EROSION PATTERN BELOW A CONCRETE APRON BY FLOW FROM A TAILRACE TUNNEL

By

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FINAL PROJECT REPORT

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in Partial Fulfillment of the Requirements
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CERTIFICATION OF APPROVAL

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Approved by,

(AP Dr Saied Saidi)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

JULIANA ZAKARIA

ABSTRACT

The analysis erosion occurrence below a concrete apron by flow from a tailrace tunnel is presented. The outcome from the analysis was used to determine the appropriate arrangement and sizes of baffle blocks to protect the bed material of the physical model from being eroded by the flow. The project was started with literature review on the basic concept of dam, sediment transport, properties of sediment, armoring and hydraulic jump. Study on erosion pattern which was conducted by other professional is also highlighted in the literature review. The study on analyzing scour occurrence has been conducted to explain the similarity existing in the scour process and profile including dune in the downstream of the scour hole. Altogether, twelve experiments to study the erosion profile have been carried out using six types of baffle block arrangements including two experiments without using the baffle blocks. The experiments took place at Pergau Pond Model in UTP lab. Sieve analysis test was conducted prior to the beginning of the experiment to determine the size of sediments that were used throughout the project. Sediments size used in the project range from 300μm to 350μm. Two discharges used in the project were 12L/s and 30L/s. The purpose of choosing the discharge are to ensure that the constant parameter being used. The reason being is also to observe the severity of the erosion occurrence if the discharge is too small and also if it is too large. It took one hour to complete each test. The pictures of scour pattern were taken as materials to be analyzed. Also, the patterns were drawn to scale whereby a plastic cover was spread onto the sediments. The maximum distance of scour dispersion from the apron were measured. Five lines of measurements were selected to measure the scour profile downstream the apron. The result indicated that the most severe erosion occurred at the downstream of the incoming flow from the tailrace tunnel. From the observation and comparison of maximum scour depth, the findings proved that Set 4 is the most efficient energy dissipater.

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CHAPTER 1

INTRODUCTION

In natural rivers, sand particles are moved by water flow near the bed. Sediment transport is a natural occurrence in the flowing of water in open channel. It is influenced by interrelationship between flowing of water and sediment particles. However, the continuous sand transportation near the riverbed incorporate with the inappropriate flow of water will lead to erosion and eventually a scour hole is formed near the riverbed.

Scouring is a natural phenomenon caused by the flow of water particularly in river or streams. Experience has shown that scouring can progressively destabilize the foundation of a structure. Due to the protection against scouring is usually excessively expensive, the designer must seek guide and control the process to minimize the risk of failure. The guidance can be established by study from laboratory and field from experience, both the successes and failures.

Scouring occurs naturally as part of the morphologic changes of rivers and as the result of man-made structures. The development of river valleys reveals such activity through millennia, long before man's effort had any appreciable impact on them. The addition of many types of structures has greatly altered rivers regime and significant impacts on the transport and deposition of sediment have resulted.

Natural scouring can cause changes in the plan, cross-section and even location of a river. Bends and narrows of a river channel tend to scour during floods and fill at low flows. Structural failures caused by scour usually occur in extreme cases of unsteady flows interacting with a given structure and with changing channel conditions. The composition of the sediments which is usually a mixture of alluvial sands, clay and weathered rock has also become the difficulties.

A stretch of river can display alluvium, clay banks, rock outcrops and bar of sand and gravel. The designer provides a further complexity by producing a wide variety of structural shapes and arrangements. The most dramatic and the most useful of the various types of guidance available are the failures that have occurred as a result of inadequate protection against scour.

Flow from a tailrace of hydropower station carries an enormous energy which has the capability to erode the riverbed. Severe and prolonged erosion at the upstream will cause the riverbed at downstream to rise due to sand deposition and eventually will result to the flood occurrences. To mitigate this situation from getting worsen, the energy from the supercritical flow must be reduced before it is released directly to the river.

The transition from supercritical flow to subcritical flow is called as hydraulic jump. The idea of forming hydraulic jump is to dissipate energy of supercritical flow from the spillway before it is discharged into the river. Therefore, an investigation on interactions between the fluid and sediment particles in open-channel flows is quite important in hydraulics and river engineering.

1.1) Background of project

The flow from the tailrace of hydropower station is supercritical carrying much energy capable of eroding the unprotected riverbeds. Depending on the flow Froude number, tailwater depth and the bed material an erosion profile will develop immediately, below any rigid bed that is placed immediately downstream of the incoming flow from the spillway, chute or tailrace tunnel. The laboratory test will be conducted on the existing tailrace outfall structures of a physical model at the UTP lab.

1.2) Problem statement

The flow from the tailrace of hydropower station is supercritical carrying much energy capable of eroding the unprotected river beds. The laboratory test will be conducted on the existing tailrace outfall structures of a physical model at the UTP lab.

1.3) Objectives

- To identify the erosion pattern below a concrete apron by flow from a tailrace tunnel.
- To come up with the solution to minimize the effect of erosion to the riverbeds.

1.4) Scope of study

- Reading the familiarity with erosion and stilling basin
- Data collection through Internet, library and correspondence
- Lab test in the available Pergau Pond Model in UTP lab
- Data analysis

CHAPTER 2

LITERATURE REVIEW

2.1) Dam

A dam is a barrier across flowing water that obstructs, directs or retards the flow, often creating a reservoir, lake or impoundment. Most dams have a section called a spillway or weir so that the water will flow either intermittently or continuously. Dams can be formed by human agency, natural causes, or by the intervention of wildlife such as beavers.

Dams which are formed by human agency are typically classified according to structure, intended purpose or height. It functions as :-

- a flood control structure
- an irrigation diversion structure
- tourists attraction.
- reservoir of water to supply industrial uses

The dams are classified based on the structural and material used in the construction. The common types of dam are :-

- **Gravity dam** : very stable as it size and shape that it will resist overturning, sliding and crushing at the toe.
- **Arch dam** : the stability is obtained by a combination of arch and gravity action
- **Embankment dam**: this dam is made of concrete rely on their weight to hold back the force of water

Large dams and weirs, for instance, have an important effect on the natural sediment transportation, resulting in :-

- the retention of sediment upstream of dams. The accumulated sediment has to be extracted to maintain the river's depth for hydropower generation and navigation.
- the loss of sediment downstream of dams, meaning that material must be artificially imported to stabilize the river bed .

2.2) Properties of Sediment

Size and shape: highly influence the transportability of sediment. Natural sediments consist of various irregular shapes. Granular sediments or coarse sediment are classified according to particle size, as in British Standard BS 1377: 1075, as shown in Table 1.

Table 1 Classification of granular sediments according to particle size, BS 1377: 1975

Type of sediments	Size	Types of sediments	Size
Very fine clay	0.24-0.5μm	Very fine gravel	2-4mm
Fine clay	0.5-1.0 μm	Fine gravel	4-8mm
Medium clay	1.0-2.0 μm	Medium gravel	8-16mm
Coarse clay	2.0-4 μm	Coarse gravel	16-32mm
Very fine silt	4-8 μm	Very coarse gravel	32-64mm
Fine silt	8-16 μm	Small cobbles	64-128mm
Medium silt	16-31 μm	Large cobbles	128-256mm
Coarse silt	31-62 μm	Small boulders	256-512mm
Very fine sand	62-125 μm	Medium boulders	512-1024mm
Fine sand	125-250 μm	Large boulders	1024-2048mm
Medium sand	250-500 μm	Very large boulders	2048-4096mm
Coarse sand	0.5-1.0 mm		
Very coarse sand	1.0-2.0mm		

Therefore, any single diameter used to characterize a certain group of grains must be chosen according to some convenient method of measurement. The usually adopted diameters or common definition of particle sizes are as follows ;-

- Triaxial diameter (a,b and c) : represent the major, intermediate and minor dimension of the particle measured along mutually perpendicular axes.

- Sieve diameter (*D*) : indicates the size of the size of the sieve opening through which the particle will just pass.
- Sediment diameter (D_s) : represent the diameter of sphere of the same specific weight and fall velocity as the given particle in the same sedimentation fluid with the same temperature. Also called as fall diameter.
- Nominal diameter (D_n) : represent the diameter of a sphere having the same volume as the given particle.
- Median diameter (D_{50}) : this diameter corresponds to the 50% finer by weight in the size distribution curve called the gradation curve.

Measurement of size distribution: size determination by sieving methods can be used for particles as small as 50 μm, but gives good result for particles down to 75 μm(sand fraction). The natural mean diameter is normally calculated by using d_{50}- size. It is the sieve analysis through which 50% of particles by weight pass. By using log-normal distribution, the geometric mean diameter can be determine by defined as :-

$$D_{50} = (D_{84} \times D_{16})^{1/2} \tag{E.1}$$

where D_{84} and D_{16} indicate that 84% and 16% has diameter smaller than D_{84} and D_{16} respectively. For instance, a sample with d_{84} =0.35mm, 84% by weight of the sample is less than 0.35mm in diameter. While the geometric standard deviation of a normally distributed particle-size distribution is

$$\sigma_g = \left(\frac{d_{84}}{d_{16}}\right)^{1/2} \tag{E.2}$$

in natural sand-bed streams, σ_g ranges between 1.4 and 2, but in gravel stream, it may reach values greater than 4.

2.3) Sediment Transport

Finer materials such as silts and clays can be transported very easily once they enter a channel and are washed through with only trace amounts left in the beds. The wash load is that part of the total suspended load that is finer than the bed material. The transport of larger size materials found in the bed material called the bed-material load. The various sediment transportations are shown below (Mays, 2001) :-

- Sediment load : Material in suspension/or in transport
- Bed-material load : Total rate at which bed material is transported by a given location on a stream(both bed load and suspended load)
- Bed Load : Material moving on or near the stream bed by rolling, sliding and sometimes making brief excursion into the flow a few diameters above the bed
- Wash Load : Part of total suspended load that is finer than bed material(wash load limited by supply not hydraulic
- Suspended solid : Includes both suspended bed material load and wash load. Sediment moves in suspension.

Suspension is a very important mode of transport of sediment since the quantities transported in suspension are usually much larger than those in bed load. Although the methods of description of suspensions are much more advanced than those in bed loads, these still yield only the distribution of sediment concentration with depth, given a reference concentration. It is not possible to compute the suspended sediment transport capacity of a given flow.

Another type of transport is wash load. The wash load consist of very fine particles, usually clay and fine silt. These particles are brought into the stream by bank erosion are usually are presented in quantities in the bed material. An additional source of wash load is the abrasion of gravel in transport. Wash load cannot be computed because it is not related to local hydraulic parameters.

2.4) Armoring

Armoring is the process of progressive coarsening of the bed layer by removal of fine particles until a layer is formed that becomes resistant to scour for a particular discharge. The armoring is a function of the applied shear stress. As the shear stress is increases, a condition will be reached where the surface does not armor anymore and all particles are indiscriminately transported by the flow. up to the limiting shear stress, the d50 particle sizes of the armor layer increases with shear stress.

2.5) Hydraulic Jump

Hydraulic jump is a transition from rapid flow to tranquil flow. By definition, hydraulic jump is a transition from supercritical flow to subcritical flow in open channel. The formation of jump will result to the increment of water depth after the jump. The important characteristics in dealing with hydraulic jump are :-

i. Classification of jump
ii. Depth after jump
iii. Length of jump
iv. Energy loss
v. Turbulence characteristic entrainment

The types of flow are determined by using Froude number, Fr as shown below:-

$$Fr_1 = \frac{V_1}{\sqrt{gy_1}} \tag{E.3}$$

where V_1 = velocity before jump, y_1= depth before jump

Following are the types of the hydraulic jumps in the horizontal rectangular channel corresponding to the Froude number:-

i. Undular Jump : $1.0 < F_1 \leq 1.7$
ii. Weak Jump : $1.7 < F_1 \leq 2.5$
iii. Oscillating Jump : $2.5 < F_1 \leq 4.5$

iv. 'Steady' Jump : $4.5 < F_1 \leq 9.0$

v. Strong or Choppy Jump : $F_1 > 9.0$

The jumps are also classified as follows :-

i. Free jump :when the tail water depth (y_t) which is available at the end of the jump is equal to the conjugate depth, y_2

ii. Force jump : where the formation of jump is aided by use of appurtenances such as chute blocks, baffle blocks or high end sills.

iii. Submerged jump :the available tail water depth, y_t is greater than conjugate depth y_2.

The expression for conjugate depths and hydraulic jump can be expressed by using the following equation:-

$$\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1+8F_{r1}^2} - 1\right) \qquad \text{(E.4)}$$

Meanwhile, the energy dissipation within the hydraulic jump can be derived from the energy equation as follows:-

$$\frac{\Delta E}{y_c} = \frac{\left(E_2 - E_1\right)^3}{4y_1y_2y_c} \qquad \text{(E.5)}$$

Figure 1 shows the typical formation of hydraulic jump in open channel. The section 1 is a supercritical flow with initial depth, h_1 and initial velocity, v_1 meanwhile at the section 2 after the jump occurs, the flow has become subcritical as the height increased and velocity is constant.

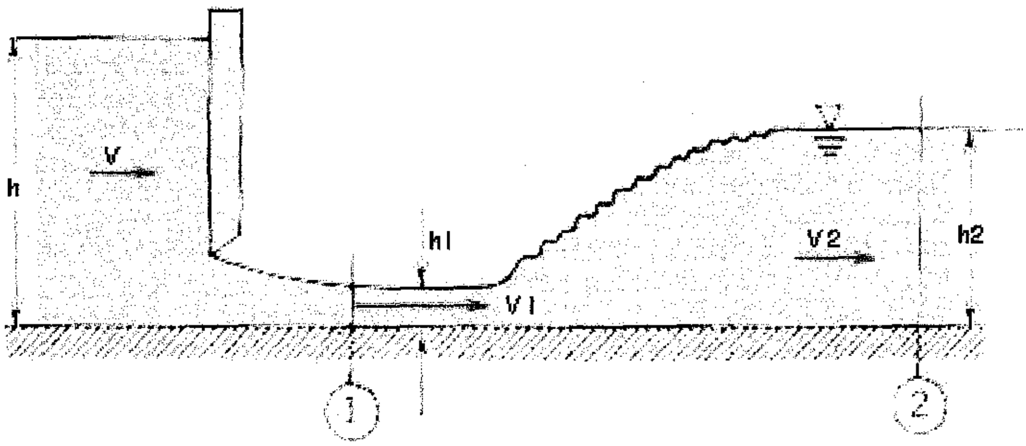

Figure 1 Hydraulic jump occurrence in open channel flow

2.6) Scour Downstream of Horizontal Apron in Stilling Basin

The most serious problem with the hydraulic jump dissipator is more of structural strength rather than hydraulic efficiency. In many years, it was found that many stilling basin suffer serious damage arising from uplift, vibration, cavitations and hydrodynamic loading. As Froude number increases, the turbulent size activity downstream of the basin also increases. Complete energy dissipation does not occur only within stilling basin, but also beyond the basin exit. As a result, scour hole may occur downstream of the basin. Damaging scour downstream of the stilling basin may result in structural damage or complete failure of the structure.

The scouring process downstream of a horizontal apron due to hydraulic jump occurrence leads to the abrupt change of flow characteristic on the sediment bed with time. The sediment bed following a smooth rigid apron of length L was initially planar and the stream flows in a direction parallel to the bed surface. This situation will increase the depression of free surface in the presence of sediment bed downstream of an apron which will enhance the erosive power of the hydraulic jump.

Scour starts at the downstream edge of the apron when the bed shear stress induced by the hydraulic jump exceeds the threshold bed shear stress for sediment movement. The evolution of the vertical dimension of the scour hole was faster than the longitudinal one.

In the initial stage, the suspension of sediment, in addition to the bed-load, was the main means of sediment transport. However, with the increase of the vertical dimension of the scour hole, the mode of sediment transport changed to bed-load only. The down-slope sliding and rolling movement of sediment took place when the bed shear stress induced by the hydraulic jump was reduced considerably with the development of the scour hole. The bed shear stress τ acting on the equilibrium scoured bed is estimated from the measured Reynolds stress profiles extended to the scoured bed.

Scour downstream of an apron due to submerged wall jets was studied by Dey and Sarkar in 2006. The experiment was carried out in an open channel flume with fixed and mobile bed which has the dimension of 0.6m wide, 0.7m deep and 10 m long. In the mobile-bed experiment, test was performed on scour of non-cohesive sediment beds downstream of a rigid apron. Figure 2 shows the schematic view of the experimental setup for the experiment.

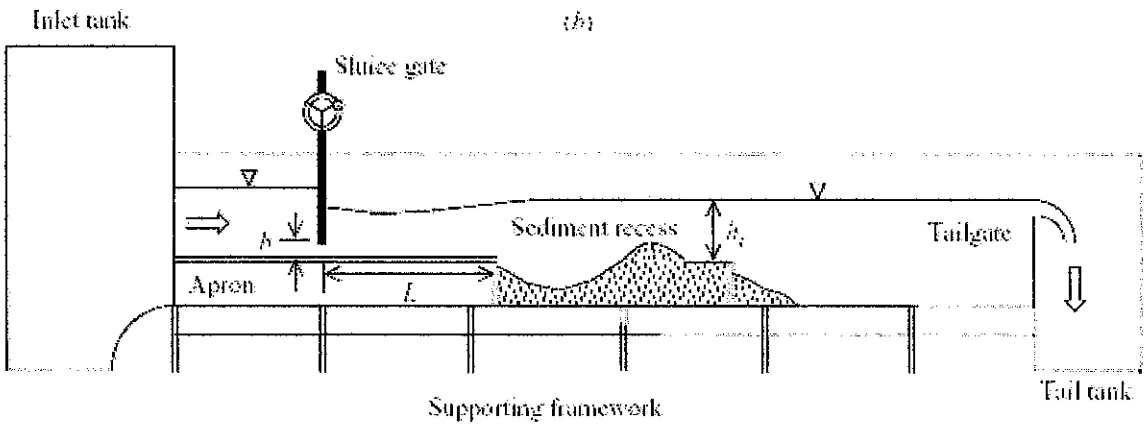

Figure 2 Schematic diagram of mobile bed experimental setup for scour downstream an apron due to submerged jet issuing from sluice opening (Dey and Sarkar, 2006)

In order to avoid the undesirable erosion, the flume was initially filled with water from the downstream side of the sediment recess. Once the water level reached the desired depth, the experiment was run by adjusting the desired value. The scour profiles were traced on a transparent Perspex sheet attached to the outside glass wall. Equilibrium scour profiles were obtained after 10 to 12 hours.

The forces acting on a sediment particle lying on the equilibrium scoured bed, shown in Figure 3 are the drag force F_D , lift force F_L and the submerged weight of a sediment particle F_G.

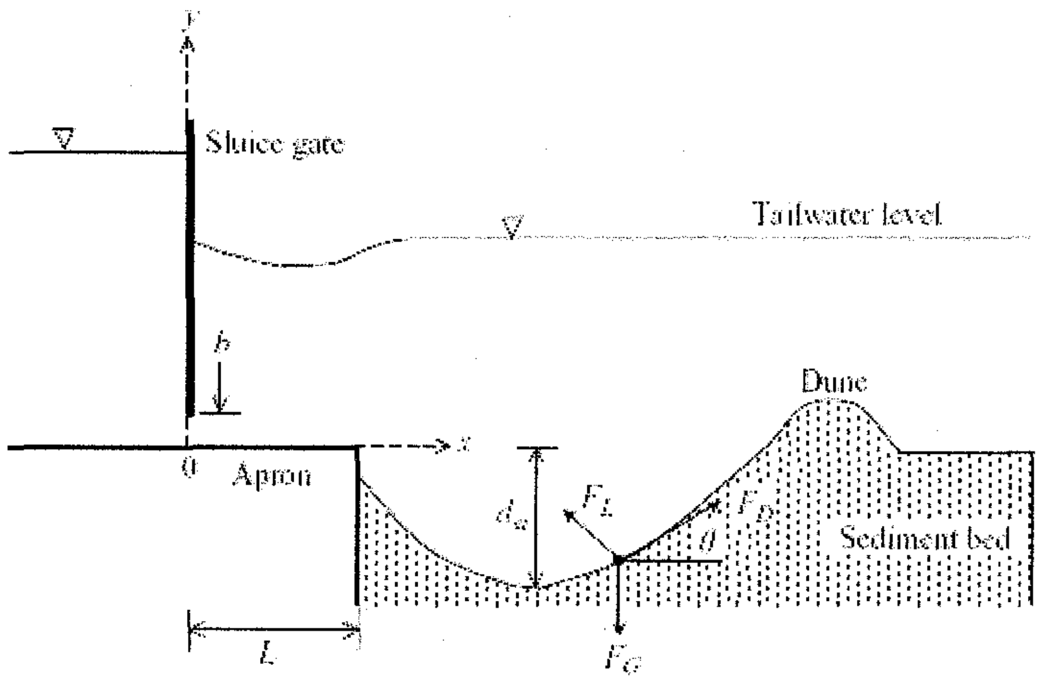

Figure 3 Schematic diagram of scour downstream of a horizontal apron (Dey and Sarkar, 2005)

It was assumed that the bed shear stress for the two-dimensional submerged wall jet on scoured bed is equivalent to that for the two-dimensional submerged wall jet on a smooth bed followed by a rigid rough bed given by the following equation, $\hat{\tau} = \tau / (\rho U^2)$.

