ROLE OF GROYNES IN CONTROLLING RIVER EROSION

Submitted in partial fulfilment of the requirements of the degree of

Master of Technology in

Hydraulics and Flood Control Engineering

SUBMITTED BY

Mohd. Amir Jafri

Roll No. 2K13/HFE/10

Under the Supervision of

Mr. S. Anbu Kumar

Assistant Professor

Department Of Civil Engineering

CIVIL ENGINEERING DEPARTMENT

DELHI TECHNOLOGICAL UNIVERSITY

DELHI-110042

(Formerly Delhi College of Engineering)

Bonafide Certificate

This is to certify that the project report entitled, "**Role of Groynes in Controlling River Erosion**" is a record of the bonafide dissertation work carried out by me, Mohd. Amir Jafri, towards the partial fulfillment of requirements for the award of the degree of Master of Technology in Hydraulics and Flood Control Engineering, Delhi Technological University, Delhi-110042.

Also, I do hereby state that I have not submitted the matter embodied in this thesis in any other University/ Institute for the award of any degree as per my knowledge and belief.

Mohd. Amir Jafri

M.Tech (Hydraulics and Flood Control)

Roll No: 2K13/HFE/10

Delhi Technological University, Delhi

This is to certify that the above statements made by the candidate are correct to the best of my knowledge.

Mr. S. ANBU KUMAR

ASSISTANT PROFESSOR

Department of Civil Engineering

Delhi Technological University, Delhi

Declaration

I certify that the work contained in the dissertation is original and has been done by myself under the general supervision of my supervisor. The work has not been submitted to any other institute for any degree or diploma. I have followed the guidelines provided by the institu I certify that the work contained in the dissertation is original and has been done by myself under the general supervision of my supervisor. The work has not been submitted to any other institute for any degree or diploma. I have followed the guidelines provided by the institute in writing the report. I have conformed to the norms and guidelines given in the Ethical Code of Conduct of the institute. Whenever, I have used materials (data, theoretical analysis and text) from other sources, I have given due credit to them by citing them in the text of the dissertation and giving their details in the references. Whenever, I have taken material from other sources, I have put them under quotation marks and given due credit to the sources by citing them and giving required details in the references.

Mohd. Amir Jafri

Acknowledgement

I feel privileged in extending my earnest obligation, deep sense of gratitude, appreciation and honor to my advisor, **S. Anbu Kumar**, Assistant Professor, Department of Civil Engineering, Delhi Technological University, Delhi, whose benevolent guidance, apt suggestions, unstinted help and constructive criticism have inspired me in successful completion of making of this dissertation report.

Sincere gratitude is extended to Prof. Nirendra Dev, HOD, Department of Civil Engineering, Prof. R.K ARYA, Dr. Himanshu Sharma, Mr T. Vijay Kumar & Sardar Keval Singh and all my friends of Delhi Technological University, Delhi, for their valuable suggestions.

I express my appreciation and thanks to all the faculty members and staff of the Department of Civil Engineering, Delhi Technological University, and Delhi for free exchange of ideas and discussions which proved helpful. I wish to acknowledge the affection and moral support of my family and friends for being so understanding and helpful during this period.

Finally, I am thankful and grateful to God the Almighty for ushering his blessings on me for fulfillment of requirements for the award of the degree of Master of Technology in Hydraulics and Flood Control Engineering, Delhi Technological University, Delhi-110042.

.

Date: Mohd. Amir Jafri

Place: Delhi Roll No: 2K13/HFE/10

Abstract

The main objective of Installation of groynes in rivers is to save the destruction of river banks caused by sediment erosion in the form of flood.

The hydraulic features (the water level, the velocity of flow, flow of main stream, depth of sand) depend on the groyne that affects the bank protection. The design factors, the spacing, length of groynes & thickness of groynes also affect the flow in a river. If length of groyne increases, it helps in increasing bank protection but if it is increased over a desired limit, it leads to chocking of flow in a river. If simultaneously net head of groyne & velocity in the main channel change considerably, this will result in risk of causing severe local scours on structures. Recirculation flow between groynes develops because of launching of groyne series.

It is necessary that groynes should be designed with appropriate spacing to save banks as erosion of banks may take place depending on spacing between groynes that may generate strong reverse flow.

The experimental analysis provided information about the following:

(i) The X-stream distribution of the velocity

(ii) The cross stream distribution of the depth of sand

(iii) The depth of water for all cases for plain sand bed as well as well as groyne bed

(iv) The morphological developments in the groyne fields in different flow conditions

The results lead to the following conclusions:

(i) The depth of sand curves, the velocity distribution curves & the Froude number curves are analysed all along the length of the flume in main river channel, along the centre line & in the groyne field for all tested cases.

(ii) In all tested cases, there was net import of sediments into the groyne fields

(iii) We chose that case in which there is least erosion of soil and that was determined from the depth of sand curves and also from the weight of sediment sample taken from each set of experiment during flow condition

In our case of submerged groynes, the sediment is transported to the groyne fields across the whole length of normal line. Diffusion through the mixing layer & secondary flow circulation play a role.

Contents

List of Illustrations

Figures

Tables

CHAPTER 1

INTRODUCTION

Chapter 1

Introduction

Groynes are embankment structures that are constructed perpendicular to the river flowing starting from the bank into the river up to a defined limit.

The basic aim of constructing groynes is to save the bank that is supporting them by diverting the water current away from the river bank. The additional advantage of groynes is that they promote channel navigation by deepening the river at the channel centerline. They promote scouring & transportation of sediments where required. Groynes provide an economical &eco-friendly solution for calculation of scouring along the outer banks of the channel bends.

Fig:1.1: **Groynes on the European Coast**

In Netherlands in the River Waal groynes were used from the 1700s starting. The initial use of groynes was by land owners to save their property from flood and to manage sediment flow in the river. A management type committee was established named RIJKSWATERSTAAT to monitor the systematization of groynes.

For reduction of flooding & bank erosion losses the RIJKSWATERSTAAT suggested extra placing of groynes at regular intervals & all these groynes were placed normal to the bank of the river.

One more important European river controlled by groynes is River Elbe. During the Nineteenth and twentieth century, 7000 groynes were constructed on the River Elbe in order to improve navigability as per Wirtz (2002). During these many years, most of the groynes got spoiled & lost their hydraulic function & this was assumed that around 2900 are still remaining.

A case study of **Carsen River** in Nevada is reported here as a reference. The river suffered considerable bank erosion & damage in a 1997 event of flood. A meander of 4.5 m bend was cut in the flood & it was handled with a number of ways i.e. bioengineering methods, use of groynes & re-vegetation.

Piper-et al 2001(this site served as a best model for practical analysis of students, workshops & for other purposes giving different methods of bank protection). For extra safety of river banks, five groynes were built with numerous planting and vegetation between the groynes. In this way good results were obtained by observing the site (Piper-et-al 2000). It was very successful method to protect the river banks. The groynes deviated the flow from the bank of the river with whatever the water level by creating pockets of still water, deposition of sediments & planting vegetation (bio-engineering treatment) in between the groynes. The contribution to achieve land & habitat was the deposition of sediments between the groynes and the motion of Thalweg that was deviated from the outer bank.

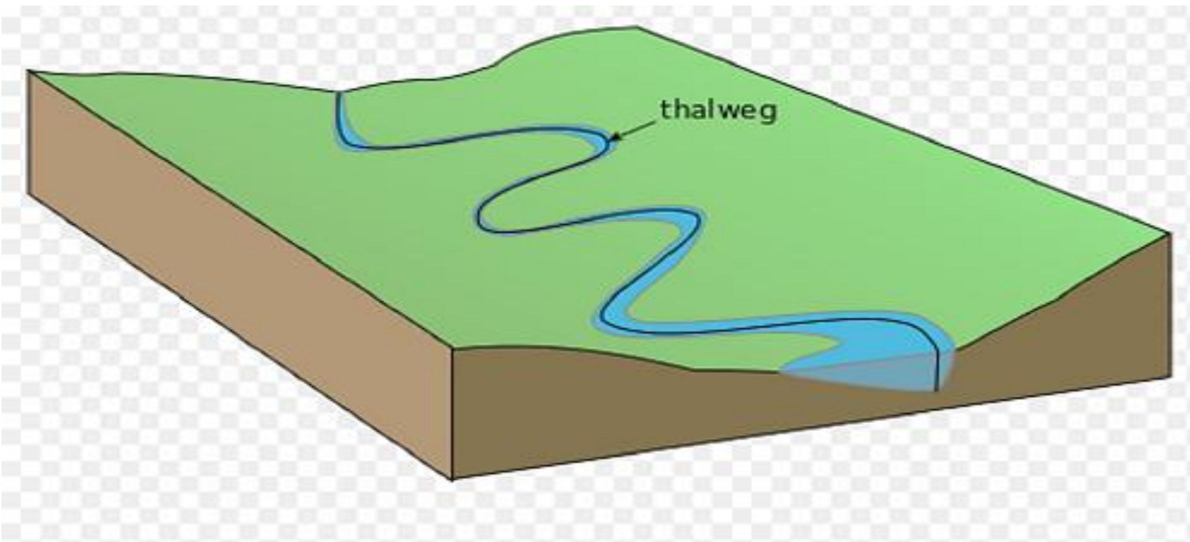

Fig: 1.2: **Thalweg in a River.**

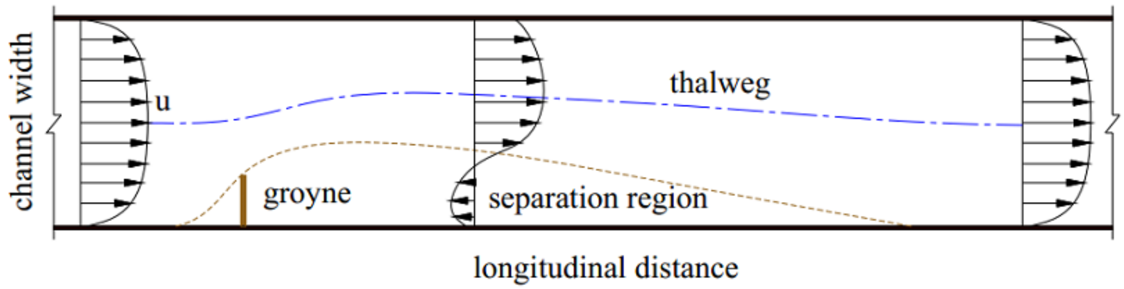

Fig: 1.3: Flow Thalweg and Separation around a Single Groyne

It was concluded by **Piper-et-al** that for such specific bio-engineering projects observation must be done for 2 years or a flood occurrence should be observed.

Another reference of **Washington State Department of Transport (WSDOT)** has used groynes for saving shallow rivers & also to save crossings & betterment of aquatic bodies (Papanicolaon-et-al 2004).On the basis of their investigation it was found that for gravel-bed rivers groynes can be utilized in the Pacific North West.

The WSDOT along with IOWA University worked out laboratory analysis to find out the details regarding

(i) flow properties along a single submerged groyne
(ii) Estimation of scouring in the clear water scouring condition for a groyne.

The basic features for Designing **STREAM BARBS** are

(1) Spur length perpendicular to river bank
(2) The distance between two continuous stream barbs
(3) Top of Groynes
(4) Scouring at the head of stream barbs

We can make the stability of river banks with the help of construction of groynes very easily. For the protection of river bank & embankment, single groyne can't help unless we construct more groynes along the river bank.

To enlarge & improve the efficiency of river navigation, a series of groynes is preferred as compared to a single groyne. Composite groynes are highly effective as compared to a single groyne.

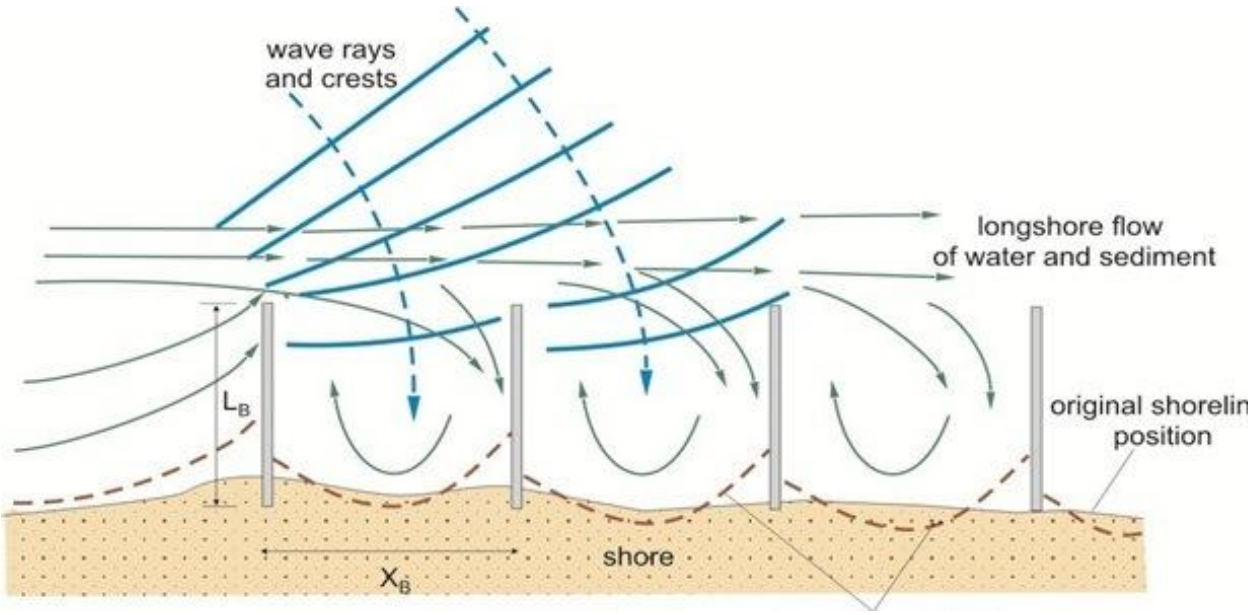

Fig: 1.4: Change in Shoreline position after Application of groynes

It is considered that series of groynes are causing sufficient obstruction in the river flow but actually it is making good alignment of the river & thus making a smooth river flow but in single groyne, its effect is only localized. Both these aspects affect the morphology of the river as well as smooth flow of the river. Therefore the current research analysis deals with the role of series of groynes in a river.

Types of Groynes

On the basis of their design, building & effect on river flow, groynes can be put in different groups:

(1)On the basis of used material and Building Technology

Permeable Groynes: Permeable Groynes are those which allow water to pass through it. They are made of Bamboo & Wooden material. They are used in those rivers that have low velocity of flow.

Fig: 1.5: **Permeable Groynes**

Impermeable Groynes: Impermeable Groynes are those that don't allow water to pass through it. Their construction is done with rubble masonry stone work. They are used in those rivers that have high velocity of flow.

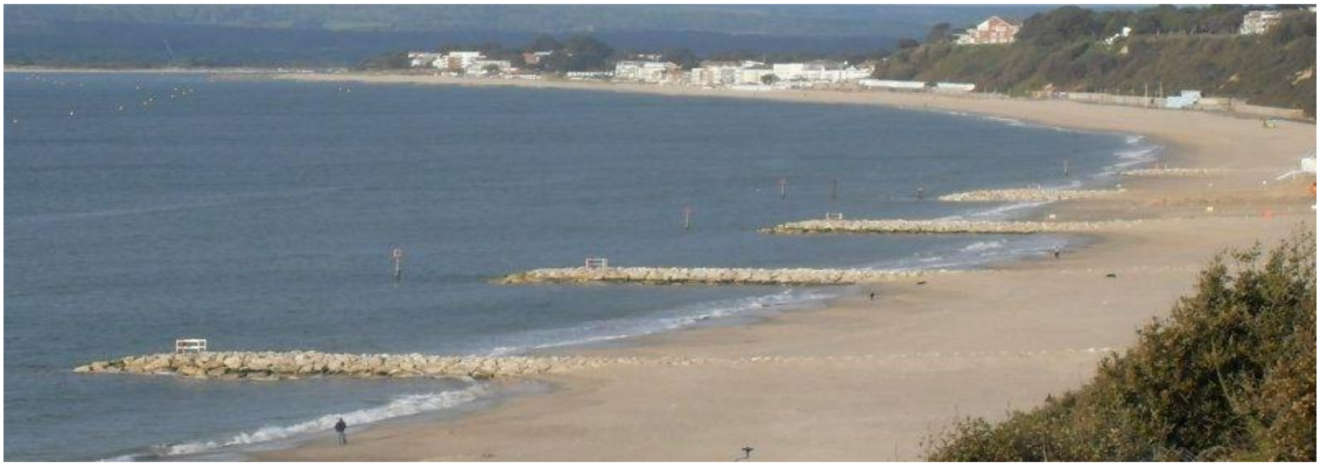

Fig: 1.6: **Impermeable Groynes**

(2)On the basis of Immersion

The design of Groyne also depends on whether it is emerged or submerged.

Emerged Groynes are those whose top remains above the surface of the water whereas submerged groynes are those which remain totally under water.

In case of flooding period and non-flooding period, the condition of emergence and submergence also varies.

(3)On the basis of Alignment of River Flow

The groynes are constructed normal to the river bank or are having certain inclination upstream or downstream w.r.t the river.

(a) Normal Groyne:

A normal groyne is that which is made perpendicular to the river bank and is also called as an ordinary bank.

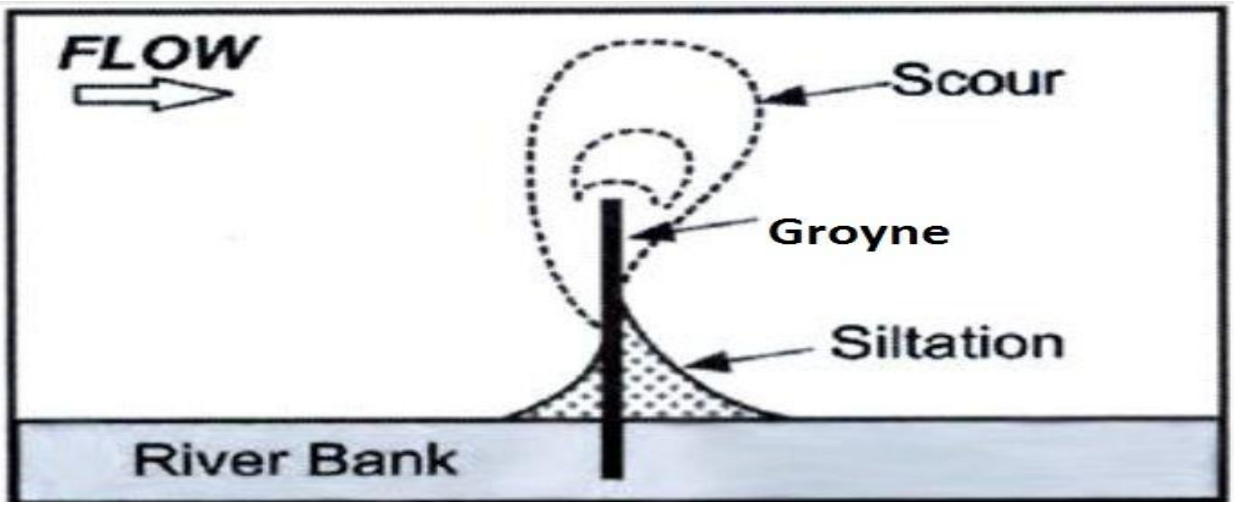

Fig: 1.7: Normal Groynes as per Barkdoll-et-al(2007)

(b) Repelling Groyne:

A repelling groyne is one which chases away the river water from it & is bend upstream. The use of such groynes can be seen in case of major channels.

When the groynes are sufficiently long, still pockets can be seen in the upstream part of the groynes.

