INTRODUCTION

1.1   GENERAL

Landslide is the phenomenon which encompasses movement of a mass of rock, debris, or soil down a slope. Slopes in mountainous areas are subjected to various destabilizing forces. These slopes strive to become stable by attaining a natural equilibrium under a specific set of conditions and become unstable once this natural equilibrium is disturbed, resulting in landslides. Landslides are an inherent dilemma of the mountainous areas and have been observed and recorded for several centuries worldwide. The oldest landslides on record occurred in Honan Province in central China in 1767 B.C. (Xue-Cai and An-ning, 1986).

The problems of landslides have caused extensive loss and damage to human life and property worldwide. In addition to the loss of life, landslides destroy or damage residential and industrial developments as well as agricultural and forest lands and negatively affect water quality in rivers and streams. Asia suffered 220 landslides in the past century – by far the most of any world region – but those in North, Central, and South America have caused the most deaths and injuries (more than 25,000) while Europe are the most expensive – causing average damage of almost $23 million per landslide (United Nations University, 2006). Among natural disasters, landslides are the seventh ranked killer, after windstorms, floods, droughts, earthquakes, volcano, and extreme temperature, claiming 800 to 1,000 lives on average in each of the last 20 years (United Nations University, 2006). Annual property damage from landslides worldwide is estimated in the tens of billions of dollars, with more than $1.5 billion in annual losses in the USA alone (GCRIO, 2005). Damage to ecosystems has not generally been documented, but landslides may destroy habitats, for example by blocking streams and denuding slopes (GCRIO, 2005).

Murree is one of the busiest hill resorts of Northern Pakistan. A large number of tourists visit Murree every year. According to an estimate there are more than 1000 hotels and guest houses in the urban area of Murree. Moreover, population of urban Murree (which is around 30,000) rises to 300,000 during summer season. Being an attractive resort for tourists, business and commercial activities are growing at a very rapid pace. Resultantly, uncontrolled and illegal construction is mushrooming in the area. A number of important defense installations / headquarters such as PAF Base and Divisional Headquarter are also located either in the study area or in its close proximity. Furthermore, Murree also provides a very important road link to the Azad Kashmir. Owing to the fragile geology, deforestation coupled with un-controlled urbanization, the area is under constant threat of landslides and slope failures, thereby, creating high risk to human life, limb and property. Keeping in view the value of human life and property and strategic importance of the area, it is vital to assess and map / model the landslide hazard and risk of Urban Murree.

In this research study, Landslide Hazard and Risk was evaluated and mapped for the urban Murree area. The resulting maps demarcate the area into different intensity hazard (i.e., very high, high, medium, low, very low) and risk (i.e., very high, high, moderate, safe) zones. These maps could be used for the analysis and rehabilitation of the existing construction and for the design of future construction and landuse.

1.2   RESEARCH OBJECTIVES

The study aimed at developing Landslide Hazard and Risk maps for urban area of Murree. The objectives of the study are enumerated below:

- Investigation and mapping of landslide hazard zones of urban Murree area.

- Evaluation and mapping of landslide risk zones of urban Murree area.

- These maps could be utilized by the planners, designers and builders to select safe / appropriate locations and alignments for the buildings and communication infrastructure. These maps could also be used for the rehabilitation and disaster management works.

- Hazard and Risk maps / models will be able to 'predict' landsliding caused by numerous factors affecting stability of slopes under different conditions. The models will also be temporal in nature and will be able to forecast the slope instabilities with changing scenarios such as weathering of rocks, changes in geomorphology, moisture, and vegetation conditions.

- Recommendations for the mitigation and rehabilitation works required in the high hazard and risk zones.

1.3   RESEARCH PLAN

In order to accomplish the above-mentioned objectives of the research, a multi-prong research plan was prepared and is shown in Fig. 1.1. The proposed research tasks are briefly described below:

- Identification of the primary, secondary, and tertiary level factors affecting the stability of slopes in the area to be investigated.

- Identification of the factors contributing to the landslide risk in the area.

