

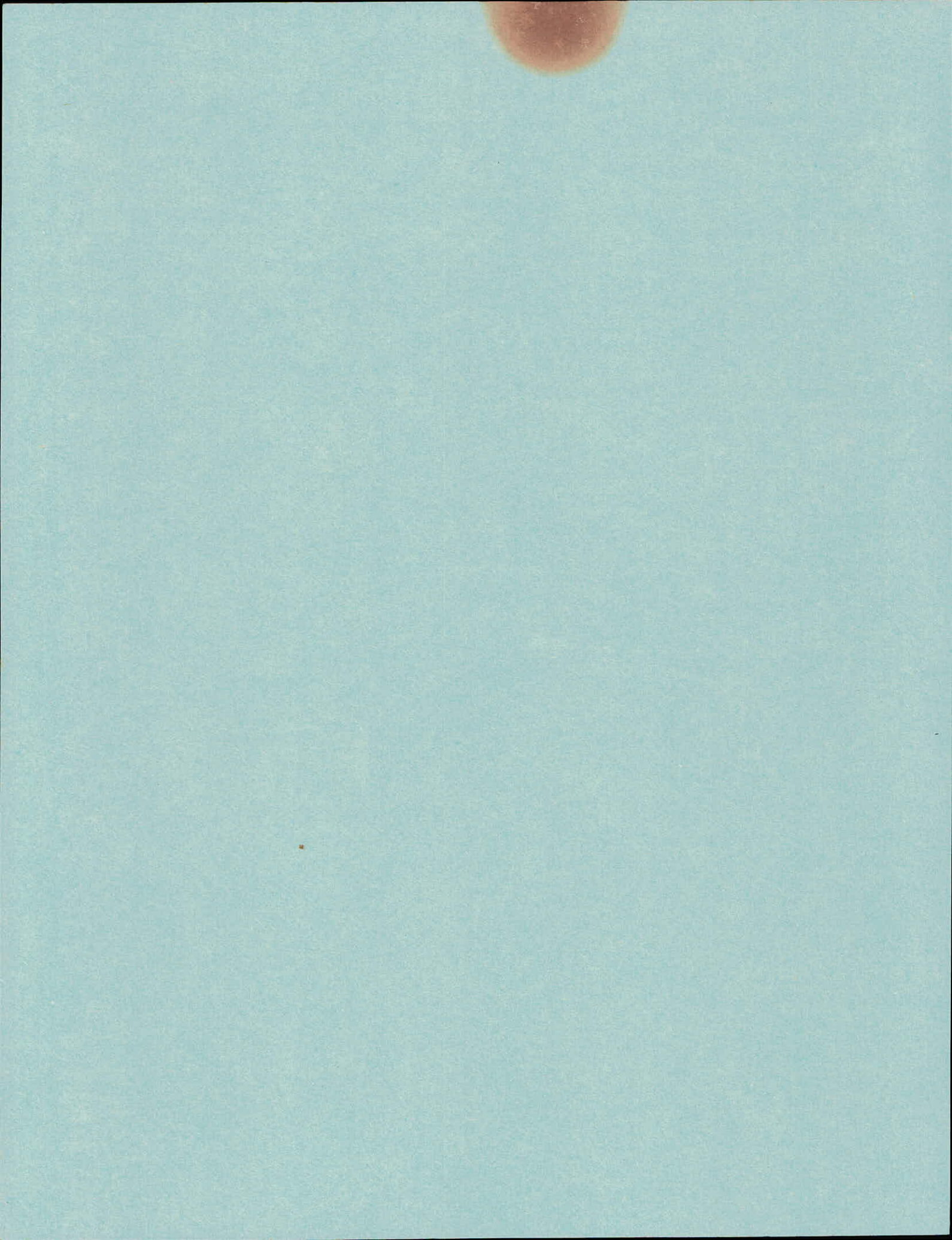
THEME-4

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MECHANISMS AND MODELS OF RUN-OFF GENERATION ON HILLSLOPES

Rama Prasad

Indian Institute of Science, Bangalore, India

It is important to understand the mechanisms of runoff production on hill slopes, which contribute the major part of any stream flow. Horton's mechanism of infiltration excess overland flow has not been observed on vegetated hillslopes in humid areas. Experiments with artificial rainfall of very heavy intensities have produced very little overland flow.

Based on published literature, there appear to be four possible mechanisms, either individually or in combination: (i) Infiltration excess overland flow, (ii) subsurface flow, (iii) saturation excess overland flow, (iv) pipe flow.