This assumption leads to the approximation that the bed profile does not influence the characteristics of the submerged wall jet, or in other words, the aspect ratio of the scoured bed is small.

Figure 4 shows the non-dimensional profile of an equilibrium scour hole. From the profile it was observed that the sediment at the edge of apron were washed away, as a result which a small vertical portion of apron was exposed. The collapse of the computed and the experimental profiles was good within the scour hole.

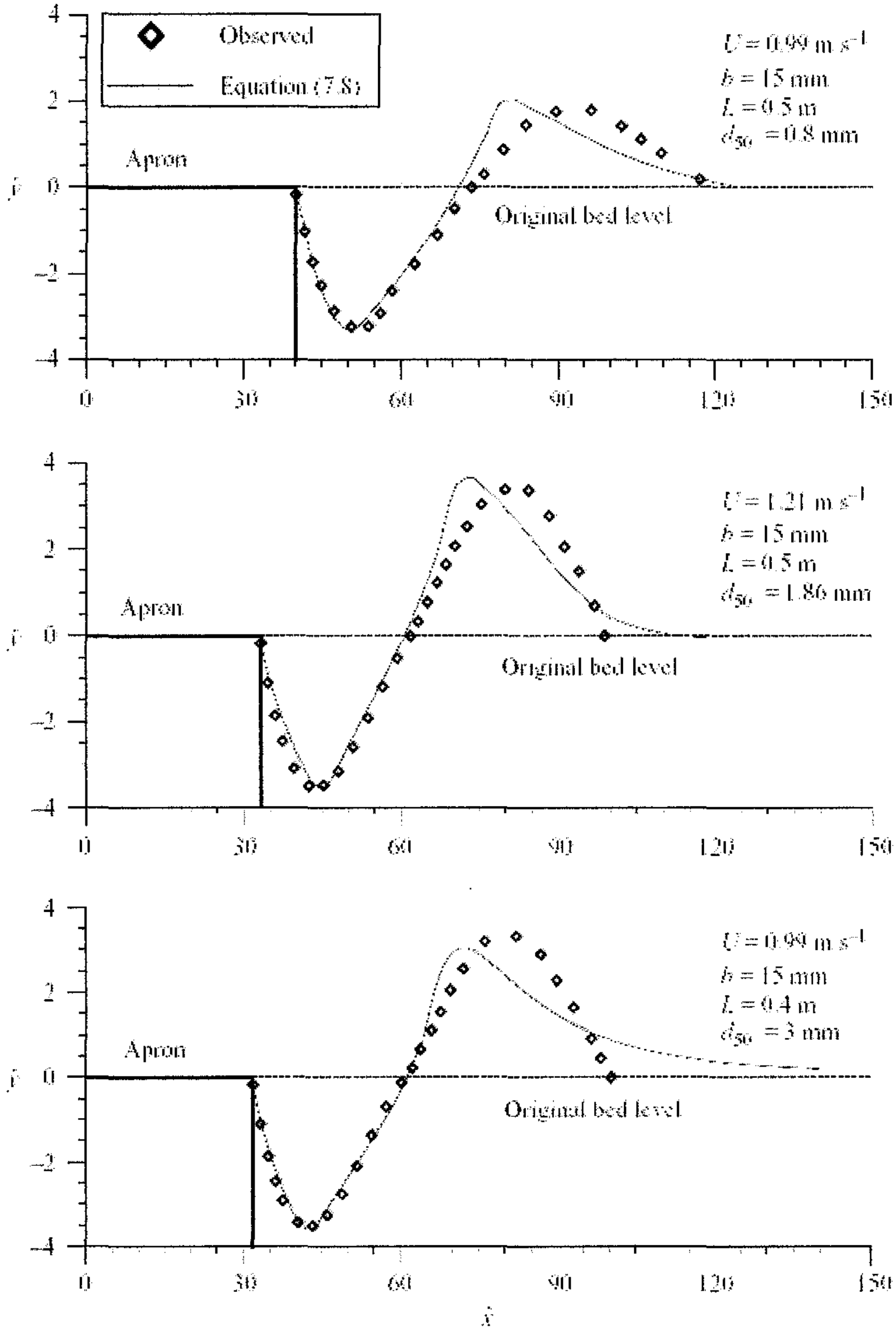

Figure 4 Comparison of computed and experimental scour profile (Dey and Sarkar, 2005)

The profile of the equilibrium scour hole has been calculated from the threshold condition of the sediment particles along the bed surface. The modification of the bed shear stress expression due to the variation of downstream scour profile has permitted the computation of equilibrium profiles of the scour holes.

As for conclusion, the profiles of the equilibrium scour hole have been calculated from the threshold condition of the sediment particles along the bed surface. The collapse of the results obtained from the model and the present experiment data was satisfactory (refer to Figure 4).

Another study has also been carried out by them to investigate the development of the scour hole in non-cohesive sediments downstream of an apron due to a submerged horizontal jet issuing from the sluice opening. The experiments were carried out in a glass-walled flume with the width of 0.6m, depth of 0.71m and length of 10m.

Scour initiates at the downstream edge of the apron when the bed shear stress exerted by the submerged the submerged jet exceeds the critical bed shear stress for the bed sediments. In the initial stage, the suspension of sediments was only means of sediment transport. But the development of the vertical dimension of the scour hole, the mode of sediment transport changed to a combination of suspended and bed loads.

The evolving scour hole at any time follows a particular profile as given in Figure 5. Typical scour profiles at different times during the development of the scour hole for run 1R8 are shown in Figure 6.

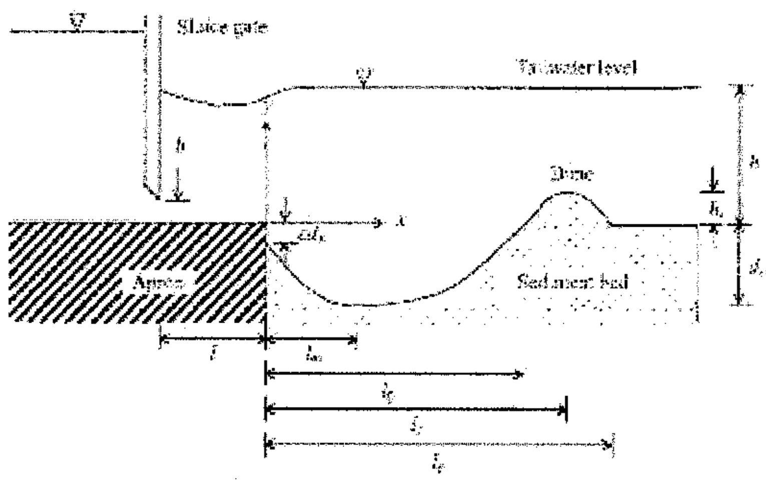

Figure 5 Schematic of scour hole (Dey and Sarkar,2006)

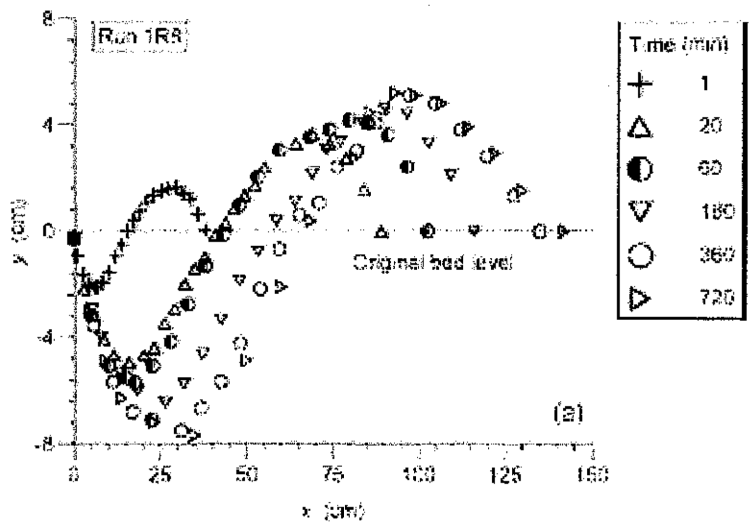

Figure 6 Scour profile of run 1R8 at different times(Dey and Sarkar,2006)

In non-cohesive sediments, a process of armoring in the scour hole commences, resulting in an exposure of coarser particles due to washing out the finer fraction. The maximum equilibrium scour depth and size of the scour hole reduce progressively increase in σ_g. Figure 7 illustrates the profile of the equilibrium scour with and without the apron. It proved that maximum equilibrium depth scour reduced significantly when a launching apron was used downstream of a rigid apron. It was observed that the maximum scour depth occurred just at the edge of the launching apron.

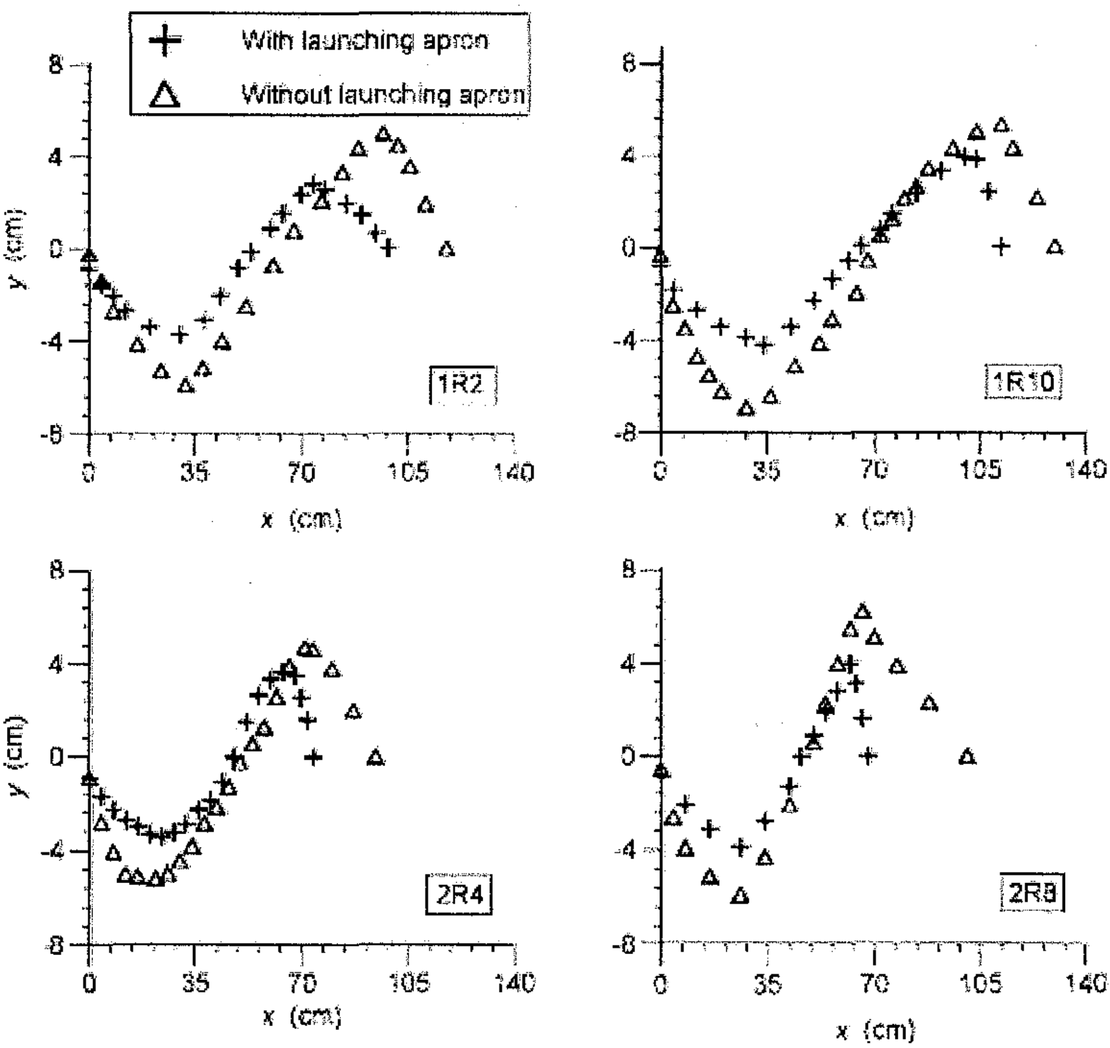

Figure 7 Equilibrium scour profile with & without launching apron(Dey and Sarkar,2006)

As conclusion, the scour profiles at different times have followed a particular geometrical similarity. The equilibrium scour depth increases with decrease in an apron length. It was also concluded that the equilibrium scour depth related to the sediment size relative to the sluice opening decrease with the increase in sediment size and sluice opening.

CHAPTER 3

METHODOLOGY

3.1) Familiarization with Pergau Pond Model

The pond as shown in Figure 8 was constructed in a 24m×12m laboratory space in Hydrology Lab. The pump, reservoir including ground and elevated, sump and most pipeline system are located in another 24m×12m Hydraulic Lab. The model was constructed in-door in order to safeguard the model against frequent scorching sunshine, accidents and loss. The model has the dimension of 27.m× 10m provided for manageable condition.

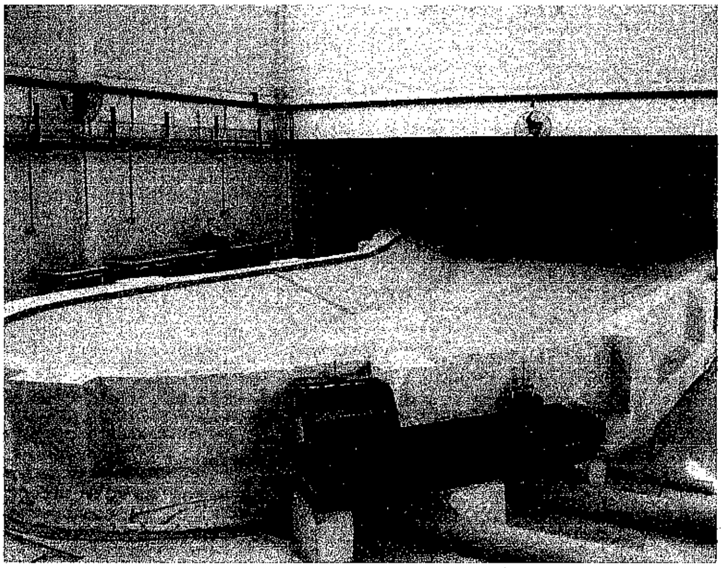

Figure 8 Pergau Pond Model

The saving water and adequacy of the water supply, circulation of water in a closed system was mandatory to ensure the sufficient water supply into the pond during the test was carried out. However, the available water storage volume introduced a serious constraint. The reason being was that in some tests, the pond and all pipes had to be filled with water while retaining reasonable volume in the sump for smooth operation in the pump.

The smallest structures of interest in the model were the baffle blocks on the concrete apron. Followings are the details of one of the baffle blocks arrangement which were used during the tests.

i. Biggest baffle block : 16.5 cm x 5.5 cm
ii. Smallest baffle block : 2.3cm x 3cm
iii. Baffle chute length : 1.37 m
iv. Riprap : 0.01cm -3cm

Tailrace outfall structure (TOS) lies in the heart of the model and study area(see Figure 9). The transition from the tunnel to the square section, small stilling basin and guide walls were made of clear Perspex as it was necessary to see the flow phenomena. The apron was made of concrete.

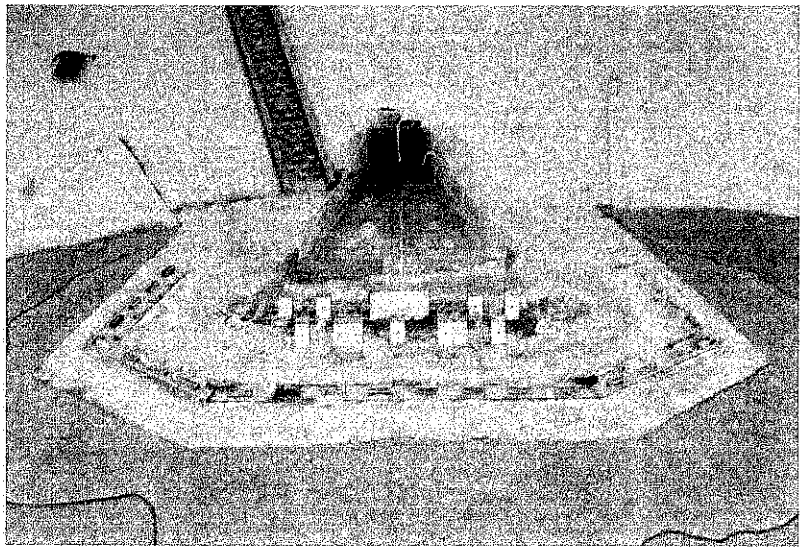

Figure 9 Tailrace Outfall Structure (TOS)

3.2) Experimental observation on the hydraulic jump formation in the flume

An experiment in the hydraulic lab was carried out to analyze hydraulic jump over a spillway in the flume with the dimension of 12 m long, 0.32 m width and 0.47 m height. Following were the procedure involved in the experiment:-

i. The pump was turned on to fill the water into the flume

ii. The flowmeter reading was set to 11L/s and 14L/s before the initial depth(y_1), depth after jump(y_2) and length of jump were recorded.

iii. The results of the experiment were analysed

3.3) Sieve Analysis of Fine Aggregate

i. The sample was weighed to the nearest 0.1g by total weight of the sample. This weight will be used to check any loss of material after the sample has been graded. A suitable sieve size in accordance with the specification was selected.

ii. The sieves were nested in order of decreasing size from top to bottom and begin agitating and the sample was shaken for a sufficient amount of time.

iii. These sieves were self-nesting and supported in a shaking mechanism at the top and bottom by a variety of clamping or holding mechanisms. Small shakers of this type require shaking times of 15 minutes to adequately grade the fine aggregate sample.

iv. Material retained was weighed on each sieve size to the nearest 0.1g. The final total of the weights retained on each sieve should be within 0.3% of the original weight of the sample prior to grading.

3.4) Analysis on the erosion occurrence below the horizontal apron.

i. The experiment was performed at Tailrace Outfall Structure of Pergau Pond Physical Model in UTP lab.

ii. The transition from the tunnel to the square section, small stilling basin and guide walls were made of clear Perspex as it was necessary to see the flow phenomena.

iii. Sediment size ranges from 300μm to 350μm were used in the tests.

iv. Two discharges utilized throughout the project were 12L/s and 30L/s.

v. The different arrangements of baffle blocks were used in order to select the best option in minimizing the erosion occurrence. The variation of baffle blocks arrangement are shown in figures below.

