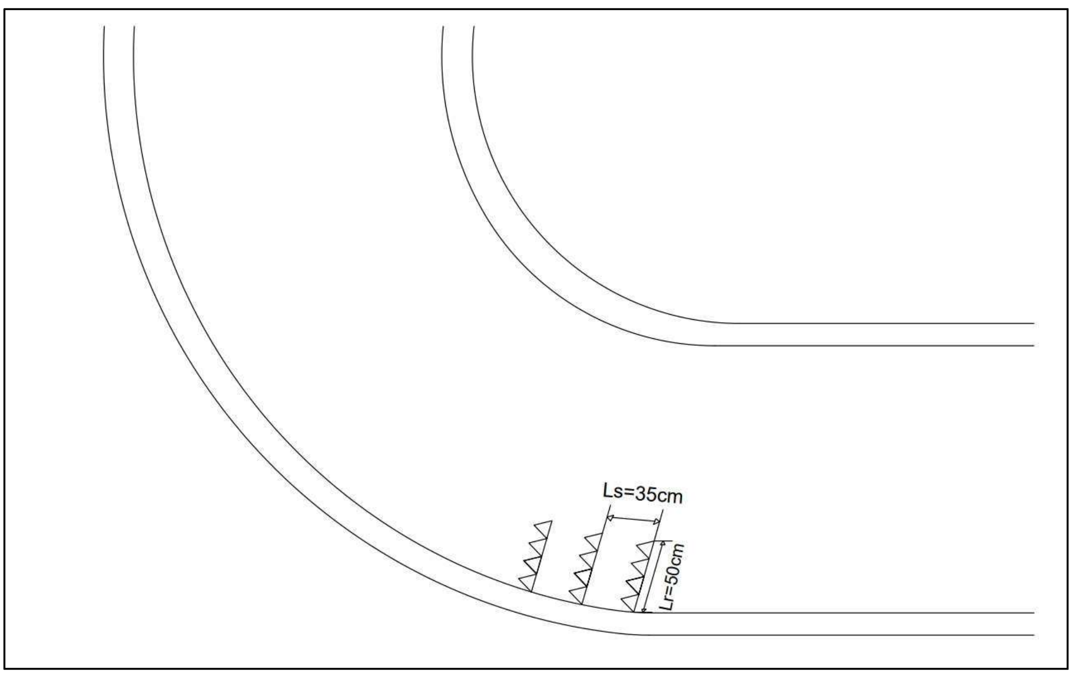


Fig.4.10:Porcupine layout in channel

Table 4.20: Range of dimensional parameters for the trial porcupine field models

Trial No.	**Angle of porcupine placed**	**Sediment Sample**	**Length of Retards, L_r, in cm**	**Spacing of Retards, L_s, in cm**	**No. of compartment**	**Weight of sand injected in kg**	**Length of compartment in cm**	PFLF L_s / L_c	PCDI L_r / L_c	PFDI L_r / L_s
1	20^0 u/s	Sediment 1	50	35	3	5	105	0.33	0.47	1.4
2	10^0 u/s	Sediment 1	50	35	3	8	105	0.33	0.47	1.4
3	20^0 u/s	Sediment 1	50	35	2	5	70	0.5	0.7	1.4
4	10^0 u/s	Sediment 1	50	35	2	8	70	0.5	0.7	1.4
5	20^0 u/s	Sediment 1	50	55	3	5	165	0.33	0.3	0.9
6	10^0 u/s	Sediment 1	50	55	3	8	165	0.33	0.3	0.9
7	20^0 u/s	Sediment 1	50	55	2	5	110	0.5	0.45	0.9
8	10^0 u/s	Sediment 1	50	55	2	8	110	0.5	0.45	0.9
9	90^0 to the bank	Sediment 1	50	55	2	5	110	0.5	0.45	0.9
10	90^0 to the bank	Sediment 1	50	55	3	8	165	0.33	0.3	0.9
11	90^0 to the bank	Sediment 1	50	35	2	5	70	0.5	0.7	1.4
12	90^0 to the bank	Sediment 1	50	35	3	8	105	0.33	0.47	1.4
13	90^0 to the bank	Sediment 2	50	55	2	3	110	0.5	0.45	0.9
14	90^0 to the bank	Sediment 2	50	55	3	5	165	0.33	0.3	0.9
15	90^0 to the bank	Sediment 3	50	55	2	3	110	0.5	0.45	0.9
16	90^0 to the bank	Sediment 3	50	55	3	5	165	0.33	0.3	0.9
17	90^0 to the bank	Sediment 2	50	35	2	3	70	0.5	0.7	1.4
18	90^0 to the bank	Sediment 2	50	35	3	5	105	0.33	0.47	1.4
19	90^0 to the bank	Sediment 3	50	35	2	3	70	0.5	0.7	1.4
20	90^0 to the bank	Sediment 3	50	35	3	5	105	0.33	0.47	1.4

4.14 Estimation of Sediment Deposition

1. For 1st trial of porcupine field model layout (figure 4.8), porcupines were placed 20^0 inclined towards upstream, following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4 Porcupine

Compartment Density Index (PCDI) = L_r / L_c= 0.47Porcupine

Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 5 kg of sediment(sediment 1) was injected.

Table 4.21: Measurement of sediment deposition at 1st trial

Ls 35; Lr 50; Lc 105, sediment 5kg									
Distance along the length of the channel (m)	Point gauge reading without porcupine field (m)			Point gauge reading with porcupine field (m)			Height of ripple of sand (m)		
	A	B	C	A	B	C	A	B	C
0	0.224	0.252	0.228	0.236	0.262	0.236	0.012	0.01	0.004
0.5	0.226	0.25	0.23	0.236	0.258	0.236	0.01	0.008	0.002
1	0.229	0.251	0.229	0.239	0.258	0.236	0.01	0.007	0.004
1.5	0.23	0.25	0.226	0.238	0.256	0.235	0.008	0.006	0.006
2	0.229	0.252	0.225	0.233	0.256	0.234	0.004	0.004	0.008
2.5	0.228	0.251	0.228	0.231	0.254	0.239	0.003	0.003	0.008
3	0.23	0.248	0.231	0.231	0.249	0.238	0.001	0.001	0.005
3.5	0.23	0.248	0.231	0.23	0.249	0.235	0	0.001	0.002
4	0.226	0.25	0.226	0.225	0.25	0.229	-0.001	0	0.001

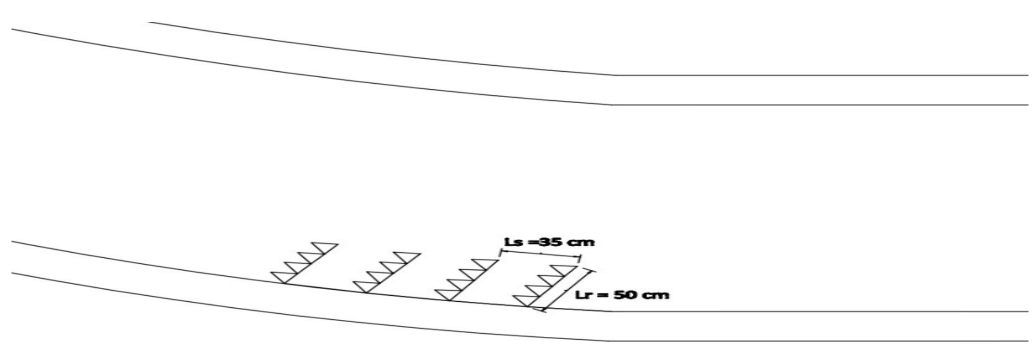


Fig.4.11: Layout of porcupine field for trial 1

Figure 4.12: Porcupine field for 1st trial

Figure 4.13: Channel bed after experimental run for 1sst trial

2. For 2nd trial of porcupine field model layout (figure 4.11), porcupines are placed 10^0 inclined towards upstream, following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4

Porcupine Compartment Density Index (PCDI) = L_r / L_c= 0.47

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 8 kg of sediment(sediment 1) was injected.

Table 4.22: Measurement of sediment deposition at 2nd trial

Ls 35; Lr 50; Lc 105 sediment 8kg									
Distance along the length of the channel (m)	Point gauge reading without porcupine field (m)			Point gauge reading with porcupine field (m)			Height of ripple of sand (m)		
	A	B	C	A	B	C	A	B	C
0	0.236	0.248	0.24	0.25	0.259	0.247	0.014	0.011	0.007
0.5	0.238	0.249	0.238	0.25	0.259	0.248	0.012	0.01	0.01
1	0.237	0.25	0.237	0.248	0.256	0.248	0.011	0.006	0.011
1.5	0.237	0.252	0.236	0.247	0.258	0.249	0.01	0.006	0.013
2	0.239	0.25	0.236	0.245	0.254	0.251	0.006	0.004	0.015
2.5	0.241	0.251	0.238	0.245	0.255	0.254	0.004	0.004	0.016
3	0.24	0.251	0.24	0.242	0.254	0.254	0.002	0.003	0.014
3.5	0.238	0.248	0.241	0.239	0.249	0.254	0.001	0.001	0.013
4	0.238	0.249	0.237	0.237	0.249	0.247	-0.001	0	0.01

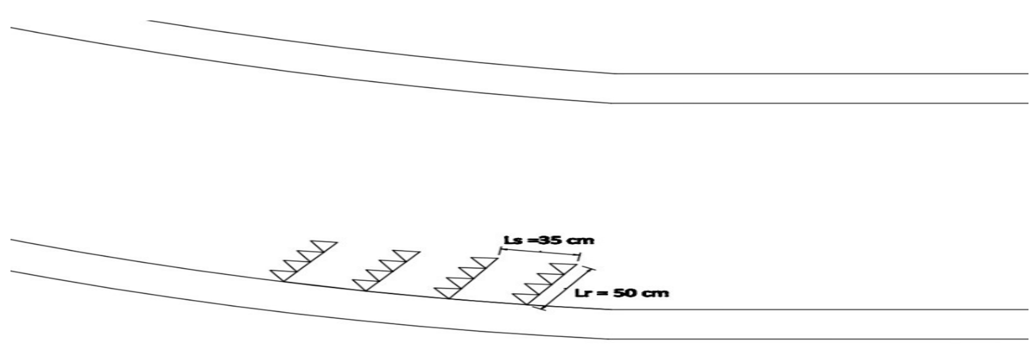


Figure 4.14: Layout of porcupine field for trial 2

Figure 4.15: Porcupine field for 2nd trial

Figure 4.16: Channel bed after experimental run for 2nd trial

3. For 3rd trial of porcupine field model layout (figure 4.14), porcupines are placed 20^0 inclined towards upstream,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.7

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 5 kg of sediment(sediment 1) was injected.

Table 4.23: Measurement of sediment deposition at 3rd trial

Ls 35; Lr 50; Lc 70 sediment 5kg									
Distance alongthe length of the channel (m)	Point gauge reading without porcupine field (m)			Point gauge reading with porcupine field (m)			Height of ripple of sand (m)		
	A	B	C	A	B	C	A	B	C
0	0.24	0.248	0.242	0.25	0.255	0.246	0.01	0.007	0.004
0.5	0.239	0.25	0.243	0.248	0.257	0.248	0.009	0.007	0.005
1	0.24	0.252	0.246	0.248	0.258	0.253	0.008	0.006	0.007
1.5	0.24	0.249	0.242	0.247	0.254	0.249	0.007	0.005	0.007
2	0.241	0.248	0.241	0.247	0.253	0.249	0.006	0.005	0.008
2.5	0.238	0.253	0.242	0.241	0.256	0.251	0.003	0.003	0.009
3	0.237	0.253	0.243	0.238	0.255	0.25	0.001	0.002	0.007
3.5	0.239	0.252	0.243	0.239	0.253	0.247	0	0.001	0.004
4	0.24	0.251	0.24	0.24	0.251	0.243	0	0	0.003

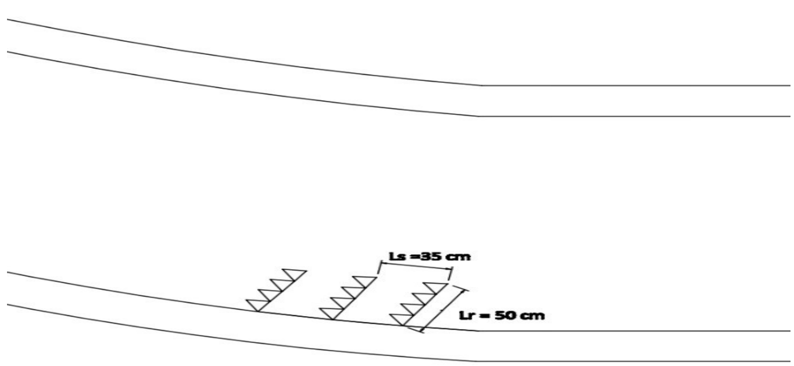


Figure 4.17: Layout of porcupine field for trial 3

Figure 4.18: Porcupine field for 3rd trial

Figure 4.19: Channel bed after experimental run for 3rdtrial

4. For 4th trial of porcupine field model layout (figure 4.17), porcupines are placed 10^0 inclined towards upstream,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.7

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 8 kg of sediment(sediment 1) was injected.

Table 4.24: Measurement of sediment deposition at 4th trial

Ls 35; Lr 50; Lc 70 sediment 8kg									
Distance along the length of the channel (m)	Point gauge reading without porcupine field (m)			Point gauge reading with porcupine field (m)			Height of ripple of sand (m)		
	A	B	C	A	B	C	A	B	C
0	0.242	0.251	0.239	0.258	0.261	0.244	0.016	0.01	0.005
0.5	0.241	0.25	0.24	0.255	0.261	0.245	0.014	0.011	0.005
1	0.242	0.251	0.238	0.255	0.259	0.245	0.013	0.008	0.007
1.5	0.242	0.252	0.239	0.253	0.258	0.249	0.011	0.006	0.01
2	0.24	0.249	0.241	0.25	0.255	0.252	0.01	0.006	0.011
2.5	0.238	0.25	0.24	0.245	0.255	0.25	0.007	0.005	0.01
3	0.237	0.252	0.239	0.242	0.255	0.247	0.005	0.003	0.008
3.5	0.236	0.248	0.238	0.239	0.25	0.243	0.003	0.002	0.005
4	0.235	0.249	0.237	0.237	0.25	0.241	0.002	0.001	0.004

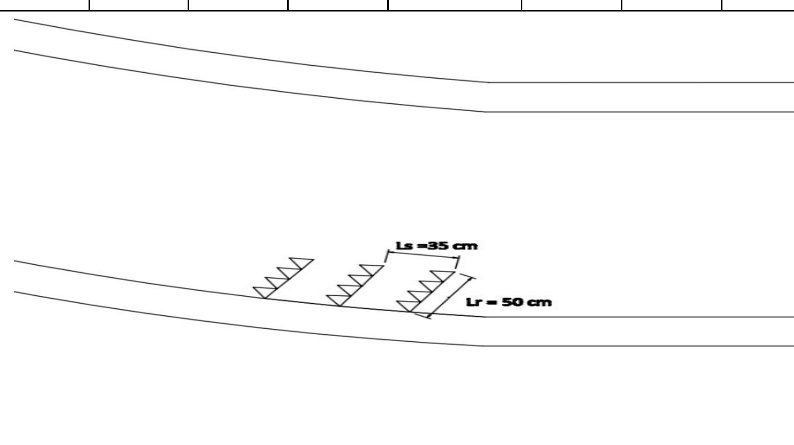


Figure 4.20: Layout of porcupine field for trial 4

Figure 4.21: Porcupine field for 4th trial

Figure 4.22: Channel bed after experimental run for 4thtrial

5. For 5th trial of porcupine field model layout (figure 4.20), porcupines are placed 20^0 inclined towards upstream, following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.3

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 5 kg of sediment(sediment 1) was injected.

Table 4.25: Measurement of sediment deposition at 5th trial

Ls 55; Lr 50; Lc 165 sediment 5kg									
Distance alongthe length of the channel (m)	Point gauge reading without porcupinefield (m)			Point gauge reading with porcupine field (m)			Height of ripple ofsand (m)		
	A	B	C	A	B	C	A	B	C
0	0.233	0.246	0.238	0.244	0.254	0.241	0.011	0.008	0.003
0.5	0.236	0.247	0.235	0.245	0.254	0.236	0.009	0.007	0.001
1	0.235	0.246	0.237	0.245	0.253	0.238	0.01	0.007	0.001
1.5	0.232	0.246	0.236	0.239	0.25	0.24	0.007	0.004	0.004
2	0.233	0.25	0.233	0.239	0.253	0.24	0.006	0.003	0.007
2.5	0.234	0.251	0.234	0.238	0.254	0.242	0.004	0.003	0.008
3	0.235	0.25	0.233	0.239	0.251	0.238	0.004	0.001	0.005
3.5	0.232	0.258	0.234	0.233	0.258	0.236	0.001	0	0.002
4	0.231	0.259	0.236	0.231	0.259	0.237	0	0	0.001

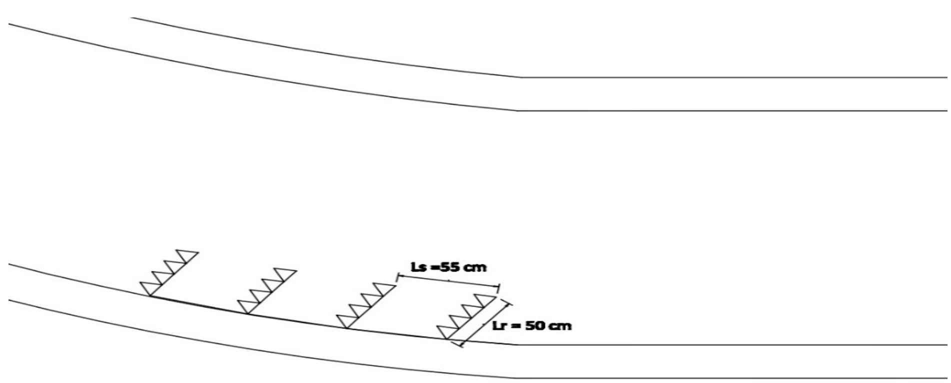


Figure 4.23: Layout of porcupine field for trial 5

Figure 4.24: Porcupine field for 5th trial

Figure 4.25: Channel bed after experimental run for 5th trial

6. For 6th trial of porcupine field model layout (figure 4.23), porcupines are placed 10^0 inclined towards upstream,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.3

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 8 kg of sediment(sediment 1) was injected.