Runoff generation is often characterised by variable source areas. A number of models have been proposed in the literature ranging from those needing very detailed information to relatively simpler models using the water balance approach. No model appears to have been proposed for runoff resulting pipe flow.

SEDIMENT YIELD FROM DIFFERENT LAND USES IN SMALL INDIAN CATCHMENTS

K.K.S. Bhatia

National Institute of Hydrology, Roorkee, India

The problems of erosion and sedimentation are widespread and of great concern to water resources engineers. The movement and/or deposition of sediments in water bodies is of further interest to water resources planners and engineers as it influences the downstream hydrology, causing sedimentation in reservoirs, lakes, rivers, and creates water quality problems. The deposition of sediments in the channels/rivers can produce changes in flow conditions, changes in geometry of channels, changes in river regime, degradation and aggradation and meandering.

The present paper summarises the results of studies done on smaller runoff plots and small watersheds relating amount of sediment produced to various land uses. The various land uses those have been considered include forests, grass land, agricultural lands, fallow lands, ravinous lands, bare lands and horticultural lands. The results of these studies have been summarised in tabular form indicating soil loss as affected by various land uses in various agroclimatic regions of the country. The general range of soil loss in ton/ha/year for forests (well managed) is 0.05 - 0.9 while for ill managed forests it is 20-60. For agricultural lands the range is 20-40 (for hilly regions) and 5-20 for plain regions without having soil conservation measures. The values have been found to reduce to 1-19 in hilly areas and 0-3.0 in plains after soil conservation measures were adopted. In cultivated fallow lands, soil loss of 4-7.7 ton/ha/yr is found for slopes ranging from 1-9%. In denuded ravinous lands the range is 10-20 while in treated ones it is 0.5-5.0. The grass lands with good management have given 0-1 ton/ha/yr soil loss while in case of ill managed it is about 20-40.

The review of various available studies indicate that there is a need to get better understanding of the various land uses as they affect the sediment yield from large watersheds. This will help in estimating soil erosion and computing subsequent sedimentation as affected by various land uses. Need for studies to be conducted on larger watersheds has been emphasised. These studies will lead to estimation of changes in hydrological regime of a watershed, specifically sediment production, as a result on alteration of land uses.

DEVELOPMENT OF A SEDIMENT AND CHEMICAL TRANSPORT MODEL FOR AGRICULTURAL WATERSHEDS

Vito A. Copertino, Bruno Molino*, Vito Telesca* & Vijay P. Singh***

* University of Basilicata, Potenza, Italy

** Louisiana State University, USA

This paper analyzes the analytical structure of an integrated model on the simulation of the sediment

and non-point chemical transport for agricultural watersheds. The proposed model simulates the hydrodynamic of the flow, the transport of the sediment, the chemical transport by water and associated with sediments. The dynamic modelization uses two sub-models; the first one is based on the hydrodynamics and sediment transport phenomena including the interactions between suspended load and bed load; the chemical transport by water and associated with sediments.

The dynamic modelization uses two sub-models chemical transport by water and associated with sediments the first one is based on the hydrodynamics and sediment transport phenomena, including the interactions between suspended load and bed load; the second one is based on the chemical transport by water (by water flow and molecular diffusion) and associated with sediments in suspension and in bed, by accounting for adsorption/desorption processes and chemical growth/decay phenomena. Furthermore non-point pollution is a function of the spatial variability of the morphological characteristics of the observed catchment, therefore the mathematical model is inserted into the GIS, containing all the necessary informations for the optimization of the input and output parameters of the model.

A CONCEPTUAL FRAMEWORK FOR MODELING SEDIMENT PROCESSES IN UPLAND WATERSHEDS

Vicente L. Lopes & Peter F.Ffolliott

University of Arizona, Tucson, USA

A modeling framework is presented as the basis for developing numerical models of sediment processes on upland watersheds. Sediment processes are described in terms of both broad shallow flow areas and concentrated flow systems. Basic assumptions and governing equations are presented for broad shallow flow and concentrated flow sediment processes. The effects of space and time averaging on the predictive equations are described. Starting from the most general one-dimensional, unsteady model, simpler model structures are obtained and the successive simplifications made on the governing equations to obtain simpler and

less detailed formulations are described. Although progress has been made in modeling sediment processes on upland watersheds, the development of improved modeling approaches must be based on a better understanding of runoff mechanisms and the mechanics of sediment generation, transport, and deposition occurring over a range of catchments scales and environmental conditions. Future research must address the development of boundary conditions, model components, the scales over which the governing equations are valid, and integration of the equations in space and time.

