MSc Theses Abstract

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Thesis Title: **REGIONALIZATION OF HYDROLOGIC PARAMETERS USING WATER BALANCE**

Submitted by: **Basistha Raj Adhikari**

Supervisor: **Dr. Narandra Man Shakya**

ABSTRACT:

Given the unavailability of sufficient hydro meteorological information at the sites of water resources projects of medium and small sizes, prediction of monthly stream flow is of prime concern for the designers. This thesis work mainly deals wilh the applicability of conceptual rainfall runoff model with few meteorological data requirements in hilly catchments. Crawford water balance model- a simple three-parameter conceptual model was used in ten selected rainfed catchments, Kankai (1148 km2), East Rapti (579 km), Jhiku (111 km2), Rosi (87 km2), Bagmati (17 km2), Tadi (653 km2), Andhikhola (496 km2), Jhimruk (683 km2). Chepekhola (308 km2) and Chameliya (1150 km2) were selected for their range of sizes and locations. The hydrologic behavior of these rivers represents the large part of the country having rainfed watersheds. Ten years stream flow data were calibrated and performance of model simulation were assessed using various quantitative as well as qualitative indicators. The

quantitative indicators are relative error, root mean square error, coefficient of determination and efficiency while qualitative measures are annual water balance coefficient flow duration curve and residual analysis. The estimated model parameters were analyzed in order to develop the regionalized concept of parameters. But sensitivity analysis of these parameters indicated similarity in most of these studied basins. Application of estimated parameters were carried out in Maikhola river (377 km2) of Kankai river basin and the results are satisfactory. The comparison of model simulation with existing WECS and MIP methods showed better performances with respect to long-term flow assessment and time series flow generation in ungauged catchments.

Thesis Title: **SUITABLE INTAKES STRUCTURE IN SMALL SCALE MOUNTAINOUS RIVER (FOCUSING ON HILL IRRIGATION PROJECTS)**

Submitted by: **Bhola Chhatkuli**

Supervisor: **Dr. Raghunath Jha, Dr. Narendra Man Shakya**

ABSTRACT:

Since more than 3 decades, government of Nepal is providing its continuous efforts to the development of hill irrigation, in order to up lift the living standard of the hill farmers. However such a long and costly efforts are not giving inspiring results. There might be several reasons behind these but some major causes are the inefficiency in the repair maintenance, operation, management, identification and defective design of the systems. In Nepal it has been usual practice of development workers, planners to introduce technology developed elsewhere without thought for their relevance for the management of indigenous irrigation systems. Therefore proper selection and design of a suitable intake structure with appropriate technology is one of the main challenges for reliable and sustainable hill irrigation development.

From the study it is revealed that an efficient intake/head work is a foundation stone for the success of an irrigation system. Due to

the lack of proper knowledge about the hostile environment of the hills and violent nature of the Ncpalese rivers, problems were not adequately addressed during the design of intake structures. Many intake structures are burden to the users, as it needs high cost for the operation and maintenance. Due to the failure of intakes, many irrigation projects are in defunct condition although huge investment has been made for the development of these projects. Therefore selection of an intake is a most important and also difficult task for a designer, which affects the projects in all aspects in the future.

Normally the selection and design of an intake depends upon many factors. The intake construction site or river size, the type and the size of the project, socio-economical condition of the area, policy and responsibility of post - construction management etc. Results of the study show that the intake structure which does not affect much to the present geo-morphological condition of the river and the local environment, which are more user friendliness and economically cheaper for construction as well as for O & M, seems more suitable for the hill irrigation systems- The tunnel side intake without diversion structure, side intake with traditional farmers diversion and side intake with combination of gabion and rigid core wall up to river bed level found more appropriate for mountainous river in small and medium size hill irrigation projects. Bottom Rack intake found suitable lor the project having more than 200-300 ha and where the source nver is sleep, confined and does not carry much bed load during flood season. Findings of the study show that concrete and rock fill weir found more expensive for construction as well as 0 & M. Therefore while selecting these type of intake the designer should analyzed carefully the expected benefit, construction as well as 0 & M cost of the project, the river gee-morphological condition and socio-economical condition of the area.

Thesis Title: **APPLICATION OF PROBABILITY DISTRIBUTED INTERACTING SOIL MOISTURE STORAGE CAPACITY (PDISC) RAINFALL - RUN OFF MODEL IN NEPALESE CATCHMENT**

Submitted by: **Durga Dutt Kharel**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

Lumped conceptual rainfall-runoff models, by virtue of being lumped, cannot represent the actual-spatial variation of llie hydrological parameters in a catchment. On the other hand, the physically based distributed rainfall-runoff models attempt to lake account of the actual spatial configuration of hydrological variables over a basin but are hugely data demanding so that it is rarely possible to procure all the data required in practice. Hence an attempt has been made in this study to examine the applicability of a conceptual model called Modified Probability Distributed Interacting Soil Moisture Storage Capacity (PDISC) Model in Nepalese catchments, using the least possible hut sutTicieni information on the different hydrological parameters in a catchment. Daily runoff, rainfall and evapotranspiration are the only input data used in the study.

The study has selected Four catchments with varying sizes and location, namely, Khukhuri (0.72 sq, km.). Manahari (427 sq.

km.). West Rapti (3380 sq, km.) and Sunkoshi (17660 sq. km). The model's performance has also been evaluated in King catchment of Ireland (414 sq. km.).

The model's performance is very poor in Khukhuri. Manahari and West Rapti basins. Though its results arc very encouraging in the case of Sunkoshi basin at Kampughat with model efficiencies higher than 80%, simulation of peak Hows are very poor wilh rekitive errors as high as 31 to 47 %. King catchment also gives similar result as given by the Sunkoshi. On the whole, the model, in its present form, can not be considered applicable for the Nepalese catchments.

The poor performance of (he model can be attributed lo many factors such as the reliability and adequacy of the available data, inappropriateness of the selected reflected power distribution for the spatial variability of the storage capacity of the catchments for the Nepalese geographical conditions. Hence selection of proper distribution function could be a subject of further study for the Nepalese environment. In addition to this, the spatial variation of the other hydrological parameters, like rainfall and evaporation, can also be considered. The model can be tested with different catchments with reliable data.

Thesis Title: **PERFORMANCE ASSESSMENT OF RAINFALL RUN OFF MODELS (NAM AND UBC) IN HILLY CATCHMENT OF NEPAL**

Submitted by: **Satish Bastola**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

This thesis paper deals with the performance assessment of continuous, lumped and conceptual rainfall runoff models NAM and UBC in hilly areas in Nepal. NAM model was used to simulate response of catchment of various sizes lying in middle mountain physiographic region of Nepal. In addition UBC was also applied to Kukhure Khola watershed. The quality of simulation was initially judged by comparing the simulated flow with observed How. In addition to the classical method, a range of quantitative and qualitative measures judged the model performances. The quantitative techniques such as efficiency, coefficient of determination, standard deviation, and relative errors in annual runoff were used for the performance assessment. The quantitative techniques used alone are rarely sufficient to determine the quality of the model performance. So the qualitative techniques such as monthly flow regimes and flow duration curve are also used in addition to quantitative criteria to judge the model performances. Sensitivity analysis was

performed to identify the most sensitive parameters, which further helped in calibration.

The model was calibrated using daily stream flow, rainfall and temperature data. Single response split sample test was adopted using independent data to assess models predictive reliability. It was found that NAM simulated the annual discharge within 12% in most of the time. The daily stream flow estimation was promising at Jhimruk and Bagmati and was satisfactory at Kukhure, Manahari and Kankai. The prospects of model's (NAM) applicability is promising and the model is inevitably a good engineering tool for water resources investigation in medium watershed lying in middle mountain physiographic region of Nepal.

Thesis Title: **APPLICABILITY OF BTOPMC MODEL AND TANK MODEL SUB - CATCHMENTS OF SUNKOSHI BASIN, NEPAL**

Submitted by: **Nawaraj Pradhan**

Supervisor: **Dr. Raghunath Jha**

ABSTRACT:

BTOPMC - a physically based distributed hydrological model based on the blockwise use of TOPMODEL with Muskingum-Cung flow routing method - was selected to evaluate the applicability in Sun Kosi watershed, Nepal. The major rivers of Nepal like the Sun Kosi river originates from the Tibetan plateau where the data information is not available. Thus to cope with this problem further modification in the model was suggested that lead to the development of BTOPMC version II. To suit the Nepalese catchment further modification in the model was suggested that lead to the development of BTOPMC version II. The quality of simulation is classically judged by comparing the simulated flow with observed flow. Model performance was judged by a range of quantitative and qualitative measures of fit applied to both the calibration and validation periods. The daily stream flow estimation in Sun Kosi river basin was promising. BTOPMC can be successfully used as a tool for integrated water

resources investigation in large watershed, mountain physiographic region, of Nepal.

On the other hand Tank Model was used in small subcatchments of Jhikhu Khola watershed. The result proved that storage and land use effect played a dominant role in rainfall runoff process of small catchments. From the results ofJhikhu subcaichments it was found that parameters estimated for one subcatchment did not match the next subcatchment response. However, from the results of Sun Kosi catchments-large scale- the estimaied parameters for one large-scale subcalchment also proved to give good response for the next large scale subcatchment. It was also concluded that if the basin is large, the effects of random hydrological phenomenon will cancel each other out and the change will be minimal. However, in a small basin these effects of random hydrological and geomorphological phenomenon may cause instability. All these analysis of homogeneity was based on Tank Model response. Thus Tank Model is not a mere black box but has physical meaning.

Thesis Title: GIS ASSISTED WATER RESOURCES DEVELOPMENT AND MANAGEMENT: A CASE STUDY IN INDRAWATI RIVER BASIN, NEPAL

Submitted by: Roshan Kumar Shrestha

Supervisor: Dr. Raghu Nath Jha

ABSTRACT:

A large mass of water users, especially farmers in the Indrawati River Basin, faces scarcity of irrigation water. Existing farmer-managed and other irrigation systems do not supply sufficient irrigation water in dry seasons. Inadequate irrigation water usage results in poor crop yield. This is one major reason to cause the food deficit in the zone. Besides irrigation, the other sectors of water use have not observed as major trouble at present.

Present annual consumptive water-use in the irrigation and drinking water sectors reaches to a maximum of approximately 250-mm. From the water balance model, the water available from rain is 2760 mm annually; of this about 2250-mm drains out from the basin. Since the demand of water in dry season is quite below the available water, this indicates that the water availability is enough for the basin.

Map calculation and overlaying processes using Geographic Information System (GIS) has given the quantity and map of

potential agricultural land. The input information taken were slope profile, river networks and land-use map. Remotely sensed satellite data and digitized maps were used to derive the land-use map. Approximately 8900 ha land are irrigable without any difficulties, and additional 12000 ha land can be planned for the terrace agricultural practice with cascade irrigation system. With perennial tree crops, about 775 ha forest area can be developed as the agro-forestry practice zone. Provided enough water for irrigating these lands, the water demand becomes 360 mm; this amount is less than the flow of water in the driest season in the river basin. This fact shows that there is enough water available, but needs suitable management for its better efficiency.

To meet the demand of water to a maximum level in dry season at needy places, some small reservoirs may be required to build at some places. As there is still more lands to irrigate, several new canals have to be constructed. This analysis is based upon the limited information and resources available. It, therefore, is recommended to conduct another detail analysis for deciding the location; size and operational rules of the reservoirs and additional water Structures.

Thesis Title: **RIVER BASIN SIMULATION MODELING: A CASE STUDY OF KOSHI RIVER BASIN OF NEPAL**

Submitted by: **Bikash Man Singh Dongol**

Supervisor: **Dr. Divas Bahadur Basnet, Dr. Narendra Man Shakya**

ABSTRACT:

This thesis deals with the application of the steady slate, deterministic Water Resources Planning and Management Simulation Computer Model that optimizes the different water resources components i.e. irrigation, hydropower generation, water supply, inter basin transfer etc. of the river basin as per user's specified demands, priorities and zoning penalty concepts for the Kosi river basin of Nepal. The simulation has been carried out using 31 years of hydrological data from 1965 to 1995. The various scenarios have been simulated in order to determine the surplus or deficit for the different water uses and priorities of the water resources components of the river basin for the present as well as future uses.

The simulated results show that the natural flow of the rivers of the basin fulfills the present water demand. The future irrigation water demands are fulfilled in most of the years except in the

month of March and April of some dry years simulation period. It can be concluded that the irrigation water demands can be fulfilled in most of the simulated years under study.

With the implementation of Kosi High Dam, all the irrigation water demands can be fulfilled under all conditions of the hydropower generation. The maximum energy thai can be generated according 10 a certain demand pattern is 16,228 GWh. Proper reservoir operation can lead to the fulfillment of all demands including 72m'/s of the inter basin transfer of water from Sun Kosi River to Kamala River.

Various scenarios of development in the basin including combinations of Kosi High Dam Reservoir, Dudh Kosi Reservoir and Sun Kosi No- 2 Reservoir Projects were simulated. The implementation of the above projects improve the satisfaction of irrigation demand for all cases, generate considerable hydropower generation, enhances flood control and other benefits.

It can be concluded that trade off and inter relationships of various water uses and of regions exist. There may be a conflict between the transfer of 72 m^3/s of How from Sun Kosi river to Kamala river and satisfaction of all the future (potential) irrigation demand. This may lead to setting priorities for meeting the demands in different regions. Similarly, priorities on irrigation, hydropower, and flood control will result in various levels of demand satisfaction. Hence, it can be concluded that a "Decision Support System" like the one used in the present study can be of great use for making rational and optimum decisions.

Thesis Title: **APPROPRIATE GENERATION MIX FOR INTEGRATED NEPAL POWER SYSTEM**

Submitted by: **Sanjib Man Rajbhandari**

Supervisor: **Dr. Janak Lal Karmacharya**

ABSTRACT:

The electricity demand of Nepal in a day and over a year is not uniform and has a sharp peak during evening time of'a day and during winter evening peak demand shoots up- The day load is comparatively very small. Because of the hydrological characteristic and the type ofpro|ect in the system, there is a distinct mismatch between Hie supply and demand resulting in the deficit of capacity in the winter peak and spilling of energy in the wet season. In order to meet the demand in electricity in a cost effective way and ensure least cost investment, it is considered highly desirable to find out the appropriate generation mix for the system From the purely economic point of view, it is obvious that a generation mix based on hydropower plants and thermal plants is the most appropriate for a system with high short duration winter peak and low base summer peak. However, desirable option would be a combination of different types of hydropower plants with a small thermal back-up as reserve. The study is instigated by the need' to find an answer to the problem.

To find a solution for this problem, a model using inter related worksheets is formulated to minimize the annual cost of the system fulfilling all the supply constraints. The objective function include corresponding capital recovery factor for all the possible projects namely ROR,, PROR. Storage and Thermal along with the corresponding operation and maintenance cost, fuel cost and emission cost. The study is carried out for the design year of 2073/74 B.S. which is the last year in the available projected demand

With the primary objective of finding the optimum generation mix in terms of economical, reliable, flexible and least cost aspects, two sets of optimisation study were carried out. 'I he one was unconstrained and another was constrained. The justification for a constrained optimization, where hydropower plants only were allowed in generation expansion, was to avoid risk and uncertainly in Hie generation of plants and lessen the perpetual pressure on the limited foreign currency resources.

From the study it is found that the mix option with thermal generation is more economical to meet the projected demand of Integrated Nepal Power System (INPS). The investment cost in the case of hydro only scenario is substantially high, more than double in comparison to the mixed hydro thermal generation. Likewise, the annual cost for the hydro only scenario is more than 50% higher in comparison to the mixed hydro thermal generation. Further, hydro only scenario is associated with heavy spill energy during wet season.

If a hydro only generation system is adopted to avoid uncertainly and risk in the supply and minimize the pressure of foreign resources, it is important that this should be accompanied by increasing the market of seasonal energy both in domestic and export fronts.

Thesis Title: **OPTIMIZATION OF CATCHMENT OF ROUTING PARAMETERS OF JHIKBU WATERSHED IN NEPAL**

Submitted by: **Surya Prasad Rijal**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

No water resources projects incur targeted costs and benefits without scientifically studied of its resources, water. But on the other hand, complexity in catchment- extreme variahility of climate and precipitation pattern, inadequate knowledge of hydrology etc. are most significant problems to be encountered dunna study, in spite of above problems, many computer based hydrological models have been developed so far in order to carryout analytical study with more accuracy. These models either be continuous type or event based, The event-based models simulate flood flow and determine volume, peak and time to peak of flood flow generating by any storm event. Hence, HEC HMS and TANK. models have been selected to use for simulation. The HEC HMS requires lumped or conceptual input parameters i.e. unit hydrograph parameters. Distributed model parameters of modified Clark' s method and kinematics wave method can also be utilized. The effectivc rainfall can be determined either by Green and Ampt, Constant ioss rate or SCS

curve number method. The TANK model is also lumped type with conceptual element of Infiltration and surface runoff generation in term of tanks arranged vertically in series. The main objectives of the study are to understand the application procedure of selected models and to calibrate model parameters in the selected basin. Moreover, the study aims to establish certain relationships between rainfall, runoff and other catchment routing parameters.

These two models have been applied in Jhiku Watershed in Nepal (111.4 km2), This watershed Is selected so as to represent mid size catchment hydrologically and middle mountain Catchment topographically.

Through optimization options available in HEC HMS, different model parameters have been optimized, dark's and Snyder Synthetic unit hvdrograph have been prepared on the basis of average parameter values. Graphical correlation between total loss and total precipitation has been established. Moreover, certain relations between lolaf catchment flow and effective rainfall- between time of concentration and Snyder's nine to peak has been observed. Furthermore, the study proposes a trial and error procedure to adjust total loss in term of initial and constant loss rate in order to get time distribution of effective rainfall.

Thesis Title: **DETERMINATION OF OPTIMAL WATER REQUIREMENT AND IRRIGATION SCHEDULE FOR WHEAT IN BANAGANGA IRRIGATION SYSTEM**

Submitted by: **Niwash Chandra Shrestha**

Supervisor: **Dr. Indra Lal Kalu**

ABSTRACT:

The problem of allocating optimal water for a single crop and scheduling irrigation at decade intervals for limited water is considered in this study. The formulation is based on a dated water production -function, soil water balance for decade periods, and a heuristic assumption that water stress in the early decades of a crop growth leads to sub optimal yields. The allocation problem is solved at decade level first and then the sum of decade allocations for each stage is evaluated sequentially for maximum relative yield. At the decade level the actual evapotranspiration for the period is computed and added to the values computed for the succeeding decades till the end of stage. The relative yield is computed by using dated water production function. The relative yield for each stage under given initial soil moisture and available supply are maximized by using simulation-dynamic programming with a multiplicative objective function. Primary decision variable is water allocation to decade

within the given constraints while the return is evaluated is stages because the yield response factors are valid only for growth stages. The sum of optimal decade allocations for the whole season can be taken as the optimal water requirement (Secondary Decision Variable) for planning crop area to get maximum total production. Similarly the sum of optimal decade allocations for individual stages can be taken as optimal allocation to stages.

The results of the study suggest that information on pre-season soil moisture can be used as supplementing water input to the growth of crop to apply optimal irrigation under limited water supply and achieve maximum production by irrigating more area with the saved water. Two sets of values representing optimal water requirement are compared with initial soil moisture ranging from 28-84 mm/m of root zone depth. One set of values demand higher amount of water per hectare for little higher relative yield while the other set demand lower amount to produce little lower relative yield in the same initial soil moisture . But the total yield is observed greater in the case of second set of values for optimal water requirements due to multiplicative effect caused by larger area irrigated and slightly lower yield per hectare.

Having a reservoir like in Banganga Irrigation System is recommended for implementing deficit irrigation policy because the supply has to be allocated with higher degree of control. Fieid experiment is suggested for verification of the results on application of the model and further investigation helps to formulate practical system operation policy.

Thesis Title: **A DECISION SUPPORT SYSTEM FOR RIVER BASIN PLANNING: A CASE STUDY OF INDRAWATI RIVER BASIN**

Submitted by: **Ramesh Prasad Koirala**

Supervisor: **Dr. Narendra Man Shakya, Dr. Divas Bahadur Basnyat**

ABSTRACT:

River basin Management and Planning for a basin may broadly be conceived as an attempt to identify the best possible utilization of the available water resources given certain soil, land, agricultural, engineering and social constraints of the basin.

There are two types of river basins in Nepal, surplus basin and dry basins. So far, Nepal has put its maximum effort on the basis of project to project planning. But for the optimal benefit, an integrated system or holistic approach has to be applied while planning for ihe river basin use. Through this study an attempt has been made lo look into the long term planning aspect of lndrawati River Basin.

The MIKE BASIN modeling system is a software package developed by Danish Hydraulic. Institute (DHI), provides the possibility to investigate various water resources development options and identify potential conflicts arising from utilization

oflhe same water source for many sectoral purposes. The model is based on a basic water (mass) balance equation. It uses a graphical interface which links MIK.E BASIN with ArcView GIS.

With the various data as the input, the simulations (various scenarios) have been run successfully through the MIKIE BASIN model. The outputs are analyzed in details.

Thesis Title: **STEADY FLOW ANALYSIS IN OPEN CHANNEL SYSTEM**

Submitted by: **Phatta Bahadur Thapa**

Supervisor: **Dr. Purushottam Shrestha**

ABSTRACT:

The Various literatures related to Gradually Varied Steady Flow in open channel system were reviewed. Various computer models like HECRAS, MTKE11, WSPRO etc. capable of analyzing Steady Flow in open channels were also studied. The Steady Flow Analysis Model (SFAM), which was to be calibrated, was also reviewed in detail. The Physical Model of a 500m river reach at intake site of Melamchi Diversion Scheme, built in Hydrolab Pulchowk was run with different discharges to avail the actual field observation data, and data were obtained. The physical model run data obtained includes cross section data, length of river reach at every cross section points, discharges and the water surface elevations at each cross section point. Computer models HECRAS and MIK.E11 were run using the data obtained from the physical model run. The computer model SFAM based on the St. Venant Equations and Newton Raphson technique, written in FORTRAN77, developed by Shreslha (1998) during his M.Sc. thesis at Calgary University, Canada was run using the data obtained from physical model. The results

thus obtained from computer models SFAM, HECRAS and MIKE11 were compared both in tabular as well as graphical form with the results obtained from Physical Model. It is found, from the comparison of various model run results, that the Water Surface Elevations of SFAM is closer to observed Water Surface Elevations in most of the sections except in few location. The differences in some sections are due to the limitation of the SFAM- SFAM can not rout steady flow in mixed flow condition within a single reach.

The water Surface Elevations of SFAM compared to the Water Surface Elevations of HECRAS run with the same inputs shows that the profiles do not differ so much. The Water Surface Elevations of SFAM and HECRAS are closer in most of the sections except in few sections. The comparison of SFAM results with the results of MTKE11 shows that the profile of SFAM is closer to MIKE11 profile too, except the profile at few locations. Thus, all the water surface elevations resulted from physical model, HECRAS and MIKE11 were compared and verified with the water surface elevations resulted from SFAM.

Thesis Title: **DETERMINATION OF OPTIMAL CROPPING PATTERN IN AN IRRIGATION SYSTEM HAVING AND INTERMEDIATE RESERVOIR AND ITS OPERATING POLICY**

Submitted by: **Ram Das Maskey**

Supervisor: **Dr. I. L. Kalu, Dr. N. M. Shakya**

ABSTRACT:

The major bottleneck for agricultural production from an irrigation system is the uncertainty of flow availability in the source. So it becomes more difficult in crop planning of the command area in defining the operating policy of regulating structures like a reservoir made for releasing water for irrigation purpose. Because inflow to the reservoir is uncertain and may never be same in all the year at the same period. Under such situation, optimal water resources management and crop planning of the command area can be achieved for optimal benefit by applying chance-constrained linear programming. A chance-constrained linear programming (CCLP) model is formulated with different level of' irrigation reliability of reservoir for the command area of Jagdishpur Reservoir or Banganga Irrigation System. The model establisned a considerable improvement in the economic return as well as utilization of land and water resources by adopting optimal

cropping pattern. The model is solved at different chance of exceedence of inflow to the reservoir as 50%, 20% and 10% so that it may help trie decision makers in the management of water resources and crop planning of the command area accordingly. According to the results, it lias been found that inflow to the reservoir, conjunctive use of ground-surface water and expansion of the reservoir capacity has no effect in the cropping areas of paddy, sugarcane, vegetables and mustard. The difference is only in cropping areas of wheat and maize (dry season crops). From this study we can say that willi the existing capacity using only surface water the crops and (heir area can be sown in each year are

Paddy 3260-00 ha

Sugarcane 585.00 ha

Mustard 585.00ha

Potato 293.00ha

But if there will be changed in present market price of different product, llie cropping pattern will be different. When present market price of wheat is increased by at least 20%, there is increased in crop area of wheat and area of mustard to be sown is reduced to zero. So this study will certainly assist the planner and decision maker in the management of reservoir of Banganga Irrigalion System.

Graduation Year 2002

Thesis Title: **STUDY OF SPATIAL AND TEMPORAL DISTRIBUTION OF SEDIMENT CONCENTRATION, TOTAL NITROGEN AND TOTAL PHOSPHORUS IN BAGMATI RIVER NETWORK**

Submitted by: **Ambikesh Kumar Jha**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

Bagmati River has served the people living in its basin from lime immemorial and has contributed towards the development of Nepal. At the same time it has also posed serious problems to the residents through the floods and its deteriorating water quality. The monsoon floods brings heavy amount of sediments. Sedimentation of agricultural lands causes loss of fertility- High sediment concentration in river water is also undesirable for construction of reservoirs, irrigation channels, headwork. etc. It is therefore essential to properly know the amount of sediment present in the river water during different periods of the year for the decision making processes. An understanding of the effect of various changes in the watershed such as the changes in land use,

agricultural practices, urbanization, etc. on sediment yield can prove helpful for decision makers.

River water contains nitrogen and phosphorus washed off from soil and decomposed organic materials in forest- agricultural fields, towns and cities. Industrial waste adds to the nitrogen and phosphorus content of river waters. Nitrogen and phosphorus present in irrigation water adds to its nutritional value. However its presence in significant proportions in reservoirs and in river water used for drinking, bathing, and recreational purposes is deleterious for human health.

The present study which covers an area of 2700 square kilometers of the Bagmati River Basin from the Shivapuri hills at north of Kathmandu valley to the Bagmati Irrigation Project Headwork site at Karmahiya in Sarlai district, has focused on determining the long term daily average sediment, nitrogen and phosphorus concentrations at Karmahiya and also at various other desired locations. Soil and Water Assessment Tool and GIS ArcView have been used for the purpose- Hydrological and Meterological data from the year 1991 A.D to 2000 A.D have been used for the simulation purposes. The outcome of the research shows high sediment concentrations during the monsoon months from June through September. The model can effectively be used lo predict sediment yield for future years. A sediment concentration as high as 12000 ppm is expected during monsoon season. The model effectively predicts daily, monthly and yearly discharges resembling the observed one and hence can be used for future water balance and high flood predictions- The research shows that there is significant increase in nitrogen and phosphorus concentrations in river water at Karmahiya due to the urban settlement of Kathmandu valley.

Thesis Title: **APPLICATION OF GEO-TECHNICAL ZONING SYSTEM (GTZS) IN TUNNEL SUPPORT DESIGN**

Submitted by: **Baburam Bhardwaj**

Supervisor: **Dr. Indra Raj Humagain**

ABSTRACT:

As the ground surface is becoming more and more congested the use of underground space has become inevitable. Tunnels are getting popularity in the field of transportation as road tunnels, railway tunnels; in the field of hydropower as water conveyance tunnels, diversion tunnels; in the field of drinking water supply as water supply tunnels and in construction sites as material transport tunnels. In developed countries large underground caverns are extensively used for storage of materials- as exhibition and shopping mall. as sports complex and parking area. Tunnels are one of the highly expensive structures in civil engineering- The consequences of failure of a tunnel are critical to national economy as well as prone to mass fatality of the users. They bear high risks during construction because the underground conditions are largely unpredictable. Thus the importance of adequate design of tunnel support is recognized everywhere.

Many scholars have worked in the field of tunnel support design in the past. Terzaghi (1946) has defined secondary rock pressure as the pressure developed after excavation of tunnel on the tunnel surface. He introduced the concept *of* Ground Arch. If the tunnel is left unsupported after excavation then overbreak will extend to some limit above the roof. The limit of this overbreak depends upon various parameters like stratification of deposits, type of rock, size of opening, etc. Thus. it is the load of the rock mass bound within the ground arch which is acting on the cavity and the job of the designer is to design a suitable support system to take care of this load. Based upon this concept Terzaghi gave his well known table of rock loads under various conditions. The above phenomenon was first studied by Terzaghi and latter by Ikeda, Tanaka and Higuchi.

The modem tunnel designers, however, do not believe in supporting the rock load, which is likely to be developed on account of opening made in the rock. Although the rock mass is composed of broken rocks, it can be a material of considerable strength if it can kept in place and some deformation is accepted- Thus the present concept is that the rock be reinforced immediately it is disturbed so that no scope is given for rock loads to develop. Based upon this concept, the CSIR, NGI and NATAM methods of tunnel support design have been evolved.

These methods are based on the classification of rock mass into different categories. Each of them has suggested different rock mass classification systems.

The existing rock mass classification systems are facing difficulties in their practical application in the complex geological condition of the Himalayan region because they include limited number of parameters responsible for in-situ strength build-up of the rock mass. In such geological conditions any short of unlined underground structures if not designed and constructed with due consideration of local geological/geotechnical conditions, are risky. The existing rock mass classification systems are based on empirical approach and unable to cover some of the important parameters of in-situ rock mass. which has to be assessed more in the context of its geological setting. Hence they need adjustments or modifications to make them compatible to Himalayan geology. CS1R and NGI systems include only 6 parameters. The NGI does not include the orientation of joints. Both of them do not include the result of UNWEDGE analysis for key block stability.

Geo-technical Zoning Index (Z-value) demonstrated in the present work expresses a better representation of in-situ rock mass strength and provides a more compatible excavation and rock support guidelines for underground structures in the Himalayan region. The study is based on the engineering geological logs of the 8 different tunnels of Modi Khola Hydroelectric Project in Nepal. To compare the results the Z-values, determined from the GtZS, are compared with the RMR values of the same locations. The corresponding Z-value and RMR-value comparison curves are included in the thesis report. From the comparison curves it is obvious that Z-value curves are smoother than RMR-value curves as the former includes 10 parameters against the 5 parameters of RMR. The Z-values are distributed in more wide ranges of parameters responsible for the strength build-up of in-situ rock mass. The Z-value expresses a better representation of in-situ rock mass strength and provides a more compatible excavation and support guidelines for underground structures in Himalayan region.

The separation of "homogeneous zones" of the geology along the tunnel alignment based on their geo-technical properties during the tendering period will make the scope of works of the BOQ items more specific. This will reduce the chances of arising conflicting situations between the concerned parties of project construction. The sudden jumps in the value of Z are relatively low compared to the RMR values resulting to a smoother Z-value curve. The designer of the permanent rock support will have to cover the worst case scenario asking for more concrete and steel while using RMR than Z. This implies that a considerable saving in tunnel support cost may be achieved by using GtZS over RMR system. The Z-value and RMR curves follow the same pattern but the RMR values show sharp ups and downs.

The key block stability analysis results will help in deciding the length and size of rock bolts required. The excavation and support guidelines, recommended in this research work. will be very useful for tunneling works. The test study carried out in the tunnels of Modi HEP shows the applicability of the GtZS in order to reduce the errors of the existing rock mass classification. Application of the GtZS is not only in the excavation and support design during the execution of the tunnel, but also useful for the preparation of the tender documents, the supervision of the construction and in special cases also for monitoring system in view of long-term operation.

Thesis Title: **USE OF ARTIFICIAL NEURAL NETWORK IN RAINFALL RUN OFF MODELING**

Submitted by: **Bashnta Dhoj Shrestha**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

This Thesis deals with the Artificial Neural Network (ANN) based system identification approach for the modeling of rainfall-runoff process- The study has investigated the applicability of ANN techniques for simulating the highly complex, non-linear hydrologic behavior of three river basins, Mai Khola, Jhimruk Khola and Man Khola. The investigation considers different combination of variables for the simulation of system behavior. To have the comparison of model performance, TANK model is also applied in these catchments with the same sets of calibration and validation data. Also, the simulation result of NAM model in Jhimruk Khola is considered for the model comparison.

The quality of simulation was initially judged by comparing the simulated flow with observed flow. The quantitative judgment was performed using statistical analysis for the performance assessment. As the quantitative techniques alone are rarely sufficient to determine the quality of the model performance, the

qualitative techniques such as monthly flow regimes, flow duration curves are also used to judge the model performance. The analysis reveals that ANN models compute the river flow efficiently and clearly demonstrates the potential of ANN approach in modeling the system behavior.

The study indicates that the ANN models are capable of reproducing the unknown relationship existing between a set of input variables descriptive of the system. Despite its limitations, the ANN approach has proven its superiority and is promising for the application in hydrology. The ANN approach is a viable alternative to the traditional techniques for developing input-output simulation and forecasting models.

Thesis Title: **CONJUNCTIVE USE OF SURFACE WATER AND GROUND WATER FOR BETTER WATER MANAGEMENT: A CASE STUDY OF EAST-RAPTI IRRIGATION PROJECT**

Submitted by: **Binod Chandra Devkota**

Supervisor: **Dr. Narendra Man Shakya, Dr. L. P. Devkota**

ABSTRACT:

This thesis deals wilh the conjunctive use of surface water and ground water for better water management, a case study of East - Rapti Irrigation Project, Chitwan District, Nepal. The command area is divided into four zones consisting of 76 Farmer Managed Irrigation Schemes. The first three zones receive irrigation water from seasonal streams flowing through the command area. The surface water avalability at the intake of each scheme is derived by using Water and Energy Comsission Secretariat (WECS) method. WECS has derived twelve regression equations to predict the mean monthly flow of the streams at required location. The surface water is summed zone - wise. Zone four receives water from East - Rapti river, whose records are available.

Four cropping pattern scenarios are used to calculate crop water requirement in each zone by using cropwat 4 Windows software.

The total crop water requiremnt is calculated by incorporating additional water required for paddy fields.

The groundwater storage is determined hy using groundwater model Processing Mod Flow Windows (PMWIN 41). The sensitivity analysis is carried out hy increasing or decreasing the assumed data individually or in combind form. After several sensitivity analysis, the groundwater storage iavailable is used in the analysis.

Primarily, surface water shall be used to meet the crop water demand and deficit demand shall be met by the use of groundwater storage available. Paddy needs additional warter for land preparation and deep percolation than other crops suggested in cropping pattern such as maize, oilseed, wheat, pulses and small vegetables. Hence, the analysis is carried out for paddy, more water consumed crop.

The results reveal that early paddy can be planted in 12% area of zone one, 12% area of zone two and 10% area of zone three. Similarly monsoon paddy can be planted in 47% area of zone one, 41% area of zone two and 30% area of zone three by using .surface water and groundwater conjunctively when surface waler availability is only 40% of the total mean monthly flow for irrigation. The result depends on the maximum water deficit occur at tlie period in which crop water demand is more than surface water and groundwater availability in cropping pattern scenarios in each zone. In other period the available surface water is to be used for the crops, the deficit crop demand is to he managed from groundwater.

Similarly, in zone four early paddy *60%* of llie area and monsoon paiddy 80% of the area can be planted by using surface water alone. Hence, conjunctive use is not necessary in zone four.

Thesis Title: **PERFORMANCE EVALUATION OF INTAKE STRUCTURE AND HEADRACE CANAL OF SMALL HYDROPOWER PROJECTS: A MULTIPLE CRITERIA DECISION MAKING (MCDM) APPROACH**

Submitted by: **Bishnu Prasad Dhungana**

Supervisor: **Dr. Narendra Man Shakya, Dr. Divas Basnyat**

ABSTRACT:

The main objective of Small Hydropower Projects (SHPs) are to uplift the living standard of the people, especially in remote hill and mountainous regions. His Majesty's Government of Nepal (HMG/N) has laid a great emphasis on the development of SHPs. Thirty-one SHPs in those regions have been studied. Performance evaluation (ranking) of various types of intake structures and headrace canals were carried out in order to generalize the overall features of failures in those SHPs. These projects are located in all five development regions of the country; nine in eastern region, three in central region, seven in the western region, five in the mid-western region and seven in the tar western region. Out of the selected thirty-one projects, private companies have operated two projects, eleven have been leased out and remaining eighteen have been operated by Small

Hydropower Department/Nepal electricity Authority (SHPD/NEA).

Most of the projects failed during the operation and maintenance period. The study has ranked the various types of Intake structures and headrace canals, analyze and evaluate the major causes of failure of those structures in terms of power generation on the basis of multiple criteria decision making (MCDM) techniques, namely, ELECTRE I and compromise programming on those projects. Data used in this study were collected through literatures, reports and booklets, published by NEA, government agencies and interaction with the concerned agencies and project personnel. Primary data are collected directly from the field by interviewing the Proicet Personnel, SHPD, Consultants, Private and Leased out Project Personnel, etc. and the questionnaire survey through various experts. Eight different types (alternatives) of intake structures and three headrace canals are considered. Six different criteria of both the structures are analyzed, For the application of MCDM tools, professionals from different fields are taken as decision makers (DMs), namely, (Academic Professional, AP), (Hydropower Engineer, HE), (Civil Engineer, CE), (Electrical Engineer, EE), and (Sociologist and Geologist. SG).

Findings of the study have been summarized after the performance evaluation of various types of intake structures and headrace canals for all the thirty-one projects. Intake structure with under sluice and overflow weir is found to be the best and Side intake with partial diversion weir is the last alternatives. All the oilier alternatives come in between these two alternatives. Recommendations are made on the basis of the conclusion drawn from the findings to overcome such type of failure during operation and maintenance period. Based on it. Intake structure with under sluice and overflow weir is strongly recommended and other alternatives are also recommended provided the side conditions,

Hydrological and non-hydrological flood, site selection, quality of the works, design/drawing of the structures, management and operation & maintenance (O &M), etc. are found the major causes of failures. Further performance evaluation should be continued for other than intake structure and headrace canal. Hence this study helps to reduce such failures on the future project of SHPs and it can be developed for the welfare of Nepal.

Thesis Title: **RIVER BASIN PLANNING AND MANAGEMENT USING A DECISION SUPPORT SYSTEM: CASE STUDY OF KANKAI RIVER BASIN**

Submitted by: **Bishwa Malla**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT:

This study deals with the application of the steady state, deterministic Water Resources Planning and Management computer model, MIKE BASIN. It optimizes the water availability analysis for the different regions and sectors of use such as irrigation, hydropower generation and Hood control as per the user specified priorities of use and reservoir operation rules on a basin approach for the Kankai basin.

The simulations have been carried out with the help of the available historical data as well as synthetically generated data because all the available observed data were not for sufficient duration.

The various scenarios for analysis were developed taking into consideration the present situation with its existing structures and demand, and the future conditions with future demands and the proposed projects within the basin.

The simulated results indicate that the natural flow in the river meets the present demands for irrigation in the upper reaches and just falls short, during the dry months, to fulfill the Kankai Irrigation Project (KIP) irrigation water requirements.

The future irrigation requirements with the existing infrastructure are not met in the dry months. This clearly indicates the need of a storage scheme to store the excess monsoon water to be used during the dry months.

The implementation of the Kankai Multipurpose Project (KMP) ensures full satisfaction of the irrigation demands in the lower reach of the basin, under both sectoral priorities -irrigation or hydro generation- When priority is given to Hydro-generation- the water released from the turbines alone is not sufficient to meet the irrigation demands. The balance water is pre-defined to be drawn from the KMP reservoir. The KMP also enhances flood control and other benefits downstream.

The implementation of the Mai-Loop Hydroelectric Project to the present situation. apart from generating power, amounting to an annual energy of 255 Gwh. regulates the flow more uniformly.

The different scenarios analyzed included the combinations of the KMP and the Mai-Loop Hydroelectric Project. The combined implementation of the two projects does not change the annual water balance scenario significantly apart from the additional power generated from the Mai even though the flow into the KMP reservoir is much better regulated during the five dry months from January to May. It amounts to an increase on an average in the five monthly of around 7 m^3/s. This is mainly because the live storage of the Mai_Loop is very limited (69 MCM equivalent to 4.15% of annual average).

It can be concluded that a river basin approach ensures that any inter-region or inter-sectoral tradeoff is recognized. To avoid conflicts and come to an acceptable solution. priorities need to be defined for the water use between the different regions and the sectors within the regions so that the available water is optimally utilized. Although the implementation of a reservoir project like the Kankai Multipurpose Project provides substantial regulation to meet all the future demands within the Kankai basin, there are possibilities of conflicts that need to be tackled.

Thesis Title: **AN OPTIMAL OPERATION STRATEGY OF MIXED HYDRO THERMAL GENERATING SYSTEM: A CASE STUDY OF THE NEPAL POWER SYSTEM**

Submitted by: **Buddha Krishna Manandhar**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT:

The main objective of the study is to find the optimal operation strategy of a mixed hydro thermal power system. The objective is the minimization of the annual system operation cost. The cost consists of the thermal operation cost, import cost and the cost of energy not served (demand not fulfilled).The operation cost of hydropower plants is neglected as it is negligible compared to the thermal generation cost.

The operation policy or strategy of a hydrodominated power system is dependent on the system configuration. The generation pattern of a hydropower plant (especially reservoir project) will vary from one year to the other depending on the types and capacity of other plants in the system. The operation strategy of a hydrothermal power system is important for two reasons. The first is for the optimal operation of the existing power system to meet the given demand for the particular year (the plannning

horizon for operation planning). The second is for the long term generation expansion planning.The generation from the thermal plant is dependent upon the capacity available and the outage rate (Forced and scheduled), whereas the generation from the hydroplant depends mainly on the available flow (Hydrology) and the system configuration. The hydrogeneration also depends upon the type of plant iike Run-of-River (ROR), Peaking Run-of-River (PROR) and Storage.

The optimal operation strategy is based on the economic utilization of the available capacity and energy available of the different types of hydropower plants and thermal plants. The optimal operation also depends upon the maintenance of the thermal and hydroplants as the maintenance of one-plant effects the generation of other plant.

Valoragua model developed by IAEA, 1992 is used in this research .The model is developed to find the optimal operation strategy with the objective of minimizing the thermal operation cost (thermal. Imports) and unserved energy costs.The present study attempted to assess the variation of hydropower generation pattern for the different power system configuration and demand scenarios- The system configuration for the years 2000, 2005 and 2010 were adopted from the latest system expansion plan of Nepal Electricity Authority (NEA).

From the study, it was found that operation cost is higher in dry season and minimum in wet season- The study also shows the possibility of more energy export than import. The marginal cost of generation during the peak hour is much higher than the other periods. The generation from storage plant in wet season is allowed in order to minimize the spill from the reservoir. Inclusion of one more storage plant increases the utilization of the storage project in the dry period due to proper regulation. The model will be a great help to the system manager to use the power plants in an efficient and economic way. It would also be useful in defining the optimal generation pattern of hydro plants useful for long term generation expansion planning.

Thesis Title: OPTIMUM LOCATION OF SPLIT POINT IN SPLIT AND SETTLE CONCEPT. A HYDRAULIC MODEL APPROACH

Submitted by: Lekh Nath Kharel

Supervisor: Dr. N. M. Shakya, Mr. P.M.S. Pradhan

ABSTRACT:

Settling Basins are major cost component in high head run of river hydropower plants. A new concept - Split and Settle has been proposed by Dr. H. Stole. Professor of Norwegian University of Science and Technology (NTNU) that has not been tried in prototype.

Splitting of sediment-laden water by split at proper location in approach channel (tunnel) is focal point of the concept. A hydraulic model study was carried at Hydro Lab in Kathmandu Nepal to measure the performance of approach channel (tunnel) in terms of *flow* diversion and sediment diversion capability.

The Study was focused on two aspects: Observation and measurement of hydraulic and sediment characteristics. From the study, it was observed that, the effect of discharge split to average approach velocity was insignificant i.e. V_{av}# f *(Split)* and formation of eddies was found infront of split at 20% flow diversion towards the lower channel.

Sediment simulation was carried out using natural sand and artificial sediment like plastic grains and coals. Model test showed satisfactory results with artificially sorted coal having d_{50}=0.64mm equivalent to 0.23 mm size of sand in prototype neglecting the effect of hydraulics of intake and transition.

Model tests showed good agreement between calculated sediment diversion ratios per Rouse diagram with observed sediment diversion ratio. It showed the results of more than 70% sediment diversion can be achieved at 20% flow diversion through lower channel at tested conditions.

It is concluded that this study has provided a solid base towards the finding of optimum location of split point in split and settle concept. Based on the study, it is recommended the need of flow and sediment simulation by further modification.

Thesis Title: **A PHYSICAL MODELING APPROACH FOR DESIGN OF IMPERMEABLE SPURS AT BASANTAPUR SITE OF GIRUBARI RIVER**

Submitted by: **Pradeep Shrestha**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

Since the behavior of river is unpredictable so there are no definite design guidelines for the design of river training structures like spurs. The design is done usually by experiences and/or guideline provided for any other sites. By doing so either cost may be more and the structures may not work efficiently for longer time. Hence it is always worthy to use physical modeling approach for design of river training structures.

The Department of Water Induced Disaster Prevention is going to construct river training structures at Basantapur site of Girubari River. The model of that reach was constructed, as per the design by Froude's law of similarity, in 1:150 horizontal and 1:50 as vertical scale (distorted model) with mobile bed and fixed bank. A test with the proposed series of spurs was conducted which gives satisfactory result. Other tests were carried out for different length, spacing and orientation for searching for one of the best combination with same physical conditions. One of the best alternative for the proposed series of

spur is 3nos having projected length of 24m, 71m and 88m with spacing of 80m and 94m on left bank and two numbers of spurs having length of 25m & 41m with spacing of 112 meter. If this alternative is used then, area of 20,000 square meters will be reclaimed as well as bank will be protected. The evaluating parameter was bank protection with minimum total spur length, as the main purpose of spur is to protect bank by deflecting current away. In this thesis work depth of scour are also noted so that the design of launching apron can be done.

The length of spurs was taken as 10% and 15% of distance between desired banks and spacing was calculated by formula S= L cot 9where L is effective length, S is spacing between two spurs and 9 is expansion angle which is almost constant 17 degree for impermeable spur. Spur height was assumed as the highest bank level.

Thesis Title: **SIMULATION METHOD OF STABLE ALLUVIAL CANAL DESIGN FROM THE CASE STUDY OF SUNSARI, MORANG IRRIGATION PROJECT**

Submitted by: **Purushottam Shrestha**

Supervisor: **Dr. Narendra Man Shakya, Dr. Narendra Kumar Lal**

ABSTRACT:

The study is focussed on simulation methods of stable alluvia! canal design, which is related to the sediment transport in irrigation canals. The Chatara main canal of Sunsari Morang Irrigation Project in Nepal is considered as an example for application. Sediment transport has a serious impact on the design, operation, and maintenance activities. Clogging of turnouts and reduction of the conveyance capacity of canals by siltation are problems frequently met in irrigation system.

This study presents design philosophy that must he adopted for ihe appropriate design of irrigation canals in Terai of Nepal. The simulation methods of canal design is the modern approach for the design of stable alluvial canal where input variables such as incoming sediment characteristics and discharge is varies instead of fixed sediment input and discharge in traditional regime theory. The present practice of design of irrigation canals in

Nepal has serious deficiency, and there is a need of change in method of design from regime theory to rational theory.
Annually, high investment is required for rehabilitation of irrigation systems in order to keep them suitable for this purpose. Applicability of existing sediment transport relationships on irrigation canals has to be better understood. In this way predictions on sediment deposition in irrigation canals will be more reliable.

The design of canal system cither should he based on the transport of all the sediment present in water to the Held or to places on the canal system, where llie deposition can he removed with least costs. Sedimentation should be prevented in canals and near structures, as it will hamper and endanger a proper irrigation management. In the design and operation of irrigation canals with sediment - laden water several aspects related to irrigation criteria and sediment transport must be taken into consideration. The need for conveying different discharges at a required water level to meet me irrigation requirement and at the same time to convey the sediment load with a minimum deposition and or erosion on canal system should be the main criteria for canal design.

Defective design makes the canal system either in heavy sedimentation requiring extensive sediment clearance cost and improper water management or requiring large protection works due to scouring. The present study presents a detailed analysis of the transport processes, a physical and mathematical description of the behavior of sediment transport under flow conditions encountered in irrigation canals and to predict sediment transport and deposition or entertainment rate for various flow conditions and sediment inputs.

Thesis Title: **FLOOD FREQUENCY ANALYSIS OF NEPALESE BASIN USING L-MOMENT**

Submitted by: **Rajendra Shrestha**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

A regional frequency analysis of annual maximum series (AMS) of floods from major basins of Nepal has been carried out using index flood procedure with L - Moments which includes the identification of the homogeneous region and suitable regional distribution. The basic idea behind regional frequency analysis is to make the use of similarities in the characteristics of flood at different sites within a region. The study is carried out in three stages. In the first stage, homogeneity of each of major basin is checked and regional best distribution is declared. Based on the analysis of flood data of Koshi. Narayani and Karnali river basins, all three basins are hydrologically homogeneous and Generalized Logistic distribution is the regional best distribution. For Bagmati basin, Generalized normal distribution is the best distribution. The L - Moment ratio diagram is used to choose the best-fit distribution. Regional curves are developed for each basin using the regional best distribution, which can be used to carry out the flood frequency analysis at both gauged and ungauged sites. In the second stage, Cluster analysis is performed

to group the whole area of Nepal into four clusters. It is seen that each of the clusters represents the major basins on Nepal. Then, each of the clusters is checked for the homogeneity and the best regional distribution is found. The result indicates that the Generalized Logistic distribution is best distribution for ail three clusters except cluster 4. For cluster 3 generalized normal distribution is the best one and Generalized logistic is also suitable distribution- In the third stage, the best-fit distributions for each of 70 gauging stations are investigated using L - Moment. The result shows that Generalized Logistic distribution is the best distribution for 36 sites where as for six sites not a single three-parameter distribution is suitable. The probability plot supports the findings of the L - Moment ratio diagram.