Table 4.26: Measurement of sediment deposition at 6^{th} trial

Ls 55; Lr 50; Lc 165 sediment 8kg									
Distance along the length of the channel (m)	Point gauge reading without porcupine field (m)			Point gauge reading with porcupine field (m)			Height of ripple of sand (m)		
	A	B	C	A	B	C	A	B	C
0	0.241	0.246	0.245	0.256	0.257	0.253	0.015	0.011	0.008
0.5	0.243	0.247	0.244	0.259	0.257	0.25	0.016	0.01	0.006
1	0.244	0.246	0.245	0.259	0.254	0.252	0.015	0.008	0.007
1.5	0.245	0.24	0.245	0.259	0.246	0.254	0.014	0.006	0.009
2	0.245	0.239	0.243	0.259	0.243	0.252	0.014	0.004	0.009
2.5	0.246	0.239	0.245	0.256	0.243	0.256	0.01	0.004	0.011
3	0.243	0.24	0.246	0.249	0.243	0.253	0.006	0.003	0.007
3.5	0.241	0.242	0.249	0.245	0.243	0.253	0.004	0.001	0.004
4	0.24	0.241	0.248	0.242	0.241	0.251	0.002	0	0.003

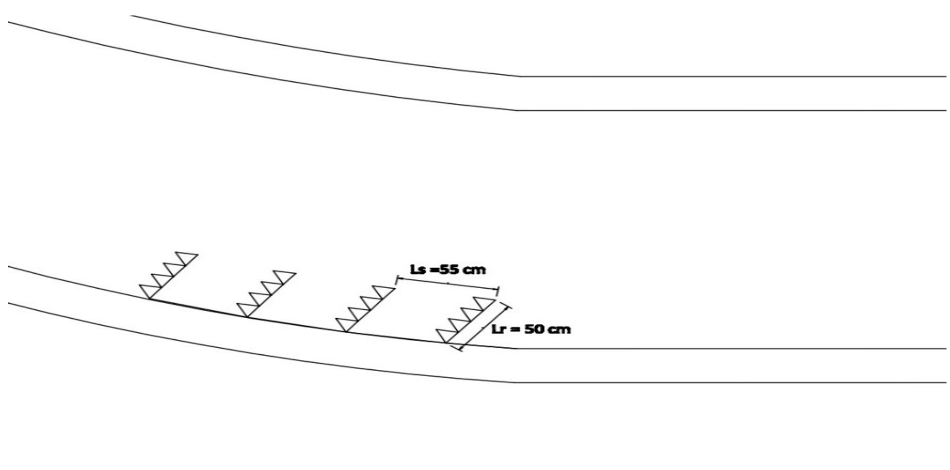


Figure 4.26: Layout of porcupine field for trial 6

Figure 4.27: Porcupine field for 6^{th} trial

Figure 4.28: Channel bed after experimental run for 6^{th}trial

7. For 7th trial of porcupine field model layout (figure 4.26), porcupines are placed 20^0 inclined towards upstream,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c= 0.45

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 5 kg of sediment(sediment 1) was injected.

Table 4.27: Measurement of sediment deposition at 7th trial

Ls 55; Lr 50; Lc 110 sediment 5kg									
Distance along the length of thechannel (m)	Point gauge reading without porcupine field (m)			Point gauge reading with porcupine field (m)			Height of ripple of sand (m)		
	A	B	C	A	B	C	A	B	C
0	0.243	0.251	0.241	0.253	0.259	0.245	0.01	0.008	0.004
0.5	0.242	0.25	0.24	0.25	0.257	0.245	0.008	0.007	0.005
1	0.244	0.252	0.24	0.254	0.258	0.246	0.01	0.006	0.006
1.5	0.243	0.253	0.235	0.25	0.259	0.241	0.007	0.006	0.006
2	0.243	0.252	0.241	0.251	0.255	0.248	0.008	0.003	0.007
2.5	0.24	0.253	0.242	0.246	0.255	0.246	0.006	0.002	0.004
3	0.241	0.253	0.243	0.245	0.255	0.246	0.004	0.002	0.003
3.5	0.241	0.258	0.241	0.243	0.259	0.242	0.002	0.001	0.001
4	0.24	0.257	0.241	0.241	0.257	0.242	0.001	0	0.001

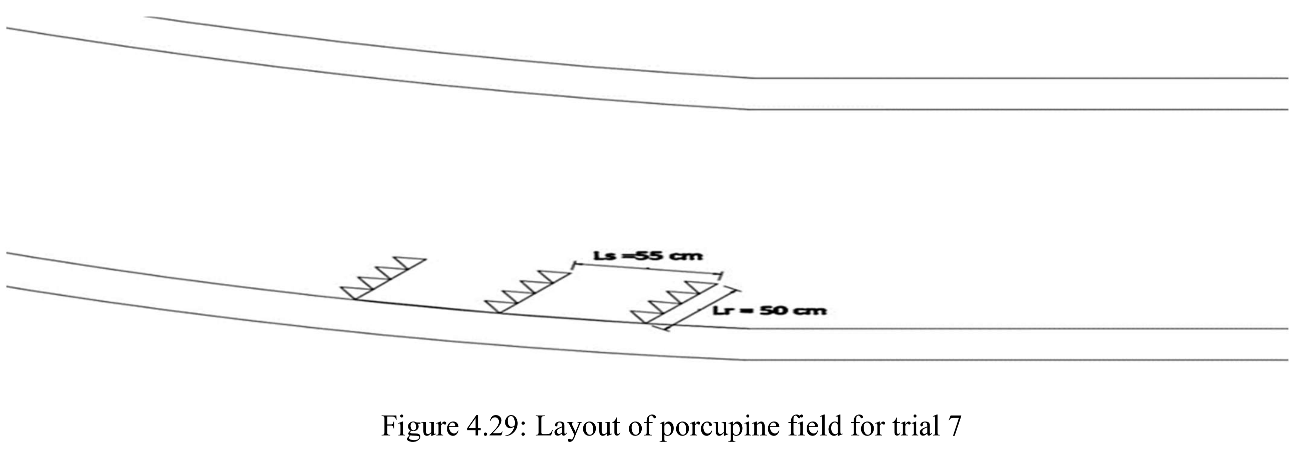


Figure 4.29: Layout of porcupine field for trial 7

Figure 4.30: Porcupine field for 7^{th} trial

Figure 4.31: Channel bed after experimental run for 7^{th}trial

8. For 8th trial of porcupine field model layout (figure 4.29), porcupines are placed 10^0 inclined towards upstream,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c= 0.45

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 8 kg of sediment(sediment 1) was injected

Table 4.28: Measurement of sediment deposition at 8th trial

Ls 55; Lr 50; Lc 110 sediment 8kg									
Distance along the length of the channel (m)	Point gauge reading without porcupine field (m)			Point gauge reading with porcupine field (m)			Height of ripple of sand (m)		
	A	B	C	A	B	C	A	B	C
0	0.245	0.254	0.24	0.26	0.265	0.248	0.015	0.011	0.008
0.5	0.244	0.253	0.239	0.257	0.263	0.246	0.013	0.01	0.007
1	0.245	0.254	0.24	0.257	0.263	0.245	0.012	0.009	0.005
1.5	0.245	0.255	0.24	0.256	0.262	0.247	0.011	0.007	0.007
2	0.243	0.252	0.241	0.253	0.258	0.25	0.01	0.006	0.009
2.5	0.241	0.251	0.238	0.249	0.255	0.248	0.008	0.004	0.01
3	0.24	0.249	0.237	0.245	0.251	0.242	0.005	0.002	0.005
3.5	0.239	0.248	0.239	0.242	0.25	0.243	0.003	0.002	0.004
4	0.238	0.247	0.24	0.239	0.248	0.243	0.001	0.001	0.003

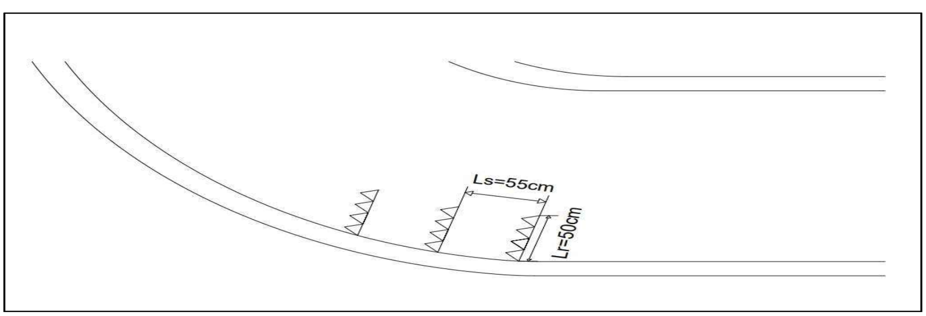


Figure 4.32: Layout of porcupine field for trial 8

Figure 4.33: Porcupine field for 8th trial

Figure 4.34: Channel bed after experimental run for 8thtrial

9. For 9th trial of porcupine field model layout (figure 4.32), porcupines are placed perpendicular to the bank, following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.45

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 5 kg of sediment(sediment 1) was injected.

Table 4.29: Measurement of sediment deposition at 9th trial

Ls 55; Lr 50; Lc 110 sediment 5kg									
Distance alongthe length of the channel (m)	Point gauge reading without porcupine field (m)			Point gauge reading with porcupine field (m)			Height of ripple of sand (m)		
	A	B	C	A	B	C	A	B	C
0	0.239	0.245	0.239	0.252	0.257	0.241	0.013	0.012	0.002
0.5	0.236	0.244	0.235	0.248	0.255	0.239	0.012	0.011	0.004
1	0.235	0.246	0.237	0.246	0.256	0.242	0.011	0.01	0.005
1.5	0.233	0.246	0.236	0.243	0.255	0.242	0.01	0.009	0.006
2	0.233	0.248	0.235	0.241	0.254	0.242	0.008	0.006	0.007
2.5	0.236	0.251	0.234	0.243	0.256	0.24	0.007	0.005	0.006
3	0.235	0.25	0.233	0.238	0.254	0.238	0.003	0.004	0.005
3.5	0.232	0.245	0.234	0.234	0.248	0.236	0.002	0.003	0.002
4	0.231	0.246	0.231	0.231	0.247	0.233	0	0.001	0.002

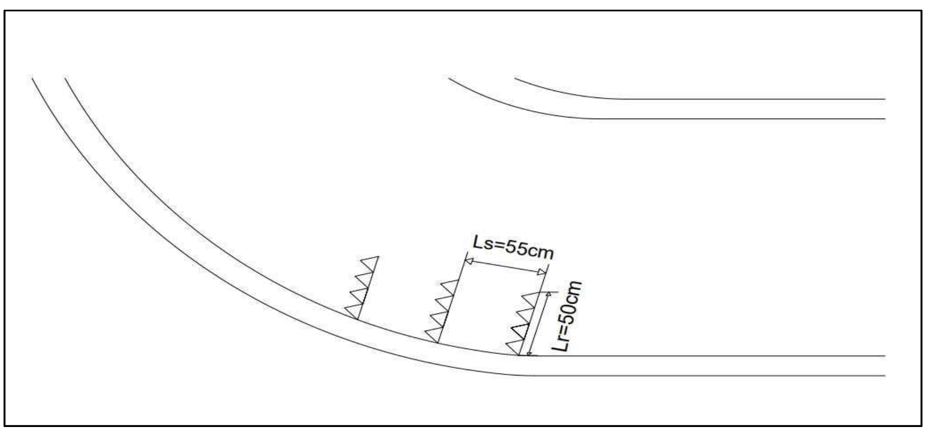


Fig 4.35: Layout of porcupine field for trial 9

Figure 4.36: Porcupine field for 9th trial

Figure 4.37: Channel bed after experimental run for 9thtrial

10. For 10th trial of porcupine field model layout (figure 4.32), porcupines are placed perpendicularto the bank, following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.3

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 8 kg of sediment(sediment 1) was injected.

Table 4.30: Measurement of sediment deposition at 10th trial

	Ls 55; Lr 50; Lc 165 sediment 5kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.243	0.247	0.243	0.259	0.262	0.244	0.016	0.015	0.001
0.5	0.242	0.245	0.244	0.257	0.26	0.246	0.015	0.015	0.002
1	0.244	0.246	0.245	0.256	0.26	0.249	0.012	0.014	0.004
1.5	0.243	0.241	0.242	0.254	0.253	0.248	0.011	0.012	0.006
2	0.243	0.239	0.243	0.252	0.249	0.251	0.009	0.01	0.008
2.5	0.24	0.238	0.245	0.246	0.247	0.251	0.006	0.009	0.006
3	0.241	0.24	0.246	0.245	0.245	0.249	0.004	0.005	0.003
3.5	0.241	0.239	0.246	0.242	0.242	0.248	0.001	0.003	0.002
4	0.24	0.237	0.245	0.241	0.239	0.246	0.001	0.002	0.001

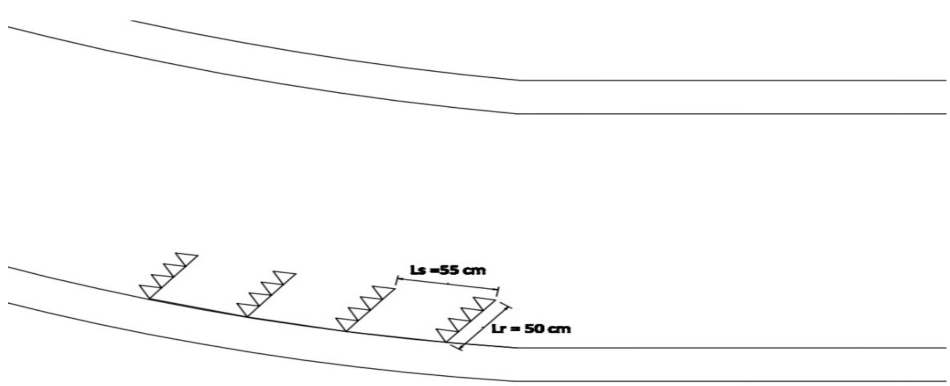


Fig 4.38: Layout of porcupine field for trial 10

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Figure 4.39: Porcupine field for 10th trial

Figure 4.40: Channel bed after experimental run for 10thtrial

11. For 11th trial of porcupine field model layout (figure 4.17), porcupines are placed perpendicular to the bank,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.7

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 5 kg of sediment(Sediment 1) was injected.

Table 4.31: Measurement of sediment deposition at 11th trial

	Ls 35; Lr 50; Lc 70 sediment 5kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.239	0.245	0.239	0.251	0.256	0.242	0.012	0.011	0.003
0.5	0.236	0.244	0.235	0.247	0.254	0.24	0.011	0.01	0.005
1	0.235	0.246	0.237	0.244	0.256	0.241	0.009	0.01	0.004
1.5	0.233	0.246	0.236	0.241	0.255	0.242	0.008	0.009	0.006
2	0.233	0.248	0.235	0.24	0.256	0.242	0.007	0.008	0.007
2.5	0.236	0.251	0.234	0.241	0.258	0.243	0.005	0.007	0.009
3	0.235	0.25	0.233	0.239	0.256	0.239	0.004	0.006	0.006
3.5	0.232	0.245	0.234	0.234	0.248	0.239	0.002	0.003	0.005
4	0.231	0.246	0.231	0.231	0.247	0.233	0	0.001	0.002

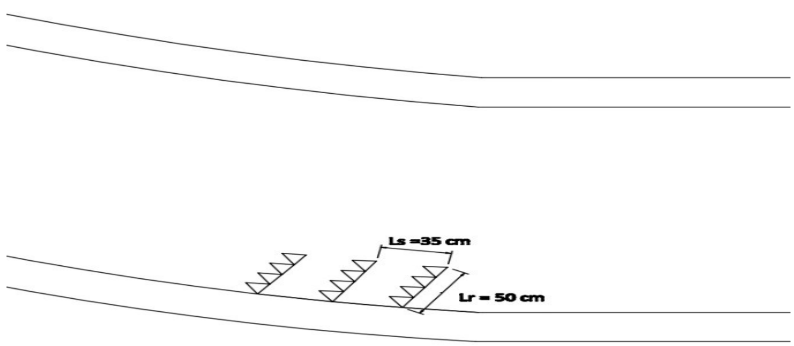

Fig 4.41: Layout of porcupine field for trial 11

Figure 4.42: Porcupine field for 11^{th} trial

Figure 4.43: Channel bed after experimental run for 11^{th}trial

12. For 12th trial of porcupine field model layout (figure 4.17), porcupines are placed perpendicular to the bank,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.47

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 8 kg of sediment(Sediment 1) was injected.