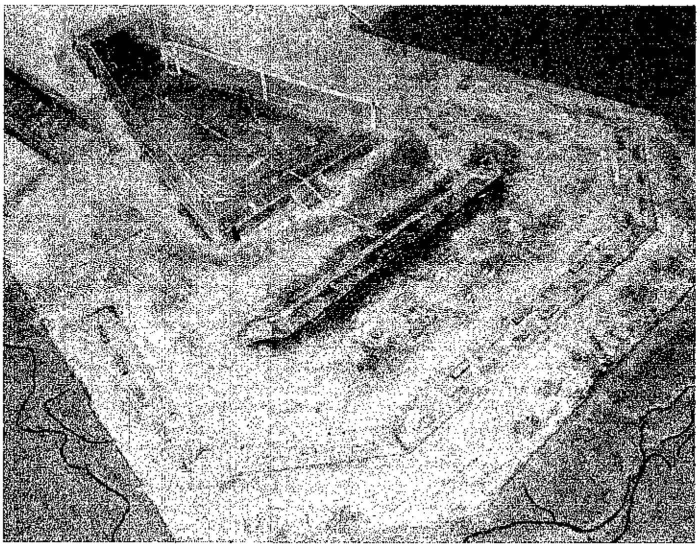

Figure 10 Baffle Block Arrangement Set 1

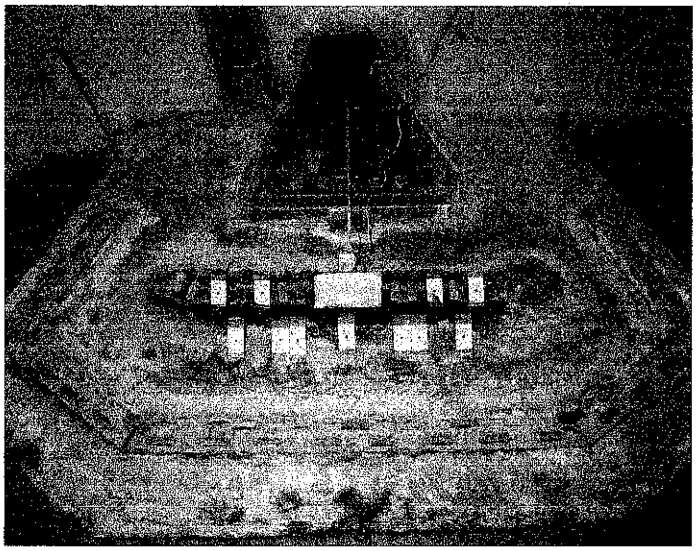

Figure 11 Baffle Block Arrangement Set 2

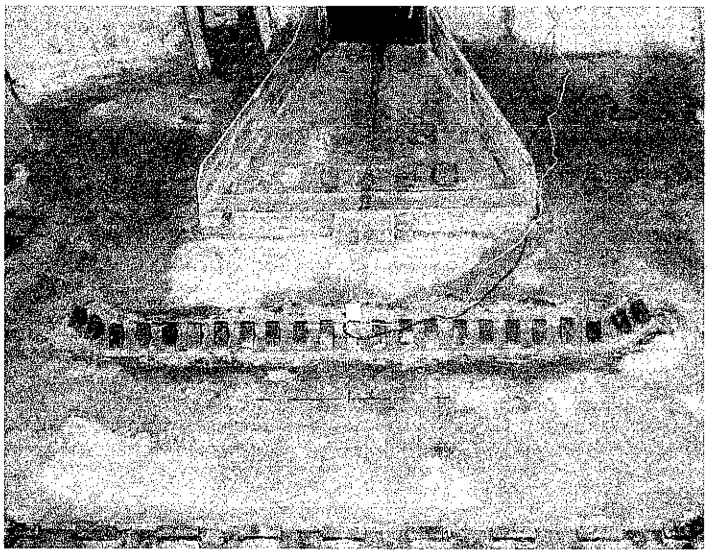

Figure 12 Baffle Block Arrangement Set 3

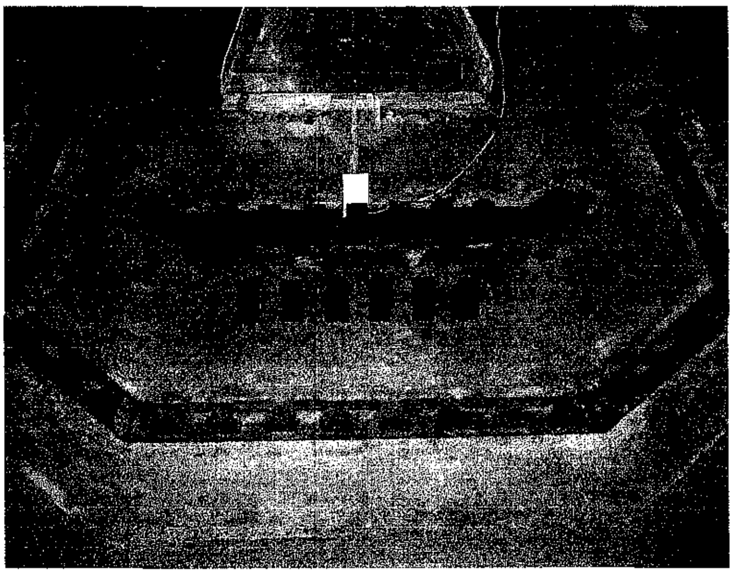

Figure 13 Baffle Block Arrangement Set 4

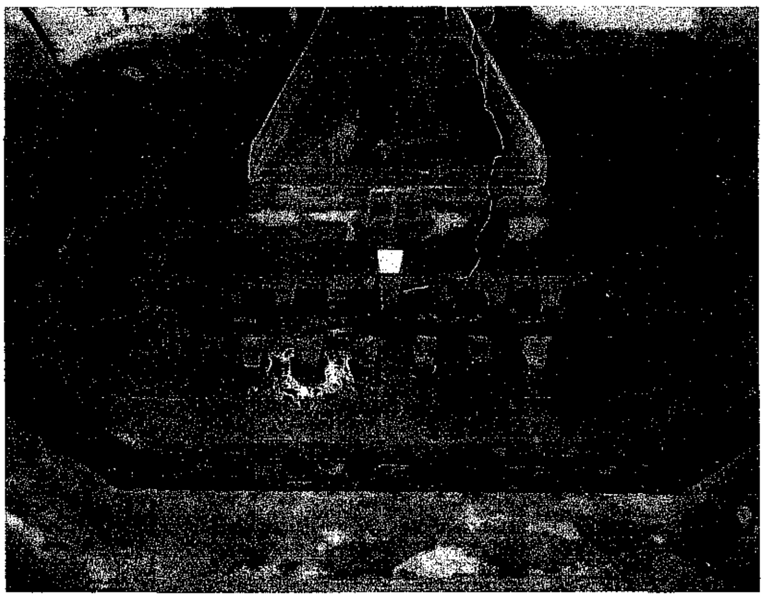

Figure 14 Baffle Block Arrangement Set 5

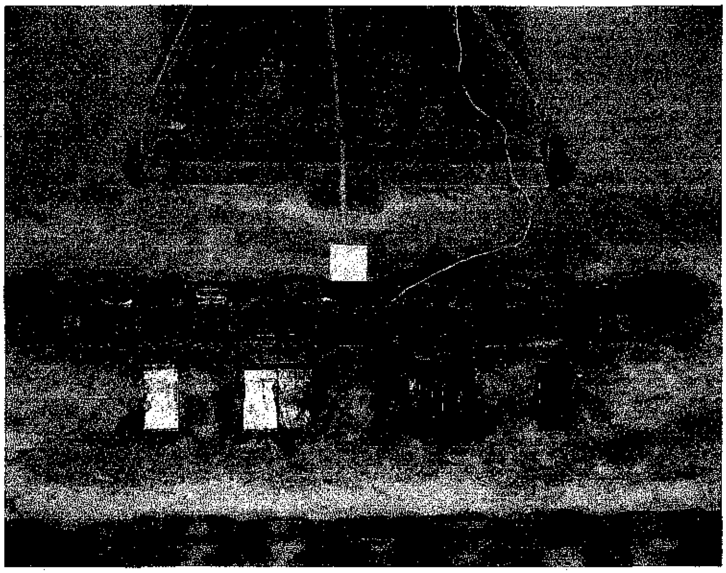

Figure 15 Baffle Block Arrangement Set 6

vi. The bed was leveled between in such a way so that the top of sediment particles was aligned with the surface of the apron as illustrated in Figure 16.

Figure 16 Experimental setup

vii. The pond was initially filled up with water with initial depth to avoid undesirable erosion.

viii. When the initial depth was achieved, the desired flowrate was selected while the outlet was opened.

ix. After the flow had run through the basin for 1 hour, the flow was stopped and the pond was dried.

x. Depth and extent of scour were recorded, photographs taken of scoured areas. Point gauge, ruler and strings were used during the measurements were taken(see Figure 17

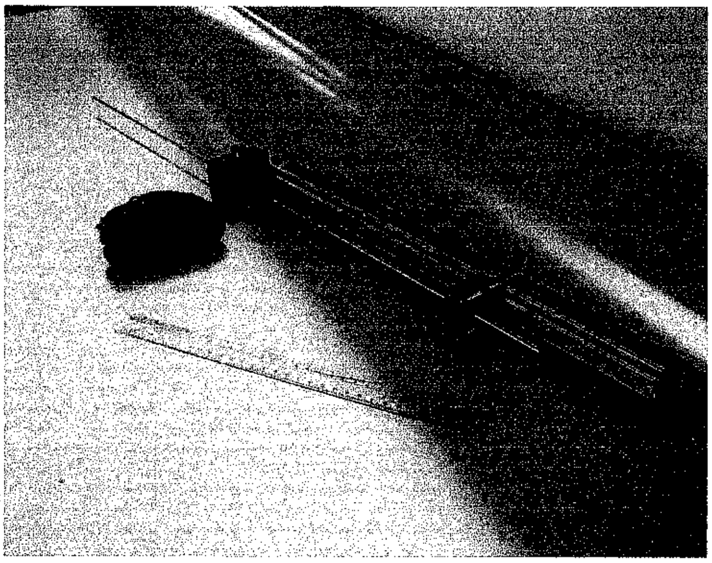

Figure 17 Equipment used in analysis

CHAPTER 4

RESULT AND DISCUSSION

4.1) Experimental observation on Hydraulic Jump (Flow over an Ogee Spillway)

Table 2 shows the result obtained from the experiment and calculation by using the appropriate equation. The value of y_1, y_2,y_c and length of jump were measured during the experiment meanwhile the rest of other characteristics such as velocity, Froude number and energy loss were obtained by using calculation. The samples of calculations to find Fr number and percentage of energy loss by using the results from the experiment were shown in the Appendix A. Figure 18 and Figure 19 show the specific energy curve obtained for both discharges. Meanwhile, Figure 20 and Figure 21 are the pictures taken during the experiment was conducted.

Table 2 Characteristic of Hydraulic Jump

Discharge, Q (m^3/s)	0.011	0.014
Upstream water depth,y_1, (m)	0.03	0.03
Downstream water depth, y_2, (m)	0.09	0.095
Critical water depth, y_c, (m)	0.060	0.060
Length of jump, L, (m)	0.69	0.81
Upstream velocity, V_1, (m/s)	1.146	1.458
Downstream velocity, V_2, (m/s)	0.382	0.461
Upstream Froude no, Fr_1	2.11	2.69
Upstream Specific Energy, E_1, (m)	0.096	0.138
Energy Loss, ΔE, (m)	0.020	0.024
Percentage Energy Loss, E_L, (%)	21%	17%
Type of hydraulic jump	Weak	Oscillating

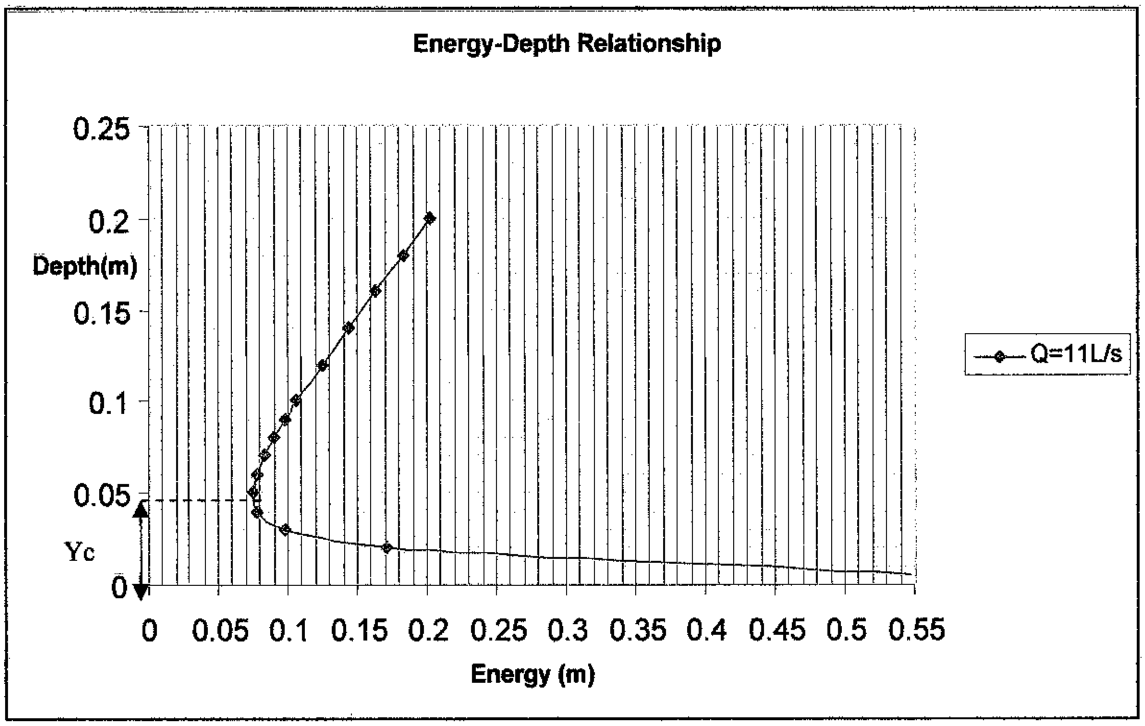

Figure 18 Energy-Depth Relationships for Q= 11L/s

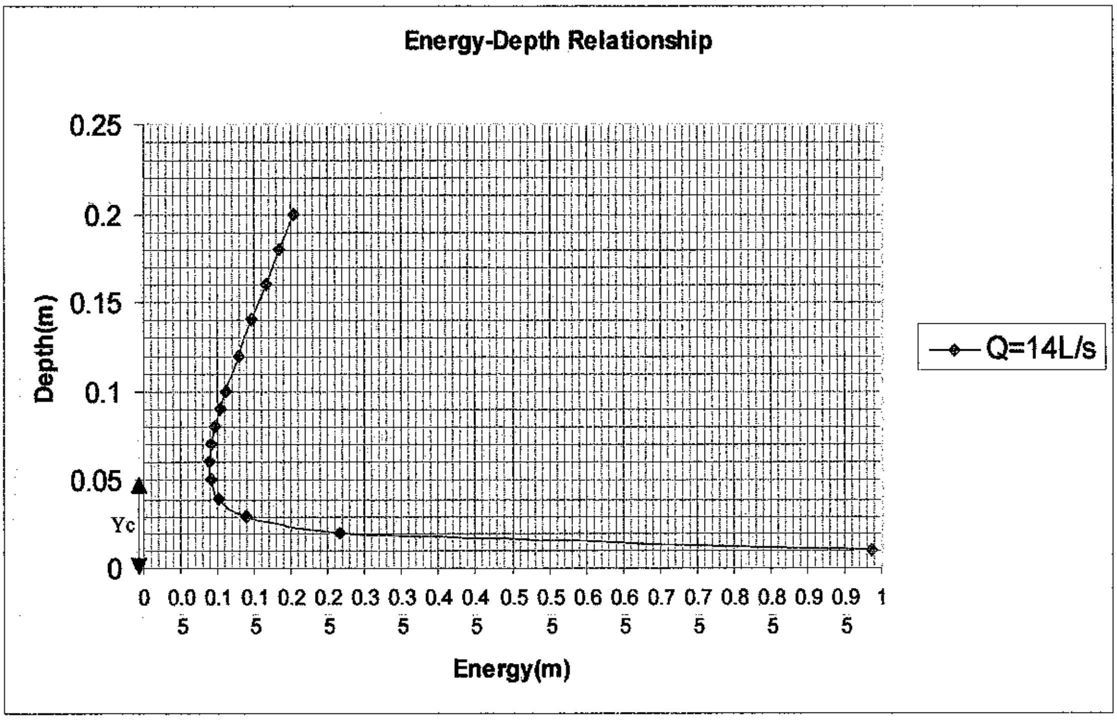

Figure 19 Energy-Depth Relationships for Q= 14L/s

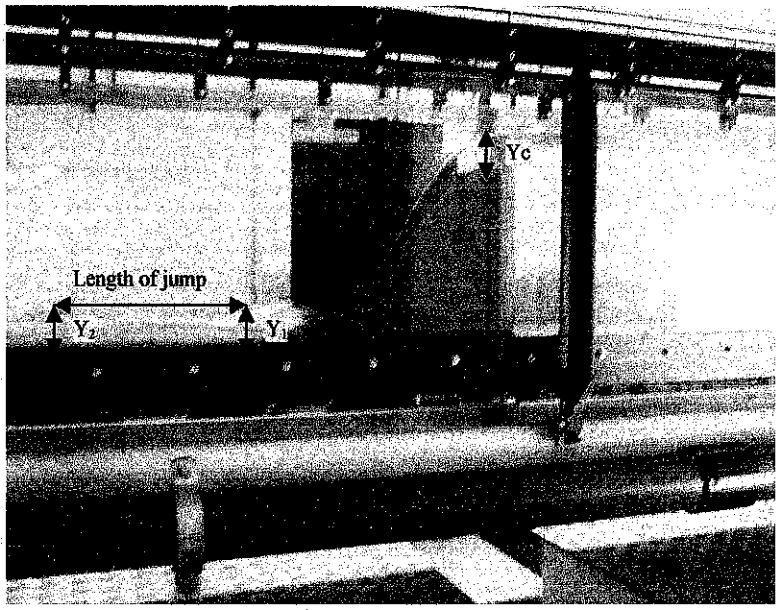

Figure 20 The hydraulic jump occurrence at discharge of 11 L/s

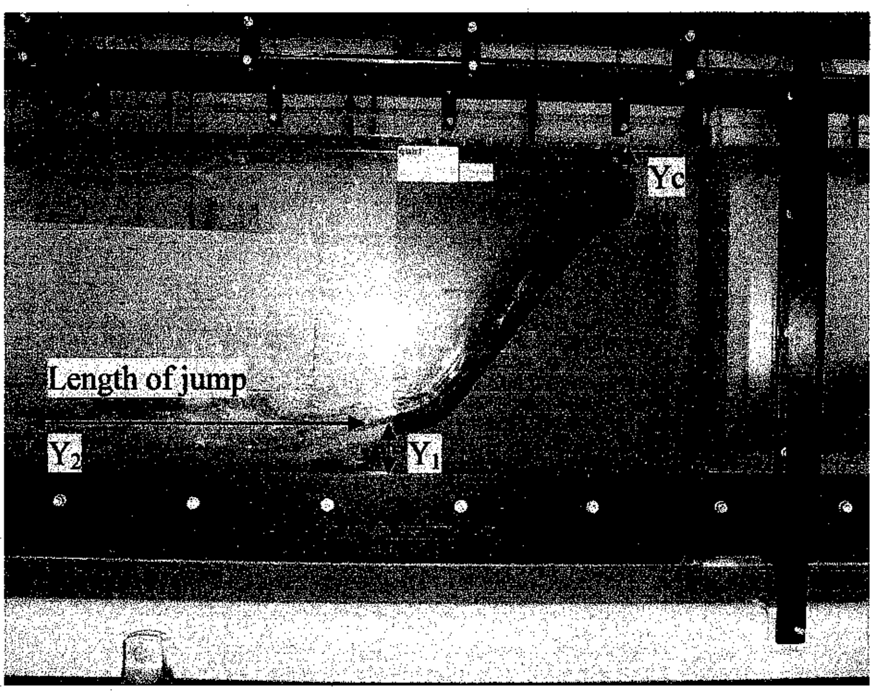

Figure 21 The hydraulic jump occurrence at discharge of 14L/s

According to the experiment, it was found that the stream with the different discharges produced hydraulic jump after it flowed over spillway. The hydraulic jump functioned to dissipate excess energy of flowing water downstream of hydraulic structure. The water depth after the jump has increased as a result to the formation of hydraulic jump. Two types of hydraulic jump occurred in the experiment were weak hydraulic jump and oscillating hydraulic jump. The energy losses for both types of hydraulic jump were small ranges from 17% to 20%.

In order to determine the accuracy of the discharges recorded from the flowmeter, the readings were compared with the discharges obtained by using the following methods:-

i. A paper bud was dropped onto the flowing water. The distance and the time of the moving bud were measured to calculate the velocity by using V= d/t. The sample of calculation to obtain the discharge, Q by using measured velocity is shown in Appendix B.

ii. Use $Fr = \frac{V_1}{\sqrt{gy_1}}$,when y_1= yc ,Fr= 1. The sample of calculation to obtain the discharge, Q when y_1=yc is shown in Appendix C. Both of discharges, Q were calculated by using the equation Q= AV. The comparisons discharges obtained from various methods are shown in the Table 3.