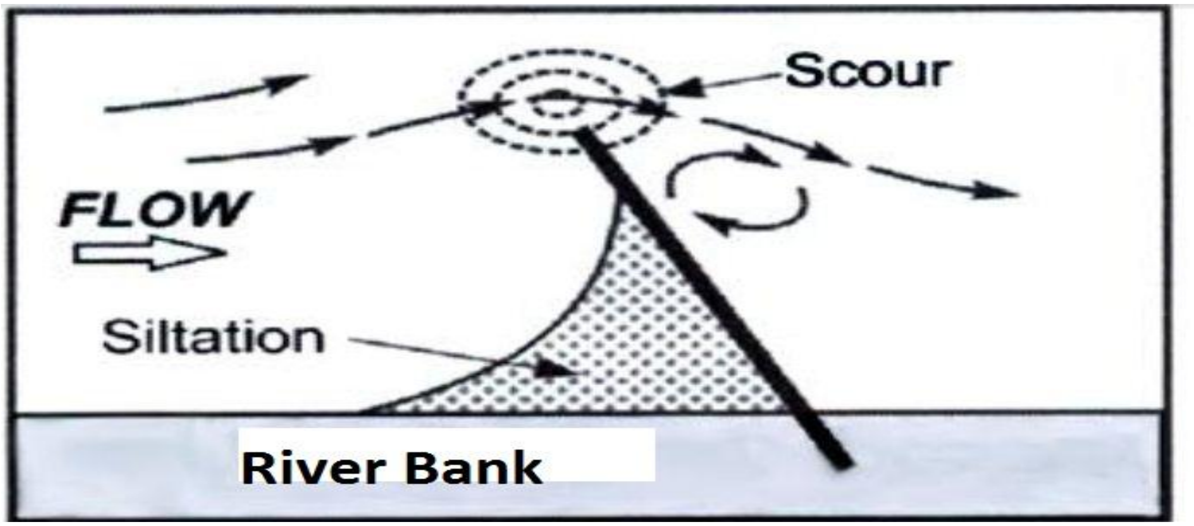

Fig: 1.8: Repelling Groynes as per Barkdoll-et-al(2007)

(c) Attracting Groyne:

As the name suggests, attracting groynes are attracting in nature & attracts the river flow towards it & are bent upstream.

On the downstream slope of the river in case of attracting groynes, use of heavy protection is not required. The formations of scour holes in an attracting groyne are near the bank of the river whilst in repelling groyne they are developed away from the bank.

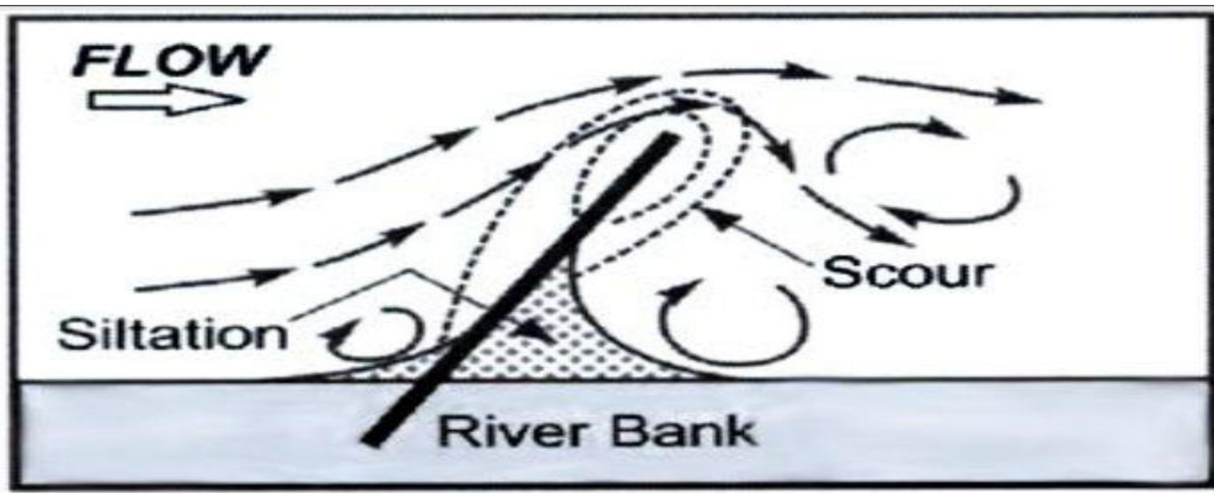

Fig: 1.9: Attracting Groynesas per Barkdoll-et-al(2007)

The attracting groynes make the scour holes very close to the river bank & also invite eddy currents near bank & thus give a chance to flood water to easily erode the river bank. That is why, they are not preferred as compared to repelling groynes.

Design Consideration of Groynes

The basic features for designing stream barbs taken into consideration are as follows:

(i) Groyne Length

(ii) Spacing between groynes

(iii) Orientation of Groynes

(iv)Height of Groynes & Bottom of Groynes

(i) Groyne Length:

The land available on the bank of the river helps us in deciding the length of the river.

Reposing angle of Sand **2.5H: 1V**

The groynes that are much larger in length may make the river narrower & will chock the river flow. Such groynes can’t control a flood event of very heavy discharge.

The ratio of the groyne length and the river width should not go beyond 1:5 otherwise it will cause hindrance in the river flow.

We may face failure and damage of river banks when we are making too lengthy groynes. The length of groyne should be started by starting from a small length & increasing length on the basis of silting inside the river up to a saturation point.

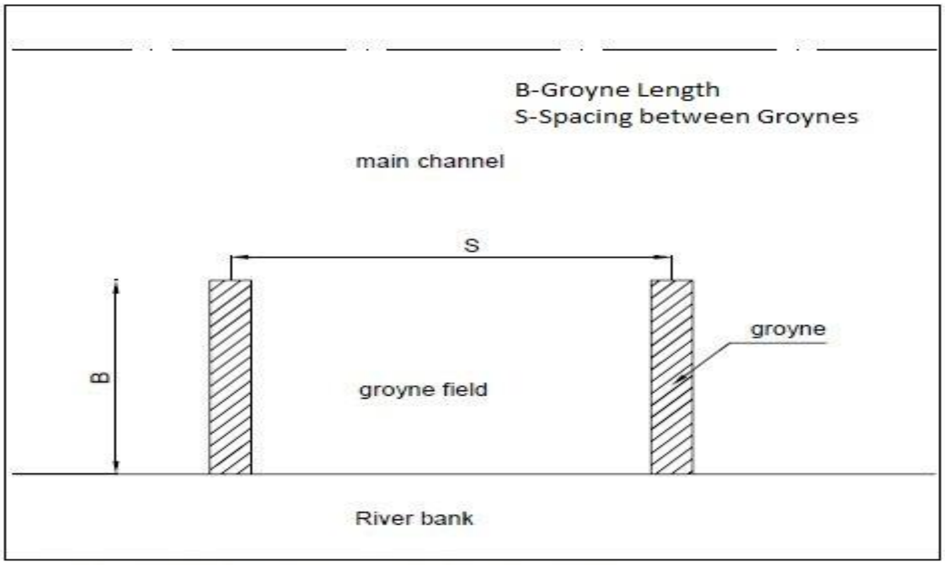

Figure 1.10: Details of a Groyne Field Top View

However for constructing the length of stream barbs no general rule can be used. It all depends on experimental & physical conditions. A long groyne can be useful to change the direction of the whole river flow. If it is compulsory, the erosion in the river on the opposite bank on which the groynes are not provided should be predicted & allowed.

(ii)Spacing between Groynes:

The measurement of spacing of groynes depends on the length of groynes. The length of groyne is very important factor for protection of the river banks.

The ratio of spacing between groynes to length of groynes is used for the determination of horizontal eddies that are formed along the head of the groyne. The ratio of spacing to length of groynes from 2 to 4 forms two types of circulation patterns, one big eddy current that is formed in groyne's downstream part and a heavy vortex formation in upstream part of groyne. The formation of meandering loop like may take place when groynes are spaced too apart.

On the other hand, when these stream barbs are placed very close to each other, it will be totally uneconomical & thus will result in reduction of efficiency & improper utilization of each groyne.

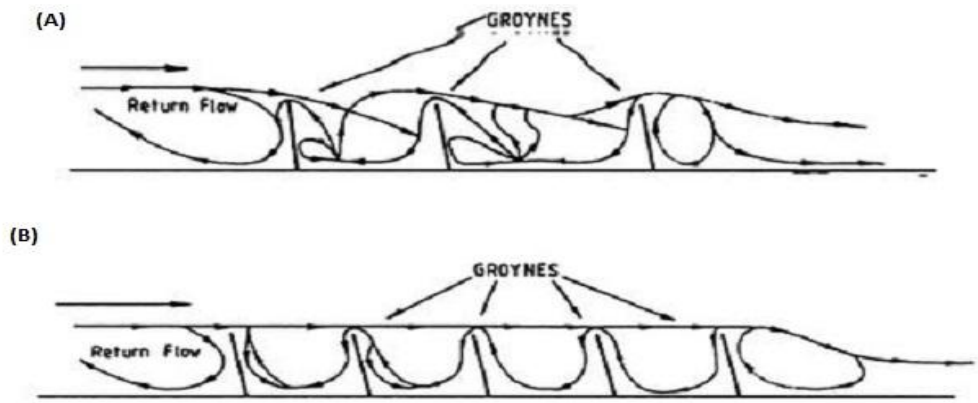

Fig:1.11: Action of a Series of Upstream Groynes (Joglekar, 1971)

(iii)Orientation of Groynes:

The straight groynes may be aligned perpendicular to the direction of flow of the river or they may be inclined upstream or downstream according to desired condition unlike other types of groynes.

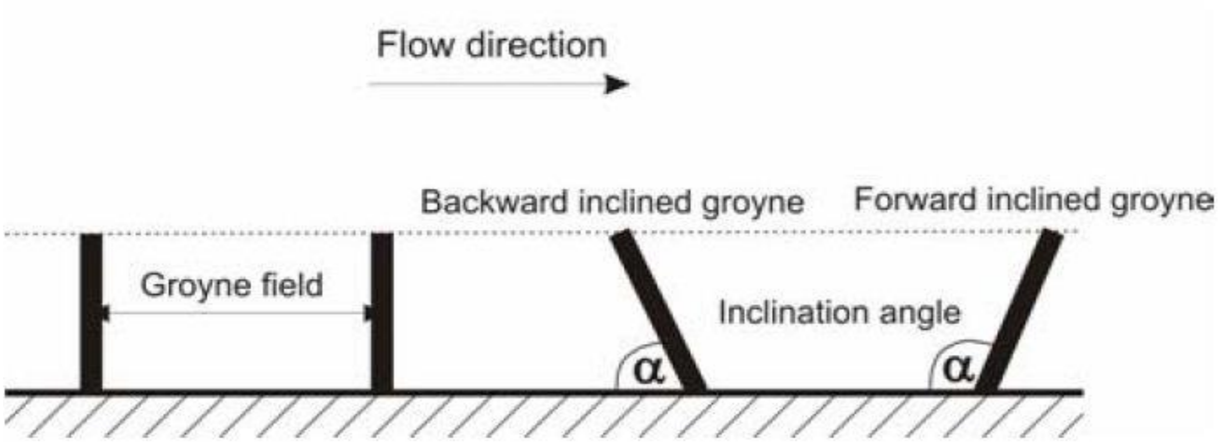

Figure 1.12: Inclination of Different Angles in Straight Groynes

The sediment deposition patterns near groynes are dependent on the orientation of groynes whether they are inclined upstream or downstream. The angle of deflection of groynes w.r.t banks varies between 70 ® to 120® as per **Klingeman-et-al 1984**.

The designer of the groyne can decide the length, shape & orientation of stream barbs on the availability of the site. The design, length, angle etc. can be judged from model experiments & from these the fixing lengths can be determined.

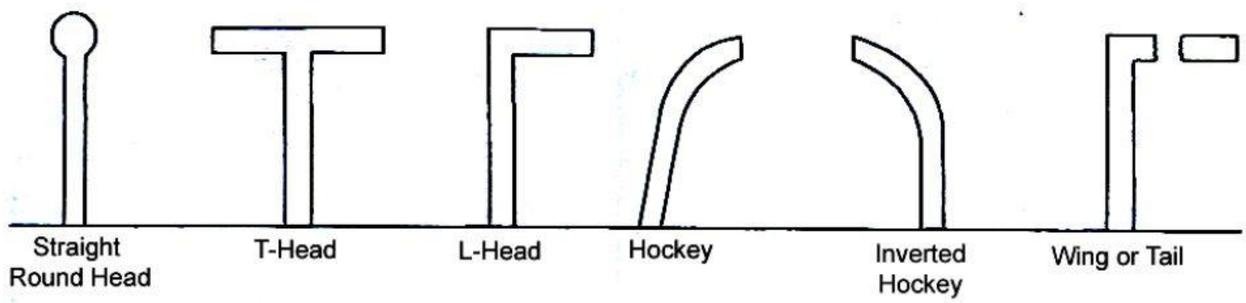

Fig: 1.13: Classification of Groynes by Appearance in Plan View (as Przedwojski-et al 1995)

T-head stream barbs when constructed are aligned perpendicular to the bank. When the spacing between 2 L-Shaped groynes 1.5 times the length of head of groynes, the groynes become more efficient for navigation purposes. The formation of scour holes in T-head groynes is less extensive in comparison with hockey headed groynes.

(iv)Height of Groynes and Bottom:

The height of the groyne for a good result should be above the HFL having sufficient free board. When the top level of groynes is less as compared to HFL, it is less costly but its efficiency is less as compared to above stated case.

Submerged groynes can be called as bed bars or deflectors when the height of Groynes is less than depth of flow.

For the determination of the base depth of stream barbs, the effect of scouring & depth of scour needs to be analyzed. For easy transportation and navigation in a river, the top width of groynes should be 3m. Provision of apron should be given to toe protection & pitching of nose must be done heavily.

Flow near Groynes

The efficiency of a group of groynes in comparison to a single groyne is totally different in case of river flow. This current research work deals with series of groynes & its importance.

Emerged Groynes

The flow near groynes is not significant in the cross section of the river when groynes are emerged. Thus the discharge in the main river is not affected by the flow pattern in a groyne area. Flow pattern will be least affected if velocity of the main stream is decreased.

When the geometry of the flow is changed, the pattern of the flow may also change. The pattern of flow near a single groyne is shown below.

Submerged Groynes

In comparison to emerged groynes, less research is done to submerged groynes because mostly functioning groynes are emerged. Since submerged groynes can be analyzed properly with three dimension techniques that require advance computation techniques & more powerful calculation methods, that is why more research is not done on submerged groynes.

The analysis on submerged groynes have shown reduction in the level of water from upstream to downstream sides of groynes as analyzed by some researchers namely Aya-et-al(1997), Krebs-et-al(1999) &Tominga-et-al(2001). The results show that the slope in the main channel region is more than between the slope between 2 consecutive groynes.

The analysis done by Peng-et-al(1997) showed that experimental laboratory tests when compared with 3-D numerical results that there is formation of 3-Dimensional features behind groynes. An upward motion is formed due to hindrance effect and is seen on the upstream face of the groyne. A detaching flow over the groynes reattaches the river bed in the case of groynes kept at a greater distance.

To keep the bed shear stress at a smaller value groynes are placed nearby & thus will control reattachment of flow to the bed.

CHAPTER 2

LITERATURE REVIEW

Chapter 2

Literature Review

The literature review deals with the role of groynes in controlling river erosion. For this purpose 8 research papers by different authors have been taken into consideration. Mostly the researchers have dealt with velocity of flow in water, velocity of sand movement, depth of flow, spacing between the groynes, depth of groynes, thickness of groynes & others. This research discusses the role of groynes in controlling river erosion. For this purpose researcher investigates on the following topics

(1) Detailed analysis of velocity of water, analysis of sand bed velocity, depth of sand bed, depth of water, groyne spacing & dimensions of groyne. These are the main parameters which will be taken into deep consideration during into the entire research process.

(2)With these parameters, we determine the discharge of water, Froude number, Reynolds number and with these parameters we also determine the type of flow whether it is laminar, turbulent or transitional.

(3)We also compare the flow properties of sand and water at different sand bed depths & water depths.

(4)In this case, the analysis is done on uniform spacing between groynes and all groynes are of same dimension.

(5)Various types of case studies and discussions will be made on the basis of all these above studies.

Scour Distribution

The distribution pattern of scouring shows area of high turbulence & flow structures. It also indicates information of groyne designs & how they affect pattern of scouring.

A series of controlled experiments made by **Elawady-et-al (2001a, 2001b, 2001c)** showed attracting, repelling & straight groynes. The result shown by them was the formation of maximum scour depth at the tip of groyne in case of attracting groynes.

Fig: 2.1: Scour Distribution patterns Adapted from **Elawady-et-al(2007)**

(a)Attracting Groyne (b) Repelling Groyne (c) Straight Groyne

In the case of repelling groynes, maximum scour was on the upstream side between groyne tip & channel side wall whereas in case of straight groynes, maximum scour depth was on the upstream side along the groyne length. By the increase of groyne length & height, scour depth & area increased keeping bed shear constant.

It has been found that groyne length has the greatest influence on scour. In case of repelling & deflecting groynes, water depth increases caused decrease in scour depth and area.

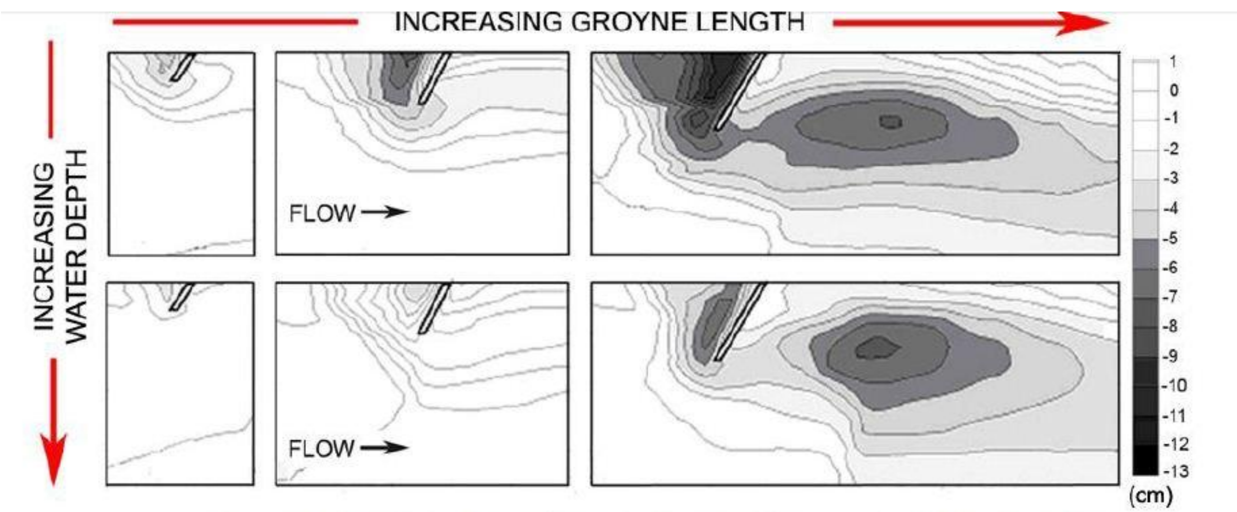

Fig: 2.2: Scour Distribution for repelling groynes with increasing groyne length, and water depth for repelling groynes. Columns show constant groyne length, while rows show constant water depth (Adapted from **Elawady-et-al 2001**)

By the study of groyne height & water depth, all other study parameters remain constant including bed shear. So construction of hydraulic jump at low submergence may affect scour.

The above figure shows submergence ratios of Groyne height from 1.07 to 4.0 for water depth from 2.0 to 5.2.

The scour depth changes within the groyne location for a no. of groynes. At the first groyne & the next groyne, the scour will be more or less similar. However on the next groynes, the scour will be different. Because of the neighboring groynes the depth of the single groyne becomes very less.

By laboratory analysis, Suzuki-et-al 1987 concluded that the local depth of souring at far downstream in a no. of groynes is a function of spacing between groynes to length of groynes.

Flow in Mixing Layer

In the shallow depth of water, the ratio of flow region is broader than the depth of the river. Between the river bed & surface of water, shallow flow remains confined whereas in horizontal direction big binding structures can develop.