Table 4.32: Measurement of sediment deposition at 12th trial

	Ls 35; Lr 50; Lc 105 sediment 8kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.243	0.247	0.243	0.258	0.263	0.244	0.015	0.016	0.001
0.5	0.242	0.245	0.244	0.255	0.26	0.245	0.013	0.015	0.001
1	0.244	0.246	0.245	0.256	0.26	0.248	0.012	0.014	0.003
1.5	0.243	0.241	0.242	0.254	0.253	0.247	0.011	0.012	0.005
2	0.243	0.239	0.243	0.252	0.249	0.25	0.009	0.01	0.007
2.5	0.24	0.238	0.245	0.246	0.246	0.25	0.006	0.008	0.005
3	0.241	0.24	0.246	0.245	0.245	0.249	0.004	0.005	0.003
3.5	0.241	0.239	0.246	0.242	0.242	0.248	0.001	0.003	0.002
4	0.24	0.237	0.245	0.241	0.239	0.246	0.001	0.002	0.001

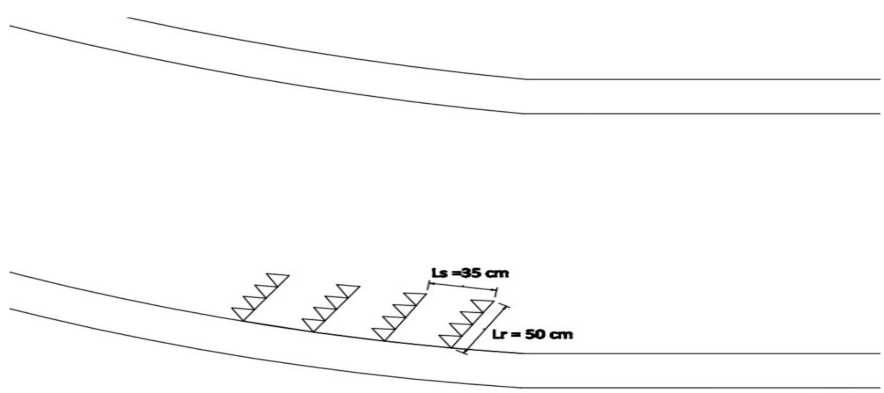

Fig 4.44: Layout of porcupine field for trial 12

Figure 4.45: Porcupine field for 12^{th} trial

Figure 4.46: Channel bed after experimental run for 12^{th} trial

13. For 13th trial of porcupine field model layout (figure 4.20), porcupines are placed perpendicular to the bank, following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.45

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 3 kg of sediment(Sediment 2) was injected.

Table 4.33: Measurement of sediment deposition at 13th trial

	Ls 55; Lr 50; Lc 110 sediment 3kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.224	0.252	0.228	0.237	0.264	0.236	0.013	0.012	0.003
0.5	0.226	0.25	0.23	0.238	0.261	0.236	0.012	0.011	0.004
1	0.229	0.251	0.229	0.24	0.261	0.236	0.011	0.01	0.006
1.5	0.23	0.25	0.226	0.239	0.258	0.235	0.009	0.008	0.008
2	0.229	0.252	0.225	0.237	0.258	0.234	0.008	0.006	0.009
2.5	0.228	0.251	0.228	0.233	0.255	0.239	0.005	0.004	0.007
3	0.23	0.248	0.231	0.232	0.249	0.238	0.002	0.001	0.005
3.5	0.23	0.248	0.231	0.23	0.249	0.235	0	0.001	0.002
4	0.226	0.25	0.226	0.225	0.25	0.229	-0.001	0	0.001

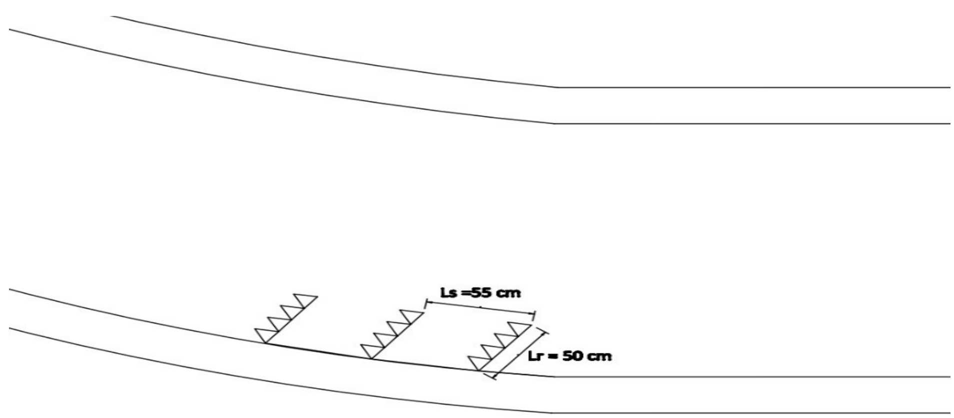

Fig 4.47: Layout of porcupine field for trial 13

Figure 4.48: Porcupine field for 13th trial

Figure 4.49: Channel bed after experimental run for 13th trial

14. For 14th trial of porcupine field model layout (figure 4.20), porcupines are placed perpendicular to the bank, following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.3

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 5 kg of sediment(Sediment 2) was injected.

Table 4.34: Measurement of sediment deposition at 14th trial

	Ls 55; Lr 50; Lc 165 sediment 5kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.236	0.248	0.24	0.249	0.259	0.248	0.013	0.011	0.008
0.5	0.238	0.249	0.238	0.25	0.259	0.248	0.012	0.01	0.01
1	0.237	0.25	0.237	0.248	0.258	0.248	0.011	0.008	0.011
1.5	0.237	0.252	0.236	0.247	0.258	0.249	0.01	0.006	0.013
2	0.239	0.25	0.236	0.245	0.254	0.251	0.006	0.004	0.015
2.5	0.241	0.251	0.238	0.244	0.255	0.252	0.003	0.004	0.014
3	0.24	0.251	0.24	0.242	0.254	0.252	0.002	0.003	0.012
3.5	0.238	0.248	0.241	0.238	0.249	0.252	0	0.001	0.011
4	0.238	0.249	0.237	0.237	0.249	0.247	-0.001	0	0.01

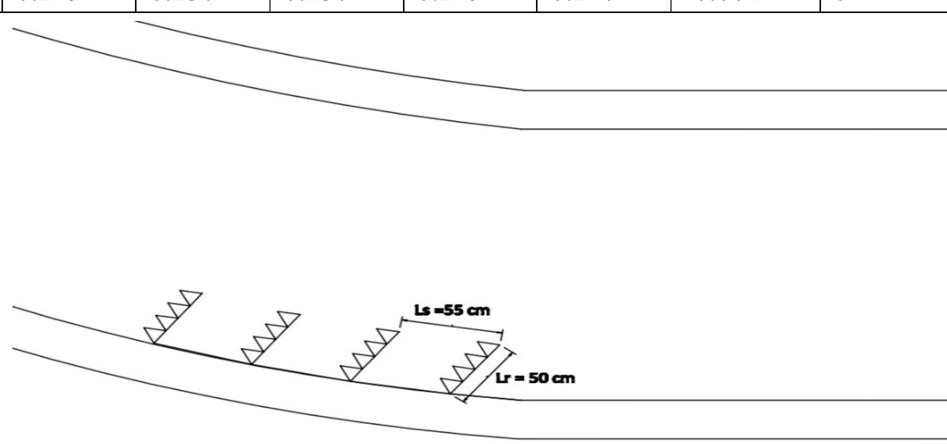

Fig 4.50: Layout of porcupine field for trial 14

Figure 4.51: Porcupine field for 14^{th} trial

Figure 4.52: Channel bed after experimental run for 14^{th} trial

15. For 15th trial of porcupine field model layout (figure 4.29), porcupines are placed perpendicular to the bank ,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c=0.45

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 3 kg of sediment(Sediment 3) was injected.

Table 4.35: Measurement of sediment deposition at 15th trial

	Ls 55; Lr 50; Lc 110 sediment 3kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.24	0.248	0.242	0.253	0.259	0.247	0.013	0.011	0.005
0.5	0.239	0.25	0.243	0.251	0.259	0.249	0.012	0.009	0.006
1	0.24	0.252	0.246	0.251	0.26	0.254	0.011	0.008	0.008
1.5	0.24	0.249	0.242	0.248	0.254	0.252	0.008	0.005	0.01
2	0.241	0.248	0.241	0.247	0.253	0.252	0.006	0.005	0.011
2.5	0.238	0.253	0.242	0.241	0.256	0.251	0.003	0.003	0.009
3	0.237	0.253	0.243	0.239	0.255	0.252	0.002	0.002	0.009
3.5	0.239	0.252	0.243	0.24	0.253	0.249	0.001	0.001	0.006
4	0.24	0.251	0.24	0.24	0.251	0.244	0	0	0.004

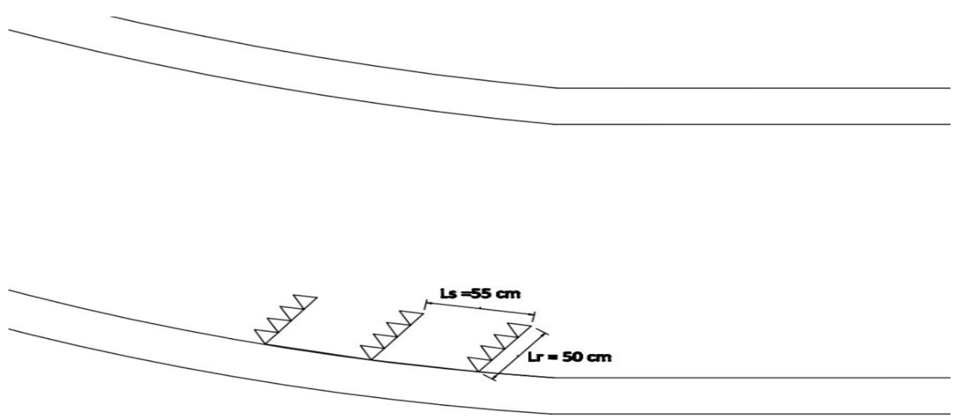

Fig 4.53: Layout of porcupine field for trial 15

Figure 4.54: Porcupine field for 15th trial

Figure 4.55: Channel bed after experimental run for 15th trial

16. For 16th trial of porcupine field model layout (figure 4.29), porcupines are placed perpendicular to the bank ,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 0.9

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.3

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 5 kg of sediment(Sediment 3) was injected.

Table 4.36: Measurement of sediment deposition at 16th trial

	Ls 55; Lr 50; Lc 165 sediment 5kg								
Distance along the length of the channel (m)	Point gauge reading without porcupine field (m)			Point gauge reading with porcupine field (m)			Height of ripple of sand (m)		
	A	B	C	A	B	C	A	B	C
0	0.242	0.251	0.239	0.258	0.266	0.249	0.016	0.015	0.01
0.5	0.241	0.25	0.24	0.256	0.264	0.249	0.015	0.014	0.009
1	0.242	0.251	0.238	0.255	0.259	0.245	0.013	0.008	0.007
1.5	0.242	0.252	0.239	0.253	0.258	0.249	0.011	0.006	0.01
2	0.24	0.249	0.241	0.25	0.255	0.252	0.01	0.006	0.011
2.5	0.238	0.25	0.24	0.245	0.255	0.25	0.007	0.005	0.01
3	0.237	0.252	0.239	0.242	0.255	0.247	0.005	0.003	0.008
3.5	0.236	0.248	0.238	0.239	0.25	0.243	0.003	0.002	0.005
4	0.235	0.249	0.237	0.237	0.25	0.241	0.002	0.001	0.004

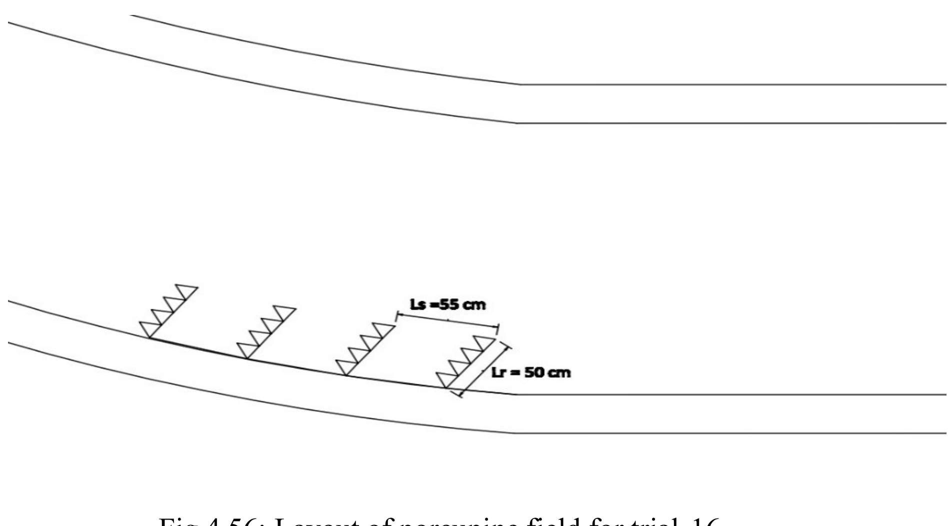

Fig 4.56: Layout of porcupine field for trial 16

Figure 4.57: Porcupine field for 16th trial

Figure 4.58: Channel bed after experimental run for 16th trial

17. For 17th trial of porcupine field model layout (figure 4.8), porcupines were placed perpendicular to the bank, following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.7

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 3 kg(Sediment 2) of sediment was injected.

Table 4.37: Measurement of sediment deposition at 17th trial

	Ls 35; Lr 50; Lc 70 sediment 3kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.233	0.246	0.238	0.247	0.257	0.242	0.014	0.011	0.004
0.5	0.236	0.247	0.235	0.249	0.257	0.238	0.013	0.01	0.003
1	0.235	0.246	0.237	0.247	0.253	0.243	0.012	0.007	0.006
1.5	0.232	0.246	0.236	0.243	0.252	0.243	0.011	0.006	0.007
2	0.233	0.25	0.233	0.241	0.256	0.241	0.008	0.006	0.008
2.5	0.234	0.251	0.234	0.24	0.256	0.243	0.006	0.005	0.009
3	0.235	0.25	0.233	0.24	0.252	0.238	0.005	0.002	0.005
3.5	0.232	0.258	0.234	0.233	0.259	0.236	0.001	0.001	0.002
4	0.231	0.259	0.236	0.231	0.259	0.237	0	0	0.001

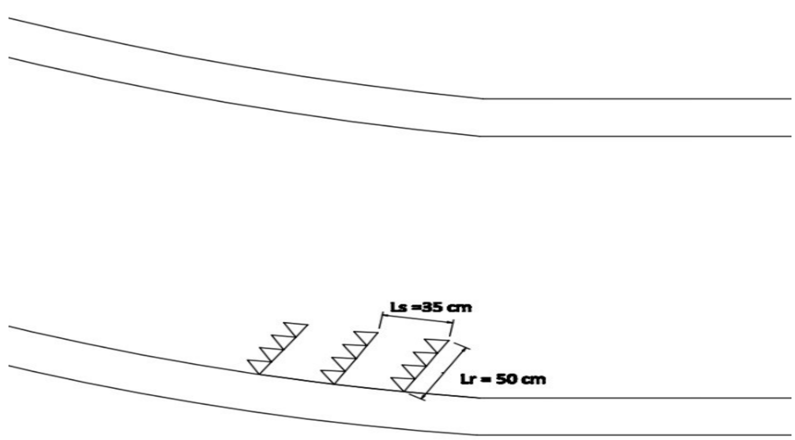

Fig 4.59: Layout of porcupine field for trial 17

Figure 4.60: Porcupine field for 17th trial

Figure 4.61: Channel bed after experimental run for 17th trial

18. For 18th trial of porcupine field model layout (figure 4.8), porcupines were placed perpendicular to the bank, following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4

Porcupine Compartment Density Index (PCDI) = L_r / L_c= 0.47

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 5 kg(Sediment 2) of sediment was injected.

Table 4.38: Measurement of sediment deposition at 18th trial

	Ls 35; Lr 50; Lc 105 sediment 5kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.241	0.246	0.245	0.256	0.257	0.253	0.015	0.011	0.008
0.5	0.243	0.247	0.244	0.259	0.257	0.25	0.016	0.01	0.006
1	0.244	0.246	0.245	0.259	0.254	0.252	0.015	0.008	0.007
1.5	0.245	0.24	0.245	0.259	0.246	0.254	0.014	0.006	0.009
2	0.245	0.239	0.243	0.259	0.243	0.252	0.014	0.004	0.009
2.5	0.246	0.239	0.245	0.256	0.243	0.256	0.01	0.004	0.011
3	0.243	0.24	0.246	0.249	0.243	0.253	0.006	0.003	0.007
3.5	0.241	0.242	0.249	0.245	0.243	0.253	0.004	0.001	0.004
4	0.24	0.241	0.248	0.242	0.241	0.251	0.002	0	0.003

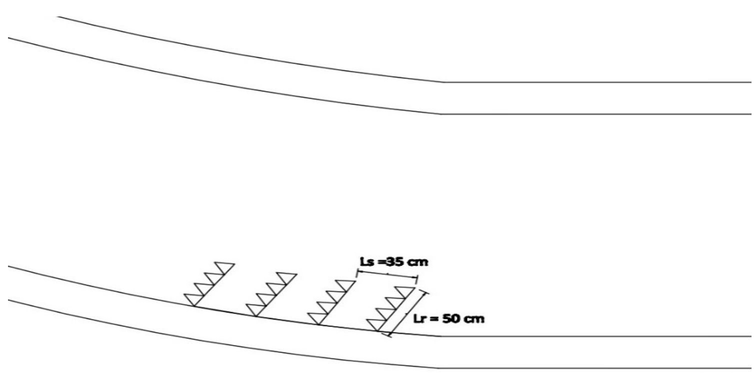

Fig 4.62: Layout of porcupine field for trial 18

Figure 4.63: Porcupine field for 18th trial

Figure 4.64: Channel bed after experimental run for 18th trial

19. For 19th trial of porcupine field model layout (figure 4.17), porcupines are placed perpendicular to the bank ,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.7

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.5

Here 3 kg of sediment(Sediment 3) was injected.