Table 3 Comparison of discharges which are obtained from various methods

	Reading taken from Flowmeter	**Velocity measurement,** V=d/t	**$Fr = 1 = \frac{V_1}{\sqrt{gy_1}}$, when y_1=yc .**
	13.9	22.5	14.7
Q,L/s	11.1	20.5	14.7

The accuracy of the result of the result was determined by comparing the experimental energy loss to the theoretical value which was obtained by using curve in Fig. 6.3 of Subramanya(1998). For the Froude number of 2.11, the theoretical energy loss was 0.01m which was smaller than the calculated energy loss meanwhile for the Froude number of 2.69, the energy loss from the curve was 0.05m which was higher than the experimental value.

The theoretical length jump was obtained by using Fig. 6.6 of Subramanya(1998).For the Froude number of 2.11, the theoretical length of jump was 0.43m, 60% smaller than the experimental value. Meanwhile, for the Froude number of 2.69, the theoretical length of jump was 0.5, 62% smaller than the experimental value.

The theoretical y_c also can be calculated by using following equation

$$y_c = \left(\frac{q^2}{g}\right)^{1/3}$$

From the calculation, it was found that the theoretical critical depths for discharge of $0.011m^3/s$ was 0.05m which was approximately 20% smaller than the experimental value. Meanwhile, the theoretical value of discharge of 0.014m3/s was 0.058m, approximately 3% smaller than the experimental values.

4.2) Sieve Analysis Test for Fine Sediments

Percentage of finer sediment will be dominant factor to determine the degree of sedimentation. Different sediment sizes with similar d_{50} will form different characteristic of sediment transport. The amount of sediment particle in relation to the size of particle is very important to show how sediment will function in various implementations

Table 4 comprises of data obtained from the sieve analysis test. Grading curve from the test is illustrated in Figure 22. The diameters correspond to 10%, 30% and 60% finer are plotted in the graph. The diameters D_{10}, D_{30} and D_{60} are approximately 0.33mm, 0.42mm and 0.5mm respectively.

Table 4 Grading of Fine Aggregates

Sediment Size	Mass after dry	Total % retained	Total passing
0	1.18	0	2.5
63µm	0.6	3	5
150µm	0.425	5	31
212µm	0.3	12	58
300µm	0.212	22	80
425µm	0.15	27	92
600µm	0.063	26	97
1.18mm	0	5	100

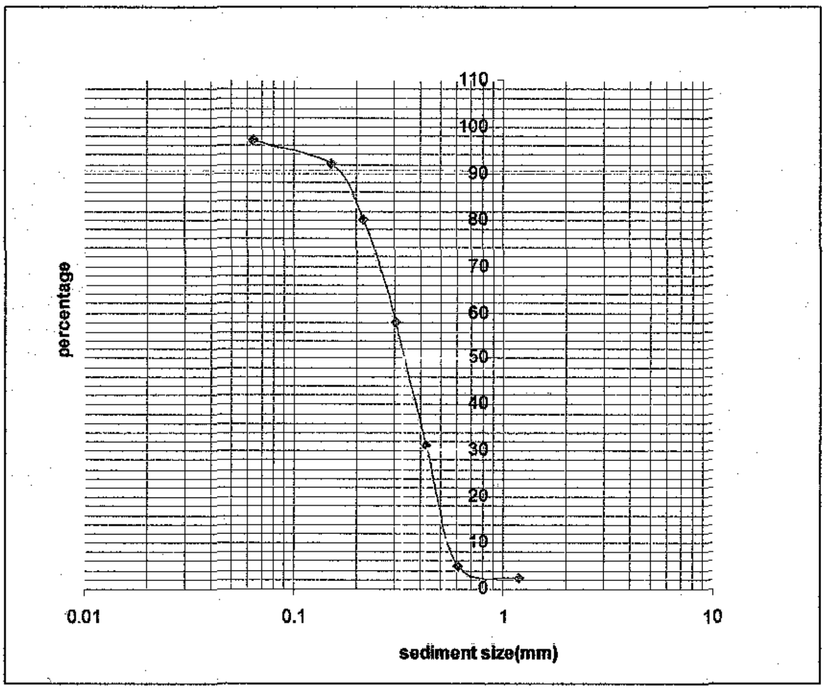

Figure 22 Gradation-Size Curve of Fine Aggregates

4.3) Analysis on erosion occurrence below the horizontal apron.

Twelve experiments have been carried out to observe the differences of scour pattern and maximum scour depth. Ten experiments were carried out by using five types of different arrangement of baffle blocks and the remaining two experiments were carried out without using baffle blocks. Each experiment was conducted in one hour with initial depth of 5cm for discharge of 12L/s and 14cm for discharge of 30L/s. From the observation, it was found that the different arrangements of baffle blocks have influenced the formation of scour pattern in each test.

Two discharges have been used throughout the project which were 12L/s and 30L/s. At discharge of 30L/s, the scour pattern dispersed farther from the apron compared to dispersion distance at discharge of 12L/s. It shows that the greater discharge used has produced a massive energy which capable to wash the sediments away from the horizontal apron.

Every scour pattern observed was sketched back onto scaled paper to measure the distance of scour dispersion downstream the apron. To make the task easier, a scaled plastic mat was spread onto the sediments so that the line of scour pattern can be sketched almost exactly similar to the actual pattern as shown in Figure 23.

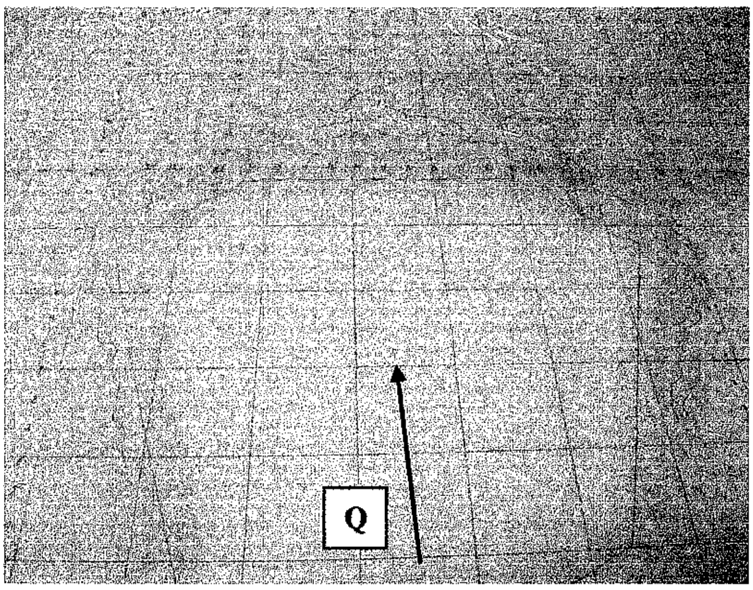

Figure 23 Scour Pattern Sketched on Scaled Plastic Mat

Figure 24 shows the scour pattern occurrence without using baffle blocks. The scour pattern distributed evenly when discharge of 12L/s was used. A small energy carried by the flow was only capable to wash a small portion of the sediments away from the horizontal apron. It was different when discharge of 30L/s was used. The pattern was observed directed towards the pond outlet. As the pattern were sketched on the scaled paper as illustrated in Figure 25, it was observed that the scour dispersed 350mm away from the apron for 12L/s while the energy carried by stream with the discharge of 30L/s capable to wash the sediment 1350mm away from the apron.

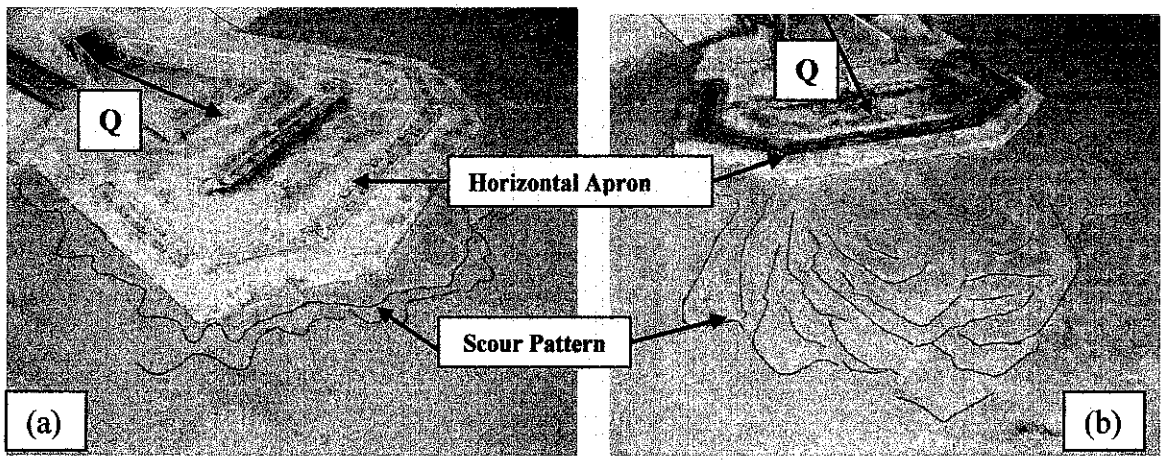

Figure 24 Scour Pattern as Observed at the Model at (a) 12L/s and (b) 30L/s using Set 1

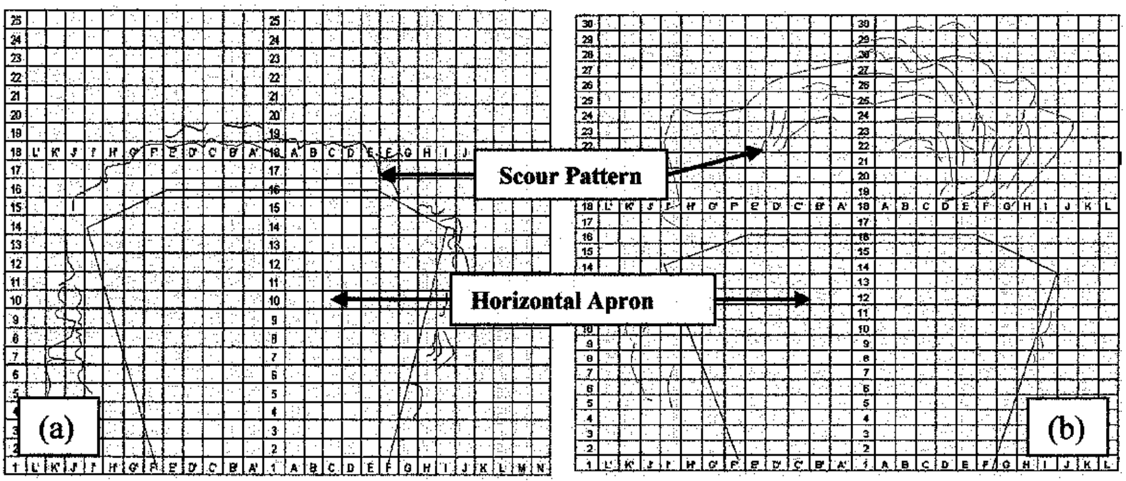

Figure 25 Scour Pattern Sketched to Scale at (a) 12L/s (b) 30L/s using Set 1

Figure 26 shows the scour pattern occurrence using Set 2. The scour pattern distributed evenly when discharge of 12L/s was used. A small energy carried by the flow was only capable to wash a small portion of the sediments away from the horizontal apron. It was different when discharge of 30L/s was used. The scour lines were formed in a bigger distance and further away from the apron. However, the formation of scour pattern by using Set 2 is more evenly distributed which shows that the baffle blocks has functioned well to dissipated energy from the flow. As the pattern were sketched on the scaled paper as illustrated in Figure 27, it was observed that the scour dispersed 550mm away from the apron for 12L/s while the energy carried by stream with the discharge of 30L/s capable to wash the sediment 1050mm away from the apron.

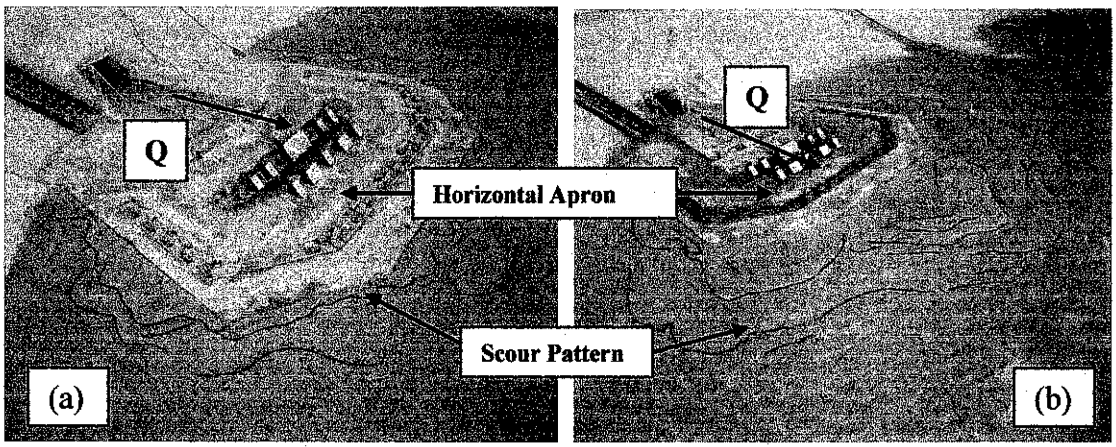

Figure 26 Scour Pattern as Observed at the Model at (a) 12L/s and (b) 30L/s using Set 2

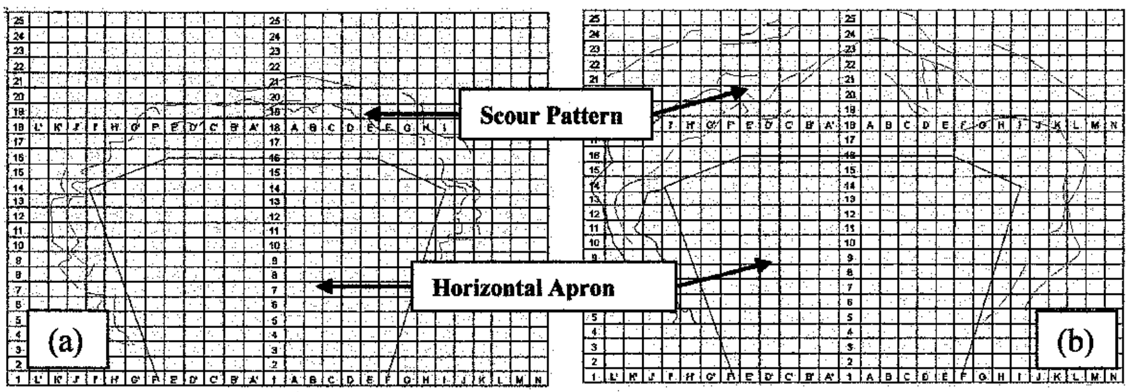

Figure 27 Scour Pattern Sketched to Scale at (a) 12L/s (b) 30L/s using Set 2

Figure 28 illustrates the scour pattern occurrence using Set 3. A small energy carried by the flow with discharge of 12L/s was only capable to wash a small portion of the sediments away from the horizontal apron. It was different when discharge of 30L/s was used. The scour lines were formed further away from the apron. The formation of scour pattern by using Set 3 shows that the baffle blocks has functioned well to dissipated energy from the flow. The other portions of the apron were not really affected by scour. As the pattern were sketched on the scaled paper as illustrated in Figure 29, it was observed that the scour dispersed 450mm away from the apron for 12L/s while the energy carried by stream with the discharge of 30L/s capable to wash the sediment 2350mm away from the apron.

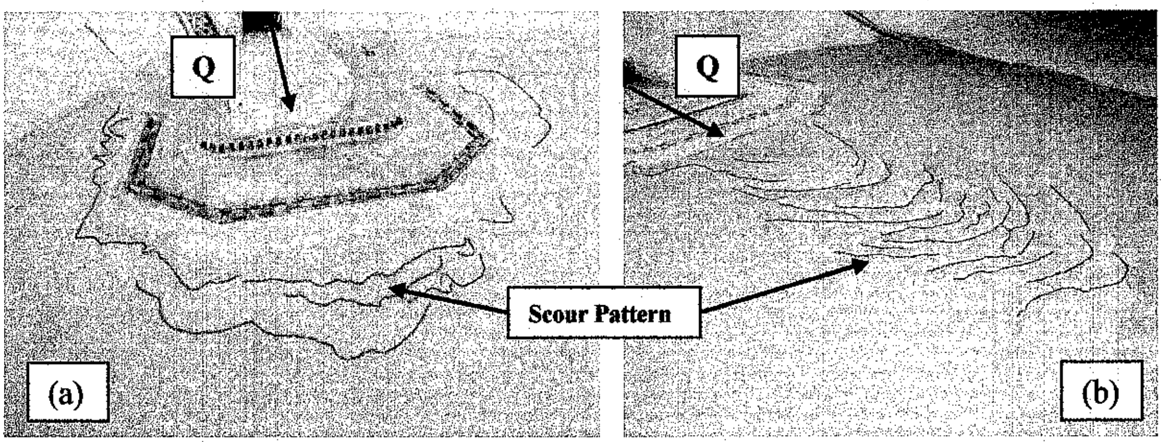

Figure 28 Scour Pattern as Observed at the Model at (a) 12L/s and (b) 30L/s using Set 3

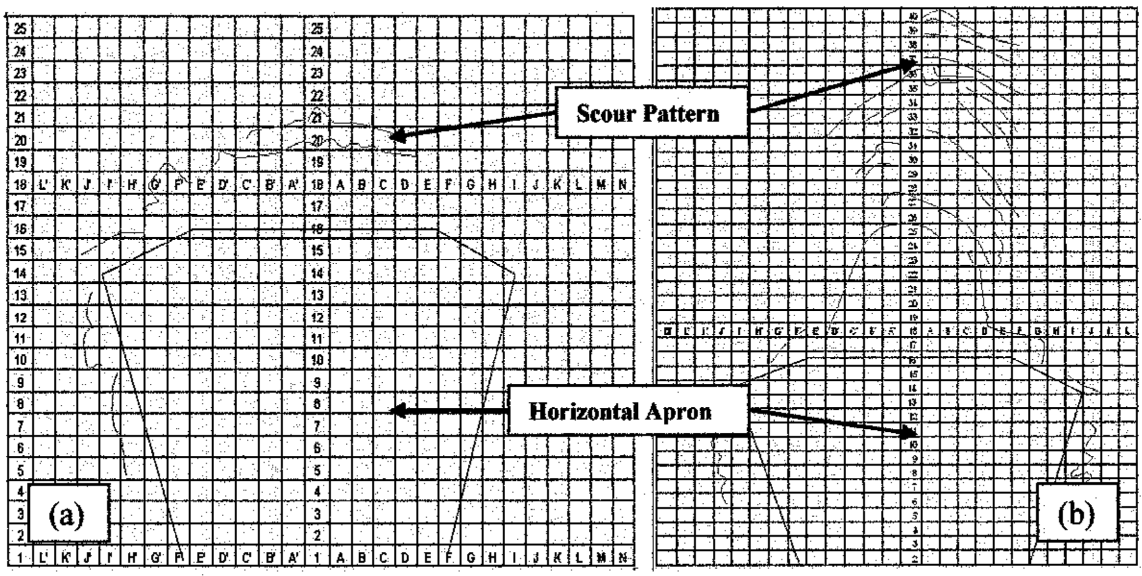

Figure 29 Scour Pattern Sketched to Scale at (a) 12L/s (b) 30L/s using Set 3

Figure 30 shows the scour pattern occurrence using Set 4. The scour pattern distributed evenly when discharge of 12L/s was used. A small energy carried by the flow was only capable to wash a small portion of the sediments away from the horizontal apron. It was different when discharge of 30L/s was used. In Figure 30(b), the scour lines were formed further away from the apron. However, the formation of scour pattern by using Set 4 was more evenly distributed which shows that the baffle blocks has functioned well to dissipated energy from the flow. It was observed that the scour pattern around the other portions of the apron was not very as severe as compared to those occurred in front of the apron. As the pattern were sketched on the scaled paper as illustrated in Figure 31, it was observed that the scour dispersed 550mm away from the apron for 12L/s while the energy carried by stream with the discharge of 30L/s capable to wash the sediment 2350mm away from the apron.