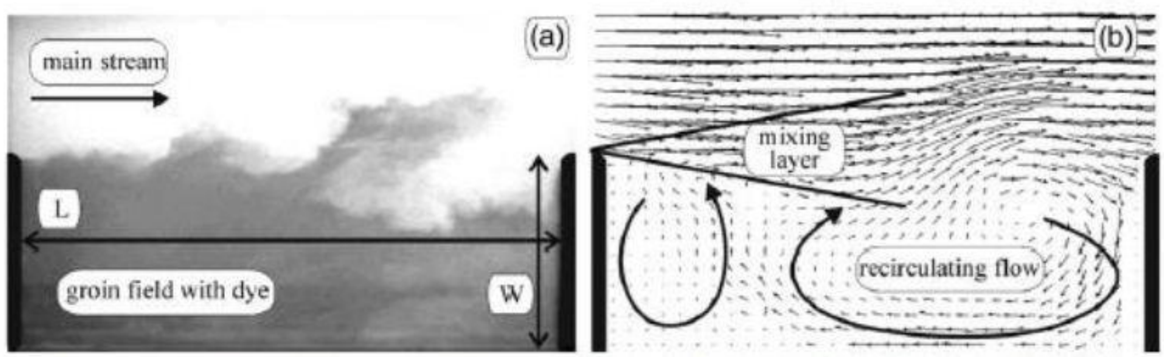

Fig: 2.3: Detached mixing layer at the interface of embayment between two groynes shown from dye visualizations (left) and PIV measurements (right) as per **Weitbrecht-et-al (2007)**

The extension of turbulent boundary layer goes up to the whole water depth& it is an identification mark of shallow flows. Energy dissipation & formation of bottom turbulence takes place when river surface is rough causing formation of shear stress on the water body.

With merging of different velocities like river confluence between fields of stream barbs, flood plains & the main channel mixing of layers develop. The control of exchange between mass & momentum composed of dissolved substances is done by mixing layer.

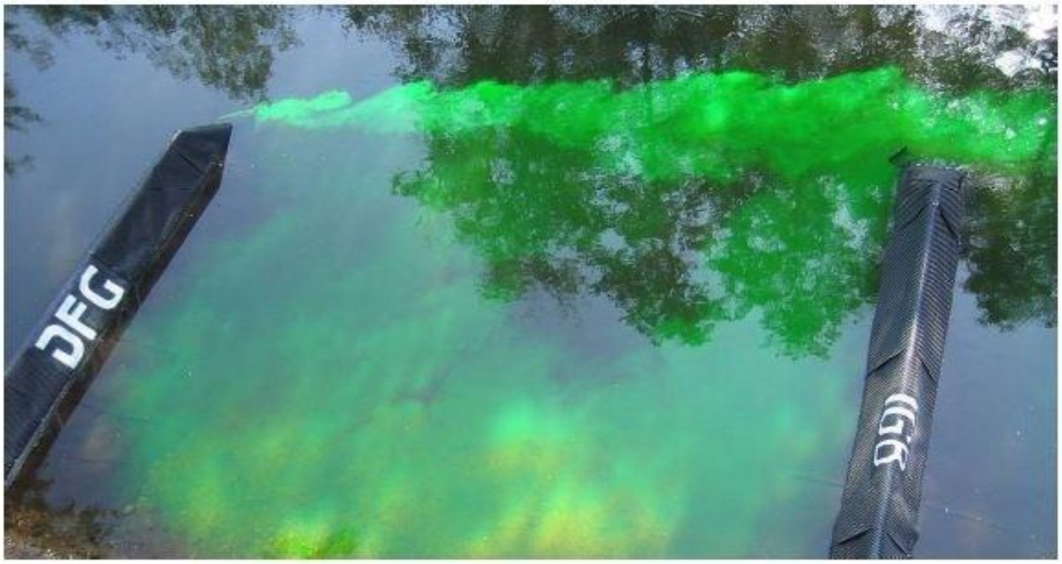

Figure 2.4: Development of Mixing Layer at the Groyne Tip (River Spree 2007)

As per **Wim S.J Uilltewaal**, flow patterns are shown in the stream barb field. The different groynes have different effects of the water flow and sediment transportation. This will help in transportation & flood control. If we make a design of groyne tip and shape adjustable a long term profitability of the flow & ecology will be controlled.

Sediment Transport

Transportation of sediments is an important aspect of the river morpho-dynamics.

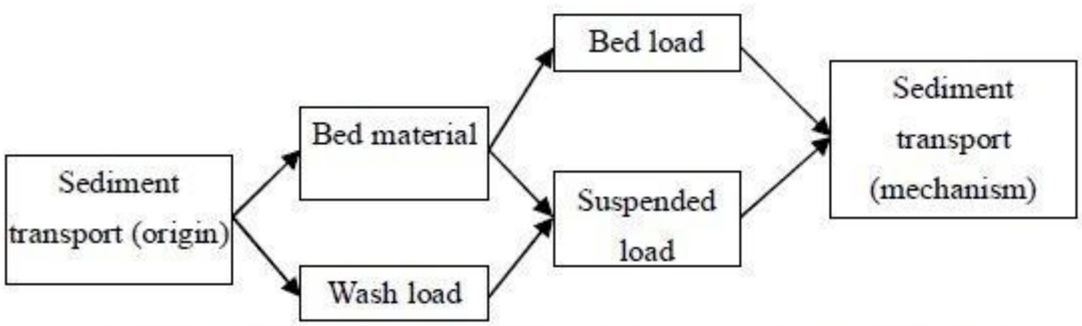

Figure 2.5: Classification of Sediment Transport as per **Jansen-et-al(1994)**

On the basis of size of sediments, different authors have analyzed various types of relations of particles size with the navigation methods & these particles are put in 2 categories:

(1) Bed material

(2) Wash load

The fine size material of the river has contribution only in case of flood but has no effect on morphology of river. The eroded material in the catchment area is used for the calculation of rate of wash load. As per **Asselmen 1997**, the material transferred as suspended load was 93% of the total load of sediment of Rhine River.

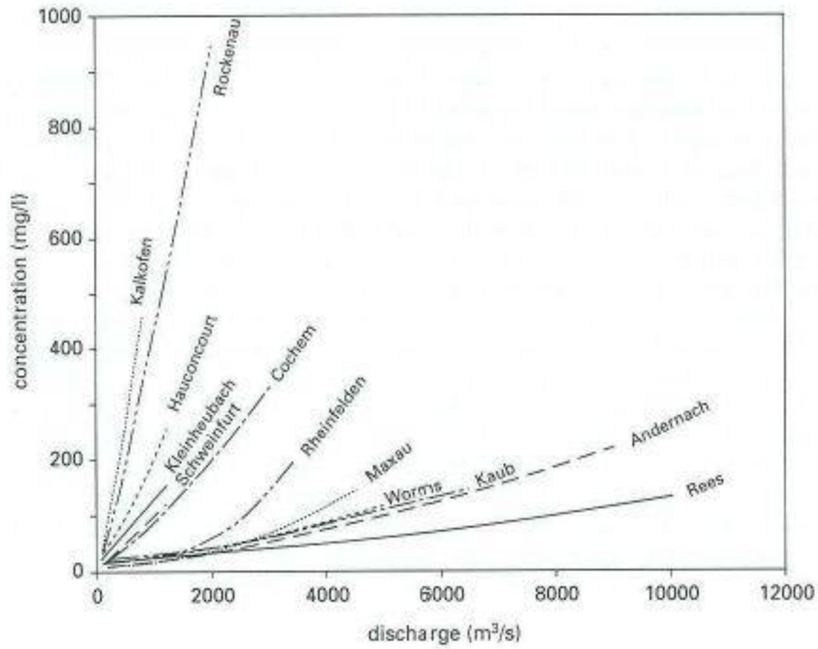

Fig: 2.6: Sediment Rating Curves Developed for Locations along the River Rhine & its Tributaries **(as per Asselman 1997)**

As observed by **H.Friedrich & B.W.Milwille**, erosion of sediment is governed by three ways:

(1)At a downstream of a groyne erosion takes place due to flow turbulent field.

(2)The main water currents cause erosion near main channel.

(3)The main water current has effect of erosion in the flood plain.

H. Friedrich & B.W. Milwille has studied pollution & biodiversity relations in flooding period in stream barb area. The groyne structure areas have much scouring during flood and field area remains silent water zone, the rest of channel area have low deposits of sediments. They gave three flow patterns at the stream barbs, one current pattern in summer discharge, and double current pattern in winter discharge & transitional flow in seasonal flood time. Finally it has been found by the author that a balanced scouring took place in long duration of flood and complete removal of silt didn't take place.

Change in Morphology of River caused by Lowering of Stream barbs

In 1997 Verheji invented the lowering effects of stream barbs. The results made by him showed the groynes under submerged water conditions where the water flow capacity is more.

Also between the main channel & the stream barbs, a slight velocity gradient is seen in the zone of mixing. When he analyzed the flow, he found that water flow velocity is inversely proportional to the width of the stream. Because of this effect, if the flow velocity reduces, the thickening of the river bed starts.

CHAPTER 3

DESCRIPTION OF THE WORK

Chapter 3

Description of Work

The main aim of work is to analyze the effect of installation of groynes in a river. If we don't do the training of the river, it will lead to the destruction of the banks of the river.

We need to protect the banks of the river so as to avoid destruction in the river bank area. In this work we have seen the installation of groynes in a river at different depths of river & at different depths of sand bed. Initially we go for plain bed analysis, and then we install 5 similar groynes that are in certain scale with reference to the groynes that were installed in Van Der Waals River & some research papers on Sediment exchange between a river & its groyne fields. We are going to take that case in to consideration in which there is least erosion of soil.

It has been found that the effect of groynes is highly beneficial in the area where the flood plains are continuously affected due to the meandering of the river. By studying the effect of groynes, we can control the worst effects of flood; prevent the devastating effects of our farm land, inhabitation, crops & human life. It also has considerable effects on scouring on the river bed.

In this research work, we carried out a number of tests on the river flume with plain sand bed as well as with installed groynes.

We have done the analysis on 5 submerged groynes of 12cm length, 1.2 cm thickness & height of groynes as 4cm. The effective length of the flume to be considered is 250 cm with readings taken at every 50cm starting from 0cm to 250cm. All the groynes are of same dimension & with uniform spacing of 40.6cm between each groyne.

The depth of sand bed to be taken into consideration is 2cm for plain sand bed & in the first case after installation of groynes. But in the 2^{nd} case of groynes experiment, the thickness of sand bed is 1.5cm.

We did the experiments with different depths of water & we analyzed the bed form propagation & flow velocities at various points along the length of the flume.

CHAPTER 4

EXPERIMENTAL ANALYSIS

Chapter 4

Experimental Set Up

The experimental set up includes

(1)Flume of 4m length & 30cm width in which 2.5m length is taken into consideration for Experiment

(2) Sand bed of 2cm thickness in case of Plain sand bed & in 1^{st} case of groynes. In the 2^{nd} case of groynes, the thickness of sand bed being 1.5cm

(3)5 Equal Submerged groynes of dimension 6cm length, 4cm height & 1.2cm thickness

(4)A Point gauge to measure the depth of water and depth of sand

(5)Manometric setup with pitote tube to measure the velocity of water

Experimental setup consists of a flume which is certain scale of a section of a river. The length of the flume is 4m but the analysis of flow takes place only on 2.5m length of the flume. The flume is cleaned by allowing free discharge through it.

Sand is taken and spread all along the 2.5m length with uniform thickness of 2cm. Initially, the flow takes place on plain sand bed with depth of water, depth of sand & velocity of water being measured at every 50cm all throughout the length of the flume & every reading is being measured at all these readings at 7.5cm, 15cm & 22.5cm width of the river.

After carrying out the experiments on plain sand bed, then 5 uniform groynes are installed in the flume with uniform spacing between them. The flow is then carried out with different depths of water and changes in bed form are analyzed. The same process is repeated with different set of experiments. In the first case after installation of groynes, the depth of sand is 2cm & in the other case, the depth of sand is 1.5cm initially. In each case, the depth of water, the depth of sand &flow velocity of water is determined at every 50cm at 3 points along the width of the river. With these parameters, we determine the discharge of water, the Froude Number, the Discharge of water & the Reynolds Number of flow.

Observations:

Observations were carried out on a model of a section of river i.e. flume for the following set of experiments with 3 different conditions, i.e. plain sand bed, Groynes installed with sand depth of 2cm & Groynes Installed with sand depth of 1.5cm.

Case 1: Plain sand bed with depth of sand bed 2 cm thick

Case 2(a): Five Uniform Groynes Installed in River flume with depth of sand bed 2cm thick

Case 2(b): Five Uniform Groynes Installed in River flume with depth of sand bed 2cm thick with different depths of water and different discharges of water

Case 2(c): Five Uniform Groynes Installed in River flume with depth of sand bed 2cm thick again analyzed again with more discharge & more depth of water

Case 3(a): Five Uniform Groynes Installed In River Flume with depth of sand bed 1.5cm

Case 3(b): Five Uniform Groynes Installed In River Flume with depth of sand bed 1.5cm

Analyzed with different depths of water and different discharges of water.

Case 3(c): Five Uniform Groynes Installed In River Flume with depth of sand bed 1.5cm

Again analyzed again with more discharge & more depth of water.

Case 1: Plain Sand Bed with Depth of sand bed 2cm.

At left side of flume (7.5 cm Width)

Table 4.1: Flow Properties at Left Side of Flume (7.5cm of Width) Case I

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.101	0	0.485	0.0146955	0.487244054	55039.32584
0.106	0.032	0.2426	0.00771468	0.237904885	28893.93258
0.108	0.018	0.2801	0.00907524	0.272123926	33989.66292
0.112	0.02	0.3132	0.01052352	0.29879838	39413.93258
0.113	0.024	0.3132	0.01061748	0.297473325	39765.8427
0.11	0.018	0.5425	0.0179025	0.522238513	67050.5618

Figure 4.1: View of Plain Sand Bed after Flow has taken Place

At middle of Flume (15cm width)

Table 4.2: Flow Properties at Middle of Flume (15cm of Width) Case I

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.103	0	0.5425	0.01676325	0.539692803	62783.70787
0.105	0.022	0.3706	0.0116739	0.365154168	43722.47191
0.106	0.021	0.3962	0.01259916	0.388532216	47187.86517
0.109	0.022	0.2801	0.00915927	0.270872774	34304.38202
0.111	0.022	0.2426	0.00807858	0.232484928	30256.85393
0.113	0.023	0.4202	0.01424478	0.399100547	53351.23596

Fig 4.2: Front View of Plain Sand Bed Experiment

At Right Side of Flume (22.5cm width)

Table 4.3: Flow Properties at Right Side of Flume (22.5cm of Width) Case I

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.102	0	0.6264	0.01916784	0.6262059	71789.66292
0.107	0.03	0.5241	0.01682361	0.5115496	63009.77528
0.109	0.02	0.505	0.0165135	0.488364	61848.31461
0.11	0.019	0.14	0.00462	0.1347712	17303.37079
0.112	0.016	0.4202	0.01411872	0.4008783	52879.10112
0.112	0.018	0.3431	0.01152816	0.3273235	43176.62921