Table 4.39: Measurement of sediment deposition at 19th trial

	Ls 35; Lr 50; Lc 70 sediment 3kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.243	0.251	0.241	0.257	0.263	0.246	0.014	0.012	0.005
0.5	0.242	0.25	0.24	0.254	0.262	0.247	0.012	0.012	0.007
1	0.244	0.252	0.24	0.255	0.263	0.248	0.011	0.011	0.008
1.5	0.243	0.253	0.235	0.253	0.261	0.244	0.01	0.008	0.009
2	0.243	0.252	0.241	0.251	0.257	0.25	0.008	0.005	0.009
2.5	0.24	0.253	0.242	0.246	0.255	0.246	0.006	0.002	0.004
3	0.241	0.253	0.243	0.245	0.255	0.246	0.004	0.002	0.003
3.5	0.241	0.258	0.241	0.243	0.259	0.242	0.002	0.001	0.001
4	0.24	0.257	0.241	0.241	0.257	0.242	0.001	0	0.001

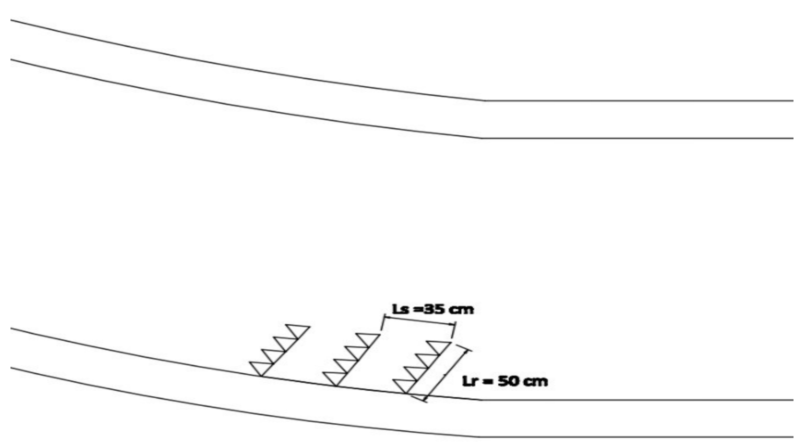

Fig 4.65: Layout of porcupine field for trial 19

Figure 4.66: Porcupine field for 19th trial

Figure 4.67: Channel bed after experimental run for 19th trial

20. For 19th trial of porcupine field model layout (figure 4.17), porcupines are placed perpendicular to the bank ,following values of the indices described above are adopted-

Porcupine Field Density Index (PFDI) = L_r / L_s = 1.4

Porcupine Compartment Density Index (PCDI) = L_r / L_c = 0.47

Porcupine Field Length Factor (PFLF) = L_s / L_c = 0.33

Here 5 kg of sediment(Sediment 3) was injected.

Table 4.40: Measurement of sediment deposition at 20th trial

	Ls 35; Lr 50; Lc 105 sediment 5kg								
Distance along the length of the channel (m)	**Point gauge reading without porcupine field (m)**			**Point gauge reading with porcupine field (m)**			**Height of ripple of sand (m)**		
	A	B	C	A	B	C	A	B	C
0	0.245	0.254	0.24	0.261	0.269	0.247	0.016	0.015	0.007
0.5	0.244	0.253	0.239	0.259	0.266	0.247	0.015	0.013	0.008
1	0.245	0.254	0.24	0.258	0.266	0.248	0.013	0.012	0.008
1.5	0.245	0.255	0.24	0.256	0.265	0.249	0.011	0.01	0.009
2	0.243	0.252	0.241	0.253	0.261	0.252	0.01	0.009	0.011
2.5	0.241	0.251	0.238	0.249	0.257	0.248	0.008	0.006	0.01
3	0.24	0.249	0.237	0.245	0.253	0.242	0.005	0.004	0.005
3.5	0.239	0.248	0.239	0.242	0.25	0.243	0.003	0.002	0.004
4	0.238	0.247	0.24	0.239	0.248	0.243	0.001	0.001	0.003

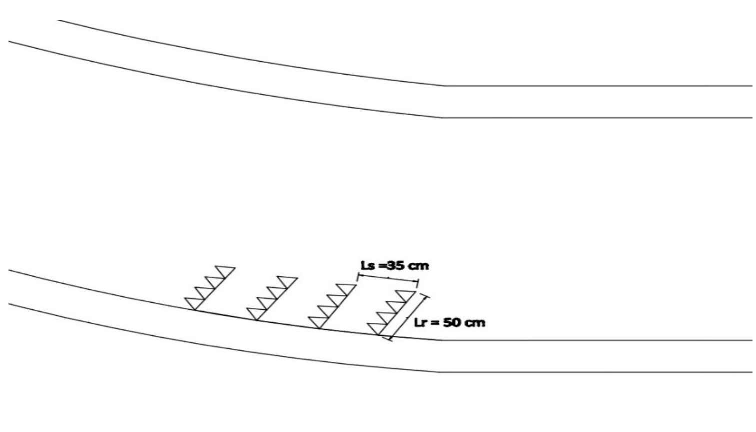

Fig 4.68: Layout of porcupine field for trial 20

Figure 4.69: Porcupine field for 20th trial

Figure 4.70: Channel bed after experimental run for 20th trial

4.15 Calculation of Sediment Deposition for Each Trial

For 1st trial of porcupine field model layout

Table 4.41: Estimation of sediment deposition in the porcupine field at section A for 1st trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V- 34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.012	0.0218	0.000005979	0.000003946	0.0080501
0.5	0.01	0.0182	0.000003460	0.000002284	0.0046586
1	0.01	0.0182	0.000003460	0.000002284	0.0046586
1.5	0.008	0.0145	0.000001772	0.000001169	0.0023852
2	0.004	0.0073	0.000000221	0.000000146	0.0002982
2.5	0.003	0.0055	0.000000093	0.000000062	0.0001258
3	0.001	0.0018	0.000000003	0.000000002	0.0000047
3.5	0	0.0000	0.000000000	0.000000000	0.0000000
4	-0.001	-0.0018	-0.000000003	-0.000000002	-0.0000047
					0.02018

Table 4.42: Estimation of sediment deposition in the porcupine field at section B for 1st trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.01	0.0182	0.000003460	0.000002284	0.0046586
0.5	0.008	0.0145	0.000001772	0.000001169	0.0023852
1	0.007	0.0127	0.000001187	0.000000783	0.0015979
1.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
2	0.004	0.0073	0.000000221	0.000000146	0.0002982
2.5	0.003	0.0055	0.000000093	0.000000062	0.0001258
3	0.001	0.0018	0.000000003	0.000000002	0.0000047
3.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.01008

Table 4.43: Estimation of sediment deposition in the porcupine field at section C for 1st trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2570 Kg/m³
0	0.004	0.0073	0.000000221	0.000000146	0.0002982
0.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
1	0.004	0.0073	0.000000221	0.000000146	0.0002982
1.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
2	0.008	0.0145	0.000001772	0.000001169	0.0023852
2.5	0.008	0.0145	0.000001772	0.000001169	0.0023852
3	0.005	0.0091	0.000000433	0.000000285	0.0005823
3.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.00703

Total weight of sand deposited in the first trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.02018 + 0.01008+ 0.00703) kg = 0.03729 kg

For 2nd Trial,

Table 4.44: Estimation of sediment deposition in the porcupine field at section A for 2nd trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V- 34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.014	0.0255	0.000009494	0.000006266	0.0127832
0.5	0.012	0.0218	0.000005979	0.000003946	0.0080501
1	0.011	0.0200	0.000004605	0.000003040	0.0062006
1.5	0.01	0.0182	0.000003460	0.000002284	0.0046586
2	0.006	0.0109	0.000000747	0.000000493	0.0010063
2.5	0.004	0.0073	0.000000221	0.000000146	0.0002982
3	0.002	0.0036	0.000000028	0.000000018	0.0000373
3.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
4.00000000	-0.001	-0.0018	-0.000000003	-0.000000002	-0.00000466
					0.03303

Table 4.45: Estimation of sediment deposition in the porcupine field at section B for 2nd trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.011	0.0200	0.000004605	0.000003040	0.0062006
0.5	0.01	0.0182	0.000003460	0.000002284	0.0046586
1	0.006	0.0109	0.000000747	0.000000493	0.0010063
1.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
2	0.004	0.0073	0.000000221	0.000000146	0.0002982
2.5	0.004	0.0073	0.000000221	0.000000146	0.0002982
3	0.003	0.0055	0.000000093	0.000000062	0.0001258
3.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.01360

Table 4.46: Estimation of sediment deposition in the porcupine field at section C for 2nd trial

Distance along the length of theflume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan ØØ= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂V' ∂ = 2040 Kg/m³
0	0.007	0.0127	0.000001187	0.000000783	0.00160
0.5	0.01	0.0182	0.000003460	0.000002284	0.00466
1	0.011	0.0200	0.000004605	0.000003040	0.00620
1.5	0.013	0.0236	0.000007602	0.000005017	0.01023
2	0.015	0.0273	0.000011678	0.000007707	0.01572
2.5	0.016	0.0291	0.000014172	0.000009354	0.01908
3	0.014	0.0255	0.000009494	0.000006266	0.01278
3.5	0.013	0.0236	0.000007602	0.000005017	0.01023
4	0.01	0.0182	0.000003460	0.000002284	0.00466
					0.08517

Total weight of sand deposited in the second trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.03303 + 0.01360 + 0.08517) kg = 0.13181

For 3rd Trial,

Table 4.47: Estimation of sediment deposition in the porcupine field at section A for 3rd trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.01	0.0182	0.000003460	0.000002284	0.0046586
0.5	0.009	0.0164	0.000002522	0.000001665	0.0033961
1	0.008	0.0145	0.000001772	0.000001169	0.0023852
1.5	0.007	0.0127	0.000001187	0.000000783	0.0015979
2	0.006	0.0109	0.000000747	0.000000493	0.0010063
2.5	0.003	0.0055	0.000000093	0.000000062	0.0001258
3	0.001	0.0018	0.000000003	0.000000002	0.0000047
3.5	0	0.0000	0.000000000	0.000000000	0.0000000
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.01317

Table 4.48: Estimation of sediment deposition in the porcupine field at section B for 3rd trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.007	0.0127	0.000001187	0.000000771	0.00198
0.5	0.007	0.0127	0.000001187	0.000000771	0.00198
1	0.006	0.0109	0.000000747	0.000000486	0.00125
1.5	0.005	0.0091	0.000000433	0.000000281	0.00072
2	0.005	0.0091	0.000000433	0.000000281	0.00072
2.5	0.003	0.0055	0.000000093	0.000000061	0.00016
3	0.002	0.0036	0.000000028	0.000000018	0.00005
3.5	0.001	0.0018	0.000000003	0.000000002	0.00001
4	0	0.0000	0.000000000	0.000000000	0.00000
					0.00687

Table 4.49: Estimation of sediment deposition in the porcupine field at section C for 3rd trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V- 34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.004	0.0073	0.000000221	0.000000144	0.00037
0.5	0.005	0.0091	0.000000433	0.000000281	0.00072
1	0.007	0.0127	0.000001187	0.000000771	0.00198
1.5	0.007	0.0127	0.000001187	0.000000771	0.00198
2	0.008	0.0145	0.000001772	0.000001152	0.00296
2.5	0.009	0.0164	0.000002522	0.000001640	0.00421
3	0.007	0.0127	0.000001187	0.000000771	0.00198
3.5	0.004	0.0073	0.000000221	0.000000144	0.00037
4	0.003	0.0055	0.000000093	0.000000061	0.00016
					0.01474

Total weight of sand deposited in the third trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.01317+ 0.00687+0.0474) kg = **0.03478kg**

For 4th Trial

Table 4.50: Estimation of sediment deposition in the porcupine field at section A for 4th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.016	0.0291	0.000014172	0.000009354	0.01908
0.5	0.014	0.0255	0.000009494	0.000006266	0.01278
1	0.013	0.0236	0.000007602	0.000005017	0.01023
1.5	0.011	0.0200	0.000004605	0.000003040	0.00620
2	0.01	0.0182	0.000003460	0.000002284	0.00466
2.5	0.007	0.0127	0.000001187	0.000000783	0.00160
3	0.005	0.0091	0.000000433	0.000000285	0.00058
3.5	0.003	0.0055	0.000000093	0.000000062	0.00013
4	0.002	0.0036	0.000000028	0.000000018	0.00004
					0.05530

Table 4.51: Estimation of sediment deposition in the porcupine field at section B for 4th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.01	0.0182	0.000003460	0.000002284	0.00466
0.5	0.011	0.0200	0.000004605	0.000003040	0.00620
1	0.008	0.0145	0.000001772	0.000001169	0.00239
1.5	0.006	0.0109	0.000000747	0.000000493	0.00101
2	0.006	0.0109	0.000000747	0.000000493	0.00101
2.5	0.005	0.0091	0.000000433	0.000000285	0.00058
3	0.003	0.0055	0.000000093	0.000000062	0.00013
3.5	0.002	0.0036	0.000000028	0.000000018	0.00004
4	0.001	0.0018	0.000000003	0.000000002	0.00000
					0.01601

Table 4.52 Estimation of sediment deposition in the porcupine field at section C for 4th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V- 34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.005	0.0091	0.000000433	0.000000285	0.00058
0.5	0.005	0.0091	0.000000433	0.000000285	0.00058
1	0.007	0.0127	0.000001187	0.000000783	0.00160
1.5	0.01	0.0182	0.000003460	0.000002284	0.00466
2	0.011	0.0200	0.000004605	0.000003040	0.00620
2.5	0.01	0.0182	0.000003460	0.000002284	0.00466
3	0.008	0.0145	0.000001772	0.000001169	0.00239
3.5	0.005	0.0091	0.000000433	0.000000285	0.00058
4	0.004	0.0073	0.000000221	0.000000146	0.00030
					0.02155

Total weight of sand deposited in the forth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.05530 + 0.01601 + 0.02155) kg =**0.09286kg**

For 5th trial,

Table 4.53: Estimation of sediment deposition in the porcupine field at section A for 5th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.011	0.0200	0.000004605	0.000003040	0.00620
0.5	0.009	0.0164	0.000002522	0.000001665	0.00340
1	0.01	0.0182	0.000003460	0.000002284	0.00466
1.5	0.007	0.0127	0.000001187	0.000000783	0.00160
2	0.006	0.0109	0.000000747	0.000000493	0.00101
2.5	0.004	0.0073	0.000000221	0.000000146	0.00030
3	0.004	0.0073	0.000000221	0.000000146	0.00030
3.5	0.001	0.0018	0.000000003	0.000000002	0.00000
4	0	0.0000	0.000000000	0.000000000	0.00000
					0.01746

Table 4.54: Estimation of sediment deposition in the porcupine field at section B for 5th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.008	0.0145	0.000001772	0.000001169	0.0023852
0.5	0.007	0.0127	0.000001187	0.000000783	0.0015979
1	0.007	0.0127	0.000001187	0.000000783	0.0015979
1.5	0.004	0.0073	0.000000221	0.000000146	0.0002982
2	0.003	0.0055	0.000000093	0.000000062	0.0001258
2.5	0.003	0.0055	0.000000093	0.000000062	0.0001258
3	0.001	0.0018	0.000000003	0.000000002	0.0000047
3.5	0	0.0000	0.000000000	0.000000000	0.0000000
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.00614

Table 4.55: Estimation of sediment deposition in the porcupine field at section C for 5th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.003	0.0055	0.000000093	0.000000062	0.0001258
0.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
1	0.001	0.0018	0.000000003	0.000000002	0.0000047
1.5	0.004	0.0073	0.000000221	0.000000146	0.0002982
2	0.007	0.0127	0.000001187	0.000000783	0.0015979
2.5	0.008	0.0145	0.000001772	0.000001169	0.0023852
3	0.005	0.0091	0.000000433	0.000000285	0.0005823
3.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.00504

Total weight of sand deposited in the fifth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.01746+0.00614 + 0.00504) kg =**0.02864kg**

For 6th trial,

Table 4.56: Estimation of sediment deposition in the porcupine field at section A for 6th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.015	0.0273	0.000011678	0.000007707	0.01572
0.5	0.016	0.0291	0.000014172	0.000009354	0.01908
1	0.015	0.0273	0.000011678	0.000007707	0.01572
1.5	0.014	0.0255	0.000009494	0.000006266	0.01278
2	0.014	0.0255	0.000009494	0.000006266	0.01278
2.5	0.01	0.0182	0.000003460	0.000002284	0.00466
3	0.006	0.0109	0.000000747	0.000000493	0.00101
3.5	0.004	0.0073	0.000000221	0.000000146	0.00030
4	0.002	0.0036	0.000000028	0.000000018	0.00004
					0.08209