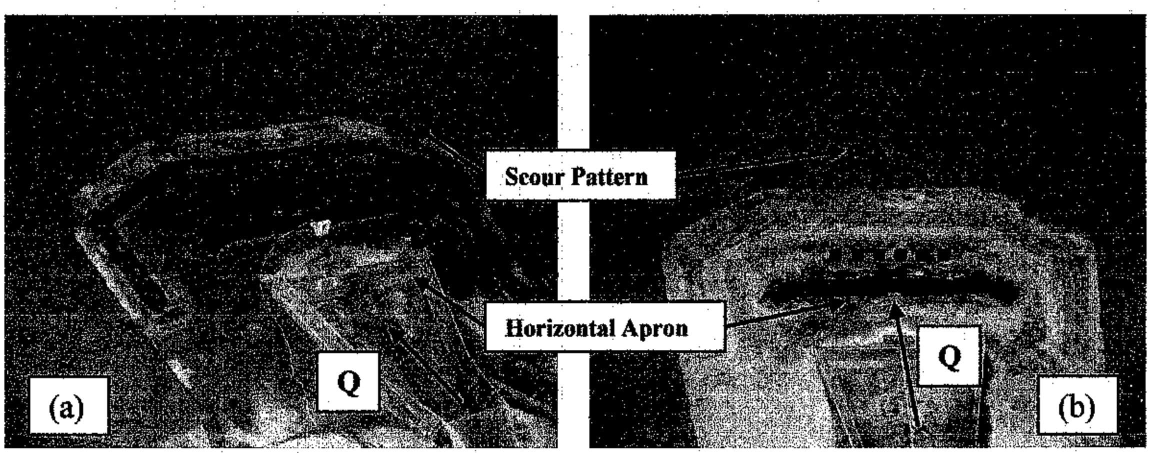

Figure 30 Scour Pattern as Observed at the Model at (a) 12L/s and (b) 30L/s using Set 4

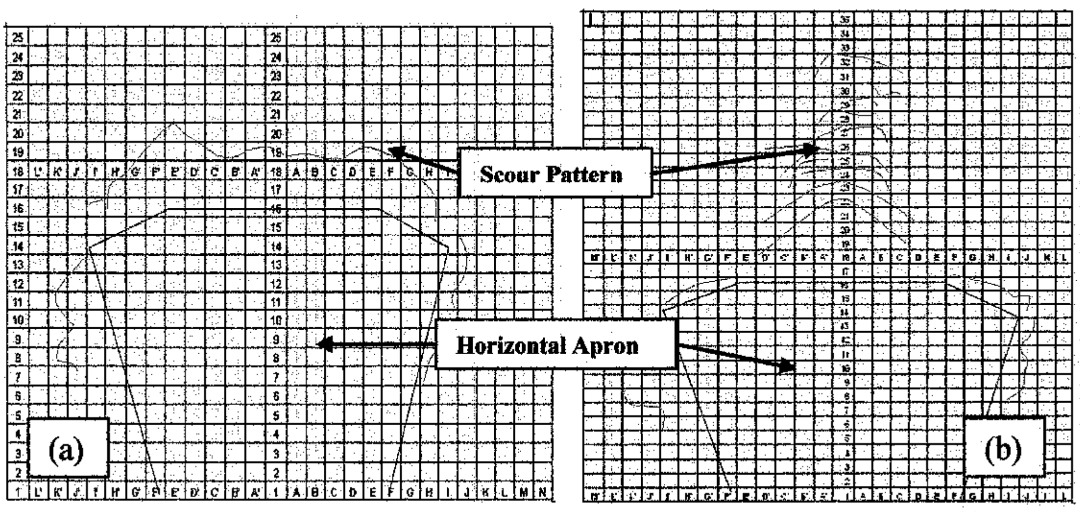

Figure 31 Scour Pattern Sketched to Scale at (a) 12L/s (b) 30L/s using Set 4

A small energy carried by the flow with discharge of 12L/s was only capable to wash a small portion of the sediments away from the horizontal apron. It was different when discharge of 30L/s was used. In figure 32(b), the scour lines were formed further away from the apron. However, the formation of scour pattern by using Set 5 shows that the baffle blocks has functioned well to dissipated energy from the flow. The other portions of the apron were not really affected by scour. As the pattern were sketched on the scaled paper as illustrated in Figure 33, it was observed that the scour dispersed 250mm away from the apron for 12L/s while the energy carried by stream with the discharge of 30L/s capable to wash the sediment 1450mm away from the apron.

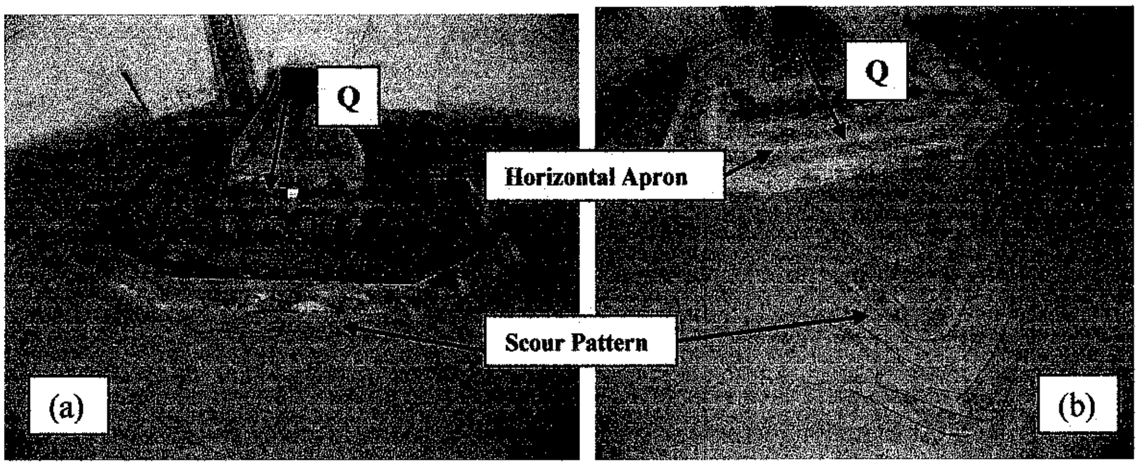

Figure 32 Scour Pattern as Observed at the Model at (a) 12L/s and (b) 30L/s using Set 5

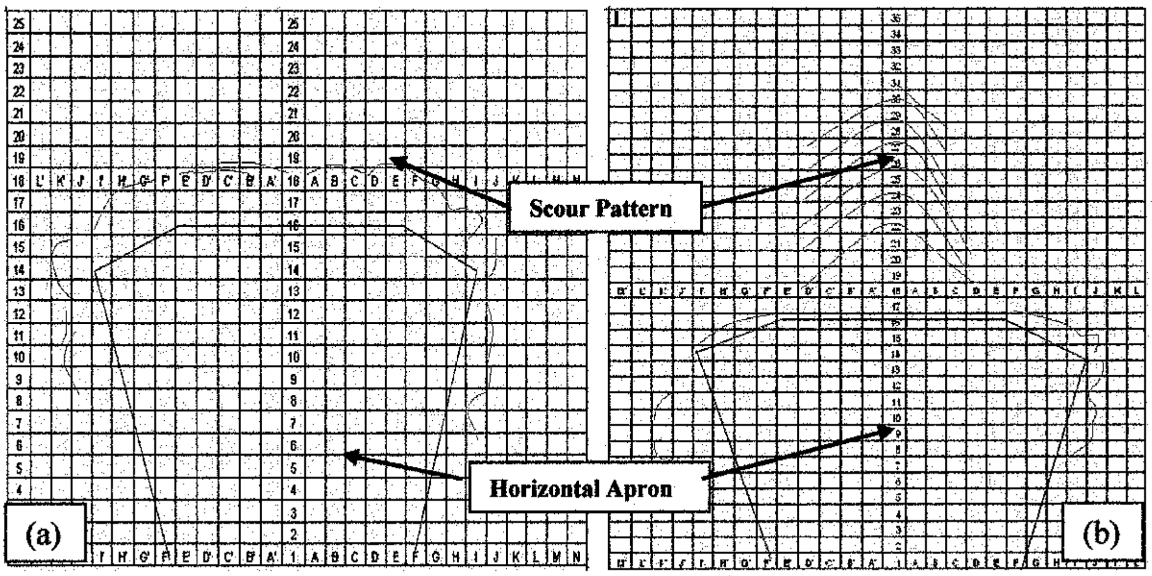

Figure 33 Scour Pattern Sketched to Scale at (a) 12L/s (b) 30L/s using Set 5

Figure 34 illustrates the scour pattern occurrence using Set 6. A small energy carried by the flow with discharge of 12L/s was only capable to wash a small portion of the sediments away from the horizontal apron. It was different when discharge of 30L/s was used. The scour lines were formed further away from the apron. The formation of scour pattern by using Set 6 shows that the baffle blocks has functioned well to dissipated energy from the flow. As the pattern were sketched on the scaled paper as illustrated in Figure 35, it was observed that the scour dispersed 300mm away from the apron for 12L/s while the energy carried by stream with the discharge of 30L/s capable to wash the sediment 1350mm away from the apron.

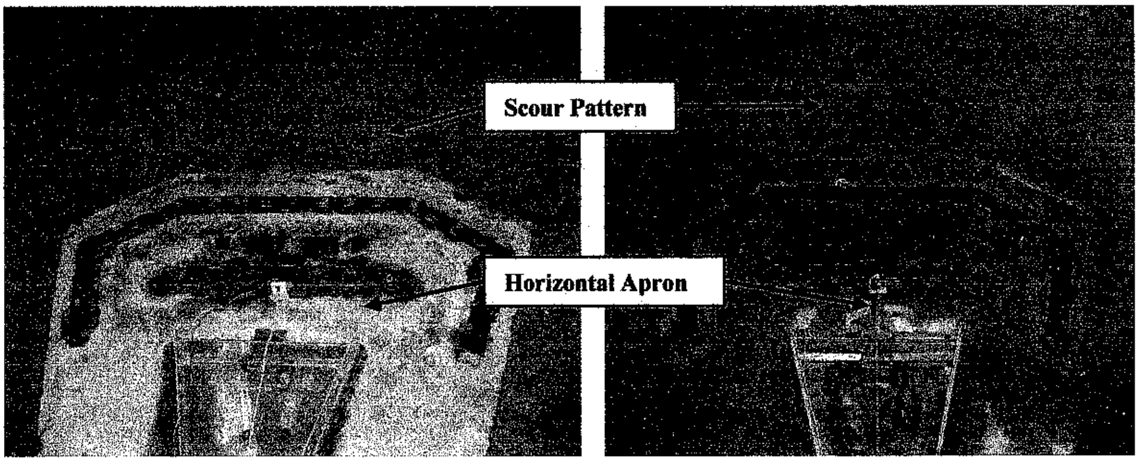

Figure 34 Scour Pattern as Observed at the Model at (a) 12L/s and (b) 30L/s using Set 6

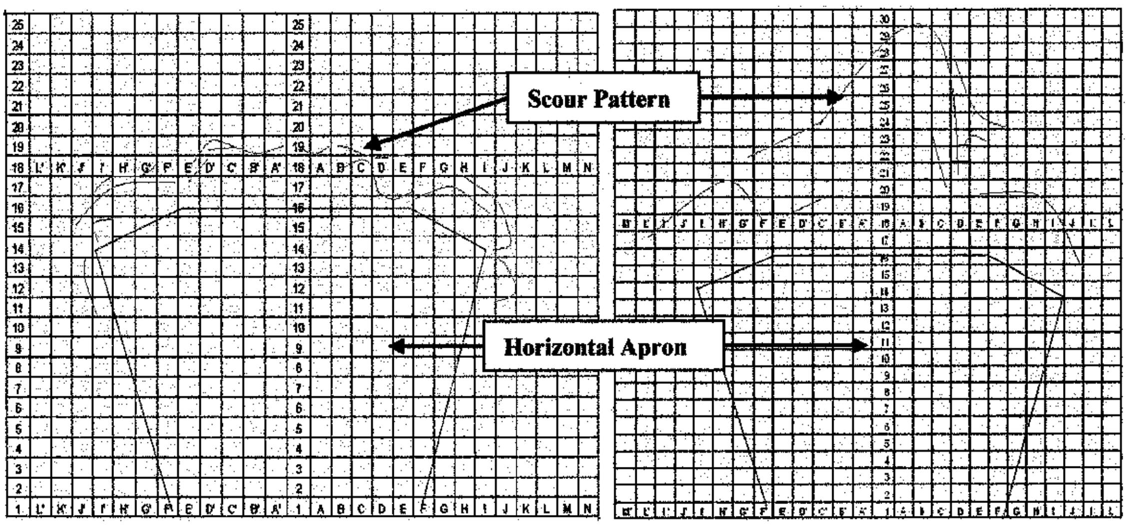

Figure 35 Scour Pattern Sketched to Scale at (a) 12L/s (b) 30L/s using Set 6

The differences of scour pattern formations at discharge of 30L/s were more obvious compared to the patterns at discharge of 12L/s. It was also found that the use of baffle blocks which function to dissipate energy from the flow has affected the distance of scour dispersion. An effective baffle blocks arrangement minimized the distance of scour dispersion. The maximum dispersion distance of the scour was also analyzed.

It was also discovered that the use of baffle block has been effective to reduce the maximum erosion depth. The scour profile was measured in every test to determine the maximum erosion. Five lines downstream the apron were selected as shown in Figure 36. The efficiency of baffle blocks was determined by comparing the maximum erosion depth at every point. The maximum erosion was observed to occur at point 1 since the water flows directly towards point 1.

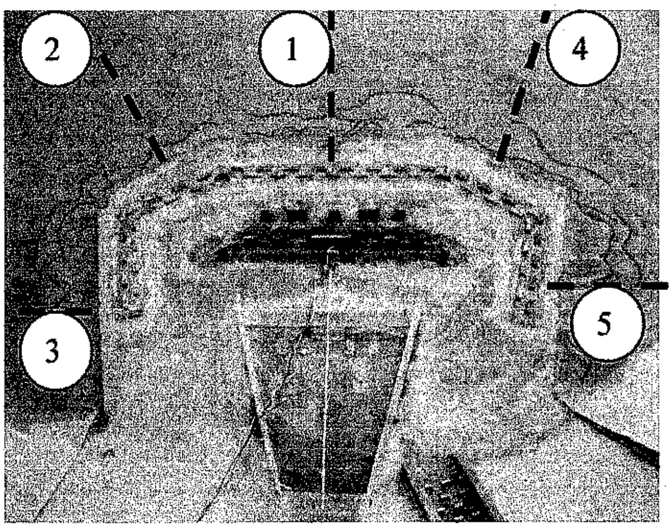

Figure 36 Lines of Measurement

Followings are the scour profiles measured downstream the horizontal apron at point 1. With the discharge of 12L/s, the scour profiles at each point for various baffle blocks arrangements are shown in Figure 37. The scour profiles at 4 points around the horizontal apron are shown in Appendix D.

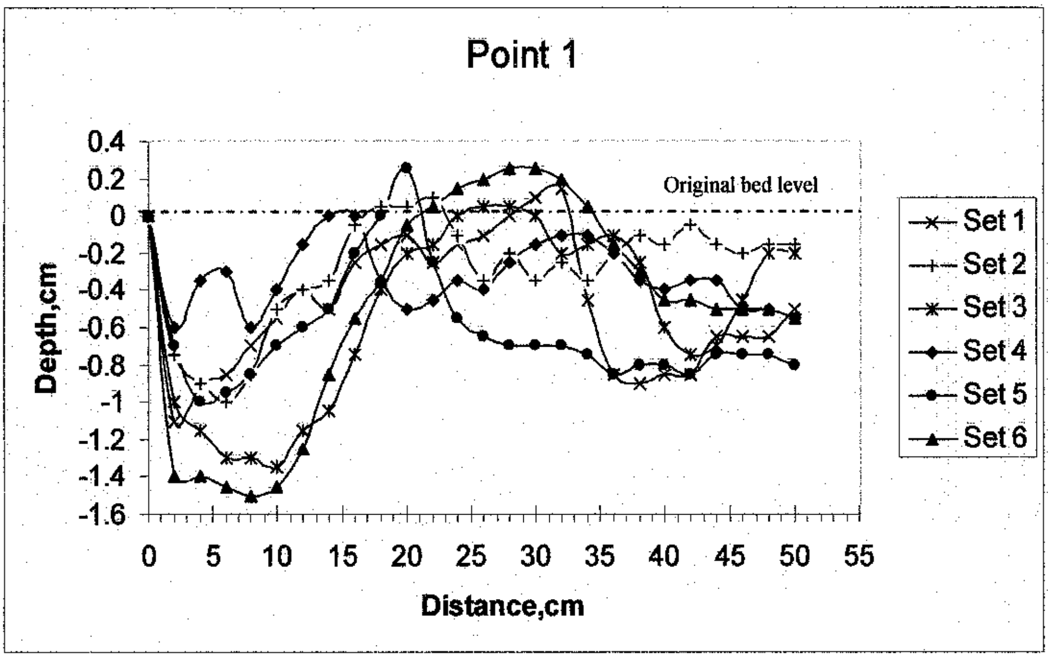

Figure 37 Scour profiles at various points by using different sets of baffle blocks arrangements at 12L/s

The maximum erosion depths were measured at point 1 of every set of baffle blocks arrangements. This is due to the reason that the water flows directly to the point 1 when it was released from the tunnel. The most severe erosion at this point occurred when set 6 was used with the depth of 150mm. However, the erosion depth was reduced to the depth of 6mm when Set 4 was used.

Table 5 demonstrates the maximum erosion depths for every set of baffle blocks used and the effect of the arrangement to the distance of scour dispersion. From the table, it was found that set 4 has become most effective to dissipate energy of the flow. The smallest erosion depth of 60mm and scour dispersion distance of 300mm indicated that the energy of the flow has been dissipated effectively before it flowed to the downstream of apron.

Table 5 Effect of various baffle block arrangement of maximum erosion depth and maximum dispersion distance for 12L/s

Set	Max. Erosion Depth,mm	Max. Dispersion Distance,mm
1	11	400
2	10	550
3	13.5	600
4	6	300
5	10	350
6	15	350

Scour profiles measured downstream the horizontal apron at point 1 are shown in Figure 38. With the discharge of 30L/s, it was observed that the maximum erosion depth were greater than those profiles measured for discharge of 12L/s. The scour profiles measured at 4 points around the horizontal apron are shown in Appendix E.

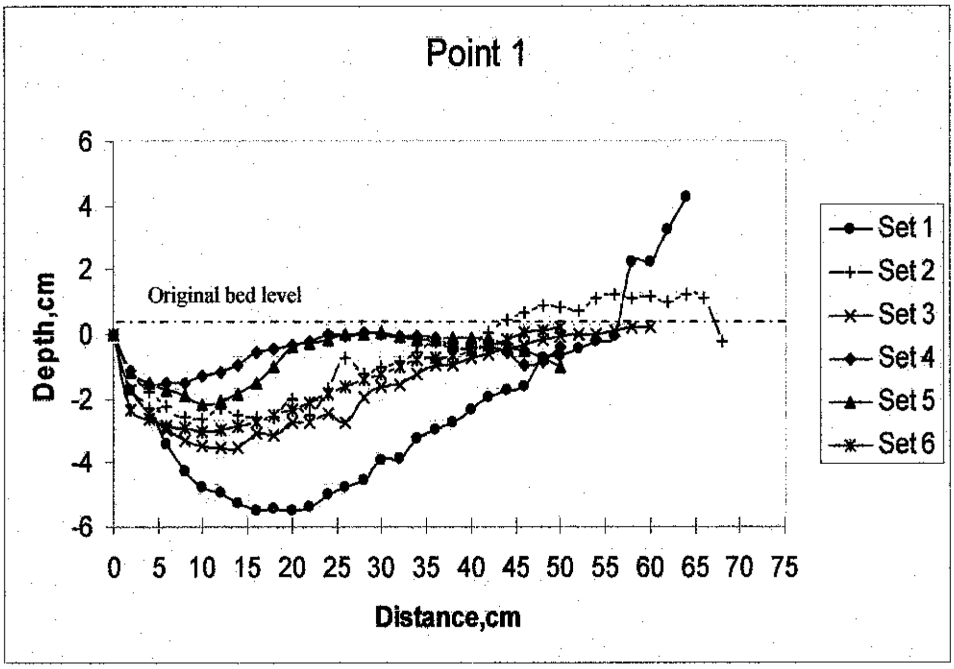

Figure 38 Scour profiles at various points by using different sets of baffle blocks arrangements at 30L/s

The maximum erosion depths were measured for every set of baffle blocks arrangements at point 1. This is due to the reason that the water flows directly to the point 1 when it was released from the tunnel. The most severe erosion at this point occurred when set 1 was used with the depth of 54.5mm. However, the erosion depth was reduced to the depth of 15mm when Set 4 was used.