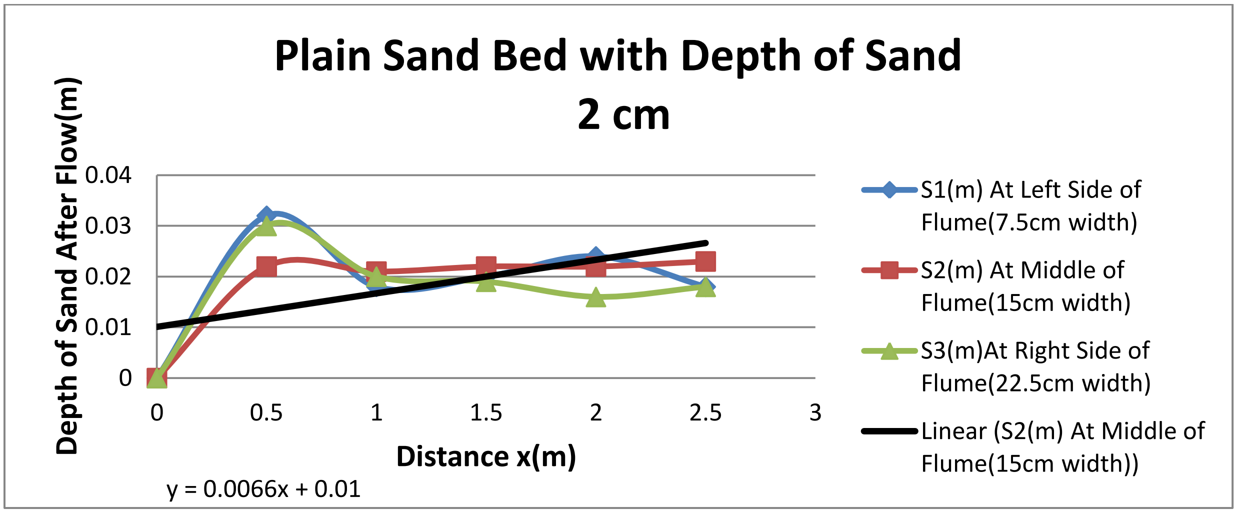

Fig. 4.3: Depth of Sand Curves for Plain Sand Bed

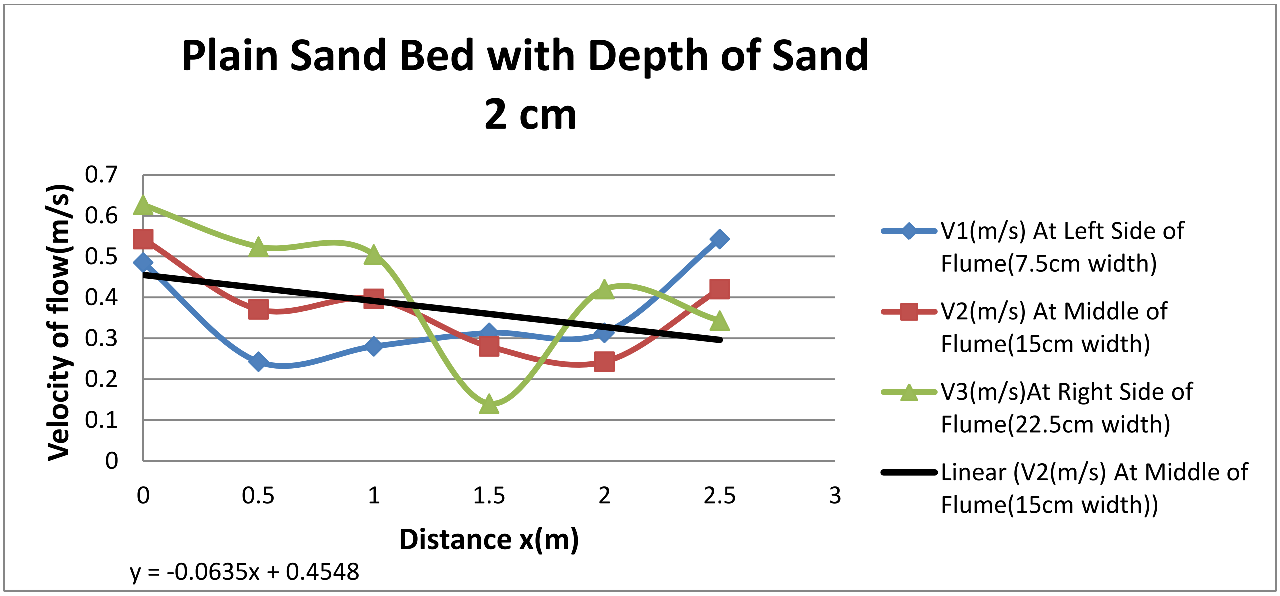

Fig. 4.4: Velocity of Flow Curves for Plain Sand Bed

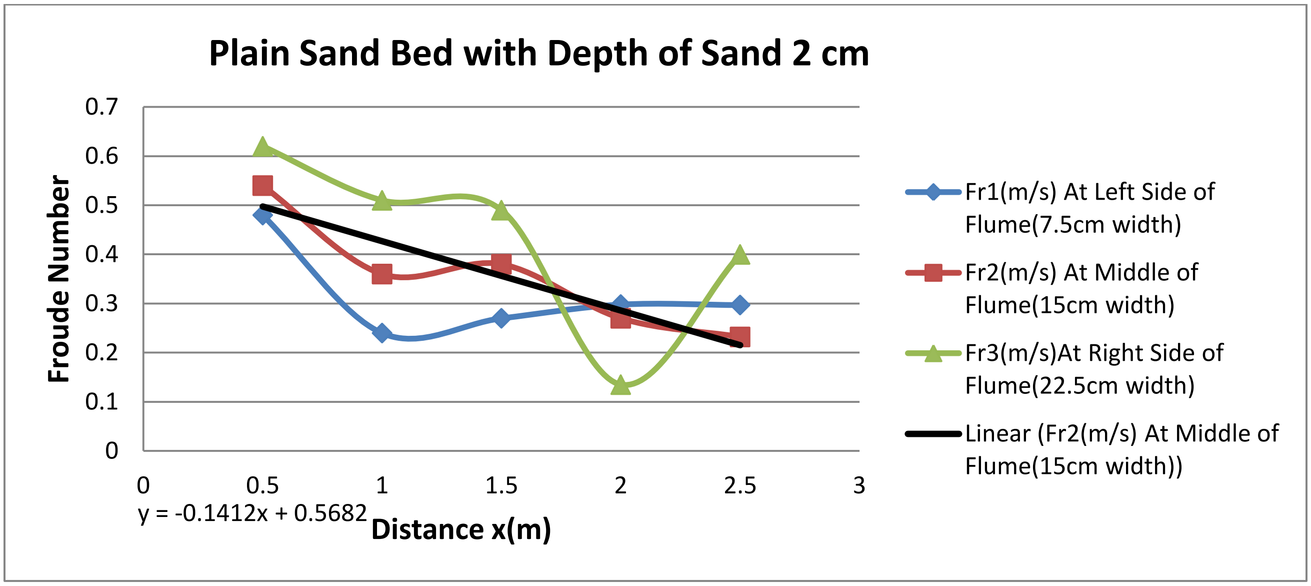

Fig. 4.5: Froude Number Curves for Plain Sand Bed

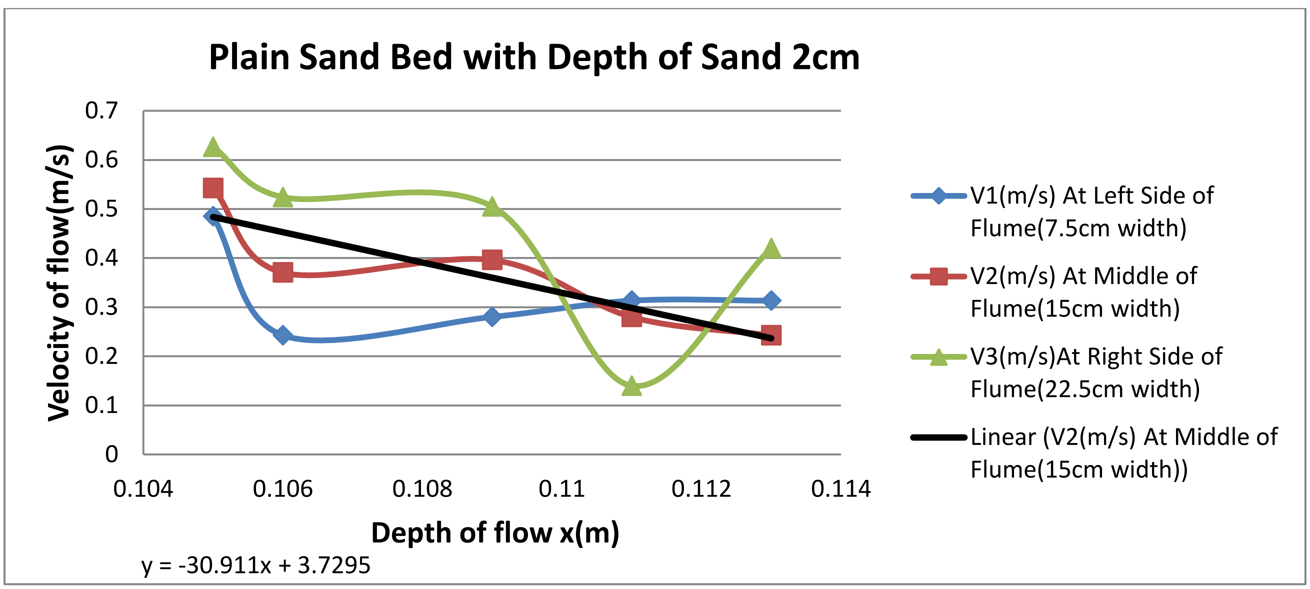

Fig. 4.6: Velocity of flow vs Depth of flow graphs for Plain Sand Bed

Case II(a): Five Uniform Groynes Installed in River flume with depth of sand bed 2cm thick

Fig 4.7: Flow of Water inside Flume for Case II (a)

At Left Side of Flume (7.5cm width)

Table 4.4: Flow Properties at Left Side of Flume (7.5cm of Width) Case II(a)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.081	0	0.198	0.0048114	0.222120262	18020.22472
0.087	0.025	0.198	0.0051678	0.214324125	19355.05618
0.089	0.012	0.2801	0.00747867	0.299766848	28010
0.093	0.013	0.2426	0.00676854	0.253988948	25350.33708
0.096	0.012	0.2426	0.00698688	0.249988872	26168.08989
0.106	0.016	0.2426	0.00771468	0.237904885	28893.93258

At Middle of Flume (15cm width)

Table 4.5: Flow Properties at Middle of Flume (15cm of Width) Case II(a)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.083	0	0.24256	0.006039744	0.268810132	22620.76404
0.089	0.021	0.3431	0.00916077	0.367190309	34310
0.092	0.017	0.2801	0.00773076	0.294838838	28954.1573
0.094	0.014	0.1401	0.00395082	0.145894764	14797.07865
0.098	0.013	0.2801	0.00823494	0.285670613	30842.47191
0.101	0.023	0.24256	0.007349568	0.243682305	27526.47191

Fig 4.8**:** Top View of Full Flume during Flow for Case II(a)

At Right Side of Flume (22.5cm width)

Table 4.6: Flow Properties at Right Side of Flume (22.5cm of Width) Case II(a)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.082	0	0.2801	0.00689046	0.3122998	25806.96629
0.088	0.019	0.3132	0.00826848	0.33709	30968.08989
0.091	0.017	0.2801	0.00764673	0.2964544	28639.4382
0.094	0.02	0.3706	0.01045092	0.3859286	39142.02247
0.097	0.014	0.3132	0.00911412	0.3210712	34135.2809
0.105	0.008	0.2801	0.00882315	0.275984	33045.50562

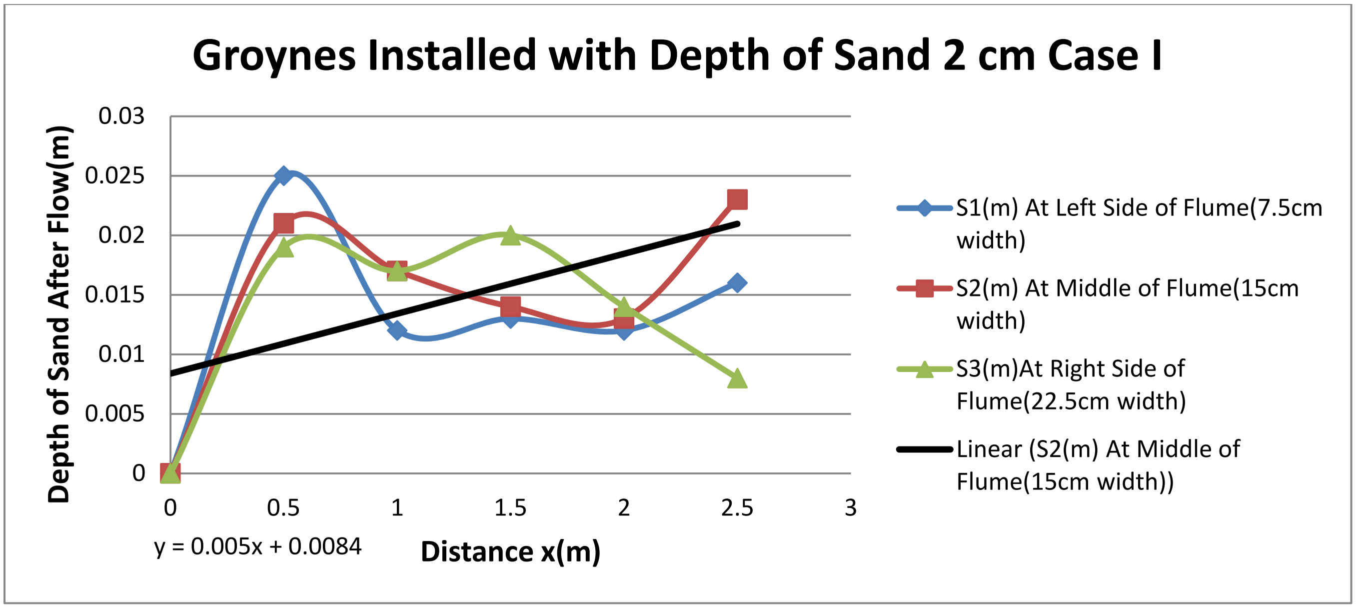

Fig. 4.9: Depth of sand Curves for Case 2(a)

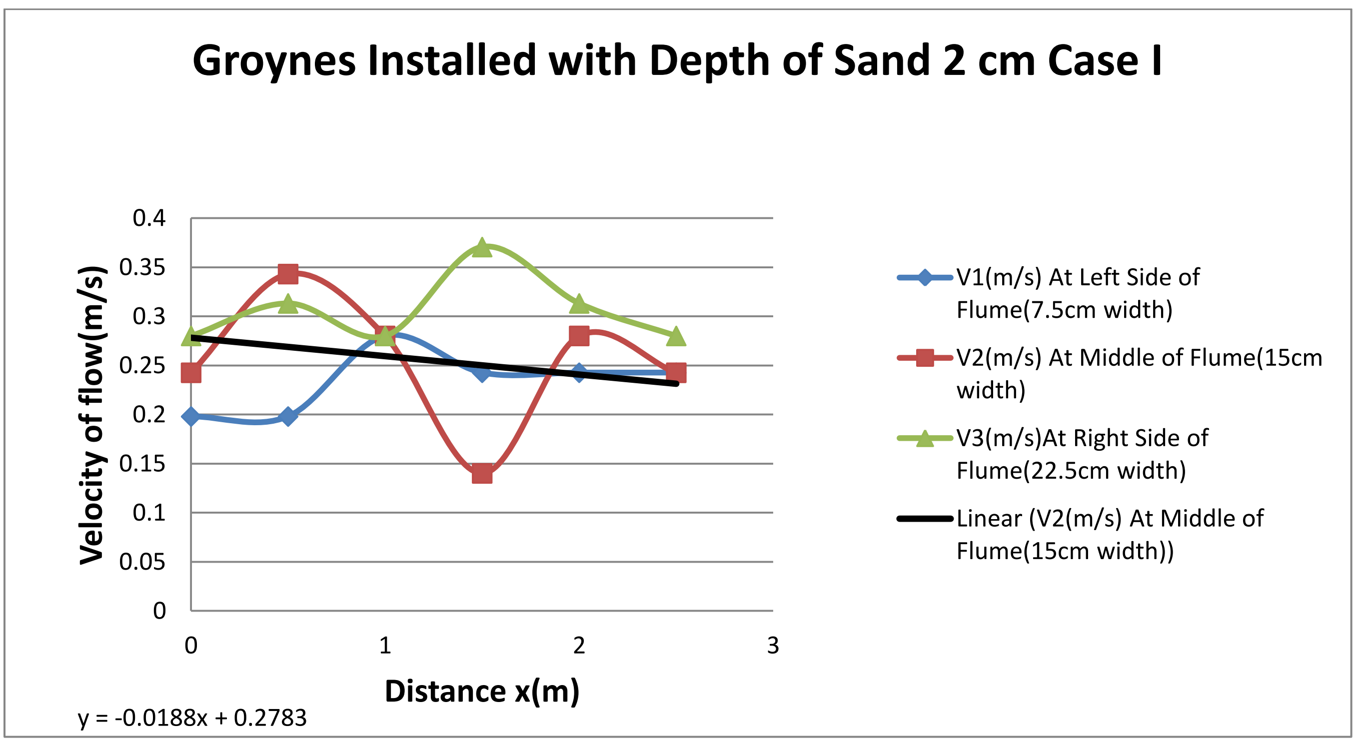

Fig.4.10: Velocity of flow Curves for Case 2(a)

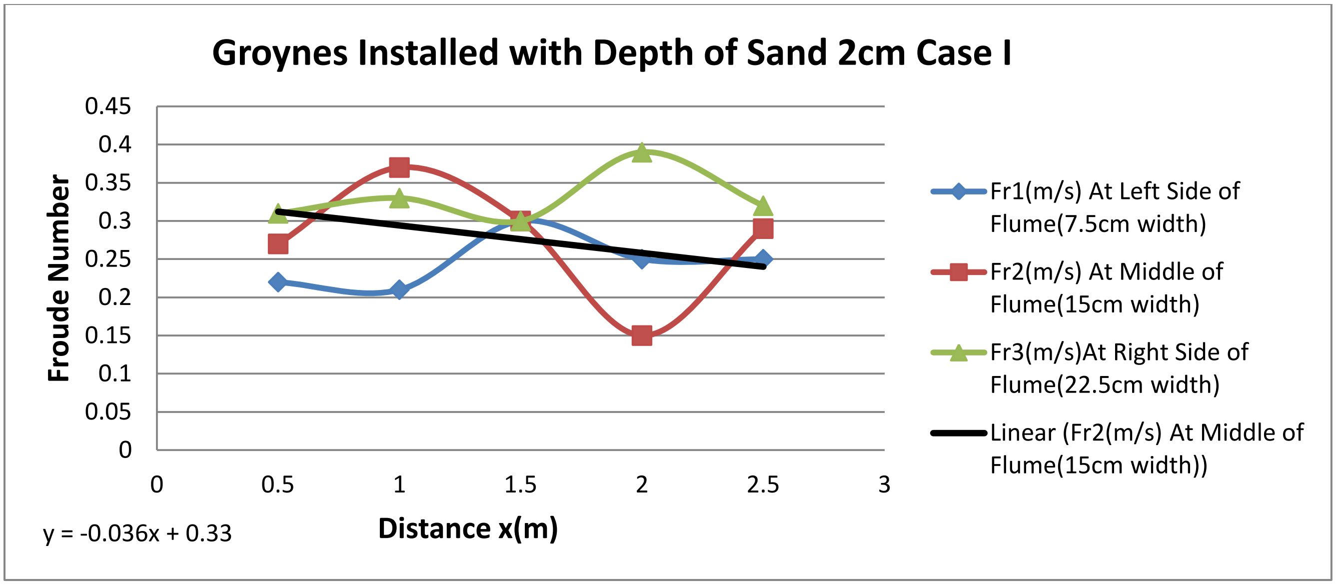

Figure 4.11: Froude Number Curves for Case 2(a)

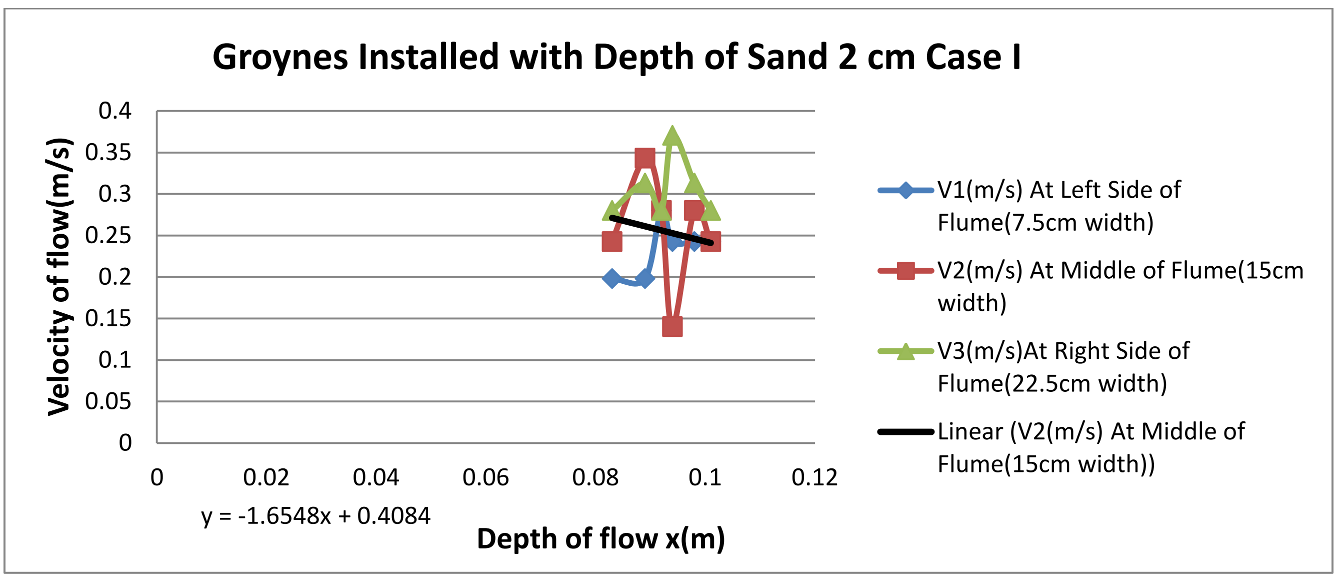

Fig. 4.12: Velocity of flow vs Depth of flow graphs for Case 2(a)

Case 2(b): Five Uniform Groynes Installed in River flume with depth of sand bed 2cm thick

At Left Side of Flume (7.5cm width)

Table 4.7: Flow Properties at Left Side of Flume (7.5cm of Width) Case II(b)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.122	0	0.14	0.005124	0.127971605	19191.01124
0.125	0.033	0.198	0.007425	0.178803362	27808.98876
0.13	0.013	0.3132	0.0122148	0.277341956	45748.31461
0.131	0.013	0.3132	0.01230876	0.276281371	46100.22472
0.134	0.013	0.2426	0.00975252	0.211594266	36526.29213
0.145	0.015	0.2801	0.01218435	0.234852184	45634.26966

Figure 4.13: View of dry River Bed of Flume after flow has taken place for Case 2(b)

At Middle of Flume (15cm width)

Table 4.8: Flow Properties at Middle of Flume (15cm of Width) Case II(b)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.124	0	0.3132	0.01165104	0.28397258	43636.85393
0.125	0.021	0.2801	0.01050375	0.252943544	39339.88764
0.128	0.017	0.3962	0.01521408	0.353569653	56981.57303
0.132	0.014	0.3132	0.01240272	0.275232861	46452.13483
0.135	0.013	0.4646	0.0188163	0.403717725	70473.03371
0.144	0.023	0.3431	0.01482192	0.288672204	55512.80899

At Right Side of Flume (22.5 cm width)

Table 4.9: Flow Properties at Right Side of Flume (22.5cm of Width) Case II(b)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.123	0	0.3431	0.01266039	0.3123444	47417.19101
0.125	0.022	0.3962	0.0148575	0.3577873	55646.06742
0.127	0.019	0.505	0.0192405	0.4524338	72061.79775
0.131	0.02	0.3132	0.01230876	0.2762814	46100.22472
0.135	0.017	0.505	0.0204525	0.4388236	76601.1236
0.145	0.012	0.198	0.008613	0.1660148	32258.42697