Thesis Title: **RAIN STORMS INDUCED HAZARDS ASSESSMENT USING GIS AND NUMERICAL MODELS**

Submitted by: **Raj Hari Sharma**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

In mountain torrents, intense and localized storms cause slope failures and transports huge volume ofsediment to the downstream alluviall fans. Upstream portions of the watersheds are generally affected by the landslides whereas the downstream alluvial fans are periodically exposed to catastrophic events from debris deposition transported by flash floods.

The rainfall characteristic is one of the major triggering factors for the landslide. Topography, soil strength properties, vegetation are other influencing parameters. Due to the rainfall of higher intensity and longer duration in the monsoon season, it becomes the major triggering faclor of the landslide in the Estern Himalayan Region of Nepal. Landsiide hazard mapping proves a useful tool for disaster prevention and oilier land resources development. Methods such as statistical and site inventory are used for landslide hazard mapping but deterministic approach is superior especially after the evolution of GIS and last processing

computers, because of its simplicity and direct linkage to the physics.

In this thesis, the effect of rainfall in the shallow landslide is assessed by coupling Digital Elevation Model (DEM) with the slope stability and hydrologic model. Results show that the proposed GIS based technique of shallow landslide potential analysis is highly applicable due to its simplicity, low cost and case of use. Results also indicate that besides the rainfall, slope is dominating factor for the shallow landslide. The influnce of rainfall is high for the stability to some limit of threshold intensity but beyond that, the impact is inconsequential.

Debris flow is another rainstorm induced disaster. Debris flow is usually treated as an open channel analysis with the friction factor being different. Different researchers have proposed different shear stress equation, some based on experiments and some with a semi - theoretical background. Takahashi's three category flow theory is used in this study for the preparation of One-dimensional (ID) debris flow model in FORTRAN. Set of differential equations are solved using first order upwind scheme since it provides better solulion for the hyperbolic equations. Results show that only 20% of major rainstorms transport more than 90% of debris. The ID debris flow model adequately calculates the sediment volume transported by individual rainstorm. Regression analysis shows good correlation between 30 minutes rainfall intensity and the rainfall volume, with the debris volume transported.

Thesis Title: **SOIL EROSION ASSESSMENT IN THE MIDDLE MOUNTAIN REGION OF NEPAL: A CASE STUDY IN BAGMATI WATERSHED**

Submitted by: **Ram Chandra Poudel**

Supervisor: **Mr. B. K. Rimal, Dr. R. N. Jha**

ABSTRACT:

Soil erosion is a crucial problem in Nepal where more than 80% of the land area is mountainous. The soil erosion assessment, a persistent and serious research problem, is a capital intensive and time consuming exercise because of its myriad complexities and variables. Empirical soil erosion .models though relatively simple, may simplify the erosion processes which are easy to interpret physically, require minimal resources and can be worked out with readily available input values to pinpoint the areas exposed to high erosion risk. For the water and soil conservation planning the capacity of the models to locate the erosion pattern correctly may be more useful than the ability to accurately quantify erosion losses.

The main aim of this study was testing two commonly used empirical water erosion models, the Revised Universal Soil Loss Equation (RUSLE) and Revised Morgan, Morgan and Finney (RMMF). in predicting the soil loss rate and spatial erosion pattern in a small sub-watershed (57 ha) at Simlang and in

Bagmati Watershed (2800 Km^2). The available data set comprised the climatic data, topographical maps. land use maps and land system maps. Field survey was conducted to gain detail in the sample study area. Both the models were incorporated in the ArcInfo GIS. The predicted results and the erosion pattern were compared with measured data and with the erosion rates in the relevant literatures. The RUSLE resulted in high erosion rates (174 t/ha/y on average), whereas the Revised MMF model predictions were low (1.35 t/ha/y). The prediction of soil erosion by RMMF model results are in good agreements with the actual soil loss rates at Kalchi Khola sub-watershed. RUSLE predictions are far from the real figures. However the prediction by both the models seemed to be wrong in case Bagmati Watershed. RUSLE resulted in high erosion rates (98 t/ha/y on average) and the RMMF model predicted low erosion rates (2.3 t/ha/y on average), the prediction by RUSLE being better than the RMMF predictions.

It is concluded that the RMMF model is the better empirical model to predict annual soil erosion rate at the sub-watershed scale which has steep slope and where it is possible to get more details through field survey, In the watershed scale the empirical soil loss models can be used as qualitative 'screening' tools to identify areas prone to erosion risk rather than quantification of actual soil loss rates.

Thesis Title: **LOCAL RESOURCES MOBILIZATION IN REHABILITATION OF IRRIGATION SYSTEMS IN NEPAL**

Submitted by: **Danda Pani Jaishy**

Supervisor: **Mr. K. R. Shrestha**

ABSTRACT:

His Majesty's Government of Nepal is rehabilitating various Farmer Managed Irrigation Systems (FMIS) through people's participation to develop a feeling of ownership among the beneficiary farmers and also to reduce the government share of cost in the subproject development. The beneficiaries' contribution during the construction stage is one way of involving people in the subprojccts. However, realization of the beneficiaries' contribution in an irrigation system has remained an important issue. The minimum share of WUA contribution is worked out according to Irrigation Policy, on a percentage basis of the subproject cost. Various irrigation sub projects were constructed and completed according to this policy in the recent past. The stains of beneficiaries' contribution in the completed subprojects and nature, volume and location of works allocated is need to be analyzed so that ways can be suggested in future irrigation development programmes where farmers and DOI can work together in the rehabilitation of irrigation projects.

An assessment of the beneficiary farmers' contribution and the type of physical works they were assigned to for the rehabilitation of a total of 2S7 farmer managed irrigation schemes (231 in the hills and 56 in the terai) which were completed as of July 5, 2001 irrigating about 30,000 hectares in all the five development regions of the country under the Department of Irrigation executed Nepal Irrigation Sector Project (NISP) and the Second Irrigation Sector Project (SISP was carried out. The study mainly relied on the secondary sources of information, which included thie project documents and the official records on the total area covered, number of households served, expenditure incurred per unit area and households along with the contribution on the part of the farmer beneficiaries and the nature of works.

As per Irrigation Policy 2049 (First Amendment 2053), a minimum of 12 percent of the construction cost in the rehabilitation of hill suhprojects and 15 percent in the rehabilitation of terai subprojects is to be contributed by the beneficiary farmers. Overall trend in the completed subprojects is close-to the anticipated percentage points with 11-86% in the hills and 14.11% in the terai. However, hi many subprojects the beneficiaries could not contribute the stipulated amount with few schemes surpassing the expectations. In the hills, sixty percent of the completed subprojects of eastern region, sixty two percent in the centra! region, forty one percent in the western region, forty percent in the Mid-western region and fifty six percent in the far western region have fulfilled !he WUA requirement of 12 percent contribution. Similarly in the terai projects 28 percent in the eastern region, 50 percent in the central region, 71 percent in the western region, 25 percent in the mid-western region and 43 percent in the far-western region have fulfilled llie IP recuiiremeni of 15 percent contribution. According to the procedural guidelines of NISP and SISP, a minimum amount of lead time is required in the subprojects to mobilize the people in different singes of project development. But most of the subprojects of both hills and lerai were completed within one year. Some were completed in just three months after the approval. People could not be mobilized in decision-making and they could not comply with the assigned percentage of contribution in such a short period of time. Though it is mandatory to register WUAs before making the irrigation systems eligible for government assistance, the WUA need considerable time to mobilize the farmers and derive (he anticipated contribution.

Beneficiaries were found hard pressed to do all types of works by contribution. Works were not classified as easy, hard and very hard whereas, only the simple and easy works should have been allocated for the farmers' contribution part. More people could have been involved in the subprojects, if easy works had been allocated to them. In some of tlie hill subprojects, hard rock cutting, gabion box filling including supply of stones and holder mixed soil excavation were reported to have been done by WUA contribution. Such works are cons id creel as hard works for the beneficiary farmers. Most of the WUA contribution part in tlie terai suhprojects was made in the earthwork excavation and backfillingof main canal. Very little contribution was made on other structures.

The conlribulion required per household, DOI expenditure required per household, average land holding per households etc could be linked to capability of the people living in the project area. The present trend of project appraisal is found mainly to focus on per hectare expenditure, EIRR, environmental issues, and institutional viability of the project. A realistic contribution could better be drawn from the beneficiaries if the WUA contribution was fixed on the basis of average per household contribution and expenditure required along with the present set of parameters. The average per household and per hectare contribution in most of the subprojects was found to range between Rs 5000 to 10,000 depending on the landholding and the financial status of the households. This figure could be taken as the capability of the people to contribute in the subprojecis.

As provisional in the financial regulations of the government, the construction contracting to WUAs up to 2.5 million lias opened an avenue for the farmers' active involvement in the irrigation system rehabilitation. As a legal entity, the WUA in a system should he encouraged to manage the simple contractual works and llieir institutional capability need to be enhanced through occasional training activities. Though government principle requires single contract works assigned lo WUA if they are willing, it is normally the working relationship between the agency staff and the WUA officials that plays the vital role on this. Given that tlic WUA has attained certain degree of institutional capability including the technical and managerial ability to handle the contracts, provisions could be made to split the bigger volume of contract works and mobilize the farmers for making quality works along with the increased contribution on the part of the farmers.

For the sustainability of irrigation subprojects, beneficiary farmers should be involved in all the stages of project development. Sufficient lime for the local resources mobilization and institutional development should he given to them so that a genuine contribution is achieved through the involvement of beneficiary fanners.

Thesis Title: **EFFECT OF CHANGE IN DISCHARGES ON EXPANSION ANGLE OF FLOW IN IMPERMEABLE SPURS: A PHYSICAL MODELING APPROACH**

Submitted by: **Janak Das Koirala**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

Since the 19th century- extensive experimental study on hydraulics engineering as well as river training works have been carried out all over the world, and fruitful achievements have been made. The importance of experimental study is highlighted and felt in deeper than before with the development of technology and better understood of theory. Here, experimental study is concentrated on an impermeable spur of different length in percentage (10, 20 and 30) of channel width, different orientation of the spur as 90°, 120° and 150° to find the expansion angle of flow when the discharge on the channel is changed as 5,6,7,8 and 9 lps at hydro lab of Department of Water Induced Disaster Prevention. From this experimental study the change in expansion angle with length, orientation and discharge variation is studied. From tlie laboratory experiments, the change in expansion angle with respect to change in length of spur, change in orientation and change in discharges; it is found that the length is most significant factor than orientation and

discharge on the river, in addition to the expansion angle variation, the scouring depth at the spur tip on an impermeable spur at different length and orientation is also measured for the same conditions. The scouring pattern in these conditions revel that scouring increases with the increase in length of spur. From the measured data the scour in spur tips decreases with the increase of orientation from 90° to 150°.

Thesis Title: OPTIMIZATION OF CROPPING PATTERN IN SURFACE IRRIGATION SYSTEM

Submitted by: Ananta Kumar Gajurel

Supervisor: Dr. R. N. Jha

ABSTRACT:

Rapid increase in food requirement, due to fast growth in population, has necessitated increasing food production in the country. This means that there is a need to increase the food production per unit area. Nepal being predominantly agricultural country, growth in agricultural production with judicious use of resource is of paramount importance for national economy, Terai though it covers 12% of total land is a Food basket for the country producing more than 60% of cereal crops in the country. Optimal allocation of cropped area for different crops and adjustment of optimum cropping pattern in an irrigation system is the most important aspect of irrigation management. The study has attempted to look into the allocation of cropped area and choice of crop for generating maximum benefit front the project.

The present study used the Bagmati Irrigation Project as a case study in order to analyze the optimal use of available irrigation water to obtain maximum net benefit. The present study is

limited to area commanded by western main canal of Bagmati Irrigation Project.

Linear Programming (LP) model is one of the most widely used techniques water resources management and planning purpose. The UNDO software is used to solve the linear programming model lor (lie optimization of cropping pattern under the optimal use of available irrigation water and with ground water as Ihe conjunctive use. With Ihe project implementation, the available irrigation water is being used properly for the present cropping pattern. The present study is about optimizing the cropping pattern under the prevailing social and cropping conditions in order to realise maximum net benefit with the optimal use of available irrigation water. The river run off data since 1979, and rainfall data since 1975 with 80 % exceedance probability, is used in the present study.

The present study lias shown that under (lie prevailing situation, the net benefit can be improved by 3 % by optimization in llie present cropping pattern with the considerations of same command area available irrigation water, and with the limitation of maximum and minimum area of any particular crops area- Net benefit could he increased by 18.5%, with the removal of upper limitation on maximum area of any particular crop, which increases the production of two vegetable crops by 4.6 times the present production, provided the increase in production of such vegetables does not affect the market price.

The study on optimization of cropping pattern with llie optimal use of available irrigation water, has also shown that there is a potential of extending the command area under the prevailing social and cropping conditions, with llie limitations in maximum area of any particular crop other than four vegetable crops in (lie above case, but maintaining the minimum crop area within 80 % and maximum crop area of vegetable crops within 120% of the cultivation of present crop area. Net benefit could he increased by 32% with the increase in command area *by* 53%. The optimal cropping pattern obtained from this scenario is round to be justifiable for the project. The net benefit can be further increased by 48.5 % and the increase in command area by 47% with the removal of upper limitation on maximum area of any particular crop, which increases the production of two vegetable crops by 4.6 limes the present production, provided the increase in production of such vegetables does not affect Ihe market price.

The study on optimization of cropping p;illern wilh ground water as conjunctive use in addition to available irrigation water lias also shown that there is a large potential of extending the command area under llie prevailing social and cropping conditions, with ihe limitations in maximum area of any particular crop other than four vegetable crops in the above case, but maintaining the minimum crop area within 80 % and maximum crop area of vegetable crops within 120% of the cultivation of present crop area. Net benefit could be increased by 107% with the increase in command area by 126%. The optimal cropping pattern obtained from this scenario is found to be justifiable for the project.

Hence the study in optimization of cropping pattern with optimal use of available water is found to be useful in planning the project to increase the agriculture production with increase in net benefit of the project. The study has reflected Ihe potential of increasing benefit from the large irrigation projects in the prospect of the country as well. This study can be a useful tool to replicate the analysis in other projects as well in the present contest of water shortage and limitation of cultivation areas.

Graduation Year 2003

Thesis Title: **OPTIMAL IMPROVEMENT OF IRRIGATION SYSTEM (A CASE OF SUNSARI - MORANG IRRIGATION PROJECT)**

Submitted by: **Pramod Kumar Shrestha**

Supervisor: **Dr. Indra Lal Kalu**

ABSTRACT:

This study develops a mixed integer linear programming model to incorporate decision variables for the optimal allocation of crops area along with the optimal measures. Land leveling, lining, farm pond and shallow tube well are considered as four improvement measures in this study. Crop area, area of land leveling, farm pond area are treated as continuous variables while shallow tube well is an integer and lining is a binary variable in the model. The feasibility of farm pond and shallow tube well are assessed from the demand and supply situation of the system while land leveling and lining are considered on the basis of water saving measures.

The objective function of the model is to maximize the net benefit under improved condition of irrigation operation and it is subjected to constraints water availability, crop area, farm pond

area, area of land leveling, lining reach and shallow tube well. Input data of water saving from lining and land leveling, quantity of water obtained from shallow tube well and farm pond are analyzed on the basis of available data. Field irrigation requirement of proposed crops are obtained by CROPWAT software developed by FAO. The model is solved using the LINGO version 8.0 package programme.

Model results obtained under the present cost value of improvement measures are tested in four different scenarios of crop boundary. It is again checked with 25% cost of improvement measures increment and reduction. To incorporate the flow reduction condition, results are again obtained with the 25 % flow reduction case. Land leveling appears to be an effective measure for the improvement of the irrigation system. The next effective measure shallow tube well is found totally dependent on ground water storage. Lining seems feasible under no crop bound conditions. Due to high unit cost of farm pond as compare to storage capacity farm pond seems to be not feasible. The rate of reduction of net return is found more in case of cost increment as compared to the case of flow reduction. This shows model is more sensitive to cost of improvement options rather than the flow conditions.

The methodology applied in SS14AB sub-secondary canal of S-14 canal system of Sunsari-Morang Irrigation Project, Nepal is recommended as a general analytical tool for the planning of improvement of irrigation system.

Thesis Title: **A STUDY ON GROUND WATER SUSTAINABILITY IN TERAI DISTRICT OF JANAKPUR ZONE OF NEPAL**

Submitted by: **Chandeswar Prasad Kurmi**

Supervisor: **Dr. Laxmi Prasad Devkota**

ABSTRACT:

Groundwater has historically been based on the safe of sustainable yield of the aquifer system. However, with the complexity of the system and the widespread use of the resources, a detailed hydrological data collection, analysis, and evaluation of the resources is needed to perform in an integrated manner with proper respect to the objectives to be achieved for a particular system, it plays an ever increasing role in water resource systems so, integration of groundwater development plans into the total water resource system is considered while formulating the water resource master plan of an area. It is necessary to combine the surface water and groundwater facilities to allow their conjunctive use, which will enhance sustainability of the resources.

Terai districts of Janakpurzone (Dhanusha, Mahottary and Sarlahi) of Nepal have high potential for agricultural growth and have groundwater resources in phreatic and confined (with artesian pressure in Dhanusha and Mahottary) aquifers, which is

being utilized for the agricultural as well as domestic and industrial uses from a long time and it will continue for future also.

The study for groundwater sustainability of the area has performed by Processing MODFLOW at a grid of 5000 m x 5000 m in phreatic and confined aquifers considering recharge components; river system and rainfall and discharge components: evapo-transpiration and lube well pumping used for agricultural and domestic uses. Water level observed data of 1998 to 1999 AD has compared with simulated data and il has been verified by the data of 2000 AD at different places of the area. The discharges of the wells has estimated 7327, .3941.67and 5650.83 cum/day per grid for 2001 AD and it will be 19320, 24508.33 and 28816,67 cum/day per grid in 2025 AD for Sarlahi, Mahottary and Dhanusha districts respectively as number of Sallow Tube Wells (STWs) targeted by Agricultural Perspective Plan (1995) up to 2015 AD and after then according to potentials of the districts assuming 550 hours operation per year at the rate of 10 liter per second discharge per well and no recharge due to return flow after consumption of the water. It has been assumed that recharge to the groundwater due to surface irrigation system being balanced by output due to out going discharges ofChuria range originated rivers, like Manusmara, Ratu and Jamuni etc.

Which vanish near foot hills and appear in mid terai normally in dry season.

It has been find that water level decreasel.13 m at Janakpur .03 m at Kisanpur in Dhanusha; 0,17m at Jaleshwar, 2.32 m at Ratauli and 0.12m at Sangrampur and Gobaraia in Mahottary and 0,79 m at Malangwa, 0.11 m at Bela in Sarlahi districts but at Mohanpur in Sarlahi district the water level rise 0,8 m up to 2025 AD . Similarly on most of the places potential for STWs irrigation the water level is on nominal decreasing trained.

This study shows that the area has plenty of the groundwater reserve and would sustain for next 25 years, however, a careful utilization with proper management is essential for further sustainability.

Thesis Title: **ASSESSMENT OF GROUND WATER POTENTIAL OF KATHMANDU VALLEY**

Submitted by: **Guna Raj Ghimire**

Supervisor: **Dr. Laxmi Prasad Devkota**

ABSTRACT:

The demand of water in Kathmandu Valley is sharply increasing and the surface water system alone is not adequate to supply the increased demand- So the ground water in Kathmandu Valley is being extracted to fulfill the increasing demand. But very few researches have been done about the ground water resources of Kathmandu Valley and are conflicting too. The study of ground water potential of Kathmandu Valley is, therefore, carried out to estimate the sustainable quantity of water that can be extracted from the under ground resources.

Ground water simulation models are important tools in water resources planning and management. Numerical models are often used to represent heterogeneous hydrogeological parameters and boundary conditions in ground water flow studies. The tool used for the present study is the familiar ground water flow model, Processing Modflow for Windows (PMWIN). The main program of the tool is divided into 'modules', which permits the user to examine the specific hydrologic features of any model independently. It directly calculates the hydraulic heads,

drawdowns, cell-by-cell flow terms etc, with the given data. The mil version of the model has the facility of parameter estimation too. The other important benefit of the model is the capability to specify the model grid irregularly as required. Simulation results can be extracted for any stress period in a spreadsheet.
The assessment of ground water potential of Kathmandu Valley was carried out analyzing different scenarios. From the different scenarios analyzed and permitting the maximum draw down of 15m, it is found that the total present deficit quantity of water cannot be withdrawn from the proposed 8 locations only. A constant rate of 8 MLD and 6 MLD in dry and wet season can be withdrawn from each Mahadevkhola, Gongabu, Bansbari, Bode and Nayapati area from the confined aquifer assuming Melamchi and Yangri come in operation by 2006 and 2011 respectively. Similarly at a rate of 4 MLD and 3 MLD can be extracted in dry and wet season respectively from each Boudha, Mulpani and Bode area.

Thus, with the given data, it is found that the additional maximum quantity of water that can be extracted from the confined aquifer is 52 MLD in dry season and 39 MLD in wet season within the given limit of draw down from the proposed 8 locations. Moreover, if the pumping stations are scattered in other areas also in addition to the proposed area, even more quantity of water can be obtained from the ground water resources. This additional extraction should be decreased after Melamchi comes in operation by 2006 for the recovery of the declined head. Deficit quantity of water if Melamchi operated by 2006 will be small and can be supplied from ground water resources till 2011 until Yangri with supply capacity of 170 MLD comes in operation.

Thesis Title: **SEDIMENT SIMULATION MODELING OF PHEWA LAKE WITH THE COMPUTATIONAL FLUID DYNAMICS**

Submitted by: **Buddha Ratna Tuladhar**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

Sediment flow is an inherent natural phenomenon, which is unavoidable in natural watercourses. Sediment brings problem in such aspects of water related structures as intake, water conveyance system and electromechanical parts like turbine and metal pipes. The major sedimentation problem is considered in the reservoir, as the overall life of the project depends on the rate of the sedimentation.

Phewa Lake situated in Kaski district, which has major economical value in tourism sector, must be kept out of the environmental degradation in aspect of the quality and amount of the water. The major problem associated with the capacity of the lake is sedimentation. Since many tributaries flow into the lake, it loses its capacity and lake cover area as well. The Phewa Lake is considered to be one of the prominent tourist attractions in Nepal. The national interest is growing towards the conservation of the lake. The sedimentation of the lake is being monitored for different time intervals.

The computer program SSIIM (Sediment Simulation in Intake with Multiblock Option) is the one of the numerical models based on the computational fluid dynamics. This model simulates the sediment movement in the reservoir or in the intake and finds variables regarding the sediment such as sediment concentration, kinetic energy, bed level changes, velocity of the flow and bed deposition pattern etc. Since the objective of the study is to predict the bed level changes, this model is used to calculate the bed level changes in the lake and to find the total volume changes in the lake for definite interval of the time.

The quantitative analysis is performed on the basis of the average bed level changes and extent of the bed level change within the lake by the SS11M model. The trend of the bed level changes with inflow sediment volume is determined and single year bed variation is predicted. The result is verified on the basis of the data available in the report of he sediment monitoring. The sensitivity analysis is performed for the uncertainties involved in the simulation. The conclusion is made on the basis of the result and analysis and graphical and quantitative outputs by the SSIIM are presented.

Thesis Title: **FLOOD PLAIN DELINE AND CHECKING OF EXISTING LEVEES: A CASE STUDY OF BAKRAHA RIVER**

Submitted by: **Dhruba Kumar Shrestha**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

The Department of Water Induced Disaster Prevention (DWIDP) is responsible for hundreds of Floodplain Management Works throughout Nepal. These include the construction of river facilities to cope with the flood, to develop the non-structural measures for the flood mitigation works. An important design component of these facilities involve hydraulic analyses to determine conveyance capacity. Computer models play a pivotal role in these analyses by adding in the determination of water surface profiles associated with different flow conditions. Unfortunately, the Department is using the old technology, as often the computed water surface elevations are manually plotted on paper maps in order to delineate flood plains, etc. Automating this manual plotting would result in significant savings of both time and resources. Geographic Information Systems (GIS) and Hydraulic Engineering Center River Analysis System (HEC-RAS) offer the ideal environment for this type of work. The approach establishes a connection between the HEC-RAS one-

dimensional hydraulic model and Arc View GIS. allowing for improved visualization and analysis of floodplain data.

In this work, Triangulated Irregular Network (TIN) generated with the contour and point elevation data layer from Survey Department and river cross section data. Finally digital terrain model (DTM) is synthesized from HEC-RAS cross sectional coordinate data and the TIN of the study area. This study involved the preparation of geometric model of Bakra River for the situation before and after the construction of levees in Arc View GIS with its extension HEC Geo RAS and run the steady flow model in HEC-RAS. The models were applied to determine the critical locations within the study area in different return period flood profiles, which were unknown after the completion of the 1100 cumecs master plan work in Flood Mitigation Program in Bakra River. The main objective of the research is focused on the above shortcomings and the results of the thesis is a small approach to fulfill the void between the mitigation work and reality.

Output of the thesis work without levee situation predict 3492 to 7239 hectares of area could be inundated with 2 to 100 years return period flood. In most of the reaches the left levee is greater in height. At an existing situation with revised maximum flood

1700 cumecs, there are overflows at two places on the left levee and twelve places on the right levee. In an average 0.75m and 1.0m height (including 1.5m freeboards for 2 years flood and 1m for 100 years flood) should be raised for left and right levees respectively. Maximum inundated area will be approx. 1200 hectares in case of the breaching of the right levee at the upstream of the Jhapdtal, This method can be applied to the numerous existing levees and in the design of the new levees of the forthcoming projects. In overall conclusion, the GIS in association with HEC-RAS are the effective tools to save time and resources.

Thesis Title: **APPLICABILITY OF COMPUTER - BASED TOOL IN FLOOD PLAIN ANALYSIS IN INCORPORATING HYDROLOGICAL IMPACT OF GLOBAL CLIMATE CHANGE: A CASE STUDY OF BAGMATI RIVER IN TERAI.**

Submitted by: **Pawan Kumar Thapa**

Supervisor: **Dr. Narendra Man Shakya, Dr. Raghu Nath Jha**

ABSTRACT:

Hydrological extremes like flood and droughts have always been a major concern. As floods are becoming an increasing menace throughout the world, it has become clear that the problem has to be assessed at a river basin scale. This requires the evaluation of various hydrological, hydraulic, topographic and social parameters. Geographic Information System (GIS) links the hydraulic models that can provide the fiunctionality capable of assessing and analyzing the parameters and visualizing the results.

Water resources management has been traditionally based on the assumption of unchanged climate and land-use conditions. Recent floods and droughts of exceptional severity raise the question on this stationary assumption. Precipitation being the

most significant aspect of climate change, the assessment of climate change impacts on the hydrologic resources becomes an important assessment to be carried out for defining how mankind adapts in future to the expected global climate change.

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This thesis presents a systematic approach for the analysis of the floodplain and the assessment of flood risk incorporating the impact of Global Climate Change on flood hazard. A case study of Bagmati River in Terai of Nepal is undertaken using HEC-RAS and ArcView GIS. GeoRAS extension is used for interfacing the two systems. Remote Sensing data-MODIS is processed using ENVI 3.4 to demonstrate more speedy and accurate flood plain delineation. TANK hydrologic modeling uses the predicted rainfall data impacted by Global Climate Change and simulates to result the expected runoff.

For the automated flood plain analysis. Triangulated Irregular Network (TIN) is prepared and exported to HEC-RAS to calculate water surface profiles. The results of the model are then, exported to GIS for floodplain mapping. Further analyses include the flood risk assessment by dividing the risk into vulnerability associated with the land use pattern and hazard associated with hydrological and hydraulic parameters. Results of these two analyses are combined to develop the land use-flood depth relationship.

To assess the impact of climate change on runoff, threshold band of ($\mu \pm \sigma$) has been set, where μ, and. σ are mean monthly flows and standard deviation respectively. Any event above this threshold band is considered as high extreme event or flood and the changes in the present and expected total number and duration of flooded days has been determined.

This study has thus, made an attempt to present an approach that facilitates "a transition from a flood hazard model bawd on the field investigation (post-flood mapping) to a knowledge-bawd model that can he related to flood intensity that loo incorporating the 'future impact of Global Climate Change."' This can, therefore, help the decision makers, planners, engineers and general public alike to perceive the flood-related problems in a better way and take appropriate measures for flood protection.

Thesis Title: **OPTIMIZATION OF WATER USE IN FRAME MANAGED IRRIGATION SYSTEM (A CASE STUDY OF CHHATTIS MAUJA IRRIGATION SYSTEM**

Submitted by: **Jebachh Yadav**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

The demand of water for agriculture, industry and domestic use is increasing day by day with the continuous and rapid growth of population and pressing the agriculture system to produce more food. So, it becomes necessary to allocate the available resources land, water and agriculture practices more effectively for producing more agricultural benefits. The primary objective of irrigation system is to provide reliable, adequate and equitable irrigation and there by increases the socio-economic conditions of the farmers. However, due to large temporal and spatial variation in irrigation water and high increasing cost of O & M, Chhattis Mauja Irrigation System has not been in position to provide reliable and adequate services because of uncertainty and inadequate surface water resources. This situation can be improved by planning a suitable cropping pattern in accordance with the availability of How and introduction of crop diversification. Further more, integrated use of surface and

ground water has also been planned as a planning strategy to meet the irrigation demands in water scarcity period for achieving optimal net benefit.

A linear programming model has been developed to solve the problem of maximizing net agricultural benefit with available resources using UNDO super 6.1, employing irrigation demand, system capacity, cultivable area, groundwater safe yield, number of tube-well and other nonnegative as constraints. Six different scenarios with available surface water and six with conjunctive water use are formulated and tested within the model. The net return obtained from scenarios 2, 5, and 6 with the use of surface water and scenarios 8, 11 and 12 with conjunctive water use are NRs. 121.03, 117.58, 134.79 and 145.6, 186.49 and 139.77 million respectively. Results obtained from the model indicate that the existing cropping pattern is not optimal and should be replaced to optimal cropping patterns resulted from the model application,

The sensitivity analysis has also been implemented, as well. It is worth to see the effect of changes of available discharge, benefit and groundwater development cost to the optimal solution. The increase or decrease of available discharge and net unit benefit have strong effects while groundwater development cost has very less effect on optimal solution.

Thesis Title: RESOURCE ORIENTED BAGMATI RIVER WATERSHED PLANNING AND MANAGEMENT (FOCUS IRRIGATION SECTOR)

Submitted by: Pragya Pradhan Shrestha

Supervisor: Dr. Raghu Nath Jha

ABSTRACT:

The uneven distribution of water resource in nature results in the scarcity of resources in a place while in another place the same resource is available in greater extent. Thus, there is lack of proper utilization of the resource. Water resource management implements and utilize the comprehensive data resource in planning, regulation and management of a watershed. Basin wise study for optimal water use plan sets the guidelines to allocate the water distribution for the various sectors of water use in the future.

Nepal, being rich in water resource though faces the problem of water scarcity in most of parts of the country. This is because of the variation in spatial and temporal distribution of water. Therefore for the effective use of the available resource, a management plan needs to be developed.

The Bagmati watershed under consideration includes whole of the area under Bagmati River drainage from its origin to

Karmaiya of about 2720 km. The study intends to identify the potential land resource and the probability to develop the area to agricultural expansion. This is done by matching the availability of extra water resource with the land resource identified through GIS.

The water balance is performed with the use of MIKE BASIN for the major consumption area of water use. The water balance is estimated for the different nodes at the boarder of one or more districts along the Bagmati river.

The CROPWAT 4.0 Windows software is used for the estimation of main consumption of water requirement and irrigation requirement. The drinking water requirement is taken as 135 Ipcd for urban areas and 50 Ipcd for the rural areas.

With the extra water available after fulfilling the downstream requirement, the extra land can be irrigated for the increment of agricultural area in the study area.

The extra water available is then used to identify the additional irrigable area. The Digital Elevation Model analysis with the constraint in the land classification, slope classification and soil type criteria are used to find the potentiality of land resource is expressed through GIS.

Thesis Title: **DECISION SUPPORT SYSTEM FOR WATER SUPPLY MANAGEMENT IN THE KATHMANDU VALLEY**

Submitted by: **Ram Gopal Lageju**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT:

Kathmandu Valley is historically known as best place for settlement and agriculture. There were number of spouts (Stone Taps), wells, ponds and irrigation canals (Raj Kulos) constructed by the rulers during Mall Period. About 150- 200 numbers of spouts are still existing. Kathmandu had Pipe water supply system more than a century .Birdhara System was the first piped Water Supply scheme established in 1895, based on abstraction from two spring fed streams in Shivapuri watershed area in the upper ridge of Budhanilkantha.Tri-Bhimdhara system established in 1930 lapped water from water from five springs in Balaju area. Only after the completion of Sundarijal System in the Northest of the valley under Indian Co-operation Mission aid programme in 1966,private taps were connected in the Kathmandu Valley. Effective efforts had been paid to address for management of Water Supply in the valley after Binnie & Partners, in 1973, with assistance of UNDP prepared " Master Plan for Water Supply and Sewerage for Greater Kathmandu and

Bhaktapur".This study comprise of improvement of existing water supply system and establishment of new system like Pharping System, Shainbu System ,Bansbari well-field System etc.They were implemented in First Project (Executed in May 1974),Second Project (Executed in August l979) and Third Project(Execuled in September 1980).Population growth in Kathmandu valley is so intense from last three decades that created crisis in the valley. JICA carried out" Master Plan Study on Ground Water Management Project in Kathmandu Valley" .Full scale feasibility study of Melamchi Project scheme was carried out from 1990 to 1992 to manage scarcity of water supply.

Management of Water Supply in the Kathmandu valley in integrated and sustainahle manner is in terms of space, time, quantity and quality is being challenging. Melamchi Project is on the way to construction. In coming days there will be private operator in the place of NWSC, ground water licensing restrictions, waste water improvement projects, Distribution Network Rehabilitation/Improvement project will be here. Government has proposed Kathmandu Valley Water Authority (KVWA) which will be solely responsible for making policies and managing water in Kathmandu va]ley.And,water management in the valley is going to be more complex and broad.

MIKE BASIN is a versatile tool for Integrated Water Resources Planning and Management. It is developed by DHI and based on basic water (mass) balance equation and uses Graphical User Interface with Arc View GIS tool. The main objective of this study is to develop a model for simulating different policies. For this, MIKE BASIN RR Module (NAM Model), lumped conceptual type Rainfall Runoff Model, is first calibrated .validated and used to generate yield of surface water yield. Results from physical Based Integrated Yield Model using MIKE SHE carried out by the "Optimizing Water Use in the Kathmandu Valley Project" is also followed.

Model is set up to simulate to account surface as well as ground water uses in conjunctive uses and inter-basin transfer option. Developed tool simulated different demand scenarios success fully. This Decision Support System can be therefore used to test the performances of various water resource development, management, options and policies.

Thesis Title: **OPERATIONAL PLANNING AND MANAGEMENT OF A MULTIPURPOSE RESERVOIR (A CASE STUDY OF BAGMATI MULTIPURPOSE PROJECT)**

Submitted by: **Surendra Prasad Rauniyar**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

In Irrigation, Hydropower and Water Supply planning it is often desired to know the minimum conservation storage required to meet reservoir or downstream *flow* and diversion requirements. The solution is an iterative process of assuming different storage volumes until the minimum Storage is found that will *meet* the requirements. The inverse is also common. Given a fixed storage volume, the maximum desired flow- required flow- or diversion which the reservoir will yield can be determined. This task of rinding minimum storage or maximum yield is handled in HEC-5 through its yield determination capability. Geographical Informalion System (GIS) makes easy in the preparation of all thematic maps for later analysis by different others computer models. CROPWAT Model is used widely in the calculation of irrigation water requirement as it uses the modified Penman-Montcith equation.

The storage projects available in Nepal particularly to fulfill the year round irrigation water supply to Terai agricultural lands are limited. Sapta- Koshi. Kamali (Chisapani) and Pancheswor Multipurpose Projects are extraordinarily large while Kamala and Sarda storage sites have very small active storage capacity. The medium size storage sites identified so far arc only Kankai (in the east). Bagmati (in the center) and Rapti at Bhaiubang or at Naumore (mutually exclusive in the west) multipurpose dam sites. Multi - Purposes projects are of utmost importance for Nepal to boost the agricultural production through year round irrigation water supply to Terai, The Bagmati Multipurpose Project (BMP) in particular, therefore, should receive highest priority for year-round irrigation of the land located in the central Terai and enclosed between main Bagmati river in the east. Helauda-Birgunj corridor in the west and Nepal Eastern Canal and Nepal- India border in the south keeping in view that there is no other dependable surface water source than the regulated Bagmati flow.

This study which incorporates the maximum irrigable area available downstream oflhc dam site (125000 Ha), has focused on determining the optimum reservoir size for providing [lie year round irrigation. The optimum size of reservoir has also been determined for possible scenarios with different irrigable area keeping in view of others alternatives to fulfill irrigation demand.

The optimum size of reservoir is determined by HEC-5 and the results so obtained arc verified by the Mike Basin Computer Model in terms of (he percentage of time the demand iy satisfied. The power generation and the flood controls are taken as the extra benefits from the size The research shows that the dam lieigiits to irrigate the areas of 125000 ha. 63700 ha and 48700 ha are 95 m. 87 m and 85 m. The increase in inflow up to 20% doesn't have so much decreasing effect on height. Whereas the increase in monthly irrigation water demand by 50% increases the dam height to 113m.

Thesis Title: **RAINSTORMS INDUCED EROSION AND SEDIMENT DEPOSITION: A CASE STUDY OF KULEKHANI WATERSHED**

Submitted by: **Uttam Bahadur Amatya**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

About ten million year ago, the Himalayan range begins to form due to collision of Indian plate with Tibetan Plate. With rising of the geologic formation down cutting of rivers resulted in erosion and mass wasting. The mountains are geologically new, exceptional rains, earthquake and other natural phenomena inducing erosion is common. It is important to understand the erosion process under normal conditions and to assess the magnitude of the problem, so that effective measures can be implemented.

The High Mountain and valley provides ample opportunities for construction of hydroelectricity system. Kulekhani Storage Hydroelectric Project built with 114-m high rock fill dam impounding 2.2 sq.km of reservoir area was under severe threat due to excessive sedimentation from the unprecedented rainfall of 1993. It became important to assess the soil erosion in the watershed.

The main aim of the study was testing the physically based WEPP model in predicting the soil loss rate and spatial erosion pattern in Kulekhani watershed. The available data set comprises the climate data, topographical maps, land use maps and soils maps. The predicted results and erosion patterns were compared with measured data and with erosion rates in relevant literatures including sedimentation in the reservoir.

Results obtained by running the Geo-WEPP model in GIS environment for randomly selected sub-catchments and interpreted to the watershed scale show that annual soil erosion is as high as 95.36 t/ha/yr for the cultivated areas with mean soil loss rate of 52.42 t/ha/yr, are far from the erosion plot studies conducted in the watershed. However it is in the range of the measured soil loss. The comparison with the actual sedimentation rate in the reservoir are in comparable limits except in the year 2002. The model result shows the sediment yield before 2000 is less than actual sedimentation in the reservoir, while it is more after 2000. The sediment yields estimated from the model do not include the sediment delivery ratio.

It is concluded that the physical based model are better than the empirical models to predict annual soil erosion rate at the sub watershed scale or for small catchments, where it is possible to get more details data and spatial variation of the parameter. In larger watershed, the model can be used as qualitative tools to identify areas prone to erosion risk rather than quantification of actual soil loss rates. WEPP is a very power model and complete set of database should be created.

Thesis Title: **APPLICATION OF STUDY AND UNSTEADY FLOW MODEL AND GIS FOR FLOOD PLAIN ANALYSIS AND DISK MAPPING: A CASE STUDY OF LAKHANDEL RIVER, NEPAL**

Submitted by: **Ripendra Awal**

Supervisor: **Dr. Narendra Man Shakya, Dr. Raghu Nath Jha**

ABSTRACT:

Flooding is one of the serious, common, and costly natural disasters that several countries are facing. One of the non-structural measures for risk reduction strategy is the delineation of flood prone areas. Flood risk mapping involves the modeling of complex interaction of hydraulics of the river How with topographical and land use features of the floodplains. This can be facilitated by integrating hydraulic numerical models with Geographic Information System (GIS) technology by the transition from conventional flood hazard mapping technique based on the field investigation to a knowledge based system. This thesis presents a systematic approach for this application with a case study of Lakhandei River in Nepal.

The study's focus was on the preparation of Triangulated Irregular Network (TIN) from available cross section data. contours and spot elevations, calculation of water surface profiles

by steady and unsteady How analysis, delineation of the flood areas, risk mapping and creation of flood animation. The major tools/models used for this method are the one-dimensional numerical model HEC-RAS, ArcView GIS and HEC-GeoRAS extension for ArcView GIS to interface between the two systems for data pre-processing and postprocessing.

The application is extended to risk mapping by using the spatial analysis functionality of the GIS. The approach adopted for the study is based upon the division of the risk into vulnerability associated with land use pattern, and hazard associated with hydrological and hydraulic parameters. The results of these analyses are combined to develop such relationships as discharge-flood area and flood depth-land use. A series of maps are also prepared depicting these relationships for the visualization. This gives a new perspective the modeled data and provides an effective and efficient decision making tool which will help the administrators and planners to identify areas of risk and prioritize their mitigation/response efforts. It will also help to general publics to aware of the flood risk and for the preparedness and mitigation activities.

The study further makes the assessments of change in river course using satellite image Landsat ETM+.

Thesis Title: COMMUNITY APPROACH TO NON-STRUCTURAL MEASURES OF FLOOD MANAGEMENT (A CASE STUDY OF BRAMAPURI VDC OF RAUTAHAT DISTRICT)

Submitted by: Ram Chandra Dangal

Supervisor: Dr. Narendra Man Shakya, Dr. Raghu Nath Jha

ABSTRACT:

This study is focused on community approach to non-structural measures of flood management, which can provide the measures for floodplain occupants to reduce the damage to life and movable property in the Terai region of Nepal. The lower part of Rautahat district (Bramapuri Village Development Committee) settled upon the right bank of Bagmati River is considered as an example for application.

Inundation due to hank overtopping and bank erosion is a common problem in the Terai plain of Nepal during the rainy season (June to September). The effect of flood hazard is an ever increasing trend. Human activities within the floodplain are continuously growing due to the increased population which adds flood hazard more. No structural measures are sufficient for an overhelming flood. Moreover, to protect the whole river

system with structural measures is unfeasible economically due to huge resource-demanding, which cannot be afforded by the country under Ihe present conditions. Non-structural measures with only the most essential structural measures are the modern concept of floodplain management.

Among the major non-structural measures—conservation of upper watershed, floodplain management, flood proofing of facilities, etc,—flood forecasting and warning for temporary evacuation can be managed in a short run with a nominal cost. Similarly, flood proofing of future construction can be maintained on the basis of plinth height. No modernized forecasting system based on computer data transfer, processing ami forecasting system is found in Nepal due to the financial constraints and low institutional capability. Thus, a simple statistical community approach forecasting relation can be developed with basin rainfall vs. peak floods correlation which can be again related with inundation depth of the area. That depth is obtained by using Arc View GIS wilh ill'.C-Geo RAS extension and HEC-RAS software. In this study, time of concentration up to study area is about 2U hours. In this case two day rainfall con-elated Hood forecasting has been found best on the basis of R2 value (0.8047). This has been again correlated with inundation depth obtained from hazard map to develop the flood forecasting graph with triangular relation of weighted rainfall, discharge and inundation. This methodology can be applied for other such flood hazard areas also.

Thesis Title: **KULEKHANI DAM BREAK FLOOD ANALYSIS AND FORMULATION OF EMERGENCY ACTION PLAN**

Submitted by: **Rajendra Prasad Hada**

Supervisor: **Dr. Narendra Man Shakya, Dr. Raghu Nath Jha**

ABSTRACT:

The existing trend for fighting the extreme flood scenario in Nepal considers only the spillway or the gate operation rule. Disastrous floods are fought without any preplanned downstream procedures and loss of life and damage to property are common, The disastrous Hood event of 1993 in Kulekhani and destruction of small hydropower project at Namche in 1984 are the few examples, which were fought without any emergency action plan at the hands of local supervisory staffs since no communication link was available at the location of river.

Communication facilities unavailable during the flood creates communication gap between the executive office and field office, and there is no other option than to act accordingly without any authoritative instruction from the Central body. The Emergency Action Plan plays vital role in such situation, which could be easily executed to minimize the loss of life and properties

downstream without consulting the higher authority for the given scenario.

The study demonstrates the development of an Emergency Action Plan. Thus in order to formulate Emergency Action Plan, the study illustrates preparation of inundation map delineates the flood area and time available for response. The NWS dam break model DAMBRK is utilized to route the water stored behind the dam and obtained the arrival time for flood and maximum stages at various location in the downstream reaches between Kulekhani Dam and Bagmati Irrigation Barrage. The result from the dam break analysis is incorporated in the graphical users interface (GUI) HEC-GeoRAS in GIS and the maximum inundation area in downstream reach is obtained. Using the GIS tool such as Spatial Analyst, 3D Analyst and Xtools, the flood inundation affects 88 VDCs in six districts viz. Makawanpur, Lalitpur, Sindhuli, Kabhrepalanchowk, Rautahat and Sarlahi.

Referring to the major events occurred during the 1993 disastrous flood in the area formulation for the Emergency Action Plan consisting of emergency identification plan, notification plan and evacuation plan is suggested in the form of various formats.

The research work provides working a methodology for dam break analysis, inundation map preparation and formulation of frame work for EAP.

Thesis Title: **APPLICATION OF GIS IN THE PLANNING OF IRRIGATION PROJECT: A CASE STUDY OF WEST KOSHI IRRIGATION PROJECT**

Submitted by: **Prem Kumar**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

The demand of water is increasing day by day in different sectors such as irrigation, hydropower, drinking water and industry.

Due to increase of population, the demand of food grain is increasing. So it is necessary to allocate available resources, land and water more effectively and improve irrigation practices for optimum agricultural production. The surplus water should be transfered to water deficit area and priority should be given to fertile land. In Nepal, Terai area is limited and more fertile land is available for producing paddy, wheat and other cereal crops.

The West Koshi Irrigation Project (WKIP) area covers Saptari, Sirha and Udaypur districts. The major command area lies in Saptari and Sirha districts. The source river is Sapta Koshi where abundance of water is available. The Sapta Koshi river water has not been utilized properly in irrigation development of Saptari and Sirha districts. So this project is an attempt to utilize the

water resource of Sapta Koshi river for irrigation development and ultimately uplift the economy of the country.

In the planning of WKIP, GIS is used as tool. The GIS is used to find the command area, canal alignment, and details of structure. The model Cropwat 4.0 windows is used to calculate water requirement. To optimize the project out put, four different canal alignment alternatives are selected. The command areas of all four canal alignments are 83799 ha, 80695 ha, 71265 ha and 46088 ha respectively.

The linear programming model TORA' is used to maximize the net crop benefit -The constraints consider cultivated land, cropping practice, cropping intensity and other non-negative constraints.

The tentative cost estimate of different canal alternative and net crop benefit is calculated. The economic internal rate of return of different canal alternative are 12.92%, 7.17%, 12.69% and 11.39% respectively. The project is selected based on the optimum economic internal rate of return.

The sensitive analysis has been done for decrease in net crop benefit, increase in net crop benefit and increase in the cost of the project. The sensitive analysis shows that 10 or 20 percent change in cost and benefit has little effect in optimal solution.

Graduation Year 2004

Thesis Title: OPTIMUM ALLOCATION OF DRINKING WATER IN KATHMANDU VALLEY

Submitted by: Arjun Babu Dhakal

Supervisor: Dr. Laxmi Prasad Devkota

ABSTRACT:

The Kathmandu valley has been developed in an haphazard way due to a rapid increase in population density. Most of the available resources within the valley were utilized for drinking water but the demand is not fulfilled. His Majesty's Government of Nepal (HMG/N) has laid a great emphasis on the development of water supply project for (he Kathmandu valley. Melamchi Water Supply Project is one of the commencing ones that takes long time for completion. Therefore, currently effective management of the available water has become a need for the well distribution to the public. This study utilized a management tool optimize the drinking water supply in various demand centers of the Kathmandu valley. The considered constrains while optimizing the water allocation in the valley are minimum water demand fulfilment constraints, water availability at the source and existing water supply capacity of the system.

The analysis was done by linear programming using What's Best, of Excel having add in facility. The most appealing part of this program is it can be used in other cities to optimise the existing water supply by only changing the parameters like water availability, water demand, system capacity, price for domestic and commercial purposes.

The analysis for optimum water allocation has been done for 2004, 2011, 2021, 2031 and 1 day minimum for return periods of 20 yrs, 50 yrs and 100 yrs How as well as for driest year 1991 and wettest year 1978 without consideration of Melamchi and for the year 2011 and 2031 with consideration of Mclamchi on line. The guaranteed water supply in percentage of total demand for the corresponding demand centres were estimated and tabulated in Annex C.

Population growth rate for the Katbmandu valley is taken as 2.54%. Since the system is very old, system leakage is considered 25 % of the total supply for the analysis. Consumer of the valley categories into three types namely fully plumped. Yard type and Stand post and its distribution for urban areas is 50%, 37% and 13% and for rural areas is 10%, 15% and 75% respectively. The domestic demand for both areas are taken as 175, 116 and 45 litres per capita per day respectively for Fully plumped, Yard type and Stand post. For the case 2004 AD most of the demand centres have guaranteed water supply coefficient around 0.4. As the time increases demand goes on increasing and if the additional new sources will not add to the system then for 2031 AD the guaranteed coefficient fall below 0.025 thus all the taps become almost dry. Therefore it is required to add new sources for fulfilling the total demand. Even with Melamchi projects there is no sufficient water available to fulfill the demand. Therefore techniques like water recycling and reuse & rainwater harvesting are recommended to be considered immediately.