Table 6 illustrates the maximum erosion depths for every set of baffle blocks used and the effect of the arrangement to the distance of scour dispersion. From the table, it was found that set 4 has become most effective to dissipate energy of the flow. The smallest erosion depth of 15mm and scour dispersion distance of 1350mm indicated that the energy of the flow has been dissipated effectively before it flowed to the downstream of apron when Set 4 was used. The detail measurements of erosion depths for each points are shown in Appendix F.

Table 6 Effect of various baffle block arrangement of maximum erosion depth and maximum dispersion distance for 30L/s

Set	Max. Erosion Depth,mm	Max. Dispersion Distance,mm
1	54.5	1400
2	26.5	1550
3	35.5	2350
4	15	1350
5	22	1750
6	30	1550

The study conducted by Dey and Sarkar entitled Scour Downstream of an Apron due to Submerged Horizontal Jets in 2006 was analyzed. The similarities and difference with this project are discussed. Figure 39 displays the profile of the scour with and without apron. The findings from study by the researchers have proved that the use launching apron downstream of an apron has produced a tremendous impact in reducing the maximum scour depth. The use of the launching apron has been very beneficial as it covered the eroded bed sediments from being washed by the submerged jet after the initial periods of scour.

The same phenomena occur in this project when the erosion depth has been reduced when baffle blocks were placed on the concrete apron. Figure 40 illustrates the scour profile with and without using baffle blocks. The use of baffle blocks have been very useful to dissipate energy from the flow before it was released downstream the apron. It is important to point out that the equilibrium scour profile from the study was reached after 3 hours while in the project, it took 1 hour to complete each run.

The experiment by the researchers took place in flume while the tests carried out in the project took place in Pergau Pond Model which indicates a huge difference of environment of the tests. However, both experiments from the study as well as from this project have proved various effective solutions that can be implemented in order to reduce scour depth downstream apron.

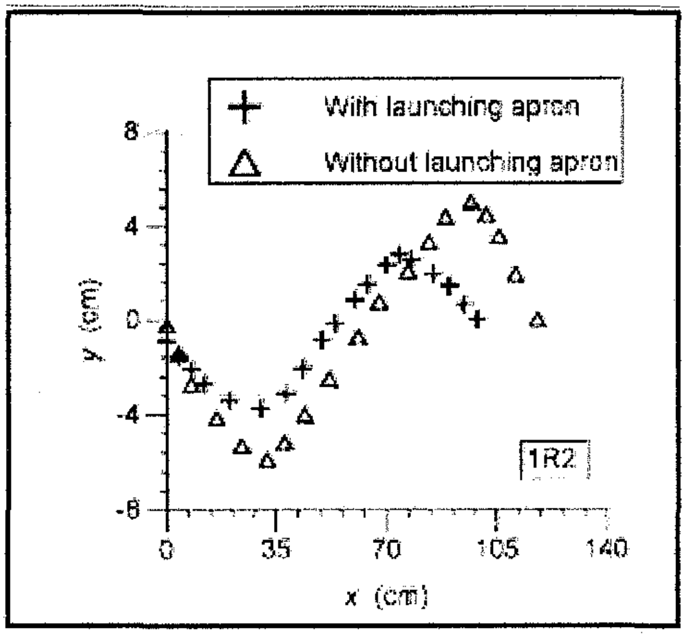

Figure 39 Equilibrium scour profiles for different runs(Dey & Sarkar, 2006)

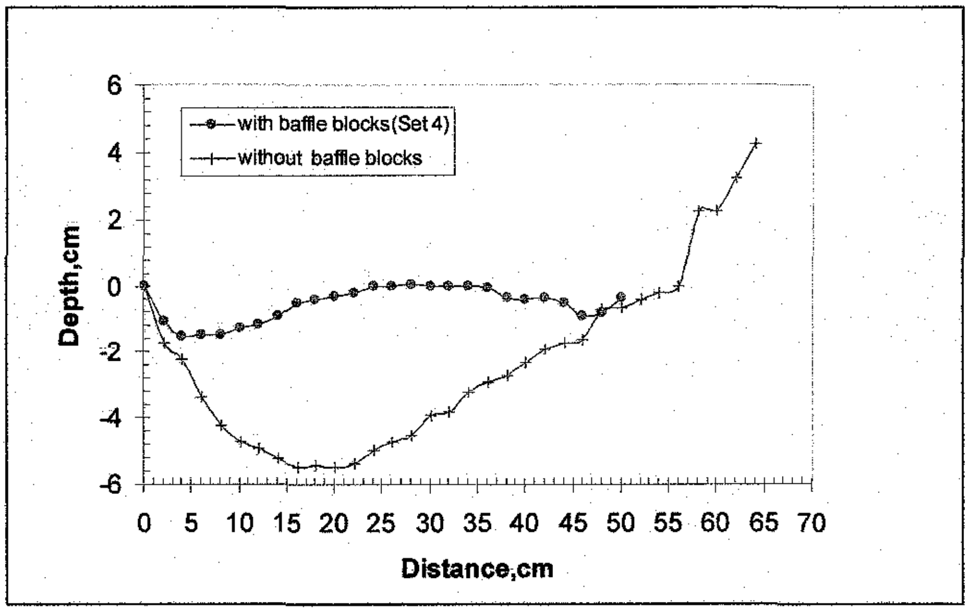

Figure 40 Equilibrium scour profiles for different runs

CHAPTER 5

CONCLUSIONS

Experiments to analyze the scour patterns and scour profiles were performed by using six different arrangements of baffle blocks including experiment without using baffle blocks. Two discharges used are e12L/s and 30L/s. The findings are summarized as follows:-

i. The scour profile occurs at downstream of horizontal apron and the most severe erosion occurred at the point where the water came from.

ii. The maximum scour depth increases as the discharge increases.

iii. An effective set of baffle blocks is capable to reduce the distance of scour dispersion due to effective energy dissipation.

iv. Set 4 is the most effective set of baffle block arrangement to be used as energy dissipater in this project, hence reduce the severity of the erosion occurrence.

In the future, it is suggested to increase the number of tests for each set of baffle blocks in order to get more precise result. It is recommended to reduce the number of baffle blocks arrangements so that the student be able to focus on implementing the best arrangement by using existing set to reducing the scour depth. The sediment size used in the experiment should be varied so that the impact of sediment size to the scour occurrence can be discussed.

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APPENDIX A

Sample of calculation to find Fr number and percentage of energy loss by using the results from the experiment

ımple of calculation to find Fr number and percentage of energy loss by using the ısults from the experiment

- For $Q = 0.011\ m^3/s$

Upstream velocity, V_1, (m/s) = Q/A_1

$= 0.011/(0.32*0.03)$

$= 1.14$ m/s

Downstream velocity, V_2, (m/s) = Q/A_2

$= 0.011/(0.32*0.09)$

$= 0.46$ m/s

Upstream Froude no, $Fr_1 = \dfrac{V_1}{\sqrt{gy_1}}$

$$= \frac{1.146}{\sqrt{9.81 \times 0.03}}$$

$= 2.11$

Upstream Specific Energy, E_1, (m) = $y_1 + \dfrac{V_1^2}{2g}$

$$= 0.03 + \frac{1.14^2}{2 \times 9.81}$$

$= 0.10$ m

Energy Loss, ΔE, (m) = $\dfrac{(y_2 - y_1)^3}{4y_1y_2}$

$$= \frac{(0.09 - 0.03)^3}{4 \times 0.03 \times 0.09}$$

$= 0.02$ m

Percentage Energy Loss, E_L, (%) = $\Delta E/E_1 \times 100\%$

$= (0.0200/0.0969) \times 100\%$

$\approx 21\ \%$

- For Q = 0.014 m^3/s

Upstream velocity, V_1, (m/s) = Q/A_1

= 0.014/(0.32*0.030)

= 1.46 m/s

Downstream velocity, V_2, (m/s) = Q/A_2

= 0.014/(0.32*0.095)

= 0.382 m/s

Upstream Froude no, $Fr_1 = \frac{V_1}{\sqrt{gy_1}}$

$= \frac{1.458}{\sqrt{9.81 \times 0.03}}$

= 2.69

Upstream Specific Energy, E_1, (m) = $y_1 + \frac{V_1^2}{2g}$

$= 0.03 + \frac{1.458^2}{2 \times 9.81}$

= 0.138 m

Energy Loss, ΔE, (m) = $\frac{(y_2 - y_1)^3}{4y_1y_2}$

$= \frac{(0.095 - 0.03)^3}{4 \times 0.03 \times 0.095}$

= 0.0241 m

Percentage Energy Loss, E_L, (%) = $\Delta E/E_1$

= (0.0241/0.1384) x 100%

$\approx$ 17%

APPENDIX B

Sample of calculation to obtain the discharge, Q by using measured velocity

Sample of calculation to obtain the discharge, Q by using measured velocity

1)$Q_{flowmeter} = 0.014\ m^3/s$

Distance, d = 1.5 m

Time, t = 8.50 s

Depth, y = 0.40 m

Velocity, V = d/t = 0.1765 m/s

Discharge, Q = AV

$= (0.4)(0.32)(0.176)$

$= 0.0225\ m^3/s$

$$\%\ \text{of difference} = \frac{(0.0225 - 0.014)}{0.0225} \times 100 \approx 38\%$$

2)$Q_{flowmeter} = 0.011\ m^3/s$

Distance, d = 1.5 m

Time, t = 9.12 s

Depth, y = 0.39 m

Velocity, V = d/t = 0.1645 m/s

Discharge, Q = AV

$= (0.39)(0.32)(0.1645)$

$= 0.0205\ m^3/s$

$$\%\ \text{of difference} = \frac{(0.0205 - 0.011)}{0.0205} \times 100 \approx 46\%$$

APPENDIX C

Sample of calculation to obtain the discharge, Q when y_1=yc

ample of calculation to obtain the discharge, Q when y_1=yc

/hen yc =0.06m

r=1

sing the equation $Fr_1 = \frac{V_1}{\sqrt{gy_1}}$

$_1 = 1 \times \sqrt{9.81 \times 0.06}$

$_1 = 0.76$ m/s

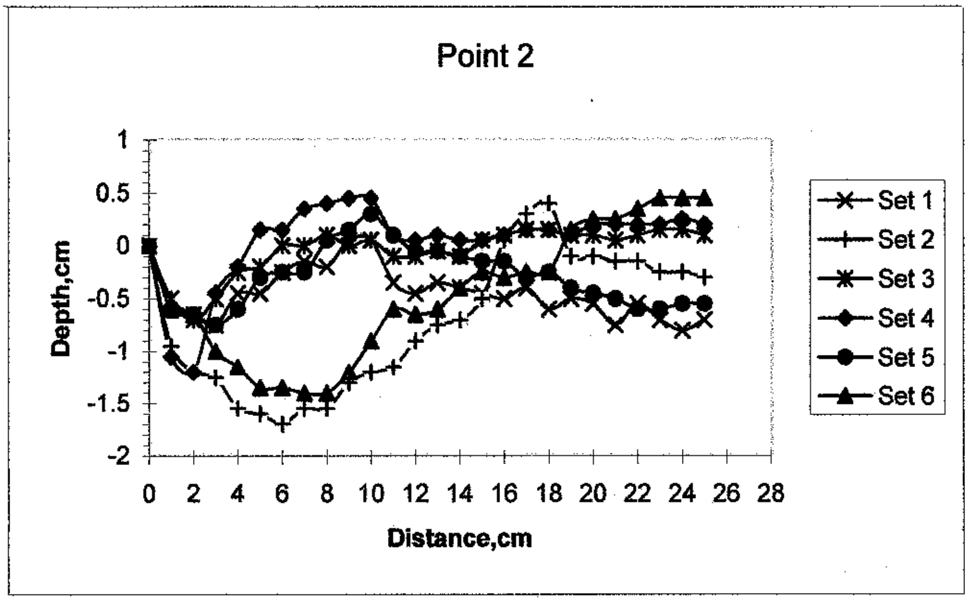
=AV

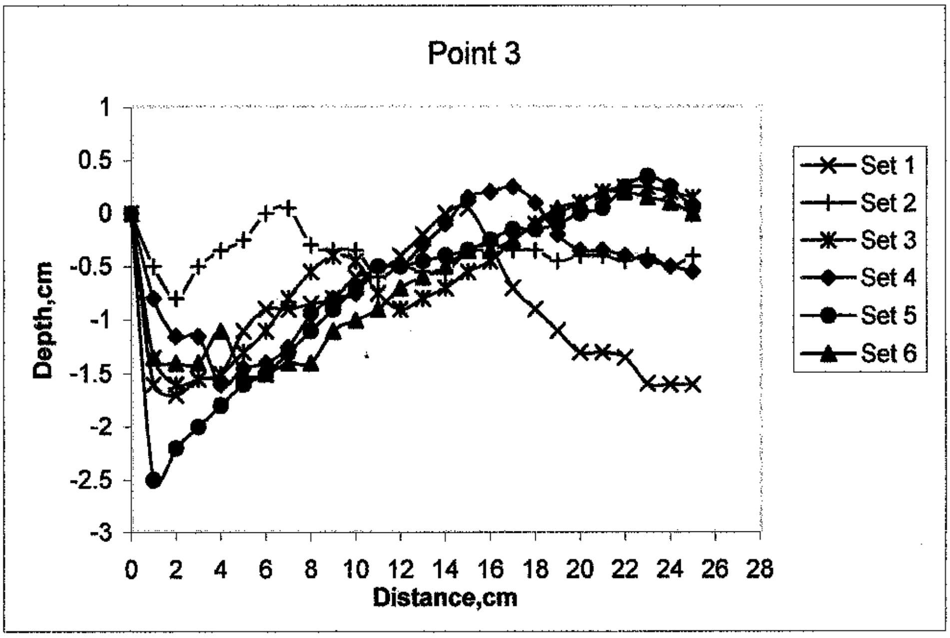
$= 0.32\text{m} \times 0.06\text{m} \times 0.76\text{m/s}$

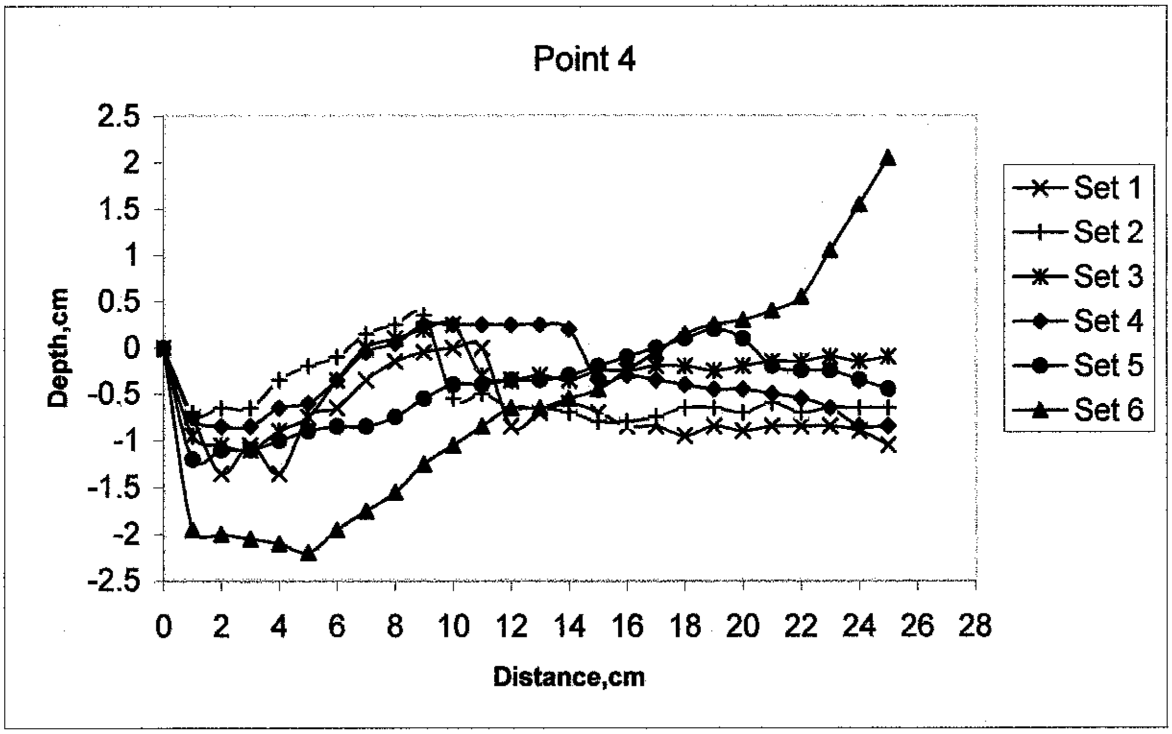
$= 0.014\text{m}^3\text{/s}$

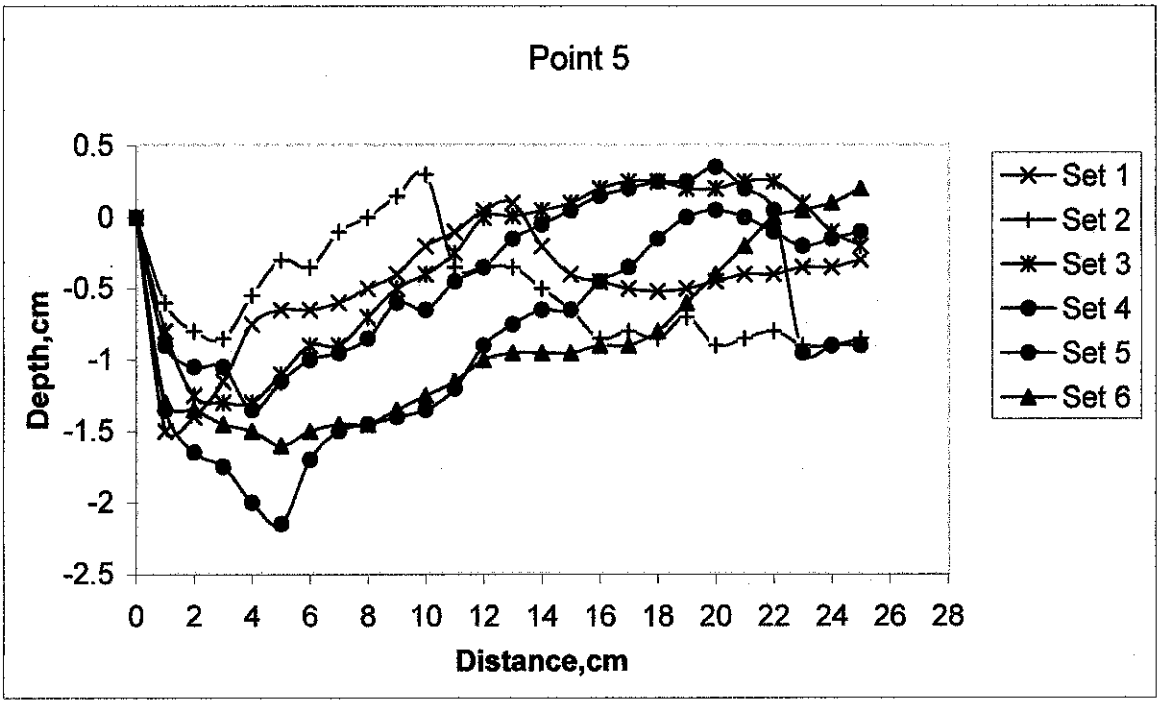
APPENDIX D

Scour profiles at 4 points around apron for 12L/s


Point 2
Depth,cm
1
0.5
0
-0.5
-1
-1.5
-2
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Distance,cm
Set 1
Set 2
Set 3
Set 4
Set 5
Set 6