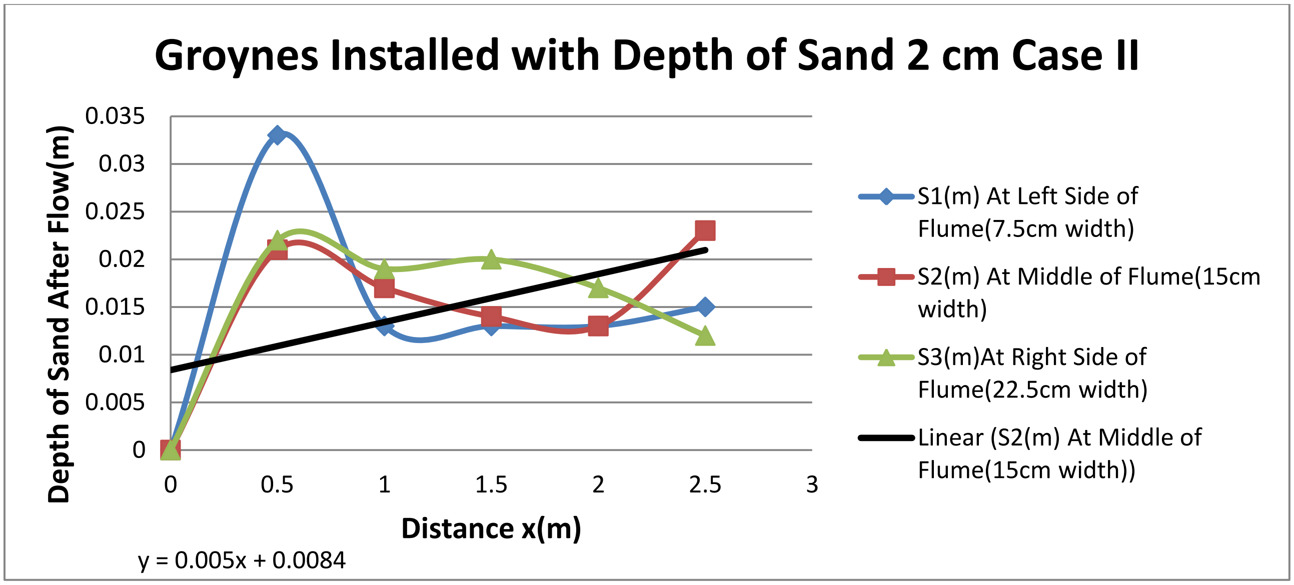

Figure 4.14: Depth of sand Curves for Case 2(b)

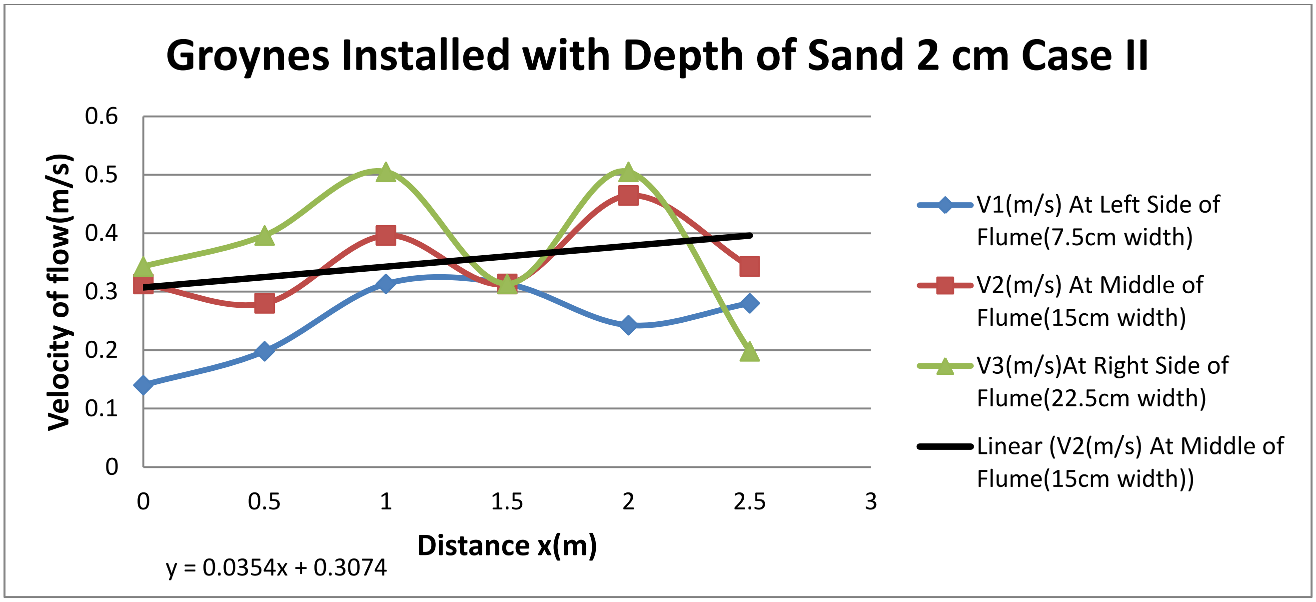

Figure 4.15: Velocity of flow Curves for Case 2(b)

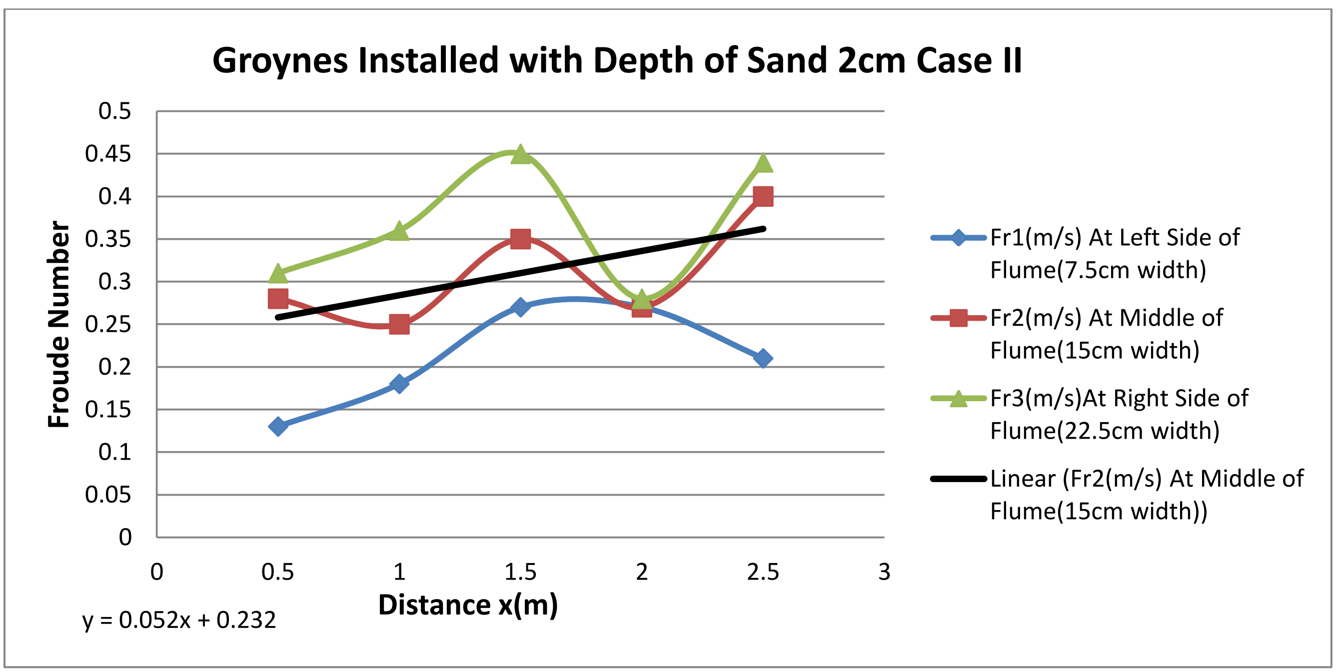

Figure 4.16: Froude Number Curves for Case 2(b)

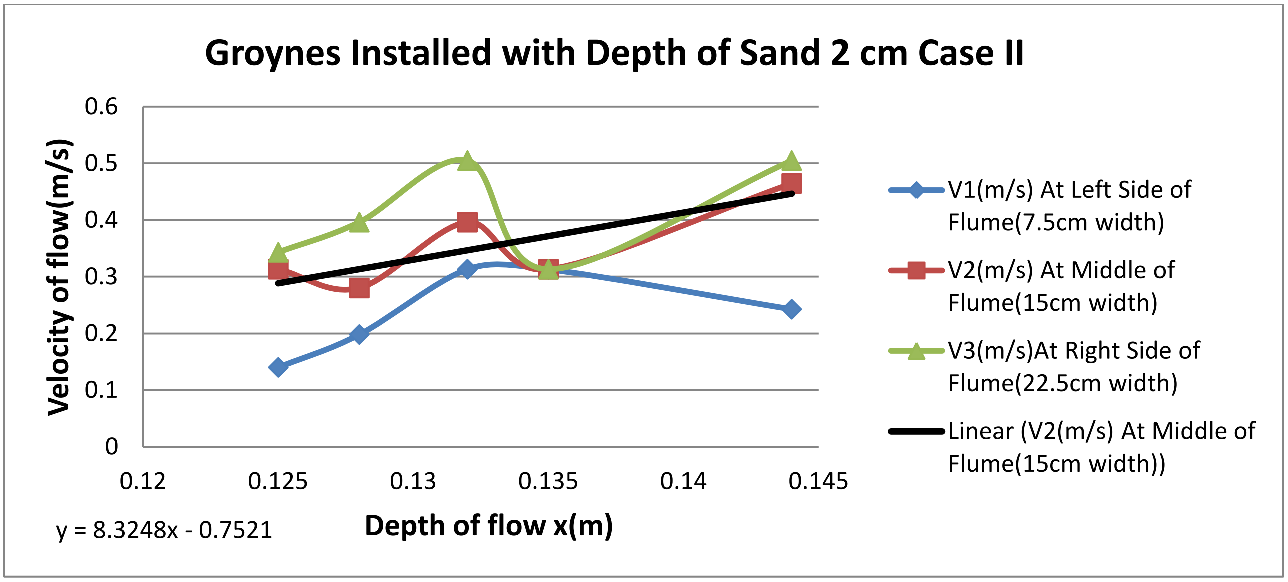

Figure 4.17: Velocity of flow vs Depth of flow graphs for Case 2(b)

Case 2(c): Five Uniform Groynes Installed in River flume with depth of sand bed 2cm thick

At left side of Flume (7.5cm Width)

Table 4.10: Flow Properties at Left Side of Flume (7.5cm of Width) Case II(c)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.143	0	0.3962	0.01699698	0.33451219	63659.10112
0.172	0.034	0.3431	0.01770396	0.264132591	66306.96629
0.178	0.012	0.4202	0.02243868	0.317988595	84040
0.184	0.011	0.2426	0.01339152	0.180570741	50155.50562
0.189	0.012	0.3132	0.01775844	0.2300151	66511.01124
0.198	0.014	0.3132	0.01860408	0.22472669	69678.20225

At Middle of Flume (15cm Width)

Table 4.11: Flow Properties at Middle of Flume (15cm of Width) Case II(c)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.151	0	0.2426	0.01098978	0.199327775	41160.22472
0.173	0.038	0.3132	0.01625508	0.24041646	60880.44944
0.179	0.015	0.5241	0.02814417	0.395506058	105408.8764
0.183	0.017	0.5241	0.02877309	0.391159706	107764.382
0.19	0.017	0.443	0.025251	0.324483354	94573.03371
0.196	0.026	0.443	0.0260484	0.319478169	97559.55056

Figure 4.18: Dry River Bed of Flume after flow has taken place for Case 2(b)

At Right Side of Flume (22.5 cm width)

Table 4.12: Flow Properties at Right Side of Flume (22.5cm of Width) Case II(c)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.152	0	0.198	0.0090288	0.162147	33815.73034
0.165	0.028	0.4646	0.0229977	0.3651764	86133.70787
0.18	0.021	0.5603	0.0302562	0.4216478	113319.1011
0.185	0.022	0.5775	0.03205125	0.4286784	120042.1348
0.189	0.019	0.5241	0.02971647	0.3849007	111297.6404
0.197	0.014	0.3431	0.02027721	0.2468045	75944.60674

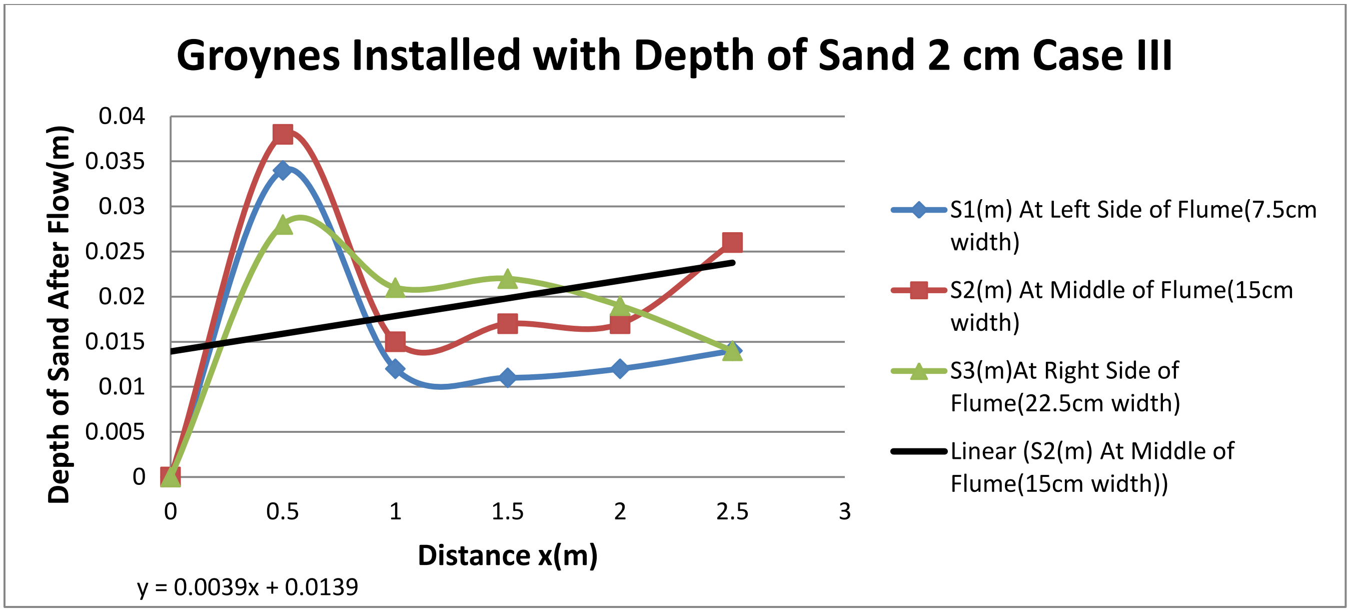

Figure 4.19: Depth of sand Curves for Case 2(c)

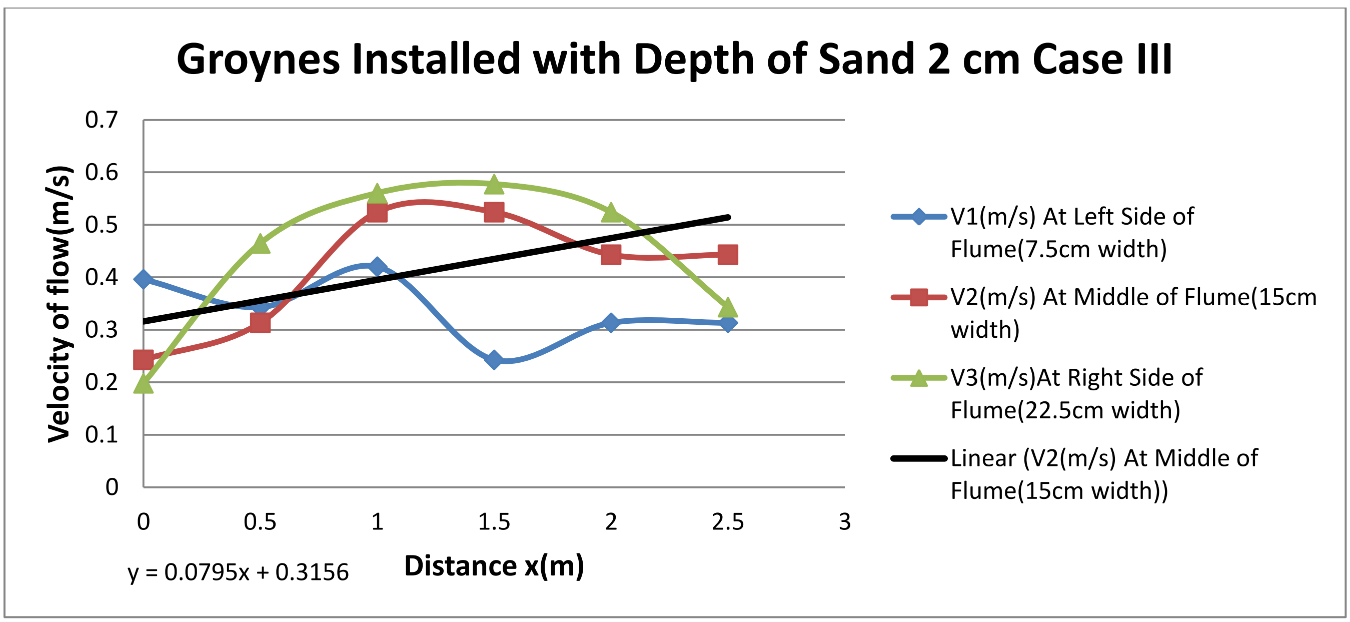

Figure 4.20: Velocity of flow Curves for Case 2(c)

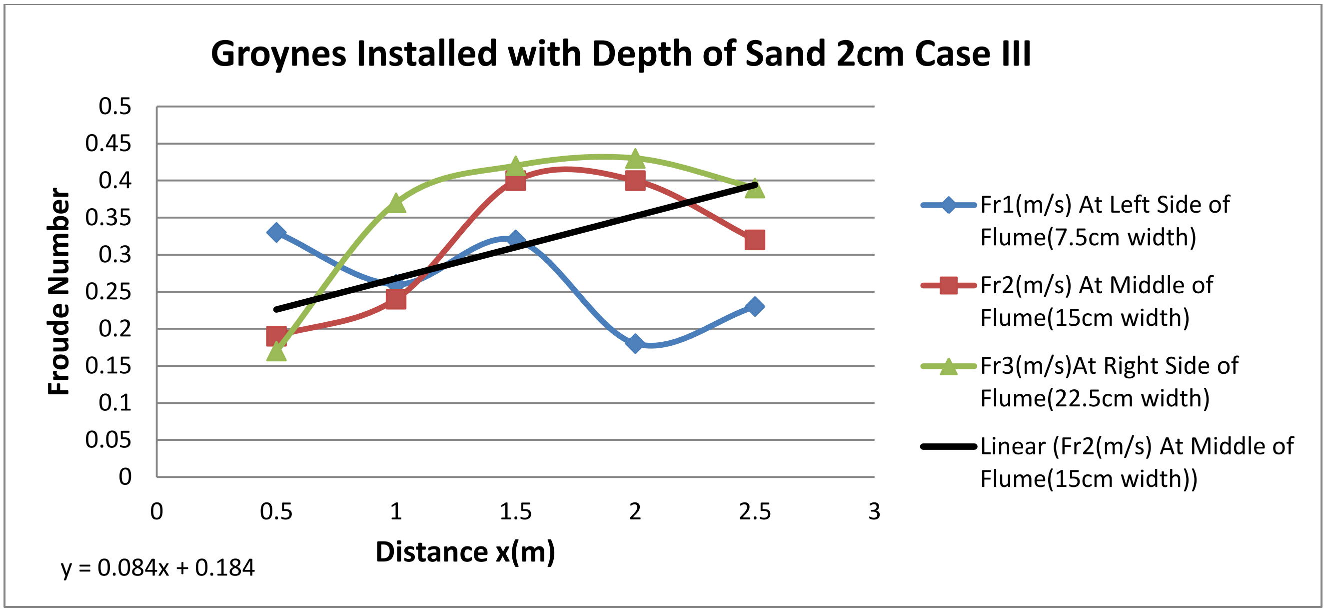

Figure 4.21: Froude Number Curves for Case 2(c)