Table 4.57: Estimation of sediment deposition in the porcupine field at section B for 6th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V- 34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.011	0.0200	0.000004605	0.000003040	0.0062006
0.5	0.01	0.0182	0.000003460	0.000002284	0.0046586
1	0.008	0.0145	0.000001772	0.000001169	0.0023852
1.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
2	0.004	0.0073	0.000000221	0.000000146	0.0002982
2.5	0.004	0.0073	0.000000221	0.000000146	0.0002982
3	0.003	0.0055	0.000000093	0.000000062	0.0001258
3.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.01498

Table 4.58: Estimation of sediment deposition in the porcupine field at section C for 6th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.008	0.0145	0.000001772	0.000001169	0.00239
0.5	0.006	0.0109	0.000000747	0.000000493	0.00101
1	0.007	0.0127	0.000001187	0.000000783	0.00160
1.5	0.009	0.0164	0.000002522	0.000001665	0.00340
2	0.009	0.0164	0.000002522	0.000001665	0.00340
2.5	0.011	0.0200	0.000004605	0.000003040	0.00620
3	0.007	0.0127	0.000001187	0.000000783	0.00160
3.5	0.004	0.0073	0.000000221	0.000000146	0.00030
4	0.003	0.0055	0.000000093	0.000000062	0.00013
					0.02000

Total weight of sand deposited in the sixth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.08209+ 0.01498 + 0.02000) kg =**0.11708kg**

For 7^{TH} trial,

Table 4.59: Estimation of sediment deposition in the porcupine field at section A for 7th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V- 34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.01	0.0182	0.000003460	0.000002284	0.0046586
0.5	0.008	0.0145	0.000001772	0.000001169	0.0023852
1	0.01	0.0182	0.000003460	0.000002284	0.0046586
1.5	0.007	0.0127	0.000001187	0.000000783	0.0015979
2	0.008	0.0145	0.000001772	0.000001169	0.0023852
2.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
3	0.004	0.0073	0.000000221	0.000000146	0.0002982
3.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.01703

Table 4.60: Estimation of sediment deposition in the porcupine field at section B for 7th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.008	0.0145	0.000001772	0.000001169	0.0023852
0.5	0.007	0.0127	0.000001187	0.000000783	0.0015979
1	0.006	0.0109	0.000000747	0.000000493	0.0010063
1.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
2	0.003	0.0055	0.000000093	0.000000062	0.0001258
2.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
3	0.002	0.0036	0.000000028	0.000000018	0.0000373
3.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.00620

Table 4.61: Estimation of sediment deposition in the porcupine field at section C for 7th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2570 Kg/m³
0	0.004	0.0073	0.000000221	0.000000146	0.0002982
0.5	0.005	0.0091	0.000000433	0.000000285	0.0005823
1	0.006	0.0109	0.000000747	0.000000493	0.0010063
1.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
2	0.007	0.0127	0.000001187	0.000000783	0.0015979
2.5	0.004	0.0073	0.000000221	0.000000146	0.0002982
3	0.003	0.0055	0.000000093	0.000000062	0.0001258
3.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.00492

Total weight of sand deposited in the seventh trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.01703+ 0.00620 + 0.00492) kg =**0.02816**kg

For 8th Trial,

Table 4.62: Estimation of sediment deposition in the porcupine field at section A for 8th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.015	0.0273	0.000011678	0.000007707	0.0157228
0.5	0.013	0.0236	0.000007602	0.000005017	0.0102350
1	0.012	0.0218	0.000005979	0.000003946	0.0080501
1.5	0.011	0.0200	0.000004605	0.000003040	0.0062006
2	0.01	0.0182	0.000003460	0.000002284	0.0046586
2.5	0.008	0.0145	0.000001772	0.000001169	0.0023852
3	0.005	0.0091	0.000000433	0.000000285	0.0005823
3.5	0.003	0.0055	0.000000093	0.000000062	0.0001258
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.04797

Table 4.63: Estimation of sediment deposition in the porcupine field at section B for 8th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.011	0.0200	0.000004605	0.000003040	0.0062006
0.5	0.01	0.0182	0.000003460	0.000002284	0.0046586
1	0.009	0.0164	0.000002522	0.000001665	0.0033961
1.5	0.007	0.0127	0.000001187	0.000000783	0.0015979
2	0.006	0.0109	0.000000747	0.000000493	0.0010063
2.5	0.004	0.0073	0.000000221	0.000000146	0.0002982
3	0.002	0.0036	0.000000028	0.000000018	0.0000373
3.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.01724

Table 4.64: Estimation of sediment deposition in the porcupine field at section C for 8th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V- 35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2570 Kg/m³
0	0.008	0.0145	0.000001772	0.000001169	0.0023852
0.5	0.007	0.0127	0.000001187	0.000000783	0.0015979
1	0.005	0.0091	0.000000433	0.000000285	0.0005823
1.5	0.007	0.0127	0.000001187	0.000000783	0.0015979
2	0.009	0.0164	0.000002522	0.000001665	0.0033961
2.5	0.01	0.0182	0.000003460	0.000002284	0.0046586
3	0.005	0.0091	0.000000433	0.000000285	0.0005823
3.5	0.004	0.0073	0.000000221	0.000000146	0.0002982
4	0.003	0.0055	0.000000093	0.000000062	0.0001258
					0.01522

Total weight of sand deposited in the eighth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.04797 + 0.01724 + 0.01522) kg = **0.08043** kg

For 9th Trial,

Table 4.65: Estimation of sediment deposition in the porcupine field at section A for 9th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V- 34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.013	0.0236	0.000007602	0.000005017	0.0102350
0.5	0.012	0.0218	0.000005979	0.000003946	0.0080501
1	0.011	0.0200	0.000004605	0.000003040	0.0062006
1.5	0.01	0.0182	0.000003460	0.000002284	0.0046586
2	0.008	0.0145	0.000001772	0.000001169	0.0023852
2.5	0.007	0.0127	0.000001187	0.000000783	0.0015979
3	0.003	0.0055	0.000000093	0.000000062	0.0001258
3.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.03329

Table 4.66: Estimation of sediment deposition in the porcupine field at section B for 9th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.012	0.0218	0.000005979	0.000003946	0.0080501
0.5	0.011	0.0200	0.000004605	0.000003040	0.0062006
1	0.01	0.0182	0.000003460	0.000002284	0.0046586
1.5	0.009	0.0164	0.000002522	0.000001665	0.0033961
2	0.006	0.0109	0.000000747	0.000000493	0.0010063
2.5	0.005	0.0091	0.000000433	0.000000285	0.0005823
3	0.004	0.0073	0.000000221	0.000000146	0.0002982
3.5	0.003	0.0055	0.000000093	0.000000062	0.0001258
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.02432

Table 4.67: Estimation of sediment deposition in the porcupine field at section C for 9th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V- 35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2570 Kg/m³
0	0.002	0.0036	0.000000028	0.000000018	0.0000373
0.5	0.004	0.0073	0.000000221	0.000000146	0.0002982
1	0.005	0.0091	0.000000433	0.000000285	0.0005823
1.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
2	0.007	0.0127	0.000001187	0.000000783	0.0015979
2.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
3	0.005	0.0091	0.000000433	0.000000285	0.0005823
3.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
4	0.002	0.0036	0.000000028	0.000000018	0.0000373
					0.00519

Total weight of sand deposited in the ninth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.03329 + 0.02432+ 0.00519) kg = 0.06280 kg

For 10th Trial,

Table 4.68: Estimation of sediment deposition in the porcupine field at section A for 10th trial

Distance along the length of the flume (m)	**Ripple Height 'h' (m)**	**Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°**	**Total Volume of sand V=(∏r² h)/3**	**Volume of sand taking porosity into consideration (m³) V' = V-34% V**	**Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³**
0	0.016	0.0291	0.000014172	0.000009354	0.0190817
0.5	0.015	0.0273	0.000011678	0.000007707	0.0157228
1	0.012	0.0218	0.000005979	0.000003946	0.0080501
1.5	0.011	0.0200	0.000004605	0.000003040	0.0062006
2	0.009	0.0164	0.000002522	0.000001665	0.0033961
2.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
3	0.004	0.0073	0.000000221	0.000000146	0.0002982
3.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.05377

Table 4.69: Estimation of sediment deposition in the porcupine field at section B for 10th trial

Distance along the length of the flume (m)	**Ripple Height 'h' (m)**	**Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°**	**Total Volume of sand V=(∏r² h)/3**	**Volume of sand taking porosity into consideration (m³) V' = V-34% V**	**Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³**
0	0.015	0.0273	0.000011678	0.000007707	0.0157228
0.5	0.015	0.0273	0.000011678	0.000007707	0.0157228
1	0.014	0.0255	0.000009494	0.000006266	0.0127832
1.5	0.012	0.0218	0.000005979	0.000003946	0.0080501
2	0.01	0.0182	0.000003460	0.000002284	0.0046586
2.5	0.009	0.0164	0.000002522	0.000001665	0.0033961
3	0.005	0.0091	0.000000433	0.000000285	0.0005823
3.5	0.003	0.0055	0.000000093	0.000000062	0.0001258
4	0.002	0.0036	0.000000028	0.000000018	0.0000373
					0.06108

Table 4.70: Estimation of sediment deposition in the porcupine field at section C for 10th trial

Distance along the length of the flume (m)	**Ripple Height 'h' (m)**	**Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°**	**Total Volume of sand V=(∏r² h)/3**	**Volume of sand taking porosity into consideration (m³) V' = V-34% V**	**Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³**
0	0.001	0.0018	0.000000003	0.000000002	0.0000047
0.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
1	0.004	0.0073	0.000000221	0.000000146	0.0002982
1.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
2	0.008	0.0145	0.000001772	0.000001169	0.0023852
2.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
3	0.003	0.0055	0.000000093	0.000000062	0.0001258
3.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.00491

Total weight of sand deposited in the tenth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.05377 + 0.06108+ 0.00491) kg = 0.11975 kg

For 11th Trial,

Table 4.71: Estimation of sediment deposition in the porcupine field at section A for 11th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.012	0.0218	0.000005979	0.000003946	0.0080501
0.5	0.011	0.0200	0.000004605	0.000003040	0.0062006
1	0.009	0.0164	0.000002522	0.000001665	0.0033961
1.5	0.008	0.0145	0.000001772	0.000001169	0.0023852
2	0.007	0.0127	0.000001187	0.000000783	0.0015979
2.5	0.005	0.0091	0.000000433	0.000000285	0.0005823
3	0.004	0.0073	0.000000221	0.000000146	0.0002982
3.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.02255

Table 4.72: Estimation of sediment deposition in the porcupine field at section B for 11th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.011	0.0200	0.000004605	0.000003040	0.0062006
0.5	0.01	0.0182	0.000003460	0.000002284	0.0046586
1	0.01	0.0182	0.000003460	0.000002284	0.0046586
1.5	0.009	0.0164	0.000002522	0.000001665	0.0033961
2	0.008	0.0145	0.000001772	0.000001169	0.0023852
2.5	0.007	0.0127	0.000001187	0.000000783	0.0015979
3	0.006	0.0109	0.000000747	0.000000493	0.0010063
3.5	0.003	0.0055	0.000000093	0.000000062	0.0001258
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.02403

Table 4.73: Estimation of sediment deposition in the porcupine field at section C for 11th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.003	0.0055	0.000000093	0.000000062	0.0001258
0.5	0.005	0.0091	0.000000433	0.000000285	0.0005823
1	0.004	0.0073	0.000000221	0.000000146	0.0002982
1.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
2	0.007	0.0127	0.000001187	0.000000783	0.0015979
2.5	0.009	0.0164	0.000002522	0.000001665	0.0033961
3	0.006	0.0109	0.000000747	0.000000493	0.0010063
3.5	0.005	0.0091	0.000000433	0.000000285	0.0005823
4	0.002	0.0036	0.000000028	0.000000018	0.0000373
					0.00863

Total weight of sand deposited in the eleventh trial = Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.02255+ 0.02403+ 0.00863) kg = **0.05521**kg

For 12^{th} Trial,

Table 4.74: Estimation of sediment deposition in the porcupine field at section A for 12th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.015	0.0273	0.000011678	0.000007707	0.0157228
0.5	0.013	0.0236	0.000007602	0.000005017	0.0102350
1	0.012	0.0218	0.000005979	0.000003946	0.0080501
1.5	0.011	0.0200	0.000004605	0.000003040	0.0062006
2	0.009	0.0164	0.000002522	0.000001665	0.0033961
2.5	0.006	0.0109	0.000000747	0.000000493	0.0010063
3	0.004	0.0073	0.000000221	0.000000146	0.0002982
3.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.04492

Table 4.75: Estimation of sediment deposition in the porcupine field at section B for 12th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r^2 h)/3	Volume of sand taking porosity into consideration (m^3) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m^3
0	0.016	0.0291	0.000014172	0.000009354	0.0190817
0.5	0.015	0.0273	0.000011678	0.000007707	0.0157228
1	0.014	0.0255	0.000009494	0.000006266	0.0127832
1.5	0.012	0.0218	0.000005979	0.000003946	0.0080501
2	0.01	0.0182	0.000003460	0.000002284	0.0046586
2.5	0.008	0.0145	0.000001772	0.000001169	0.0023852
3	0.005	0.0091	0.000000433	0.000000285	0.0005823
3.5	0.003	0.0055	0.000000093	0.000000062	0.0001258
4	0.002	0.0036	0.000000028	0.000000018	0.0000373
					0.06343

Table 4.76: Estimation of sediment deposition in the porcupine field at section C for 12th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 29°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2040 Kg/m³
0	0.001	0.0018	0.000000003	0.000000002	0.0000047
0.5	0.001	0.0018	0.000000003	0.000000002	0.0000047
1	0.003	0.0055	0.000000093	0.000000062	0.0001258
1.5	0.005	0.0091	0.000000433	0.000000285	0.0005823
2	0.007	0.0127	0.000001187	0.000000783	0.0015979
2.5	0.005	0.0091	0.000000433	0.000000285	0.0005823
3	0.003	0.0055	0.000000093	0.000000062	0.0001258
3.5	0.002	0.0036	0.000000028	0.000000018	0.0000373
4	0.001	0.0018	0.000000003	0.000000002	0.0000047
					0.00307

Total weight of sand deposited in the twelveth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.04492 + 0.06343+ 0.00307) kg = 0.11141 kg

For 13th Trial,

Table 4.78: Estimation of sediment deposition in the porcupine field at section A for 13th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø, Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m^3) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m^3
0	0.013	0.0245	0.000008186	0.000005403	0.0110544
0.5	0.012	0.0226	0.000006439	0.000004250	0.0086946
1	0.011	0.0208	0.000004959	0.000003273	0.0066971
1.5	0.009	0.0170	0.000002716	0.000001793	0.0036680
2	0.008	0.0151	0.000001908	0.000001259	0.0025762
2.5	0.005	0.0094	0.000000466	0.000000307	0.0006290
3	0.002	0.0038	0.000000030	0.000000020	0.0000403
3.5	0	0.0000	0.000000000	0.000000000	0.0000000
4	-0.001	-0.0019	-0.000000004	-0.000000002	-0.0000050
					0.03335

Table 4.79: Estimation of sediment deposition in the porcupine field at section B for 13th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.012	0.0226	0.000006439	0.000004250	0.0086946
0.5	0.011	0.0208	0.000004959	0.000003273	0.0066971
1	0.01	0.0189	0.000003726	0.000002459	0.0050316
1.5	0.008	0.0151	0.000001908	0.000001259	0.0025762
2	0.006	0.0113	0.000000805	0.000000531	0.0010868
2.5	0.004	0.0075	0.000000238	0.000000157	0.0003220
3	0.001	0.0019	0.000000004	0.000000002	0.0000050
3.5	0.001	0.0019	0.000000004	0.000000002	0.0000050
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.02442

Table 4.80: Estimation of sediment deposition in the porcupine field at section C for 13th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.003	0.0057	0.000000101	0.000000066	0.0001359
0.5	0.004	0.0075	0.000000238	0.000000157	0.0003220
1	0.006	0.0113	0.000000805	0.000000531	0.0010868
1.5	0.008	0.0151	0.000001908	0.000001259	0.0025762
2	0.009	0.0170	0.000002716	0.000001793	0.0036680
2.5	0.007	0.0132	0.000001278	0.000000844	0.0017258
3	0.005	0.0094	0.000000466	0.000000307	0.0006290
3.5	0.002	0.0038	0.000000030	0.000000020	0.0000403
4	0.001	0.0019	0.000000004	0.000000002	0.0000050
					0.01019

Total weight of sand deposited in the thirteenth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.03335 + 0.02442+ 0.01019) kg = 0.06796 kg

For 14th Trial,

Table 4.81: Estimation of sediment deposition in the porcupine field at section A for 14th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.013	0.0245	0.000008186	0.000005403	0.0110544
0.5	0.012	0.0226	0.000006439	0.000004250	0.0086946
1	0.011	0.0208	0.000004959	0.000003273	0.0066971
1.5	0.01	0.0189	0.000003726	0.000002459	0.0050316
2	0.006	0.0113	0.000000805	0.000000531	0.0010868
2.5	0.003	0.0057	0.000000101	0.000000066	0.0001359
3	0.002	0.0038	0.000000030	0.000000020	0.0000403
3.5	0	0.0000	0.000000000	0.000000000	0.0000000
4.00000000	-0.001	-0.0019	-0.000000004	-0.000000002	-0.00000503
					0.03274