- Recording the identified factors for the entire area using walk-over surveys. The data has been collected along the following roads of the urban Murree area (Fig. 1.2):

  o   Jhika Gali- Lawrence College Road –LCJG
  o   Lawrence College- Station Headquarter Road – LCSHQ
  o   Station Headquarter – Sunny Bank Road- SHQSB
  o   Jhika Gali- Kuldana Road – JGK
  o   Jhika Gali- GPO Road (Upper Jhika Gali Road) – JGGPO
  o   Kuldana-GPO Chowk Road – KGPO

- o GPO Chowk-Kashmir Point – Bank Road
- o Kashmir Point-GPO Chowk – Hall Road
- o Upper Jhika Gali - Kashmir Point - Veiw Forth Road
- o GPO Chowk – Pindi Point – Mall Road

- Field investigations to determine geotechnical strata / parameters required for the stability analysis of the area. Field investigation of the strata was carried out through:

  - o Geophysical Testing (1-D and 2-D Electrical Resistivity tests)
  - o Excavation, sampling and in-situ testing (Vane Shear and Cone Penetration) of test pits
  - o Drilling, sampling, in-situ testing (Standard Penetration Tests) of boreholes and installation of piezometers

- Laboratory investigations includes:

  - o Classification of soil samples (Grain size analysis and Atterberg limits tests)
  - o Strength and stiffness testing using Triaxial and Direct Shear tests and Odometer testing
  - o Weathering study using slake durability test

- Based on the recorded, collected, and generated data, Landslide Hazard was evaluated using statistical models based on Fuzzy Logic Technique.

- Using Landslide Hazard and the data collected for risk analysis, Risk Models have been prepared.

- Preparation of Landslide Hazard and Risk maps.

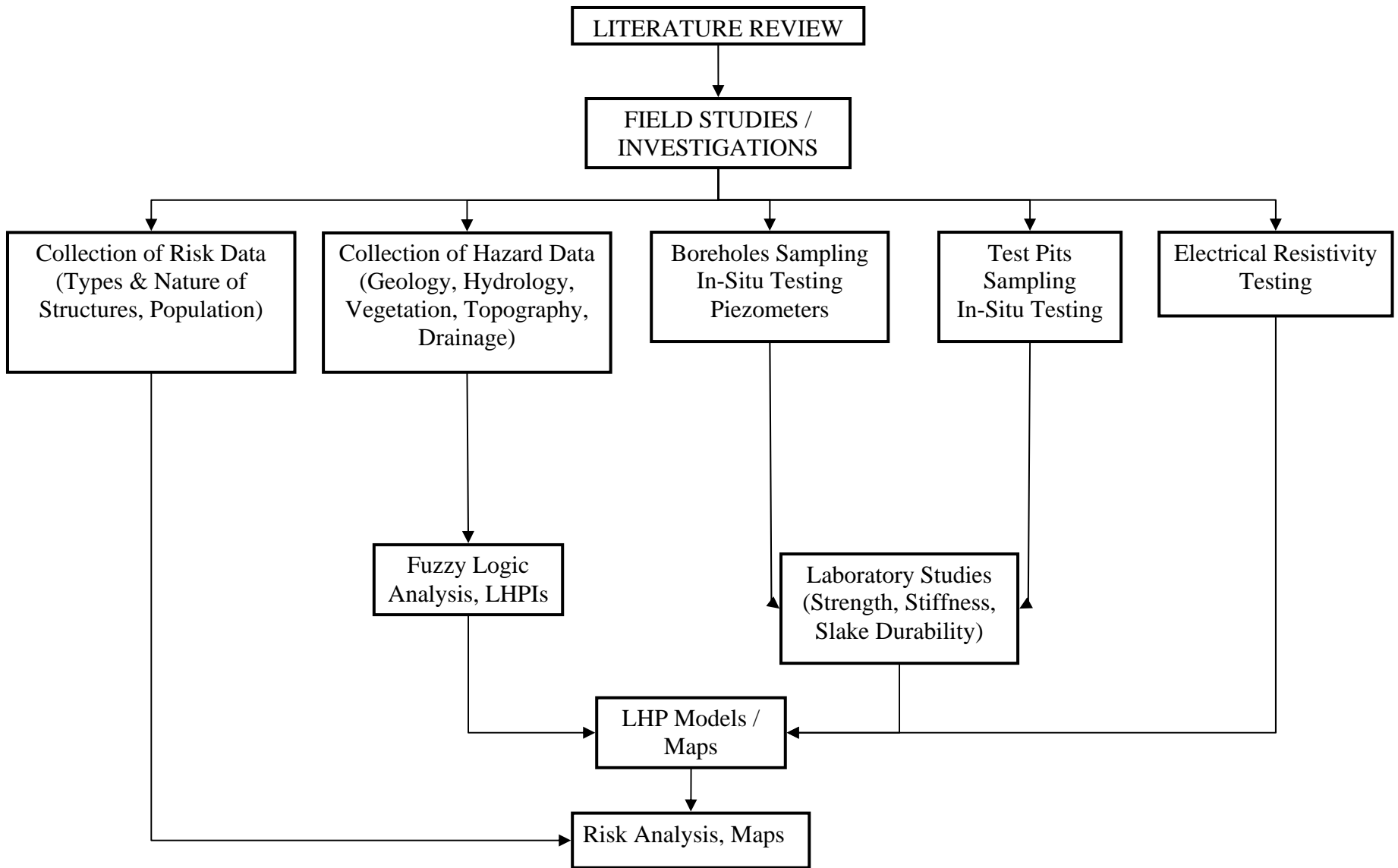- Provision of recommendations for mitigation and rehabilitation of the high hazard and Risk zones

