CHAPTER ONE

INTRODUCTION

1.1 PROBLEM JUSTIFICATION:

The study of non-linear equations of unsteady flow in all hydraulic problems is of greater concern for hydraulic engineers throughout the world. The water hammer pressure study in surge tank and in pressure conduit is a very complex and difficult problem for the water engineers in hydropower development schemes and other situations involving large flow and therefore, this problem has remained a continued interest for researchers. The unsteady equations of flow producing water hammer are always challenging. The basic solution involves the numerical solution of non-linear equations of continuity and momentum with correct assessment of pressure with suitable resistance equation. The flow situation varies from steady to turbulent unsteady with damping of dynamic pressure with time inside the pipe system. Sudden closure of penstock valve induces excess pressure in a pipe. Water hammer or hydraulic transient, as used more recently, refers to pressure fluctuations caused by a sudden increase or decrease of flow. This unsteady state phenomenon deals with the change between kinetic energy and pressure energy, which may be positive or negative. If the pressure induced exceeds the pressure rating of a pipe given by the manufacturer, the pipe may rupture. Detrimental consequences may result unless a pressure protection device is installed. The hydraulic engineer, water supply designer and pumping system operator have the responsibility to ensure the surges due to water hammer be within acceptable limits, and can be dampened as quickly as possible. The study on the problem leads to its research leading to its basic concept, causes of
flow, materials to resist such high pressure fluctuation with economic application, the control device design, manufacturing and prediction of rise of pressure etc.

The main function of a surge tank in high head hydropower plant is to eliminate the extra water hammer pressure rise due to closure of the penstock valve to study initial flow of water to turbine. The flow conditions in the pressure conduit in the surge tank starts from turbulent transitional and finally laminar to static when the valve is suddenly closed. Therefore, evaluation of the friction factor at every time step with a proper resistance equation is essential.

1.2 OBJECTIVES:

Hydraulic transient events are disturbances in the water caused during a change in state, typically from one steady or equilibrium condition to another. The principal components of the disturbances are pressure and flow change at a point that causes propagation of pressure waves throughout the distribution system. The pressure waves travel with the velocity of sound (acoustic or sonic speed), which depends on the elasticity of the water and that of the pipe walls. As these waves propagate, they create transient pressure and flow conditions. Damping actions and friction reduces the waves with time until the system stabilizes at a new steady state. Normally, only extremely slow flow regulation can result in smooth transitions from one steady state to another without large fluctuations in pressure or flow.

In general, any disturbance in the water generated during a change in mean flow conditions will initiate a sequence of transient pressures (waves) in the water distribution system. Disturbances will normally originate from changes or
actions that affect hydraulic devices or boundary conditions. Typical events that require transient considerations include:

1. Pump startup or shutdown;
2. Valve opening or closing (which causes variation in cross-sectional flow area);
3. Changes in boundary pressures (e.g. closing overhead storage tank, adjustments in the water level at reservoirs, pressure changes in tanks, etc.);
4. Rapid changes in demand conditions (e.g. hydrant flushing);
5. Changes in transmission conditions (e.g. power supply main breakdown or line freezing);
6. Pipe filling or draining air release from pipes; and
7. Check valve or regulator valve action.

Potentially, these disturbances can create serious consequences for water utilities if not properly recognized and addressed by proper analysis with appropriate design and operational considerations. Hydraulic systems must be designed to accommodate both normal and abnormal operations and be safeguarded to handle adverse external events such as power failure, pipeline fracture, etc. The modern concept of fluid friction can be traced to the theoretical and practical investigation of Prandtl and Von–Karman which were based on classical approach of Nikuradse. These studies have become a pioneer in this field as the resistance to flow in pipes as well as in open channel flow. The exact solution of pressure conduit flow does not exist as the equation of continuity and momentum equation have not included the suitable resistance formula to find the energy losses for the friction.
There are approaches for trial and error method, graphical method which are tiresome and tedious as available in the literature. The physical model study may be adopted, but it becomes laborious and rather expensive. Small parameters also affect the result to a greater extent.

The numerical model study in water hammer situation for pressure variation is the best tool to study these solutions. This model can be treated with different numerical approaches. The literature survey also suggests some of them. The present work is to find out the best possible model study using computer techniques with numerical methods.

1.3 METHODS OF INVESTIGATION:

The theoretical investigations of few renowned researcher like Nikuradse(1933), Prandtl(1905) and Von-Karman(1931) on modern concept of fluid friction and resistance laws are the basis of the study. These studies will cover the present concept of resistance to flow in pipes and open channel. A suitable resistance equation have been developed by Barr(1975) based on logarithmic concept have been used with computer facility.

The basic review of non-linear unsteady equation of flow has been made along with Thoma's(1910) analytical solution. The numerical solution by Jakobsen(1969) method is also discussed with the merits and demerits. Analysis with the data of experimental work on surge tank pressure head is analysed with the numerical approach. A review of experimental data with the available result in the literatures is also done with relative comparison to establish the perfection of the present study. The results obtained for fluctuation of surge height and friction factor by modified Jakobsen's method and Explicit Finite Difference method are presented.
It was observed how friction affects the damping of pressure rise. This also helps to determine the design height and area of surge tank, and also the length and diameter of the pressure conduit. The nonlinear equation of continuity and momentum for pressure conduit without a surge tank have been solved by Method of Characteristics and Lax explicit finite different scheme. In both the mathematical models, the initial condition is imposed from steady state of flow in the conduit when the valve is open. The infinite reservoir concept is applied as boundary condition with pressure head remaining constant at upstream, and at downstream principle of orifice is used in valve closing period. The result obtained with different fluctuations of pressure head with discharge at various sections are presented and analysed graphically. The pattern of damping pressure and discharge can be observed from the presentations. Comparison of numerical solutions with experimental data of surge tank has been made to assess the mathematical model. A close agreement has been observed.

1.4 CONCLUSIONS:

The complex problem of water hammer pressure evaluation with or without surge tank has become a continued interest for hydraulic engineers owing to its importance in hydro-electric project. But unfortunately, equations of continuity and momentum are non-linear in nature. Therefore, methods of numerical solution with finite difference scheme are essential. Three such different numerical solutions have been developed in this study. Parallel investigations have also been made on how the transient friction factors of the pipe have played a dominant role to damp down the inertia pressure. The result obtained by the numerical solution has been assessed by the experimental data. A close agreement has been seen in the comparison. Details of the work done and scope for the future research have been outlined at the end.