Table 4.82: Estimation of sediment deposition in the porcupine field at section B for 14th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.011	0.0208	0.000004959	0.000003273	0.0066971
0.5	0.01	0.0189	0.000003726	0.000002459	0.0050316
1	0.008	0.0151	0.000001908	0.000001259	0.0025762
1.5	0.006	0.0113	0.000000805	0.000000531	0.0010868
2	0.004	0.0075	0.000000238	0.000000157	0.0003220
2.5	0.004	0.0075	0.000000238	0.000000157	0.0003220
3	0.003	0.0057	0.000000101	0.000000066	0.0001359
3.5	0.001	0.0019	0.000000004	0.000000002	0.0000050
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.01618

Table 4.83: Estimation of sediment deposition in the porcupine field at section C for 14th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.008	0.0151	0.000001908	0.000001259	0.00258
0.5	0.01	0.0189	0.000003726	0.000002459	0.00503
1	0.011	0.0208	0.000004959	0.000003273	0.00670
1.5	0.013	0.0245	0.000008186	0.000005403	0.01105
2	0.015	0.0283	0.000012576	0.000008300	0.01698
2.5	0.014	0.0264	0.000010224	0.000006748	0.01381
3	0.012	0.0226	0.000006439	0.000004250	0.00869
3.5	0.011	0.0208	0.000004959	0.000003273	0.00670
4	0.01	0.0189	0.000003726	0.000002459	0.00503
					0.07657

Total weight of sand deposited in the fourteenth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.03274+ 0.01618+ 0.07657) kg = 0.12548 kg

For 15th Trial,

Table 4.84: Estimation of sediment deposition in the porcupine field at section A for 15th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.013	0.0255	0.000008841	0.000005747	0.0117920
0.5	0.012	0.0235	0.000006954	0.000004520	0.0092748
1	0.011	0.0216	0.000005356	0.000003481	0.0071439
1.5	0.008	0.0157	0.000002060	0.000001339	0.0027481
2	0.006	0.0118	0.000000869	0.000000565	0.0011593
2.5	0.003	0.0059	0.000000109	0.000000071	0.0001449
3	0.002	0.0039	0.000000032	0.000000021	0.0000429
3.5	0.001	0.0020	0.000000004	0.000000003	0.0000054
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.03231

Table 4.85: Estimation of sediment deposition in the porcupine field at section B for 15th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.011	0.0200	0.000004605	0.000002993	0.00769
0.5	0.009	0.0164	0.000002522	0.000001640	0.00421
1	0.008	0.0145	0.000001772	0.000001152	0.00296
1.5	0.005	0.0091	0.000000433	0.000000281	0.00072
2	0.005	0.0091	0.000000433	0.000000281	0.00072
2.5	0.003	0.0055	0.000000093	0.000000061	0.00016
3	0.002	0.0036	0.000000028	0.000000018	0.00005
3.5	0.001	0.0018	0.000000003	0.000000002	0.00001
4	0	0.0000	0.000000000	0.000000000	0.00000
					0.01652

Table 4.86: Estimation of sediment deposition in the porcupine field at section C for 15th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.005	0.0091	0.000000433	0.000000281	0.00072
0.5	0.006	0.0109	0.000000747	0.000000486	0.00125
1	0.008	0.0145	0.000001772	0.000001152	0.00296
1.5	0.01	0.0182	0.000003460	0.000002249	0.00578
2	0.011	0.0200	0.000004605	0.000002993	0.00769
2.5	0.009	0.0164	0.000002522	0.000001640	0.00421
3	0.009	0.0164	0.000002522	0.000001640	0.00421
3.5	0.006	0.0109	0.000000747	0.000000486	0.00125
4	0.004	0.0073	0.000000221	0.000000144	0.00037
					0.02845

Total weight of sand deposited in the fifteenth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.03231 + 0.01652+ 0.02845) kg = 0.07728 kg

For 16th Trial,

Table 4.87: Estimation of sediment deposition in the porcupine field at section A for 16th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.016	0.0314	0.000016483	0.000010714	0.02198
0.5	0.015	0.0294	0.000013581	0.000008828	0.01811
1	0.013	0.0255	0.000008841	0.000005747	0.01179
1.5	0.011	0.0216	0.000005356	0.000003481	0.00714
2	0.01	0.0196	0.000004024	0.000002616	0.00537
2.5	0.007	0.0137	0.000001380	0.000000897	0.00184
3	0.005	0.0098	0.000000503	0.000000327	0.00067
3.5	0.003	0.0059	0.000000109	0.000000071	0.00014
4	0.002	0.0039	0.000000032	0.000000021	0.00004
					0.06710

Table 4.88: Estimation of sediment deposition in the porcupine field at section B for 16th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.015	0.0294	0.000013581	0.000008828	0.01811
0.5	0.014	0.0275	0.000011042	0.000007177	0.01473
1	0.008	0.0157	0.000002060	0.000001339	0.00275
1.5	0.006	0.0118	0.000000869	0.000000565	0.00116
2	0.006	0.0118	0.000000869	0.000000565	0.00116
2.5	0.005	0.0098	0.000000503	0.000000327	0.00067
3	0.003	0.0059	0.000000109	0.000000071	0.00014
3.5	0.002	0.0039	0.000000032	0.000000021	0.00004
4	0.001	0.0020	0.000000004	0.000000003	0.00001
					0.03877

Table 4.89: Estimation of sediment deposition in the porcupine field at section C for 16th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.01	0.0196	0.000004024	0.000002616	0.00537
0.5	0.009	0.0176	0.000002934	0.000001907	0.00391
1	0.007	0.0137	0.000001380	0.000000897	0.00184
1.5	0.01	0.0196	0.000004024	0.000002616	0.00537
2	0.011	0.0216	0.000005356	0.000003481	0.00714
2.5	0.01	0.0196	0.000004024	0.000002616	0.00537
3	0.008	0.0157	0.000002060	0.000001339	0.00275
3.5	0.005	0.0098	0.000000503	0.000000327	0.00067
4	0.004	0.0078	0.000000258	0.000000167	0.00034
					0.03276

Total weight of sand deposited in the sixteenth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.06710+ 0.03877+ 0.03276) kg = 0.13864 kg

For 17th Trial,

Table 4.90: Estimation of sediment deposition in the porcupine field at section A for 17th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.014	0.0264	0.000010224	0.000006748	0.01381
0.5	0.013	0.0245	0.000008186	0.000005403	0.01105
1	0.012	0.0226	0.000006439	0.000004250	0.00869
1.5	0.011	0.0208	0.000004959	0.000003273	0.00670
2	0.008	0.0151	0.000001908	0.000001259	0.00258
2.5	0.006	0.0113	0.000000805	0.000000531	0.00109
3	0.005	0.0094	0.000000466	0.000000307	0.00063
3.5	0.001	0.0019	0.000000004	0.000000002	0.00001
4	0	0.0000	0.000000000	0.000000000	0.00000
					0.04455

Table 4.91: Estimation of sediment deposition in the porcupine field at section B for 17th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m^3) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m^3
0	0.011	0.0208	0.000004959	0.000003273	0.0066971
0.5	0.01	0.0189	0.000003726	0.000002459	0.0050316
1	0.007	0.0132	0.000001278	0.000000844	0.0017258
1.5	0.006	0.0113	0.000000805	0.000000531	0.0010868
2	0.006	0.0113	0.000000805	0.000000531	0.0010868
2.5	0.005	0.0094	0.000000466	0.000000307	0.0006290
3	0.002	0.0038	0.000000030	0.000000020	0.0000403
3.5	0.001	0.0019	0.000000004	0.000000002	0.0000050
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.01630

Table 4.92: Estimation of sediment deposition in the porcupine field at section C for 17th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.004	0.0075	0.000000238	0.000000157	0.0003220
0.5	0.003	0.0057	0.000000101	0.000000066	0.0001359
1	0.006	0.0113	0.000000805	0.000000531	0.0010868
1.5	0.007	0.0132	0.000001278	0.000000844	0.0017258
2	0.008	0.0151	0.000001908	0.000001259	0.0025762
2.5	0.009	0.0170	0.000002716	0.000001793	0.0036680
3	0.005	0.0094	0.000000466	0.000000307	0.0006290
3.5	0.002	0.0038	0.000000030	0.000000020	0.0000403
4	0.001	0.0019	0.000000004	0.000000002	0.0000050
					0.01019

Total weight of sand deposited in the seventeenth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.04445+ 0.01630+ 0.01019) kg = 0.07104 kg

For 18th Trial,

Table 4.93: Estimation of sediment deposition in the porcupine field at section A for 18th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.015	0.0283	0.000012576	0.000008300	0.01698
0.5	0.016	0.0302	0.000015262	0.000010073	0.02061
1	0.015	0.0283	0.000012576	0.000008300	0.01698
1.5	0.014	0.0264	0.000010224	0.000006748	0.01381
2	0.014	0.0264	0.000010224	0.000006748	0.01381
2.5	0.01	0.0189	0.000003726	0.000002459	0.00503
3	0.006	0.0113	0.000000805	0.000000531	0.00109
3.5	0.004	0.0075	0.000000238	0.000000157	0.00032
4	0.002	0.0038	0.000000030	0.000000020	0.00004
					0.08867

Table 4.94: Estimation of sediment deposition in the porcupine field at section B for 18th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.011	0.0208	0.000004959	0.000003273	0.0066971
0.5	0.01	0.0189	0.000003726	0.000002459	0.0050316
1	0.008	0.0151	0.000001908	0.000001259	0.0025762
1.5	0.006	0.0113	0.000000805	0.000000531	0.0010868
2	0.004	0.0075	0.000000238	0.000000157	0.0003220
2.5	0.004	0.0075	0.000000238	0.000000157	0.0003220
3	0.003	0.0057	0.000000101	0.000000066	0.0001359
3.5	0.001	0.0019	0.000000004	0.000000002	0.0000050
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.01618

Table 4.95: Estimation of sediment deposition in the porcupine field at section C for 18th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 28°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-34% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2046 Kg/m³
0	0.008	0.0151	0.000001908	0.000001259	0.00258
0.5	0.006	0.0113	0.000000805	0.000000531	0.00109
1	0.007	0.0132	0.000001278	0.000000844	0.00173
1.5	0.009	0.0170	0.000002716	0.000001793	0.00367
2	0.009	0.0170	0.000002716	0.000001793	0.00367
2.5	0.011	0.0208	0.000004959	0.000003273	0.00670
3	0.007	0.0132	0.000001278	0.000000844	0.00173
3.5	0.004	0.0075	0.000000238	0.000000157	0.00032
4	0.003	0.0057	0.000000101	0.000000066	0.00014
					0.02161

Total weight of sand deposited in the eighteenth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.08867+ 0.01618+ 0.02161) kg = 0.12645 kg

For 19th Trial,

Table 4.96: Estimation of sediment deposition in the porcupine field at section A for 19th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.014	0.0275	0.000011042	0.000007177	0.0147280
0.5	0.012	0.0235	0.000006954	0.000004520	0.0092748
1	0.011	0.0216	0.000005356	0.000003481	0.0071439
1.5	0.01	0.0196	0.000004024	0.000002616	0.0053673
2	0.008	0.0157	0.000002060	0.000001339	0.0027481
2.5	0.006	0.0118	0.000000869	0.000000565	0.0011593
3	0.004	0.0078	0.000000258	0.000000167	0.0003435
3.5	0.002	0.0039	0.000000032	0.000000021	0.0000429
4	0.001	0.0020	0.000000004	0.000000003	0.0000054
					0.04081

Table 4.97: Estimation of sediment deposition in the porcupine field at section B for 19th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.012	0.0235	0.000006954	0.000004520	0.0092748
0.5	0.012	0.0235	0.000006954	0.000004520	0.0092748
1	0.011	0.0216	0.000005356	0.000003481	0.0071439
1.5	0.008	0.0157	0.000002060	0.000001339	0.0027481
2	0.005	0.0098	0.000000503	0.000000327	0.0006709
2.5	0.002	0.0039	0.000000032	0.000000021	0.0000429
3	0.002	0.0039	0.000000032	0.000000021	0.0000429
3.5	0.001	0.0020	0.000000004	0.000000003	0.0000054
4	0	0.0000	0.000000000	0.000000000	0.0000000
					0.02920

Table 4.98: Estimation of sediment deposition in the porcupine field at section C for 19th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.005	0.0098	0.000000503	0.000000327	0.0006709
0.5	0.007	0.0137	0.000001380	0.000000897	0.0018410
1	0.008	0.0157	0.000002060	0.000001339	0.0027481
1.5	0.009	0.0176	0.000002934	0.000001907	0.0039128
2	0.009	0.0176	0.000002934	0.000001907	0.0039128
2.5	0.004	0.0078	0.000000258	0.000000167	0.0003435
3	0.003	0.0059	0.000000109	0.000000071	0.0001449
3.5	0.001	0.0020	0.000000004	0.000000003	0.0000054
4	0.001	0.0020	0.000000004	0.000000003	0.0000054
					0.01358

Total weight of sand deposited in the nineteenth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.04081+ 0.02920+ 0.01358) kg = 0.08360 kg

For 20th Trial,

Table 4.99: Estimation of sediment deposition in the porcupine field at section A for 20th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.016	0.0314	0.000016483	0.000010714	0.0219846
0.5	0.015	0.0294	0.000013581	0.000008828	0.0181148
1	0.013	0.0255	0.000008841	0.000005747	0.0117920
1.5	0.011	0.0216	0.000005356	0.000003481	0.0071439
2	0.01	0.0196	0.000004024	0.000002616	0.0053673
2.5	0.008	0.0157	0.000002060	0.000001339	0.0027481
3	0.005	0.0098	0.000000503	0.000000327	0.0006709
3.5	0.003	0.0059	0.000000109	0.000000071	0.0001449
4	0.001	0.0020	0.000000004	0.000000003	0.0000054
					0.06797

Table 4.100: Estimation of sediment deposition in the porcupine field at section B for 20th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.015	0.0294	0.000013581	0.000008828	0.0181148
0.5	0.013	0.0255	0.000008841	0.000005747	0.0117920
1	0.012	0.0235	0.000006954	0.000004520	0.0092748
1.5	0.01	0.0196	0.000004024	0.000002616	0.0053673
2	0.009	0.0176	0.000002934	0.000001907	0.0039128
2.5	0.006	0.0118	0.000000869	0.000000565	0.0011593
3	0.004	0.0078	0.000000258	0.000000167	0.0003435
3.5	0.002	0.0039	0.000000032	0.000000021	0.0000429
4	0.001	0.0020	0.000000004	0.000000003	0.0000054
					0.05001

Table 4.101: Estimation of sediment deposition in the porcupine field at section C for 20th trial

Distance along the length of the flume (m)	Ripple Height 'h' (m)	Radius of Cone (r) in (m) r=h/tan Ø Ø= 27°	Total Volume of sand V=(∏r² h)/3	Volume of sand taking porosity into consideration (m³) V' = V-35% V	Weight of sand trapped (kg) W= ∂ V' ∂ = 2052 Kg/m³
0	0.007	0.0137	0.000001380	0.000000897	0.0018410
0.5	0.008	0.0157	0.000002060	0.000001339	0.0027481
1	0.008	0.0157	0.000002060	0.000001339	0.0027481
1.5	0.009	0.0176	0.000002934	0.000001907	0.0039128
2	0.011	0.0216	0.000005356	0.000003481	0.0071439
2.5	0.01	0.0196	0.000004024	0.000002616	0.0053673
3	0.005	0.0098	0.000000503	0.000000327	0.0006709
3.5	0.004	0.0078	0.000000258	0.000000167	0.0003435
4	0.003	0.0059	0.000000109	0.000000071	0.0001449
					0.02492

Total weight of sand deposited in the twenteeth trial= Sand deposited at A + Sand deposited at B + Sand deposited at C = (0.06797+ 0.05001+ 0.02492) kg = 0.14291 kg

Chapter 5

RESULTS AND DISCUSSIONS

5.1 Velocity Index

Porcupine Field Velocity Index, PFVI = $\left(\frac{u/s - mid}{mid - d/s}\right)$ is calculated for each experimental trial.