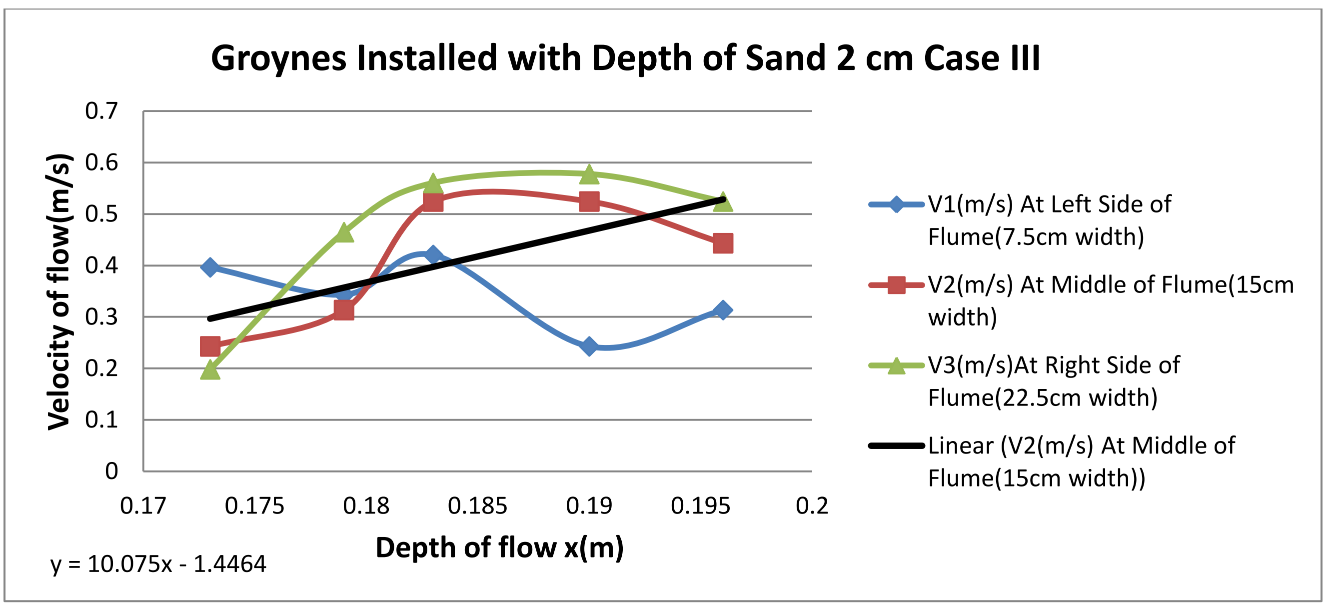

Figure 4.22: Velocity of flow vs Depth of flow graphs for Case 2(c)

Case 3(a): Five Uniform Groynes Installed In River Flume with depth of sand 1.5cm

Fig 4.23: View of Sand bed after test on Groynes with depth of sand initially 1.5cm

At left Side of Flume(7.5cm width)

Table 4.13: Flow Properties at Left Side of Flume (7.5cm of Width) Case III (a)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.087	0	0.714	0.0186354	0.772865786	69795.50562
0.096	0.023	0.2426	0.00698688	0.249988872	26168.08989
0.1	0.009	0.2801	0.008403	0.282799479	31471.91011
0.102	0.012	0.2801	0.00857106	0.280013209	32101.34831
0.104	0.017	0.3132	0.00977184	0.310077733	36598.65169
0.109	0.011	0.3431	0.01121937	0.33179739	42020.11236

Fig 4.24: Flow of Water in the flume for Case 3(a)

At Middle of Flume (15cm Width)

Table 4.14: Flow Properties at Middle of Flume (15cm of Width) Case III (a)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.083	0	0.767	0.0190983	0.850005653	71529.21348
0.095	0.033	0.2801	0.00798285	0.290146144	29898.31461
0.101	0.01	0.2426	0.00735078	0.24372249	27531.01124
0.111	0.015	0.3132	0.01042956	0.300141301	39062.02247
0.108	0.015	0.3132	0.01014768	0.304281376	38006.29213
0.11	0.019	0.2801	0.0092433	0.269638724	34619.10112

Fig 4.25: Formation of Scour Holes near Groyne tip for case 3(a)

At Right Side of Flume (22.5 cm width)

Table 4.15: Flow Properties at Right Side of Flume (22.5cm of Width) Case III (a)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.084	0	0.754	0.0190008	0.8306101	71164.04494
0.096	0.028	0.2426	0.00698688	0.2499889	26168.08989
0.102	0.01	0.2801	0.00857106	0.2800132	32101.34831
0.109	0.014	0.2801	0.00915927	0.2708728	34304.38202
0.11	0.013	0.3132	0.0103356	0.3015025	38710.11236
0.109	0.015	0.3132	0.01024164	0.3028824	38358.20225

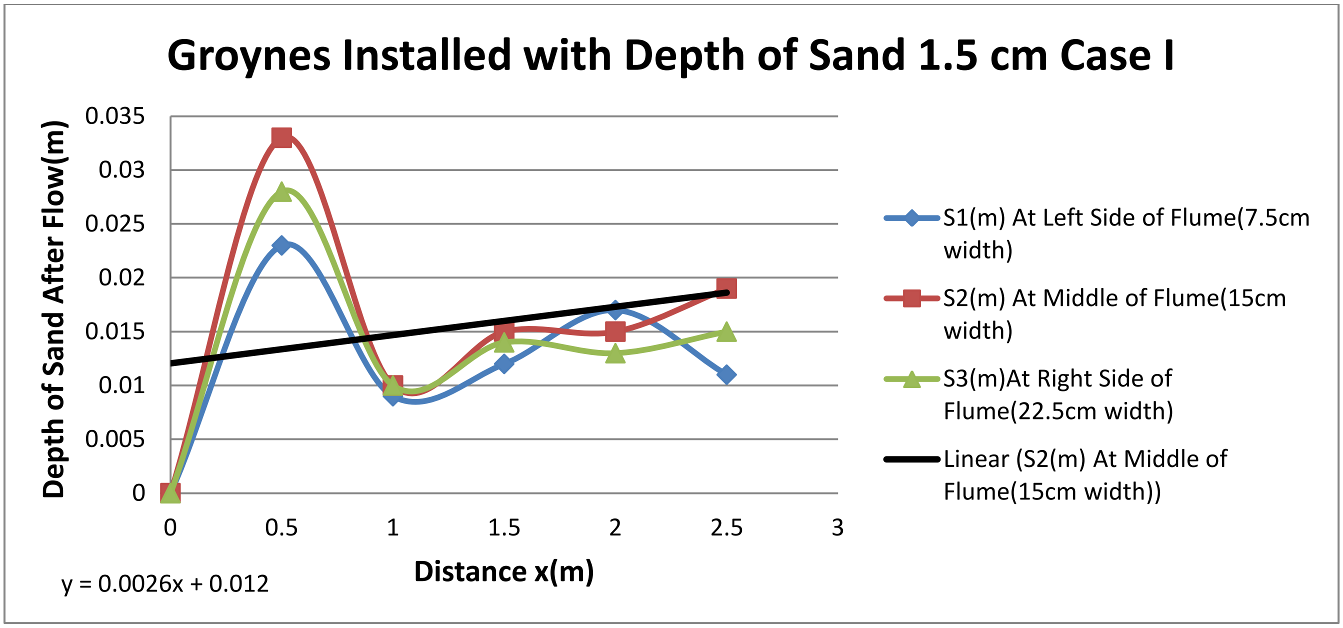

Fig. 4.26: Depth of sand Curves for Case 3(a)

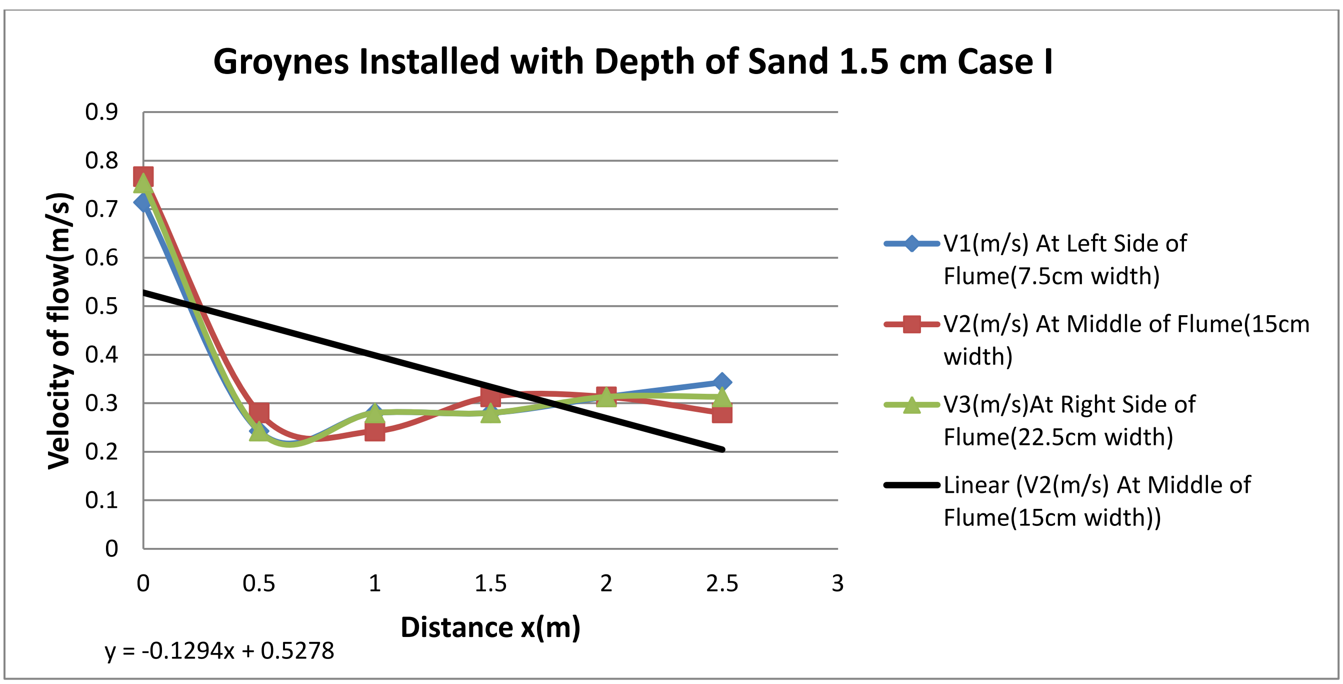

Fig 4.27: Velocity of flow Curves for Case 3(a)

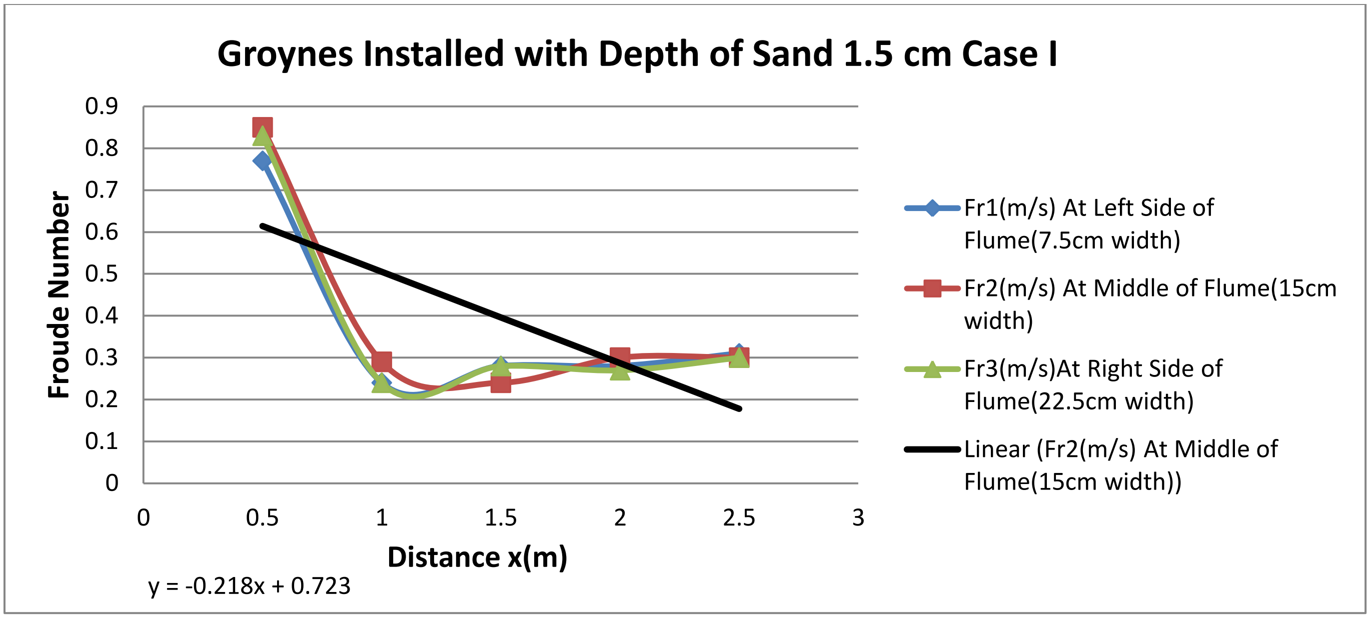

Fig 4.28: Froude Number Curves for Case 3(a)

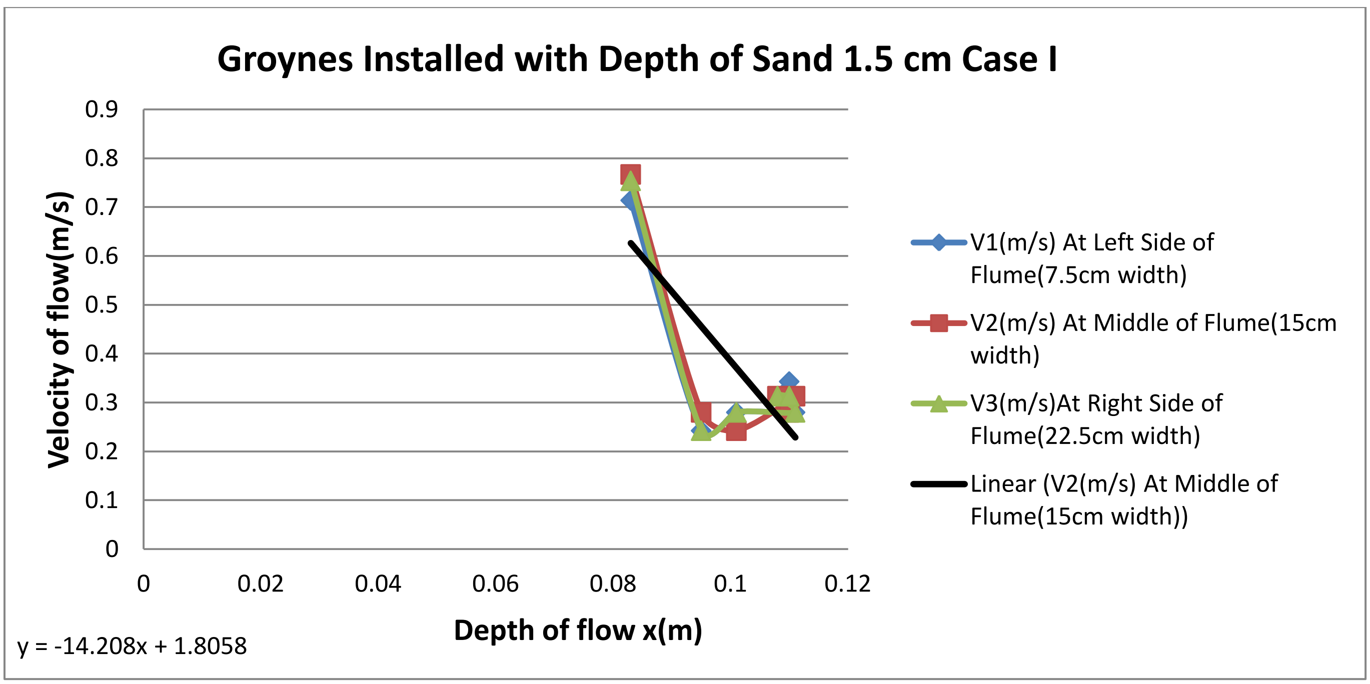

Fig 4.29: Velocity of flow vs Depth of flow graphs for Case 3(a)

Figure 4.30 Bed form Developed near Groyne tip for Case 3(a)

Case 3(b): Five Uniform Groynes Installed In River Flume with depth of sand bed 1.5cm

At Left Side of Flume (7.5 cm width)

Table 4.16: Flow Properties at Left Side of Flume (7.5cm of Width) Case III (b)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.118	0	0.4646	0.01644684	0.43182094	61598.65169
0.125	0.022	0.443	0.0166125	0.400049946	62219.10112
0.128	0.013	0.3132	0.01202688	0.279500291	45044.49438
0.13	0.013	0.3962	0.0154518	0.350839345	57871.91011
0.134	0.012	0.198	0.0079596	0.172694413	29811.23596
0.144	0.013	0.198	0.0085536	0.166590197	32035.95506

Figure 4.31: View of Sand bed after flow for Case 3(b)

At Middle of Flume (15cm Width)

Table 4.17: Flow Properties at Middle of Flume (15cm of Width) Case III (b)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.115	0	0.4646	0.0160287	0.437417125	60032.58427
0.127	0.021	0.2426	0.00924306	0.217347392	34618.20225
0.127	0.011	0.485	0.0184785	0.434515601	69207.86517
0.133	0.016	0.443	0.0176757	0.387831788	66201.1236
0.134	0.017	0.4202	0.01689204	0.366495921	63266.06742
0.141	0.014	0.2801	0.01184823	0.238160125	44375.39326

At Right Side of Flume (22.5cm width)

Table 4.18: Flow Properties at Right Side of Flume (22.5cm of Width) Case III (b)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.118	0	0.4202	0.01487508	0.3905535	55711.91011
0.125	0.023	0.3431	0.01286625	0.3098355	48188.20225
0.13	0.01	0.4646	0.0181194	0.4114083	67862.92135
0.131	0.014	0.443	0.0174099	0.3907811	65205.61798
0.134	0.016	0.443	0.0178086	0.3863819	66698.8764
0.142	0.016	0.4646	0.01979196	0.3936412	74127.19101

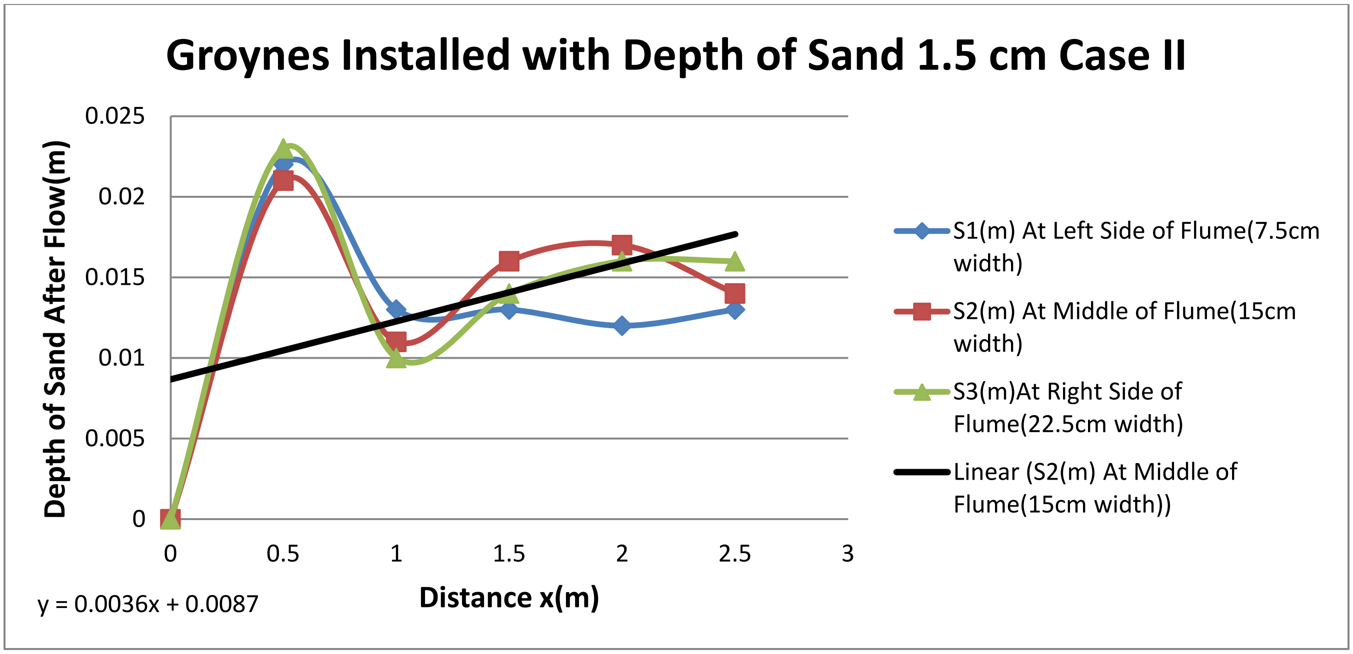

Fig 4.32: Depth of sand Curves for Case 3(b)