Thesis Title: **AN ASSESSMENT OF EROSION AND SEDIMENTATION YIELD AND FORECASTING CONSERVATION MEASURES IN MID MOUNTAIN REGION OF NEPAL: A CASE STUDY OF KALCHHI KHOLA WATERS**

Submitted by: **Uddab Raj Chaulagain**

Supervisor: **Dr. Raghu Nath Jha, Dr. Narendra Man Shakya**

ABSTRACT:

Land degradation is a crucial issue in mountainous areas due to slope steepness and fragile soil condition. Soil loss caused by sheet erosion and man movement process is common in such fragile environments. Although deforestation, overgrazing and intensive agriculture, in many case related to population pressure cause accelerated erosion, natural phenomena such as exceptional rains or earthquakes also induced erosion.

Soil erosion is indeed a persistent and serious research problem with its myriad complexities and variables, one that is terrible difficult for scientists to accurately measure. Hence to cope with erosion induced problems establish effective measures a better insight and a reliable assessment for the soil erosion, WEPP and Geo-WEPP is selected, which compute sediment yield

considering sheet erosion, rill erosion, gully erosion important and deposition. The study demonstrated the physical based WEPP and Geo-WRPP model in predicting the soil loss rate in Kalchhi Khola sub watershed (57ha) of Kulekhani and Pair Catchment studies. This tool can be used to select management like increase in plantation, change in agriculture practices and improvement of low cost structures etc.

A case study describes and assess the Kalchhi Khola in mid mountain region. WEPP and Geo-WEPP shows the erosion is highest under unmanaged agriculture land 112.00 t/h/yr and lowest to forest land 1.4 t/h/yr lands. The soil losses increase with respect to increase slope, it is noticed that soil losses for more than 7% slope in conventional agricultural land is hazardous. Hence, it is require to make terrace or increase plantation as well.

The erosion rates of Kalchhi Khola Pair catchment in WEPP in the case of 20 cm soil depth is 0.71 t/h/y which is near about observed value 0.62 t/h/yr of the pair catchment. The erosion rates in Kalchi Khola is obtained 65.5 t/h/yr which is nearly range of other studied and observation in the same type of land and topography. The results show the managerial agriculture land has less soil loss 61.6 t/ha/y than poorly managed agriculture land 112.0 t/h/yr. It is concluded that, the water erosion prediction project (WEPP) model, a physical based simulation model is better than other empirical models to predict soil erosion rate and sediment balance in small watersheds and on hill slope profile within those watersheds since it consider more physical features such as rill erosion, gully erosion, channel erosion, deposition and all climatic parameters. WEPP is a very powerful model can be used as qualitative tools to identify areas prone to erosion risk rather than quantification of actual soil loss rates and can be useful for the soil conservation planner for erosion management.

Thesis Title: **HYDRAULIC SIMULATION AND FLOOD INUNDATION NEAR NEPAL - INDIA BORDER: A CASE STUDY OF MARCHAWAR AREA IN THE FLOOD PLAIN OF DANO RIVER**

Submitted by: **Thakur Prasad Sharma**

Supervisor: **Dr. Raghu Nath Jha, Dr. Narendra Man Shakya**

ABSTRACT:

Flooding and subsequent inundation during the time of extreme flood events are becoming a serious issue for society and nation as a whole. The situation is aggravated when man-made structures are added on top of it. When the rivers flow across to another nation or share the boundary between the nations, tackling of such an issue becomes complicated, as it requires political and technical desire to solve such problems. Since the political aspect is not the focus of this study, the thesis deals only with technical aspects such as hydrology, hydraulics, and surveying.

This study is focused on the floodplain of Dano River in the Marchawar area upstream of Nepal-India border in the Rupandehi District of Nepal. The inundation issue of this area is a bi-lateral issue/agenda after the construction of embankment

parallel to the Nepal-India international border namely; "Rasiawal Khurd Lotan Bandh". This study utilizes a simulation model (HEC-RAS) and GIS to develop a methodology that can be used to assess inundation situation arisen due to extreme Hood events and, decreased floodway and floodplain of the river due to embankments/dams downstream of Nepal-India border.

In the normal state of the floodplain; the extreme event flood (100 years return period flood), the flood area coverage by depth ranging from 0.5m-2.5 m is about 66% of the total area under flood. When the road embankment acts as leeve; there is no visible increase in the inundation depth apart from about 7% increase in area (maximum) in the depth class of 1.0-1.5m for 100 years return period Hood. The impact is visible with the addition of inline structure (road embankment parallel to the international boundary) as increase in area coverage in depth class of 0.5-1.5m to about 50% for the flood of 50 years and 100 years.

The results of the study with a one dimensional steady stale application shows that the obstruction of the natural flows of the flood water does have qualitative impact on the increase in the depth of inundation spread over the upstream of the constructed embankment (left bank of Dano River) in the Nepal side. The situation may worsen if the embankment is extended to the right bank of the Dano River, narrowing the channel to less than 300 m. When the river channel width is restricted to 200m the increase in area coverage is more than 70% in the depth range of 0.5-2.0m for flood of 50 and 100 years return period.

Thesis Title: **SOIL EROSION ASSESSMENT: A CASE STUDY OF KULEKHANI**

Submitted by: **Ram Chandra Kaphle**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

Nepal is a mountainous country. About 80% of the land area is mountainous. Soil erosion is crucial problem in Nepal due to steep slope, over animal grazing and deforestation, cutting of rivers resulting in erosion and mass wasting. Other natural phenomena such as heavy rain, earthquake etc also induces erosion. Assessment of soil erosion is a capital intensive and time-consuming process, because of its extremely large no of complexities and constraints. It is important to understand the erosion process under normal conditions and to assess the magnitude of the problem, so effective measures can be implemented, Physical based models though complex, may simplify the erosion process that are easy to interpret physically require minimal resources can be worked out with readily available input values to indicate the areas exposed to high erosion risk. For water and soil conservation planning the capacity of the models to locate the erosion pattern correctly may be more useful than the ability to accurately quantify erosion losses.

The main aim of this study was testing the physically based AnnAGNPS model, in predicting the soil loss rate and spatial erosion pattern in small watershed at Simlang and in Kulekhani watershed. The available data set comprised the climate data, Topographical maps, land use maps and land system maps. The model has good interface with ARC-View GIS. The predicted results and the erosion pattern were compared with measured data and with erosion rates in the relevant literatures. The result from the model showed that average annual soil erosion of 9,8 t/ha/yr, and 1,61 t/ha/yr, in forest, 16.78 t/ha/yr, in agricultural land, which is close to accurate result to the typical Nepalese middle hills.

It is concluded that the physical based models are more accurate than the empirical models to predict annual soil erosion rate at the sub watershed and watershed scale, where it is possible to get more details data and spatial variation of the parameters. In larger watershed the model can be used as qualitative tools to identify areas prone to erosion risk rather than quantification of actual soil loss rates, AnnAGNPS is very good model for large watershed if complete set of database is created.

Thesis Title: **SIMULATING FULLY- COUPLED RUNOFF AND SEDIMENT CONCENTRATION EQUATION USING KINEROS2 AND OPTIMIZATION OF MODEL PARAMETERS FOR USE IN AGWA**

Submitted by: **Bidur Ghimire**

Supervisor: **Dr. Raghu Nath Jha, Dr. Narendra Man Shakya**

ABSTRACT:

Land degradation due to soil erosion by water is a widely recognized problem. It is a serious environmental problem affecting areas of different landscapes and land uses. For conservation planning assessment of soil credibility and erosion rates is essential. These problems have to be addressed with distributed models that can compute runoff and erosion at different spatial and temporal scales. The extensive data requirements and the difficult task of building input parameter files, however, have long been an obstacle to the timely and cost-effective use of such complex models by resource managers.

It has been observed that more than 90 % of the total annual erosion occurred in less than 15 annual events, suggesting that the timing of these needs to be examined more closely before any positive preventive actions to mitigate erosion can be suggested.

Also the events, which occur in the pre-monsoon period, have high sediment yielding than that occurring in other periods.

The main aim of the study was applying the physically based event oriented model KINHROS2 in predicting the runoff and soil erosion in the watershed and to see the scale effect and reliability in the prediction.

In the first the mode! parameters have been calibrated and the validated for the events occurring in five erosion plots (100 m^2). Then in the second part the KJNBROS2 model have been applied to the whole Jhikhu Khola watershed (111.4 km^2) as well as to Kubinde basin (163 ha): one of the subwatersheds of Jhikhu watershed with the help of AGWA tool; a GIS interface to visualize the KINEROS2 results.

The results of the analysis showed different results for different scale. For the small plot scale the results showed that there is a dynamic state of sediment credibility to be considered for better prediction.

It is concluded that the model can be a better tool for the decision makers in prioritizing the management and conservation works. The physical based models are better than the empirical models to predict soil erosion rate at the sub-watershed scale or for small catchments, where it is possible to get more detail data and spatial variability of the parameters .In larger watershed, the model can be used as a qualitative tool to identify areas prone to adverse erosion rate due to the change in land use pattern.

The changes of watershed response due to land cover changes between 1947 and 1981 have been clearly identified by the increase in sediment yield with the reduction of forest land.

Thesis Title: **IMPACT STUDY OF URBANIZATION ON WATERSHED AND OPTIMIZATION OF CATCHMENT PARAMETERS**

Submitted by: **Ram Raj Sharma**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

Many activities in water resources engineering evolves the accurate prediction ofrunoff rates and volume. Runoff generation is a direct result of soil moisture condition in a catchments area and a distribution of the soil moistures is govern by process at the hill slope scale. Hill slope hydrology involve many mechanism for runoff generation including infiltration, overland flow, saturation excess overland flow etc.

This study is mainly focus an urbanizing basin i.e. Kathmandu valley, this watershed is very large in scale, the area of catchments are is 585.04 km^2 so it is divided into seven sub basin and each sub basin. From the few last years the impervious area of this watershed is being increasing due to increase in pavement surface and rapid rate of growth of buildings and others structure, which ultimately affects the rate of discharge at the outlet of the valley.

The main objective this study is to determine the system behavior and determine the optimize catchments parameter and peak discharge, for this work two model are used one is TOPURBAN and other is TR-55. Two other supporting software are also used i.e. GIS ARC VIEV and GRIDTAB to determine the main model parameters. TOPURBAN model has two options one is optimization of catchments parameter and other is sensitivity analysis where as TR-55 gives the Curve no., travel time and peak discharge. Optimization is carried out by considering the rainfall and runoff data of 1996 to 2001 and this calibrated parameters are used for separate years data i.e. for 1996 to 2001 individually and observed and simulated discharge is compared, since the model has self optimize the parameter so value of objective function is very small. Sensitivity analysis is done for three different cases i) for fraction of urban are is 0.00% ii) fro fraction of urban area 30% and iii) for fraction of urban area 50%. This sensitivity analysis shows how much rate of discharge will increase or decrease with respect to the urban area and how much it is sensitive. Tr-55 programme determine the time of concentrations travel time and curve no for each sub catchments and peak discharge of the total watershed area.

Five parameters are optimized by TOPURBAN model i) Recession parameter (m): m ii) Catchments average saturated hydraulic conductivity (m/h): K iii) Maximum size of the root zone for the catchments (m): (Sr_{max}iv) Urban area calibration parameter: Uacp v) Urban flow recession parameter (h): zk. And peak discharge is determined by both model between these two model result of TOPURBAN is closer than the TR-55 model for each year.

Thesis Title: **MODELING OF CANAL OPERATION PLAN: A CASE STUDY OF SUNSARI - MORANG IRRIGATION PROJECT**

Submitted by: **Bhila Nand Yadav**

Supervisor: **Dr. Indra Lal Kalu**

ABSTRACT:

Nepal being a predominantly agricultural country, large population as well as greater part of national economy depends on farming. Lacking growth of food production in comparison to that of population in the country has necessitated to increase the food production in the country- Among the other components required to increase the production of food grain, irrigation is a vital constituent. Timely and adequate amount of irrigation is essential for optimal crop production.

Rotation system of water delivery is common practice in the irrigation systems suffering from insufficient supply. Generally farmers are not satisfied with the scheduling of operation in most of the irrigation systems. They assert either shortage of irrigation water or not receiving irrigation water in proper time.

The present study intended assessment of the existing system of operation and to suggest the better scheduling of operation in the

Sunsary - Morang irrigation project. The study is limited to the sub-secondary canals (8 Nos.) offtaking from S14 (secondary canal) of SMIP.

Since the capricious nature of hydrological and climatic statistics as well as patchy command area, it is so tedious & time consuming for scheduling of irrigation manually. Therefore a computer program in FORTRAN has been developed with the available informations about rainfall, climate and crops in the command area.

This study has shown that the present operation system of S14 canal network is not satisfactory. Shortage of irrigation water has been observed during Jan - Feb and Aug -Sep. Similarly over irrigation has been found to be supplied during Apr - May and Nov - Dec. Delivery schedule of S14 does not match with the demand pattern of the command area. The present operation of sub-secondary canals on the principle of "ON/OFF" mode in 1:2 operational groups is found to be unsatisfactory due to insufficient water in the canals during winter and low flow periods. It is customary to operate the canals at about 50% of their design capacity during low flow periods if 1:2 mode of operation is practiced, which is mis-matched with the principle of operation presumed at the design stage.

Thesis Title: **NUMERICAL SIMULATION MODELATOR FOR HYDRAULIC AND WATER QUALITY DISTRIBUTION IN WATER BODIES: A CASE STUDY OF THE PHEWA LAKE, POKHARA, NEPAL**

Submitted by: **Roshan Khadka**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

All surface water is subject to external contaminants. Some of these come from the water body's own substrate. Animals and plants that live in the lake also make contributions, Decomposing biomass and animal waste is an important source of coliforms. Contaminants also reach surface water from adjacent land in the form of runoff. When a heavy rain falls, water that does not infiltrate into the soil immediately puddles, and Hows into the water body, carrying soil and other materials with it. This will increase the nutrient load in water bodies and may initiate eutrophication. biological growth and consequent decrease oxygen in the lake. Excessive nutrient discharge from wastewater and runoff from agricultural field containing nitrogen and phosphorous represent major causal agents of accelerated eutrophication.

To conserve the water bodies from deterioration of water quality, it is necessary to formulate a water quality management plan for the water body and its basis. In order to attain this objective, a means to assess the impact of the water quality improvement measures is required. The most commonly used assessment means is the Numerical Simulation Model.

This Thesis presents a development of Numerical Simulation Model that will be used to reproduce the hydrological characteristics of lake and lake water quality if river runoff load is adopted. This model is useful for water quality management plan including sewage treatment plan for checking water quality deterioration of the lake by restricting inflow of polluted water from both point and non point source. A case study of Phewa Lake in Pokhara is undertaken using this numerical model- The output of the model is the distribution of current pattern and distribution of chlorophyll-a. Total Nitrogen (T-N) Total phosphorous (T-P) and Chemical Oxygen Demand (COD) in the lake.

The spatial distribution of TN predicted by the mode! is above 0.5mg/l near the boundary and greater than 0.3mg/l for most of the area. The concentration of TP is above 0.2 mg/1 near boundary and greater than 0 08 mg/I for most of the area. The result of the study also show a high concentration of chlorophyll-a at the deepest part of the reservoir zone. The concentration at this zone is greater than 20 μg/1. This indicate serious potential condition of future outbreak of algal bloom or high growth of aquatic filamentous plant in the lake.

Thus the spatial distribution of pollutants predicted by the model clearly indicate that the water quality is beyond the permissible standard in most part of the lake. The simulation run was carried out with various combination of inflowing load into the lake to determine the sensitive inflow point to bring the water quality of Phewa lake to permissible limit. The simulation result after 100% reduction in inflowing load by means of diversion sewerage system brings water quality of most part of the lake to a permissible limit. For the presentation of results an Are view GIS is used. For this. Triangulated irregular Network (TIN) is prepared, taking concentration of T-N, T-P, chlorophyll-a and COD as basis parameters. AutoCad Land Development is used to present the current pattern at its corresponding grid (Mesh).

Thesis Title: **APPLICATION OF GIS IN RISK-BASED FLOOD DAMAGE ASSESSMENT AND DESIGN OF LEVEE: A CASE STUDY OF KAMALA RIVER**

Submitted by: **Bishwanand Mishra**

Supervisor: **Dr. Narendra Man Shakya, Dr. Raghu Nath Jha**

ABSTRACT:

Nepal is prone to various types of natural and manmade disasters such as floods, landslides, fires, earthquakes, epidemics, windstorms, hailstorms, lightning, avalanches, and others among losses due to floods and landslides cover one third of total losses. These statistics are rough estimates only. Until now traditional calculation methods for flood alleviation projects are practiced in Nepal. These methods may not be cost effective with least risk. A methodology which incorporates cost effectiveness and risk associated with it is felt necessary from long time. In the country like Nepal having limited resources this necessity is much more.

In traditional design practice minimum width of river (Lacy*s width), scour depth and high flood level are found based on flood discharge of a pre-selected return period. Damages from historical data are calculated. Though damage is function of depth and magnitude of flood it is not incorporated. With this damage and construction cost, benefit -cost ratio is calculated

and project is justified. But this method may not represent actual damage condition and hence benefit-cost ratio found in this way may be questionable. No methodology for calculation of inundation area has been adopted.

In this study it is attempted to recommend a methodology which covers shortcomings of traditional practice. Kamala Rive Basin has been taken as study area. GIS with its extensions is an useful tool for flood damage assessment which gives accurate results in limited time and resources. Digital Elevation Model is generated from topographical map and surveyed data of river cross sections- Flood inundation maps for various return periods are prepared with Hec-GeoRAS and Hec-RAS. This identifies flood prone areas. Inundated areas and inundated depths can be easily drawn from these results. After defining depth-damage curve for residential building, decrease in land value due to siltation and damages of crops (paddy), damages under different flood levels were calculated. With known water surface profiles (generated from Hec-RAS) levee can be easily designed for various return period and hence construction cost estimation. With suitable discount rate and project life period construction costs were annualized. Various scenarios with different discount rate can be achieved by sensitivity analysis.

Risk Based Analysis is a procedure, which evaluates different alternatives by considering trade-off between the investment cost and the expected economic losses due to failures. In
the risk-based design, the design return period is a decision variable instead of being a pre-selected design parameter value as with the return period design procedure. The development and use of Risk-based Analysis in flood damage reduction project formulation studies permits informed decisions because detailed information on project economics and project performance is now available to decision maker. This method enables decision maker to explicitly and analytically integrate risk and data uncertainty directly into the analysis. Risk-Based Analysis is thus formulated to provide safe, efficient and effective protection to lives and properties in flood prone areas.

The most common economic framework for flood plain management is minimization of expected annual damages and flood management expenses. This form of probabilistic benefit-cost analysis has largely replaced older forms of economic analysis performed by examining only a particular design flood.

In Kamala River within the reach considered 14038 ha. to 24280 ha. of land whereas 21189 to 35920 households are under inundation by 2 yr to 500 yr return period floods. Total Damages varies from 115 million rupees to 783 million rupees whereas cost of protection varies from 135 million rupees to 358 million rupees for 2 yr to 500 yr return period floods. From analysis it is seen that benefit cost ratio and incremental benefit cost ratio is higher for 500 return periods but from risk based analysis it is clear that protection work for 100 year return period is cost effective with least risk.

This methodology can be applied for deciding optimal size of flood alleviation project i.e. a tool for decision making. Since in our context, we decide the project size without comparing various scenarios, selected project size may not be optima!, cost effective with least risk. Calculation of flood damage i.e. benefits are not reliable in our traditional design methods. This methodology can also be used for checking safety level (i.e. probable damage and risk associated) with existing levee or other flood alleviation structure. This methodology is recommended to represent hazard level, flood damage assessment and design of protection work. This method is very much suitable for selection of protection methods among channel modification, flood control reservoirs, diversion structures and levee or combination of Hood allevialion methods.

Thesis Title: **NUMERICAL MODELING OF DEBRIS FLOWS AND ITS STRICTURAL COUNTER MEASURE BY SABO DAM**

Submitted by: **Badri Bhakta Shrestha**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

Debris flows are common in mountainous areas throughout the world. Often triggered as mudflows by torrential rains, debris flows contain varying amounts of mud, sand, gravel, boulders, and water. In addition to causing significant morphological changes along riverbeds and mountain slopes, these flows are frequently reported to have brought about extensive property damage and loss of life- Debris flows constitute a significant natural hazard that can cause fatalities, damage structures, and diminish land productivity.

In this research study debris flow is modeled in 1D with taken into account both coarse and fine sediment fraction and it is also modeled with taken into account coarse sediment fraction only. Density of interstitial fluid plays the vital role in debris flows modeling and variable density fluid is also considered in debris flows modeling. Debris flow is modeled using the dynamics of a liquid-solid mixture. A first order upwind scheme is applied to

solve the resulting set of differential equations in one dimension. The numerical method is first order in both space and time. Density change in space and time in momentum equation is also modeled in this study. Different researchers have proposed different shear stress equation, some based on experiments and some with a semi-theoretical background- Takahashi's three category flow theory is used in this study for the preparation of ID debris flow mode! in FORTRAN. The friction term of governing equation is modeled according to as Takahashi's debris flow regimes condition and also as Chezy type non dimensional constant equations.

Sabo dam is commonly used for preventing the sediment disaster due to debris flow by storing the harmful sediment discharge. Even after the debris flow storage capacity of the dam has been filled up, the dam has a debris flow control function by reducing peak debris flow discharge due to the temporal storage during debris flows. The effects of counter measure by closed type Sabo dam against debris flow disaster is also investigated by using one dimension model. The simulated results show the good agreement with the experimental flume data.

Thesis Title: **SEDIMENT SEPARATION USING HYDRO CYCLONE**

Submitted by: **Bicky Shakya**

Supervisor: **Mr. Hari Prasad Pandit**

ABSTRACT:

Tins thesis paper presents the hydrocyclone operation with focus in sediment separation. The hydrocyclone use a tangential injection flow process, enhancing the centrifugal forces and moving solid particles outwards. The hydrocyclone is easy to install, operate and require very limited space. It represents an unsophisticated piece of equipment, which runs in a continuous manner and it can be operated at lower costs than of the solid-liquid separation technique.

Installation of 220 mm diameter fiberglass hydrocyclone with necessary setup was done to develop and understand its working principle, to study its efficiency and to know different relations. Very good efficiencies were observed for all the runs performed with different sediment concentrations of different particle size distributions, different heads, different inlet and outlet discharges. Sieve analyses were performed to observe different separation efficiency for different size and separation parameters. Separation parameters also found affected by feed concentration.

Due to the action of the centrifugal forces in hydrocyclones, coarse particles behave differently from the fines. They are concentrated at wall and are transported to the underflow outlet. Progressively increased storage of these panicles can be observed in the cone as a consequence of increases feed solids flux results in partial upward transport of these particles under the influence of the overflow stream.

Hydrocyclone technology has been suggested as a practical alternative and additional technique for sediment separation especially in small and micro hydropower, irrigation and water supply. Places like hilly regions in Nepal, were proper location for settling basins are very hard to find, hydrocyclone can be the solution.

Graduation Year 2005

Thesis Title: **OPTIMUM ALLOCATION OF DRINKING WATER IN BUTWAL MUNICIPALITY**

Submitted by: **Bharat Mani Pandey**

Supervisor: **Mr. Laxmi Prasad Devkota**

ABSTRACT:

The Butwal Municipality has been developed in a haphazard way due to a rapid increase in population. Most of the available resources within the Municipality were utilized for drinking water but the demand is not fulfilled. His Majesty's Government of Nepal (HMG/N) has laid a great emphasis on the development of water supply project for the Butwal Municipality. Sisne Khola Water Supply Project is one of the commencing ones that takes long lime for completion. Therefore, currently effective management of the available water has become a need for the well being of the public. This study utilized a management tool to optimize the drinking water supply in various demand centers of the Butwal Municipality. The considered constraints while optimizing the water allocation in the Municipality are minimum water demand fulfilment constraints, water availability at the source and existing water supply capacity of the system.

The analysis was done by linear programming using What's Best, an add in facility of Excel. The most appealing part of this program is it can be used in other cities to optimise the existing water supply by only changing the parameters like water availability, water demand, system capacity, price for domestic and commercial purposes.

The analysis for optimum water allocation has been done for 2004, 2011, 2021, 2031 and I day minimum flow for return periods of 10 yrs, 25 yrs, 50 yrs and 100 yrs as well as for driest year and wettest year with out consideration of Sisne Khola and for the year 2011, 2021 and 2031 with consideration of Sisne Khola on line. The demand fulfilment coefficient for the corresponding demand centres were estimated and tabulated in Annex.

Population growth rate for the Butwal Municipality is taken as 4.64%. Since the system is also old, system leakage is considered 45 % of the total supply for the analysis. Consumer of the municipality categories into three types namely fully plumped. Yard type and Stand post and its distribution is 50%, 20% and 30%. The domestic demand are taken as 175, 116 and 45 litres per capita per day respectively for Fully plumped. Yard type and Stand post- For the case 2004 AD most of the demand centres have demand fulfilment coefficient above 0.8, but few demand centres have demand fulfilment coefficient less than 0.5. As the time increases demand goes on increasing and if the additional new sources will not be added to the system, the demand fulfilment coefficient will fall below required condition. For 2021 AD, the demand fulfilment coefficient fall below 0.14 incase of demand center 6, in case of demand center 7, the coefficient fall below 0.24. Similarly for DCs 1 to 5, the demand fulfilment coefficient lies between 0.37 to 0.60. For 2031 AD, the demand fulfilment coefficient fall below 0.39 in DCs 1 to 5, similarly for DCs 6 and 7, the demand fulfilment coefficient fall below 0.089 and 0.15, thus all the taps become almost dry. Therefore it is required to add new sources for fulfilling the total demand. Even with Sisne khola water supply projects, there is no sufficient water available to fulfill the demand for future condition. Therefore techniques like reuse, rainwater harvesting program and increasement of pumping capacity in case of Tinau river are recommended for immediate solution.

Thesis Title: **RISK ASSESSMENT OF HYDROPOWER PROJECTS: CASE STUDIES ON HYDROLOGICAL RISK**

Submitted by: **Basant Bagale**

Supervisor: **Dr. Narendra Man Shakya, Mr. Narayan Pokharel**

ABSTRACT:

Reliable estimation of hydrological parameters dealing with energy generation and design discharge is one of the key issues to determine a hydropower project's financial viability. During Feasibility due to lack of long-term average hydrological data basis of estimating available monthly flows for power generation depends on a number of parameters and assumptions. Therefore it is worthwhile comparing deviation from the original estimate during the feasibility stage to operational data in case of gauged river and recommends method in case of ungauged rivers.

So far such studies not conducted for Nepalese rivers, this study will try to identify possible extent of errors, which may happen in various projects so that it will be easy to minimize such risk in future hydropower projects.

From this study, methodology of hydrological risk assessment, quantification of hydrological risk related to hydro logical

parameter such as monthly average river discharge, qualitative risk assessment by risk assessment matrix and the financing risks on hydropower projects due to possible hydrological uncertainties will be obtained. This will very much useful to provide clear picture of probable values for the developers in the similar basins in Nepal.

This thesis particularly focuses on hydrological risks associated with energy generation and design discharge only.

Thesis Title: **IMPACT STUDY OF IMPERVIOUSNESS I PEAK DISCHARGE DUE TO LAND USE CHARGE IN URBANIZING BASIN: A CASE STUDY OF KATHMANDU VALLEY**

Submitted by: **Suresh Sharma**

Supervisor: **Dr. Narendra Man Shakya, Dr. Raghu Nath Jha**

ABSTRACT:

Kalhmandu Valley is an emerging urbanizing basin with the constant and rapid urbanization Land use in Kathmandu valley has been drastically changed for the last few years. Every year, the agricultural land has been converted into the developed built up area. This change in land use practice and development of the area brings significant changes in hydrology- Hydrology is a science of water which deals with the occurrence, circulation and distribution of water of the earth's atmosphere. So as the earth surface and its characteristics changes it is obvious to have some effect on hydrology. Out of the total precipitation, certain amount of water is sent back to the atmosphere through the evapotranspiration process. The precipitation reaching the ground surface after meeting the needs of infiltration and evaporation appears on the surface as a surface runoff. Therefore

the infiltration and surface runoff is highly affected due to the land use type and soil characteristics.

In undeveloped virgin land surface run-off are affected by natural surface detention- soil characteristics and infiltration characteristics. As the surface area is developed due to the construction of building, roads, parking lots, and other structures, the impervious area of the watershed will be considerably increased which brings dramatic changes in hydrology.

The rapid growth of haphazard urbanization and industrialization with the least attention given to the proper planning of the city are some of the contributors to bring the hydrological changes in urban areas like Kathmandu valley. Large number of passers by and vehicle are exposed to the immediate and flash flood even due to the few hours of storms. Hence it is the proper time Kathmandu Valley realized the necessity of suitable modeling to incorporate the increased imperviousness due to land use change. Numerical models are found to be very effective and very beneficial for predicting the runoff due to land use change. A number of rainfall runoff models came in use in order to incorporate the land use effect. Several physically based and empirical models came in use and found to be useful depending upon the watershed characteristics and availability of the data. The performance and efficiency of the model cann't be estimated and overlooked with their performance in a particular catchment

A model which suits in a particular watershed may or may not be better in a similar other catchments. Even the modeling in some cases such as in case of TR55 was also found to be carried out without linking the time of concentration with the changed CN due to land use change which is the essence of every modeling. So attempt has been made in this study to link the land use change in terms of imperviousness with the time of concentration and basin lag using the physically based as well as empirical model so as to predict the peak flood in the similar metereologicai conditions. A physically based Green and ampt model and TR 55 model are used using HEC-HMS software which is linked with the Geographic Information Systems (GIS) having an extension Hec-GeoHMS 1.1 to carry out the impact study in runoff.

The comparative study is carried out with two G& A model and SCS curve number method in TR55. The general concept of generation of excessive surface runoiff and flow in extreme cases of landuse change for diffeent subhasins in different rainfall event is presented in this study which can be taken as guideline for drainage development in future. Due to the continuous land use change, every year the discharge is found to be increased by almost 0.7 % in Khokana. Analysis shows that the G&A model is comparatively better in comparison to other two methods. Analysis also reflects the lack of necessary data to carry out the urbanization study. Available land use change information shows that the imperviousness is increasing by almost 0.4% every year with a constant rate.

Thesis Title: OPTIMAL DEVELOPMENT PLAN OF MULTIPURPOSE RESERVOIR: A CASE STUDY OF KOSHI HIGH DAM

Submitted by: Pavan Kumar Yadav

Supervisor: Dr. Divas Bahadur Basnyat

ABSTRACT:

The main objective of this study is to develop a suitable model for deriving an optimal operation policy for a multipurpose water reservoir system. The uncertainty in hydrological inflow is considered and Transition Probability Matrix represents serial correlation between successive inflows. The Stochastic Dynamic Programming (SDP) algorithm has been used in this study.

The developed model is applied to the case of Koshi High Dam Project (KHDP), The SDP model is used to derive the optimal operating policy for the given objective function and constraints. Simulation runs are then made with the derived operating policy using historical data from 1947 to 2001.

Various scenarios e.g. maximizing total annual energy generation, maximizing the minimum monthly energy generation, maximizing the irrigation benefit and maximizing flood control benefit have been developed for the KHDP and llic

simulated results show that the future water demands can be fulfilled comfortably at all the times under all conditions with or without Sun Koshi- Kamala inter basin transfer of 72 m^3/s.

Simulation result shows that the total annual energy is comparatively high with objective function maximizing the total annual energy but the minimum energy is very low.

Further it is observed that the target set for irrigation as well as total power generation may be fulfilled by reducing the dam height upto 10%.

It can be concluded that this model may be of important use for making optimal decision regarding reservoir operation of KHDP, optimizing the dam height and other project parameters (power capacity, energy generation, irrigation uses etc.) and also in assessing the implication of Sun Koshi -Kamala Diversion Scheme.

Thesis Title: **USE OF AUTOMATED TOOLS CORRELATE RAINFALL AND RUNOFF AND IDENTIFICATION OF RELIEF ROUTES BASED ON FLOOD HAZARDS MAPPING: A CASE STUDY OF RATU RIVER BASIN IN NEPAL**

Submitted by: **Ram Krishna Regmi**

Supervisor: **Dr. Narendra Man Shakya**

ABSTRACT:

The Ratu River originates in the Siwaliks region and is highly prone to flooding. Annually thousands of hectares of fertile land are washed away and many lose their lives. The Jaleshwar municipality and its surrounding areas are being seriously affected though there are some emergency defenses in the municipal region. This study presents a, systematic approach for correlating rainfall and runoff of the Ratu River basin of Nepal and identification of flood relief shelters and routes towards it for the specific area of the Jaleshwar Municipality and its surroundings based on Hood hazard mapping.

This study is focused on the identification of the flood relief shelter and evacuation routes towards it based on the hazard map. The hazard map is developed on the basis of enhanced topographic information of the study area. The study also

presents the regression equations to predict the runoff of a particular rainfall for the months vulnerable to flood hazards.

A detail topographic survey is carried out focusing within the area of BaJarahi, Ratwada. Ramaul, Campus area and Northen part of the Jaleshwar Bazaar (including Mahadev temple and Jaleshwar pond) of the Jaleshwar Municipality; and Bela to enhance the topographic information with the development of contour map having interval of 10cm. Hazard maps of different flood events, resulting from the corresponding rainfall ri\ents. of the study area is prepared with the help of the software Arc View GIS with HEC-GeoRAS and HEC-RAS on the basis of this topographic information. The flood relief shelters and routes for the study area during extreme floods are identified on the basis of these flood hazard maps. Rainfall runoff correlation for the basin is developed by using TANK model. The calibrated mode] parameters of the Bagmati basin are used to run the TANK model for this basin. Flood relief shelter and routes towards it is identified from the developed hazard maps. The identified routes are only levees and road networks. During flood most part of these routes will be covered by flowing water with depth exceeding 15 cm (threshold value as per FEMA recommendation).

As the result obtained from the study, the flood event of $160m^3/s$ is the threshold value and the rainfall of different months to response this flood event are the threshold rainfall value for the respective months. The locality of Bela is found to be a vulnerable to flood hazard. It is highly required to identify escape routes and establishment of new shelters so that the community of the study area could escape from the sudden flood havoc.

Thesis Title: **IMPACT OF LAND CHANGES ON RUNOFF USING REMOTE SENSING AND GIS: A CASE STUDY OF BAGMATI BASIN (U/S OF KHOKANA)**

Submitted by: **Binaya Kumar Mishra**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

This thesis deals with the impact of land use changes on surface runoff in a hydrological basin. Bagmati River Basin above Khokana hydrological station, which covers most of the portion of Kathmandu Valley, Nepal, was chosen as a basin under study. Runoff is one of the most important hydrologic variables used in planning, design and operation of water resources projects. The conventional hydrological data arc inadequate for purpose of design and operation of water resources systems. In such cases, remote sensing data can serve as model input for the determination of river catchment's characterstic, such as land cover, geomorphology, slope, drainage etc. In this thesis, a physically based distributed continious model SWAT2000 has been used to assess the runoff changes due to change in land-use. In year 2001, the forest area is found decreased to 21.93 %, urban area is increased to 8.09 % and agricultural land is increased to 69 % as compared to year 1992 which had forest area of 29.67%, urban area of 4.28% and agricultural area of

65.37% of the whole catchments. The change in land-use has been evaluated in terms of curve number (CN) and surface runoff for different conditions. The changes in the CN values and the changes in the runoff values were then assessed by the difference in runoff values produced by the same rainfall on different land-use. Comparing between 1992 and 2001, the average CN is found to be increased by 2.54%. The annual surface flow is found to be increased by 9.04% whereas an average increase of 8.9% is found in monthly flow based on land use 1992 and 2001. An average increasing deviation of i 6.5% and 12.5% is found from the estimated runoff to the observed runoff annually and monthly respectively. This increase may have taken place due to ground water extraction and water brought from other basin to meet the water requirements for domestic and industrial uses for rapidly growing Kathmandu, Lalitpur and Bhaktapur city.

Thesis Title: **EXPERIMENTAL ANALYSIS OF STRENGTH OF LOCAL GRASS AND SHRUB ROOTS USED FOR SLOPE STABILIZATION**

Submitted by: **Shree Ram Neupane**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

This study was undertaken to evaluate the increment pattern of root strength, root numbers and soil cross-sectional area covered by roots at different maturity periods- For chosen grass and shrub species (especially Amiiso, Assure and Nilkanda for this particular study) laboratory tests are conducted and the results are interpreted in terms of the following findings:

- Increase in tensile strength, rooted soil cross-sectional area, depth of roots and number of roots with maturity period,
- Increase in shear strength due to root reinforcement.
- Comparison of average diameter and average tensile strength values.
- Determination of relationship between shear and tensile strengths and root diameter.

A laboratory experiment has been conducted to find out the value of empirical coefficients a and α in the equation $T_r = \alpha D\beta$

which is used to analyze the relationship between root diameter and tensile strength of some local grass Amiiso and shrubs Assure and Nilkanda used for slope stabilization. In this thesis, the experimental data obtained from laboratory test are used to analyze tensile strength of grass and shrub roots and shear strength of soil due to root reinforcement. The primary objective is to evaluate factors, which greatly influence the shear strength of soil, and ultimately affects the behavior of shallow surface landslide-Roots are composed differently and different plant species have different structures. So it is difficult to find accurate experimental study on the mechanical performance of root tensile strength and increase in shear strength of soil due to root reinforcement.

Amiiso has higher mechanical performance followed by Nilkanda and Assure. So the. different plant varieties decide the discrepancy of its mechanic performance. Till now, experimental analysis on tensile strength of distinct grass and shrub roots like Amliso, Assure and Nilkanda have not been conducted in Nepal and very less in worldwide. The results of this experiment proved that the tensile strength of root increases with the reduction in diameter. Also, it is found that a relationship does exist between shear and tensile strength.

Graduation Year 2006

Thesis Title: **RELEVANCE OF INTEGRATED WATER RESOURCES MANAGEMENT (IWRM) IN WATER RESOURCE CONFLICT RESOLUTION AT LOCAL LEVEL: A CASE STUDY IN SURKHET**

Submitted by: **Fanindra Baral**

Supervisor: **Dr. Divas Bahadur Basnet**

ABSTRACT:

In recent years, the demand for water for both agricultural and non-agricultural sector is increasing. As the available supply of water is the same, the demands for water is leading to water use conflict between regions e.g. Districts. Villages and among various uses Environmental degradation has further increased pressure on water resource both at local and national level. These issues necessitated the need for an integrated approach in the management of water resources at all levels. At present IWRM is an emerging tool/instrument and HMG/N too has recently adopted this in the Water Resources Strategy (2002) and the National Water Plan (2005). This study proposes negotiation as a tool of lWRM. Various ingredients of conflict have been assessed for better management of multiple water uses and water resources conflict resolution at local level. The main principles

adopted are enhancing equity, conserving natural environment and using the available water resources efficiently and economically.

The main objective of the study is to explore the relevance of IWRM principles in local water resource conflict resolution. A case study of Gumkhola, a tributary of Bheri River is selected in this study, The main uses of the water from the river are: irrigation, water supply (including the adjacent village), ghatta (water mills) and Community Forest. The study has made an assessment of the available water resources and demand for various uses. The assessment shows that the available water resource has not been used efficiently. Similarly, all users are not receiving the water in an equitable manner especially in the dry four months of the year. As the water demands are barely met at the present situation, each group of users are claiming ownership of the available water.

An opinion survey was undertaken to gauge the perspectives and the views of the different users on the main issues, for water management, principles of IWRM and various ingredients of negotiation to resolve such conflict. Lack of awareness about integrated management of water resources and the coordination among various users are the other reason of conflict over its use at local level.

Assessment of the available water resource and the demand for various purposes of the area shows that there is scarcity of water in the Feb, Mar, Apr and May of every year. So the demands for various purposes are not met during these months. There is a possibility of changing the cropping pattern to insure the demand for other purposes like ghatta operation and in stream flow requirements even in the dry season. The assessment also shows that the available water resource has not been used efficiently. So, if the efficiency of the irrigation system is improved by canal improvement and other measures available flow can be increased. There is a need for the water management institution and local bodies present in the area to coordinate with each other and be active and perform their duties as fixed by the present legislation regarding the management of the available water resource.

This study has assessed the various ingredients of negotiation that can be the basis for water resources conflict resolution. The water assessment and the opinion survey carried out during this study present the options that can be agreed by the major stakeholders. The actual resolution of the water resources conflict in the Gumkhola was not implemented due to the prevalent security condition in the area and is beyond the scope of the present study. However, it is proposed that the findings and recommendations of the study can be used in Gumkhola water management as well as replicated in other similar cases.

Thesis Title: **SUSTAINABLE GROUND WATER MANAGEMENT OF KATHMANDU VALLEY**

Submitted by: **Yogendra Mishra**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

Due to mounting population of Kathmandu valley, change in the life style, and declination in the surface water resources, the rate of extracting ground water is ever increasing. Several depressing impacts have been identified while extracting the ground water beyond its safe-yields. As the extraction rate is skyrocketing, ground water table is waning rapidly day-by-day and land subsidence occurs. By identifying its significance, this topic has been selected for research.

Here water table depletion per year is calculated by using Finite Element Subsurface Flow & Transport Simulation System (FEFLOW). Using present extraction-recharge rate, prevailing boundary condition, land use pattern and lithological data of Katmandu valley, the drawdown for 2002-2012 AD is determined. The result for 2012 AD showed a maximum drawdown at Patan Industrial Districts (35.67 m) and minimum drawdown at Sundarijal (10.56 m). The predicted drawdown alarms the risk of severe land subsidence and increase the cost of ground water extraction.

After identifying the problem, and examining it, its best solution is to drop off the ground water withdrawal rate. But this may not be practical in Katmandu valley and the next alternative is to boost up the recharge rate. The sensitivity analysis of the model has given some solution to this problem. One of the methods is to increase recharge rate. By increasing the recharge rate in urban area from 3% (present condition) to *50%* of total rainfall and keeping the recharge rate for other landuse pattern constant, the water table depletation some how restore. Another alternative is to increase recharge rate in forest and cultivation area from 17 % (present condition) to 30% of total rainfall and keeping the recharge rate for other landuse pattern constant, we can gradually elevate the water table.

This study depicts the entire scenarios of ground water table and its depletion in Katmandu valley, which may be paramount to sustain water level and for any water-resources research in the resent future.

Thesis Title: **CONJUNCTIVE USE OF GROUND WATER AND SURFACE WATER FOR WATER RESOURCE MANAGEMENT: A CASE STUDY OF RUPANDEHI DISTRICT**

Submitted by: **Rajesh Kumar Bhochhibhoya**

Supervisor: **Dr. Laxmi Prasad Devkota**

ABSTRACT:

Conjunctive use of groundwater and surface water is significant for management of water resource to meel the demand of water in agriculture as well as water supply. This thesis deals with the conjunctive use of surface water and groundwater for water resource management of Rupandehi District. Rupandehi District is located in south-western part of Nepal. It borders with India in the south, in the east with Nawalparasi. in the west with Kapilvastu and in the North with Palpa districts. The total area of the district is about 1,38,367 ha. The total population of the District is 7.08.419 and the population growth rate is 2-97 %.

The study area is divided into five zones. The estimation of surface water had been done with regression equation developed by WECS and groundwater potential was estimated by using Groundwater Modeling System (GMS 3.0). The availability of groundwater as well as surface water were summed up zone wise to get the total water potential in each zone. Three cropping

pattern scenarios were used to calculate crop water requirement in each zone. The analysis was carried out using Cropwat4 model. The drinking water supply demand is estimated with the population forecast for the coming next 20 years.

The simulation of groundwater model had been carried out under different recharge and groundwater extraction situations. The analyses of conjunctive use were done with different case of surface water availability and different scenarios of cropping intensity.

The results of the analysis revealed that there was plenty of groundwater as well as surface water available for the rice dominated cropping pattern in 3 zones out of 5 zones. In other two zones, availability of water is not enough for present condition of cropping pattern. Therefore, either groundwater resource developments are required or adaptation of cropping pattern with less water-consuming crops is recommended for that zones. In two zones out of five zones, currently excess groundwater has been. In these zones the analysis showed that there was no need of groundwater extraction. The study found that there was ample groundwater potential for the further development of groundwater irrigation scheme in the study area for conjunctive use with higher cropping intensity in future.

Thesis Title: **NUMERICAL MODELING OF DESANDING BASIN: A CASE STUDY OF DESANDING BASIN OF CHILIME HYDRO POWER PLANT**

Submitted by: **Madhav Prasad Koirala**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT:

Sediment transport is an inherent natural phenomenon occurring in almost all of the natural water courses around the world. As a consequence each and every type of water resources projects has some sort of sediment related problems. Chilime Hydropower Plant is one of such project, which is not exception to this sediment problem.

In case of run of the river type of power plants, sedimentation is the major area of consideration in designing desanding basins. The desanding basin is provided to remove fine grained suspended matter from water so that structural components can be protected from abrasive actions of fine sediment particles. As wear and tear due to abrasion by sediment in the hydro/clectro mechanical parts can, in a short period of time, result in serious damage on its surfaces and considerable reduction in its efficiency, the overall life of hydro power projects depend on performance of desanding basin.

Chilime Hydropower Plant is located in Rasuwa district of Nepal. It contributes 20MW power as its installed capacity to the national grid. In context of the present situation of national power system suffering from a huge deficit, the primary area of concern with regards to Chilime Hydropower Plant is an efficient operation and continuous production of power at its full capacity. As sediment laden water can reduce the efficiency and interrupt operation of power plant through its abrasive actions, it is always advisable to make a quantitative prediction of sediment through the desanding basin. A numerical modeling approach is recognized fur such predictions.

In this thesis, SSIIM (Simulation of Sediment Movement in Water Intakes with Mulli Block Option) has been used as a computational tool to simulate the water and sediment flow of the desanding basin considered in the case study. The simulation process has been carried out in the existing flow pattern, modified flow pattern with the use of racks and modified geometry of the basin by changing bend angles of bifurcation channel. The simulated result is then compared with the field observed data. The flow magnitudes, sediment discharges at the inlet and existing bed geometry of the desanding basin are used as input data for the simulation- The sensitivity analysis is performed for the uncertainties involved in the input data and

Computational Fluid Dynamic (CFD) model in the simulation. The conclusion is made on comparison of the quantitative outputs given by the SSIIM with the field observed results.

Thesis Title: **RIVER MANAGEMENT THROUGH STRUCTURAL MEASURES APPROACH: A CASE STUDY OF BAGMATI RIVER**

Submitted by: **Bishnu Dev Yadav**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

Nepal is suffering from various types of natural and manmade disasters such as floods, landslides, tires, earthquakes, epidemics, windstorms, hailstorms, lightning, avalanches etc resulting heavy losses of lives and properties every year. Among them, flood and landslides are solely responsible for one third of entire losses. This phenomenon put major obstacles on overall social and economical development of the country. Therefore it is the crucial matters of search for finding out the window solutions to mitigate the damaging impacts of such phenomenon. Several flood alleviation and land erosion control projects are in implementation and planning phases adopting conventional approaches till now. In the conventional method minimum width of river (Lacy's width), scour depth and high flood level are found based on flood discharge of pre-selected return period. Damages from historical data are calculated without considering the importance of depth and magnitude of flood on the damaging impact. This method is not cost effective as well as least risk

involvement. There will also be doubt in representation of actual damage conditions. Benefit-cost ratio found in this method may be questionable. Therefore it is a great challenge for researchers and concerning authorities to develop a methodology that will properly diagnose the causes and impacts of such natural phenomenon adopting physical sciences and latest technology, [n this study it is attempted to recommend a methodology pursuing the above-mentioned requirements partly. Cost effectiveness and consisting least risk are the major attractions of this study. It will serve one of the options of required methodology. It overcomes the drawbacks of the conventional approaches.

Lower Bagmati River Basin has been taken as study area. GIS with its extensions is a useful tool for analysis of flood damage assessment, which gives accurate results in limited time and resources. Flood hazard maps for different return periods are prepared with Hec-GeoRAS and Hec-RAS. Effect of existing levees and its validation period could be easily determined by observations of flood hazard maps of different return periods. Optimal size of proposed levees could also be located based on the hazard maps. Levees are designed with respect to known water surface profiles (Generated by Hec-RAS) for different return periods and estimating construction cost accordingly. With suitable discount rate and project life period construction costs are annualized. Risk based Analysis is a procedure, which evaluates different alternatives by comparing the investment cost and the expected economic losses due to failures. Thus the design return period is a decision variable instead of a pre-selected return period for design procedure of levees. Detailed information about the project economics and project performance are now available adopting risk based analysis method to the decision makers. It facilitates decision maker to explicitly and analytically integrate risk and data uncertainty directly into the analysis. It is thus formulated to provide safe, efficient and effective protection to lives and properties in flood prone areas. From the study it is seen that existing levee is valid for 50 year return period. Benefit cost ratio and incremental benefit cost ratio are higher for 100 and 50 years return periods respectively. But it is observed that protection work for 50 year return period is most cost effective and least risk involvement.

This methodology can be applied for deciding optimal size of flood alleviation project i.e. a tool for decision-making. This methodology can also be used for checking safety level (i.e. probable damage and risk associated) with existing levee or other flood alleviation structure. This methodology is recommended to represent vulnerability level of hazard, flood damage assessment and design of protection work.

There are some major limitations of the study even though optimal effort is made to represent the actual scenarios of the field during the study period within the limited time and resources. Lack of topographical data of recent year, land use pattern data to estimate Manning's coefficient (n), unable to represent actual constriction scenarios of Railway Bridge at international border and Highway Bridge at National Rajmarg (east west highway) and excluding the unsteady flow conditions are the major limitations of this study. Therefore it is suggested to make available the topographical data of recent year, Manning's coefficient (n) as per actual land use pattern and consider the effect of constriction due to above mentioned railway and highway bridges under the unsteady flow conditions for refinement of the results in the further research works.