Table 5.1: Velocity Index calculation

Trial No.	Sediment Concentration	PFDI	Velocity			PFVI
			upstream	mid	downstream	
1	300	1.4	0.1798	0.138	0.0942	0.95
2	600	1.4	0.1677	0.1382	0.0911	0.63
3	300	1.4	0.1754	0.132	0.098	1.28
4	600	1.4	0.1771	0.1311	0.095	1.27
5	300	0.9	0.1812	0.1318	0.0951	1.35
6	600	0.9	0.1736	0.1385	0.091	0.74
7	300	0.9	0.1622	0.1239	0.099	1.54
8	600	0.9	0.1781	0.1265	0.0985	1.84
9	300	0.9	0.1724	0.1391	0.097	0.79
10	600	0.9	0.1734	0.1381	0.0981	0.72
11	300	1.4	0.1726	0.132	0.0973	0.75
12	600	1.4	0.1808	0.138	0.0975	0.62
13	300	0.9	0.1752	0.1386	0.0982	1.02
14	600	0.9	0.1742	0.1388	0.0977	1.14
15	300	0.9	0.1782	0.1351	0.0963	1.11
16	600	0.9	0.1752	0.1364	0.0965	0.97
17	300	1.4	0.1758	0.1318	0.0975	1.08
18	600	1.4	0.1718	0.1312	0.0921	1.16
19	300	1.4	0.1799	0.1341	0.0976	1.17
20	600	1.4	0.1715	0.1338	0.0983	1.06

5.2 Calculation of Trap Efficiency (Phase 1)

Table 5.2: Trap Efficiency calculation

Trial No.	Angle of porcupine placed	PCDI (L_r/L_c)	PFLF (L_s/L_c)	PFDI (L_r/L_s)	Velocity Index	Water Depth (cm)	Sediment Concentration q_s (ppm)	Weight of sand deposited(kg)	Weightof sand injected (kg)	Trap Efficiency(%)
1	20^0 towards upstream	0.47	0.33	1.4	0.95	21	300	0.03729	5	0.75
2	10^0 towards upstream	0.47	0.33	1.4	0.63	21	600	0.13181	8	1.65
3	20^0 towards upstream	0.7	0.5	1.4	1.28	21	300	0.03478	5	0.70
4	10^0 towards upstream	0.7	0.5	1.4	1.27	21	600	0.09286	8	1.16
5	20^0 towards upstream	0.3	0.33	0.9	1.35	21	300	0.02864	5	0.57
6	10^0 towards upstream	0.3	0.33	0.9	0.74	21	600	0.11708	8	1.46
7	20^0 towards upstream	0.45	0.5	0.9	1.54	21	300	0.02816	5	0.56
8	10^0 towards upstream	0.45	0.5	0.9	1.84	21	600	0.08043	8	1.01
9	90^0 to the bank	0.45	0.5	0.9	0.79	21	300	0.06280	5	1.26
10	90^0 to the bank	0.3	0.33	0.9	0.88	21	600	0.11975	8	1.49
11	90^0 to the bank	0.7	0.5	1.4	0.75	21	300	0.05521	5	1.84
12	90^0 to the bank	0.47	0.33	1.4	0.62	21	600	0.11141	8	2.23

5.3 Comparison of Trap Efficiency with Different Indices and Their Graphical Representation

Table 5.3: PFDI versus Trap efficiency for q_s = 300 ppm and q_s = 600 ppm

PFDI	Trap Efficiency (%) for q_s = 300 ppm	Trap Efficiency (%) for q_s = 600 ppm
0.9	0.56	1.01
1.4	0.70	1.16

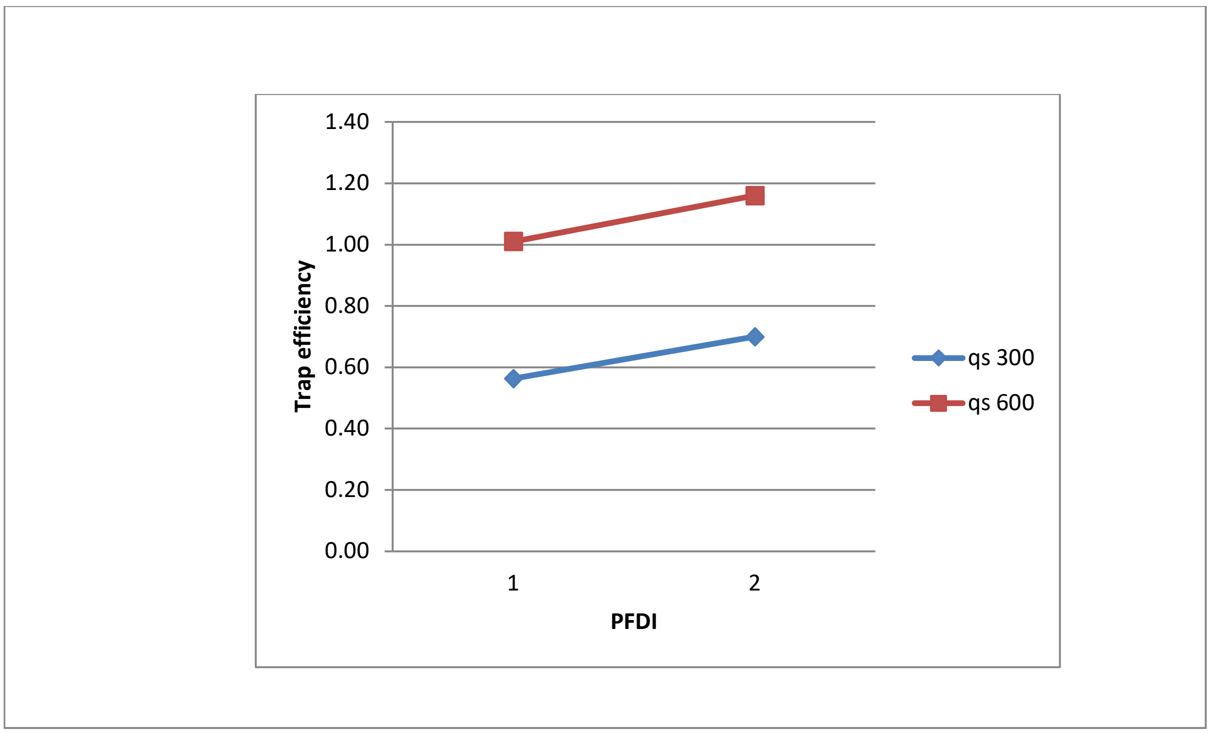

Fig.5.1: Plot of Trap efficiency versus PFDI

Series 1 represents plot of trap efficiency versus PFDI for q_s = 300 ppm

Series 2 represents plot of trap efficiency versus PFDI for q_s = 600 ppm

Conclusion: From figure 5.1, it is observed that there is more deposition of sediment for more sediment concentration and vice-versa. This means that trap efficiency increases with increase in sediment concentration, i.e. trap efficiency is directly proportional to sediment concentration

Table 5.4: PFDI versus Trap efficiency for PFLF = 0.5 and PFLF = 0.33, when 8 kg of sediment was injected

PFDI	**Trap Efficiency (%) for PFLF = 0.33**	**Trap Efficiency (%) for PFLF = 0.5**
0.9	1.46	1.01
1.4	1.65	1.16

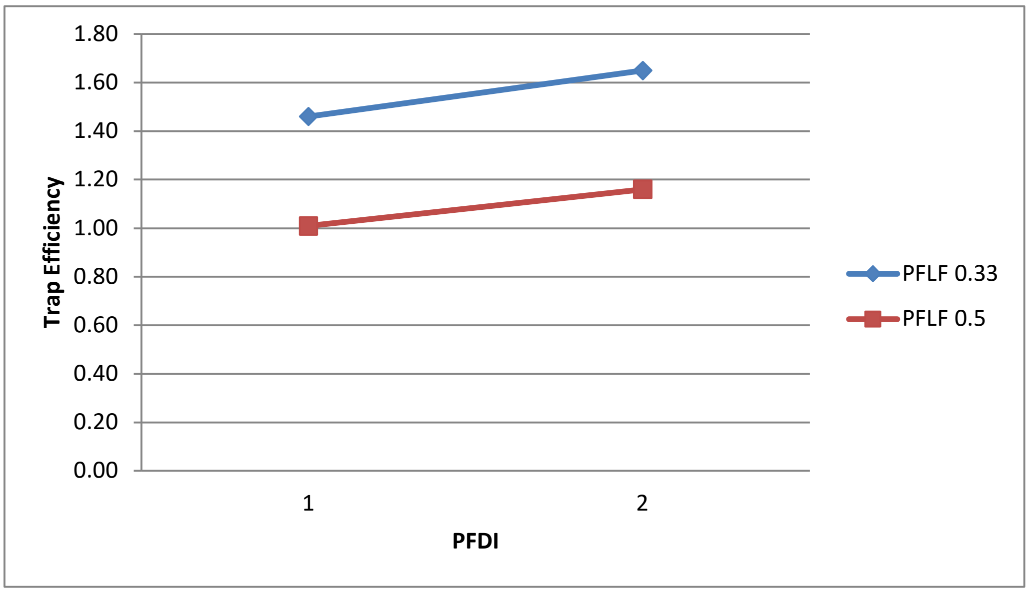

Fig 5.2: PFDI versus Trap efficiency for PFLF = 0.5 and PFLF = 0.33, when 8 kg of sediment

Series 1 represents plot of trap efficiency versus PFDI for PFLF = 0.33, when 8 kg of sediment was injected

Series 2 represents plot of trap efficiency versus PFDI for PFLF = 0.5, when 8 kg of sediment was injected

Table 5.5: PFDI versus Trap efficiency for PFLF = 0.5 and PFLF = 0.33, when 5 kg of sediment was injected

PFDI	Trap Efficiency (%) for PFLF = 0.33	Trap Efficiency (%) for PFLF = 0.5
0.9	0.57	0.56
1.4	0.75	0.70

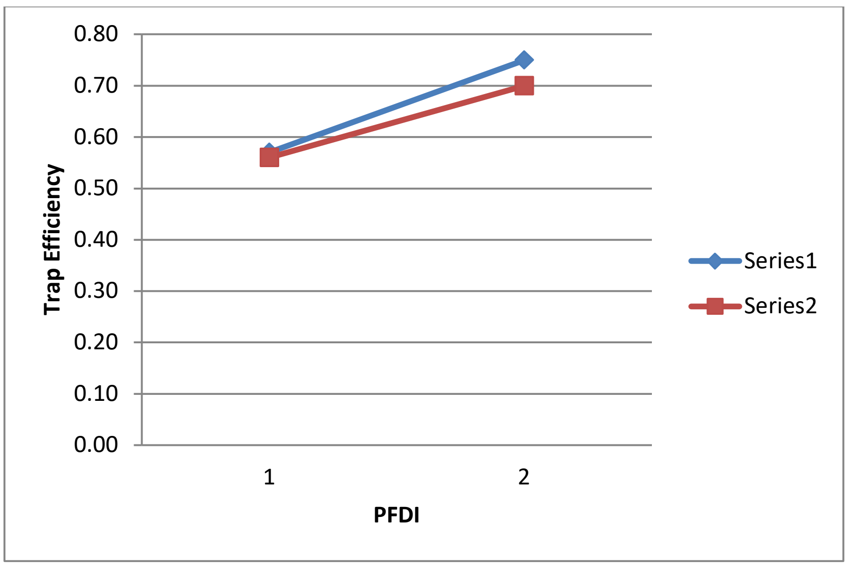

Fig 5.3: PFDI versus Trap efficiency for PFLF = 0.5 and PFLF = 0.33, when 5 kg of sediment was injected

Series 1 represents plot of trap efficiency versus PFDI for PFLF = 0.33, when 5 kg of sediment was injected

Series 2 represents plot of trap efficiency versus PFDI for PFLF = 0.5, when 5 kg of sediment wasinjected

Conclusion: From figure 5.2 and 5.3, it is observed that trap efficiency decreases with increase in PFLF i.e., trap efficiency is inversely proportional to PFLF

Table 5.6: PFDI versus Trap efficiency for PFLF = 0.5, when 5 kg and 8 kg of sediment was injected

PFDI	Trap Efficiency (%), when 5 kg sediment was injected	Trap Efficiency (%) when 8 kg sediment was injected
0.9	0.56	1.01
1.4	0.70	1.16

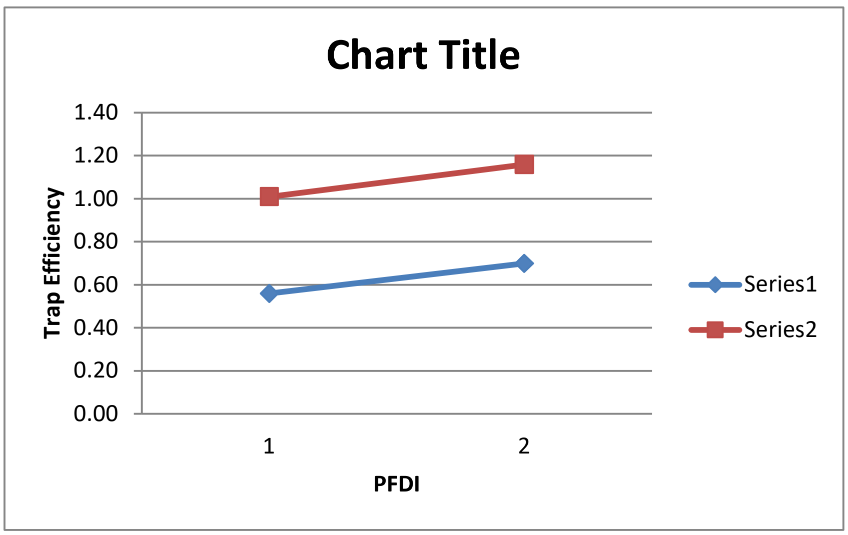

Fig 5.4: PFDI versus Trap efficiency for PFLF = 0.5, when 5 kg and 8 kg of sediment was injected

Series 1 represents plot of trap efficiency versus PFDI for PFLF = 0.5, when 5 kg of sediment was injected

Series 2 represents plot of trap efficiency versus PFDI for PFLF = 0.5, when 8 kg of sediment was injected

Table 5.7: PFDI versus Trap efficiency for PFLF = 0.33, when 5 kg and 8 kg of sediment was injected

PFDI	Trap Efficiency (%), when 5 kg sediment was injected	Trap Efficiency (%) when 8 kg sediment was injected
0.9	0.57	1.46
1.4	0.75	1.65

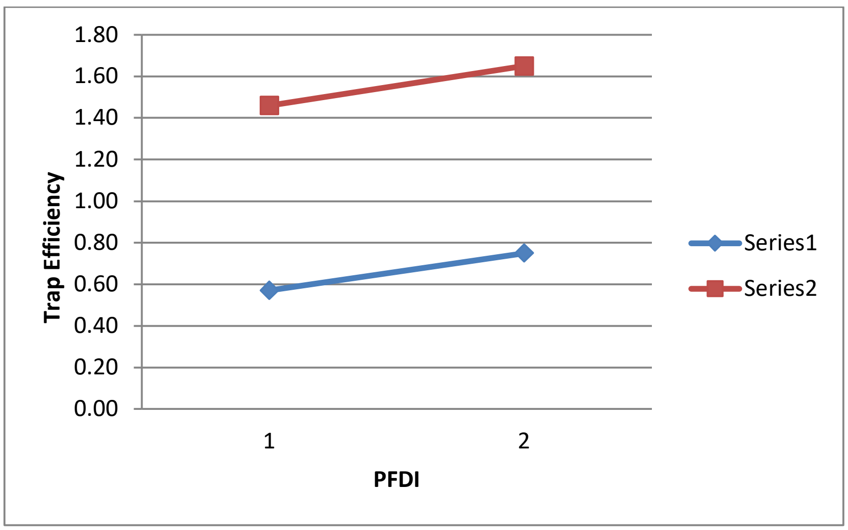

Fig 5.5: PFDI versus Trap efficiency for PFLF = 0.33, when 5 kg and 8 kg of sediment was injected

Series 1 represents plot of trap efficiency versus PFDI for PFLF = 0.33, when 5 kg of sediment was injected

Series 2 represents plot of trap efficiency versus PFDI for PFLF = 0.33, when 8 kg of sediment was injected

Conclusion: From figure 5.4 and 5.5, it is observed that trap efficiency increases with increase in amount of sediment injected i.e., trap efficiency is directly proportional to amount of sediment injected.

Table 5.8 : PFVI versus Trap efficiency for q_s = 300 ppm

PFVI	Trap Efficiency (%)
0.75	1.84
0.79	1.26
0.95	0.75
1.28	0.70
1.35	0.57
1.54	0.56

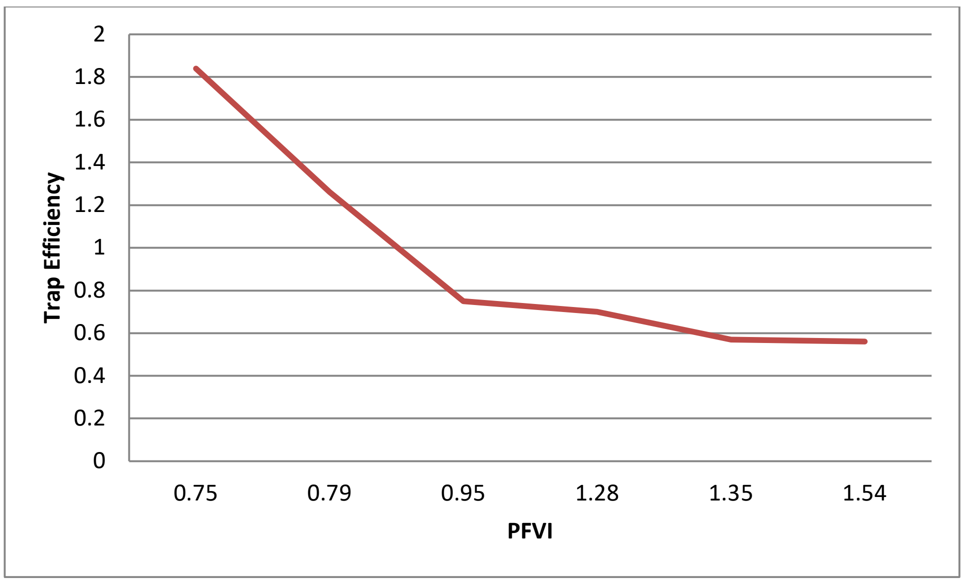

Fig 5.6: PVFI versus Trap efficiency for q_s = 300 ppm

Table 5.9 : PFVI versus Trap efficiency for q_s = 600

PFVI	Trap Efficiency (%)
0.62	2.23
0.63	1.65
0.72	1.49
0.74	1.46
1.27	1.16
1.84	1.01

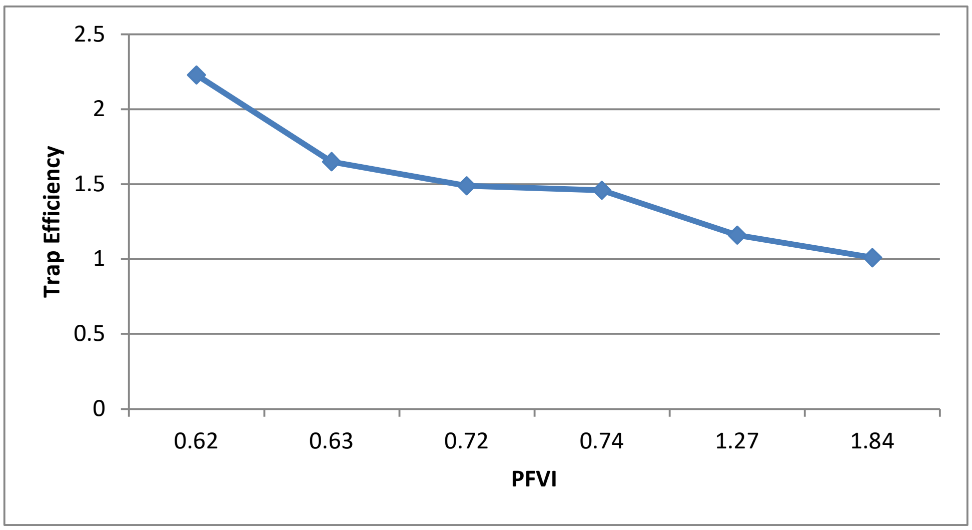

Fig 5.7: PVFI versus Trap efficiency for q_s = 600 ppm

Conclusion: From figure 5.6 and 5.7, it is observed that trap efficiency decreases with increase in PFVI and vice-versa i.e., trap efficiency is inversely proportional to PFVI. Also it is observed that velocity decreases with increase in sediment concentration and vice-versa.