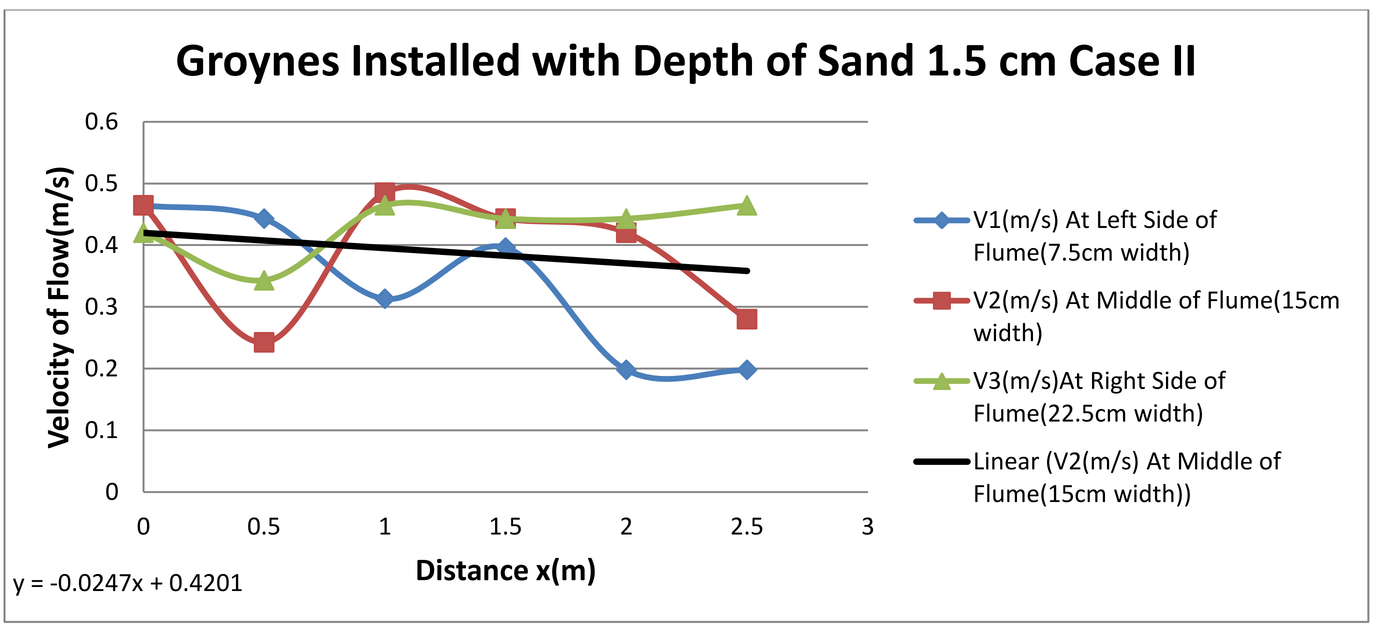

Fig 4.33: Velocity of flow Curves for Case 3(b)

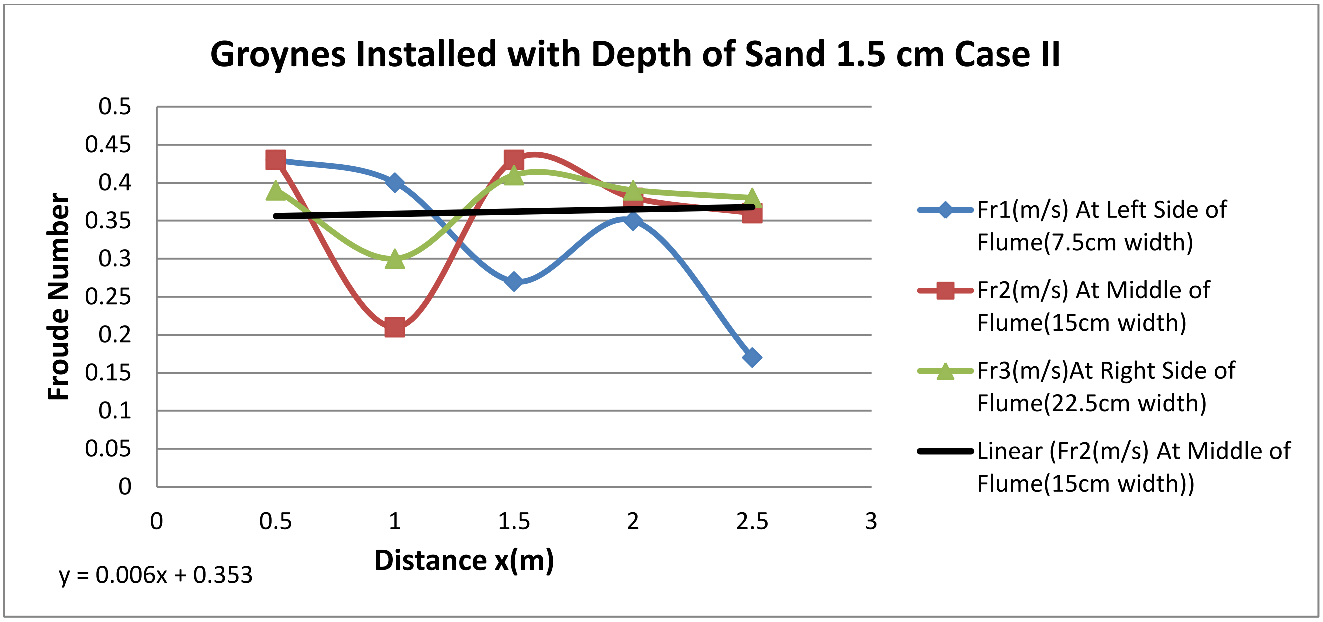

Fig 4.34: Froude Number Curves for Case 3(b)

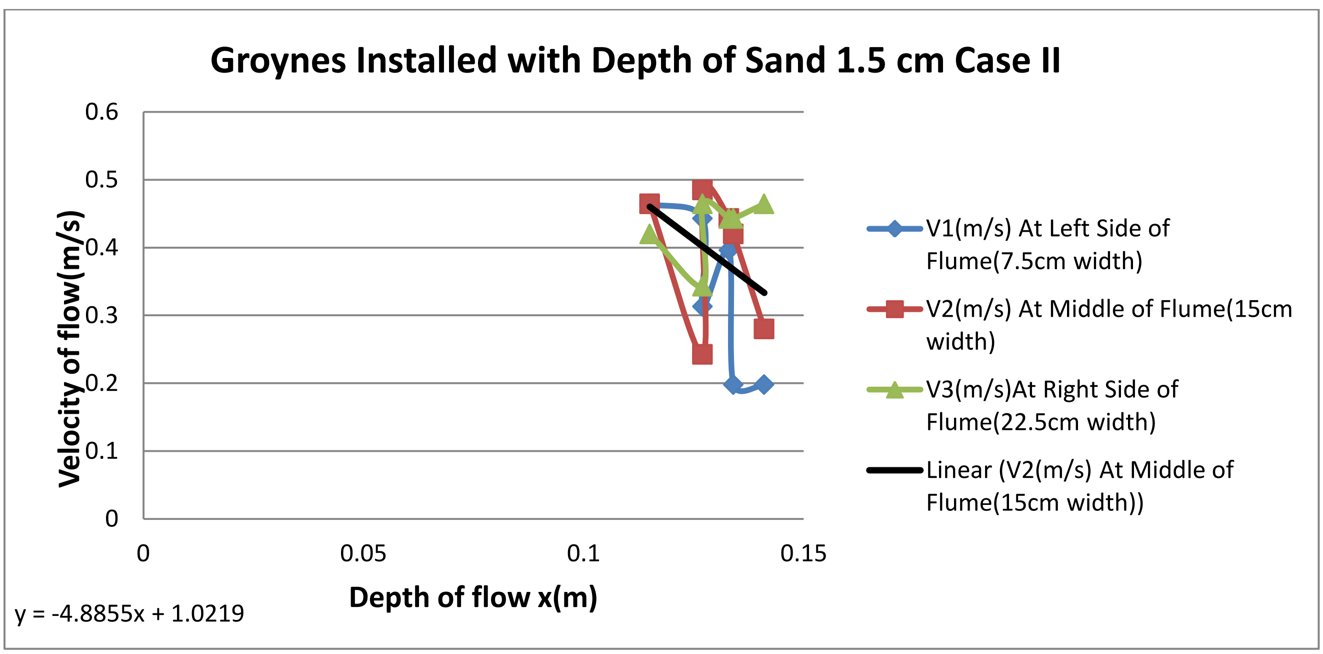

Fig 4.35: Velocity of flow vs Depth of flow graphs for Case 3(b)

Case 3(c): Five Uniform Groynes Installed In River Flume with depth of sand bed 1.5cm

Fig 4.36: Turbulence created in the flow by upstream currents for case 3(c)

At Left Side of Flume (7.5 cm width)

Table 4.19: Flow Properties at Left Side of Flume (7.5cm of Width) Case III(c)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.125	0	0.443	0.0166125	0.400049946	62219.10112
0.135	0	0.3431	0.01389555	0.29813937	52043.25843
0.137	0.017	0.2426	0.00997086	0.209264716	37344.04494
0.134	0.015	0.3132	0.01259064	0.273171162	47155.95506
0.14	0.011	0.3706	0.0155652	0.316232785	58296.62921
0.148	0.019	0.2801	0.01243644	0.23245974	46578.42697

Fig. 4.37: View of Sand bed after flow for case 3(c)

At Middle of Flume (15 cm width)

Table 4.20: Flow Properties at Middle of Flume (15cm of Width) Case III(c)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.126	0	0.3962	0.01497636	0.356364714	56091.23596
0.134	0	0.2801	0.01126002	0.244301541	42172.35955
0.137	0.015	0.2426	0.00997086	0.209264716	37344.04494
0.137	0.015	0.2426	0.00997086	0.209264716	37344.04494
0.138	0.015	0.3431	0.01420434	0.294880919	53199.77528
0.148	0.014	0.3706	0.01645464	0.307567225	61627.86517

Fig. 4.38: Formation of Scour Holes near Groyne tip for case 3(a)

At Right Side of Flume (22.5 cm width)

Table 4.21: Flow Properties at Right Side of Flume (22.5cm of Width) Case III(c)

Depth of flow(m)	Depth of Sand(m)	Velocity of Flow(m/s)	Discharge(cu.m/s)	Froude No.	Reynolds No.
0.127	0	0.3962	0.01509522	0.3549589	56536.40449
0.131	0.028	0.3132	0.01230876	0.2762814	46100.22472
0.13	0.017	0.4202	0.0163878	0.3720916	61377.52809
0.135	0.013	0.4202	0.0170181	0.365136	63738.20225
0.139	0.02	0.3962	0.01652154	0.3392912	61878.42697
0.148	0.023	0.2426	0.01077144	0.2013379	40342.47191

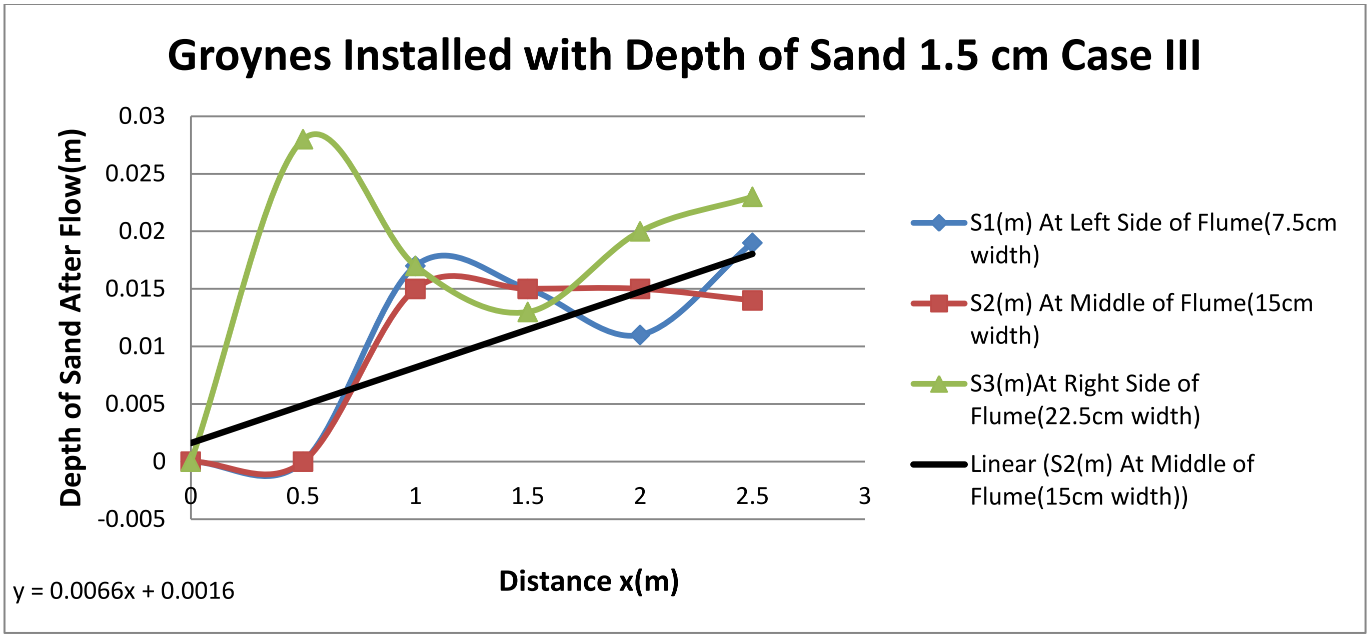

Fig. 4.39: Depth of sand Curves for Case 3(c)

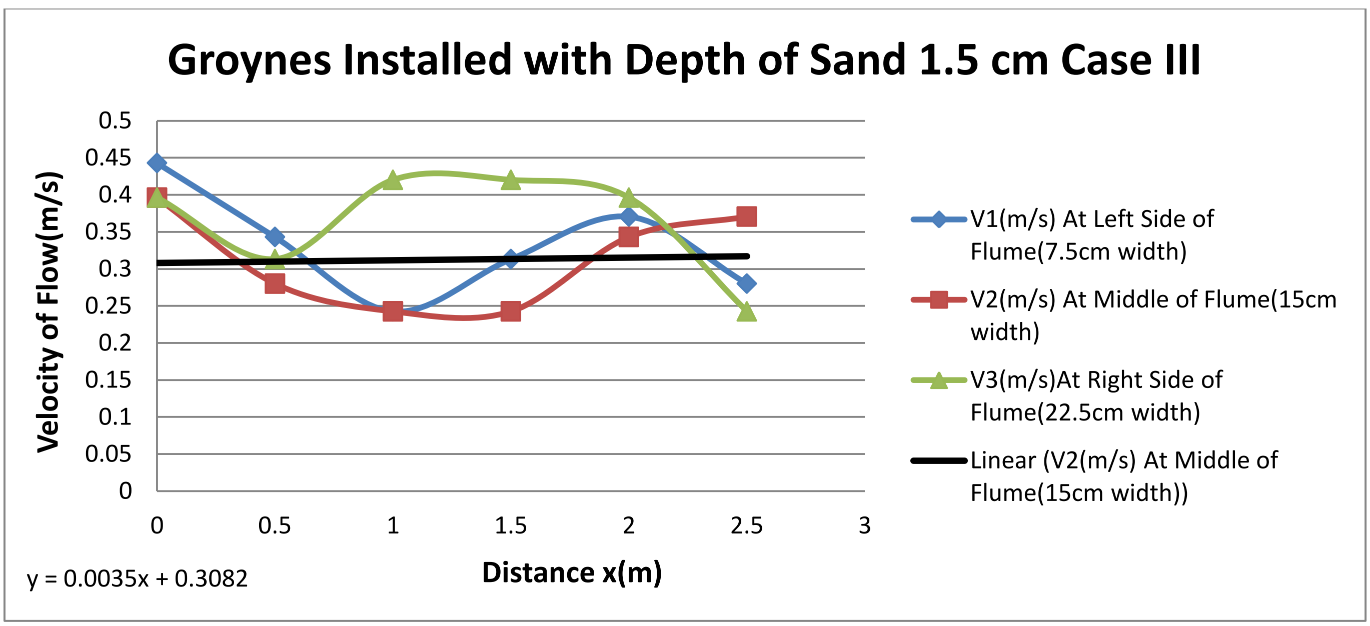

Fig. 4.40: Velocity of flow Curves for Case 3(c)

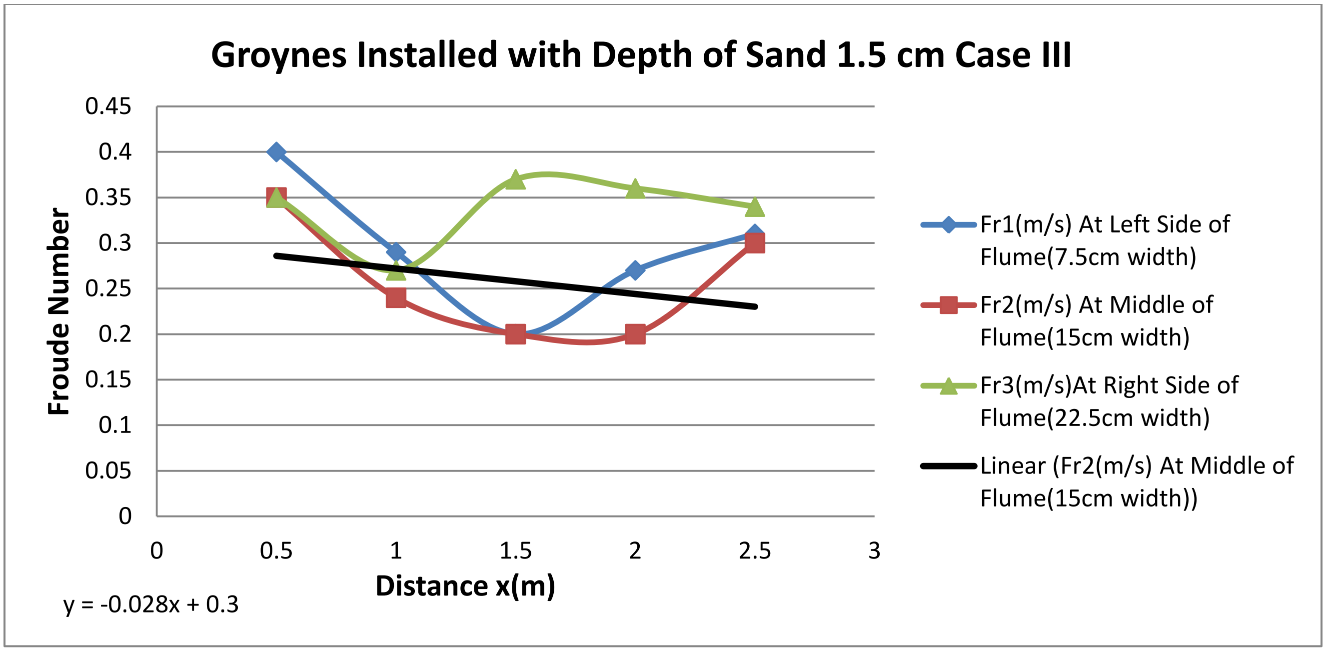

Fig. 4.41: Froude Number Curves for Case 3(b)