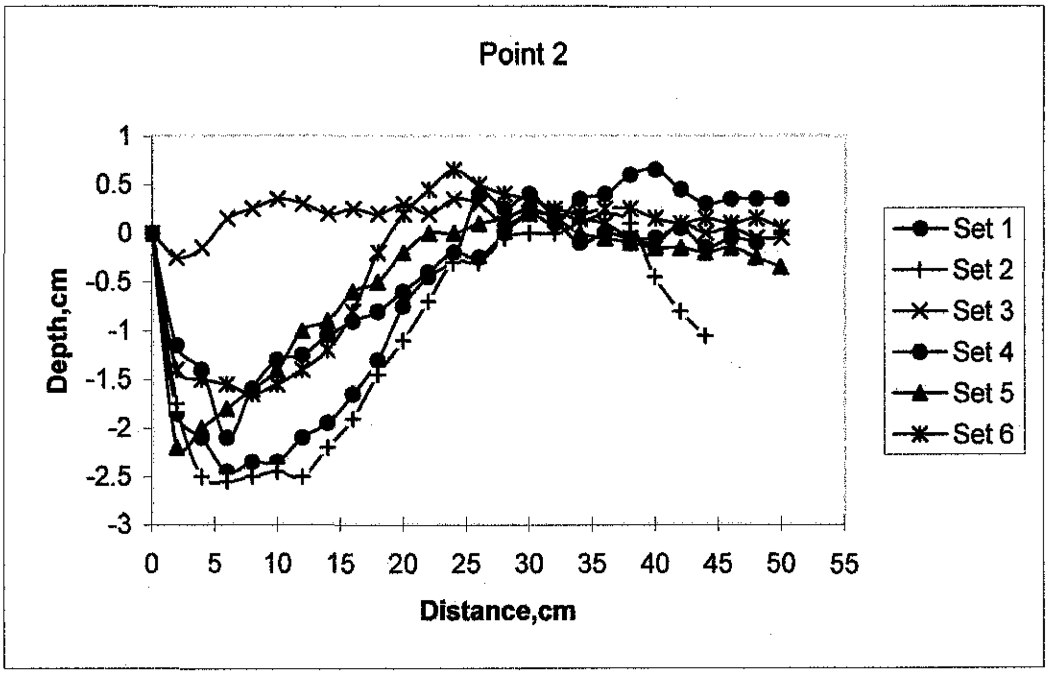

Point 3
Depth,cm
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Distance,cm
Set 1
Set 2
Set 3
Set 4
Set 5
Set 6

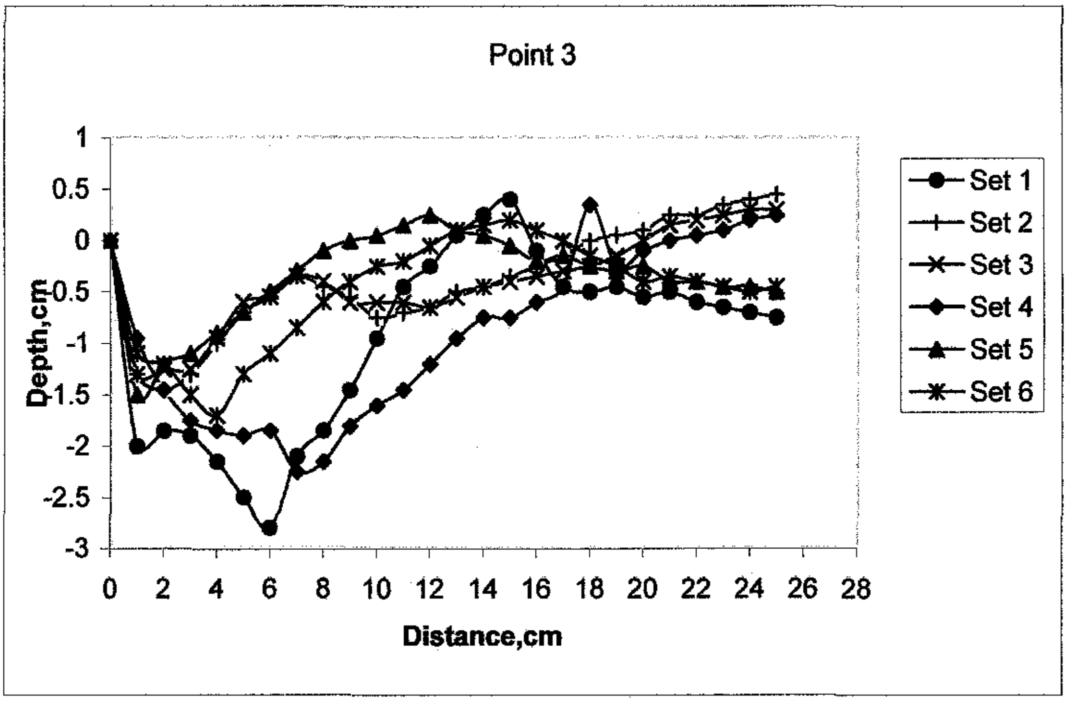

Point 4
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
Depth,cm
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Distance,cm
Set 1
Set 2
Set 3
Set 4
Set 5
Set 6

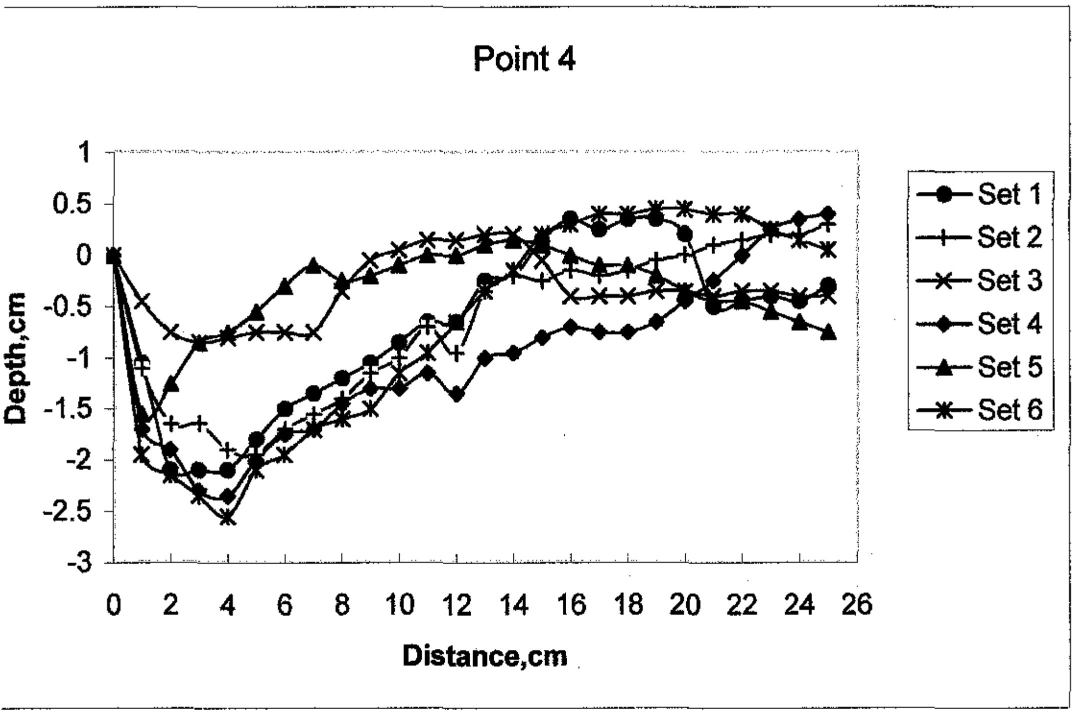

Point 5
0.5
0
-0.5
-1
-1.5
-2
-2.5
Depth,cm
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Distance,cm
Set 1
Set 2
Set 3
Set 4
Set 5
Set 6

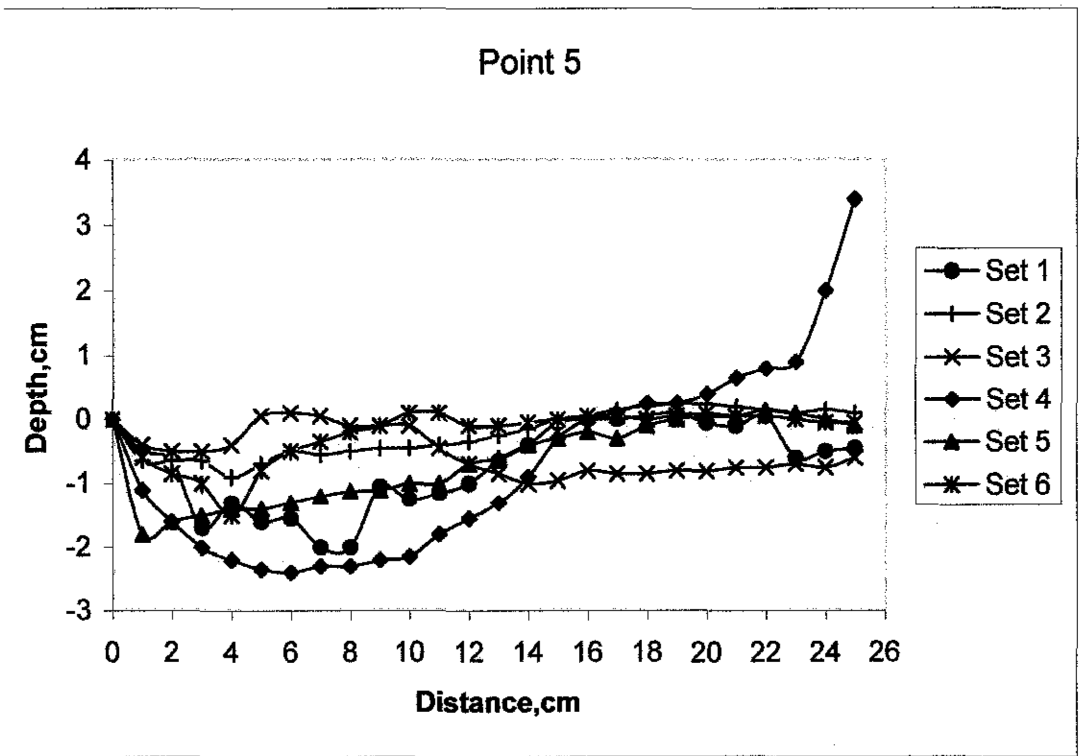
APPENDIX E

Scour profiles at 4 points around apron for 30L/s


Point 2
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Depth,cm
0 5 10 15 20 25 30 35 40 45 50 55
Distance,cm
Set 1
Set 2
Set 3
Set 4
Set 5
Set 6


Point 3
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
Depth,cm
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28
Distance,cm
Set 1
Set 2
Set 3
Set 4
Set 5
Set 6


Point 4
Depth,cm
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Distance,cm
Set 1
Set 2
Set 3
Set 4
Set 5
Set 6


Point 5
Depth,cm
4
3
2
1
0
-1
-2
-3
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Distance,cm
Set 1
Set 2
Set 3
Set 4
Set 5
Set 6

APPENDIX F

Measurement of Erosion Depths

Measurement of Erosion Depths

Set 1 (12L/s)

Point 1

Distance	Depth
0	0
1	-0.75
2	-0.9
3	-1
4	-0.85
5	-0.5
6	-0.4
7	-0.35
8	-0.05
9	0.05
10	0.05
11	0.1
12	-0.1
13	-0.35
14	-0.2
15	-0.35
16	-0.25
17	-0.35
18	-0.2
19	-0.1
20	-0.15
21	-0.05
22	-0.15
23	-0.2
24	-0.15
25	-0.15

Point 2

Distance	Depth
0	0
1	-0.95
2	-1.2
3	-1.25
4	-1.55
5	-1.6
6	-1.7
7	-1.55
8	-1.55
9	-1.3
10	-1.2
11	-1.15
12	-0.9
13	-0.75
14	-0.7
15	-0.5
16	0.05
17	0.3
18	0.4
19	-0.1
20	-0.1
21	-0.15
22	-0.15
23	-0.25
24	-0.25
25	-0.3

Point 3

Distance	Depth
0	0
1	-0.5
2	-0.8
3	-0.5
4	-0.35
5	-0.25
6	0
7	0.05
8	-0.3
9	-0.35
10	-0.35
11	-0.6
12	-0.5
13	-0.55
14	-0.55
15	-0.35
16	-0.3
17	-0.35
18	-0.35
19	-0.45
20	-0.4
21	-0.4
22	-0.45
23	-0.4
24	-0.5
25	-0.4

Point 4

Distance	Depth
0	0
1	-0.7
2	-0.65
3	-0.65
4	-0.35
5	-0.2
6	-0.1
7	0.15
8	0.25
9	0.35
10	-0.55
11	-0.5
12	-0.65
13	-0.65
14	-0.7
15	-0.8
16	-0.8
17	-0.75
18	-0.65
19	-0.65
20	-0.7
21	-0.6
22	-0.7
23	-0.65
24	-0.65
25	-0.65

Point 5

Distance	Depth
0	0
1	-0.6
2	-0.8
3	-0.85
4	-0.55
5	-0.3
6	-0.35
7	-0.1
8	0
9	0.15
10	0.3
11	-0.35
12	-0.35
13	-0.35
14	-0.5
15	-0.65
16	-0.85
17	-0.8
18	-0.85
19	-0.7
20	-0.9
21	-0.85
22	-0.8
23	-0.9
24	-0.9
25	-0.85

Set 1 (30L/s)

Point 1

Distance	Depth
0	0
2	-1.1
4	-1.8
6	-2.25
4	-2.3
8	-2.6
10	-2.65
12	-2.3
14	-2.5
16	-2.6
18	-2.6
20	-2
22	-2.5
24	-1.7
26	-0.75
28	-1.25
30	-1
32	-0.85
34	-0.55
36	-0.25
38	-0.45
40	-0.4
42	0.05
44	0.45
46	0.65
48	0.9
50	0.85
52	0.75
54	1.1
56	1.25
58	1.1

Point 2

Distance	Depth
0	0
2	-1.75
4	-2.5
6	-2.55
8	-2.5
10	-2.45
12	-2.5
14	-2.2
16	-1.9
18	-1.45
20	-1.1
22	-0.7
24	-0.3
26	-0.3
28	-0.05
30	0
32	0
34	0.1
36	0.2
38	0.1
40	-0.45
42	-0.8
44	-1.05

Point 3

Distance	Depth
0	0
1	-2
2	-1.85
3	-1.9
4	-2.15
5	-2.5
6	-2.8
7	-2.1
8	-1.85
9	-1.45
10	-0.95
11	-0.45
12	-0.25
13	0.05
14	0.25
15	0.4
16	-0.1
17	-0.45
18	-0.5
19	-0.45
20	-0.55
21	-0.5
22	-0.6
23	-0.65
24	-0.7
25	-0.75

Point 4

Distance	Depth
0	0
1	-1.05
2	-2.1
3	-2.1
4	-2.1
5	-1.8
6	-1.5
7	-1.35
8	-1.2
9	-1.05
10	-0.85
11	-0.65
12	-0.65
13	-0.25
14	-0.2
15	0.15
16	0.35
17	0.25
18	0.35
19	0.35
20	0.2
21	-0.5
22	-0.45
23	-0.4
24	-0.45
25	-0.3

Point 5

Distance	Depth
0	0
1	-0.5
2	-0.65
3	-1.7
4	-1.3
5	-1.6
6	-1.55
7	-2
8	-2
9	-1.05
10	-1.25
11	-1.15
12	-1
13	-0.65
14	-0.4
15	-0.05
16	0
17	0
18	0.05
19	0.1
20	-0.05
21	-0.1
22	0.05
23	-0.6
24	-0.5
25	-0.45

Set 2 (12L/s)

Point 1

Distance	Depth
0	0
2	-1.1
4	-0.9
6	-0.85
8	-0.7
10	-0.55
12	-0.4
14	-0.5
16	-0.25
18	-0.15
20	-0.1
22	-0.25
24	-0.15
26	-0.1
28	0
30	0.1
32	0.15
34	-0.45
36	-0.85
38	-0.9
40	-0.85
42	-0.85
44	-0.65
46	-0.65
48	-0.65
50	-0.5

Point 2

Distance	Depth
0	0
1	-0.5
2	-0.65
3	-0.75
4	-0.45
5	-0.45
6	-0.25
7	-0.15
8	-0.2
9	0.05
10	0.05
11	-0.35
12	-0.45
13	-0.35
14	-0.4
15	-0.45
16	-0.5
17	-0.4
18	-0.6
19	-0.5
20	-0.55
21	-0.75
22	-0.55
23	-0.7
24	-0.8
25	-0.7

Point 3

Distance	Depth
0	0
1	-1.6
2	-1.7
3	-1.55
4	-1.5
5	-1.1
6	-0.9
7	-0.9
8	-0.85
9	-0.8
10	-0.6
11	-0.55
12	-0.4
13	-0.2
14	0
15	0.05
16	-0.3
17	-0.7
18	-0.9
19	-1.1
20	-1.3
21	-1.3
22	-1.35
23	-1.59
24	-1.6
25	-1.6

Point 4

Distance	Depth
0	0
1	-0.75
2	-1.35
3	-1.05
4	-1.35
5	-0.75
6	-0.65
7	-0.35
8	-0.15
9	-0.05
10	0
11	0
12	-0.85
13	-0.7
14	-0.6
15	-0.7
16	-0.85
17	-0.85
18	-0.95
19	-0.85
20	-0.9
21	-0.85
22	-0.85
23	-0.85
24	-0.9
25	-1.05

Point 5

Distance	Depth
0	0
1	-1.5
2	-1.4
3	-1.15
4	-0.75
5	-0.65
6	-0.65
7	-0.6
8	-0.5
9	-0.4
10	-0.2
11	-0.1
12	0.05
13	0.1
14	-0.2
15	-0.4
16	-0.45
17	-0.5
18	-0.52
19	-0.5
20	-0.45
21	-0.4
22	-0.4
23	-0.35
24	-0.35
25	-0.3

Set 2 (30L/s)

Point 1

Distance,cm	Depth,cm
0	0
2	-1.75
4	-2.25
6	-3.4
8	-4.25
10	-4.75
12	-4.95
14	-5.25
16	-5.5
18	-5.45
20	-5.5
22	-5.4
24	-5
26	-4.75
28	-4.55
30	-3.95
32	-3.85
34	-3.25
36	-2.95
38	-2.75
40	-2.35
42	-1.95
44	-1.75
46	-1.65
48	-0.75
50	-0.7
52	-0.45

Point 2

Distance,cm	Depth,cm
0	0
2	-1.85
4	-2.1
6	-2.45
8	-2.35
10	-2.35
12	-2.1
14	-1.95
16	-1.65
18	-1.3
20	-0.75
22	-0.45
24	-0.25
26	0.4
28	0.25
30	0.4
32	0.15
34	-0.1
36	0
38	-0.05
40	-0.05
42	0.05
44	-0.15
46	-0.05
48	-0.1

Point 3

Distance,cm	Depth,cm
0	0
1	-1.3
2	-1.45
3	-1.3
4	-1
5	-0.7
6	-0.55
7	-0.35
8	-0.45
9	-0.55
10	-0.75
11	-0.7
12	-0.65
13	-0.5
14	-0.45
15	-0.35
16	-0.25
17	-0.15
18	0
19	0.05
20	0.1
21	0.25
22	0.25
23	0.35
24	0.4
25	0.45

Point 4

Distance,cm	Depth,cm
0	0
1	-1.1
2	-1.65
3	-1.65
4	-1.9
5	-1.95
6	-1.7
7	-1.55
8	-1.4
9	-1.15
10	-1
11	-0.7
12	-0.95
13	-0.35
14	-0.2
15	-0.25
16	-0.15
17	-0.2
18	-0.15
19	-0.05
20	0
21	0.1
22	0.15
23	0.2
24	0.2
25	0.3

Point 5

Distance,cm	Depth,cm
0	0
1	-0.65
2	-0.65
3	-0.65
4	-0.9
5	-0.7
6	-0.5
7	-0.55
8	-0.5
9	-0.45
10	-0.45
11	-0.4
12	-0.35
13	-0.25
14	-0.15
15	0
16	0.05
17	0.15
18	0.2
19	0.25
20	0.25
21	0.2
22	0.15
23	0.1
24	0.15
25	0.1

Set 3 (12L/s)

Point 1

Distance,c	Depth,cm
0	0
2	-1
4	-1.15
6	-1.3
8	-1.3
10	-1.35
12	-1.15
14	-1.05
16	-0.75
18	-0.4
20	-0.2
22	-0.15
24	0
26	0.05
28	0.05
30	0
32	-0.2
34	-0.15
36	-0.1
38	-0.25
40	-0.6
42	-0.75
44	-0.7
46	-0.45
48	-0.2
50	-0.2