Table 5.10: PFLF versus Trap efficiency for **PFDI = 1.4**, when porcupine is laid at 10^0 and 20^0 towards upstream and perpendicular to the bank

PFLF	Trap Efficiency		
	Perpendicular	**10^0**	**20^0**
0.33	2.23	1.65	0.75
0.5	1.84	1.16	0.70

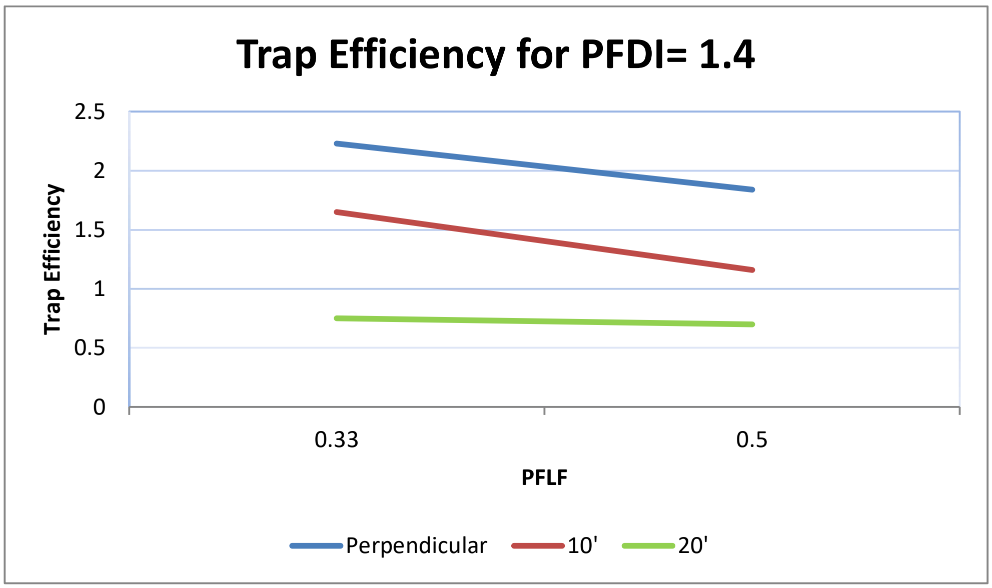

Fig. 5.8 PFLF versus Trap efficiency for PFDI = 1.4, when porcupine is laid at 10^0 and 20^0 towards upstream and perpendicular to the bank

Table 5.11: PFLF versus Trap efficiency for **PFDI = 0.9**, when porcupine is laid at 10^0 and 20^0 towards upstream and perpendicular to the bank

PFLF	Trap Efficiency		
	Perpendicular	**10^0**	**20^0**
0.33	1.49	1.46	0.57
0.5	1.26	1.01	0.56

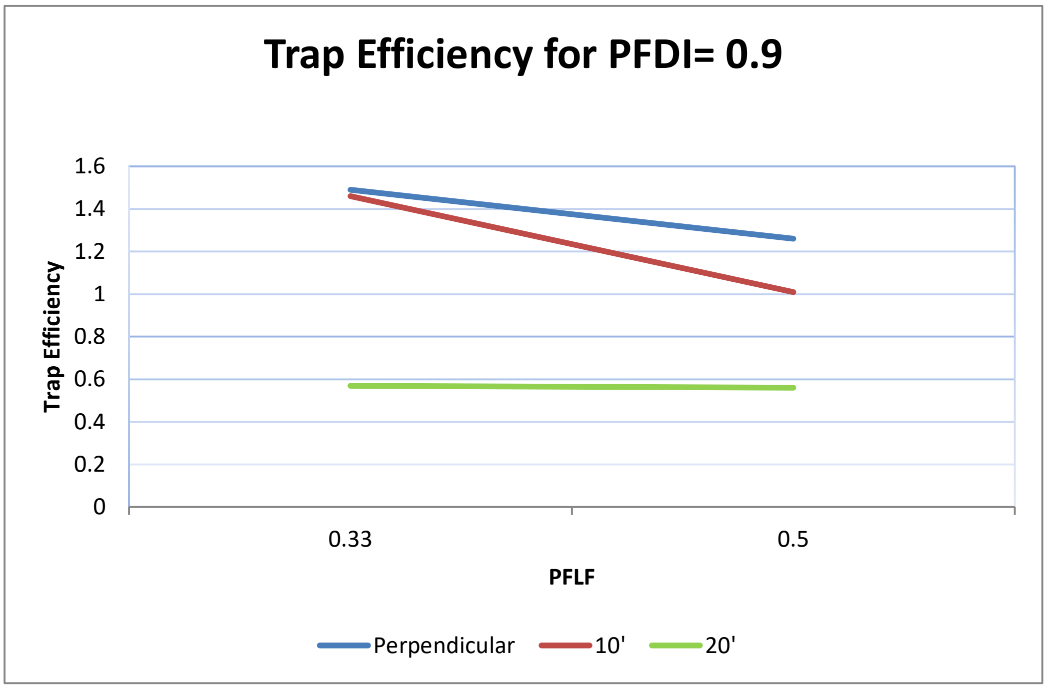

Fig. 5.9 PFLF versus Trap efficiency for PFDI = 0.9, when porcupine is laid at 10^0 and 20^0 towards upstream and perpendicular to the bank

Conclusion: From fig 5.8 and 5.9 it is observed that trap efficiency decreases with increase in PFLF i.e trap efficiency is inversely proportional to PFLF. On the other hand, porcupines kept perpendicular to the bank resulted in higher efficiency compared to those inclined at 10^0 and 20^0 towards the upstream direction. So, the highest trap efficiency is observed when porcupines are perpendicular to the bank and the lowest trap efficiency observed when porcupines are placed 20^0 towards upstream.

5.4 Comparison of Trap efficiency with different sediment sample (Phase 2)

Since porcupine placed perpendicular to the bank has higher trap efficiency then the porcupine placed 10^0 and 20^0 towards upstream (result got from phase 1), therefore all the porcupine fields at Phase 2 are placed perpendicular to the bank.

Table 5.12: Trap efficiency calculation

Trial No.	**Angle of porcupine placed**	**Sediment Sample**	**PCDI**	**PFLF**	**PFDI**	**Velocity Index (PVFI)**	**Water Depth (cm)**	**Sediment Concentration (ppm)**	**Weight of sand deposited (kg)**	**Weight of sand injected (kg)**	**Trap Efficiency (%)**
9	90^0 to the bank	**Sediment 1**	0.45	0.5	0.9	0.79	21	300	0.06280	5	1.26
10	90^0 to the bank	**Sediment 1**	0.3	0.33	0.9	0.88	21	600	0.11975	8	1.49
11	90^0 to the bank	**Sediment 1**	0.7	0.5	1.4	0.75	21	300	0.05521	5	1.84
12	90^0 to the bank	**Sediment 1**	0.47	0.33	1.4	0.62	21	600	0.11141	8	2.23
13	90^0 to the bank	**Sediment 2**	0.45	0.5	0.9	0.91	21	300	0.06796	3	2.27
14	90^0 to the bank	**Sediment 2**	0.3	0.33	0.9	0.86	21	600	0.12548	5	2.51
15	90^0 to the bank	**Sediment 3**	0.45	0.5	0.9	1.11	21	300	0.07728	3	2.58
16	90^0 to the bank	**Sediment 3**	0.3	0.33	0.9	0.97	21	600	0.13864	5	2.77
17	90^0 to the bank	**Sediment 2**	0.7	0.5	1.4	1.28	21	300	0.07104	3	2.37
18	90^0 to the bank	**Sediment 2**	0.47	0.33	1.4	1.04	21	600	0.12645	5	2.53
19	90^0 to the bank	**Sediment 3**	0.7	0.5	1.4	1.17	21	300	0.08360	3	2.79
20	90^0 to the bank	**Sediment 3**	0.47	0.33	1.4	1.06	21	600	0.14291	5	2.86

Table 5.13: PFLF versus Trap efficiency for **PFDI = 1.4** for different Sediment Sample when porcupine is laid perpendicular to the bank

PFLF	**Trap Efficiency**		
	Sediment 1	**Sediment 2**	**Sediment 3**
0.33	2.23	2.53	2.86
0.5	1.84	2.37	2.79

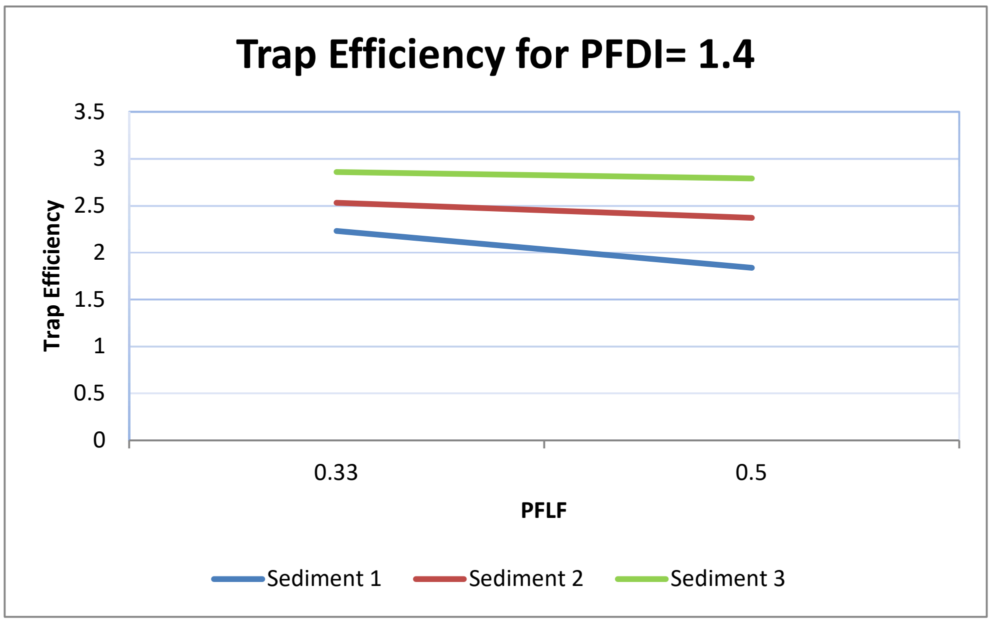

Fig. 5.10 PFLF versus Trap efficiency for PFDI = 1.4 for different Sediment Sample when porcupine is laid perpendicular to the bank

Table 5.14: PFLF versus Trap efficiency for **PFDI = 0.9** for different Sediment Sample when porcupine is laid perpendicular to the bank

PFLF	**Trap Efficiency**		
	Sediment 1	**Sediment 2**	**Sediment 3**
0.33	1.49	2.51	2.77
0.5	1.26	2.27	2.58

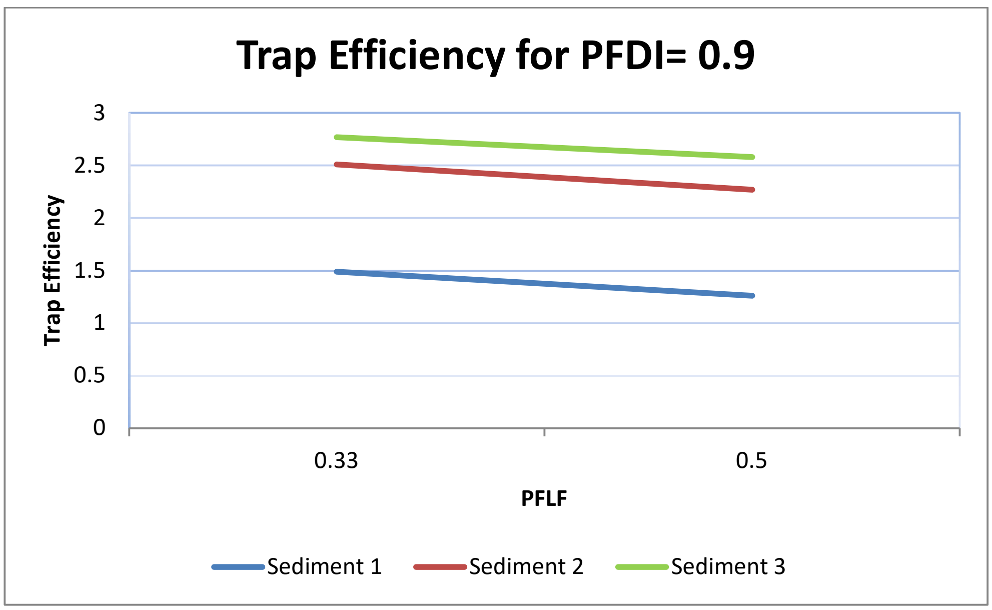

Fig. 5.11 PFLF versus Trap efficiency for PFDI = 0.9 for different Sediment Sample when porcupine is laid perpendicular to the bank

Conclusion: From fig 5.10 and 5.11 it is observed that for constant PFDI, trap efficiency decreases with increases in PFLF. On the other hand for constant PFDI Sediment 3 has higher trap efficiency than Sediment 1 and Sediment 2 i.e. Sediment 1 the has lowest trap efficiency and Sediment 3 has the highest trap efficiency.

Chapter 6

CONCLUSIONS AND FURTHER SCOPE OF THE STUDY

6.1 Conclusions

Twenty-four experiments were carried out to study the impact of various factors on sediment deposition patterns, including the length and spacing of retards, sediment concentration, water depth, and the inclination angle of porcupines towards the upstream direction. The sediment deposition patterns were calculated and visualized using contour plots created with Surfer software. The velocity was measured using the Acoustic Doppler Velocimeter (ADV) and the results were analysed to determine the relationship between different indices and trap efficiency. The results were then graphically represented to better understand the findings.

The results of the experiments showed that:

1. The trap efficiency increased proportionally with the increase in sediment concentration.
2. The trap efficiency decreased as the Porcupine Field Length Factor (PFLF) increased.
3. The trap efficiency was directly proportional to the amount of sediment injected.
4. The trap efficiency decreased as the Porcupine Field Velocity Index (PFVI) increased.
5. The Porcupine Field Velocity Index (PFVI) decreased inversely with the increase in sediment concentration.
6. The porcupines kept perpendicular to the bank resulted in higher trap efficiency compared to those inclined at 10^0 and 20^0 towards the upstream direction. So, the highest trap efficiency is observed when porcupines are perpendicular to the bank and the lowest trap efficiency observed when porcupines are placed 20^0 towards upstream.
7. Increasing sediment size increases the trap efficiency of sediment. For sediment 3 trap efficiency is the highest and for sediment 1 trap efficiency is the lowest.

The use of the porcupine system has been proven to be an efficient and cost-effective method for river training. It helps prevent scouring by promoting sediment deposition through the reduction of flow intensity caused by the decrease in flow velocity from the porcupines. The construction of these structures is straightforward and requires only basic materials such as concrete and steel rods, along with a limited number of nuts and bolts. The installation process is uncomplicated, involving simply placing the structures successively and connecting them using wire rope, requiring no specialized labour.

6.2 Further Scope

1. To create a comprehensive model for predicting sediment deposition patterns, and to evaluate its accuracy by comparing the results obtained from the model with those from various theoretical approaches.
2. To expand the scope of the experimental trials to include a wider range of variables, in order to gain a more thorough understanding of sediment deposition patterns in different conditions.
3. To investigate the effect of different porcupine shapes, such as prismatic shapes, on sediment deposition patterns. This could help to optimize the design of porcupine systems for specific river training application.

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