Thesis Title: **ASSESSMENT OF LAND USE AND RIVER MORPHOLOGY CHANGES AT SIWALIK ORIGINATED RIVER BASIN USING REMOTE SENSING AND GIS: A CASE STUDY OF LAKHANDEN RIVER BASIN**

Submitted by: **Chakra Rawal**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

Land use is determined by environmental factors such as soil characteristics, climate, topography, and vegetation, but it also reflects land's importance as a fundamental factor of production. So, understanding past changes in land use and projecting future land use trajectories requires perception of the interactions of the basic human forces that motivate production and consumption- Understanding [he significance of land use changes for climate, biogeochemistry, or ecological complexity is not possible, however, without additional information on land use practices. This is because most land use change is now driven by human activities and because land use practices themselves have major direct effects on environmental processes and systems.

This study presents the application of Remote Sensing with GIS based tools for the systematic assessment of the land use and river morphology changes. The study also comprises the use of

hydrologic tool such as TOPMODF-L in generation of stream-flow time series data and SCS- CN method to compute peak runoff. In this context, the study has assisted in identifying pro-change pattern for fairly- accurate future change pattern of land use and its effect on peak runoff.

The study reveals that land use has changed significantly during 1979 to 2003. It was prominent that the forest has suffered 13.55% net loss of total area during this period from which it was limited to 41.45% of the total area in 2003. On the other hand, agriculture land expansion reached more than 50 % of the total area with a net increment of 13.51% of the total area. These caused peak runoff increase by 21.93%, 13.9%, and 12.25% for 109 mm, 175 mm and 200 mm rainfall storms respectively. The predicted land use for 2020 indicates that the forest land will shrink to 32.38%; agriculture land expands to 59.81% of the total area. Consequently, these developments will cause the increased peak runoff by 37.62%, 26.54% and 23.23% as compared to land use in 1979 for the same storms. Furthermore, the increasing and decreasing trend of the stream width in different period indicates that the area is most susceptible to inundation and flooding. Also, stream course shifting was prominent during the study period.

The result of this study has facilitated the visualization and the quantification of the land use and stream morphology changes. This can thus help the decision makers, planners and general public alike to perceive the land use change and its impacts in a better way and take appropriate measures.

Thesis Title: **QPF AND HYDRODYNAMIC MODELING USING RS AND GIS: A CASE STUDY OF NARAYANI BASIN**

Submitted by: **Murari Paudel**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

Rainfall runoff process is one of the complex hydrological behaviors of a catchment. As a vital component of Flood Forecasting and Warning System, hydrodynamic modeling has significant importance in flood management. The most fundamental part of such forecasting models is associated with peak flow estimation and estimation of time of occurrence. Today, researches are being carried out in the combined use of hydrological & hydraulic numerical models and Remote Sensing technique. Quantitative Precipitation Forecast (QPF) is increasingly gaming popularity in countries with adverse geographical situation.

This thesis presents a systematic approach for the combined use of GIS and remote sensing (RS) technique in Quantitative Precipitation Forecast (QPF) and development of a hydrodynamic model at basin and sub basin level in large watersheds. A case study of Narayani River Basin of Nepal was

undertaken as the study area. Some of the comprehensive modeling tools like HEC-HMS 2.2, ARC GIS 9 (Evaluation Version), ERDAS imagine 8.7 (Evaluation Version) etc were used for data preparation, modeling and analysis.

Brightness temperature of cloud from NOAA-AVHRR data was used to predict rainfall for July 2000 and 2003 over Narayani Basin. The forecasted rainfall was further analyzed statistically to determine the relevancy of such technique in Nepalese watersheds. The research has revealed a positive result regarding the applicability of Quantitative Precipitation Forecast (QPF) in Nepal.

In another part of study, a hydrodynamic model was developed for Narayani River basin using self-optimization algorithm of HEC-HMS 2.2. The peak flow simulation was done with good R^2 values and better Nash Efficiencies.

This work, as an important part of Flood Forecasting and Warning System, has been expected to initiate the integrated use of RS and GIS in both precipitation forecast and hydrodynamic modeling.

Thesis Title: **FINANCE HYDROPOWER IN NEPAL FOR POVERTY ALLEVIATION: EXPERIENCES AND FUTURE PERSPECTIVES**

Submitted by: **Mukesh Raj Kafle**

Supervisor: **Dr. Govinda Raj Pokharel**

ABSTRACT:

Nepal is an underdeveloped country. Poverty in Nepal is widespread particularly in rural areas and that it is deeper and more sever among those living in backward areas. The overriding objective of development efforts is poverty alleviation. There are various proposed plans and strategies for the poverty reduction. Among of them, one of the strategies is the development of hydropower. Development of hydropower in one side creates economic activities and employment opportunities. On the other side, it provides energy to support socio-economic activities which ultimately help to address the pillars of poverty alleviation activities. For the development of such a potential the required financial resources could be mobilized in such a way that the country would not be subjected to the burden of huge debt as well as lucrative foreign investment. People who are the owner of natural resources in their region should also benefit directly as well as indirectly. Therefore in the water resources sector it has become challenges

for the planners and policy makers to apply the best "financing modalities" which results the cheapest production of hydropower energy and also provides benefits directly to the people especially local people who own the resources. This will help in the poverty reduction/alleviation objective of the country. So far a study on the formulation or modification of existing financing modalities incorporating the lacking aspects of past models which may be applied in the development of hydropower projects to achieve the broader goal of poverty alleviation, socio-economic development as well as commercialization of hydropower development have not been conducted seriously.

There are different modalities of financing applied in the development of hydropower projects in Nepal. Since the beginning of first five year plan (1956-61) HMG/N was only the developer as well as promoter of all types of hydropower projects in the country. In the beginning of the Eighth plan the concept of involvement of private sector and use of water resources / energy for the poverty reduction was induced. However, such a "Financing Modality" that directly addresses the poverty reduction of the country by increasing their per capita income directly from the project with justified sharings have not been implemented so far.

In this context, the proposed financing modality proves that per capita income of local poor people can be increased significantly by using the "sweat equity" of the local community people (who own the resources) in the hydropower projects.

So, this study recommends that development of hydropower projects in Nepal may be one of the effective tools for poverty alleviation if the financing of project should be done incorporating the local poor people not affecting the contribution of private developer/ producer.

Thesis Title: **APPLICATION OF GIS BASED FULLY DISTRIBUTED HYDROLOGIC MODEL IN MANAGEMENT RIVER BASIN**

Submitted by: **Sujan Koirala**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT:

Most hydrological processes are complex phenomena to comprehend due to tremendous spatial and temporal variability of watershed characteristics such as soil and vegetation characteristics, snow pack, precipitation patterns, as well as a number of variables involved in modeling the physical processes. Besides these, the land use patterns and climatic factors within the catchment are also constantly changing. Due to these natural and man made variations, the hydrologic processes within the catchment are being affected and consequently the response of the catchment to the same input is also certain to change.

Moreover, the use of distributed model is becoming increasingly popular in the simulation of impacts of these variations. Distributed Hydrology Soil Vegetation Model (DHSVM) is used for the simulation of impacts of these changes. DKSVM is a fully distributed physically based model which involves the division of the catchment into the grid elements and attributing

each grid cell with the characteristics based on elevation, soil and vegetation type. Similarly, meteorological data at the model time step are used to force the model.

This study largely focuses on the use of DHSVM to simulate the response of the Bagmati River Basin upon different changes that may occur in the catchment. Particularly, this provides to the study of impact of four scenarios namely; urbanization in cultivation land, urbanization in forest area, forest clearance for cultivation land and global warming by 3 degree centigrade.

The study has revealed that the dry weather flow will be largely affected by urbanization and global warming. Furthermore, the decrease in dry weather flow is as much as 18.6 % for global warming, forest clearance will result in an increase of runoff volume by 16,20 % and the peak flow will increase by 14.45 %. As far as widening of the extremity of flow is concerned, global warming seems to have the most adverse affect. It will increase the maximum flow by 1.76 % on the other hand decrease the minimum flow by 37.93 %.

By appraising its secondary impacts on flows, the reduction in dry weather flow will adversely affect the disposal of the crematory waste products in the river in Pashupati region.

However the forest clearance will have beneficiary impact on this problem due to increase in dry weather flow though this will result to a large wet weather flow. Due to large wet weather flow, the lower regions of Bagmati will be affected by frequent flooding and inundation.

Thesis Title: BAGMATI RIVER BASIN OPTIMIZATION

Submitted by: Prem Shah

Supervisor: Dr. Divas Bahadur Basnyat

ABSTRACT:

This study develops a network flow optimisation model for long-term supply demand analysis for basin-wide water resources planning. A set of nodes form the network of the basin. The set of nodes consists of supply nodes, demand nodes, hydropower nodes, reservoir nodes, water diversion nodes and outlet nodes. The decision variables are reservoir storage, water supply and demand for public and agricultural use, reservoir releases, irrigable area, and energy generation. Two objective functions are considered: one with an objective function of minimizing the demand deficit and other with an objective function of maximizing the total benefit from various purposes. The constraint in the model includes water supply and demand, minimum and maximum irrigable area, reservoir storage, reservoir capacity, minimum energy generation, minimum instream flow, evaporation losses, net benefit, net crop water requirement, cropping location possibility and crop calendar. The formulated model is solved by CONOPT GAMS solver. The developed model is applied to the Bagmati river basin.

Two different models are developed, one with an objective function of minimizing demand deficit and other with an objective function of maximizing total benefit from various purposes. Several sub-models are developed by changing the constraints, demands and priorities. The performance evaluation of the model is based on the percentage demand satisfaction at each public and agricultural demand nodes. It also assesses the hydropower generation at hydropower nodes along with the operation of reservoir. Minimum instream flow is considered a hard constraint that is always met while meeting the required demand of public, irrigation and hydropower. At the same time trade-off among the minimum instream flow, various demand satisfaction and the cropping pattern and cropping area during different flow conditions can be assessed.

It is seen that the existing demand satisfaction in Kathmandu valley is very poor and contributes less in the water balance of the basin. The other nodes like Kulekhani junction, Durling, Kokhajor, Marine and JanJh achieve about (80%-100%) demand satisfaction on optimization. When Bagmati basin is optimized with existing irrigation demand to irrigate 41,000 at Bagmati Irrigation Project (BIP), the demand is not fully satisfied during dry months. On and average it can irrigate only 26.600 ha of command area. Also when the demand is increased at Bagmati

Irrigation Project (BIP) in-order to irrigate 122,000 ha, then there is decrease in demand satisfaction at all nodes. Hence, Bagmati Multi-Purpose Project (BMPP) is considered as an intervention to meet the demand of the potential irrigation area. A good trade off between irrigation and hydropower can be assessed using the model developed.

With the water available in the basin, the demand of the whole basin cannot be increased beyond 30% because there will be shortage of supply. However, with the interventions such as BMPP, the water utilization for irrigation and hydropower can be substantially increased. Similarly, the flow augmentation in the form of minimum instream flow can be increased upto 50%. From the study, it can be concluded that the developed models can be used for the river basin wise optimal water resource planning.

Thesis Title: **OPTIMIZATION OF IRRIGATION WATER MANAGEMENT: A CASE STUDY OF NEPAL WEST GANDAKI IRRIGATION SYSTEM**

Submitted by: **Fanindra Bahadur Shrestha**

Supervisor: **Dr. Indra Lal Kalu**

ABSTRACT:

This study has attempted to find the optimal irrigation planning with due consideration to time of maintenance period for maximum benefit from available resources by using linear programming model. Due to lack of sufficient budget, resources as well as of knowledge, an optimal utilization of irrigation system has not been up to planned way. Further if the resources is not used properly in right time we may loss actual benefit from these resources. In this study, a Linear Programming model was formulated to determine optimal cropping pattern for two seasons. Area of irrigated crops and area of rain fed crops are considered as decision variables. Available water, land area and boundary conditions are considered constraints of this mode!. Labor constraints and fertilizer constraints are also used to see whether available labor and fertilizer in the study area is , sufficient. Upper bound, Sower bound and no bound situation constraints are used to study the different scenarios of area constraint and compare with existing situation and to each other.

This study is applied in Nepal West Gandak Irrigation System. For this study two bed level conditions and three cases of canal desilting timing have been considered. In condition A original design bed level of 356.75ft above mean sea level is considered for calculating available water. In condition B available water is considered when bed level is maintained at 357.95ft above mean sea level.

In condition B about 1 -2ft depth of canal is filled by silt. Inquiry to the DOI staff shows that this depth of silt is not removed usually due to lack of budget. For these two conditions timing of removal of sediment is considered as three cases. In case I silt is proposed to be removed on each month of June, July, August and September. In case II it is to be done in November and in case III in the month of April only. Liner programming model was formulated separately for all there six situations. Crop mix varied for different situations resulting into varied maximum benefit. For both condition of bed levels Case I that is silt removal found most beneficial. In each moths was Among the above three cases case I is found best beneficial and case II is found appropriate time for removing the silt. It will be appropriate to remove silt during monsoon (June, July, August and September) through the disposal canal of silt ejector.

Lingo 9 version of linear programming is used to evaluate the optimality of above cases. Model is found sensitive to water availability at different step of time. This methodology applied in Nepal West Gandak Irrigation System can be a general analytical tool for planning other irrigation systems.

Thesis Title: **STOCHASTIC ANALYSIS, PREDICTION AND FORECASTING OF FLOW IN MID WESTERN RIVERS IN NEPAL**

Submitted by: **Suraj Lamichhane**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT:

This thesis paper deals with the performance assessment of time series models in different physiographic regions of High Himalayas and Middle Mountain Physiographic Regions within mid -western part of Nepal, "time scries model deals with the statistical and probabilistic approach- The model is used to simulate the river flow characteristics of various sized catchments'. Quality of model is initially judged by comparing the simulated flow with the observed flow. In addition to the classical method, a range of qualitative and quantitative measures are used to judge the model performance. The quantitative techniques such as efficiency, coefficient of determination, standard deviation and relative errors in annual and monthly flows are used for the performance assessment. Those techniques are found to be sufficient to determine the quality of model performance.

The model is calibrated using the historical river flow data. Due to the varying nature of catchments, rivers are classified in two types e.g., spring and snowfed types. Annual series of both type of river flows was easily described and generated by the AR (1) model. Similarly for the monthly periodic series of river flow, periodic AR (1) and periodic AR (2) models were used for spring and snowfed types respectively. From the historical flow data, the trend of river flow was found to be slightly decreasing in order. For the generation of flow in ungauged river, the model parameters were described by the regression analysis of similar catchments and flow parameters were found by the features of topographical values. The prospect of time series model's applicability is found to be promising and the model is inevitably a good engineering tool for water resources development in different sized rivers in High Himalayan and Middle Mountain Physiographic Regions of Nepal.

Thesis Title: **NUTRIENT MODELING BY USING SOIL AND WATER ASSESSMENT TOOL (SWAT): A CASE STUDY FEWA LAKE BASIN**

Submitted by: **Ramesh Bahadur Thapa**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT:

Nutrient flow is an inherent natural process, which is unavoidable in natural water courses. When a rain fall occurs, water that does not infiltrate into the soil immediately puddles and flows into the water body which increases the nutrient load in such water bodies. Nutrients also bring problems in the environment and degrade the quality of water in rivers, lakes, ponds etc. Overall value of lake water depends on the nutrient concentration.

Fewa Lake is situated the tourist town of Pokhara in Kaski district. It has major economical value in tourism sector and must be kept out of any environmental degradation and free from rise in nutrient concentration. The lake is considered as heart of tourist attraction in Nepal. The major problem associated with the water quality of the take is its rising nutrient concentration which increases algae growth. This is because a number of rivers and a few sewer outlets carrying nutrients from agricultural land and municipal sewerage respectively within the walershed enter

into the Fewa Lake. In order to conserve Fewa Lake from deteriorating water quality, it is necessary to formulate water management plans for the lake basin. For attaining this objective nutrient management tools are required.

SWAT and GIS, which have become common and popular these days, have been used in this study as the tools for formulating plans of controlling and managing nutrients in sub basins and sewerage point sources entering Fewa lake. Hydrological, meteorological and nutrient data have been used for the simulation purposes. This model can effectively be used for formulation of water quality management plans including cropping management in the whole basin.

The results show that the maximum concentration of nitrogen is 3.3 mg/1 if corn and vegetable is practiced at harpan Khola similarly the minimum concentration of nitrogen is 0.85 mg/1 if paddy and vegetable is practiced at Harpan Khola. Also the maximum amount of nitrogen (1935.0 KgN) is stored at Fewa Lake in the month of June and the minimum amount of nitrogen (694.0 KgN) is stored in the month of February when the point source from the different point is not considered (case 1). Similarly, the maximum amount of phosphorus (262.15 K.gP) is stored at Fewa Lake in the month of July when the point source from the different point is considered (case2) and the minimum amount of phosphorus (102.KgP) is stored in the month of February for the case l.

Thesis Title: **WATER ASSESSMENT STUDY OF WEST RAPTI RIVE BASIN**

Submitted by: **Ashish Man Bhandari**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT:

This thesis is an attempt to identify the best possible utilization of the available water resources given certain constraints of the basin. In the present context, Nepal is concentrating more on the project-to-project planning. But for the optimal benefit, an integrated system of holistic approach has to be applied while planning for the river basin use. A Decision Support System (DSS) using simulation model would thus assist in assessing the water resources available in the basin and planning for optimum utilization of the water resources in future. This study is an attempt to look into the long term planning aspect of West Rapti River Basin.

Various scenarios have been simulated in order to determine the water balance (surplus and deficit) for the different water uses and priorities of the water resources components of the river basin for the present as well as future uses. The total irrigation potential area in the basin is 57,000 ha out of which only 25,500 ha of land is presently irrigated. Jhimruk Hydropower Project

(12.5 mw) is in operation in the Jhirmruk Khola, a tributary of the West Rapti River.

With intervention in West Rapti River by implementation of West Rapti Multipurpose Project additional area of 80.350 ha can be irrigated. Naumure Storage Project produces average annual energy of 733 GWh/yr while West Rapti Reservoir produces about 255 GWh/yr. With diversion of 39 m^3/s to Kapilbastu, additional energy can be generated at Surai Naka. The downstream flow during dry season increases significantly with the flow regulation from reservoir. This can be termed as the downstream benefit because the increased dry season flow can be beneficial for further irrigation development, hydropower generation, environmental reasons and navigation.

River Basin Models like WEAP is found to be an appropriate tool for decision support, as all the ingredients of decision support system (DSS); inventory of basin's water resources and related lands, summary of basin's present water uses, projection of future water needs and identification of alternative decisions to meet or not to meet the indicated water needs, can be addressed. This model is based on a basic water balancing equation. It can be concluded that the procedure adopted like the one used in the present study can be of great use for making rational and optimal decisions.

Thesis Title: **FUZZY DYNAMIC PROGRAMMING MODEL FOR OPTIMAL OPERATION PLAN OF A MULTIPURPOSE RESERVOIR: A CASE STUDY OF KANKAI MULTIPURPOSE RESERVOIR**

Submitted by: **Umesh Dangal**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT:

Optimal operation of reservoir has been an active area of research for many years. Various techniques have been developed and adopted for reservoir operation incorporating the uncertainty due to stochastic nature of inflows and demands. However, there is not much literature reported on models incorporating uncertainty caused due to imprecise goals and objectives- In the present research, fuzzy dynamic programming model is presented for optimal operation of a multipurpose reservoir. Fuzzy optimization model has capability to incorporate the uncertainly involved in the objectives and variable demands, and fuzzy rules are relatively easy to explain and understand.

The main objectives of this research are to develop fuzzy dynamic programming model for optimization of operation plan of a multipurpose reservoir and compare the performance of reservoir operation policy with and without fuzzy logic. Fuzzy

logic allows something to be partly this and partly that, rather than having all belonging to either this (or) that (binary logic). The belongingness to a set or a category can be described numerically by a membership grade between 0 and 1. In the current model, the objectives of reservoir i.e. hydropower generation, irrigation and Hood control are considered as fuzzy. The objective function of current model is to maximize the minimum expected satisfaction level of fuzzy objectives. The level of satisfaction of an objective is a function of reservoir release (Xi) for irrigation and hydropower and initial reservoir storage (Si) for flood control. The FDP model is used recursively until steady state operation policy is obtained.

The operation of the reservoir is simulated using the optimal operation policies derived from both Fuzzy Dynamic Programming and Stochastic Dynamic Programming models and the performance of the reservoir is evaluated. Level of satisfaction of Irrigation water requirement is 98% with FDP Model and 97% with SDP Model. Similarly, level of satisfaction of hydropower generation is 92% and 78% and for .Flood Control objective, it is 92% and 48% respectively. Hence, the comparisons show that the performance of reservoir is better with the operation policy obtained from FDP Model than the performance of operation policy obtained from SDP Model.

Thesis Title: **APPLICATION OF TOPOGRAPHY BASED RAINFALL - RUNOFF MODEL IN BAGMATI RIVER BASIN**

Submitted by: **Abinashi Sigdel**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT:

Topography is one of the most important factors controlling stream-flow. The infiltration, movement and recharge to ground water at a point are mainly governed by the contributing area and local slope. Generally steep slope exhibit as potential recharge area and infiltrated water moves laterally and collects towards the foot of the hills where the slope is gentle, mild or convergent. This phenomenon of movement and collection of subsurface water raises the ground water table and saturated overland runoff is generated by rain falling over the saturated area- As more and more water infiltrates, the percent saturation area, known as contributing area, increases and extends towards upstream. The local ground water table and movement of subsurface water is controlled by soil topographic index and decay coefficients oftransmissivity.

In this study distributed version of TOPMODEL (TMOD9502) is applied to the Upper Bagmati River Basin. The model is used to

study the hydrological process within the catchment, thus simulating runoff from the catchment.. G1S tools are used for topographic analysis and preparation of input data needed for TOPMODEL. Data required for TOPMODEL are Topographic Index, Distance-area histogram, Basin average precipitation, evapotranspiration, observed runoff and simulation parameters.

For preparation of data. Topographic Index is derived from ASCII raster elevation data using GRIDTAB program. Flow area from catchment outlet and corresponding maximum flow distance is calculated using Hydrotools. The aerial coverage of each rain-gauge is determined by generating thessien polygon which is then used to derive basin average precipitation in each subcatchment. Similarly, daily evapoiranspiration is calculated using FAO Penman method and Muakingum cunge channel routing is used to rout subcatchment's inflow hydrograph to basin's outlet. Other computer programs have been developed in Fortran Language for computing evapotranspiration and channel routing.

The model is calibrated and validated for 1997, 1998 and 2001, 2002 daily rainfall runoff. Both subjective and objective methods are applied to test the goodness of fit of simulated and observed hydrographs. The results are satisfactory with Nash efficiency as much as 84.8% in calibration and 82.5% in validation. The annual peak, monthly average stream flow, and monthly high and low flow simulation using the model is relatively good. The limited available resources used to achieve these results showed that TOPMODCL is applicable in steep (hilly) catchment of Nepal.

Thesis Title: **OPTIMUM OPERATION OF A HYDRO DOMINATED POWER SYSTEM**

Submitted by: **Rajendra Sapkota**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT:

Optimal operation strategy of a mixed hydrothermal power system needs to consider the operational characteristics of various types of hydropower plants and thermal plants available in the system. The main objective is to study the implications of optimum design discharge if candidate projects, introduction of seasonal tariff and increase of export on the optimum operation of the power system.

VALORAGUA model developed by IAEA (1992) is used in this research- The model is suitable for a hydrodominated power system. The hydrological variation and power regulation possible in hydropower plants are taken care in the model.

Project level optimization and system optimization are two different aspects. It is a normal practice to optimize the design discharge (via. Installed capacity) of a project based on the cost and benefit of a individual project alone. This approach does not

address the system requirements, which is dependent on the load curves and the types of various projects (hydro and thermal) in the system. Hence, selection of an optimal design discharge needs to be based on system operation study like they are carried out in this research.

The present demand pattern of Integrated Nepal Power System shows that there is a peak in the morning and evening. Similarly, the demand in winter is more than in summer whereas the flow available in the hydropower plants is just the opposite. This has led to a generations of spell energy during ant wet season. One policy intervention to address this issue is the introduction of seasonal and lime of day tariff. Similarly increased of export energy can help in the utilization of spell energy. This research has attempted to asses the benefits and implications of seasonal and time of day tariff, and the magnitude of export.

It can be concluded from the research that an optimal operation strategy of a hydro-dominated power system needs to be based on the approach used in this study. Hydropower project parameters cannot thus be optimized in isolation but should be based on a system operation study. Similarly other interventions like seasonal tariff and export (or even exchange) of power needs to tested by a power system optimization study.

Thesis Title: **ASSESSMENT OF HYDROPOWER POTENTIAL USING GIS: A CASE STUDY OF MADI RIVER BASIN**

Submitted by: **Gopal Raj Suwal**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT:

Continuous semi distributed model such as HMS (Hydrologic modeling system) provide a promising new approach to sparsely gauged catchment rainfall-runoff modeling. In this study, the use of GIS (Geographic information System) tools and continuous semi distributed model HMS are used for the assessment of hydropower potential of sparsely gauged Madi river basin in the western development region of Nepal. A continuous simulation technique, based on the soil moisture accounting method, is used to derive long term daily discharges for the entire catchment including the sub catchments of the Madi River Basin, using 16 years of daily rainfall data. The physical parameters of the catchments required for the model are derived from GIS.

In order to calculate the power potential of Madi River basin, the hydrography of the basin is derived from the digital elevation model (DEM). This provides the elevation data at the upstream and downstream ends of each river segment of the sub

catchments. The long term daily discharges for the upstream and downstream ends of river segment are derived from the HECHMS model with Nash efficiency ranging from 59% and 64% for the calibration period and 64% to 88 % for validation period. Combining the design discharges corresponding to 65' percentile, 95th percentile and mean annual discharges with the hydraulic head determined from the DEM, the power potential of the river segment could be estimated. The total power potential of the entire catchment is a linear summation of the power potential of all individual sub catchments.

The gross hydropower potential of the study area, Madi river basin is estimated at 497.03 MW with 424.95 MW for main river channel and 72.08 MW for tributaries. The Median power potential i.e. theoretical capacity at 65 percentile is estimated at 314.86 MW with 258.13MW for main river channel and 56.73 MW for tributaries. The small power potential i.e. theoretical capacity at 95 percentile is estimated at 171.92 MW with 140.41 MW for main river channel and 31.71 MW for tributaries. The total annual energy is estimated at 3908.12GWh, 1542.02CWh and 992.i3GWh for discharges at annual mean, 65th percentile and 95 percentile. The firm energy for the whole catchment is 149.09GWh.

Thesis Title: ASSESSMENT OF DIVERSIFIED MODES OF HYDROPOWER DEVELOPMENT IN NEPAL

Submitted by: Lila Nath Bhattarai

Supervisor: Dr. Divas Bahadur Basnet

ABSTRACT:

Available literatures discuss emerging issues in hydropower development including linkages and capacity building and theorize backward linkages in national economy. However, the procedure for quantification of the extent of backward linkages is not very clear. This research works out the details of the problems associated with the issues raised in hydropower development and suggests the method of computing money retained in the country out of the total investment made. The major factors contributing to backward linkages are: support to allied industries, support to services, employment generation, investment linkages, fiscal linkages, rural electrification, etc. This research proposes the use of money retained factor (MRF) as the quantitative indicator of the extent of backward linkages. For this purpose money outflow factor (MOF) and money retained factor (MRF) and their relationships are defined using mathematical expressions. The result of the study has presented the level of backward linkages as "Very Strong", "Strong",

"Good", "Acceptable", "Weak" and "Very weak" depending upon the MRF.

In the past hydropower developments in Nepal have been generally carried out by government under donor assistance, by national private developer and by international private developers. All donor assisted projects are normally considered in the same basket without acknowledging the extent of assistance and different procurement guidelines followed. The present study has clustered the donor assisted projects in four groups based on the type of assistance and the extent of the supports available. The projects developed by national developer are clustered into two categories, viz., private developer and public developer.
Traditionally unit cost of development (in US$/kW /or US Cents/kWh) is the most common basis for comparing project alternatives. However, this study has carried out the assessment of diversified mode of hydropower development in Nepal acknowledging the conflicts in the choice/preference of different stake holders and decision makers on criteria such as technical aspects, project cost and schedule, environmental and social aspect, capacity building, national hydro industries, NEA's perspective and linkage in local economy including contribution to self reliance. Furthermore, some of the criteria required for the

assessment can be quantified in economic terms whereas others are more difficult or impossible to quantity. Owing to this, Multi Criteria Decision Making (MCDM) tool that can combine both qualitative and quantitative criteria/attributes is used to evaluate hydropower development alternative. A numeric rating and priority weighting scheme is used to evaluate 36 sub-criteria / attributes that are considered important for hydropower development in Nepal, which are grouped into seven main criteria or objectives for the nine altematives (projects). Analytical Hierarchy Process (AHP) is used to get the responses from stakeholders based on value judgment and for determining weights of different criteria and sub-criteria/attributes A survey was made with stakeholders representing technical, political, economist and activist groups. An enhanced weighted average method is applied for prioritization of hydropower development alternatives practiced in Nepal.

The result of this research study shows that the hydropower development model requires giving maximum weightage to national perspective including linkages to local economy. It is followed by capacity building and involvement of national hydropower industries. It is also recommended to apply Multi Criteria Decision Making (MCDM) tool for planning of complex water resources problems with conflicting subjective and objective criteria and to deal with different stakeholders and decision makers. The study recommends giving highest priority to national developers such as private, public and NEA self promoted projects and the projects funded almost entirety by the donor (s).

[Keywords: Backward linkages. Fiscal linkages. Investment linkages, capacity building, money retained factor, money outflow factor, contribution to self reliance, key decisions, sitting of the structures, Multi Criteria Decisions Making, Analytic Hierarchy Process, Criteria, Attributes, Impact Analysis Matrix].

Graduation Year 2007

Thesis Title: **CONTRIBUTION OF TRADITIONAL STONE SPOUTS TO MEET THE WATER DEMAND IN THE COMMUNITY OF LALITPUR SUB METROPOLITAN CITY AREA**

Submitted by: **Govinda Prasad Poudel**

Supervisor: **Dr. Divas Bahadur Basnet**

ABSTRACT

Kathmandu Valley is facing a severe water supply crisis both due to limited supply aggravated by the rapidly increasing demand due to urbanization and migration of people to the valley from all over the country. In the past, people relied more on traditional water sources such as community wells, stone spouts and spring. However, with the introduction of piped water supply network, people started using less of these traditional water sources, which resulted in their degradation. Now importance of these traditional sources has been again realized due to the shortage in the piped water supply. Lalitpur Sub-metropolitan city (LSMC) is no exception to this.

This research is therefore undertaken with main objectives of surveying and analyzing the present condition of public's water consumption pattern from traditional stone spouts and to assess the contribution of traditional stone spouts to meet the water demand of the community in LSMC area. Water management options from traditional stone spouts were also explored .This is entirely based on Held research and various steps of field research tools were used. Field observation and Key Informant Survey were carried out to collect general data of the stone spouts and then to categorize them on the basis of their performance. Structured questionnaire survey was undertaken with the stone spout users to assess the quantity and response of water use from the stone spouts and to find about the other sources used their socio-economic profile etc. Case studies of some good types of stone spouts were then done to explore the general community water management practices in LSMC area. Discharge measurement in dry and wet season for all stone spouts in LSMC area was also done.

It is found from the key informant survey that stone spouts of LSMC are serving more than 65,000 people. Per capita water consumption of the users varies from a max 85 1pcd to a minimum is 29 1pcd. This is mainly fulfilled by stone spouts, NWSC- supply, well, lanker supplies and NWSC provided collection tanks provided in different places in the LSMC area. Maximum consumption rate from stone spout water in the LSMC area is 50 1pcd in place of good type of stone spout area and minimum of 9 1pcd in average type of stone spouts.

Socio economic parameter shows that all category of people are using stone spouts but majority are from poor and medium class. It is found that only 20% of users are from higher socio economic status.

People's perception for quality and quantity of water is very good in case of good types of stone spouts whereas, as expected, they have a bad perception in both quality as well as quantity of water in other stone spouts. It can be indicated that only twelve good types of stone spouts in the LSMC area contributing substantially to the community. Community water management practices in Iku hiti, Aiko Hiti and Haku Hiti were found to be very good and it is recommended to apply similar practices in other good types of stone spouts.

Hence, it can be concluded that the contribution of stone spouts is high in LSMC area and it serves mainly the urban poor and middle class people. Due to the inadequacy of NWSC supplies, stone spouts are considered to be an important secondary source of water in LSMC area.

Thesis Title: **IDENTIFICATION OF HYDROLOGICAL SIMILAR CATCHMENT USING CONCEPTUAL MODEL**

Submitted by: **Ramesh Kumar Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Prediction of monthly stream flow is of prime importance to over all water resource management of the basin and to design the hydraulic structures. But it is true that most of the rivers in Nepal are ungauged. Regularly observed streamflow data were available for only 51 stream gauging stations in Nepal. Rainfall data were available for 309 precipitation gauging station. Hence, unavailability of streamflow data is major problem confronting TO horologist and engineers. A number of rainfall - runoff models have been developed to overcome this problem. This thesis has therefore chosen a simple conceptual model named Crawford water balance model as its input parameters are less and can somehow be available. The model itself is simple due to its less number of model parameters namely Psub, Gwfand C.

In this study Crawford water balance model was used in twelve basins of eastern region of Nepal whose catchment area varies from 87 to 5640 km^2. Eleven years monthly streamflow data

except for Bagmati basin were taken for calibration of the model parameter and performance of model simulation were assessed through different statistical indicators.

The data selected for this study for the purpose of classification of catchments consist of 9 characteristic variables (5 basin characteristics and 4 land use pattern data) of the selected basins under study. Correlation of 3 model parameters has been checked with 9 characteristics variables of the basins separately. Based on the correlation coefficient this study did analysis to develop the regionalized concept of model and basin parameters.

Thesis Title: **EFFECTS OF CLIMATE CHANGE ON LOCAL HYDROLOGY OF NEPALESE RIVERS AND ITS IMPACT ON HYDROPOWER GENERATION**

Submitted by: **Chirasmriti Prakash Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT:

The most critical impacts of climate change in Nepal can be expected to be on its water resources facilities. The change in magnitude and timing of water flow, floods droughts, shifting of hydrograph etc are the indicators of climate change in river hydrology. Reduction of dry season flows; in particular possess serious risk to the dependability of existing hydropower projects. Changes in the river flow would have a direct impact on amount of hydropower generation, because hydropower generation decreases with lower flows. Given Nepal's electricity infrastructure heavily relies on hydropower -nearly 91 % of nation's power comes from this source -the reduction in hydropower generation will eventually lead to serious disruption of national power system. In other words, the failure to adapt to climate induced risks to hydropower might give rise to power crisis in future.

Almost all hydropower plants are designed on the assumption of unchanged climate i.e. the design flow, minimum flow and maximum flow etc will not be changed in long term.

The present study aims to figure out the impact of climate change on power production by different Hydropower projects in Nepal. The thirteen major hydropower projects namely; Kulekhani I and II, Marshyangdi, Khimti, Bhotekoshi, Andhi Khola, Kaligandaki "A", Sunkoshi, Trisuli, Devighal, Modi, Jhimruk, Puwa are selected for the study. The current trend in the river flow is analysed focusing on the dry season flow which is of particular importance for power production in dry season. The tank model parameters for the concerned watershed area are estimated after the sensitivity analysis of the tank model (calibration and validation) of the hydrological and meteorological data for each area. With these estimated parameters, the availability of discharge for each Hydroelectric Plant (HEP) station are calculated and compared with the present context. The effect of climate change on the discharge and then of energy generation of each Hydropower Station is calculated.

The analysis shows that trend of river flow in dry season is decreasing. The flow duration curve also shows that in the dry season the water availability is decreasing where as the flow in monsoon season is increasing. The power production trend of almost all HEP is decreasing year by year. The analysis also shows that for the projected period of 2041-2060 A.D, there will be the decrease in dependability of flow for the design discharge it is using in present for generation. Ultimately .the energy generation of the corresponding flow will also be decreased. The result shows that the energy decline may be from 5- 40 % for single hydropower and the effect of this decrease in each study area cause the decrease in energy of the system by 2.1 % in 20 years of predicted period.

The implications of climate change are greater in the water systems that currently are highly stressed (the power projects functioning on the minimum discharge of river flows). For the planning of sustainable power production and to reduce the impact of the climate change on national power system which is basically dependent on hydropower, the current practice of design methods should be changed. In the long run sufficient water may not be available as estimated today: hence design capacity of existing hydropower plants should be revised. Also for the new plants the incorporation of climate change should be done to calculate the design discharge so that the project will be economically feasible in long run.

Thesis Title: **COMPARATIVE STUDY OF ONE DIMENSIONAL AND TWO DIMENSIONAL STEADY SURFACE FLOW ANALYSIS**

Submitted by: **Laxmi Bhakta Maharjan**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Mostly, rivers are the source of surface water for the development of hydropower, irrigation, water supply and other developments. Nepal is the country with high potential of hydropower development. Complete hydrological and hydraulic analysis is necessary for the development of these projects. Most of the Nepalese rivers are with large floodplains and with complicated geology of the riverbanks. Detail study of the rivers is needed to know the impacts of the different floods before any projects are developed.

Classical approach of analyzing the river flow using empirical formula and one-dimensional flow analysis can provide some information about the flow behavior of the river for different return period floods. The entire physical phenomenon should be incorporated to get the detail information about the river flow. To

do this, complete two-dimensional flow analysis of river should be done.

In this research study the water flow is modeled in both One-dimension and Two-Dimension. GIS, HEC-GEORAS and HECRAS are used for one-dimensional surface water *flow* analysis and FESWMS-2DH is used for two-dimensional surface water flow analysis. Analysis is done by considering different flood discharges, which are applied to flow at up stream of the river, The basis governing equations for the analysis are continuity equations and momentum equations. Comparative study of 1-D and 2-D analysis of surface water flow for two different channels is done for different floods considering the steady flows. The analysis showed that the results obtained from 1-D and 2-D is different and two-dimensional analysis must be done for the effective result. The Manning's coefficient has minor affect in the result.

One-Dimensional analysis is sufficient for the surface water analysis for prismatic Channel. But, at channel bend, two dimensional velocity distributions is necessary which cannot be studied from One-Dimensional analysis. Two-Dimensional analysis is required for this study. In case of non-prismatic channel, Two-Dimensional analysis provides a better result for surface water flow analysis.

Thesis Title: **IDENTIFICATION OF HYDROLOGICAL SIMILAR CATCHMENT USING CONCEPTUAL MODEL**

Submitted by: **Pradeep Adhikari**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

This thesis work entitled as "Identification of Hydrological Similar Catchment Using conceptual Model" include study of the gauged basins from Mid and Far Western Regions of Nepal. The gauged catchments under study are Babai Basin at Chepang, Budhi Ganga at Kakarsant, Budhi Ganga at Mangalsen, Chameliya, Chham Gad, Chingar at Simlikhet, Mari Basin, Sakayal Khoia, Sani Bheri, Sharada basin, Sinja Khola, Sumaya Gad, Ti!a River at Nagma. Tila River at Serighat. West Rapti. This also includes sixteen ungauged catchments from the Mid and Far Western Regions of Nepal. Basins under study are small and medium sized area ranging from 150km^2 to 3700 km^2.

The conceptual model used for the study is Crawford Water Balance Model. The input variables are precipitation, potential Evapotranspiration, observed discharge.

From the study of the model parameters, the model parameters have been regionalized into six groups based on area. The area of

the basin is the primary and sensitive basin characteristics for the identification of the hydrological similar catchment in case of Mid and Far Western Regions of Nepal. Study of thirty one catchments in Mid and Western Regions of Nepal show that once it has been classified on the basis of the area, other basin parameters come more and less same. For the Mid and Far Western Regions of the Nepal, for hydrological assessments of the river basin having area from 150^2 km to 3700^2 km (small and medium sized river basin). HSC can be found out on the basis of the area. The monthly flow assessments for the ungauged catchment in the Mid and Far Western Regions of Nepal can be done simply finding out the HSC .The identification of HSC could be a alternative and even much accurate solution than exiting flow assessments method like WECS and MIP methods in Mid and Far Western Regions of Nepal.

The identification of could be alternative method with better monthly flow assessments for small hydro project (pre feasibility study, PPA) in small and medium sized basin in only Mid and Far Western Regions of Nepal.
Considering the sparse hydro meteorological stations in the country, the Crawford model demonstrated positive indication of its applicability to cope with the limited hydro meteorological data conditions.

Thesis Title: **VALIDATION OF TOPMODEL IN SMALL MOUNTAINOUS CATCHMENT OF NEPAL (A CASE STUDY OF JHIKHU KHOLA WATERSHED) AND ITS APPLICATION FOR CLIMATE CHANGE**

Submitted by: **Mohan Kumar Tuladhar**

Supervisor: **Dr. Mahesh Raj Gautam**

ABSTRACT

This study largely focuses on the validation and appropriate use of TOPMODEL to simulate the response of the Jhikhu Khola Watershed which is a sub basin of Sun Kosi River basin of Nepal. The study concentrates to emphasize appropriate use of the model considering the size of basin and especially grid size to capture the true topography of the river basin. Seven scenarios with different combination of projected changes in precipitation and temperatures were presented based on the previous studies.

The TOPMODEL has been calibrated with 20 m DEM for the year 2002 to 2003 and the Nash efficiency is found to be 60.7% and similarly the model is validated for years 2004 and efficiency obtained is 60.5 %.

The different grid sizes for 20 m, 50 m and 100 m DEMs are created and analyzed for the performance of the model with respect to Nash efficiency criteria. This study shows that there is not much change in Nash efficiency when the grid size increases from 20m to 50m but there is significant decrease of about 16% in model efficiency (Nash 1 Efficiency) when grid size changes from 50m to 100m. So it implies that this variation is of significant amount for prediction of hydrological extremes such as floods and droughts. These hydrological extremes are very much sensitive to the local people of this study area.

The effect of topographic index distribution which is the most important parameter of the TOPMODEL is used to derive the conclusion of its importance in the small mountainous catchment of Nepal. The present study shows that there is not much effect of the runoff generation with different topographic index distribution as it is expected to be.

The study shows that runoff is more sensitive to precipitation change as compared with temperature change.

The result of this study has facilitated the visualization and the qualification of the effect of climate change within watershed considered. The TOPMODEL can be suitably applied to study to hydrological response in such middle mountainous catchments where no snowmelt component contributes the runoff. This can thus help to understand the appropriate application of the hydrological model suitability to our catchments. The decision makers, planners and concerned authority to visualize the potential impacts of climate change and take appropriate measures to cope with plausible adverse effects within the river basin for future plans and program to avoid the some unseen adverse effect on hydrologic response of this small watershed.

Thesis Title: **APPLICATION OF DISTRIBUTED HYDROLOGICAL SOIL VEGETATION MODEL (DHSVM) IN PLAIN REGION OF NEPAL**

Submitted by: **Rajan Bhattarai**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

A hydrological simulation model use mathematical equations that establish relationships between inputs and outputs of water system and simulates the catchment response to the rainfall input. Several hydrological models have been developed to assist in understanding of hydrologic system and water resources management. A model, once calibrated and verified on catchments, provides a multi-purpose tool for further analysis. The mode! can be used to test hypotheses and gain a better understanding of how the catchments behaves under different conditions in the future, that is, to make predictions.

Distributed models in hydrology are usually physically based in that they are defined in terms of theoretically acceptable continuum equations. They do, however, involve some degree of lumping since analytical solutions to the equations cannot be found, and so approximate numerical solutions, based on a finite

difference or finite element discretization of the space and time dimensions, are implemented.

Many rivers in Nepal are either ungauged or poorly gauged due to extreme complex terrains, monsoon climate and lack of technical and financial supports. In this context the role of hydrological models are extremely useful. There is various type of distributed model and they have their own capabilities and efficiency to simulate the catchment's response.

This thesis presents a way to widen the applicability of DHSVM such that it can be used perfectly in the mountainous as well as flat terrain. The huge amount of surface storage in plain area in the results of DHSVM is reduced by the modification of Input DEM and forcing water to flow in the direction of river network. The use of a subroutine named as Non-Ponding model after DEM burning technique heavily reduce the surface storage and gives more accurate simulated flow. The reduction of surface storage up to 65% increases the efficiency by more than 10% in case of the study area. The study area taken for this study purpose was Bagmati basin at Gaurighat and ARC VIEW GIS had been applied for preparation of input data. The Nash efficiency and the volume of surface storage after applying the modified DEM are parameters which show the enhancement of results after applying DEM modification technique using Non Ponding model.

This study has thus, make an attempt to present an approach to reduce the surface storage and enhance the output of the DHSVM in flat area.

Thesis Title: **RESERVOIR MANAGEMENT CONSIDERING DIFFERENT HYDROLOGICAL CONDITIONS: A CASE OF KULEKHANI RESERVOIR**

Submitted by: **Gopal Prasad Mainaili**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT

Kulekhani reservoir is the only power plant with seasonal regulation capable of meeting the peak power demand of the power system of Nepal. The historical operation of Kulekhani reservoir is found to be done without taking into consideration of the variations in the hydrological conditions from one year to another. This research is thus aimed at developing an optimal operation policy of Kulekhani reservoir considering three hydrological conditions, namely, the wet, normal and dry conditions. A Discrete Dynamic Programming (DDP) model with an objective function of minimizing the squared deviation between demand and supply is developed and applied.

The historical streamflow data for the Kulekhani River is analyzed to define three types of hydrological conditions. Normal hydrological condition is defined as the years with the streamflows within 20% of the long-term average flows. If the

yearly flow is less than 80% of the long-term average flow is considered "dry" and years with more than 120% of the long-term average is considered wet.

Rule Curves for dry, wet and normal years is generated using the DDP model. Using the available 40 years of data, a synthetic 100 years of data was generated using the Thomas Fiering method. The generated rule curves are then simulated for 100 years.

Performance Evaluation of the simulated results was then carried out in terms of hydropower generation. The performance of the three types of rule curves for three hydrological conditions was evaluated. The performance indicators used were the average, 80% dependable and 20% dependable monthly energy generation. Reliability analysis in meeting the given energy demand was also undertaken using indices such as reliability, vulnerability and resilience. The performance of the three rule curves, Dry Rule Curve (DRC), Wet Rule Curve (WRQ and Normal Rule Curve (NRC), were found to perform better in the respective hydrological conditions. Hence, it is recommended that the operation of the Kulekhani reservoir should not be based on a single general policy, as has been the practice, but should be based on appropriate hydrological condition.

Thesis Title: **OPTIMIZATION OF DRINKING WATER SUPPLY IN KATHMANDU VALLEY**

Submitted by: **Ashish Pradhan**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT

Over recent years, the level of water supply services provided to the urban population of Kathmandu Valley has been very poor. Water supply service is only available on an intermittent basis for about two hours every two to three days and even then the pressure is low and the quality poor. Resultantly, users have suffered acute shortages and inequitable and unhygienic distribution.

It is one of the challenging tasks to maintain efficient water supply distribution in rapidly urbanizing city like Kathmandu Valley. The study is thus aimed to optimize water supply in this present inequitable supply scenario. The study is carried out by defining three different models with different objective functions. Model 1 has the objective function of minimizing demand deficiency considering only magnitude of demand. Model 2 has the objective function of minimizing the percentage of demand deficiency thereby ensuring equity in demand centres.

And, Model 3 defines the objective function which minimizes the maximum demand deficiency.

The main input data used in model are Supply Source Data and Demand Data. The present water supply in Nepal is governed by NWSC (Nepal Water Supply Corporation). In this study the Kathmandu Valley is divided into 20 demand centres. There are altogether 8 water supply systems. These systems are served with surface water sources and groundwater sources.

GAMS (General Algebraic Modelling System) is used to solve the developed models. There are altogether 6 scenarios analyzed in this study considering present, future and hydrological conditions (dry and wet). Prioritizing in meeting the demand in certain demand centres are applied using a penalty function that penalizes the deficit in supply in demand centres which has higher priority. The water allocation in different demand centres are analyzed for different hydrological conditions of supply. A scenario after Melamchi project is also assessed.
It can be concluded from the present study that the water supply condition in Kathmandu Valley is not enough to meet the water demand. However, this use for the model presented here can help in proceeding supply to certain demand centres as well as ensuring equitable water distribution.

Thesis Title: **BENCHMARKING SMALL HILL IRRIGATION SCHEMES: A CASE STUDY OF 5 SCHEMES AS SURKHET AREA**

Submitted by: **Man Bahadur Rai**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT

As water is a precious and scarce resource, importance of its optimum utilization is obvious. Benchmarking irrigation is a recent tool to assist the irrigation management body to improve the performance of organization. The benchmarking irrigation is a performance evaluation and external comparison technique, which finds the gap between the reference scheme and the best performing scheme. This gives the opportunity to improve the operation and management procedure. There are six stages in benchmarking: 1. Planning and identification, 2. Data collection, 3. Analysis, 4. Integration, 5. Action and 6. Monitoring and evaluation.

The main objective of present study was to find the suitable indicators for benchmarking small hill irrigation schemes. It is also intended to compares the five small hill irrigation schemes around Surkhet area with the help of benchmarking technique. Indicators generally used in large irrigation and drainage system

are revenue and environment oriented, which is not relevant to small hill irrigation schemes. These schemes .are to be benchmarked for food production and sustainability.

Multiple Criteria Decision Making Technique (MCDM) is used to rank the projects based on 16 criteria under three main criteria of resource delivery, financial performance and productive efficiency regarding multiple criteria's. The alternative with shortest distance is the best project. Without using this tool we can only compare the project in the one by one basis of indicators. This tool enabled to have overall evaluation and comparison of the projects.

Thesis Title: **APPLICATION OF A DISTURBED HYDROLOGICAL MODEL - BTOPMC IN NARAYANI RIVER BASIN**

Submitted by: **Sagar Aryal**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT

Nowadays, many researchers focus on the distributed hydrologic process, because it is regarded as more physically based and much closer to reality. BTOPMC (Block wise use of TOPMODEL with Muskingum-Cunge flow routing method) is one of the physically based distributed hydrological models.