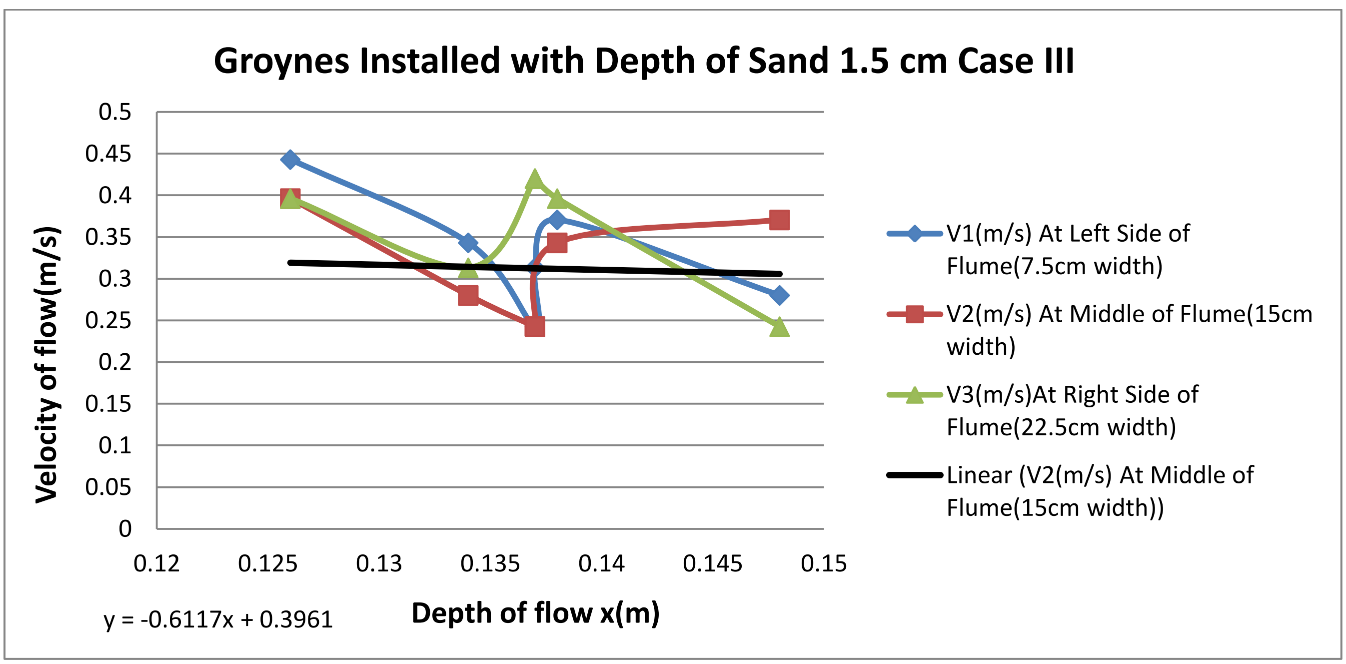

Fig. 4.42: Velocity of flow vs Depth of flow for Case 3(c)

CHAPTER 5

RESULTS AND DISCUSSIONS

Chapter 5

Results and Discussions

The areas between groynes were monitored to help understand the sediment transport process. The sediment deposition takes place in case of submerged groynes in the groyne field along the normal flow of the river and the sediments are transported into the groynes because of the mixing layer.

The linear pattern of the ripples in the half way of the groynes field show that some sediments deposit on the groynes. From the experimental photographs, it can be easily seen that the upstream part of the flume has got most of the soil eroded & deposition on the inner side of the upstream groynes.

The size of scour and the alignment depend on the level of water in case of submerged groyne. If the submergence of the groyne level increases, the scour depth reduces.

The various results that are generated from all experiments are as below:

(1)Plain Sand Bed with thickness of sand layer 2cm

(a)Sand Size: 0.125cm

(b)Thickness of sand layer: 2cm

(c)Weight of dry Sediment Sample: 12.793 gm

(d)Reynolds Number:

Maximum = 71789

Minimum= 17303

It clearly indicates that the flow is turbulent.

(e)Froude Number

Maximum =0.626

Minimum =0.1347

From tables and also from graph between Froude Number and depth of flow, we can easily see that the Froude number is less than 1. It clearly indicates that the flow is subcritical.

From fig 5.3, it has seen that the depth of sand initially increases and then decreases & from the best fit curve, it can be seen that there is deposition of sediments in the river in case of plain sand bed.

After seeing the graphs between distance of flume & the velocity of flow from fig.5.4, the velocity of flow has finally reduced in middle part of flume along the thalweg line & also in the groyne field, but has increased in the main river channel.

(2)(a)Five Uniform Groynes Installed in River Flume with thickness of sand layer 2cm

(a)Sand Size: 0.125cm

(b)Thickness of sand layer: 2cm

(c)Weight of dry Sediment Sample: 17.512 gm

(d)Reynolds Number:

Maximum =34135

Minimum= 14797

It clearly indicates that the flow is turbulent.

(e)Froude Number

Maximum =0.3859

Minimum=0.2143

From tables and also from graph between Froude Number and depth of flow, we can easily see that the Froude number is less than 1. It clearly indicates that the flow is subcritical.

From fig 5.9, it has seen that the depth of sand initially increases all along the flow. But later on in the main river there is deposition of sediments seen that there is erosion of sand in the groyne field area.

After seeing the graphs between distance of flume & the velocity of flow from fig.5.10, the velocity of flow has finally reduced in the groyne field, but has increased in the main river channel.

(2)(b)Five Uniform Groynes Installed in River Flume with thickness of sand layer 2cm with different depth of flow

(a)Sand Size: 0.125cm

(b)Thickness of sand layer: 2cm

(c)Weight of dry Sediment Sample: 14.175 gm

(d)Reynolds Number:

Maximum = 76601

Minimum= 19191

It clearly indicates that the flow is turbulent.

(e)Froude Number

Maximum =0.45

Minimum =0.128

From tables and also from graph between Froude Number and depth of flow, we can easily see that the Froude number is less than 1. It clearly indicates that the flow is subcritical.

From fig 5.14, it has seen that the depth of sand initially increases all along the flow and then decreases then decreases & again increases, and from best fit curve, it can be seen that there is deposition of sediments in the river in this particular case i.e. erosion is reduced.

After seeing the graphs between distance of flume & the velocity of flow from fig.5.15, the velocity of flow initially increases and then becomes same at 1.5m length for all widths of flume and the again increases and decreases all along the channel in the groyne field as well as the main river channel.

(2)(c)Five Uniform Groynes Installed in River Flume with thickness of sand layer 2cm again with different depth of flow

(a)Sand Size: 0.125cm

(b)Thickness of sand layer: 2cm

(c)Weight of dry Sediment Sample: 16.977 gm

(d)Reynolds Number:

Maximum = 111297

Minimum= 33815

It clearly indicates that the flow is turbulent.

(e)Froude Number

Maximum =0.428

Minimum =0.16

From tables and also from graph between Froude Number and depth of flow, we can easily see that the Froude number is less than 1. It clearly indicates that the flow is subcritical.

From fig 5.19, it has seen that the depth of sand initially increases for all cases and then decreases in groyne field and Main River channel but increases in the centre of the channel. The best fit curve tells us that it can be seen that there is deposition of sediments in the river in case of plain sand bed.

After seeing the graphs between distance of flume & the velocity of flow from fig.5.20, the velocity of flow initially increases. In the groyne field it increases up to a point & then starts decreasing. In the main river, it increases & decreases and again increases.

(3)(a)Five Uniform Groynes Installed in River Flume with thickness of sand layer 1.5 cm

(a)Sand Size: 0.125cm

(b)Thickness of sand layer: 1.5cm

(c)Weight of dry Sediment Sample: 16.836 gm

(d)Reynolds Number:

Maximum = 71529

Minimum= 26168

It clearly indicates that the flow is turbulent.

(e)Froude Number

Maximum =0.85

Minimum =0.243

From tables and also from graph between Froude Number and depth of flow, we can easily see that the Froude number is less than 1. It clearly indicates that the flow is subcritical.

From fig 5.26, it has seen that the depth of sand initially increases and then decreases. In the main river there is finally erosion of sand, but in the groyne field & the middle of the channel, there is deposition of sediments. From the best fit curve, it can be seen that there is net deposition of sediments in the river in this case. i.e where groynes are installed, there is control of erosion as compared to main river bed

After seeing the graphs between distance of flume & the velocity of flow from fig.5.27, the velocity of flow has finally reduced all along the length of flume & also in the groyne field & the best fit curve has also gone down.

(3)(b)Five Uniform Groynes Installed in River Flume with thickness of sand layer 1.5 cm with different depth of flow

(a)Sand Size: 0.125cm

(b)Thickness of sand layer: 1.5cm

(c)Weight of dry Sediment Sample: 15.723 gm

(d)Reynolds Number:

Maximum = 74127

Minimum= 29811

It clearly indicates that the flow is turbulent.

(e)Froude Number

Maximum =0.437

Minimum =0.166

From tables and also from graph between Froude Number and depth of flow, we can easily see that the Froude number is less than 1. It clearly indicates that the flow is subcritical.

From fig 5.32, it has seen that the depth of sand initially increases all along the flume and then decreases upto 1m distance & is then variable for all the 3 cases and near the downstream part of the channel it becomes same for all the cases. From the best fit curve, it can be seen that there is deposition of sediments in this case also.

After seeing the graphs between distance of flume & the velocity of flow from fig.5.33, the velocity of flow initially reduces all along the width of flume. In the main river, it reduces and again reduces, but in the groyne fields, after 0.5 cm length it increases & then becomes almost constant all along the length of flume.

(3)(c)Five Uniform Groynes Installed in River Flume with thickness of sand layer 1.5 cm again with different depth of flow

(a)Sand Size: 0.125cm

(b)Thickness of sand layer: 1.5cm

(c)Weight of dry Sediment Sample: 5.512 gm

(d)Reynolds Number:

Maximum =63738

Minimum= 37344

It clearly indicates that the flow is turbulent.

(e)Froude Number

Maximum =0.4

Minimum =0.201

From tables and also from graph between Froude Number and depth of flow, we can easily see that the Froude number is less than 1. It clearly indicates that the flow is subcritical.

From fig 5.38, it has seen that the depth of sand initially increases & there is huge increase in case of groyne bed as compared to main river channel up to 0.5m length of groyne and then decrease in depth of sand and then again increase in depth of sand for main channel as well as groyne bed. From the best fit curve, it can be seen that there is very large deposition of sediments in the river in this particular case.

After seeing the graphs between distance of flume & the velocity of flow from fig.5.39, the velocity of flow has initially reduced up to 0.5 m length of the flume & then it increases for groyne area & decreases for main channel of river & finally decrease for main channel as well as groyne area. The best fit curve for velocity is almost constant along the length of the flume.

CHAPTER 6

CONCLUSIONS

Chapter 6

Conclusions

The results lead to the following conclusions

(.1.)From all the above cases & their results, it is found that the Froude Number is less than one in all cases i.e. subcritical flow takes place in all cases & the full is fully turbulent. Although Reynolds number also tell the same thing, but in rivers it is turbulent flow only.

(.2.) In all tested cases, there was net import of sediments into the groyne fields except for the plain sand bed since there were no groynes in plain sand bed.

(.3.)From all set of experiments, the depth of sand is higher in case of groyne area as compared to main river channel. Although there is formation of scour holes near groyne tip but these help to deepen the channel surface where required so as to increase navigability in rivers.

The last case i.e. 3(c) has the least weight of sediment sample & also has the best curve among all samples of groynes as well as plain sand bed. The erosion control in this case is maximum as compared to other 6 experimental setup cases.

(.4.)In our case of submerged groynes, the sediment is transported to the groyne fields across the whole length of normal line. Diffusion through the mixing layer & secondary flow circulation play a role.

(.5.) There is formation of Scour holes near groyne tip. The scour holes are deeper in case of upstream groynes and are shallow in case of downstream groynes.

References

(1) Abad, J.D., Bruce, L.R., Güneralp, İ., García, M.H. 2008. "Flow structure a different stages in a meander-bend with bendway weirs," *Journal of Hydraulic Engineering*, 134(8), 1052-1063.

(2) Abe, S., 1982. On the effects of cross dykes on alternate bars, *Proc. of the Exeter symposium*. IAHS Publ. no. 138.

(3) Alauddin M. and Tsujimoto T., 2010a. Alignment of groynes for bank protection and maintaining thalweg for navigation in alluvial river with fine sediment. *Proc. Int. Conference on Hydro-Science and Engineering*, Chennai, India, pp.51-60.

(4) Alauddin, M. and Tsujimoto, T., 2010b. Interaction of groynes with large-scale sandbars at lowland rivers. *Proc. Int. Conference on Modern Hydraulic Engineering*, London Science Publishing Limited, pp. 51-54.

(5) Alauddin, M. and Tsujimoto, T., 2011a. Optimum design of groynes for stabilization of lowland rivers. *Annual Journal of Hydraulic Engineering*, *JSCE*, Vol.55, pp.145-150.

(6) Alexander Sukhodolov, Christof Engelhardt, Angela Kru¨ger; and Heinz Bungartz, 2004, *Case Study: Turbulent Flow and Sediment Distributions in a Groyne Field*.

(7) Bahar, S.M.H. and Fukuoka, S., 1999. The influence of submersible groins in series on bed geometry. *Annual Journal of Hydraulic Engineering, JSCE*, vol. 43, pp.671-676.

(8) Barkdoll, B., Ettema, R., Melville, B.W. 2007. *Countermeasures to protect bridge abutments from scour*, NCHRP Report 587, Transportation Research board, Washington, DC.

(9) Bathurst, J.C., Thorne, C.R., Hey, R.D. 1979. "Secondary flow and shear stress at river bends." *J. Hydraul. Div.*, ASCE, 105(10), 1277-1295

(10) Beckstead, G.R.E. 1978. *Groyne Design*, Master of Science Thesis, Colorado State University, Fort Colins, Colorado.

(11) Bradford, S. F. and Sanders, B. F., 2002. Finite volume model for shallow-water flooding arbitrary topography. *Journal of Hydraulic Engineering*, 128(3),pp.289–298.

(12) Charlton, R. 2008. "*Fundamentals of fluvial geomorphology"*, Routledge, New York, NY, 234p.

(13) Hassan Safi Ahmed, Mohammad Mahdi Hasan, Norio Tanaka, 2010, *Analysis of flow around impermeable groynes on one side of symmetrical compound channel: An experimental study*.

(14) Hong Koo Yeo, Joon Gu Kang, and Sung Jung Kim, *An Experimental Study on Tip Velocity and Downstream Recirculation Zone of Single Groynes of Permeability Change.*

(15) Henderson, F.M., 1966, *Open channel flow,* The Macmillan Company, New York.

(16) Jain, S. C., 2001, *Open-channel flow,* John Wiley and Sons, New York.

(17) Joongu Kang, Hongkoo Yeo, Changsung Kim, 2012, *An Experimental Study on a Characteristics of Flow around Groyne Area by Install Conditions.*

(18) Kandaswamy, P.K., Rouse, H., 1957, "*Characteristics of flow over terminal weirs and sills.*" J.Hydr. Engrg. Div., ASCE, 83, No. 4, 1345-1-1345-13.

(19) Lakshmana Rao, N.S., 1975, "*Theory of weirs, advances in hydroscience*." V.T. Chow, ed. Vol. 10, Academic press, New York, N.Y., 309-406.

(20) Leeuwen, van K.C. 2005, "*Kribben, literatuurstudie*", Universiteit Twente, Enschede.

(21) Mohamed F. M. Yossef and Huib J. de Vriend , 2011, *Flow Details near River Groynes:Experimental Investigation.*

(22) Mohamed F. M. Yossef and Huib J. de Vriend, 2010, *Sediment Exchange between a River and Its Groyne Fields:Mobile-Bed Experiment*

(23)Mosselman, E., Struiksma, N., 1992, *The effect of lowering groynes*, (Report No. Q1462), WL Delft Hydraulics, Delft.

(24) McCoy, A., Constantinescu, G., Weber, L. 2007. "A numerical investigation of coherent structures and mass exchange processes in channel flow with two lateral submerged groynes," *Water Resources Research*, 43, W05445, doi: 10.1029/2006WR005267.

(25) Melville, B.W. 1992. "Local scour at bridge abutments," *Journal of Hydraulic Engineering*, 118(4), 615-613.

(26) Melville, B.W. 1997. "Pier and abutment scour: integrated approach," *Journal of Hydraulic Engineering*, 123(2), 125-136.

(27) MuCullah, J., Gray, D. 2005. "Environmentally sensitive channel- and bank-protection measures." *NCHRP Report 544*, Transportation Research Board, Washington, D.C.

(28) Minor, B. 2006. *Barbs (submerged groynes) for river bend bank protection: application of a three-dimensional numerical model*, M.A.Sc. Thesis, University of Ottawa, Ottawa, ON.

(29) Minor, B., Rennie, C.D., Townsend, R.D. 2007a. ""Barbs" for river bend bank protection: application of a three-dimensional numerical model," *Canadian Journal of Civil Engineering*, 34, 1087-1095.

(30) Ockenfeld, K. and H. Guhr 2003: Groyne fields – sink and source functions of "flow-reduced zones" for water content in the River Elbe (Germany). *Water Science and Technology*, Vol. 48 No. 7 pp 17-24.

(31) PIANC Netherlands Section 1988: *Six-barge pushtow trials*. Excerpt from Bulletin No 62, Den Haag.

(32) PIANC 2003: *Guidelines for sustainable inland waterways and inland navigation*. EnviCom, Report of WG 6.

(33) Pilarczyk, K.W., H. Havinga, G.J. Klaassen, H.J. Verhey, E. Mosselman and J.A.A.M. Leemans 1990: *Control of bank erosion.*

(34) Rajaratnam, N., Nwachukwu, B.A. 1983a. "Flow near groin-like structures," *Journal of Hydraulic Engineering*, 109(3), 463-480.

(35) Rajaratnam, N., Nwachukwu, B.A. 1983b. "Erosion near groyne-like structures," *Journal of Hydraulic Research*, 21(4), 277-287.

(36) Rodi, W. 1993. "On the simulation of turbulent flow past bluff bodies," *Journal of Wind Engineering And Industrial Aerodynamics*, 46&47, 3-19.

(37) Rozovskii, I. L. 1965. "*Flow of water in bends of open channels*." Israel Program for Scientific Translation, Jerusalem, Israel.

(38) Rüther, N., Reidar, Olsen, N. B. 2005. "Three-dimensional modeling of sediment transport in a narrow 90º channel bend." *Journal of Hydraulic Engineering.*, 131(10), 917-920.

(39) Schetz, J.A., Fuhs, A.E. (eds) 1999. *Fundamentals of fluid mechanics*, John Wiley & Sons, 935p.

(40) Sukhodolov, A., Engelhardt, C., Krüger, A., Bungartz, H. 2004. "Case Study: Turbulent flow and sediment distributions in a groyne field," *Journal of Hydraulic Engineering*, 30(1), 1-9.

(41) Van der Wal, M. 2001: Approach to groyne innovation in the Netherlands. Neue Ergebnisse über physikalische und ökologische Prozesse an Buhnenfeldern (New insights in the physical and ecological processes in groyne fields)– workshop publication Magdeburg, pp. 33-37.

(42) Wallast, I. 1998: Exchange of dissolved matter between groyne field and main stream (in Dutch). MSc-thesis, Delft University of Technology, The Netherlands.

(.43.) Weitbrecht, V. and C. Hinterberger 2001: Ergebnisse von physikalischen und numerischen Experimenten an umströmten Buhnenfeldern. Neue Ergebnisse über physikalische und ökologische Prozesse an Buhnenfeldern (New insights in the physical and ecological processes in groyne fields)– workshop publication Magdeburg, pp. 63-77.

(44) Wim S. J. Uijttewaal, 2005, Effects of Groyne Layout on the Flow in Groyne Fields:Laboratory Experiments

(45) W. S. J. Uijttewaal, D. Lehmann, and A. van Mazijk, 2001, Exchange processes between a river and its groyne fields: model experiments.