Point 2

Distance,c	Depth,cm
0	0
1	-0.5
2	-0.7
3	-0.5
4	-0.25
5	-0.2
6	0
7	0
8	0.1
9	0
10	0.05
11	-0.1
12	-0.1
13	-0.05
14	-0.1
15	0.05
16	0.1
17	0.15
18	0.15
19	0.1
20	0.1
21	0.05
22	0.1
23	0.15
24	0.15
25	0.1

Point 3

Distance,c	Depth,cm
0	0
1	-1.35
2	-1.6
3	-1.55
4	-1.5
5	-1.3
6	-1.1
7	-0.8
8	-0.55
9	-0.4
10	-0.45
11	-0.75
12	-0.9
13	-0.8
14	-0.7
15	-0.55
16	-0.45
17	-0.25
18	-0.1
19	0
20	0.1
21	0.2
22	0.25
23	0.25
24	0.2
25	0.15

Point 4

Distance,c	Depth,cm
0	0
1	-0.95
2	-1.05
3	-1.1
4	-0.9
5	-0.75
6	-0.35
7	0
8	0.1
9	0.2
10	0.25
11	-0.3
12	-0.35
13	-0.3
14	-0.35
15	-0.25
16	-0.25
17	-0.2
18	-0.2
19	-0.25
20	-0.2
21	-0.15
22	-0.15
23	-0.1
24	-0.15
25	-0.1

Point 5

Distance,c	Depth,cm
0	0
1	-0.8
2	-1.25
3	-1.3
4	-1.3
5	-1.1
6	-0.9
7	-0.9
8	-0.7
9	-0.5
10	-0.4
11	-0.25
12	0
13	0.01
14	0.05
15	0.1
16	0.2
17	0.25
18	0.25
19	0.2
20	0.2
21	0.25
22	0.25
23	0.1
24	-0.1
25	-0.2

Set 3 (30L/s)

Point 1

Distance,c	Depth,cm
0	0
2	-1.75
4	-2.45
6	-2.95
8	-3.3
10	-3.45
12	-3.55
14	-3.55
16	-3.1
18	-3.15
20	-2.75
22	-2.75
24	-2.45
26	-2.75
28	-1.95
30	-1.65
32	-1.55
34	-1.25
36	-0.95
38	-0.95
40	-0.75
42	-0.6
44	-0.45
46	-0.35
48	-0.15
50	-0.05
52	0
54	0
56	0.1

Point 2

Distance,c	Depth,cm
0	0
2	-0.25
4	-0.15
6	0.15
8	0.25
10	0.35
12	0.3
14	0.2
16	0.25
18	0.2
20	0.3
22	0.2
24	0.35
26	0.3
28	0.1
30	0.2
32	0.2
34	0.15
36	0.1
38	-0.05
40	-0.1
42	0.1
44	0
46	0.05
48	-0.05
50	-0.05

Point 3

Distance,c	Depth,cm
0	0
1	-1.3
2	-1.25
3	-1.25
4	-0.95
5	-0.6
6	-0.55
7	-0.35
8	-0.4
9	-0.6
10	-0.6
11	-0.6
12	-0.65
13	-0.55
14	-0.45
15	-0.4
16	-0.35
17	-0.3
18	-0.25
19	-0.15
20	0
21	0.15
22	0.2
23	0.25
24	0.3
25	0.3

Point 4

Distance,c	Depth,cm
0	0
1	-0.45
2	-0.75
3	-0.85
4	-0.8
5	-0.75
6	-0.75
7	-0.75
8	-0.35
9	-0.05
10	0.05
11	0.15
12	0.15
13	0.2
14	0.2
15	-0.05
16	-0.4
17	-0.4
18	-0.4
19	-0.35
20	-0.35
21	-0.4
22	-0.35
23	-0.35
24	-0.4
25	-0.4

Point 5

Distance,c	Depth,cm
0	0
1	-0.4
2	-0.5
3	-0.5
4	-0.4
5	0.05
6	0.1
7	0.05
8	-0.1
9	-0.1
10	-0.1
11	-0.45
12	-0.7
13	-0.85
14	-1
15	-0.95
16	-0.8
17	-0.85
18	-0.85
19	-0.8
20	-0.8
21	-0.75
22	-0.75
23	-0.7
24	-0.75
25	-0.6

Set 3 (30L/s)

Point 1

Distance,c	Depth,cm
0	0
2	-1.75
4	-2.45
6	-2.95
8	-3.3
10	-3.45
12	-3.55
14	-3.55
16	-3.1
18	-3.15
20	-2.75
22	-2.75
24	-2.45
26	-2.75
28	-1.95
30	-1.65
32	-1.55
34	-1.25
36	-0.95
38	-0.95
40	-0.75
42	-0.6
44	-0.45
46	-0.35
48	-0.15
50	-0.05
52	0
54	0
56	0.1

Point 2

Distance,c	Depth,cm
0	0
2	-0.25
4	-0.15
6	0.15
8	0.25
10	0.35
12	0.3
14	0.2
16	0.25
18	0.2
20	0.3
22	0.2
24	0.35
26	0.3
28	0.1
30	0.2
32	0.2
34	0.15
36	0.1
38	-0.05
40	-0.1
42	0.1
44	0
46	0.05
48	-0.05
50	-0.05

Point 3

Distance,c	Depth,cm
0	0
1	-1.3
2	-1.25
3	-1.25
4	-0.95
5	-0.6
6	-0.55
7	-0.35
8	-0.4
9	-0.6
10	-0.6
11	-0.6
12	-0.65
13	-0.55
14	-0.45
15	-0.4
16	-0.35
17	-0.3
18	-0.25
19	-0.15
20	0
21	0.15
22	0.2
23	0.25
24	0.3
25	0.3

Point 4

Distance,c	Depth,cm
0	0
1	-0.45
2	-0.75
3	-0.85
4	-0.8
5	-0.75
6	-0.75
7	-0.75
8	-0.35
9	-0.05
10	0.05
11	0.15
12	0.15
13	0.2
14	0.2
15	-0.05
16	-0.4
17	-0.4
18	-0.4
19	-0.35
20	-0.35
21	-0.4
22	-0.35
23	-0.35
24	-0.4
25	-0.4

Point 5

Distance,c	Depth,cm
0	0
1	-0.4
2	-0.5
3	-0.5
4	-0.4
5	0.05
6	0.1
7	0.05
8	-0.1
9	-0.1
10	-0.1
11	-0.45
12	-0.7
13	-0.85
14	-1
15	-0.95
16	-0.8
17	-0.85
18	-0.85
19	-0.8
20	-0.8
21	-0.75
22	-0.75
23	-0.7
24	-0.75
25	-0.6

Set 4 (12L/s)

Point 1

Distance,c	Depth,cm
0	0
2	-0.6
4	-0.35
6	-0.3
8	-0.6
10	-0.4
12	-0.15
14	0
16	0
18	-0.35
20	-0.5
22	-0.45
24	-0.35
26	-0.4
28	-0.25
30	-0.15
32	-0.1
34	-0.1
36	-0.2
38	-0.35
40	-0.4
42	-0.35
44	-0.35
46	-0.5
48	-0.5
50	-0.55

Point 2

Distance,c	Depth,cm
0	0
1	-1.05
2	-1.2
3	-0.45
4	-0.2
5	0.15
6	0.15
7	0.35
8	0.4
9	0.45
10	0.45
11	0.1
12	0.05
13	0.1
14	0.05
15	0.05
16	0.1
17	0.15
18	0.15
19	0.1
20	0.2
21	0.2
22	0.2
23	0.2
24	0.25
25	0.2

Point 3

Distance,c	Depth,cm
0	0
1	-0.8
2	-1.15
3	-1.15
4	-1.6
5	-1.45
6	-1.4
7	-1.25
8	-0.95
9	-0.8
10	-0.75
11	-0.5
12	-0.5
13	-0.3
14	-0.1
15	0.15
16	0.2
17	0.25
18	0.1
19	-0.2
20	-0.35
21	-0.35
22	-0.4
23	-0.45
24	-0.5
25	-0.55

Point 4

Distance,c	Depth,cm
0	0
1	-0.75
2	-0.85
3	-0.85
4	-0.65
5	-0.6
6	-0.35
7	-0.05
8	0.05
9	0.25
10	0.25
11	0.25
12	0.25
13	0.25
14	0.2
15	-0.35
16	-0.3
17	-0.35
18	-0.4
19	-0.45
20	-0.45
21	-0.5
22	-0.55
23	-0.65
24	-0.85
25	-0.85

Point 5

Distance,c	Depth,cm
0	0
1	-0.9
2	-1.05
3	-1.05
4	-1.35
5	-1.15
6	-1
7	-0.95
8	-0.85
9	-0.6
10	-0.65
11	-0.45
12	-0.35
13	-0.15
14	-0.05
15	0.05
16	0.15
17	0.2
18	0.25
19	0.25
20	0.35
21	0.2
22	0.05
23	-0.95
24	-0.9
25	-0.9

Set 4(30L/s)

Point 1

Distance,cm	Depth,cm
0	0
2	-1.1
4	-1.55
6	-1.5
8	-1.5
10	-1.3
12	-1.2
14	-0.95
16	-0.55
18	-0.45
20	-0.35
22	-0.25
24	0
26	-0.05
28	0.05
30	0
32	-0.05
34	-0.05
36	-0.1
38	-0.4
40	-0.45
42	-0.4
44	-0.55
46	-0.95
48	-0.85
50	-0.4

Point 2

Distance,cm	Depth,cm
0	0
2	-1.15
4	-1.4
6	-2.1
8	-1.6
10	-1.3
12	-1.25
14	-1.05
16	-0.9
18	-0.8
20	-0.6
22	-0.4
24	-0.2
26	-0.25
28	0
30	0.2
32	0.1
34	0.35
36	0.4
38	0.6
40	0.65
42	0.45
44	0.3
46	0.35
48	0.35
50	0.35

Point 3

Distance,cm	Depth,cm
0	0
1	-0.95
2	-1.45
3	-1.75
4	-1.85
5	-1.9
6	-1.85
7	-2.25
8	-2.15
9	-1.8
10	-1.6
11	-1.45
12	-1.2
13	-0.95
14	-0.75
15	-0.75
16	-0.6
17	-0.45
18	0.35
19	-0.25
20	-0.1
21	0
22	0.05
23	0.1
24	0.2
25	0.25

Point 4

Distance,cm	Depth,cm
0	0
1	-1.7
2	-1.9
3	-2.3
4	-2.35
5	-2
6	-1.75
7	-1.7
8	-1.45
9	-1.3
10	-1.3
11	-1.15
12	-1.35
13	-1
14	-0.95
15	-0.8
16	-0.7
17	-0.75
18	-0.75
19	-0.65
20	-0.45
21	-0.25
22	0
23	0.25
24	0.35
25	0.4

Point 5

Distance,cm	Depth,cm
0	0
1	-1.1
2	-1.6
3	-2
4	-2.2
5	-2.35
6	-2.4
7	-2.3
8	-2.3
9	-2.2
10	-2.15
11	-1.8
12	-1.55
13	-1.3
14	-0.9
15	-0.3
16	0
17	0.1
18	0.25
19	0.25
20	0.4
21	0.65
22	0.8
23	0.9
24	2
25	3.4

Set 5 (12L/s)

Point 1

Distance,cm	Depth,cm
0	0
2	-0.7
4	-1
6	-0.95
8	-0.85
10	-0.7
12	-0.6
14	-0.5
16	-0.2
18	0
20	0.25
22	-0.25
24	-0.55
26	-0.65
28	-0.7
30	-0.7
32	-0.7
34	-0.75
36	-0.85
38	-0.8
40	-0.8
42	-0.85
44	-0.75
46	-0.75
48	-0.75
50	-0.8

Point 2

Distance,cm	Depth,cm
0	0
1	-0.6
2	-0.65
3	-0.75
4	-0.6
5	-0.3
6	-0.25
7	-0.25
8	0.05
9	0.15
10	0.3
11	0.1
12	-0.05
13	-0.05
14	-0.1
15	-0.15
16	-0.15
17	-0.3
18	-0.25
19	-0.4
20	-0.45
21	-0.5
22	-0.6
23	-0.6
24	-0.55
25	-0.55

Point 3

Distance,cm	Depth,cm
0	0
1	-2.5
2	-2.2
3	-2
4	-1.8
5	-1.6
6	-1.5
7	-1.3
8	-1.1
9	-0.9
10	-0.7
11	-0.5
12	-0.5
13	-0.45
14	-0.4
15	-0.35
16	-0.25
17	-0.15
18	-0.15
19	-0.1
20	0
21	0.05
22	0.25
23	0.35
24	0.25
25	0.05

Point 4

Distance,cm	Depth,cm
0	0
1	-1.2
2	-1.1
3	-1.1
4	-1
5	-0.9
6	-0.85
7	-0.85
8	-0.75
9	-0.55
10	-0.4
11	-0.4
12	-0.35
13	-0.35
14	-0.3
15	-0.2
16	-0.1
17	0
18	0.1
19	0.2
20	0.1
21	-0.2
22	-0.25
23	-0.25
24	-0.35
25	-0.45

Point 5

Distance,cm	Depth,cm
0	0
1	-1.35
2	-1.65
3	-1.75
4	-2
5	-2.15
6	-1.7
7	-1.5
8	-1.45
9	-1.4
10	-1.35
11	-1.2
12	-0.9
13	-0.75
14	-0.65
15	-0.65
16	-0.45
17	-0.35
18	-0.15
19	0
20	0.05
21	0
22	-0.1
23	-0.2
24	-0.15
25	-0.1

Set 5 (30L/s)

Point 1

Distance,cm	Depth,cm
0	0
2	-1.2
4	-1.5
6	-1.75
8	-1.9
10	-2.2
12	-2.05
14	-1.85
16	-1.5
18	-1
20	-0.4
22	-0.3
24	-0.15
26	0
28	0
30	0.05
32	-0.05
34	-0.15
36	-0.15
38	-0.1
40	-0.1
42	-0.1
44	-0.4
46	-0.5
48	-0.75
50	-1

Point 2

Distance,cm	Depth,cm
0	0
2	-2.2
4	-2
6	-1.8
8	-1.6
10	-1.4
12	-1
14	-0.9
16	-0.6
18	-0.5
20	-0.2
22	0
24	0
26	0.1
28	0.15
30	0.25
32	0.15
34	0
36	-0.05
38	-0.1
40	-0.15
42	-0.15
44	-0.2
46	-0.15
48	-0.25
50	-0.35

Point 3

Distance,cm	Depth,cm
0	0
1	-1.5
2	-1.2
3	-1.1
4	-0.9
5	-0.7
6	-0.5
7	-0.3
8	-0.1
9	0
10	0.05
11	0.15
12	0.25
13	0.1
14	0.05
15	-0.05
16	-0.2
17	-0.15
18	-0.25
19	-0.3
20	-0.25
21	-0.4
22	-0.4
23	-0.45
24	-0.45
25	-0.5

Point 4

Distance,cn	Depth,cm
0	0
1	-1.55
2	-1.25
3	-0.85
4	-0.75
5	-0.55
6	-0.3
7	-0.1
8	-0.25
9	-0.2
10	-0.1
11	0
12	0
13	0.1
14	0.15
15	0.1
16	0
17	-0.1
18	-0.1
19	-0.2
20	-0.35
21	-0.45
22	-0.45
23	-0.55
24	-0.65
25	-0.75

Point 5

Distance,cn	Depth,cm
0	0
1	-1.8
2	-1.6
3	-1.5
4	-1.4
5	-1.4
6	-1.3
7	-1.2
8	-1.12
9	-1.1
10	-1
11	-1
12	-0.7
13	-0.6
14	-0.4
15	-0.3
16	-0.2
17	-0.3
18	-0.1
19	0
20	0.05
21	0.05
22	0.15
23	0.1
24	0
25	-0.1

Set 6 (12L/s)

Point 1

Distance,cn	Depth,cm
0	0
2	-1.4
4	-1.4
6	-1.45
8	-1.5
10	-1.45
12	-1.25
14	-0.85
16	-0.55
18	-0.35
20	-0.05
22	0.05
24	0.15
26	0.2
28	0.25
30	0.25
32	0.2
34	0.05
36	-0.15
38	-0.3
40	-0.45
42	-0.45
44	-0.5
46	-0.5
48	-0.5
50	-0.55

Point 2

Distance,cn	Depth,cm
0	0
1	-0.6
2	-0.65
3	-1
4	-1.15
5	-1.35
6	-1.35
7	-1.4
8	-1.4
9	-1.2
10	-0.9
11	-0.6
12	-0.65
13	-0.6
14	-0.4
15	-0.25
16	-0.3
17	-0.25
18	-0.25
19	0.15
20	0.25
21	0.25
22	0.35
23	0.45
24	0.45
25	0.45

Point 3

Distance,cn	Depth,cm
0	0
1	-1.35
2	-1.4
3	-1.4
4	-1.1
5	-1.5
6	-1.5
7	-1.4
8	-1.4
9	-1.1
10	-1
11	-0.9
12	-0.7
13	-0.6
14	-0.5
15	-0.35
16	-0.35
17	-0.25
18	-0.1
19	0.05
20	0.1
21	0.2
22	0.2
23	0.15
24	0.1
25	0

Point 4

Distance,cn	Depth,cm
0	0
1	-1.95
2	-2
3	-2.05
4	-2.1
5	-2.2
6	-1.95
7	-1.75
8	-1.55
9	-1.25
10	-1.05
11	-0.85
12	-0.65
13	-0.65
14	-0.55
15	-0.45
16	-0.25
17	-0.05
18	0.15
19	0.25
20	0.3
21	0.4
22	0.55
23	1.05
24	1.55
25	2.05

Point 5

Distance,cn	Depth,cm
0	0
1	-1.3
2	-1.35
3	-1.45
4	-1.5
5	-1.6
6	-1.5
7	-1.45
8	-1.45
9	-1.35
10	-1.25
11	-1.15
12	-1
13	-0.95
14	-0.95
15	-0.95
16	-0.9
17	-0.9
18	-0.8
19	-0.6
20	-0.4
21	-0.2
22	0
23	0.05
24	0.1
25	0.2

Set 6 (30L/s)

Point 1

Distance,cm	Depth,cm
0	0
2	-2.35
4	-2.65
6	-2.85
8	-2.9
10	-3
12	-2.95
14	-2.85
16	-2.75
18	-2.55
20	-2.35
22	-2.15
24	-1.85
26	-1.6
28	-1.4
30	-1.25
32	-1
34	-0.8
36	-0.75
38	-0.65
40	-0.5
42	-0.35
44	-0.15
46	0.05
48	0.1
50	0.2

Point 2

Distance,cm	Depth,cm
0	0
2	-1.4
4	-1.5
6	-1.55
8	-1.65
10	-1.55
12	-1.4
14	-1.2
16	-0.8
18	-0.2
20	0.2
22	0.45
24	0.65
26	0.5
28	0.4
30	0.35
32	0.25
34	0.2
36	0.25
38	0.25
40	0.15
42	0.1
44	0.15
46	0.1
48	0.15
50	0.05

Point 3

Distance,cm	Depth,cm
0	0
1	-1.1
2	-1.2
3	-1.5
4	-1.7
5	-1.3
6	-1.1
7	-0.85
8	-0.6
9	-0.4
10	-0.25
11	-0.2
12	-0.05
13	0.1
14	0.15
15	0.2
16	0.1
17	0
18	-0.15
19	-0.25
20	-0.4
21	-0.35
22	-0.4
23	-0.45
24	-0.5
25	-0.45

Point 4

Distance,cm	Depth,cm
0	0
1	-1.95
2	-2.15
3	-2.35
4	-2.55
5	-2.1
6	-1.95
7	-1.7
8	-1.6
9	-1.5
10	-1.15
11	-0.95
12	-0.65
13	-0.35
14	-0.15
15	0.2
16	0.3
17	0.4
18	0.4
19	0.45
20	0.45
21	0.4
22	0.4
23	0.25
24	0.15
25	0.05

Point 5

Distance,cm	Depth,cm
0	0
1	-0.6
2	-0.85
3	-1
4	-1.5
5	-0.8
6	-0.5
7	-0.35
8	-0.2
9	-0.1
10	0.1
11	0.1
12	-0.1
13	-0.1
14	-0.05
15	0
16	0.05
17	0.05
18	0
19	0.05
20	0.1
21	0.05
22	0.05
23	0
24	-0.05
25	-0.05