In this model Muskingum-Cunge method routes the simulated block wise TOPMODEL runoff to the downstream. The Narayani River basin, one of the largest river basins of Nepal, has been selected for this research work. For this study the whole Narayani river basin is divided into six sub-basins.

During this research, the Nash efficiency at main outlet of Narayani river basin is 88.62% in calibration. Similarly, for validation the Nash efficiency is 88.03%. BTOPMC model is calibrated and validated for all sub-basins. The calibration period is from the start of 1997 to the end of 1998. The data from start

of 1999 to end of 2000 is taken to validate the calibrated parameters.

It is advantageous to use BTOPMC for poorly gauged or ungauged basins as it can utilize various global datasets available in public domain. The result shows that the model performs reasonably well for most of the sub-basins of Narayani river basin.

Thesis Title: **APPLICABILITY OF SEMI-DISTURBED HYDROLOGICAL MODEL (BTOPMC) IN BAGMATI RIVER BASIN**

Submitted by: **Sanjeeb Baral**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT

BTOPMC (Blockwise use of TOPMODEL with Muskingum cung flow routing method is a physically based semi distributed hydrological model that uses the Geographic information system in terrain modeling. The digital stream network is built after removing the pits in original Digital Elevation Model (DEM). Muskingum Cung method routes the simulated block wise TOPMODEL runoff to downstream. Introduction of block wise approach to the TOPMODEL with Muskingum-Cunge flow routing method (BTOPMC) has enhanced the applicability of TOPMODEL from hundreds of square kilometers to several ten thousand square kilometers river basins. In the block wise approach, modeled watershed is divided into several imaginary blocks and local saturation deficit which controls the depth to the saturation zone is calculated with respect to the block average saturation deficit value. The model parameters namely, lateral transmissivity under saturated conditions, decay factor, maximum root zone storage, and flood plain Manning's

coefficient, are assigned as functions of land use. Basin physical characteristics such as topography, soil and vegetational activities control the hydrological processes within the watershed. BTOPMC model has the capability of accounting these properties.

The BTOPMC model is applied to simulate hydrological processes in the Bagmati River Basin at Karmiya. The model is calibrated and validated for 1999, 2000 and 1997, 1998 daily rainfall runoff. Both subjective and objective methods are applied to test the goodness of fit of simulated and observed hydrographs. The results are satisfactory with Nash efficiency as much as 79% in calibration and 76% in validation. The annual peak, monthly average stream flow, and monthly high and low flow simulation using the model is relatively good. The results showed that BTOPMC is a good tool to model the hydrological process Bagmati river basin.

One of key inputs to hydrological modeling is the potential evapotranspiration, either from the interception (PETo) or from the soil water of root zone (PET). The Shuttle worth- Wallace (S-W) model is developed for their estimation and linked to BTOPMC. In this parameterization, neither experimental measurement nor calibration is introduced. Based on IGBP land cover classification, the typical thresholds of vegetation parameters are drawn from the literature. The spatial and temporal variation of vegetation LAI is derived from the composite NOAAAVHRR NDVI using the SiB2 method. The CRU database supplies with the required meteorological data. They are all publicly available.

The potential evapotranspiration is also calculated from the modified FAO Penman's equation by the use of local datasets available from the DHM. The reliability of using the global datasets in the distributed, hydrological model like BTOPMC is checked comparing the results with the outputs using the local datasets. Using the century monthly time series of CRU TS 2.0 and the monthly composite NOAAAVHRR NDVI from 1997 to 2000, annual PET is estimated 1106 mm over the Bagmati River basin and using the daily maximum temperature, minimum temperature and daily average relative humidity from 1997 to 1998 from DHM, the annual PET is estimated as 1107mm.

From this study, the result from the S-W model by using the global datasets and modified Penmans equation by the use of local datasets are very close. Hence, the use of public available dataset in the developed S-W model is applicable at the global scale, particularly to the data-poor or ungauged large basins.

The another purpose of this study is to analyze the effect of resolution of DEM in the hydrological response of the catchment. The Nash efficiency using 250m resolution DEM is found to be 73% in the year 1999 - 2000 and 74% in the year 1997-1998, where as the volume error is -0.3% in 1999 - 2000 and 18% in 1997-1998. The resolution of DEM does not improve the Nash efficiency but due to the finer resolution DEM the topographic index value of the grid is increased and the runoff from the watershed is increased. As the increase in the value of topographic index make it easier for the grid cell to be saturated or the easier for overland flow to occur.

Thesis Title: **COPREHENSIVE ASSESSMENT OF WATER RESOURCES AND OPTIMAL USE PLAN**

Submitted By: **Dinesh Bhattarai**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT

This thesis is an attempt to identify the best possible utilization of the available water resources given certain constraints of the basin. A study carried out by WECS in Gandaki basin revealed that the basin is not being used to its potential during the monsoon seasons, however during dry seasons; the available flow diminishes to very low level giving water shortage in the rivers that are not snowed. So there is a need of development of Basin model both comprehensive and hybrid types. The study also recommended developing geographical information system (GIS) of the basin with emphasis on water use, river system and landing utilization for better monitoring of the physical processes. This study is an attempt to look into the long term planning aspect of Marsyangdi River Basin.

This thesis presents a systematic approach for the combined use of GIS, CROPWAT 7.0 and MODSIM for optimum utilization of the water resource. With the use of GIS, performing DEM

analysis along with the land selection criteria in slope classification (less than 15%); soil type (Alluvial and Colluvial), and within the reach of 3 Km distance from the tertiary river tributaries of Marsyangdi River, the total potential irrigable land resource is reclaimed as 70,133 Ha. out of which only 22,973 ha of land is presently irrigated. Irrigation water requirement is calculated using CROPWAT 7 and drinking water demand is estimated for present and future population within the basin. Various scenarios have been simulated using MODSIM in order to determine the water balance (surplus and deficit) for the different water uses and priorities of the water resources components of the river basin .After performing water balance with MODSIM at six nodes of Marsyangdi River, average annual demand of 39 m^3/s of water is required to irrigate 70,133 ha of potential irrigable land and to meet future drinking water demand. After meeting cumulative annual demand of 469.35 m^3/s of water, there is still cumulative annual surplus water of 2062.24 m7s available for downstream riparian use.

The findings of present study provide the general guidelines for basin wise planning of water use. It can be concluded that the procedure adopted like the one used in the present study can be of great use for making rational and optimal decisions.

Thesis Title: **APPLICATION OF MASSCOTE METHOLOGY FOR MODERNIZATION OF IRRIGATION SYSTEM: A CASE STUDY OF MAHAKALI IRRIGATION PROJECT**

Submitted By: **Ran Bahadur Bam**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The effective use of irrigation system in Nepal is challenging because of the complex nature of the problems involved. Most systems are not operating at the desired level of performance due to the lack of coordination between the management and the users, resource availability for O & M, low level of awareness among the general public about the effective use of irrigation water and irrigation system management. In every irrigation system, there are three interest groups regarding the irrigation service: the farmers, the implementing authority for irrigation and drainage and the policy making central authority. Water service in irrigation sector comprises of the delivery of water to individual users or a group of users and also comprises the delivery of water from higher level of system to lower level of system.

Modernization of irrigation implies the interventions in different components of irrigation system. It provides an opportunity to define and update the procedure within the irrigation system. The present study of modernizing water services included the objective of exploring the adequacy and equity of water at main canal level and the farmers' satisfaction towards the water management done by the system. The system Mahakali Irrigation Project is taken for the case study.

The Mahakali Imgation Project is a major irrigation system in the far west of Nepal. Total net command area under Stage-I is 4800 ha, Stage-II is 6800ha and proposed (to be started from 2006) Stage-Ill is 33520 ha. Stage -I was started from 1980 and was completed in 1988. Similarly Stage-II was commenced in 1986 and completed in 1998. Both were financially assisted by (IDA) World Bank.

This study followed the MASSCOTE methodology. It began with data collection and analysis and finally ended by drawing conclusions and suggestions on how the system can be modernized to improve the water service. The study is includes several research parameters viz. water balance, sensitivity, hydraulic flexibility of control structures, cost for O & M and water management practices.

MASSCOTE has been recently developed to modernize the irrigation system. This gives the opportunity to improve the operation and management procedures and strategies. There are major 12 steps in MASSCOTE e.g. Rapid Appraisal Process (RAP), mapping system and sensitivity, mapping water networks & water balances, mapping the perturbation, mapping the cost of O&M, assessing demand for operation, identifying canal operation improvements, partitioning into management subunits, Asset Management Plan, and preparation of a Modernization Plan and its monitoring and evaluation. Out of all these steps, Asset Management plan is an additional step recommended for the irrigation system management transfer to WUA.

From the water balance analysis, it is found that water requirement is 332 MCM and supply is 216 MCM, so demand is higher than supply. In winter season water supply is fixed at 4.25 m3/s from headworks, which can irrigate only 2890 ha in continuous supply basis, but crop intensity in the winter season is seen 98.30% which means that the irrigated area to be 10497 ha. To solve this problem, rotation system should be strictly applied with one week “on” and 3 week “off” practice. All levels of performance e.g., Service Delivery Indicators, Water Balance Indicators, Financial Indicators, Agricultural Productivity and Economic Indicators have been find out and compared with 16 foreign irrigation projects and two Nepali irrigation projects which were RAP has been conducted through FAO *TTRC* and World Bank.

Graduation Year 2008

Thesis Title: **RUNOFF MODELING OF GLACIERIZED WATERSHED; A CASE STUDY OF IMJA WATERSHED**

Submitted by: **Manoranjan Kumar Singh**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Water balance model is a deterministic model developed by Crawford N. H. in 1981. This is a monthly rainfall-runoff model which defines three parameters *Nominal, PSUB* and *GWF* for a catchment. *Nominal* is a soil moisture level expressed as a fraction *C* of mean annual precipitation and an excess of moisture from this level is known as excess moisture. This excess moisture causes direct runoff and recharge to groundwater. *PSUB* is the fraction of excess moisture contributing to the ground water storage. *GWF* is a fraction of ground water storage that will flow as base flow to the stream. The excess moisture in any month is a function of soil moisture condition of that month. Crawford has given a graph in the form of S-curve for reading excess moisture for a given soil moisture condition. Similarly Actual Evapotranspiration (AET) is dependent on soils moisture conditions, Precipitation (PPT) and

Potential Evapotranspiration (PET). Crawford has given another graph for determining AET for varying soil moisture and ratio of PPT to PET. To optimize the model parameters graphs are read manually to find excess moisture and AET for every month. Several such readings of graph need to be taken manually at each trial, until the observed and simulated hydrographs approximately overlaps each other. This is a time consuming and tedious procedure for optimizations of model parameters. This is the main problem identified with the use of water balance model.

The objective of the present study is to develop software for automatic optimization of the model parameters, in order to, overcome the problem of manual optimization. The complexities associated with the graphs are solved with some simplified assumptions. The graphs are replaced by the equations of straight lines and then a formula was derived to compute discharge, ground water storage and soil moisture storage within the conceptual framework of water balance model. The discharge formula consists of PPT, PET, soil moisture storage, ground water storage and the model parameters *PSUB, C* (or *Nominal)* and *GWF*. The assumption made is that there will' be little variation in the values of AET and excess moisture obtained from reading graphs and those obtained after simplification.

For automatic optimization of the model parameters software named as HYDMODSIM is developed. In the present thesis Least Square Method (LSM) and Genetic Algorithm (GA) search techniques are applied to the water balance model in developing this software. To calibrate the model the input requirements are observed time series data of PPT, PET and discharge (Q). Minimizing the sum of squares of differences of observed and simulated discharge and hence maximizing the Nash Sutcliffe efficiency is taken as the objective function. The optimum parameters of the model for a given catchments will be the one those meet the criteria of objective function. The genetic algorithm search method used simple genetic algorithm with binary encoding and roulette wheel selection method. To run the software GA parameters are given in the beginning of run. The appropriate value of GA parameters population size (*PSize*), number of generations *(NGen*), probability of crossover *(Pc)* and probability of mutation *(Pm)* are determined by the sensitivity analysis of the GA parameters with the water balance parameters.

The Performance of the software was checked with monthly hydro-meteorological time series data (from 1981 to 1990) of two study basins in Nepal. One is Tadi basin located in Nuwakot district and another is Chamelia basin in Darchula district.

Parameters for the study basins were optimized using HYDMODSIM software.

The HYDMODSIM software proved to be fast and efficient in automatic optimization of the two of the model parameters *PSUB* and *GWF*. The third parameter C was ascertained with the visual verification of the observed and simulated hydrographs. The optimized parameters C, *PSUB, GWF* for Tadi Basin is obtained as 0.195, 0.340 and 0.190 respectively resulting in 80 % Nash efficiency and 6% relative error. Similarly the parameters *C. PSUB* and *GWF* values for Chamelia basin are 0.20, 0.63 and 0.239 respectively resulting in 82% Nash efficiency and 8% relative error. These results shows that HYDMOSIM based on the concept of water balance model with some simplification and using the genetic algorithms and least square method fulfilled the objective of the automatic optimization of the model parameters. However there is a limitation that the value of parameter C should be finalized only after the visual verification of the hydrographs of observed and simulated flows.

The results of the sensitivity analysis of the genetic algorithm parameters with respect to model parameters show that *PSize* of 100, *NGen* equal to 200, *Pc* of 0.75 to 0.80 and *Pm* of 0.02 to 0.06 successfully explored the optimum solution (parameters).

Thesis Title: **RUNOFF MODELING OF GLACIERIZED WATERSHED; A CASE STUDY OF IMJA WATERSHED**

Submitted by: **Maheswor Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Prediction of snow and glaciermelt runoff from high mountainous watersheds is essential for planning as these glaciers play a vital role in local hydrological processes, and act as a repository of information for exploring quaternary climate changes. Thus, the main objective of this study is to estimate snow and glaciermelt from both debris free and debris covered glaciers by the surface energy balance over the whole watershed and to simulate the river discharge by application of lumped conceptual precipitation runoff (TANK) model for which input variables are based on secondary data.

The model is used to simulate the daily runoff from 38% glacierized watershed of Imja Khola. The aerial distribution of watershed area having its characteristics including debris free and debris covered glaciers, meteorological variables in 20 altitude bands of 200 m and the river discharge data at the outlet of the watershed are the foremost inputs for the model. The snow and glacier melt for each altitude band is calculated by surface

energy balance and mass balance models. The glacier melt under the debris layer is estimated from thermal resistance and meteorological data. The average ratio of effective thermal resistance to critical thermal resistance (R/R_c) of the debris layer has been estimated from surface temperature of the debris which is obtained from spatial modeling of Landsat 5 (TM Band 6). A simple empirical relation is used to define the type of precipitation. The precipitation as rainfall, snow and giaciermelt in all bands are averaged and used as input to the conceptual TANK model for runoff simulation. The model efficiency is found to be around 86%. The coefficient of determination indicates a strong correlation between simulated and observed hydrograph.

The sensitivity analysis of the results with respect to input parameters such as air temperature, solar radiation, relative humidity, surface albedo and the ratio of R/R_c are performed. It is found that the melt is strongly sensitive to air temperature, relative humidity and the ratio of R/Rc. The life and volume of ice reserves are computed for present scenario and for temperature rise of 0.03°C.yr^{-1} to 0.12°C.yr"^{i}. Without further climate warming, all the glaciers in the watershed disappear by the year 2047 and if the temperature rises at the rate of 0.06°C.yr"' provided that all the other climate parameters remains same, all the glaciers will be melted out by 2025.

Thesis Title: **ASSESSMENT OF HYDROPOWER POTENTIAL (A CASE STUDY OF KALIGANDAKI RIVER BASIN)**

Submitted by: **Devi Ram Thapa**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

HEC-HMS is designed to simulate the precipitation-runoff processes of dendritic watershed systems. The extension like GEOHMS has been the most powerful tool to perform the task related with river stream generation and basin delineation. As an improvement to statistical methods and lumped models, GeoHMS coupled with HECHMS seems to be the best-suited model that satisfies the requirements to meet the objectives of this study and used in the present study.

Digital Elevation Model (DEM) is a matrix in which the elevations are given as different points, which were used to calculate the hydraulic head at upstream and downstream end of the stream segments and extract channel physical parameter. HEC-HMS model was used to predict long-term daily discharge at every node of the stream segment with Nash efficiency ranging from 44% to 55% for calibration period and 60% to 90% for validation period. It is also found that volume deviation

ranging from -8.8% to -41.2% in calibration period and 0.78% to -20.86% in validation period. Upstream and downstream ends stream flow records were used to calculate the average daily flow. Designed discharge corresponding to 65% flow, mean annual discharge and discharge at providing the suitable dam height were calculated at every node to estimate the power potential KaliGandaki River.

Gross power potential of the study area of the. KaliGandaki basin is estimated 48*44.32* MW with total energy 32818.58 GWh. At providing suitable dam, total power potential is estimated 3069.14MW with energy 20749.21 GWh.

The median power potential is estimated at 1234.36 MW with 1066.53 from Main River and 167.62 MW from tributaries. At this theoretical capacity at 65%, stream segment is divided into different pattern to calculate maximum power. When river channel is assumed to single segment power potential was obtained 1783.39 MW. River is divided into two segments in different node maximum power potential estimated 1818.75MW. River segment vary from top to bottom in different node, obtained maximum power 1837.64 MW in four segments. At river segment vary from bottom to top, obtained maximum power 1685.58MW divided into two segments. The total annual energy at median power potential is estimated 8716.45 GWh. The small power potential i.e. theoretical capacity 95 percentile is estimated at 665.40 MW with 575.34 MW for main river channel and 90.06 for tributaries. The firm energy for the whole catchment is 4996.82 GWh.

Thesis Title: **ROUTING OF THE FLOOD WAVES FROM SUBWATERSHED OF KOSHI BASIN AT CHATARA**

Submitted by: **Jaya Ram Bhattarai**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Koshi basin is the largest basin of Nepal which is sparsely gauged, so temporal and spatial variation of rainfall as well as catchment characteristics is prominent. It has not been tried to establish the system of flood forecasting in Koshi basin at outlet Chatara though daily hydrological and metrological data are available. This study might help for developing the flood warning system. To make the system effective it needs an event base data i.e. hourly data is not available in Nepalese context. Therefore the system has compelled to execute this study in semi distributed daily rainfall runoff model. Before forecasting it is essential to know the lead time of the flood wave from different watersheds to an outlet. Routing is the one of the best means of finding out the lead time at an outlet after the rainfall at different sub basin. This study is thus aimed at identifying the sub basin responsible for apparent lagging of peaks in daily flows using the technique of routing.

Continuous semi distributed model like Hydrologic modeling system provides a promising new approach to sparsely gauged catchment rainfall-runoff modeling which is daily flow model. It would be precise to forecast the time in hours if there had been event base data available in our Nepalese context. To the date, there is not the system of measuring hydrological and metrological data in hours in the context of Nepal so it has compelled to do the study in daily model. To achieve the goal of the study Geographic Information System tools has used with its extension Geospatial Hydrologic Modeling System and Hydrologic Engineering Center's River Analysis System for the generation of required parameters.

Long term daily discharge for the entire catchment is estimated using Green and Ampt infiltration loss method. All the physical parameters of river and sub basins resembling slope, length and width are generated from Hydrologic Modeling System using the Digital elevation model with. 5m contour interval. From the model it is obtained that the Nash efficiency ranges from 37% to 89% for the calibration and 35% to 87% for validation period.

Rainfall is the foremost factor for determining the flood peak and time of travel. Travel time or lead time of the flood wave from different sub basins to outlet are different in nature as per the distance located. During the course of study it is established that most of the remotely located basins which provide the peak flood to outlet Chatara in second day after the time of rainfall namely Balephi. Sunkoshi, Tamakoshi, Dudhkoshi, Likhu and Khimti whereas few sub basins which are located nearby to an outlet provide the peak flood in the same day namely Uwagaon, Tudkeghat, Majhitar and Mulghat. Likewise very few sub basins which are closely located provide the peak flood in hours. The diffusion effect has also clearly demonstrated since the peak of the flood waves return back to normal flow after 3 days which differs as per the length and cross section of the river.

Graduation Year 2009

Thesis Title: **ASSESSMENT OF SNOW AND GLACIER MELT-WATER CONTRIBUTION ION STREAM FLOW AND ITS RESPONSE TO CLIMATE CHANGE: A CASE STUDY OF KOSHI BASIN IN NEPAL**

Submitted by: **Sanat Kumar Karmacharya**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The perennial rivers that originate from high Himalayas are the major source *of* water during dry seasons when we need them the most. The flow in such rivers during dry seasons is supplied by melting of snow and glaciers-the natural frozen water reserves in the high altitudes. That's why they are often referred as the Water Towers. Besides being an important natural resource for socio-economic activities of humans, the snow and glaciers are repositories of information on global climate change scenario. *So,* this study makes a simple attempt to estimate the contribution of snow and glacier melt discharge in stream flow and to estimate the change in snow and glacier melt contribution with respect to changed temperature conditions.

In this study, Koshi basin in Nepal is selected as the study area. 22 glacierized watersheds are delineated. The snow and glacier melt discharge data for each of these watersheds are adopted from a different study in which they are estimated for year 2002 by applying energy budget method aided with a conceptual TANK model. This study uses that data as input in HEC-HMS model along with the precipitation and stream flow data. 12 stream flow gauging stations inside study area are selected. The calibrated and validated model in HEC-HMS is run for year 2002 to estimate the snow and glacier melt contribution to total flow at those stations. The glaciers are grouped into 7 sub-basins and the contribution of each of them to flow at downstream stations is also assessed. Finally, the model is simulated for snow and glacier melt data estimated for increased temperature conditions to represent the response of flow in snow and glacier fed rivers to global climate change.

At the most downstream station 'Chatara', the. contribution of snow and glacier melt discharge to annual flow is about 8.46% with a maximum monthly contribution of 22.52% in May and a minimum monthly contribution of 1.86% in January. The snow and glacier melt discharge from Dudh Koshi sub-basin has maximum contribution to annual flow at Chatara (2.51% out of total 8.46%) whereas the Indrawati sub-basin has the minimum contribution (0.15% out of total 8.46%).

Results of sensitivity tests show that, among the selected stations, increase in snow and glacier melt contribution due to rise in temperature is highest for total flow at Uwagaon station. And the flow at Indrawati (Dolalghat) has the minimum response to rise in temperature.

Thesis Title: **RUNOFF MODELING OF GLACIERIZED WATERSHEDS OF KOSHI BASIN IN NEPAL**

Submitted by: **Subash Tuladhar**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The mountainous rivers receive significant contributions from the snow and glacier melt. So, there is a pressing need for modeling ice and snow melt from the high Himalayas for sustainable water resource management, flood forecasting, as well as the in the study of glaciers' response to climate change. Koshi basin in Nepal covers the major snowfed and glacierfed rivers from the Himalayas. In this perspective, this study deals with the runoff modeling of the glacierized watersheds of Koshi basin in Nepal.

A conceptual TANK model is used for runoff modeling from the 22 glacierized watersheds above 4000 masl elevation after calculating snow melt and glacier melt from surface energy balance model for the year 2002. The glacierized watersheds are distributed into 16 altitude zones of 300m each and are differentiated into debris-covered and debris-free glacier area and rocky areas. The hydro-meteorological data from the 2 stations -

Dingboche in Khumbu and Kyanjing in Langtang are used in the study. With regards to the proximity of the stations, 11 watersheds are associated with Khumbu while the rest 11 are associated with Langtang. Thermal resistance and meteorological data are used to calculate melt from debris-covered glaciers. The calibration of model for Langtang station shows the model efficiency of 95.93% and R - value shows a good correlation between observed and simulated hydrographs. The calibrated parameters of the station are used to generate runoff from the watersheds associated with the station. While that for the watersheds associated with Khumbu station, the previously calibrated parameters are used to estimate runoff. The simulated runoff from these 22 watersheds are then passed on to the next model where they are used as inputs to simulate discharge of whole Koshi basin including snow melt and glacier melt.

Snow and glacier melt volumes from seven sub-basins of Koshi basin are also estimated. Arun sub-basin contributes higher while Likhu sub-basin contributes least in the melt volume.

Thesis Title: **ENERGY MAPPING USING GIS AND HYDROPOWER MODEL IN KARNALI, MAHAKALI AND WEST RAPTI RIVER BASINS**

Submitted by: **Sudip Prakash Adhikari**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT

The major objective of this study is to calculate the theoretical power potential of western Nepal. The Karnali, Mahakali and West Rapti River basin have been selected for this purpose.

The vital input for Hydro data model is DEM. After processing of DEM with the help of GIS, the output in the form of ESRI ASCII files is obtained. The objective function of newly developed HYDROPOWER MODEL in conjunction with hydro data model is to calculate the theoretical power potential with help of upstream and downstream discharge. Power potential of Run Off River (ROR) is calculated at 40^{th}, 50th and 60^{th} percentiles of flows for basin, sub basin and require elevation band. The result at 40 percentiles of flows is described below.

The result shows that the total energy for Karnali, Mahakali and Rapti basins are 102324 GWh, 14981 GWh, 2951 GWh and the

installed powers are 15661 MW, 2262 MW, and 439 MW for the above respective basins.

In the same way while calculating the power in elevation band, the total power potential for Karnali and Mahakali are 96325 GWh 13318 GWh for elevation below 4000 m and 5999 GWh, 1663 GWh for greater than 4000 m on respective basins. Correspondingly the installed powers are 14729 MW, 2041 MW for elevation less than 4000 m and 932 MW, 221 MW for greater than 4000 m on respective basins.

The total energy and installed power of Mahakali basin after taking into consideration India's drainage area (India and Nepal) are 40054 GWh and 6142 MW respectively.

Also, the total power potential and installed capacity of Nepal's after adding Mr. Rupesh Kumar Sah's (063/MSW/419) results (By the use of similar model during the same period for Kosi, Narayani, Bagmati and Kanakai basin) are 346538 GWh and 53836 MW respectively.

Hence, after doing the verification on existing Jhimruk Hydropower Project of western Nepal, analysis shows that the variation of installed power is within 12.5 % ranges. So it might be within tolerance. Hence, the methodology applied for this study is valid.

Thesis Title: **ENERGY MAPPING USING GIS AND HYDROPOWER MODEL IN KOSHI, NARAYANI, BAGMANTI AND KANKAI BASIN**

Submitted by: **Rupesh Kumar Sah**

Supervisor: **Dr. Raghu Nath Jha**

ABSTRACT

The major objective of this study is to evaluate the total theoretical power potential of the basin of Nepal. In this study, the observed data is processed and design discharge at different percentile is calculated. With the assistance of GIS Software, linked together with additional two new model (hydropower and Hydro data Model), the work has been accomplished. Head calculation, catchment area delineation are done with the aid of GIS and the added models.

Hydro data model is a built-in model of GIS. This model works as a pre-processor of the main model. The main model is the hydropower model which is developed in FORTRAN. The main purpose of the model is to calculate the power using monthly discharge data and output of the hydro data model.

Power is further calculated in two aspects. The aspects being Basin and Elevation wise. Gross installed power potential of the study area of Koshi, Narayani, Bagmati and the Kankai basin are estimated as 17008MW, 17800MW,424MW and 241MW with the total energy estimated as 108817 GWh,l 13373 GWh,2574 GWh and 1517GWh.

Similarly, total installed power potential and total annual energy of Koshi and Narayani basin, elevation above 4000m is estimated as 16167MW, 16120MW and 1035124GWh, 102884GWh respectively.

Likewise, total installed power potential and total annual energy of Koshi and Narayani basin elevation below 4000m is estimated as 539 MW, 1680MW and 5304GWh, 10489GWh respectively.

Hence, while sum up the result of Sudip Prakash Adhikari and Rupesh Kumar Sah, The total installed power and annual energy of Nepal using hydropower model estimated as 53836MW and 346538 GWh.
The latitude-longitude of the Klimt and Bothe Koshi are plotted in GIS and the existing data in terms of hydro power of Khimti and the Bhote Koshi is plotted over the graph with the newly

generated power of this project. The result of which is 17% to 1% in favor to the newly installed power over the existing power.

Thesis Title: **IRRIGATION OF ARTIFICIAL NEURAL NETWORK WITH CONCEPTUAL MODEL IN RAINFALL RUNOFF MODELING: A CASE STUDY OF GANDAKI RIVER BASIN**

Submitted by: **Dinesh Bhatt**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Rainfall-runoff models play an important role in water resource planning and management. The increase need for the accurate estimation of the stream flow call for the integrated approach of rainfall runoff modeling. A neural network method is considered as a robust tool for modeling many of complex non linear hydrological processes.

The present work reports the research work conducted for the application of a hybrid form of rainfall-runoff models that integrates artificial neural networks (ANNs) with Soil Moisture Accounting and Routing (SMAR), a lumped conceptual model. Based on this integrated approach, the spatial variation of the rainfall over the catchment can be investigated. The non linear transformation of the runoff generated from the individual sub catchments into the total runoff at the catchment outlet is carried

out using artificial neural network. The performance of the integrated model is compared with both the models in isolation with the same set of calibration and validation data. The simulated result is compared with the observed stream flow data at the catchment outlet and statistical analysis has been carried out for the performance assessment. The study result indicates that integration of artificial neural network with conceptual model can represent the process of rainfall runoff transformation with the acceptable degree of accuracy. While the combination approach has proven useful in Gandaki river basin, it should be applied to other catchments with a wider range of climatic variation and condition to test its generality.

Thesis Title: **ANALYSIS AND SIMULATION OF DEBRIS FAN FORMATION USING A 2D-DEBRIS MASS MODEL**

Submitted by: **Badri Prasad Sharma**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Rainfall related events like landslides; debris flows and flood are natural processes and thus cannot be avoided. But the disasters related to these phenomenon can be minimized. Nepal losses a number of human lives and billions of money for physical properties every monsoon due to water induced hazards. This is due to burial or impact of debris flows to buildings and other land.

Debris flows, which look like fast-moving rivers of wet concrete, are capable of transporting huge boulders measuring several meters in diameter and their velocity can be such more that they can destroy everything in their path. Because of their relatively high density and viscosity, debris flows can smash, move and even carry away with them the objects as large as buildings, bridges, vehicles and other properties. So houses and roads at the base of steep slopes in or near gully outlets are in the most hazardous locations. Debris flows move faster than a person can

run. Debris flows happen so rapidly that there is really no way to monitor one until it is on top of us. Thus, people living in these types of locations should have a safe time to evacuate when a debris flow is to be occurred.

By combining non-structural and structural measures, the losses due to rainstorm induced hazards can be reduced in a substantial amount. Careful and managed development of hillside, use of modern tools, techniques and methodologies to analyze and predict debris flows phenomenon can extensively reduce their impact on human lives. Non-structural measures such as zoning of the risk-prone areas, quick warning systems for flood forecasting; predicting their occurrence and impact, and safe areas to escape from such disaster prone areas are some aspects that can be considered.

This thesis focuses on analysis and simulation of debris fan formation at the outlet of a gulley, due to the debris volume produced by a rainstorm. For this, a 2D- Debris Mass Model is used which calculates the final topography after debris event, for the initial topography of the fan, provided that debris volume at the outlet of the gulley (or entrance of the debris fan) is known. Gaijuwa Watershed Basin on Dharan-Dhankuta Road is chosen as case study site for the modeling. Results indicate that for the same topography, the extent of the debris fan is much more influenced by the volume of the debris and less affected by whether the fan is formed continuously or discontinuously. The results show that the model if combined with GIS based technique can be a useful tool for the assessment of risk prone areas for burial by debris at a gulley outlet.

Thesis Title: **CDM BENEFITS FROM MICRO-HYDROPOWER PROJECTS**

Submitted by: **Babu Ram Paudel**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT

The main objective of this study is to find the contribution of MHPs for the GHGs emission reduction and assessment of plant's operational performance and its impact on socio-economic condition. This research deals with the plants ranging from 5kW to 100 kW promoted by Alternative Energy Promotion Centre (AEPC) through its two programs namely; Energy Sector Assistance Program (ESAP) and Rural Energy Development Program (REDP) under Ministry of Environment, Science and Technology (MoEST).

For the study purpose, sample plants were selected based on different criteria mainly; supporting program, ownership type, size of plants, ecological zone, development region, and installation year. Thus altogether 29 plants (around 14% of total plants (>5kW) population) and 566 households were selected for the survey. Structured questionnaires were used for both plants and households to collect the information.

This study reveals that MHPs have significant role in mitigating GHGs emission hence promoting environmentally friendly and sustainable development of the rural community. So, MHPs seem feasible from CDM perspective. The emission reduction from 1 kW installed plant in a year was found as 2.82 tons of C02e. While average load factor of plants is 34%, the emission reduction per kWh is 0.95kg C02e which is higher than IPCC default emission factor (0.8kg C02e/kWh). Financial Analysis of a hypothetical plant of 25kW installed capacity shows that financial IRR of the plant can be increased by 3.8% if revenue is generated at approximate rate of US$10 per unit CER from CDM for 15 years of project life. The revenue generated from carbon trading can help further for the implantation of other MHPs in the rural areas, thereby reducing the dependency on imported fossil fuel.

The study concluded that from emission reduction perspective, MHP will be highly feasible project if the first priority is given for cooking purposes. But, from sustainability perspective, primary purpose of electricity should be for lighting. From CDM perspective, both aspects; emission reduction and sustainability are equally important. So, it is concluded that MHP should be used in optimum way with maximizing its load factor.

The project seems one of the sustainable projects in rural areas because of its positive impact on community mainly; significant time saving in different activities especially in fuel collection, cooking and agro processing; increase in study hours for students and additional working hours for women during night; conduction of adult literacy classes during night and increase in literacy rate through non-formal education; access to media through radio and television providing opportunity & connection to the global community; establishment of small scale industry like: carpentry, grill factory, chilling centre, photocopy, x-ray, photo studio etc., and thereby creating employment opportunities and providing the modern services to the community.

Thesis Title: **EFFECT OF SUBDIVISION OF BASIN ON RAINFALL RUNOFF SIMULATION: A CASE STUDY OF KOSHI RIVER BASIN**

Submitted by: **Rajendra Kumar B.C.**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The size, scale, and number of sub-basins can affect catchments modeling process and subsequent results. The objective of this study was to determine the appropriate level of sub-basins division for simulating runoff. HEC-HMS model with a geographic information system interface (HEC-GEOHMS) was applied to Koshi basin that varied greatly in drainage area.

Study basin is subdivided in to natural sub-basins on the basin of river network, and soil type using merge and subdivision options available in the HEC-GEOHMS. The sub- basins area, slope and river networks are derived from a Digital Elevation Model (DEM). Manning's roughness and parameter for Green and Ampt model were extracted from landuse and soil map.

Annual output was analyzed from each simulation, which was executed for 2 years using climatic data representing 1995 for

calibration and 1994 for verification of model. The performance of model was evaluated by comparing both graphically and statically. The optimal threshold sub-basins size of the total drainage area to adequately predict runoff was found to be around 1042 sq km. Decreasing the size of sub-basins beyond this level does not significantly affect the computed runoff. This threshold sub-basins size can be used to optimize HEC-HMS input data preparation requirements and simplify the interpretation of results without compromising simulation accuracy.

Thesis Title: **IMPACT OF CLIMATE CHANGE ON WATER RESOURCES IN VIEW OF CONTRIBUTION OF SNOW MELT IN STREAM FLOW: A CASE STUDY OF TAMAKOSHI BASIN IN NEPAL**

Submitted by: **Raja Bhai Shilpakar**

Supervisor: **Prof. Dr. Narendra Man Shakya, Associated Prof. Dr. Akira Hiratsuka**

ABSTRACT

The Himalayas and glaciers are huge storage and very important source of fresh water. On the other hand, they are one of the most sensitive indicators of climate change as they grow and shrink m quick response to changing air temperature. Surface temperature of the earth is rising globally, which is the major indicator of global climate change. The global climate change has already greatly affected the world m many folds. The Himalayan ice and glaciers are gradually melting due to global temperature rise resulting to significant shrinkage in snow-covered area, retreating of glaciers at rate of tens of meters per year and formation of glacier lakes. These changes are greatly affecting runoff patterns and increasing the risks of Glacier Lake Outburst Flood (GLOF). Himalayan snow and glaciers are sources of many rivers m the regions and Tamakoshi River is one

of them. This research aims to assess impact of the climate change on snowmelt runoff m Tamakoshi basin. It is located at above that 1960m altitude and more than 60% area lies above 4000m. For simplicity, the Positive Degree Day (FDD) (temperature index) is used for snow and glacier melt estimation. Geographical Information System (GIS) is used for automatic delineation of watersheds from Digital Elevation Model (DEM) and ERDAS Imagine software is used to delineate the snow and glacier covered area of rugged and inaccessible terrain from processing of satellite images. Runoff pattern is analyzed using conceptual precipitation and Snowmelt Runoff Modeling *(SRM)* tools in different climatic conditions (i.e. temperature). The results highlight considerable contribution of snowmelt and glaciers to runoff, and significant effect of climate change on snowmelt runoff. The contribution of snowmelt m stream flow is found as 17.5% in winter, 13% in summer and 13% in annual flow in the average from 2002 to 2003. The study demonstrates that the impact of climate change (i.e. temperature) to stream flow is significant, which is in increasing trend resulting from snow melt contribution. Due to the snow melt contribution, stream flow increases approximately at rate of 8% in winter, 3% in summer and 3% in annual flow per one degree centigrade temperature rise.

The output if these studies are important guidance for water resources managers to make and implement approximate strategy for water resources management and hydropower development. It is also useful tool for adoptive planning i.e. more and efficient use of winter flow and minigative and preventive measure for high flood and GLOF. However the results presented here are not the predictions, but rather the model simulations in the snowmelt. For further study and refinement of the research, it is worthfull to establish the meteorological station within the catchment itself, use the more precise and more numbers of satellite images (at least one per each month) and apply the energy budget models.

Key word: Impact, Climate change, Himalayas, Nepal, Geographic Information System (GIS), Digital Elevation Model (DEM), Positive Degree Day (PDD), Snow Melt Runoff (SRM)

Thesis Title: **COMPARISION BETWEEN TWO-DIMENSIONAL AND ONE-DIMENSIONAL MODEL FOR HYDRALIC ANALYSIS OF RIVER BY NUMERICAL MODELING IN PLAIN REGION OF NEPAL: A CASE STUDY OF WEST RAPTI RIVER AT RAPTI BRIDGE LAMAHI, DANG**

Submitted by: **Narayan Prasad Subedi**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Due to upgrowing population, the optimizations of the limited resources are current challenge for the modern civilization. Energy demand is increasing geometrically to accomplish the human needs. To overcome the energy crisis, optimization of the hydropower in terms of generation, durability and sustainability have been essential. Optimized hydropower can be achieved by performing the hydraulic analyses to design the hydraulic structures like dam, weir, piers and bridge appropriately.

Due to the complex topography of Nepal including hill and plain region, erosion and deposition phenomenon are simultaneously occurring respectively. Erosion and deposition process are

responsible to shifting and changing the cross-section of the river channel and ultimately meander will be formed. Specially velocity and water surface level vary abruptly even in short reach of meandering river of plain region and also will spread inundation in larger area with maximum human and property loss. Hydraulic analysis of the river is essential to construct the hydraulic structures to make an economic, durable and sustainable project. Most of the structures were failed by the flooding due to the classical design approach. Traditional or classical design approaches for the hydraulic structures are not applicable in plain river of bend but applicable in straight river. In plain river longitudinal as well as lateral flow exists.

That is why, hydraulic analysis of such type of river is very much essential. Hydraulic analysis can be performed by using either physical or numerical modeling. There are many numerical models to simulate the flow; among them in this study CCHE2D and HECRAS are used as two-dimensional and one-dimensional flow model. Velocity and water surface profiles are the pre-requisite parameter for designing the hydraulic structure. Comparative analysis between ID and 2D had been performed for two, low flow and high flow condition. 1D analysis is applicable in straight reach but cannot be applicable even for low flow condition in bend. In river bend, longitudinal as well as lateral flow had been analyzed successfully by 2D.

Analysis had been showed that the 2D hydraulic analysis must be done while designing the hydraulic structure in bend and ID analysis had been used for straight reach. Velocity distribution along the channel is dependent on longitudinal as well as lateral depth. 1D underestimates the velocity along the bend for high flow condition and overestimates for the low flow condition.

Thesis Title: **EFFECT OF CHANNEL GEOMETRY ON ROUTING IN THE CASE OF GANDAKI RIVER BASIN OF NEPAL**

Submitted by: **Narayan Prasad Gautam**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Hydrological modeling is a powerful technique in the planning and development of integrated approach for management of water resources. Routing is the modeling process to determine the outflow at an outlet from given inflow at upstream of the channel. It affected by various topographical characteristic of watershed, land use and geometrical shape of channel. In practical application, hydrological routing methods are relatively simple to implement reasonably accurate.

In this study, physically based semi-distributed model (HEC-HMS) is used to find the efficient channel section in routing process. Gandaki river basin was taken for the study area. Kinematic wave method was used for overland routing and Muskingum Cunge method was applied for channel routing to describe the effect of the reach storage and peak flow attenuation and dispersion observed in the direct runoff hydrograph. Channel

cross section parameters are extracted using HEC-GeoRAS extension tool of GIS.

From this study result, the trapezoidal channel section is more efficient section which gives the better result on routing process. Annual runoff, Peak flow and time of peak at the outlet is similar to the observed flow in calibration and verification period using trapezoidal channel. Hence trapezoidal channel section is more suitable especially in flood routing process.

Thesis Title: **NUMERICAL MODELING OF JHIMRUK DESILTING BASIN**

Submitted by: **Sharad Raj Upadhyaya**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

A numerical model to analyze the water flow and sediment transport in settling basin was done using computational fluid dynamics (CFD) software called SSIIM. SSIIM is synonym for "Sediment Simulation in Intakes with Multi Block Option". It is developed by Dr. Nils Reider B. Olsen; Professor at NTNU, Norway and this software is freely available on net with user manual. The model was used to evaluate the efficiency of solid particles settling in the settling zone of existing settling basin. This efficiency was based on the percentage of solids removed, with settling taking place primarily in the settling zone.

The settling basing selected for model was of Jhimruk Hydropower Plant. The basin is a rectangular shape with slightly curved at inlet zone is 42.0 m long, 11.0 m wide, 5.0m deep,. The settling basin included a settling zone of approximately 21.0 m in length.

For the purpose of sediment transport modeling, three sizes of particles were used to account for the total suspended solids. The sizes of the particles selected were based on data available from sediment analysis of Jhimruk River and were 0.5 mm, 0.2 mm and ***0***.09 mm. The particle density for each size was taken as 2650 kg/m^3. Modeling was done by taking three different Manning's roughness: 0.019, 0.015 and 0.012.

Three dimensional flow and sediment calculation is evaluated over three dimensional grid using Power Law Scheme (POW) and Second order upwind scheme (SOU).

The results were analyzed, compared with actual data and discussed. Numbers of different options were tried, but only few important have been discussed. Simulation result is found in harmony with actual data.

This methodology of analyzing the efficiency of settling basin in terms of its percentage of solids removed based on CFD simulations can also be used to examine settling basin design alternatives for improving the particle removal efficiency.

Thesis Title: **CALIBRATION OF RAINFALL-RUNOFF MODEL PARAMETERS IN HECHMS: A CASE STUDY OF WEST RAPTI BASIN**

Submitted by: **Ezee G.C.**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The need for a water resources assessment is growing because of the increasing demand for fresh water for cultivation, drinking and other consumptive use but there is always issue of basin being ungauged or poorly gauged in Nepal. Water research in the Nepalese Himalaya is not particularly well advanced as the extreme terrain and monsoon climate make data collection problematic and limit transferability of hydrological principles, techniques and models developed elsewhere. In this study various hydrological parameters influencing basin runoff are calibrated for West Rapti Basin, Nepal using Semi distributed Model, HEC- HMS 3.1.1. This study also compares various options provided for sub-basin loss and reaches routing and assesses the sensitivity of parameters. It was observed that SCS CN method over estimated the flow. Initial abstraction and Suction head seems less sensitive parameter while Saturated Hydraulic conductivity and Curve No were highly sensitive. While reviewing the routing method, lag method seems

oversimplification because it does not account the diffusion and attenuation of the flow. Likewise, the storage constant of Muskingum method is highly sensitive. Total travel time for the basin was calculated 19.12 hours and it varied according to the slope and the roughness of the reach. Manning's Roughness Coefficient is the only variable for Muskingum Cunge and Kinematic method and it was calibrated within the range of 0.03-0.06 for the different section in basin. It was observed that Muskingum Cunge gives better results as it incorporated the diffusion terms.

Graduation Year 2010

Thesis Title:	**SEDIMENT STUDY IN THE HIMALAYAN RIVER OF NEPAL: A CASE STUDY OF MARDI KHOLA, AT LAHACHOWK, KASKI**
Submitted by:	**Arjun Gautam**
Supervisor:	**Prof. Dr. Narendra Man Shakya**

ABSTRACT

Simple procedure that can be followed in rural areas was selected for the sediment study in the Mardi River. Sediment samples were collected using plastic bottles once in a day from lst June to 11th September of the year 2009. Sampling site was selected as the station number 428, at Lahachowk, Kaski and simple filtration method using local materials were used for the evaluation of sediment concentration. Suspended sediment was measured during the aforementioned time and assumptions were made for the rest of the time.

The discharge in Mardi river during the study period varied from 2.02 m^3 /s to 240 m^3 /s while the suspended sediment concentration varied from zero to 3784 parts per million. Total annual sediment load for the year 2009 was 230143 tonnes. In a

single day of the month July the suspended sediment discharge was 71.6% of total monthly discharge which was 35.2% of the total suspended sediment discharge during the study period. The result revealed that the sediment discharges in a river has great variation for an individual day during pre-monsoon and in monsoon period when there was high discharge. The sediment discharge of a single day might be a significant part of the whole month, season or even a whole year.

Correlation coefficient between suspended sediment discharges versus flow discharges for the study period was 0.808 which suggested that the sediment discharge was highly correlated with How discharge. This suggested that the magnitude of discharge has great role for sediment transport. But the same discharge carried different sediment load in the river. The magnitude of sediment varied with respect to time. Therefore continuous sediment data with simultaneous discharges is necessary for the actual estimation of sediment load carried by the river.

The result of this report was also compared with the sediment data of other Nepalese Rivers with small and large watershed and with the Rivers in Lesser Himalaya. Sediment delivery of the Mardi River lies within the range of the rivers in Lesser Himalaya geologic zone.

Thesis Title: **UNCERTAINTY ISSUES IN HYDRODYNAMIC MODELING FOR STEADY FLOW ANALYSIS USING HEC-RAS**

Submitted by: **Basanta Man Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Water surface profiles computations have numerous purposes. They are used for analysis of cross drainage and other hydraulic structures, Hood hazard mitigation investigations, flood insurance studies and other design needs. The accuracy of the computed profiles has huge implications and hence is of major concern for technical personnel working on this field.

Uncertainties are usually associated with computed profiles and therefore the results need to be carefully scrutinized. Though governing equations for such modeling are well known, other sources of uncertainties remain. The objective of this study is to evaluate the effect of selected boundary conditions. Several programs are available now-a-days for the computation of water surface profiles. HEC-RAS is widely used software for this purpose. This study has been carried out using HEC-RAS.

The topographical maps prepared for hydraulic analysis of several bridges has been used in this study. Such data were processed by means of GIS and HEC-GeoRAS and finally simulated with HEC-RAS. Model boundary conditions evaluated were normal depth and known water surface elevation.

The study reveals that HEC-RAS can be reliable tool for predicting water surface profile if appropriate boundary conditions can be applied. Results show that the boundary effect propagates to significant distance into the model. The known water surface elevation boundary condition can predict the profile with high accuracy. However in absence of such data, the use of normal depth boundary condition is more suitable. The location of boundary condition should be sufficiently far so that errors associated with it is nullified before beginning of the reach under study.

Thesis Title: **NUMERICAL MODELING OF UPPER SETI HYDROPOWER RESERVOIR USING GASTRAS3**

Submitted by: **Ananda Dhungel**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

This thesis deals with the numerical modeling of sedimentation in proposed reservoir on Seti River. A numerical model GSTARS3 was used for modeling works. The sedimentation in reservoir after operation of about 50 years was investigated together with the effect of operating regime on deposition of sediment. Measured daily flow data, sediment inflow data established from rating equations, measured cross section of the liver, grain size distribution of incoming sediment and river bed was used for simulation. Three different operating patterns of fixing the reservoir water level at full supply level, varying the water level with moderate drawdown in rainy season and varying the water level with significant drawdown in rainy season for flushing were modeled.

The results obtained are qualitative in nature as quantitative verification is not possible. GSTARS3 simulated and predicted the deposition pattern in reservoir satisfactorily except for the

case where significant drawdown was considered. The reservoir will be severely affected by sedimentation ceasing its usefulness in about 50 years if sediment management option is not considered. Sediment deposit advances towards the dam in the form of delta in Upper Seti Reservoir in both the cases of maintaining fixed water level at full supply level and varying water level with moderate drawdown. Deposition is more in the former case and delta advancement towards the dam is more pronounced in the later case. In both cases, result shows that massive sedimentation will be detrimental to the reservoir and can end its life after about 50 years of operation. Sediment management is necessary to make the reservoir sustainable.

The study indicates that GSTARS3 can be used as a tool to have a view on severity and magnitude of the problem in planned reservoirs. The results of modeling can be refined using more reliable data on sediment inflow, cohesive sediment properties and grain size distribution of incoming sediment and river bed material.