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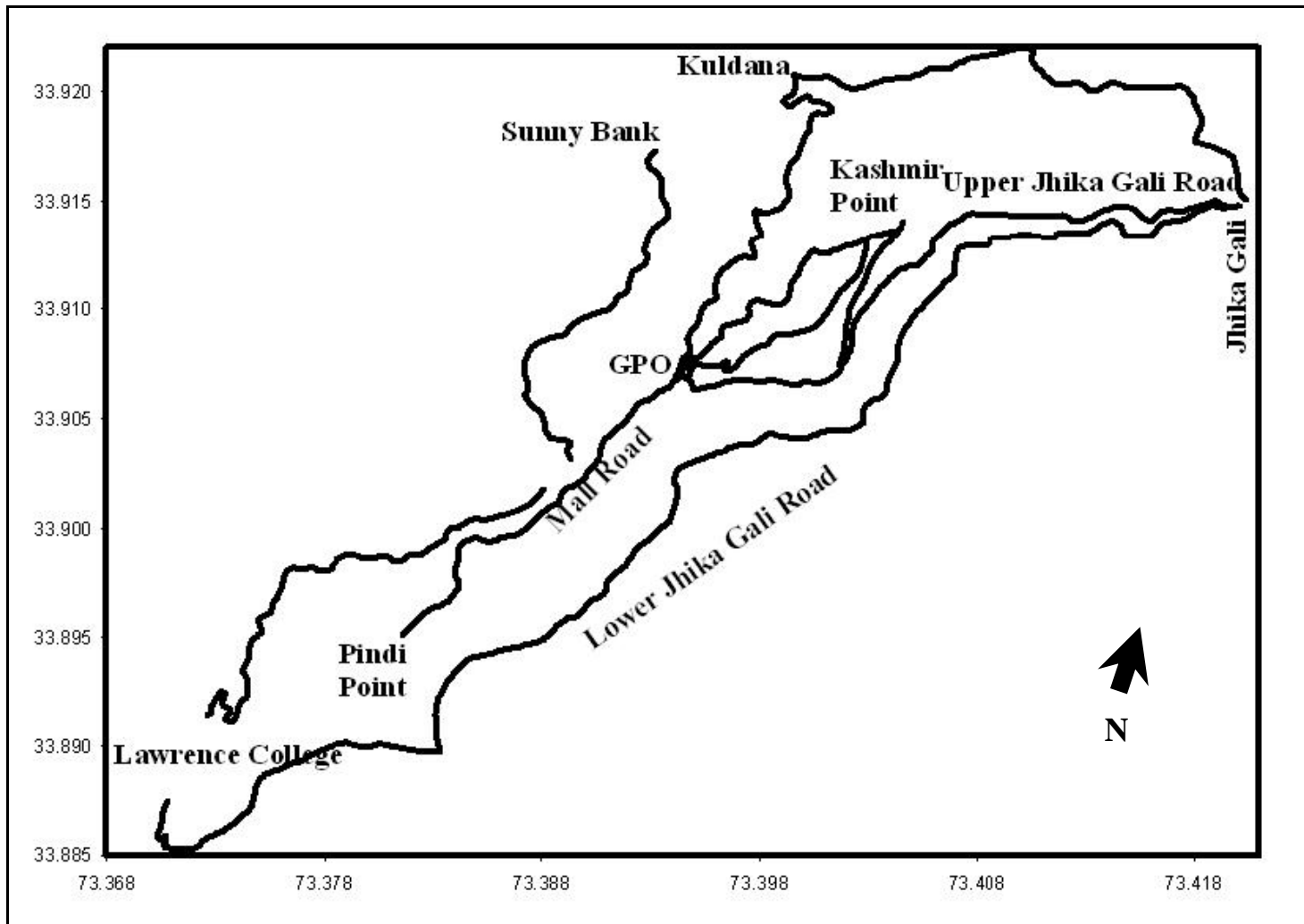**Fig. 1.1.** Research Plan – Flow Chart of Activities

Fig. 1.2. Layout of the Study Area