Thesis Title:	**CLIMATE CHANGE IMPACT ON FLOW DISCHARGE OF SNOW AND GLACIERS FED WATERSHED: A CASE STUDY OF ARUN RIVER THROUGH TIBETAN CATCHMENT**
Submitted by:	**Parshu Ram Bogati**
Supervisor:	**Prof. Dr. Narendra Man Shakya**

ABSTRACT

Climate change has become a major issue in all over the world; specially focus on Hindu Kush- Himalayan region. Mountain regions are particularly vulnerable; because warming trends are higher in altitude than plain areas. Due to these warming trends the life of Himalayans glaciers are reducing day by day, whose major significant is reduction in length of glaciers. Arun River, one of the major tributary of the Sapta- Koshi, about 95.01% catchment (reference to Uwagoan) area lies in the higher altitude and snow covered region especially in Tibet. So the flow in such rivers during dry seasons is supplied by melting of snow and glaciers.

In this study, Arun River at Uwagoan station is selected and the watershed area in Tibet above this point is taken for the study purpose. The watershed areas are divided into 26 sub basins;

snow cover, glacier with and without debris are calculated in different altitude bands in all sub basin. Snow and glaciers melt discharge data for each sub basin is calculated by using energy budget method for the year of 2002. The output from energy balance model is aided with a conceptual TANK model for calculation of discharge through each sub basin; which is the input data for the HECHMS model. The calibration of the TANK model is done for 2002 at Uwagoan station in Nepal with respect to observed discharge through HECHMS. The parameters of HECHMS with precipitation data taken from APHRODITE data are optimized for the same year and discharge is compared at Uwagoan station.

The validation of the parameters is done for the year 2003 and 2004.Finally the variation in discharge due to change in temperature at the rate of 0.25 °C increment is performed under the same condition. The total contribution in river flow discharge due to snow, glaciers melts by the influence of increase in temperature are calculated with respect to present scenario of land cover and other meteorological factors rather than temperature.

Thesis Title: **PERFORMANCE EVALUATION OF RESERVOIR OPERATION SIMULATION USING HEC RES SIM 3.0: A CASE STUDY OF UPPER SETI RESERVOIR IN NENPAL**

Submitted by: **Achyut Mangal Joshi**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Water is one of the most important natural resources and is a key element in the socioeconomic development of a country. Even though the total quantity of water available in the world is abundant, its uneven spatial and temporal distribution results in a lesser availability for human needs. Of the different intersectoral water demands, power need is one of the major one. The demand for power is ever increasing owing to extensive and intensive urbanization and industrialization. Nepal is still an under country and has a great potential for hydroelectricity. The demand for power is growing per year and differences in supply and demand are ever increasing. At present, a considerable quantity of available monsoon, water has been wasted due to lack of storage type power plants. Before the commissioning of any large storage project, optimal operating policies for effective and efficient use of the water have to be performed.

The application of simulation models is one of the most efficient ways of analyzing water resources systems, which is based on physical relations accompanied by a series of operational rules attempting to simulate a phenomena as close as possible to reality and the system behavior under a specified policy. HEC-ResSim is one of the simulation models that possess of single or multi reservoir simulators and can simulate water resources systems.

In the present study, a daily operational planning model has been developed using HEC reservoir simulation for the USHEP in Kaski, Nepal. A planning model has been developed incorporating the important features of the operational policy. In this study ,storage dam performance from starting operation to end of a typical one year period , which the time series, have a wet and a dry condition, was evaluated by the model.

The simulation starts from January 1 and ends at December 31.The operation of reservoir was performed for the maximum generation of power. Also as the top priority of the project is to cope with the differences of the supply and demand during dry season, the reservoir is maintained at FSL before the start of the dry period. The project has no mandatory downstream release but for the current study 10 % minimum downstream discharge has been considered. In case of no downstream release, it can be utilized for the generation of power during off peak load.

Thesis Title: **SIMULATION OF WATER RESOURCES THROUGH WEAP MODEL: A CASE STUDY OF KOSHI BASIN IN NEPAL**

Submitted by: **Nabin Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

This thesis deals with the application of the steady state, Water Evaluation and Planning Computer Model that optimizes the different water resources components i.e. irrigation, hydropower generation, water supply, inter basin transfer etc, of the river basin as per user's specified demands, priorities and reservoir operation for the Koshi river basin of Nepal. The simulation has been carried out using 20 years of hydrological data from 1986 to 2006. The various scenarios have been simulated in order to determine the surplus or deficit for the different water uses and priorities of the water resources components of the river basin for the present as well as future uses.

The simulated results show that the natural flow of the rivers of the basin fulfills the present as well as future water demands and also satisfies the inter basin transfer. However, there is deficit in some of the months from Rosi and Indrawati River. With the implementation of Koshi High Dam, the maximum energy

generated after fulfilling the present and future demands is 19, 059 GWh.

Various scenarios of development in the basin including combinations of Koshi High Dam Reservoir, Dudh Koshi Dam and Sun Koshi No.2 Dam Projects were simulated. The implementation of the above projects improves the satisfaction of irrigation demand for all cases, generates considerable hydropower generation, and enhances flood control and other benefits. Also it is concluded that the construction of reservoirs like Koshi High Dam, Dudh Koshi Dam and Sunkoshi No.2 Dam is uneconomical in terms of fulfilling water demand but it is feasible for hydropower generation.

There may be conflict between the transfer of 72 m^3/s of flow from Sun Koshi River to Kamala River and satisfaction of all the future (potential) irrigation demand. This may lead to setting priorities for meeting the demands in different regions. Similarly, priorities on irrigation, hydropower, and flood control will result in various levels of demand satisfaction. Hence, it can be concluded that a "Decision Support System" like the one used in the present study can be of great use for making rational and optimum decisions.

Thesis Title: **APPLICABILITY OF SATELLITE BASED RAINFALL ESTIMATION IN FLOW MODELING USING GEOSFM**

Submitted by: **Dinesh Rajbhandari**

Supervisor: **Prof. Dr. Narendra Man Shakya, Dr. Raghu Nath Jha**

ABSTRACT

Rainfall runoff process is one of the complex hydrological phenomena of a watershed. As a crucial component for devising Flood Forecasting and Warning System, hydrodynamic modeling has significant importance in flood management. The most fundamental part of such forecasting models is associated with peak flow estimation and estimation of time of occurrence. Nowadays, researches are engaging in coupled use of hydrological and hydraulic numerical models and Remote Sensing technique for formulation of Flood Forecasting and Early Warning System intending to save numerous lives and properties.

This thesis presents a methodical approach for the integrated use of ArcGIS, Arc View for development of a hydrodynamic model at basin and sub basin level in targeted river watersheds. A study of Narayani River Basin and Bagmati River Basin of Nepal was

undertaken as the case study. The study is focused on the period of 2002 AD and 2003AD over both the river basins.

In this study," a hydrologic model was developed for Narayani and Bagmati River basins using GeoSFM code as an incorporation of Arc View 3.2 a. Basin wise a comparison study was done to see the applicability of NOAA/CPC data of daily rainfall and the soundness of GeoSFM in Flow Modeling at catchment's scale. The necessary statistical analysis was conducted for the trend analysis of the GeoSFM outcomes. Particularly, the RFE product was calibrated in this study.

This study, as an imperative part of Flood Forecasting and Warning System, has been expected to initiate the integrated use ArcInfo, ArcGIS, Arc View inclusive of related extensions in complete hydrologic modeling at basin scale.

Thesis Title: **SEDIMENT SIMULATION MODELING OF WASTE RAPTI RIVER USING CCHE2D MODEL**

Submitted by: **Shiva Kumar Dahal**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Sediment transport is the natural phenomenon, which occurs in all stages of water flow in the earth surface. It is associated with sequence of geological and climatic events and can never be stopped. Rivers while flowing through mountainous and Siwalik range have high velocity and high sediment concentration. These rivers reach to flat terrain deposition in the river bed increases. This results to the rise of riverbed level in the Terai part of Nepal.

Dang valley and Terai part of Rapti basin is one of the fertile areas of Nepal. But, sediment deposit each year to the fertile land and inundation of these flat lands by the flood causes decreasing the agricultural productivity. Moreover, loss of life and property every year make the area difficult for settlement, particularly near and periphery of the river bank.

The computer program, two dimensional model of Centre fro computational Hydroscience and Engineering (CCHE2D) is one of the numerical models based on computational fluid dynamics. This model simulates the sediment movement of river basins and reservoirs and finds variables regarding the sediments such as sediment concentration, changes in bed level, velocity of flow and bed deposition pattern etc. Since the objective of the study is to predict the bed level changes, this model is used to calculate the bed level changes in the Rapti River near Nepal-India border. The quantitative analysis is performed on the basis of average bed level changes by using CCHE2D, average depth-averaged hydrodynamic model. The trend of bed level changes due to sediment deposition is determined and single year bed variation is predicted. The result is verified by the reduced level taken on a section which is also near to average bed rise of river in Terai, 6-8 cm per year. The sensitivity analysis is performed for the uncertainties involved in the simulation. The conclusion is made on the basis of the result and analysis and graphical and quantitative outputs by CCHE2D are presented.

Thesis Title: **OPTIMAL DEVELOPMENT PLAN OF INTEGRATED NEPAL POWER SYSTEM CONSIDERING HYDROLOGICAL UNCERTAINTIES**

Submitted by: **Fanendra Raj Joshi**

Supervisor: **Dr. Divas B. Basnet**

ABSTRACT

The electric system characteristics of Nepal is such that there is high load and low production capability in winter season where as reduced load and high production capability in summer season. The electricity demand of the country in a day and over a year is not uniform and has a sharp peak during evening time of a day and during winter evening peak demand shoots up. The day load is comparatively lower. Because of the hydrological uncertainties and the type of the project in the system, there is a distinct mismatch between the supply and demand resulting in the deficit of capacity in the winter peak and *spilling* of energy in the wet season. In order to meet the demand of electricity in a cost effective way and ensure least cost investment, it is considered highly desirable to find out the optimal operation strategy for the Integrated Nepal Power System. This will then be useful for the optimal development of the power system in the country.

The optimal operation strategy is based on the economic utilization of the available capacity and energy available of the different types of hydropower plants and thermal plants. It is also depends upon the maintenance of the thermal and hydro plants as the maintenance of one plant affects the generation of other plant.

To determine a solution for this problem VALORAGUA model developed by IAEA in 1992 is used for the study. The model is developed to find the optimal operation strategy with the objective of minimizing the thermal operation cost, import cost and the cost of energy not served. The operation cost of hydropower plants are not considered as it is negligible compared to the thermal generation cost.

The present study mainly attempted to assess the variation of hydropower generation pattern from different plants for the various power system configuration and demand scenarios. The system configuration for the years 2010/11 and 2015/16 have been adopted from the latest system expansion plan of Nepal Electricity Authority (NEA). System operational benefits of storage and ROR projects and demand side management were also investigated.

From the study, it is found that, there is deficit of power and energy in both scenarios of study. Moreover due to high power demand and low supply of energy during dry month the cost of generation is more in dry months compared to wet months. The study also shows that the marginal cost of generation is higher in dry month than in wet season and high in peak period than in other periods. In addition, the marginal cost of generation decreases with the inclusion of storage project of same -capacity than that of ROR .The study also suggests the use of spill energy and different tariff rates for the optimization of the system. It further shows that inclusion of one more storage project increases the utilization of the existing storage plant in the dry period due to proper regulation. The model is found suitable for management in order to use the existing plants in an efficient and cost effective way and also useful for guiding the selection of an optimal project and its capacity for long term generation expansion planning.

Thesis Title: **MODELING WATER RESOURCES PLANNING AND MANAGEMENT IN BABAI RIVER BASIN, NEPAL**

Submitted by: **Pushpa Ram Suwal**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The study attempts to develop water allocation model/DSS model in the Babai River Basin. The prevailing system of uncoordinated water resources management in the basin cannot sustain the ever-increasing water needs of the various expanding sectors. Therefore a strategy must be sought to integrate the various sectoral needs against the available water resources in order to attain both economic and ecological sustainability.

Babai River Basin is one of the dry river basins in Nepal where average supply barely meets the potential demand of the basin. The main problem is not only the shortage of water but the lack of the management also. So, it is necessary to understand the situation in the whole catchment and identify where problems exist. This can be achieved by the application of Water Evaluation and Planning Version 2.1 (WEAP21) is an Integrated Water Resource Management (IWRM) model.

The present and future water demand is hardly fulfilled within the basin. The various scenarios have been simulated in order to determine water balance for different sectoral uses and priority basis. And simulated results show that, in the existing water balance condition of the basin the minimum demand site coverage of irrigation demand site at lower babai sub-basin is of 83 percent in November month. Out of the total potential irrigation area within and its vicinity of 125000 ha, 52000ha of land is presently irrigated. Consumptive use of ground water for irrigation demand at Babai irrigation project may be a alternatives for ultimate irrigation in terai belt of the basin and its vicinity.

Similarly, with the implementation of Bheri Babai Diversion Scheme or Sarada Babai Multipurpose Project can fulfill future irrigation demand. 40m /s inter basin transfer of water from Bheri River to Babai River can best lead to fulfillment extensive irrigation demand with an average annual energy generation of 408 GWh/yr. The implementation of Sarada Babai Storage Project improves the satisfaction of irrigation demand at various sites and generates considerable hydropower with an average value of 169 GWh/yr.

Hence, the decision support system (DSS) WEAP21 that based on basic balancing equation, found to be an appropriate tool for making rational and optimal decision for the Babai Basin.

Thesis Title: **EFFECT OF STONE MINING IN THE FLOODING SCENARIO OF TINAU-DANO AND REMEDIAL MEASURES: AN ANALYSIS USING GIS AND HEC-RAS**

Submitted by: **Subhechchha Pradhan**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Stone mining is the most problematic anthropogenic activity in Tinau River downstream of Mahendra Rajmarga Bridge in Butwal area. Due to the haphazard extraction of stones in the area employing dozens of excavators, the bed level of the river has deepened alarmingly. The lowering of river bed level has changed the natural profile of the river bringing with it and possibly with much more frequency in the future, many environmental, social & economic set-backs.

This study utilizes a simulation model (HEC-RAS) and GIS to assess the inundation scenario arisen due to the lowering of bed level in 8 km stretch of Tinau River downstream of Mahendra Rajmarga Bridge and its consequences to the river banks and adjoining floodplains. Similarly, the simulation covers the flood

inundation pattern of the Dano reach where significant excavation is not reported.

The results of the study with one dimensional steady state analysis reveal that the bed mining activity in the river has qualitative impact on the inundation pattern of the area showing increased depth and reduced width of the river after the mining activities. Moreover, the results exhibit that the reduced waterway width resulting from the increase in depth causes increase in bank velocity in the Tinau reach causing bank instabilities in many reaches. Furthermore, the simulation results in the Dano reach reveal the flood inundation pattern of the adjoining floodplains. Finally, the study recommends specific remedial measures to be applied in the study area based on the results of hydrologic and hydraulic analysis.

Thesis Title: **GENERIC RIVER BASIN MANAGEMENT - DECISION SUPPORT SYSTEM USING MODISM: A CASE STUDY OF WEST RAPTI RIVER BASIN**

Submitted by: **Bikram Dhoj Shahi**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Nepal is a country with abundant water resources and also has huge water resources development potential. Present and future water uses comprise irrigation, hydropower generation, domestic and livestock consumption and industrial water use. In some local areas of Nepal, the demand for water already exceeds the available supply. The competition for limited supplies of water will increase in the future as more development take place and as Nepal enters into boundary flow agreements with India. It is essential for the orderly development of Nepal's water resources, that present and future water use be analyzed and compared to available supplies.

Water is one of the most important physical resources that can play a key role in enhancing the pace of overall development of a country. Sustainable development of water resources can

significantly contribute to poverty alleviation and economic growth.

The optimal possible utilization of the available water resources of the West Rapti River basin within certain constraints of the basin is the main purpose of the thesis. In the present context, Nepal is concentrating more on the project-to-project planning. But for the optimal benefit, an integrated system of holistic approach has to be applied while planning for the river basin use. A Decision Support System (DSS) using simulation model would thus help in assessing the water resources available in the basin and planning for optimum utilization of the water resources in future. This study is an endeavor to glance into the long term planning aspect of West Rapti River Basin.

Various scenarios have been simulated in order to determine the water balance (surplus and deficit) for the different water uses and priorities of the water resources components of the river basin for the present as well as future uses.

River Basin Management Models like Modsim is found to be an appropriate tool for decision support, as all the ingredients of Decision Support System (DSS); inventory of basin's water resources and related lands, summary of basin's present water uses, projection of future water needs and identification of alternative decisions to meet or not to meet the indicated water needs, can be addressed. This model is based on a basic water balancing equation. It can be concluded that the procedure adopted like the one used in the present study can be of great use for making rational and optimal decisions.

Thesis Title: **DECISION SUPPORT SYSTEM (DSS) FOR INTEGRATED RIVER BASIN MANAGEMENT (IRBM) USING MODISM: A CASE STUDY OF KOSHI RIIVER BASIN**

Submitted by: **Madan Kumar Dangol**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

River is not only a natural channel of flowing water. A Koshi river basin is very complex system. When responsibility for drinking water rests with one agency, for irrigation water with another and for the environment with yet another, lack of cross-sectoral linkages leads to uncoordinated water resource development and management, resulting in conflict, waste and unsustainable systems.

Integrated Water Resource Management is the process of uses of water resources in holistic approach. Use of IWRM towards Integrated River Basin Management is an approach to establish a balance between the existing natural functions of the river system and the developed aspects of the system. The management actions should fulfill the expectations of the society for domestic

and industrial use, recreation, environmental, and agricultural purposes.

Decision Support System (DSS) is the basic requirement for the IWRM and IRBM for maintaining information system containing basin maps, hydrological, water demand database, irrigation water supply and demand assessments. It is very helpful to Water mangers and decision makers for taking proper decision among different alternative scenario of water resource development.

MODSIM is a generalized river basin Decision Support System (DSS) and network flow model developed at Colorado State University designed specifically to meet the growing demands and pressures on river basin managers today. MODSIM's graphical user interface (GUI) allows users to create any river basin system topology by simply clicking on various icons and placing system objects in any desired configuration on the display.

The major and minor parameters considered in the study model deserves its full value in the decision making process for the water resource and river basin development of Nepal. So, the research work concludes that in the present context of Nepal, the most appropriate option of Koshi River Basin development is Kamala diversion along with drinking water, irrigation and run off type hydro powers in other places.

Thesis Title: **THEORETICAL ASSESSMENT OF HYDROPOWER POTENTIAL OF NARAYANI (GANDAKI) BASIN**

Submitted by: **Ranjan Raj Bhattarai**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The major objective of this study is to assess the theoretical hydropower potential of the Narayani basin. Digital Elevation' model (DEM) has been used with HEC Geo HMS and HEC Geo RAS to calculate the hydraulic head and extract channel physical parameter. HEC-HMS model has been used to predict long term daily discharge. 65th percentile flow has been used as designed discharge and the power is calculated at every node of the sub basin. Certain calibration and validation are carried out before the energy calculation.

Thesis Title: **DOWN SCALING AND RAINFALL RUN-OFF MODELING BY USING SATELLITE BASED TERM RAINFALL: A CASE STUDY OF KOSHI BASIN IN NEPAL**

Submitted by: **Hari Prasad Sharma**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Flow estimation at a point in a river is a major task for a number of hydrologic applications. Nepalese rivers are characterized by a wide seasonal fluctuation of flow with a maximum value in August and declining to their minimum in February-March. Complex Mountain physiographic and monsoon climate attributes mainly on this temporal variation of surface water flows. The extent and quality of hydrologic analysis are dependent not only on the adequate database but also on the application of modern technology to reflect the existing database limitations. So, satellite based high resolution precipitation data even upto real time is being one of the important tools to determine the operational discharge for any water resource applications. This study focus on Down-Scaling and Rainfall Run-off Modeling by using satellite based TRMM (Tropical Rainfall Measuring Mission) precipitation data for Kosi Basin in NEPAL.

In this study, Daily TRMM 3B42 V_6 (0.25° x 0.25°) product is used. The precipitation data of selected 27 raingauge stations for the year 2002 - 2006 is directly downloaded from NASA's official website Giovanni TOVAS and used for down-scaling. The temporal variation of TRMM precipitation regarding daily, weekly, monthly, seasonally as well as annually were computed and compared with same set of gauge based DHM precipitation. Similarly, spatial variation of precipitation is computed regarding longitude-wise, latitude-wise, and elevation-wise. The computed monthly percentage difference and difference of rainfall are utilized to Ground Validate (GV) in 4 raingauge station of same basin for the year 1999 - 2001. After GV at Koshi basin's raingauge station, the rainfall data of Gandaki basin's raingauge station is tested for Ground Application (GA) by using 6 number of raingauge station for the year of 2002-2006.

In addition, the Rainfall Run-off Modeling is executed by HEC-HMS model in a GIS environment. Calibration and validation of model is selected for the year 2002-2003 and 2006 and generated flow at Chatara was compared for both TRMM and DHM rainfall input.

The result reflects that the TRMM rainfall products are capable for detecting particular rainfall event within the basin but underestimating of rainfall takes place. The TRMM is underestimating rainfall by 46.5 % in annual and 66.37% in monsoon period with comparing to DHM rainfall. The elevation parameter is more responsible than other like longitude and latitude. Also, magnitude of simulated flow by TRMM rainfall is also lesser than simulated flow DHM rainfall.

Thesis Title: **GLACIERIZED WATERSHED MODELING: A CASE STUDY OF GANDAKI RIVER BAS IN OF NEPAL**

Submitted by: **Basu Dev Bhandari**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Snow and glacier melt runoff from high mountainous watersheds is essential for future planning of water resources as irrigation, hydropower, water supply and flood management system design. To design these systems glaciers/snow play vital role. Thus, the main objective of this study is to estimate snow and glacier melt from both debris free and debris covered glaciers by the surface energy balance over the whole watershed and to simulate the river discharge by application of lumped conceptual runoff model and to estimate the snow and glacier melt contribution.

The model is used to simulate the daily runoff from 16 glacierized watershed of Gandaki basin. The glacierized watershed is distributed in to 14 altitude zones of 300m interval. The aerial distribution of watershed area having its characteristics including debris free, debris covered glaciers and bare ground. Metrological data at Kyanjing in Langtang and

hydrological data at Trisuli, Budhigandaki and Narayani are used in this study.

The snow and glacier melt for each altitude band are calculated by surface energy balance models, output of this model are used as input of TANK conceptual model and HEC-HMS model is used for modeling of precipitation and outflow of each sub basins of glacierized basin. In this study, year 2002 is calibrated and year 2003 and 2004 are validated at two major sub basin Trisuli, Budhigandaki and outlet of the basin at Narayanghad. The calibration of model for Trisuli shows the Nash efficiency 89.50% and volume deviation -5.66%, Budhigandaki shows the Nash efficiency 86.36% and volume deviation -12.82%. finally at Narayanghad shows the Nash efficiency of 84.57% and volume deviation 4.97%. Similarly validate at the same stations for the year 2003- 2004.The model is validated with Nash efficiency 84.50% and the volume deviation - 15.64% at Narayanghad, Nash efficiency 87.15% and volume deviation -5.57 at Trisuli and Nash efficiency 81.60% and volume change -7.84%. Snow and glacier melt volume from each subbasins of Gandaki basin are also estimated. Budhigandaki subbasin contributes the higher percentage of melt volume. Sensitivity test shows that, ice melt from debris cover glacier is more sensitive with increase in temperature.

Thesis Title: **TEMPORAL AND SPATIAL VARIABILITY OF TEMPERATURE AND RAINFALL IN NEPAL FROM 1971 TO 2007**

Submitted by: **Pooja Bhatta**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Climate change is happening and affecting every corner of the world due to global emissions of greenhouse gases. Although Nepal is not really responsible for this phenomenon, Nepal is going to suffer from its consequences. Climate change impact is severe on Nepal because of the geographical and climatic conditions, high dependence on natural resources and lack of resources to cope with the changing climate. So, there are more likely adverse impacts of climate change in the coming days. To identify the impact of climate change in future, first of all it is necessary to identify past climate trend and develop the adaptation strategies. The study report found out of change in temperature pattern and rainfall pattern in Nepal with figures and results. *This* report also suggested recommendation for adaptation strategies as well as recommendations for future studies to lessen the impact of climate change.

The annual, monthly and seasonal rainfall and temperature were analyzed and their trends were studied as a slope of linear trend line of the observed values using Microsoft Excel Chart. After determining the trend, the significance of the estimated trend is tested using the t-statistics value by setting up statistical hypothesis.

The analysis of the rainfall and temperature data in Nepal revealed that the climate of Nepal is changing from past. The warming seems to be consistent and continuous after 1970. Increasing trend of temperature is become faster after 1990. The overall temperature is increasing despite negative trends in some of the pocket areas. The warming is found to be more pronounced in the high altitude regions of Nepal such as the high hill and mid hill region, while the warming is significantly lower or even lacking in Terai and Siwalik regions. Therefore, Nepal Mountains are highly vulnerable to climate change. As extreme hot days are observed increasing trend, days are becoming hotter than past. Annual and seasonal rainfall records do not follow the linear trend and this study could not verify the rainfall trend in Nepal. But this study verify pattern of rainfall is changing in Nepal i.e. rainfall has become more erratic in nature because there is increment in high intensity of rainfall but decrement in low intensity of rainfall as well as total annual rainy days in

Nepal. Furthermore, high amount of rainfall is received in shorter period in Nepal mainly in low land area results Terai area are more vulnerable to flash flood and inundation.

Thesis Title: **APPLICATION OF HYDRO CYCLONE IN HIGH HEAD HYDROPOWER PROJECT: A CASE STUDY OF SIURI KHOLA SAMLL HYDROPOWER PROJECT**

Submitted by: **Binod Prasad Dhakal**

Supervisor: **Dr. Hari Prasad Pandit**

ABSTRACT

Extremely high sediment transportation in the Himalayan Rivers has a great challenge to most of the hydropower projects with respect to sediment exclusion at head works. Settling basins are the common devices used to exclude sediment particles that are larger than 200 µm in water projects. But the wear and tear to the turbines and accessories in most of the medium and high head plants have been found quite high. The sediment load is one of major factor to cause wear and tear to the turbines and accessories. So, it requires comparatively larger settling basins to exclude most of sand and silt particles from the flow.

However, due to topographical limitations as well as higher cost of the gravity settling basins, construction of bigger settling basins is often not possible. Not only, it involves huge maintenance costs, but there is also a substantial revenue loss due

to reduced equipment efficiencies. To deal effectively with these constraints, alternative methods such as hydrocyclones can be applied for the removal of suspended sediment particles in medium and high head hydropower plants. In a hydrocyclone, the flow enters tangentially into a cylindrical body with high velocity. This circulating velocity generates large centrifugal fields. The centrifugal force accelerates the settling rate of the particles, thereby separating particles according to size and specific gravity.

However, the cost and performances comparison of hydrocyclone with conventional settling basins are still unknown. So, this research work identifies the suitable geometry of hydrocyclone and compares the sediment removal efficiency and cost of sediment exclusion system comprising hydrocyclone with that of conventional settling basin in case of Siuri Khola Small Hydropower Project. Due to steep topography near headworks site as well as geological constraints, application of bigger settling basin is almost impossible in this project. On the other hand, the project is a high head one with small design discharge. Hence most of fine sediments need to be excluded from the flow.

In all cases studied the hydrocyclone is observed far better than conventional settling basin especially for separating fine sediment particles. However, for the particles which are larger than 300 micron, the sediment removal efficiency of hydrocyclone and conventional settling basins are found to be not much different. The cost of installation of hydrocyclones and accessories is found to be much cheaper than any size of

conventional settling basins whose surface areas are greater than 55 m^2. While increasing the sediment removal efficiency of settling basins beyond 85%, the size of the basin increases geometrically resulting in the increment of the cost of basin unexpectedly. As the conventional settling basins are not feasible both due to the topographical limitations, high cost and low efficiency performance, installation of hydrocyclone is the best alternative for the Siuri Khola Small Hydropower Project.

Graduation Year 2011

Thesis Title: **FLOW AND SEDIMENT SIMULATION IN A MEANDERING RIVER USING THE CCHE2D: A CASE STUDY OF MANOHARA RIVER**

Submitted by: **Rupak Bastola**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The meandering of alluvial river is a continuous process dependent upon the discharge, bed and bank material composition and sediment concentration. Thus the rivers in alluvial plain are prone to damage the nearby cultivation field or habitant area either by eroding or by flooding the land due to rise in bed level and in addition to that the change in water course of the river or meander migration process may endanger the hydraulic structures and river training structures. So this study has been focused to simulate the flow and sediment in a meandering river to observe the effect in terms of flow variables like water surface level, velocity magnitude, water depth and change in bed level.

A two dimensional depth averaged hydrodynamic and sediment transport model called CCHE2D, developed by National Center for Computational Hydroscience and Engineering (NCCHE), University of Mississippi, USA has been used in this study. Manohara River, which is highly meandering river and flowing along the highly cultivated and residential area, has been selected for study. For flow and sediment simulation, steady approach has been used due to lack of long term time series data of flow and sediment concentration.

The flow and sediment simulation results has shown that the sections at bends are highly prone to bank toe cutting at the outer bend and there is aggradations on the inner bend. Similarly the result of sediment simulation along the Thalweg line has shown that the river is degrading along the Thalweg. The simulated results have been validated using the measured and simulated data with good correlation. The result of the study has been presented in graphical as well as model visualization option, relating different variables of flow and sediment simulation.

The study has concluded that the flow and sediment simulation for a meandering river using the CCHE2D model provides a quantitative prediction for flow parameter as well as sediment aggradation and degradation phenomena, which could be used in future for designing the river training or armoring structures. The study has recommended for further study for meandering river for meander migration process with enough hydrological and geotechnical data.

Thesis Title: **LABORATORY EXPERIMENTAL ANALYSIS FOR ESTABLISHMENT OF HYDROLOGICAL RAINFALL RUNOFF RELATION BY USING RAINFALL SIMULATOR (S12-BASIC HYDROLOGY SYSTEM)**

Submitted by: **Dak Bahadur Khadka**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Time of concentration of overland flow from a watershed is defined very loosely in literature and it is calculated rather subjectively in practice. The situation becomes adverse as the terrain slope approaches zero; because the slope generally appears in the denominator of any formula for time of concentration, this time goes to infinity as the slope goes to zero. The variables affecting this time parameter on flat terrains have been studied through plot scale laboratory experiments. It has been found that the antecedent moisture and rainfall rate control this. Some of the existing times of concentration methods have been compared, and it is found that the empirical models compared under predict this time parameter. At lower time of concentrations, Izzard-based model predictions show some results close as well as logical to the observed values. Regression equations have been derived based upon the experiments to

determine the overland flow times on a plot of 2.02 meter length, 1 meter wide and 0.15 m depth soil plots of sand, silt and bare clay (at the slope of 10° to the horizontal plane) with uniform rainfall intensity. It was found the exponents for the moisture content was 0.33 in negative value which showed the sensitivity of the moisture toward the concentration time for any watershed. Equations for the hydrograph slope have been determined for sand, silt and bare clay plots. The variation in the rainfall- runoff coefficient with the rainfall intensity was determined. It was found within range of rational values of 0.05 to 0.95 for each soil type. All results obtained were determined for the best value of regression coefficient.

As the outlet discharge was contributed by both seepage and overland flow, the conceptualization of the physical process governing hill slope runoff in terms of the physical properties of the soil and geometry was tested with the help of Kinematic Storage model (KSM) theory. The model was used to examine the runoff generation process on the sand slope. The Result observed showed a good agreement with the Predicted from KSM theory. This validated to the results obtained from lab test. The moisture profiles with depth on sand and silt plots due to intense rainfall of 151pm up to 5 minute was observed and the results showed a good adjustment with the hill slope model in permeable soil.

Thesis Title: **THEORETICAL ASSESSMENT OF HYDROPOWER POTENTIAL USING GIS AND HYDROLOGICAL MODELING TECHNIQUE: A CASE STUDY OF KARNALI BASIN, NEPAL**

Submitted by: **Raghunath Prajapati**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Water resources are the most important natural resources because they are not only renewable natural resources but also abundantly available in Nepal. A favorable topographic condition because of high variation of elevation makes Nepal one of the richest countries in terms of hydro power potential. Despite the vast amount of sources, not all have been used in Nepal. Many small to large scale private-run and Government owned companies operate their hydropower projects throughout Nepal.

This study is to assess the theoretical hydropower potential of the Karnali Basin by using GIS (Geographical Information System) and Continuous Semi-distributed Hydrological Model E (Hydrological Modeling System - HMS). The digital Elevation model (DEM) is used to calculate the elevation data of upstream and downstream ends of the reaches and daily discharges of the

reaches are derived from precipitation data using HEC-HMS model with Nash efficiency ranging from 61.7% to 82.02 % and the volume deviation -1.52 % to 17.3 % for calibration and validation period. Using design discharge corresponding to 40^{th} percentile flow with the hydraulic head, total power potential of 14150.80 MW is determined.

Thesis Title: **DRY SEASON EVAPORATION FROM PINE FOREST STAND IN THE MIDDLE MOUNTAINS OF NEPAL**

Submitted by: **Kapil Gnawali**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The quantification of dry season evaporation in regions, where the magnitude of dry season flows is key to the regional water supply, is essential for good water management. Also, tree transpiration has a significant role in the water balance of a catchment whenever it is tree populated, especially in water limited environments. Such is the case in the Middle Mountains of Nepal where dry season flows play a significant role in downstream water provisioning and their proper functioning is key to the welfare of millions of people. This research thesis seeks to study the transpiration of a pine forest stand in the Jikhu Khola Watershed in the Middle Mountains of Nepal. To the author's knowledge, no single study has been made so far to estimate the dry season evaporation from the planted forest stand in the Middle Mountains of Nepal. The study was carried out in planted pine forest embedded within the Jikhu Khola Catchment. Field campaigns of sap flow measurements were carried out from September, 2010 to February, 2011 in the selected plot of 15*

15m dimension, to characterize dry season evaporation. This was done by measuring sap fluxes and sapwood areas over the six trees of different Diameter at Breast Height (DBH) classes. The sap flux was assessed using Granier's thermal dissipation probe (TDP) technique while sapwood area was determined using several incremental core(s) taken with a Pressler borer and immediately dyeing with methyl orange for estimating the actual depth of sapwood area. Transpiration of the plot was estimated by considering the contribution of each tree class. For this purpose, sap flux density, sapwood area and the proportion of total canopy area were determined for each tree class of the selected plot. From these data, hourly and diurnal transpiration rates for the plot were calculated for experimental period. Finally, Cienciala model was parameterized using the data recorded by the ADAS and other terrain data collected in the field. The calibrated model allowed the extrapolation of Sap flux density (v) over a six month period, from September 2010 to February 2011. The model given sap flux density was validated with the measured sap flux density from Grainier method.

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Thesis Title: **HYDROLOGICAL MODELLING OF GLACIERIZED WATERSHED AND ITS RESPONSE TO CLIMNATE CHANGE; A CASE STUDY OF LANGTANG KHOLA BASIN**

Submitted by: **Ram Narayan Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Himalaya is the earth's unique freshwater reservoir which stores immense amounts of water and hold them to gradually release to support the lives downstream. The streams originating from Himalaya act as a source for irrigation projects, hydropower projects and water supply projects. Without snow melt, the rivers flowing down from the Himalaya would remain dry for the greater part of the year. Besides, glaciers in Himalaya play a vital role in local hydrological processes, and act as a repository of information for exploring quaternary climate changes Hence prediction of snow and glacier melt runoff of these streams is very essential for regional planning of water resource. Thus, the main objective of this study is to estimate snowmelt in glacierized watershed and simulate the discharge using a conceptual rainfall runoff Tank model. The snowmelt in water equivalent and rainfall are input for the hydrological model.

The trend analysis of minimum, maximum and mean temperature of Kyangjing station is performed. It shows that the slope of minimum temperature trend is highest among three which is found to be 0.308. The slopes of trend of mean and maximum temperature are found to be 0.262 and 0.224 respectively. It proves the positive trend of warmer climate in the study area. To assess the impact of such warming on stream flow, the hydrological model is developed first incorporating the snowmelt in it. Then the model is run under changed climatic scenario to predict the future stream flow under different scenarios.

The model is used to simulate the daily runoff from 47 % glacierized watershed of Langtang Khola. The aerial distribution of watershed area having its characteristics including debris free and debris covered glaciers, meteorological variables in 12 altitude bands of 300 m and the river discharge data at the outlet of the watershed are the foremost inputs for the model. The snow and glacier melt for each altitude band is calculated by surface energy balance and mass balance models. A lapse rate method is used to determine the temperature of each altitude band and a simple empirical relation is used to define the type of precipitation. The precipitation as rainfall, snow and glaciermelt in all bands are averaged and used as input to the conceptual TANK model for runoff simulation.

Thesis Title: **APPLICATION OF BLOCK WISE USE OF TOPMODEL AND MUSKINGUM-CUNGE (BTOPMC) IN KARNALI BASIN**

Submitted by: **Kofula Shrestha**

Supervisor: **Dr. Raghunath Jha**

ABSTRACT

The temporal and spatial variations of river flows in Nepali Rivers are mainly due to physiographic and climatic characteristics of the country resulting in time and space distribution of rainfall. Karnali River, a major river of the country has vast potential of its water use for the development of the Karnali region. Hydrology study of the river basin is essential. University of Yamanashi Distributed Hydrological Model (YHyM) is composed of Block-wise use of TOPMODEL and Muskingum-Cunge (BTOPMC) as its core hydrological model with various other sub-models. This model was tested for spatial and temporal transferability of the calibrated model parameters to predict various runoff components in different physiographic regions of Nepal, especially in Bagmati Basin. For this study, BTOPMC model was used to predict the parameters of the Karnali river basin dividing the whole basin into 6 sub basins.

Calibration was "done for the years 1997 to 2001 and validation of the parameters was from 2002 to 2007 (data of total 10 years was used). The Nash efficiency of calibration was between 21 to 61% (basin wise) while the same for validation was 33 to 75%. The value of EQsim/EQobs varied from 46 to 96 % and 49 to 98% respectively. Hence, it is concluded that BTOPMC can be used for poorly gauzed or ungauzed basins, provided that it makes use of local data as well. Use of lumped (average) global data cannot minutely represent the vast variations within a small sub-catchment (watershed). For future use of BTOPMC in Nepali River Basins (especially in the high mountains) it is suggested to make use of a large number of meteorological data, to validate each downloaded global dataset with ground conditions and to divide the basin into many number of sub-basins.

Thesis Title: **SNOWMELT RUNOFF MODELING USING WIN SRM A CASE STUDY OF IMLA KHOLA BASIN, KHUMBU REGION, NEPAL**

Submitted by: **Gopal Prasad Niure**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The estimation of runoff from ungauged glacierized Himalayan basins is important for planning water resources in remote highly rugged mountainous area. An attempt has been made to simulate the runoff from Imja Khola basin, Khumbu region of eastern Nepal. A simple temperature index semi-distributed conceptual model, Win SRM, is used. Owing to its simple data requirement and use of remote sensing to provide snow cover information, SRM is ideal for use in data sparse region, particularly in remote and in accessible high mountain watersheds. The five different seasonal satellite images are used to estimate snow/glacier coverage. The basin descriptive parameters are taken as estimated or optimized in different mountainous basin. The basin area is divided in to 13 elevation zones each having 300m elevation differences. The temperature and precipitation data are extrapolated to each zones centre.

The important model parameter, the degree day factor, is taken from previous studies. The critical temperature is taken as zero. The unsupervised image classification technique, NDSI, is used to classify the satellite image. The year round simulation is carried out and daily runoff is simulated. The runoff cycle roughly correspond to a calendar year. The results shows that two SRM average goodness of fit statistics for simulations, Nash- Sutcliff co-efficient (R) and volume differences (Dv), are 0.76 and 5.9 % respectively. The model is also run in no snowmelt simulation mode to predict the snowmelt contribution to runoff and it is found about 66% in Imja Khola basin.

On the basis of snowmelt runoff simulation, together with a set of simplified hypothetical climate scenarios, SRM is also used to simulate the effects of climate change on snowmelt runoff. For a set hypothetical temperature increase of 1 c and 2°c the snowmelt season shift towards earlier dates and snowmelt runoff, as a result, is increased significantly at the same time. Thus this study shows that the SRM with remote sensing data can be used to simulate and evaluate the climate change scenario, in Imja Khola basin, with acceptable accuracy besides the quality of data used.

Thesis Title: **THEORETICAL ASSESSMENT OF HYDROPOWER POTENTIAL USING GIS AND HYDROLOGICAL MODELING TECHNIQUE: A CASE STUDY OF KOSHI BASIN, NEPAL**

Submitted by: **Roshan Raj Giri**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

At present, the issue of hydropower Potential and development is highly raised. Harnessing hydropower needs accurate and reliable assessment of the potential. This study attempts to estimate the theoretical power potential of Koshi basin of Nepal using GIS (Geographical Information System) and continuous Semi-distributed Hydrological model (Hydrologic Modeling system), providing a new approach for rainfall-runoff modeling.

In order to calculate Power Potential of the Koshi basin, the elevation data at the upstream and downstream ends of each reaches of the basin is derived from the digital elevation model (DEM). The daily discharges for upstream and downstream ends of the river segment are derived from HEC-HMS model with Nash efficiency ranging from 64.07% to 83.65% for Calibration period and ranging from 64.07% to 79.90% for Validation

period. Combining the design discharges corresponding to 40th percentile flow with the hydraulic head determined from DEM the Power Potential is determined.

Different four cases are studied by dividing the stream segment which results the theoretical maximum Power Potential at 15870.38 MW and minimum at 14926.71 MW.

Thesis Title: **OPTIMIZATION MODEL FOR ALLOCATION OF DRINKING WATER SUPPLY - CASE STUDY OF DHARAN MUNICIPALITY**

Submitted by: **Suman Shrestha**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT

Dharan is one of the largest towns of Nepal. As the population of Dharan Municipality is increasing the available sources is insufficient to meet the present demand. There is intermittent supply of water in Dharan Municipality. The existing water sources are not sufficient to fulfill demand of water in Dharan Municipality due to leakage and maintenance losses. The study is aimed to formulate a suitable water supply optimization model considering the total cost of supply and cost of demand not met.

The objective function of the model is to minimize the total cost of supply and the cost of unserved demand. The constraints considered are the supply limit constraints and demand constraints.

The model used in the study is Linear Programming model. The input data in the model are supply data from three sources ,

Sardu-Khardu, Chatara-Dharan(proposed) and Ground water sources and demand data for each month in five demand centers (DC1 to DC5). The present water supply in Dharan is governed by NWSC (Nepal water supply corporation), Dharan. In this study the Dharan Municipality is divided in to 5 demand centers. These demand centers are supplied by three sources Sardu-Khardu, Chatara- Dharan (proposed) and Ground water.
GAMS (General Algebraic Modeling System) is used to solve the developed models. The consumer categories used for demand analysis are Fully Plumbed, Yard Type and Stand Post. There are altogether 4 scenarios analyzed in the study. The year 2010 without considering Chatara-Dharan is taken as base case. The penalty function is used that penalizes the demand centers deficit in supply.

It can be concluded from the present study that the supply condition is not enough to meet the water demand. However, this use for the model presented here can help to optimize the water supply allocation with multiple source and multiple demand centers.

Thesis Title: **INTEGRATION ECONOMIC WATER RESOURCES PLANNING AND MANAGEMENT MODEL: CASE STUDY OF BAGMATI RIVER BASIN**

Submitted by: **Bhesh Raj Thapa**

Supervisor: **Dr. Divas Bahadur Basnyat**

ABSTRACT

Planning, management and design are critical element for sustainable economic development and expansion. In the process of planning and design there is needed to critically analyze the true economic cost, benefits and environmental consequences of projects. More recently, population shift, industrial and political changes have led political leaders and planners to the conclusion that unlimited expansion and development are no longer the primary objectives in social and economic system planning and design. Simulation models are used to predict a system's response to a given design configuration with great accuracy and details, and to identify the probable cost, benefit, and impact of project. Simulation model provides only localized information regarding the response of the system to one particular design alternatives at a time. Optimization models provide a means of reducing the number of alternatives which need to be simulated in detail, i.e. screening them. These models search the space of

possible design variable values and identify an optimal design and/or operating policy for a given system design objective and set of constraints. The sensitivity of the optimal solution to changes in the model parameters can be readily determined and tradeoffs between several conflicting objectives can also be calculated with most optimization models.

This study integrates the generated time series data with the optimization model so that an optimum water resources planning and management can be achieved in different developed scenarios. In Optimization model network diagram are developed consisting of supply nodes, demand nodes, hydropower nodes, reservoir nodes, water diversion nodes and outlet nodes. The decision variables are reservoir storage, reservoir release, and irrigable area, cropping pattern and energy generation. The parameters used in this model are irrigation demand, minimum in stream flow, crop water requirement, cropping pattern, crop location possibility and crop calendar The formulated model is solved by CONOPT GAMS solver and is applied to the Bagmati River Basin.

Two different models are developed, one with an objective function of maximizing the total benefit for various purposes (economic efficiency model) and other with an objective function of minimizing the demand deficit (equity model). Several sub models are developed by changing constraints and priorities.

Proposed Bagmati Multi Purpose Project (BMPP) just above the existing Bagmati Irrigation Project (BIP) is considered as an intervention to meet the demand of potential irrigation area and to generate energy. A trade-off among economic efficiency, equity and environmental sustainability can be assessed when analyzing the design of water resources planning.
This developed model is recommended as a decision support tool in the context of 1WRM principles and River Basin planning and management concept to allocate the water in optimal way for Bagmati basin..

Thesis Title: **RESPONSE OF LAND COVER CHANGES ON SEDIMENT AND RUNOFF: A CASE STUDY OF BAGMATI BASIN**

Submitted by: **Sachindra Kumar Yadav**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Planning and assessment in land and water resource management are evolving from simple, local-scale problems toward complex, watershed-wide regional ones. Such problems have to be addressed with numerical models that can compute runoff in large (basin scale) complex watersheds with varying soils, land use and management conditions. GIS provides the framework within which spatially distributed data are collected and used to prepare model input files and evaluate model results. GIS-based tools, such as the Automated Geospatial Watershed Assessment - Soil and Water Assessment Tool (AGWA - SWAT), can be used to illustrate the effects of land use practices on runoff and sediment to support watershed-wide land use management decisions.

In this study, Bagmati basin in Nepal is selected as the study area. Bagmati watershed is delineated, descritized and

parameterized by AGWA tool to compute input parameter for SWAT model. The model is run for 1990-2003 to estimate the discharge, sediment and other data such as infiltration, distributed precipitation, percolation evapotranspiration etc at Pandhero Dhoban outlet. Estimated data from model is further validated (discharge, sediment) for accuracy. The accuracy obtained is found to be acceptable then the model is again run for the changed land use which shows that the change in land cover directly effect to the sediment load and discharge.

The results strongly suggested that the incorporation of barren with forest-mixed cultivation in the study catchment is the best management practice resulted in the highest mean annual reduction in sediment loads -33.7%, and 5% increase of stream flows in dry season similarly incorporation of agriculture, forest and grassland with barren is the worst management practice resulted in mean annual increase in sediment loads 54.2% and 13.7% decrease of stream flows in dry season.

Thesis Title: **NUMERICAL MODELING OF GROUND WATER OF KATHMANDU VALLEY, NEPAL**

Submitted by: **Ganesh K.C.**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

A three dimensional numerical model of groundwater flow in the valley of Kathmandu (capital of Nepal) has been developed to assess the impact of groundwater pumping on the flow pattern of groundwater. The scarcity and contamination of surface water, groundwater in the region constitute the main source of water supply for domestic, agricultural and even industrial. However, despite the importance of local groundwater hydrogeology of the Kathmandu valley is still not well studied. It is known that due to limited recharge and unregulated abstraction of groundwater, the groundwater level in the region has declined rapidly to values that show the unsustainability of the capture of this water resource.

Geologic and hydrologic data were integrated to develop a conceptual hydrogeologic model of the aquifer system of the Kathmandu valley, which was the basis for the development of the numerical model. The aquifer system was modeled

numerically using the program MODFLOW 4.2, steady state and defining three layers, two v corresponding to the aquifer base and the more shallow aquifer, and the third level of a low hydraulic conductivity and with an attitude of aquitard. MODPATH program was used to simulate the sense and direction of preferential groundwater flow.

The total area of the model is approximately 327 km^2 and is divided into cells of about 18,330 m^2. The boundaries were marked with the model based on topographic maps and digital terrain model extracted from a raster image. The hydraulic parameters of the aquifer system were assigned based on values from previous studies and were adjusted during model calibration. The reloading mechanism was considered as the main direct entry of water into the aquifer and occurs by infiltration of rainwater. The model was calibrated with values measured groundwater levels in boreholes and pumping stations that are monitored.

The modeling of groundwater flow in steady state allowed us to determine hydraulic gradients, apparent velocities and flow patterns within the study area. The model was used to simulate steady state conditions of pumping in 2001 and 2009, intending with this exercise to demonstrate the impact of abstraction of groundwater in the region. The sensitivity analysis allowed to determine what the most important parameters for the model and which ones need to be better studied. Groundwater recharge has been estimated with the help of sensitivity analysis. This flow model has an associated range of uncertainties arising from the simplification of input data and boundary conditions that were used to do in order to simulate a very complex case study, using available data hydrogeological conditions. It is therefore important to consider these limitations when interpreting and extrapolating the results of this modeling exercise.

Thesis Title: **A STUDY OF HYDRODYNAMIC INSTABILITY ON AN AXILIARY ROTATING PIPE FLOW**

Submitted by: **Kiran Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The present study is an experimental investigation of hydrodynamics instability of axially rotating pipe flow. An Experimental setup has been built with proper consideration of uniform flow at the inlet with no external disturbance to the facility. Flow visualization is done with small quantity of seeding particle Mearlmaid AA mixed with water to visualize as natural pearl essence on illuminating the flow from bottom by sheet of light.

The flow through the rotating pipe is analyzed at the inlet section and far downstream of the pipe. At the inlet section of rotating pipe flow, sudden solid body rotation is introduced with the uniform flow. Three types of different unstable mode as stable, wavy and unstable mode is determined for different Reynolds number and swirl parameter. Hydrodynamic instability of neutral curves is plotted for onset of instability based on the visualization. At the far downstream section, fully Hagen-

Poisuille axial flow with solid body rotation is considered. Different unstable mode is developed in a flow as stable, convective and absolute instability. The transition from stable to convective and then convective to absolute instabilities is studied quantitatively. In the region of convective to absolute instabilities, different and complex structures were observed in a range of Reynolds numbers (Re<500) that belongs to a laminar regime.

Hydrodynamic instability analysis of flow at upstream and downstream section determines the influence of absolute instability at the downstream section develop wavy flow at the inlet section. Also, the characteristics of the frequency and wavenumber for different instability state are determined for the downstream section which gives the qualitative information.

Matlab module code is developed which is verified with fake images for different wave's patterns of known frequency and wavenumber. This verified module is applied to real images developed from image processing of the videos taken during experiment. All the analysis from the beginning of generation of fake image, spatio-temporal image and the determination of frequency and wavenumber of moving wave by the help of Fast Fourier Transformation (FFT) are all done in Matlab. The research presents the effect of swirl parameter (L) and Reynolds number (0 < Re < 500) which are the non-dimensional control parameter for different hydrodynamic instability in laminar flow. Image visualization is done with image processing for the development of spatio-temporal images which later on processed with FFT. The research had led to the discovery of a new phenomenon at the inlet section of rotating pipe and even verifies the theory with the experiments for the downstream section. It is confirmed by flow visualization and the analysis of the images from the experiment that introduction of a rotation destabilizes the pipe flow. Also, the waves are appears in the developing region.

Thesis Title: **INTEGRATED ECONOMIC WATER RESOURCES PLANNING AND MANAGEMENT MODEL: CASE STUDY OF WEST RIVER BASIN**

Submitted by: **Ratna Prasad Lamichhane**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

For the development of nation it has to be proper management of all the natural resources. Nepal a developing country does not have any required study in area of investment and public demand field. In the present context, Nepal is concentrating more on the project- to-project planning. But for the optimal benefit, an integrated system of holistic approach has to be applied while planning for the river basin use. A Decision Support System(DSS) using simulation model would thus assist in assessing the water resources available in the basin and planning for optimum utilization of the water resources in future. This study is an attempt to look into the long term planning aspect of West Rapti River Basin.

This study integrates the generated time series data with the optimization model so that an optimum water resources planning and management can be achieved in different developed

scenarios. In Optimization model network diagram are developed consisting of supply nodes; demand nodes, hydropower nodes, reservoir nodes, water diversion nodes and outlet nodes. The decision variables are reservoir storage, reservoir release, and irrigable area, cropping pattern and energy generation. The parameters used in this model are irrigation demand, minimum in stream flow, crop water requirement, cropping pattern, crop location possibility and crop calendar The formulated model is solved by GAMS solver and is applied to the West Rapti River Basin.

Two different models are developed, one with an objective function of maximizing the total benefit for various purposes (economic efficiency model) and other with an objective function of minimizing the demand deficit (equity model). Several sub models are developed by changing constraints and priorities.

To minimize demand deficit in the basin various scenarios have been simulated in order to determine the water balance (surplus and deficit) for the different water uses and priorities of the water resources components of the river basin for the present as well as future uses. The total irrigation potential area in the basin is 57,000 ha out of which only 25,500 ha of land is presently irrigated. Jhimruk Hydropower Project (12.5 mw) is in operation in the Jhimruk Khola, a tributary of the West Rapti River.

While optimizing the basin with the objective function of maximizing the total benefit, different scenarios are developed. From the simulated result the proposed reservoirs Naumure and west Rapati Multipurpose reservoirs should be operate by calculating total benefit from different purposes of water resources. The downstream flow during dry season increases significantly with the flow regulation from reservoir. This can be termed as the downstream benefit because the increased dry season flow can be beneficial for further irrigation development, hydropower generation, environmental reasons and navigation.

River Basin Models like GAMS is found to be an appropriate tool for decision support, as all the ingredients of decision support system (DSS); inventory of basin's water resources and related lands, summary of basin's present water uses, projection of future water needs and identification of alternative decisions to meet or not to meet the indicated water needs, can be addressed. This model is based on a basic water balancing equation. It can be concluded that the procedure adopted like the one used in the present study can be of great use for making rational and optimal decisions.

Thesis Title: **INTEGRATED ECONOMIC WATER RESOURCES PLANNING AND MANAGEMENT MODEL: CASE STUDY OF KOSHI RIVER BASIN**

Submitted by: **Satish Tripathi**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Simulation and Optimization of the water resources system for the optimal development of the basin was done during this study. The sensitivity of the optimal solution to changes in the model parameters can be readily determined and tradeoffs between several conflicting objectives can also be calculated with most optimization models.

The formulation and use of mathematical programming in GAMS ianguage for monthly operation of Koshi River System in normal condition and under uncertainty of climate change effect was investigated. The non-linear objectives were calibrated for the large scale complex system to minimize the irrigation shortfalls, to maximize the hydropower generation, to optimize the flood storage benefit as well as sediment trap benefit and to maximize the economical benefit. Simulation program was used for the validation of each policy derived through this cycle. The

accumulation of these programs is called monthly reservoir operation model of the multi-reservoir Koshi River System.

This study integrates the generated time series data of eleven years (1993-2003) with the optimization model so that an optimum water resources planning and management can be achieved in different developed scenarios. In Optimization model network diagram are developed consisting of seven supply nodes, two demand nodes, four hydropower nodes, four reservoir nodes, two water diversion nodes and one outlet node. The decision variables are reservoir storage, reservoir release, and irrigable area, cropping pattern and energy generation. The parameters used in this model are irrigation demand, minimum in stream flow, crop water requirement, cropping pattern, crop location possibility and crop calendar. The formulated model is solved by CONOPT GAMS solver and is applied to the Koshi River Basin.

Three different models are developed, one with an objective function of maximizing the Total benefit for various purposes (economic efficiency model), second with an objective nmction of minimizing the demand deficit (equity model) and third with the model considering the climate change effect on meteorological system and its impact on the basin management.

Several sub models are developed by changing constraints and ~~priorities~~. Four reservoirs i.e. Saptakoshi High Dam Project, Sunkoshil, 2 and 3 are taken to operate to meet the demand of potential irrigation area and to generate energy. A tradeoff 2mong economic efficiency, equity and environmental sustainability can be assessed when analyzing the design of water resources planning.

This complete model may be used as a guiding tool for the optimum monthly operation of the multi- reservoirs in Koshi River System and is recommended as a decision support tool in the context of IWRM principles and River Basin Planning and Management concept to allocate the water in optimal and sustainable way for Koshi Basin of Nepal.

Thesis Title: **RESERVOIR SEDIMENTATION OF TAMAKOSHI-3 HYDROELECTRIC PROJECTS: AN ANLYSIS USING NUMERICAL MODEL GSTAR 4.0**

Submitted by: **Snajay Adhikari**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

This thesis deals with the numerical modeling of sedimentation in proposed reservoir on TA-3 Hydroelectric Project on Tamakoshi River. A numerical model GSTARS 4.0 was used for modeling works. The sedimentation in reservoir after operation of about 40 years was investigated together with the effect of operating regime on deposition of sediment. Measured daily flow data, sediment inflow data established from rating equations, cross section taken from the detail topographical survey, grain size distribution of incoming sediment and river bed was used for simulation. Three different operating patterns of fixing the reservoir water level at full supply level, varying the water level with moderate drawdown in rainy season and varying the water level with significant drawdown in rainy season for flushing were modeled.

The results obtained are qualitative in nature as quantitative verification is not possible. GSTAR 4 simulated and predicted the deposition pattern in reservoir satisfactorily except for the case where significant drawdown was considered. The reservoir will be moderately affected by sedimentation ceasing its usefulness in about 40 years. Sediment deposit advances towards the dam in the form of delta reservoir in both the cases of maintaining fixed water level at full supply level and varying water level with moderate drawdown. Deposition volume is almost equal in both case but position of delta formation is distinct. In first case deposition shape is accumulated type but in second case deposition shape is flatter type. In both cases, result shows that 50% storage capacity will be loss after about 40 years of operation. Sediment management is necessary to make the reservoir sustainable.

The study indicates that GSTAR4 can be used as a tool to have a view on severity and magnitude of the problem in planned reservoirs. The results of modeling can be refined using more reliable data on sediment inflow, cohesive sediment properties and grain size distribution of incoming sediment and river bed material.

Thesis Title: **NUMERICAL SIMULATION OF WATER AND SEDIMENT AT HEADWORKS AND DESANDING BASIN OF HYDROPOWER PROJECT: A CASE STUDY OF MODI KHOLA HYDROPOWER PROJECT**

Submitted by: **Pujan Piya**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

This study investigates the use of three-dimensional numerical model to simulate the flow of water and sediment at the head works and desanding basin of a hydropower project. The three-dimensional numerical model used for study in this thesis was SSIIM 1.0. In this study head works and desanding basin of Modi Khola Hydropower Project (MKHP) were numerically modeled for simulation of water and sediment flow. Physical model was done for MKHP at the feasibility study of project. The geometry and parameters used for numerical simulation were based on basic design and physical model. Various discharge and sediment conditions were modeled numerically as done in the case of physical model. The simulation results from SSIIM were in term of flow pattern, flow velocity, spatial concentration of sediment, performance ratio, deposition pattern, flushing pattern, trap efficiency etc.

The results from. SSIIM were qualitative and quantitative in nature. The simulation of water flow involved flow pattern, flow velocity, pressure distribution, turbulent kinetic energy and dissipation of turbulent kinetic energy (epsilon). The deposition and flushing pattern at the headworks were simulated to see the effectiveness of flushing capacity of undersluice. Performance ratio (PR) of the intake was calculated from the sediment simulation results so as to see the performance of the intakes. Also, the trap efficiency of the desanding basin was computed using the sediment simulation results. All the simulations were done for both POW and SOU schemes with various Manning-Strickler's values.

The results from SSIIM were compared with the results from the physical model. From the comparison of results from numerical and physical models, it could be seen that there were a lot of similarities. The flow pattern from SSIIM was almost similar to the flow pattern from physical model for headworks and desanding basin with very little differences. The flow velocity for headworks from numerical model had some difference with physical model, while in case of desanding basin the velocity profile is somewhat similar. The deposition and flushing pattern simulated by SSIIM had similarities with the pattern from physical model. The trend of trap efficiency for desanding basin from physical model was similar to numerical model. Performance ratio (PR) for intake was computed but could not be compared, as modeling of PR was not done during physical modeling. The results from fine grid had little difference from that of coarse grid.

Thesis Title: **BASIN - SCALE RAINFALL MODELING FOR FLOOD FORECAST: A CASE STUDY OF KOSHI BASIN**

Submitted by: **Manju Kawan**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

This paper mainly presents a rainfall runoff modeling for Koshi basin. The model is then used for flood forecasting in the Saptakoshi River of the Koshi Basin. Forecasting floods is a major task to protect human life and as well as surroundings around the natural rivers. The study is done in two parts; one is development of synthetic unit hydrograph and the other is the rainfall-runoff modeling. For an ungauged basin, synthetic unit hydrograph are developed from Snyder method to determine runoff hydrograph of the basin. The Snyder coefficients, coefficient of slope (Ct) and coefficient of peak (Cp) are calibrated for each sub basins and the values are found to be in the range from 0.35-0.67 and 0.384-0.484 for Ct and Cp respectively. The observed instantaneous maximum discharge and daily rainfall data of DHM and ICIMOD from the year 1964-2008 are used for calibrating the model parameters and verification of the model.

The HEC-HMS model is used for rainfall- runoff modeling of Koshi basin. For this rainfall - runoff is solved for each sub basin then the contributions from each sub basins to the basin outlet hydrograph are obtained using the channel flood routing and the flood hydrographs at the basin outlet are summed. This model is based on forecasting flow rate at a down-stream station using flow information at upstream and downstream stations. The peak discharge at the basin outlet is simulated to be 19960.4m3/s at 18.5h with relative error less than 10% and 20% respectively. With the use of IDF curve 2, 10, 50 and 100 years return period flood hydrograph is obtained.

The result of this study is the flood hydrograph at the basin outlet. The hydrograph can be used for warning the people about the probable flood and flooding time. Also from the use of rating curve of Chatara station the water level for the simulated discharge is determined and it is well above the danger level at simulated peak discharge. With further analysis of downstream the hydrograph obtained at Chatara outlet can also be used to obtain flooding area.

Key words: flood, sub basin, peak discharge, rainfall, hydrograph.

Thesis Title: **COMPARATIVE STUDY OF PERFORMANCE OF HYDROLOGICAL MODELS HBV AND SRM IN ESTIMATING SNOWMELT CONTRIBUTION FROM GLACIERIZED BASIN**

Submitted by: **Dip Bahadur Singh**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The use of hydrological models for estimation of snowmelt runoff is very essential and important for country like Nepal, where most of the rivers are snow fed and originated from Tibet. The Tamakoshi River Basin is one of the snow and glacier fed perennial river and its 50% of the catchment located in China. The estimation of snowmelt runoff by using the hydrological models to plan the hydropower generation in Tamakoshi Basin is very important where direct field observations are very difficult to carry out because ofrugged and remote mountain terrain.

In this research, a comparative study of performance of two hydrological models HB V and SRM have been carried out using in Tamakoshi Basin. The HBV model is extensively used in Norway for hydropower planning and generation in Norway,

Sweden and other European countries. Snowmelt Runoff model (SRM) is used in all over the world. Both the models are precipitation runoff model and designed to calculate snowmelt contribution in runoff.

In this study, Tamakoshi River at proposed intake site of Tamakoshi-3 HEP located about one km upstream of Busti gauging station is selected and the watershed area both in Nepal and Tibet above this point is taken for the study purpose. The temperature data were used from Jiri and Tshorolpa and the precipitation data were used from the meteorological stations Jiri, Salleri, Charikot, Nagdaha and Chaurikharka. The hydrological data were used at the Busti gauging station and checked with Lamabagar gauging station. From 2000 to 2004, five years hydro-meteorological data were used to calibrate the model parameters of HBV model whereas due to lack of satellite image 2002 was chosen for calibration of parameter and 2001 for validation period for SRM model. In HBV model, the four years average accuracy was found 87% where as in SRM model 87% efficiency in calibration period and 91% in the Validation period was found.

Both HBV and SRM models were run in present climate and conducted sensitivity analysis varying the temperature, degree day factor, critical temperature for both the models and threshold temperature for snowmelt (Ts) for HBV model. Similar scenario was observed in the result of sensitivity from both of the models. The result from SRM was found comparatively consistent than the HBV result for estimation of snowmelt. The HBV model can be used in any type of basin in mixed precipitation condition and its input parameters are very simple.

Thesis Title: **MODELING OF SEDIMENT YIELD IN THE KOSHI BASIN USING ARC SWAT**

Submitted by: **Dhiraj Raj Gyawali**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Planning and assessment in land and water resource management are evolving from simple, local-scale problems toward complex, watershed-wide regional ones. Such problems have to be addressed with watershed models that can compute runoff and sediment yield in large basin scale) complex watersheds with varying soils, land use and management conditions. New modeling tools in conjunction with GIS allow this quantification with high spatial and temporal resolution. GIS-based tools, such as the Soil and Water Assessment Tool (SWAT), can be used to illustrate the effects of land use practices on runoff and sediment yield to support watershed-wide land use management decisions.

In this study, SWAT model is used to delineate, discretize and parameterize the Koshi basin to compute input parameters required for the model run. The model is run for 1995- 2009 to estimate the discharge and sediment at the outlet. A combination of Latin Hypercube Sampling and One-at-time (LH-OAT) Sensitivity analysis was performed to assess the various sensitive

parameters affecting the model output. Ten highly sensitive parameters for both hydrologic and sediment components were identified. The most sensitive parameters were the Curve number (CN2) and Manning's value of channel roughness (Ch_N) for stream flow and sediment yield calibration respectively.

Model calibration and validation on both hydrologic and sediment components of the basin were also performed on a monthly basis to assess the model performance. The coefficient of determination (R^2) and Nash-Sutcliffe (Ens) were used to evaluate model calibration and validation. The results found were satisfactory for the gauging station (R^2 = 0.94 and Ens = 0.91 for calibration and R^2= 0.89 and. Ens = 0.87 for validation period for streamflow and R^z = 0.81 and E_{NS} = 0.79 for calibration and R^z = 0.83 and Ens = 0.77 for validation period for sediment yield). The stream flow and sediment yield of Koshi Basin were then quantified under different landuse change scenarios. The landuse conversion from forest and cultivation to barren land was responsible for the increased sediment yield throughout the year and decreased stream flow during dry seasons. Landuse change to forest from cultivation and barren land showed decreased sediment yield throughout the year and increased streamflow during dry months.

In conclusion, given the complexities resulting from the diverse landuse and soil types in a large watershed, the SWAT model could be effectively used to assess the water and sediment yields at the outlet.

Thesis Title: **AN APPLICATION OF GIS FOR FLOOD HAZARD AND RISK MAPPING: A CASE STUDY OF WEST RAPTI RIVER**

Submitted by: **Manoh Panthi**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

This study attempts to present the application of GIS and steady flow models for the preparation of hazard, Vulnerability and risk maps. The major tools/models used in this method is one-dimensional numerical model HEC-RAS 4.1.0 and ARCGIS 9.3.1 for spatial data processing HEC-GeoRAS for interfacing between HEC-RAS and ARCGIS.

In this study, a case study of West Rapti River upstream of Nepal India border to the Sikta Dam of Banke district in Nepal is undertaken. The aster Dem of data of the study is downloaded which is converted to point features. The DWIDP has undergone survey of the study area in 2009. As the survey data represents the real cross-section of the river so the area which contained survey data is erased from the point features of DEM. Then Topo to Raster Interpolation is done to make the DEM of the study area incorporating the surveyed data. This DEM is filled and flow direction and flow accumulation raster is generated. By

reclassifying the flow accumulation raster, the stream network can be generated which is used for the digitization of the streamline centerline. The cross-sections are automatically generated using HEC-GEORAS which is manually edited when they crossed each other or the cross-sections are insufficient. Digitization of Bank is done using the geo referenced Google image of 2007.

For the flood frequency analysis first the test of independency is done using the Andersons correlogram test and turning point test. Then the outlier is checked. There are no outliers in the given series. Then flows required for the study have been estimated based on probability distribution methods via Normal Distribution, Log Normal Distribution, Pearson Type. Ill Distribution, Log Pearson Type III Distribution, Extreme Value Type-I (EVI) Distribution, General Extreme Value (GEV) Distribution. It is found that the Log Pearson Type III Distribution fits well the chi-square test, Kolmogorov-smirnov test, and D-Index test. Flood discharges of 2722.14, 4018.49, 5010.23, 6422.19, 7594.36, 8873.64 m^3/sec is taken for return period of 2, 5, 10, 50 and 100 years respectively.

Thesis Title: **WATER RESOURCES MODELING AND OPTIMIZATION FOR PLANNING AND MANAGEMENT OF WATERSHED: CASE STUDY OF BABAI BASIN**

Submitted by: **Manoh Kumar Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya, Mr. Divas Bahadur Basnet**

ABSTRACT

The main objective of the study is to develop water allocation model/DSS model optimized with defined objective in different Scenarios in the Babai River Basin. The study comprise of developing hydrological model using HEC-HMS to simulate runoff at defined nodes of the basin by rainfall data. Then the optimization model using GAMS simulates different scenarios with or without future projects i.e. Bheri-Babai Diversion Project and Sarada-Babai Storage Hydropower^ Project to study demand satisfaction at different nodes. The developed model also generate optimum diverts for each node for minimizing demand deficit and for maximum total benefit The model generates the Optimum Cropping pattern by which maximum benefit can be achieved .The reservoir characteristics of the Sarada-Babai Storage Hydropower Project is also analyzed in the present study.

The result suggests that the Present irrigation demand in the Babai basin is not completely satisfied with the existing supply .Upper Babai basin and Sarada sub basin have comparatively higher demand deficit of around 50% demand deficit while the lower Babai have lower demand deficit of around 20% in dry season in the existing cropping pattern. With the addition of potential area of 38000 ha the deficit increases up to 48%. Further, the implementation of the Bheri-Babai river diversion completely satisfies the additional demand (For additional 38000 ha) at the Babai Irrigation Project in the existing Cropping pattern while in case of the Optimized cropping pattern for the maximum benefit, demand deficit of 60%, 30% and 80% is still observed in May, January and December.

Implementation of Sarada-Babai-Storage when optimized for minimizing demand deficit comfortably satisfies all the demand in the Babai irrigation project with the production of mean monthly energy of 18.13 Gwh. On the contrary when optimized for the maximum benefit 13.42 Gwh of mean monthly energy is generated with significant demand deficit in dry seasons irrigating more than 43863 ha of average monthly cropping area. With the implementation of both Sarada-Babai Storage HP project and Bheri-Babai Diversion Scheme when optimized for minimum demand deficit satisfies all the irrigation demand of

Babai Irrigation Project with generation of average monthly energy of 18.18 Gwh. But when optimized for the maximum benefit 20.29 Gwh of average monthly energy is produced while significant demand deficits are observed in January, May, and June.

Forty Cumecs of design discharge of Purposed Bheri-Babai Diversion meet all the irrigation demand in the existing cropping pattern ,while there is still demand deficit of 28 and 23 Cumecs observed in May and June respectively when it is applied to optimized cropping pattern maximizing the total benefit in BIP. But the practical cropping pattern is always a compromise between two scenarios and Thus purposed 40 Cumecs of design discharge of the Bheri-Babai diversion is justifiable.

Thesis Title: **IMPACTS OF CLIMATE CHANGES IN STREAM FLOW: A CASE STUDY OF MODI KHOLA IN NEPAL**

Submitted by: **Rupesh Mahat**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The IPCC (2007) report has confirmed, through observations and model-based studies, substantial hydrological changes in mountain watersheds where hydrology is dominated by cryospheric processes. The response of cryospheric processes to a warming climate in mountainous areas can be analyzed by examining the responses in the seasonal and annual hydrologic regimes of rivers where snow and ice contribute significantly to the runoff. This study utilizes a snowmelt runoff model in the Modi River Basin in the eastern Nepalese Himalaya which is driven by remotely sensed snow cover from Moderate Resolution Imaging Spectroradiometer (MODIS). The three different Seasonal Satellite images are used to estimate Snow/glacier coverage. The basin descriptive parameters are taken as estimated zones each having 500m elevation differences. The temperature and precipitation data are extrapolated to hypsometric mean elevation of these elevation zones.

The trend analysis of minimum, maximum and mean temperature of Chame station is performed. It shows that the slopes of minimum, mean and maximum temperature trend are found to be 0.264, 0.217 and 0.164 respectively. Among three the slope of minimum temperature trend is highest. It proves the positive trend of warmer climate in the study area. To assess the impact of such warming on stream flow, the hydrological model is developed first incorporating the snowmelt in it. Then the model is run under changed climatic scenario to predict the future stream flow under different scenarios.

The model parameter, degree-day factor is taken from previous studies of the study basin and runoff coefficients for snow and rain are initially derived using the observed data at different basin and adjusted while running the model. Geographical information system (GIS) is used for automatic delineation of watershed from Digital Elevation Model (DEM) and EDRAS Imagine software is used to delineate the snow and glacier covered area. The unsupervised image classification technique, NDSI, is used to classify the satellite image. Graphical display of two measured and computed runoff shows that simulation is successful. The observed discharge is simulated in the year 2002 and 2003 by SRM model with Nash efficiency 86.24% and volume deviation 8.24% during calibration for year 2002 and

Nash efficiency 82.9% and volume deviation 3.66% during validation period for 2003 .The model is also run in no snowmelt simulation mode to predict the contribution to runoff and it is found that the snowmelt contribution in stream flow is about 31.6% in Modi River. The study demonstrates that the impact of climate change (i.e. temperature) to stream flow is significant, which is increasing trend resulting from snow melt contribution. Due to the snowmelt contribution, stream flow increases approximately at rate of 3.97% in winter and 11.15% in summer and 10.32% in annual flow per one degree centigrade temperature rise. Thus this study shows that the SRM model with remote sensing data can be used to simulate and evaluate the climate change scenario, in Modi Khola basin, with acceptable accuracy besides the quality of data used. The results obtained from this study are importance for water resources managers to make and implement appropriate strategy for water resources management and hydropower development.

Thesis Title: **STREAMFLOW SIMULATION AND IMPACT ASSESSMENT OF LANDUSE CHANGES ON HYDROLOGY OF THE MADI RIVER BASIN USING SWAT**

Submitted by: **Santosh Kumar Sah**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The SWAT 2005 model was applied for the hydrological modeling and impacts assessment of landuse change in the Madi River Basin of catchment area 852 km2. The main objective of this study was to test the performance of the SWAT model for streamflow simulation as well as to apply the same model for the impact assessment of various landuse scenarios on hydrology. The SWAT model was firstly set up for 31 years of data from 1978 to 2008 in daily as well as monthly time resolution for streamflow simulation. However, model simulation was performed taking initial 5years as warm up period. The ASTER 30m resolution DEM, landuse map of Department of Survey (DOS), soil map from SOTER database for Nepal and the weather data collected from about 9 weather stations for a period of about 31 years were used to set up the model. The sensitivity analysis was performed to define the sensitive hydrological parameters and 22 parameters were ranked. Among them SCS

curve number (CN) was found to be most sensitive one. The model was then calibrated and validated at outlet of basin using SWAT-CUP/SUFI-2 and manual calibration. The NSE obtained were 0.75 to 0.79 for calibration and validation periods in daily time step and 0.87 and 0.91 for calibration and validation respectively in monthly time step.

For analysis of impact assessment/sensitivity test of landuse change, new SWAT model was calibrated for data range 1995-1999 using landuse map of 1997 and validated for two different time series landuse maps of 1986 and 2008, remaining same calibrated parameters, with respective dataset from 1984 to 1988 and 2005 to 2009 respectively. Good results for such data series with NSE of 0.82, 0.86 and 0.83 were obtained for calibration and validations respectively.

Four different landuse scenarios A, B, C, and D were developed using Arc GIS 9.3. Using the calibrated model (baseline model) with same all other parameters and datasets, only changing the landuse maps, the model was run for all four landuse scenarios A, B, C and D. The results were analyzed and were found that the response of landuse change to hydrology of basin was very sensitive. It was analyzed that greatest contributor of runoff was agriculture/cultivation, followed by barren land, bushland, grasslands and finally forest in the Madi basin. Scenario A was more sensitive for streamflow and caused up to 15.5% increase in flow in wet months whereas up to 16.2% decrease in dry months with respect to baseline model. Similarly, scenario B had same behavior as scenario A but scenario C caused decrease of flow throughout the year in general. There was increase of flow in dry months up to 4.7% and decrease little in wet months due to scenario D. There was increase of surface runoff throughout the year up to 96.9 % and 95.8 % due to scenarios A & B respectively and also had similar behavior on ET. Surface runoff due to scenarios C & D decreased throughout year up to 14.7% and 37.5% respectively, whereas ET decreased throughout year up to 43.3% due to D but increased in dry months and decreased in wet months due scenario C with respect of baseline scenario.

According to the sensitivity analysis of landuse carried out, the significance of the landuse change impacts for catchment was analyzed. As a result it might be possible to conclude that hydrological impacts were significant for the basin. Therefore, it can be deduced that landuse change impact for study areas might be the most sensitive fox catchment responses.

Graduation Year 2012

Thesis Title: **FINANCIAL VIABILITY OF PRIVATE HYDROPOWER PROJECTS UNDER CONSTRUCTION IN NEPAL**

Submitted by: **Anil Bhakta Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Nepal has tremendous potential of hydropower generation. The perennial nature of Nepalese rivers, its natural terrain and the steep gradient within the middle mountains and Himalayan areas are favourable for the development of hydropower projects.

The hydropower remains the largest source of renewable energy in the electricity sector. The total electricity generated by hydropower in 2009 is reached 3329 TWh, 16.50% of global electricity production and around 85% of total renewable electricity generation. The world leaders in hydropower are China, Brazil, Canada, the United States and Russia. Together these countries account for 52% of world's hydropower generation (IRENA, 2012).

Nepal has about 43,000 MW of hydropower potential that are technically and financially viable. Till date, it has harnessed only 1.70% of its hydropower potential. Therefore, investment in hydropower in Nepal is an ample opportunity for private sector to accomplish its untapped hydropower potential.

To attract the private sector in hydropower projects, Government of Nepal has promulgated acts, policies, legislative system. Hydropower sector has inherited characteristics of huge capital investment, high risks, long gestation period, local & social problems, congestion of transmission line for power evacuation etc. However, hydropower could be developed in Nepal with involvement of private sector.

The significant increase in hydropower capacity over the last 10 years is anticipated in many scenarios. It needs to continue in accordance with *"10 Year Hydropower Development Formulation Task Plan - 2065*" and *"20 Year Hydropower Development Formulation Task Plan - 2066*", with various environmental and social concerns perhaps the largest challenges to continue deployment if not carefully managed.

Seven different hydropower projects namely Lower Modi-1 (9.90 MW), Bijaypur-1 (4.41 MW - Ankhu-l (8.40 MW), Lower

Indrawati (4.50 MW), Lower Chaku (1.765 MW), Lower Chaku (1.8 MW) and Jiri Khola (2.20 MW) are considered for the study. The project relevant data and information are collected from the respective developers.

The contraction cost of under study hydropower projects has been found increased by maximum of 30% in comparison to the project estimate at detailed project design phase.
Numerous problems that occurred during the execution of the project make the project expensive. Change in design of hydraulic structures, increase of bank interest on loan, increase in costs of construction materials and manpower costs, inflation of Nepalese rupees with Dollars, local obstructions to construction works etc. are the main reasons for project cost overrun.

Nepal Electricity Authority has signed a power purchase agreement with 115 nos of private hydropower projects for the installed capacity of 1,641.07 MW (NEA, 2012b). Most of the hydropower projects are of run of river types and have substantial stumpy power during the dry season. Due to deficit of power meeting the demand, the load shedding is imposed in the country. Keeping it in vision, Government of Nepal had announced "*10points Load shedding Reduction Work Plan, 2068"* on 2068/10/17. With Ministerial Decision, the certain supports and incentives are provided to the problematic hydropower projects under the recommendation of Facilities Recommendation Committee.

The financial analysis of the hydropower projects based on project's revised cost and government supports has been carried out. The viability of the private hydropower projects is determined by comparing the financial indicators like IRR, NPV, B/C ratio and DSCR for both cases.

The average values of IRR, NPV, B/C ratio, min DSCR and max DSCR for projects without government are 9.89%, 8977428, 1.11, 0.82, and 1.05 respectively. Government supported projects have the average values of 12.18%, 150686570, 1.32, 1.06, and 1.35 respectively for IRR, NPV, B/C ratio, Min DSCR and Max DSCR. It indicates the financial indicators for government supports project has been found satisfactory than the project without government supports. The study reveals the need of government supports a promote private sector in hydropower. Therefore, the outputs of this study will be beneficial for the hydropower sector in Nepal.

Thesis Title: **GLACIERIZED WATERSHED MODELLING: A CASE STUDY OF KARNALI RIVER BASIN OF NEPAL**

Submitted by: **Bhusan Prasad Acharya**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The Karnali, Narayani and the Koshi are the three major glaciarized watershed basins in Nepal. Melting snow and ice supply water to much of the Himalayan region in the dry months before the summer monsoon. The importance of snowmelt contribution in the runoff regime of these watersheds has been widely accepted. On the other hand, they are one of the most sensitive indicators of climate change as they grow and shrink in quick response to changing air temperature. So it has become a prerequisite to estimate the quantity of snow and ice melt before planning for water resources management and to adapt the impact of climate change in these areas. Researches have already been conducted to work out for the contribution of snowmelt in Narayani and Koshi basin and this research has attempted to estimate the contribution of snowmelt in Karnali basin.

This study utilizes a surface energy balance over the whole watershed and to simulate the river discharge by application of

lumped conceptual runoff model and to estimate the snow and glacier melt contribution. Geographical Information System (GIS) is used for automatic delineation of watershed from Digital Elevation Model (DEM) and ERDAS Imagine software is used to delineate the snow and glacier covered area through satellite images of Landsat-7 ETM+. The unsupervised image classification technique, NDSI, is used to classify the satellite image. The model is used to simulate the daily runoff from 38 glaciarized watershed of Karnali basin. The glaciarized watershed is distributed in to 20 altitude zones of 200m interval and each band is further classified into debris free, debris covered glaciers and bare ground. Meteorological data at Kanjirowa in Hurikot and hydro logical data at Karnali Chisapani, Gopaghat and Humla Karnali in Lalighat are used in this study.

The snow and glacier melt for each altitude band are calculated by surface energy balance models, output of this model are used as input of TANK conceptual model and HEC-HMS model is used for modelling of precipitation and outflow of each sub basins of glaciarized basin. In this study, year 2002 is calibrated and year 2003 and 2004 are validated at two major sub basins Humla Karnali in Lalighat and Gopaghat and outlet of the basin at Karnali Chisapani.

The calibration of model for Humla Karnali in Lalighat shows the Nash efficiency of 86.51% and volume deviation of -3.55%, Gopaghat shows the Nash efficiency of 77.93% volume deviation of 9.20%, finally at Karnali Chisapani shows the Nash efficiency of92.15% and volume deviation of 1.98%. Likewise the validation of the model for the year 2003-2004 showed the Nash efficiency of 82.54% and the volume deviation of 8.00% at Humla Karnali, Nash efficiency of 82.32% and volume deviation of 0.32% at Gopaghat and Nash efficiency of 88.30% and volume deviation of -8.20% at Karnali Chisapani. Snow and glacier melt volume from each subbasins of Karnali basin are also estimated. The result showed the contribution of 13.86% of snow melt in Karnani Chisapani, 14.07*% of snow* melts in Gopaghat and 19.62% of snowmelt in Humla Karnali at Lalighat in the year 2002.

Thesis Title: **DEVELOPMENT OF SYNTHETIC UNIT HYDROGRAPH FOR FLOOD FORECASTING: A CASE STUDY OF BAGMATI RIVER BASIN**

Submitted by: **Bidur Adhikary**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Quantitative understanding and prediction of the processes of runoff generation and transmission to the outlet represents one of the most basic mid challenging areas of hydrology. Hydro-meteorological data are very indispensable for the assessment and development of water resources. However, most of the catchments in Nepal are unguaged and direct stream flow observations are not available at most sites for which rainfall-runoff relationships are required. In such case one resort is to develop Synthetic Unit Hydrographs (SUHs) if there are no observed discharge hydrographs. This research has been carried out for the development of Snyder unit hydrograph models for determination of the shape and dimensions of outlet runoff (flood) hydrograph in Bagmati watershed. Under this study, a flood forecasting model of the Bagmati River basin is being developed. Forecasting floods is a major task to protect human life and as well as surroundings around the natural rivers.

In this research work coefficients required for the construction of synthetic unit hydrographs using Snyder's method for sub-basins within the Bagmati basins have been determined. Lag time coefficient (Ct), peak discharge coefficient (Cp), unit hydrograph widths at 50% and 75% of the peak and base time were determined by calibrating Snyder's equations with the available maximum instantaneous discharge and corresponding rainfall data. Lag time coefficient (Ct) for the watersheds range from 0.3 to 0.34 with mean value of 0.313. The peak coefficients of the unit hydrographs of the watershed range from 0.4 to 0.47 with mean value of 0.45, these values are recommended to construct UH of the Bagmati basin. The hydrological models are calibrated with meteorological data. The hydrologic model described is HEC-HMS which is a spatially semi-distributed, physically based hydrologic model. Because of optimization ability and practicality of HEC-HMS software this program is used for simulation. This program simulates rainfall-runoff and channel routing processes.

A methodology is presented for extracting topographic, topologic, and hydrologic information, from the digital spatial data of a hydrologic system, for hydrologic modeling with HMS. Using this methodology, the determination of the spatial parameters for HMS is an automatic process that accelerates the setting up of a hydrologic model and leads to reproducible results. The peak discharge at the basin outlet is simulated to be 7902.40m^3/s at 8h with relative error less than 10%.

The comparison of the simulated and observed flow at Padherodovan showed that the HEC-HMS model performed well in simulating the flow of the Bagmati Basin. Satisfactory resemblance is observed between model results and measured discharges. However, in the high flood times, model generated river flows are found to be lower than the measured discharges.

Thus, finding of the study may help in planning and management of flood plain area of Bagmati Basin to mitigate future probable disaster through technical approach. The study, so far, has been conducted completely based on secondary data and information. Therefore, the model should be updated with adequate primary data to be collected through a comprehensive data collection campaign. The model is promising and could lead to better predictions with further work on the input characteristics.

Key words: flood, sub basin, peak discharge, rainfall, hydrograph, lag time coefficient, peak discharge coefficient

Thesis Title: **GIS BASED FLOOD HAZARD MAPPING AND RISK ASSESSMENT BASED VULNERABILITY STUDY OF PROPERTY DUE TO FLOOD IN DIFFERENT CLIMATE CHANGE SCENARIO ON FLOOD OF KAMALA RIVER BASIN**

Submitted by: **British Singh**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Flooding is one of the serious, common, and costly natural disasters that many countries are facing. One of the non-structural measures for risk reduction is the delineation of flood-prone areas. Flood risk mapping involves modeling the complex interaction of river flow hydraulics with topographical and land use features of the floodplains. From conventional flood hazard mapping technique based on field investigation to a knowledge-based system, the study integrated the hydraulic model with the Geographic Information System (GIS) and presented a systematic approach of this application.

The study focused on the preparation of Triangulated Irregular Network (TIN) from available cross section data, contours and

spot elevations, calculation of water surface profiles by steady flow analysis, delineation of the flood areas, risk assessment based vulnerability study of the property and creation of GIS Based Flood Hazard Mapping.

The approach adopted for the study consisted of dividing the risk into vulnerability associated with landuse pattern and hazard associated with hydrological and hydraulic parameters. The results of these analyses were combined to see relationships.

Next, in the change in climate scenario, flood prediction has been done with the different condition of the change in Temperature and Rainfall rise. For the prediction of the flood in climate change scenario, at first the climate properties like temperature, Rainfall and impact on runoff relation has been developed. With the developed relationship of Rainfall Vs Runoff and Temperature Vs Runoff, further runoff has been predicted and flood return period has been calculated to simulate on the Hec-Ras and HecGeo-Ras model to prepare the GIS based hazard mapping and risk assessment based on vulnerability study of property.

A series of maps were prepared depicting different relationships, such as discharge- flood area and flood depth-land use. This provided a framework that would help administrators and planners to identify areas of risk and prioritize their mitigation and response efforts.

Thesis Title: **ALTERNATIVE METHOD OF REMOVING SEDIMENT BY USING MODIFIED HYDROCYCLONE**

Submitted by: **Dipesh Rajak**

Supervisor: **Dr. Hari Prasad Pandit**

ABSTRACT

Most of the hydropower plants in Nepal that are dependent in the Himalayan rivers with excessive high sediment transportation rate. Major challenges of these hydropower plants is the removal of sediment from the sediment mixed water. Settling basin are the common devices used to exclude coarser sediment particles (>200jim) from the diverted flow, allowing finer particles to pass to the powerhouse. But the wear and tear to the turbines and accessories in most of the medium and high head plants have been found quite high. Not only it involves huge maintenance cost, but there is also a substantial revenue loss due to reduced equipment efficiencies. Recent studies have shown that fine sediment with considerable sediment load is the major factors to cause wear and tear to the turbines and accessories. So it requires comparatively larger and very expensive settling basins to exclude most of the fine sand and silt particles from the flow. So, the devices utilizing centrifugal separation such as hydrocyclones

have been recommended to apply in medium and high head hydropower plants.

This research was carried out to understand working principles of a 110 mm diameter hydrocvclone having four outlets. The main objective of this experiment is to find out the different combination of the openings that will yield maximum efficiency so as to extract sediment free flow from sediment laden flow.

20 tests were carried out to study its efficiency and find out the optimum combination of outlet openings. Very good efficiencies were observed for all runs performed with different sediment concentration of different particle size distributions, different inlet discharge with varying pressures and with different combinations of opening. It was found that 1st outlet extracted relatively finer particle, 2nd outlet and underflow extracted coarser particle and 3rd outlet extracted relatively clearer flow. Overall four combinations were used in this experiment. Out of which 4th combination yield a maximum efficiency in which 1st, 2nd and 3rd outlet were kept fully opened whereas underflow was kept half opened.

Thesis Title: **FLOOD PLAIN ANALYSIS AND RISK ASSESSMENT OF CHISAPANI – INERWA SECTION OF KAMALA BASIN**

Submitted by: **Dhruwa Kumar Jha**

Supervisor: **Dr. Hari Prasad Pandit**

ABSTRACT

Floods are among the most devastating natural hazards in the world causing huge losses of lives and infrastructure. Flooding can be partially avoided but flood hazards can never be ruled out. However, future flood prevention measures require a stronger stress on integrated approaches incorporating flood forecasting and risk uncertainties. Therefore, an appropriate flood modeling and mapping approach is needed to assess the potential damages. This study is carried out by integrating hydrological models with GIS to estimate the flood zone along the Kamala River Basin. HFIC-RAS and HEC-Geo RAS hydrological models have been used to delineate the areas vulnerable 10 flood at different discharge values.

GIS technology has been used to delineate the variation of topography and to find the inundation depths at various locations in the study area. Inundation area estimated at the maximum discharge of 100 year return period value of 5942.96 m /sec is

152 km2 is occupied under the inundation depth from 1 to 3.3 meters. Maximum inundation depth can go up to 3.3 meters for this discharge value. The Vulnerability map prepared from flood hazard map and Land use map shows that the Siraha municipality and cultivated lands are more vulnerable. Similarly the exposure map relates the population density with flood area which affects the population and thus the prepared exposure map shows that the Siraha Municipality is the most exposure for flood hazard of this study area. Lastly, the risk map prepared by adding with equal weitage of bazard map, vulnerability map and, exposure map shows that Siraha Municipality, Chatari, Balahakhar etc. and cultivated land of the study area are in Risk Zone**.**

Keywords: DEM, Hydrological modeling, Flood frequency analysis, hazard mapping, Vulnerability mapping, Exposure mapping and Risk mapping.

Thesis Title: **THEORETICAL ASSESSMENT OF HYDRPOWER POTENTIAL USING GIS AND HYDROLOGICAL MODELING TECHNIQUE: A CASE STUDY OF MID HILL BASINS (KANKAI, KAMALA, BAGMATI, WEST AND BABAI) OF NEPAL**

Submitted by: **Gopi Prasad Sah**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

At present, the issue of hydropower potential and development is one of the most prioritized agenda for any government in Nepal. The national economy and social life is crippling because of the wide deficit between supply and demand of electricity. Since, there is no other energy sources which the country could utilize, the only way out is to construct hydro-projects of its own; Harnessing hydropower needs accurate and reliable assessment of the potential. This study attempts to estimate the theoretical power potential of Run-of-River hydropower scheme for mid-hill basins (Kankai, Kamala, Bagmati, West Rapti and Babai) of Nepal by spatial analysis using Geographical Information System (GIS) and rainfall-runoff modeling using Hydrologic Modeling System (HMS).

The Digital Elevation Model (DEM) is processed using GIS extension tool HEC Geo- HMS to prepare the input basin model for HEC-HMS and daily evapo-transpiration, meteorological & discharge data are also fed to simulate discharge which is duly calibrated and validated with observed discharge to establish realistic hydrological phenomena. The model is evaluated with Nash efficiency ranging from 65.59% to 82.76% and volume deviation ranging from -17.77% to 7.36% for simulated and observed discharge during calibration and validation.

In order to calculate power potential of these five basins, the elevation data at the upstream and downstream ends of each river reaches inside the basin is derived from GIS application on the DEM. The daily discharges for upstream and downstream ends of the river segment are derived from hydrological modeling using HEC-HMS model. Combining the design discharges corresponding to forty percentile flows with the hydraulic head determined from DEM the power and energy potential are determined.

The theoretical total power and energy potential of Kankai, Kamala, Bagmati, West Rapti and Babai river basins are 127MW, 482Wh, 46MW, 199GWh, 477MW, 2036GWh, 343MW, 1319GWh, 186MW and 840GWh respectively.

Thesis Title: **SUSTAINABILITY OF RESERVOIR OF KALI GANDAKI KOBAN HYDROELECTRIC PROJECT**

Submitted by: **Jaya Ram Prajapati**

Supervisor: **Dr. Hari Prasad Pandit**

ABSTRACT

The sediment transport in the Kali Gandakl River is quite significant and has been measured as high as 46,832 ppm in June 2011. Sediment handling is the major dilemma for the sustainability of any project in Himalaya as it causes significant wear and tear of hydro-mechanical equipment and loss of efficiency of the plant. This thesis deals with sustainability of reservoir of Kali Gandaki Koban Hydroelectric Project. The numerical model, HEC-RAS 4.1 is used for the simulation of sediment transport and deposition pattern in the reservoir for storage and PROR options and proposes most suitable measures of sediment handling to ensure sustainability of the reservoir.

Five different options arc studied for the reservoir operation considering different full supply level of reservoir. Each option is studied with and without flushing of reservoirs for two months at each year. When reservoir flushing is disregarded, full seasonal storage corresponding to FSL at 2576 masl (283.11 MCM), FSL

at 2541 masl (66.36 MCM), FSL at 2535 masl (44.4 MCM) and FSL at 2520 masl (12.13 MCM) will be filled up within forty eight, twelve, seven and three years respectively. On the other hand, if two months flushing is considered, the respective reservoir life will be twenty eight, five and three years respectively resulting in thirty one to forty seven percent loss of wet energy. Hence, both of options have not been suitable because of short life of reservoir and huge energy outage.

Therefore, for sustainably of the project, sediment bypass option with two reservoirs is adopted as a feasible alternative. The lower reservoir is filled up periodically and the plant is operated using this volume, while the upper reservoir is flushed intermittently using bypass tunnel. The alternative flushing of upper reservoir at original river condition could flush 21.66% of total sediment deposited. However, the same with channel improvement with side slope stabilization and maintaining the river gradient could flush as much as 54.74% of total volume of sediment deposited. As the plant receives flow from lower reservoir during upper reservoir being flushed, there is no loss of energy generation. Hence, a diversion tunnel with bypass is taken as suitable measure for the sustainability of reservoir.

Thesis Title: **YIELD RESPONSE TO WATER, USING AQUACROP, A CROP WATER PRODUCTIVITY MODEL: A CASE STUDY OF FARM LEVEL RICE CULTIVATION IN CHITWAN OF NEPAL**

Submitted by: **Krishna Prasad Rijal**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Water is one of the scarce natural resources in the globe which is very much important for sustaining human life. Irrigation water uses more than two third of the world's developed freshwater and rice (Oryza Sativa L.) uses the greatest part of it. This study was intended to access the rice yield response to various irrigation regimes at the farm level. AquaCrop model was used for analyzing impact of soil and water related options on rice yield and water use for enhancing water productivity in irrigated environment of Chitwan district of Nepal. Performance of the model was reasonably good as indicated by close matching between simulated and measured grain yields.

The simulation conducted for the year 2009 in early rice showed that the depth of irrigation was not sensitive to yield because of

high rainfall occurred at that time. To see the sole response of irrigation water, drought condition without rainfall was considered and simulations were done for 25, 50 and 100 mm depth of irrigation with 2, 5, 10, 15, 20 and 25 days of intervals. The result showed that 25 mm depth and 10 days of interval irrigation was the best combination for optimum yield and water productivity.

In order to find yield response to unreliable irrigation of reduced depths than scheduled, 25 and 50 mm depth at 100, 90, 80, 70, 60 and 50 percent supply in 5, 10 and 15 days interval were simulated. The result showed that 25 mm depth of irrigation with 5 day interval was the most suitable combination which didn't underperform even when the scheduled depth was reduced by 50 percentage points.

Net irrigation water requirement was also determined for various levels of readily available moisture depletion; and impact on yield and water productivity was also analyzed. It was found that up to 70 percent depletion of readily available moisture no significant decrease in yield was found and up to 60 percent depletion, water productivity was increased then it remained constant.

Irrigation schedule was also generated with and without rainfall conditions at various depletion levels of readily available moisture. The model generated schedule resulted various irrigation depths and intervals for each irrigation. For a more pragmatic application, the model generated schedule was modified to uniform depth and interval for all events and tested for yield impacts. The result showed non-significant changes over yield.

Various rice irrigation methods were evaluated for yield production and water use efficiency. The traditional continuous flooding method was found inefficient and intermittent system with shallow depth was found more effective among other methods.

The impact of soil type on yield and water productivity was also studied. Very coarse and fine both soils were found less suitable for rice cultivation. Medium textured soils such as silt and loam, freely draining but retaining a fair amount of moisture required for healthy plant growth were found more effective.

In overall, this study concluded that depth of irrigation is not a governing factor for increasing rice yield, provided that the soil moisture is maintained nearly at the field capacity level. Also, irrigation of interval 10 days is found optimum for all type of soils and all depths of application under study.

Thesis Title: **HYDROLOGICAL MODELLING AND CLIMATE CHANGE IMPACT ASSESSMENT USING HBV LIGHT MODEL: A CASE STUDY OF KOSHI RIVER BASIN**

Submitted by: **Mohan Raj Acharya**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The lumped conceptual hydrological model HBV is applied to the Koshi River Basin to estimate runoff at several gauging stations and to analyze the changes in catchment hydrology and future flood magnitude due to climate change. The performance of the model is analyzed to assess its suitability to simulate stream flow in snow fed mountainous catchments. Due to the structural complexity, the model shows difficulties in modeling low and high flows accurately at the same time. It is observed that the low flows were generally underestimated and the peaks were correctly estimated except for some sharp peaks due to isolated precipitation events.

In this study, attempt has been made to evaluate the importance of snow melt discharge in the runoff regime of the basin. Quantification of contribution of snowmelt to annual, summer

and winter runoff has been done. The contribution is highest at the beginning of the hot months as the accumulated snow begins to melt. Examination of this contribution under conditions of increased temperatures indicate that global warming leading to increase in average basin temperature will significantly lead to higher contributions to runoff from snowmelt. Forcing the model with the output of HadCM3 GCM and the A1B scenario downscaled to the station level show significant changes to catchment hydrology in the 2040s. It is observed that the increase in runoff is most extreme in June - July. A shift in the hydrological regime is also observed.

Thesis Title: **RAINFALL RUNOFF MODELLING FOR FLOOD FORECASTING: (A CASE STUDY ON WEST RAPTI WATERSHED)**

Submitted by: **Rockey Talchabadel**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Floods are the most widespread climate-related hazards in the world, and they impact more people globally than any other type of natural disaster. It causes over one third of the total economic loss from natural catastrophes and is responsible for two thirds of people affected by natural disasters. On the other hand, studies and analysis have shown that damage reductions due to forecasts improvements can range from a few percentage points to as much as 35% of annual flood damages. Determining the extent of flooding is an important role of the hydrological research community and provides a vital service to planners and engineers.

The impact of flooding was not felt to the same extent in the past as it is now. This could be due to the rapid increase in population and consequent increase in the human activities. The flood plains are being increasingly occupied to meet ever-increasing requirements of food and fiber, and consequently the flood problem is exacerbated. In Nepal each year, on an average 330

lives are lost due to floods and landslides and infrastructure and property amounting to more than US$ 100 million is damaged causing negative impacts on the social and economic development of the country.

Mitigating flood damages can be done in two possible ways; structural measure and non structural measures. If a judicious mix of both the structural measures and non structural measures are introduced devastation from flood can be greatly reduced. Structural solutions are mainly preventative and focusing on curtailing the magnitude of floods using different methods such as dams, embankment, compound channels, widening of river beds, etc. However these solutions have adverse environmental, hydrologic, ecologic or economic consequences. These measures are designed to divert flood water away from the people. This type of mitigation measures are proven effective but most expensive.

The non-structural mitigating measure places people away from flood. This method is designed to reduce the impact of flooding to society and economy. It includes flood insurance, land use planning and zoning and flood forecasting and warning schemes. Hvdrologic/hydraulic models are often used in flood forecasting and early warning systems. These models when optimally calibrated and validated can be an effective tool in mitigating flood damages through non-structural means. This method is very effective, cheaper and consumes less time. So, in my thesis I used rainfall runoff modeling for the flood forecasting and warning schemes as a non-structural hydrologic method for mitigating flood damages.

Rainfall-runoff relationship is mostly used mathematical model for water resource management planning, flood forecasting and warning schemes. The relationship is nonlinear and the runoff prediction depends on many factors. Rainfall intensity and duration of rainfall has been main driving factor of the rainfall-runoff process followed by watershed characteristics that translate the rainfall input into an output hydrograph at the outlet of the basin. For this purpose, different types of models with various degrees of complexity have been developed. They are based on empirical, physically-based or combined conceptual-physically-based model. In this context due to unavailability of detail information of the study area, lumped model NAM is used for simulating rainfall into runoff.

Due to lack of hourly interval data of rainfall, development of synthetic unit hydrograph from Snyder method is also done to determine runoff hydrograph of the basin. The Snyder coefficients, coefficient of slope (Ct) and coefficient of peak

(Cp) are calibrated for each sub basins and the values are found to be in the range from 0.41-0.58 and 0.32-0.43 for Ct and Cp respectively. The observed instantaneous maximum discharge and daily rainfall data of DHM from the year 1964-2008 are used for calibrating the model parameters and verification of the model. Mike UHM rainfall runoff model is used to incorporate developed unit hydrograph.

Thesis Title: **COMPARISON OF EMPIRICAL METHODS AND ITS USE IN FLOOD RISK MAPPING: CASE STUDY OF MOHANA RIVER, KAILALI AND KANCHANPUR**

Submitted by: **Raju Sharma**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

This study attempts to compare the empirical methods for the flood frequency analysis and prepare hazard, vulnerability and risk map of an ungauged river. The major tools/models used are one-dimensional numerical model HEC-RAS 4.1.0 (Hydrologic Engineering Centre-River Analysis System), ArcGIS 9.3.1 for spatial data processing and HEC-GeoRAS (Hydrologic Engineering Centre- Geospatial River Analysis System) for interfacing between HEC-RAS and ArcGIS.

In this study, a case study of Mohana River, upstream of Nepal India border to Mahendra Rajmargh is undertaken which lie in Kailali and Kanchanpur districts. For the flood, frequency analysis accurate flood estimation is an important task. As the river selected is unguaged, so different regional empirical methods namely WECS, Modified Dickens's, Snyder's and B.D

Richard's are used for flood discharge calculation in different return periods and compared to find the best method for this type of rivers.

A field study is carried out during the study on which discharge and area of water bounded region of river is measured. Due to the difficulty in measuring discharge and area simultaneously, only area of one kilometer reach of river from the Nepal- India border is measured in the field. The measured discharge is used in HEC-RAS model and the output-flooded area is compared with the field-measured area then the level of accuracy is established. Discharge of different return period's form all empirical methods are also used to calculate the respective flooded areas which are used to develop flooded area verses discharge relationship and through this relation water bounded area is calculated using the discharge measured from field and area closer to field is identified.

The aster Digital Elevation Model (DEM) of data of the study is downloaded which is converted to point features. The survey data from Department of Water Induced Disaster Prevention of the study area is taken. As the survey data represents the real cross-section of the river, so the area which contained survey data is erased from the point features of DEM. Then tope to raster Interpolation is done to make the DEM of the study area incorporating the surveyed data.

Thesis Title: **HYDROLOGICAL MODELING AND CLIMATE CHANGE IMPACT ASSESSMENT USING HBV LIGHT MODEL: CASE STUDY OF KARNALI RIVER BASIN**

Submitted by: **Sagar Shiwakoti**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

In this study, application of the semi distributed conceptual hydrological model, HBV has been done in the Karnali River Basin to estimate runoff at several available gauging stations. It helps to analyze the changes in catchment hydrology and future flood magnitude due to climate change. Analysis of the performance of the model using various measures of fitness criteria indicate that the model is suitable to be used for simulation of streamflow in snow fed mountainous catchments. However, due to its structural complexity, the model shows difficulties in modeling low and high flows accurately at the same time. It is observed that the low flows were generally underestimated and the peaks were correctly estimated except for some sharp peaks due to isolated precipitation events.

Attempt has been made to evaluate the importance of snow melt discharge in the runoff regime of the Karnali River Basin. Quantification of contribution of snowmelt to annual, summer and winter runoff has been done. Findings from the study indicate that the contribution is highest at the beginning of the hot months when the accumulated snow begins to melt. Examination of this contribution under conditions of increased temperatures, assuming all other climatic variables to remain constant, indicate that global warming leading to increase in average basin temperature will significantly lead to higher contributions to runoff from snowmelt. Forcing the model with the output of HadCM3 GCM and the A1B scenario downscaled to the station level show significant changes to catchment hydrology in the period between 2030 to 2060 AD. It is observed that the increase in runoff is most extreme in June - July. A shift in the hydrological regime is also observed.

Thesis Title: **APPLICATION OF UNCERTAINTY ANALYSIS TECHNIQUES TO SWAT MODEL: A CASE STUDY OF WEST SETI RIVER BASIN, NEPAL**

Submitted by: **Saroj Karki**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

In recent years, hydrological models are more and more widely applied by hydrologists and water resources planners as a tool to examine watershed scale processes and to evaluate the hydrologic effect of various management scenarios. The use of watershed models is increasing in response to growing demands for economic and efficient use of available water and thus for the formulation of appropriate water management strategies to cope future water challenges. These hydrological models are simplification of reality and therefore there is always some degree of associated risk or uncertainty. It is vital that uncertainty is recognized and properly accounted for. Such scenario has presented an opportunity for this thesis to analyze different aspects of hydrological modeling focusing uncertainty estimation.

This thesis primarily focuses on different aspects of hydrological modeling like calibration, validation, and sensitivity analysis and uncertainty estimation for the streamflow with a view to check the reliability of the model. It uses multiple model evaluation techniques to assess which part of the model works good and which part of the model is weak. This study also makes use of carefully calibrated and validated hydrological model to comprehensively assess the water balance scenario of the study watershed. Because the distributed hydrological model requires the proper spatial representation of the watershed, spatially distributed satellite rainfall data were also analyzed and then used to predict the response with an objective of assessing the validity of such data. Finally uncertainties in the model prediction were estimated by two different approaches.

A popular semi-distributed hydrological model, Soil and Water Assessment Tool (SWAT), was used to perform hydrological analysis of West Seti River Basin of Nepal. Physically based models where large number of parameters involved, Sensitivity analysis of parameters proved to be helpful in selecting the parameters for calibration. Calibration and Validation for daily streamflow at the basin outlet produced good results (Nash-Sutcliffe Efficiency, NSE= 74% and 68% respectively) while for monthly streamflow, the performance improved (Nash-Sutcliffe

Efficiency= 93% and 85% respectively). This indicated the effect of time step on model performance. Further analysis revealed that model well captured the peak flows for daily time step but peak flows were underestimated for monthly time step. Decomposition of NSE performance criteria showed that the correlation component.

dominated the NSE value while the contributions of other components (bias and variability) were quite low. The analysis of daily TRMM rainfall data and its comparison with the observed data showed considerable bias though some stations showed high correlation and some low correlation. The mean monthly discharge at the basin outlet generated by TRMM data indicated satisfactory results (NSE=50% and R^2=0.84) but the results may be improved by using the TRMM data after applying proper bias correlation. Finally the uncertainty analysis of the SWAT simulated daily discharge based on meta-Gaussian approach covered most of the observed data inside the 95% confidence interval (94% and 95% during calibration and validation period respectively) band but on the expense of wide interval band. On the other hand, the uncertainty analysis of mean monthly discharge by Sequential uncertainty fitting (SUFI-2) produced a narrow 95PPU band indicating less uncertainty range. But it bracketed relatively less (58% and 64% during calibration and validation respectively) observed data within 95PPU band. Further analysis revealed that model failed to bracket most of the peak flows as well as the recession part indicating high uncertainty in peak flow and recession flow estimation. Given the high uncertainty in the model prediction, its implications in the decision making process should be properly accounted for.

In the end it can be said that the approach adopted in this study can pave a way forward for application of model evaluation techniques and uncertainty analysis in hydroiogical modeling.

Thesis Title: **HYDROLOGICAL MODELING AND CLIMATE CHANGE IMPACT ASSESSMENT USING HBV LIGHT MODEL: A CASE STUDY OF NARAYANI RIVER BASIN**

Submitted by: **Santosh Bhattarai**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The lumped conceptual hydrological model HBV-Light is applied to the Narayani River Basin to estimate runoff at several gauging stations and to analyze the changes in catchment hydrology and future flood magnitude due to climate change. The performance of the model is analyzed to assess its suitability to simulate stream flow in snow fed mountainous catchments. Due to the structural complexity, the model shows difficulties in modeling low and high flows accurately at the same time. It is observed that the low flows were generally underestimated and the peaks were correctly estimated except for some sharp peaks due to isolated precipitation events.

In this study, attempt has been made to evaluate the importance of snow melt discharge in the runoff regime of the basin. Quantification of contribution of snowmelt to annual, summer

and winter runoff has been done. The contribution is highest at the beginning of the hot months as the accumulated snow begins to melt. Examination of this contribution under conditions of increased temperatures indicate that global warming leading to increase in average basin temperature will significantly lead to higher contributions to runoff from snowmelt. Forcing the model with the output of HadCM3 GCM and the A1B scenario downscaled to the station level show significant changes to catchment hydrology in the 2040s. It is observed that the increase in runoff is most extreme in June - July. A shift in the hydrological regime is also observed.

Thesis Title: **FLOOD RISK MAPPING OF KATHMANDU VALLEY**

Submitted by: **Shuvra Bijukshe**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Floods are probably the most recurring, widespread, disastrous and frequent natural hazard of the world. Nepal is one of the most flood affected countries. Flood mitigation measures generally consists two approaches, one is structural method and another one is non-structural method. Among them flood risk mapping is one of the prominent non-structural methods for flood control and mitigation purposes. The non-structural measure for risk reduction strategy is the delineation of flood prone areas. This study attempts the application of GIS and steady flow model for the preparation of hazard, vulnerability, exposure and risk maps of Kathmandu valley. The major tools used in this study are ArcGIS 9.3 and one-dimensional numerical model HEC-RAS 4.0 with HEC-GeoRAS 4.3 for interfacing between HEC-RAS and ArcGIS.

The study describes the technical approach of probable flood hazard; vulnerability, exposure and risk analysis of Kathmandu valley. The Kathmandu valley is an intermountain valley with an

approximate area 626 sq.km. lies between latitude 27° 32' 00" N to 27° 49'16" N and longitude 85°13'28^{M} E to 85°3r53" E. The average annual rainfall in the area is 1600 mm. Flood frequency analysis for 2, 5, 10, 20, 50 and 100 years return period was done by WECS, Modified Dicken's and Snyder's method based on extreme average annual precipitation recorded at available fifteen stations around the valley.

Triangulated Irregular Network (TIN) was prepared from Digital Elevation Model (DEM) of 10 m*10 m spatial resolution in ArcGIS. Required data sets as stream, banks, flow paths and cross sections were prepared by HEC-GeoRAS thus, creating import file and imported in HEC-RAS. Similarly, maximum flood discharges among all the methods of different return periods were also entered in HEC-RAS. Steady flow analysis was done in HEC-RAS with Manning's roughness coefficient 0.035 for bed and 0.04 for flood plain and normal depth as boundaiy condition. The simulated flood is imported to GIS using HEC-GeoRAS and flood inundation map is prepared.

Hazard map is prepared based on the depth of flood. The vulnerability map is prepared based on the land use that is affected by flood and the exposure map is prepared based on the population affected by the flood. The results of hazard, vulnerability and exposure are combined to prepare the risk map of the study area. The assessment of the flood water depth shows that most of the areas under flooding have water depth less than 1.0 m. The assessment of flood vulnerability indicates that a large percentage of vulnerable area (more than 70%) is cultivation area followed by the water body and sand, comprising 18% and 7% respectively. The exposure assessment of the study area indicates that Kathmandu M.N.P., Lalitpur N.P., Jorpati and Madhyapur Thimi N.P. are highly susceptible of exposure; Sundarijal and Suntol are not likely to be affected. From the study it is found that, most of the areas are under moderate risk. Cultivation is the major affected land use pattern for all return year flood and are under moderate and high risk area.

The automated risk mapping and analysis using these tools provide more efficient, effective and standardized results and saves time and resources. The presentation of results in GIS provides a new perspective to the modeled data for better visualization. The visualization and the quantification of the flood risks as facilitated by this approach can help the decision makers better understand the problem.

Thesis Title: **EROSION MAPPING OF A WATERSHED USING MODEL WITH THE INTEGRATION OF GIS AND REMOTE SENSING: A CASE STUDY ON KANKAI MAI WATERSHED**

Submitted by: **Sunil Basnet**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The soil erosion rate in hilly and Himalayan region is increasing in alarming rate due to most fragile ecosystem with steeper slopes in conjunction with the depletion of forest cover and high seismicity. It has been the deep concern for the environmentalists, water resources planners and developers. Economically, the soil loss results in the decrease of arable land and its quality by depleting the top fertile soil and thereby affecting the land productivity as a whole. It also affects the surface water storage capacity by sedimentation of lakes and reservoirs and water quality by contaminating the water with suspended soil particles, toxic materials and pesticides. Soil erosion is a threat to the sustainable agriculture. Faulty agricultural practices, excess rainfall undulating topography are the main factors inducing soil erosion in our country. Determining the extent of soil erosion and its mapping within the

watershed plays an important role in the hydrological research and provides a vital service to planners and engineers.

Universal Soil Loss Equation Model is a parametric model used worldwide to determine the annual sediment yield. And the determination of yield depends upon mainly five factors i.e. R factor, K factor, LS factor, C factor and P factor. Normally R factor used worldwide is derived mean annually. The storm intensity and duration differ drastically for each and every month. Hence in this thesis work an attempt was made to calibrate the R factor for each individual month. In Universal Soil Loss Equation model, R factor is the only dynamic factor while other factors are assumed rather static over the period of observations. Hence, calibration is done for only rainfall erosivity factor. For the Calibration Fournier Index was obtained for each month. There is correlation between Fournier index and rainfall erosivity factor which we use as key for the calibration of the model.

For the determination of the R factor the daily rainfall data of six nearby meteorological stations 1406, 1407,1408,1410,1411, and 1415 were used. Due to lacking of hourly and sub-hourly precipitation data, R factor was calibrated from correlation between fournier index and R factor. For the determination of the soil Erodibilitv factor (K) the soil map of Kankai Mai basin produced by Food Agricultural Organization was downloaded from wwwAcric.com and K factor values for different soil types were given as per United States Department of Agriculture classification. Slope Steepness factor (LS) was obtained from the manipulation of DEM of Kankai Mai river basin in Arc GIS 9.3. For this the whole catchment was divided into 104117 grids of 100 X 100 m each and LS factors for each grid was obtained in Arc GIS 9.3 environment. Cover management factor (C) was obtained by unsupervised classification of satellite image in Erdas Imagine 9.2 environment. P factor was obtained as per the type of soil cover and Agricultural practice most common in the locality. Universal Soil Loss Equation Model gives the sediment detachment rate while the sediment delivery rate to lower catchment is governed by sediment delivery ratio. Here in this thesis work sediment delivery ratio equation suggested by Williams and Berndt's 1972 was chosen. Sediment Delivery ratio is dependent on the slope of the plot. The sediment delivered to the outlet of catchment was the calculated summing the sediment yield at each grid which was further compared with the observed values to calibrate and (3 for each month).

Mapping of soil loss rate was done within the basin after the calibration and validation of model parameters. The average sediment yield at the outlet of the basin was calculated as 21.94 tons/hectare per annum. While the range of yield obtained within the study period ranges from 18.04 to 25.07 tons/hectare per annum .The results can be used to identify the soil erosion hot spots and develop the best soil erosion management practices and help estimate the quantity of soil that was transported into the downstream of Kankai Mai basin.

Thesis Title: **DEVELOPMENT OF SYNTHETIC UNIT HYDROGRAPH FOR FLOOD FORECASTING: A CASE STUDY OF BABAI RIVER BASIN**

Submitted by: **Shiva Gopal Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Flooding is one of the major natural hazards affecting communities across Nepal and has caused damages worth millions of dollars every year. The majority of flood disasters' victims are poor people living in the flood plain. The expansion of urban areas and economic activities in flood plain is placing additional people and infrastructures at risk. There is growing realization about the importance of non-structural measures, including flood forecasting and early warning, in flood management. Establishing the flood forecasting system enhance the effectiveness of all other mitigation measures by providing time for appropriate actions. With an advance early warning system, a significant reduction in losses can be obtained by taking protective and preventive measures.

Owing to the heavy cost, structural measures are found inadequate in developing country like Nepal.The non-structural

mitigating measure places people away from flood. This method is designed to reduce the impact of flooding to society and economy. Most of the catchments in Nepal are unguaged and direct stream flow observations are not easily available at most sites where which rainfall-runoff relationships are required. Usually synthetic unit hydrographs (SUHs) technique is sought if there are no observed discharge hydrographs. This research has been carried out for the development of Snyder unit hydrograph models for determination of the shape and dimensions of outlet runoff (flood) hydrograph in Babai watershed. Under this study, a flood forecasting model of the Babai River basin is being developed.

In this research work coefficients required for the development of synthetic unit hydrographs using Snyder's method for sub-basins within the Babai basins have been determined. Lag time coefficient (Ct), peak discharge coefficient (Cp), unit hydrograph widths at 50% and 75% of the peak and base time were determined by calibrating Snyder's equations with the available maximum instantaneous discharge and corresponding rainfall data. Lag time coefficient (Ct) for the watersheds range from 0.3 to 0.75 with mean value of 0.466. The peak coefficients of the unit hydrographs of the watershed range from 0.3 to 0.49 with mean value of 0.413, these values are recommended to construct

UH of the Babai basin. The hydrological models are calibrated with meteorological data. The hydrologic model described is HEC- HMS which is a spatially semi-distributed, physically based hydrologic model.

Because of optimization ability and practicality of HEC-HMS software this program is used for simulation. This program simulates rainfall-runoff and channel routing processes.

Rainfall-runoff relationship is nonlinear and the runoff prediction depends on many factors. Rainfall intensity and duration of rainfall has been main driving factor of the rainfall-runoff process followed by watershed characteristics that translate the rainfall input into an output hydrograph at the outlet of the basin. A methodology is presented for extracting topographic, topologic, and hydrologic information, from the digital spatial data of a hydrologic system, for hydrologic modeling with HMS. Using this methodology, the determination of the spatial parameters for HMS is performed which helps in developing the rainfall runoff model. The peak discharge at the basin outlet is simulated to be 3603.6 m3/s at 16.30 h with relative error less than 10%. The comparison of the simulated and observed flow at Bargadha showed that the HEC- HMS model performed well in

simulating the flow of the Babai Basin. Satisfactory resemblance is observed between model results and measured discharges.

The result of this study is the flood hydrograph at the basin outlet. The hydrograph can be used for warning the people about the probable flood and flooding time Thus, finding of the study may help in planning and management of flood plain area of Babai Basin to mitigate future probable disaster through technical approach.

Key words: flood, sub basin, peak discharge, rainfall, hydrograph, lag time coefficient, peak discharge coefficient

Thesis Title: **EVALUATING THE IMPACT OF LAND USE LAND COVER CHANGE ON WATER AND SEDIMENT YIELD USING SWAT MODEL AT BAGMATI WATERSHED**

Submitted by: **Tej Bahadur Ale**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Rapid increases in population, forest clearing and continuing search for a farm land and urbanization have induced pressure on natural resource. In order to reverse such kind of problem, assessing the level of problem and finding solution at watershed level is necessary. The studies of land use land cover changes and their effects on soil erosion and runoff patterns at the watershed level are essential in water resource planning and management. This study provides an approach to identify the effects of land use land cover changes on water and sediment yield in Bagmati watershed. The changes in land use land cover were associated with growing demand of wood for fire, construction materials, household furniture and urbanization and expansion of farming and grazing land.

By apply Geographic Information System technique with computer model in analysis of soil erosion and runoff, this study estimates the sediment yield due to soil erosion evaluates the yearly sediment transport rates and examines the effects of change in land use land cover on water and sediment yield. Daily meteorological data, land use land cover map, soil map and daily and monthly river flow data were used and analyzed using Soil and Water Assessment Tool.

The runoff and soil loss simulation were done by dividing the watershed into thirty- three sub watersheds and by assigning a hydrological response unit based on multiple Hydro logic Response Unit definition. This study presents the calibration and validation of Soil and Water Assessment Tool for the stream flow and sediment load for two periods.

The simulation result showed that annual average water yield was decreased and annual average sediment yield was increased throughout the simulation period. Model predictions on monthly basis shows a strong relation for stream flow during the calibration and validation periods, as indicated by coefficient of determination (R^2) and Nash-Sutcliffe simulation efficiency (NSE), 0.0.876 and 0.856 for calibration period and 0.885 and 0.879 for the validation period respectively. But for sediment simulation the performance indicators were quite low compared to flow simulation which were attributed due to scarcity of observed data. The coefficient of determination (R^2) and Nash-Sutcliffe efficiency (NSE) were 0.702 and 0.645 for calibration period and 0.837 and 0.745 for validation period.

As a result the annual water yield was found within the ranges of 630.98 mm to 2144.78 mm for the 1986 land use and from 612.55mm to 2057.74mm for the land use 2006. Higher value of the surface runoff correlated with built up and forested land use system. The final actual erosion result for the catchment also shows that the value ranges from 1.53/ha/year to 300.56 t/ha/year for the land use in 1986 and from 1.47/ha/year to 352.91t/ha/year for land use type in 2006. The mean erosion rate is 83.79 t/ha/year and 84.47 t/ha/year for land usel986 and 2006, respectively. The study also indicated land use /land cover change in the last 20 years from 1986 to 2006, forested land is decreasing while cultivated land and built up area is increasing. The findings of this particular study suggested that deforestation and soil erosion problems need to be given due attention urgently to maintain the stability and resilience of the ecosystem.

Graduation Year 2013

Thesis Title: **BASIN SCALE RAINFALL-RUNOFF MEDELING FOR FLOOD FORECASTING: A CASE STUDY OF NARAYANI BASIN**

Submitted by: **Bishal Dhakal**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Flow estimation at a point in a river is vital for a number of hydrologic applications including flood forecast. This paper presents the results of a basin scale rainfall-runoff modeling on Narayani basin using the hydrologic model HEC-HMS in a GIS environment.

Floods are the most widespread climate-related hazards in the world, and they impact more people globally than any other type of natural disaster. It causes over one third of the total economic loss from natural catastrophes and is responsible for two thirds of people affected by natural disasters. On the other hand, studies and analysis have shown that damage reductions due to forecasts improvements can range from a few percentage points to as much as 35% of annual flood damages. Determining the extent of flooding is an important role of the hydrological research

community and provides a vital service to planners and engineers.

The impact of flooding was not felt to the same extent in the past as it is now. This could be due to the rapid increase in population and consequent increase in the human activities. The flood plains are being increasingly occupied to meet ever-increasing requirements of food and fiber, and consequently the flood problem is exacerbated. In Nepal each year, on an average 330 lives are lost due to floods and landslides and infrastructure and property amounting to more than US$ 100 million is damaged causing negative impacts on the social and economic development of the country.

Mitigating flood damages can be done in two possible ways; structural measure and non structural measures. If a judicious mix of both the structural measures and non structural measures are introduced devastation from flood can be greatly reduced. Structural solutions are mainly preventative and focusing on curtailing the magnitude of floods using different methods such as dams, embankment, compound channels, widening of river beds, etc. However these solutions have adverse environmental, hydrologic, ecologic or economic consequences. These measures are designed to divert flood water away from the people. This type of mitigation measures are proven effective but most expensive. The non-structural mitigating measure places people away from flood. This method is designed to reduce the impact of flooding to society and economy. It includes flood insurance, land use planning and zoning and flood forecasting and warning schemes. Hydrologic/hydraulic models are often used in flood forecasting and early warning systems. These models when optimally calibrated and validated can be an effective tool in mitigating flood damages through non-structural means. This method is very effective, cheaper and consumes less time. So, in my thesis I used rainfall runoff modeling for the flood forecasting and warning schemes as a non-structural hydrologic method for mitigating flood damages.

Rainfall-runoff relationship is mostly used mathematical model for water resource management planning, flood forecasting and warning schemes. The relationship is nonlinear and the runoff prediction depends on many factors. Rainfall intensity and duration of rainfall has been main driving factor of the rainfall-runoff process followed by watershed characteristics that translate the rainfall input into an output hydrograph at the outlet of the basin. For this purpose, different types of models with various degrees of complexity have been developed. They are based on empirical, physically-based or combined conceptual-physically-based model. In this context due to unavailability of detail information of the study area, lumped model HEC-HMS is used for simulating rainfall into runoff.

Due to lack of hourly interval data of rainfall, development of synthetic unit hydrograph from Snyder method is also done to determine runoff hydrograph of the basin. The Snyder coefficients, coefficient of slope (Ct) and coefficient of peak (Cp) are calibrated for each sub basins and the values are found to be in the range from 0.3—0.69 and 0.37- 0.4 y. The observed instantaneous maximum discharge and daily rainfall data of DHM from the year 1985-2006 are used for calibrating the model parameters and verification of the model. HEC-HMS rainfall runoff model is used to incorporate developed unit hydrograph.

Thesis Title: **THEORETICAL ASSESSMENT OF DISTRICT WISE DISTRIBUTION OF HYDROPOWER AND IRRIGATION POTENTIAL IN DIFFERENT SCENARIOS USING GIS AND HYDROLOGICAL MODELING TECHNIQUE: A CASE STUDY OF KARNALI BASIN OF NEPAL**

Submitted by: **Janga Bahadur Thapa**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Majority of population of Nepal are reliant on Irrigation. Nepal is sanctified with large Hydropower generation capacity due to its topography. The issue of hydropower potential and development is one of the most prioritized agenda for any government in Nepal. The national economy and social life is crippling because of the wide deficit between supply and demand of electricity as well as food. Since, there are no other energy sources which the country could utilize, the only way out is to use the available water resources in optimized way to irrigate the cultivable area and construct hydro-projects of its own. Harnessing hydropower needs accurate and reliable assessment of the potential. This study attempts to estimate the theoretical power potential of Run-of-River hydropower scheme for Karnali basin of Nepal by spatial analysis using Geographical Information System (GIS) and rainfall-runoff modeling using Hydrologic Modeling System (HMS) and irrigable areas by major rivers. Besides estimating the basin wise Hydropower Potential district wise distribution of thus calculated Hydropower Potential has been calculated. Irrigable areas for every district have been calculated by using land use map & GIS for selected diversion point. District wise Hydropower and irrigation potential assessed in this research has good scope in future owing to the political scenario of the country and possibility of its transformation into federal nation.

Two different scenarios has been adopted to estimate Hydropower & Irrigation Potential of each district, viz. i) Allocating the water in streams to irrigate 100% Irrigable land and Hydropower generation with remaining available water, ii) Allocating all water only for Hydropower Generation only

The Digital Elevation Model (DEM) is processed using GIS extension tool HEC Geo- HMS to prepare the input basin model for HEC-HMS and daily meteorological & discharge data are also fed to simulate discharge which is duly calibrated and validated with observed discharge to establish realistic hydrological phenomena. The model is evaluated with Nash efficiency ranging from 60% to 83.27% and volume deviation

ranging from 1% to 18% for simulated and observed discharge during calibration and validation.

In order to calculate power potential of these two basins, the elevation data at the upstream and downstream ends of each river reaches inside the basin is derived from GIS application on the DEM. The daily discharges for upstream and downstream ends of the river segment are derived from hydrological modeling using HEC-HMS model. Combining the design discharges corresponding to forty percentile flows with the hydraulic head determined from DEM the power and energy potential are determined.

From the upstream level of river, contour line is drawn in GIS for the diversion for irrigation and the area bounded by district border and contour line is considered as irrigable area. Land Use Map is used for determination of area for irrigation. The cropping pattern for the region below 4000 masl has been selected and water demand is calculated. After diverting the water from diversion point net amount of water available for power generation is calculated. Hydropower potential is calculated for each except of water deficit condition. Such obtained power potential is again distributed by above mentioned method. The theoretical total power and energy potential of Karnali basin is 13668 MW and 65989 GWh respectively.

Thesis Title: **CLIMATE, LAND USE CHANGE IMPACT ON WATER RESOURCES AVAILABILITY AND AGRICULTURAL PRACTICE: A CASE STUDY OF INDRAWATI BASIN OF NEPAL**

Submitted by: **Kiran Acharya**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Crop production is inherently vulnerable to primarily due to climate, land use and water resource availability system. Hence, this research is proposed to identify the potential impacts of climate change, land use changes on water resources availability and related effect on agriculture production. SWAT and AQUACROP models were used for the simulation of results.

The SWAT model simulation result in the Indrawati basin showed that daily average water yield was decreased with time from high land to low land areas of the sub- basin. Model predictions on daily basis at dolalghat shows coefficient of determination (R^2) and Nash-Sutcliffe simulation efficiency (NSE), 0.832 and 0.796 for calibration period and 0.859 and 0.807 for the validation period respectively. Similarly at Helambu the R^2 and NSE were 0.797 and 0.70 for calibration period and 0.848 and 0.746 for validation period. As a result the

daily water yield was found within the ranges of 1.61 mm to 7.83 mm, 0.79 mm to 7.95 mm, 2.70 mm to 7.50 mm, 2.69 mm to 7.58 mm, 2.69 mm to 7.58 mm, 2.82 mm to 7.67 mm, 2.62 mm to 7.32 mm for the 1995 land use, 2008 land use, Scenario-unchanged, Scenario-1, Scenario-2 and Scenario-3 land use respectively of different 14 classified sub-basins. Also there seems to be deficit in the water demand, for the different cropping patterns on various scenarios (i.e. considering rainfed and irrigation on run of river flow condition) which mainly occurs in the months May and September.

The AQUACROP model simulation in intra-sectoral basin indicate that the crop yield of rice decreased from 8.731 ton/ha to 0.137 ton/ha under rainfed system, and a little increase 8.753 ton/ha to 1.23 ton/ha under the irrigation system. On the other hand, the yield of crop maize remains about the same value from 15.150 ton/ha to 13.525 ton/ha in the same years from 1990 to 2060 under different scenarios on assuming the same planting/sawing dates for respective crop. But after shifting the crop calendar by appropriate days towards the preceding months (i.e. 7 days per decade), the yield of the crop seems to be in increasing order. The findings of this particular study suggested that proper irrigation system and appropriate agriculture adaptation should be given due attention urgently to maintain the irrigation and water resource management.

Thesis Title: **APPLICATION OF REAL TIME DATA IN FLOOD FORECASTING: A CASE STUDY BAGMATI & NARAYANI RIVER BASIN**

Submitted by: **Laxmi K.C.**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The most challenging work in the field of hydrology is to quantitatively understand, predict and formulate the processes of runoff generation and transmission to the outlet represents. For the purpose, Hydro-meteorological data for the assessment and development of water resources are very indispensable. However, most of the catchments in Nepal are not gauged and direct stream flow observations are not available at most sites for which rainfall-runoff relationships are required. If there are no observed discharge hydrographs, one resort is to develop Synthetic Unit Hydrographs (SUHs). This research has been carried out for the development of unit hydrograph models for determination of the shape and dimensions of outlet runoff (flood) hydrograph in Bagmati & Narayani watershed by Snyder's method and Kinematic method. Actually an attempt was made to undertake the research of all the basins in flood warning level in Nepal but due to unavailability of the sufficient data

required to run a model, a flood forecasting model of the Bagmati & Narayani River basin is being developed, one having smaller size of catchment area and the other with catchment area of a relatively larger size. Forecasting floods plays a very vital role thereby ensuring the overall security human life and as well as surroundings around the natural rivers besides any unpredictable disasters.

In this research work coefficients required for the development of synthetic unit hydrographs using Snyder's and kinematic method for sub-basins within the Bagmati & Narayani basins have been determined. Lag time coefficient (Ct), peak discharge coefficient (Cp), unit hydrograph widths at 50% and 75% of the peak and base time were determined by calibrating Snyder's equations with the available maximum hourly discharge and corresponding rainfall data. Lag time coefficient (Ct) for the watersheds range from 0.3 to 0.50 with mean value of 0.40. The peak coefficients of the unit hydrographs of the watershed range from 0.40 to 0.48 with mean value of 0.44, these values are recommended to construct UH of the Bagmati basin. The hydrological models are calibrated with meteorological data. The hydrologic model described is HEC-HMS which is a spatially semi-distributed, physically based hydrologic model. Because of optimization ability and practicality of HEC-HMS software this program is used for simulation. This program simulates rainfall-runoff and channel routing processes.

A methodology is presented for extracting topographic, topologic, and hydrologic information, from the digital spatial data of a hydrologic system, for hydrologic modeling with HMS. Using this methodology, the determination of the spatial parameters for HMS is an automatic process that accelerates the setting up of a hydrologic model and leads to reproducible results. The peak discharge at the Bagmati basin outlet is simulated to be 7750.5 m^3/s with relative error less than 10%. The comparison of the simulated and observed flow at Karmaiya showed that the HEC-HMS model performed well in simulating the flow of the Bagmati Basin and the same has been observed for the simulated and observed flow at Naraynghat for Narayani Basin. Satisfactory resemblance is observed between model results and measured discharges. However, in the high flood times, model generated river flows are found to be lower than the measured discharges.

Thus, finding of the study may help in planning and management of flood plain area of Bagmati & Narayani Basin to mitigate future probable disaster through technical approach. The study, so far, has been conducted completely based on secondary data and information. Therefore, the model should be updated with adequate primary data to be collected through a comprehensive data collection campaign. The model is promising and could lead to better predictions with further work on the input characteristics.

Key words: Flood, sub basin, peak discharge, rainfall, hydrograph, lag time coefficient, peak discharge coefficient.

Thesis Title: **DISTRIBUTED GROUNDWATER MODELING FOR ANALYSIS OF GROUNDWATER SUBSIDENCE AND ITS IMPLICATIONS**

Submitted by: **Pallav Kumar Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Amidst increasing population, land use changes and inadequate surface water, groundwater is emerging as the backbone of water demand fulfillment in the Kathmandu Valley. However, being non-perpetual and with a declining recharge, groundwater in the valley is depleting. With handful of preceding studies and large research gaps, a modeling exercise was carried out in a bid to address the future of groundwater in the valley and chances of land subsidence as its implication. The physically based distributed modeling system, SHETRAN, was parameterized for the Kathmandu Valley. The model success (r = 0.831) was an improvement over previous attempt of groundwater modeling of the catchment. Future scenarios based on sound hypothesis were applied to this model for analysis of recharge, groundwater declination and land subsidence hazard. Timely arrival of Melamchi Water Supply Project shows an increase of 143 to 155 mm in subsurface storage in first twelve years of simulation starting from 2011 whereas absence of such relief shows a decrease of 68 to 96 mm. Kapan, Besigau, Chapagaun and Machchhegaun were found to be the areas of severe groundwater declination with declination rates of up to 4.6 m/yr. Land subsidence analysis showed Besigau, and locations near Dhapasi and Machchhegaun to be the areas with highest hazard (over 10 mm/yr.). Finally a combined hazard map was prepared which could be a vital tool for decision makers in planning control measures for the future. An additional interesting finding was that the South Eastern regions of the valley were found being recharged at the driest period of the year. The coarse spatial resolution and the hypotheses adopted in this research should be born in mind while applying the results of this modeling exercise.

Keywords: Groundwater subsidence, land subsidence, Kathmandu Valley, SHETRAN

Thesis Title: **THEORITICAL ASSESSMENT OF DISTRICTWISE DISTRIBUTION OF HYDROPOWER AND IRRIGATION POTENTIAL IN DIFFERENT SCENARIOS USING GIS AND HYDROLOGICAL MODELING TECHNIQUE: A CASE STUDY IF KOSHI & KANKAI BASIN OF NEPAL**

Submitted by: **Prabhash Kumar Shah**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Majority of population of Nepal are reliant on irrigation. Nepal is sanctified with large hydropower generation capacity due to its geography. The issue of hydropower potential and development is one of the most prioritized agenda for any government in Nepal. The national economy and social life is crippling because of the wide deficit between supply and demand of electricity as well as food. Since, there are no major other energy sources which the country could utilize, the only way out is to use the available water resources in optimized way to irrigate the cultivable area and construct hydro-projects of its own. Harnessing hydropower needs accurate and reliable assessment of the potential- This study attempts to estimate the theoretical

hydro power potential of Run-of-Rrver hydropower scheme for Koshi & Kankai basin of Nepal by spatial analysis using Geographical Information System (GIS) and rainfall-runoff modeling using Hydrologic Modeling System (HMS) and irrigable areas by major rivers. Besides estimating the basin wise Hydropower Potential district wise distribution of thus calculated Hydropower Potential has been calculated. Irrigable areas for every district have been calculated by using land use map & GIS for selected diversion point.

Two different scenarios has been adopted to estimate hydropower & irrigation potential of each district, viz. i) Allocating all water only for hydropower generation ii) Allocating the water in streams to irrigate 100% irrigable land and hydropower generation with remaining available water.

The Digital Elevation Model (DEM) is processed using GIS extension tool HEC Geo- HMS to prepare the input basin model for HEC-HMS and daily meteorological and discharge data are also fed to simulate discharge which is duly calibrated and validated with observed discharge to establish realistic hydrological phenomena. The model is evaluated with Nash efficiency ranging from 70.4% to 93.1% and volume deviation ranging from -9.2% to 1% for simulated and observed discharge during calibration and validation.

In order to calculate power potential of these two basins, the elevation data at the upstream and downstream ends of each river reaches inside the basin is derived from GIS application on the DEM. The daily discharges for upstream and downstream ends of the river segment are derived from hydrological modeling using HEC-HMS model.

Combining the design discharges corresponding to forty percentile flows with the hydraulic head determined from DEM the power and energy potential are determined.

In order to distribute power in districts, the percentage of catchment area contributing flow to the river and length of river in district is considered.

For the diversion for irrigation, from the upstream level of river contour line is drawn in GIS and the area bounded by district border and contour line is considered as irrigable area. Land Use Map is used for determination of area for irrigation. Different two types of cropping pattern have been selected and water demand is calculated. After diverting the water from diversion point net amount of water available for power generation is calculated. Hydropower potential is calculated for each stream is again calculated except of water deficit condition. Such obtained power potential is again distributed by above mentioned method.

The theoretical total power potential and energy of Koshi & Kankai basin are 14,048.1 MW, 66,968.02 GWh, 187.59MW, 751.92GWh respectively if all water is used for hydropower generation only.

And the theoretical total power potential and energy of Koshi basin are 8029.03 MW, 37993.51 GWh respectively in case of using water remaining after full irrigation. Similarly there will be deficit in water and no hydropower generation when water is allocated for irrigation.

Thesis Title: **APPLICATION OF REAL TIME DATA IN FLOOD FORECASTING: A CASE STUDY OF WEST RAPTI BASIN**

Submitted by: **Prasiddha Upreti**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Flooding is the most pervasive and costly natural hazards faced by the Nepalese people. The ability to provide sufficient advance warning of flood occurrence is important in reducing the potentially disastrous effects of flooding. It may, for example, save lives by giving flood plain inhabitants time to remove themselves and their possessions to safety, and it may save property by allowing time to effect various structural and other adjustments. During the past few decades the enormous increase in the world-wide availability of computers has influenced virtually all flood forecasting organizations and has made obsolete the classical approach to traditional flood forecasting. Modern high-speed, large-capacity computers make it feasible to model the entire flood-producing process in one operation. This approach has been encouraged not only by developments in computer technology and the complexity of flood calculations, but also by advances in our hydrological understanding of the runoff process.

Flood forecasting in basins with sparse rain gauges poses an additional challenge. Using hydrologic modeling techniques, it is possible to better prepare for and respond to flood events. Use of appropriate hydrologic models can mitigate flood damage and provide support to contingency planning and provide warning to people threatened by floods.

Structural methods of flood protection are neither economically viable nor these are environment friendly. There is a growing realization about the importance of nonstructural measures, including flood forecasting and early warning, in flood management. It is important to make the flood early warning in the areas prone to flood hazards. Establishing a flood forecasting system would enhance the effectiveness of all other mitigation measures by providing time for appropriate actions. It may not be practical to avoid floods but it is a worthy target to move toward minimal flood disaster damages from severity.

The real-time flood forecasting model described in this thesis is intended for West Rapti basin. Communities in the West Rapti Basin of Nepal have been living with floods for generations. They have coped with floods of diverse origins and nature which can be explained with the study of dynamics of anthropogenic and natural systems in the river basin. The inflamed West Rapti River in the rainy seasons induces massive bank-erosion encroaching huge amount of agriculture and residential areas, causes overland flows towards the low lying areas, and inundates many human settlements severely affecting the livelihood of the people every year. The poor accessibility of the area and lack of proper institutional and effective legislative frameworks to cope with disasters, inadequate engineering practices, politically inspired domestic violence and, the socio-economic settings among many other factors have increased the vulnerability of communities in the area. Currently flood warning in the catchment of West Rapti River relies on the issuing of alerts when the river level at the monitoring station at Kusum reaches certain pre-determined levels. Warnings are shown to be fairly accurate, but there is very little lead time between the trigger being exceeded and the commencement of flooding. At present there is no method used that can forecast in advance when the trigger is likely to be reached.

Rainfall-runoff relationship is mostly used mathematical model for water resource management planning, flood forecasting and warning schemes. The relationship is nonlinear and the runoff prediction depends on many factors. Rainfall intensity and duration of rainfall has been main driving factor of the rainfall-runoff process followed by watershed characteristics that translate the rainfall input into an output hydrograph at the outlet of the basin. For this purpose, different types of models with various degrees of complexity have been developed. They are based on empirical, physically-based or combined conceptual-physically-based model. In this context semi distributed model HEC-HMS is used for simulating rainfall into runoff. Two approaches have been used in the study to predict the flood hydrograph of West Rapti River using available hourly data of 2011-2012 .The first approach is development of unit hydrograph by Snyder's method and second approach is development of unit hydrograph by least square method .The unit hydrograph so developed is then used to transfer the real time precipitation data into flood hydrograph .The flood hydrograph at the outlet is then validated with observed flood through the use of rating curve.

Thesis Title: **APPLICATION OF REAL TIME DATA IN FLOOD FORECASTING: A CASE STUDY OF BABAI BASIN**

Submitted by: **Sindhu Devkota**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

This research described the real-time flood forecasting model in Babai basin. Communities in the Babai Basin of Nepal have been living with floods for generations. They have coped with floods of diverse origins and nature which can be explained with the study of dynamics of anthropogenic and natural systems in the river basin. Also this research has been carried out for the development of Snyder Unit Hydrograph models for determination of the shape and dimensions of outlet runoff (flood) hydrograph in Babai watershed. Under this study, a flood forecasting model of the Babai River basin is being developed using real time approach as wells as Synthetic approach.

In this research work, coefficients required for the development of synthetic unit hydrographs using Snyder's method for sub-basins within the Babai basins have been determined. Lag time coefficient (Ct), peak discharge coefficient (Cp), unit hydrograph widths at 50% and 75% of the peak and base time were determined by calibrating Snyder's equations with the available maximum hourly discharge and corresponding rainfall data. Lag time coefficient (Ct) for the watersheds range from 0.37 to 0.4 with mean value of 0.385. The peak discharge coefficients (Cp) of the unit hydrographs of the watershed range from 0.39 to 0.405 with mean value of 0.3975, these values are recommended to construct UH of the Basin.

The HEC-HMS model is used for rainfall- runoff modeling of Babai basin. For this rainfall-runoff is solved for each sub basin then the contributions from each sub basins to the basin outlet hydrograph are obtained using the channel flood routing and the flood hydrographs at the basin outlet are summed.

The result of this study is the flood hydrograph at the basin outlet. The hydrograph can be used for warning the people about the probable flood. Thus, finding of the study may help in planning and management of flood plain area of Babai Basin to mitigate future probable disaster through technical approach.

Key words: hydrograph, real time data, flood, sub basin, peak discharge, rainfall

Thesis Title: **IMPACT ON HYDROLOGY BY CLIMATE CHANGE EFFECT AND CONSIDERATION FOR DESIGN PROSPECT OF STORAGE HYDROPOWER PROJECTS: A CASE STUDY OF DUDHKOSHI HYDROPOWER PROJECT.**

Submitted by: **Surya Narayan Shrestha**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

The most critical impacts of climate change in Nepal can be expected to be on its water resources facilities. The change in magnitude and timing of water flow, floods droughts, shifting of hydrograph etc are the indicators of climate change in river hydrology. Changes in the river flow would have a direct impact on design prospect of hydropower projects. In other words, the failure to adapt to climate induced risks to hydropower might give rise to power crisis in future.

Almost all hydropower plants are designed on the assumption of unchanged climate i.e. the design flow, minimum flow and maximum flow etc. will not be changed in long term.

The present study aims to figure out the impact of climate change on design prospect of Hydropower projects in Nepal. The

Dudhkoshi Storage hydropower project is selected for the study. The current trend in the river flow is analyzed both peak & base flow which are of particular importance for power production by storage hydropower projects. The HEC-HMS model parameters for the concerned watershed area are estimated after the optimization of the HEC-HMS model (calibration and validation) of the hydrological and meteorological data for each area. With these estimated parameters, the daily discharge for concern project are calculated and compared with the present context. The effect of climate change on the discharge and then design prospect of Hydropower project is calculated.

The analysis shows that trend of river flow in dry season is decreasing and increasing trend in peak flow. The flow duration curve also shows that in the dry season the water availability is decreasing where as the flow in monsoon season is found increasing pattern. The analysis also shows that for the projected period of 2030-2060 A.D, there will be the increase flow for the design discharge it is used by feasibility study of the project. Ultimately the installed capacity of the corresponding flow will also be increased. The result shows that the energy & installed capacity may be increase in study area.

The implications of climate change are greater in the water systems. For the design of storage hydropower plants the incorporation of climate change should be done to calculate the design discharge so that the project will be economically feasible in long run.

Thesis Title: **INTEGRATED ECONOMIC WATER RESOURCES PLANNING AND MANAGEMENT MODEL: A CASE STUDY OF NARAYANI RIVER BASIN**

Submitted by: **Umesh Prasad Thani**

Supervisor: **Prof. Dr. Narendra Man Shakya**

ABSTRACT

Simulation and Optimization of the water resources system for the optimal development of the basin was done during this study. The sensitivity of the optimal solution to changes in the model parameters can be readily determined and tradeoffs between several conflicting objectives can also be calculated with most optimization models.

The formulation and use of mathematical programming in GAMS language for monthly operation of Narayani River System in normal condition effect was investigated. The non-linear objectives were calibrated for the large scale complex system to minimize the irrigation shortfalls, to maximize the hydropower generation, to optimize the flood storage benefit and to maximize the economical benefit. Simulation program was used for the validation of each policy derived through this cycle. The accumulation of these programs is called monthly reservoir operation model of the multi-reservoir Narayani River System.

This study integrates the generated time series data of five years (2001-2005) with the optimization model so that an optimum water resources planning and management can be achieved in different developed scenarios. In Optimization model network diagram are developed consisting of five supply nodes, one demand nodes, two hydropower nodes and one outlet node. The decision variables are reservoir storage, reservoir release, and irrigable area, cropping pattern and energy generation. The parameters used in this model are irrigation demand, minimum in stream flow, crop water requirement, cropping pattern, crop location possibility and crop calendar. The formulated model is solved by CONOPT GAMS solver and is applied to the Narayani River Basin.

Three different models are developed, one with an objective function of maximizing the total benefit for various purposes (economic efficiency model), second with an objective function of minimizing the demand deficit (equity model). Two reservoirs i.e. Budigandaki and Upper Seti are taken to operate to meet the demand of potential irrigation area and to generate energy. A trade-off among economic efficiency, equity and environmental sustainability can be assessed when analyzing the design of water resources planning