APPLICATION OF ENTROPY PRINCIPLES IN THE RATIONALISATION OF WATER QUALITY NETWORKS

A. Kusmulyono & I.Goulter

University of Central Queensland, Australia

The increased emphasis on environmental management over the last decade or so has focussed attention on the necessity for comprehensive water quality monitoring. However, this increased emphasis on water quality monitoring has generally occurred in a climate of decreasing or effectively static budgets for monitoring. These budgetary conditions have in turn resulted in what is known as rationalisation of networks, i.e., existing water quality monitoring stations are discontinued or transferred from one location to another where the data needs are more pressing. A method whereby water quality conditions at locations of discontinued stations upstream of a continuing monitoring station can be predicted, in an unbiased fashion, from observed data at the downstream station is proposed. The predictions derived from the method can be made on the basis of data at the downstream station which are essentially unchanged from conditions existing prior to the upstream stations being discontinued or on the basis of significant changes being observed at the downstream stations. In this second case the procedure effectively predicts those locations which are most likely to be the source of the changes being observed downstream.

The procedure used is based upon Shannon's expression for entropy, namely $\sum p_i \ln p_i$ and can be applied

for a range of restrictions on the means and variances of the distributions of water quality being predicted at the upstream locations. Application of the procedure to water quality monitoring networks in Queensland, Australia, show that it performs better (predicts more accurately, more often) than classical regression techniques.

ENVIRONMENTAL IMPACT OF SMALL STORAGE RESERVOIRS IN PUNJAB

Mohinder Kumar & Tarlok Singh

Irrigation & Power Research Institute, Amritsar, India

The Punjab State in India is infested with numerous flashy streams, locally called "choes" and "khads" which emerge from the foot hills of the Lower Shivalik Range located on its north eastern periphery. These hills had lush green thick forests and vegetative cover in the past. The damaging policies followed in the watershed during the last century have resulted in near complete denuding of the hill slopes and fall in vegetative production to less than 100 Kgs/hectare. As a result, the average sediment yield has risen to 150 tonnes/hectare/year. The fertile flood plains which once induced the farmers for cultivation have started disappearing because of corresponding rise in flood peaks and frequency. For watershed treatment, to tackle twin problems of soil erosion and economic backwardness, the Punjab State has embarked upon an elaborate programme with assistance from the World Bank. The project called "Kandi Watershed and Area Development Project" entails the construction of small storage reservoirs and water harvesting tanks for flood moderation and for meeting the needs of industry and civic recreation, irrigation and domestic water supply. The hydraulics of the streams of this region being quite different from that of snow-fed rivers, the attending problem of sedimentation in these reservoirs takes place in monsoon period.

In this paper, the studies undertaken to observe the impact of construction of low dams on the environment have been reported. The data in respect of sedimentation pattern of these reservoirs is collected each year. Other data comprising effect on climatic conditions, soil erosion, water quality, ground water hydrology, effect on flora and fauna, life style characteristics

of population, employment avenues and general health have been compared for pre-construction and post construction period of these dams. The cropping pattern and yield of crops per hectare in the command areas has been studied. The change in soil characteristics due to the environmental impacts of these dams has also been highlighted.

The study concludes that the climatic change has been insignificant and the water quality of the area which, was already good, has not changed appreciably. It is also observed that economy of the area is improving as a result of better crops due to availability of water in the command area throughout the year. The cropping pattern is changing to the usual crops i.e. wheat, rice, sugarcane, fodder, previously in the pre-reservoir period the crops which needed less quantity of water were adopted. The fertility of the soil is further improving which, otherwise, was being affected by the flashy streams.

ENVIRONMENTAL ASPECTS OF SUBSURFACE DRAINAGE PROJECTS

S.K. Kamra & K.V.G.K. Rao

Central Soil Salinity Research Institute, Kamal, India.

Irrigation and drainage projects affect the physical, chemical, and biological components of the ecosystem and their eventual success depends on how adequately the environmental aspects are addressed at the planning and design phases. Drainage is generally required to combat the twin problems of waterlogging and soil salinity and to ensure sustained irrigated agriculture in the arid and semiarid regions. While the benefits of drainage can be counted in terms of improved crop yields and increased economic gains, the cost to the environment may also be high. Official policy in developing countries tends to place greater importance on traditional production related drainage objectives than on environmental considerations. Environmental impacts may be positive or negative and may occur both on and off site. Their relative importance should be considered in the context of the socio-economic

conditions and evaluated on both short and long term basis. The positive on site impacts of drainage projects, besides increased agricultural production and improved water regime and microclimate, also include reduction in water borne diseases due to drainage of waterlogged and swampy areas as well as increased social, cultural, recreational and employment opportunities. Among the negative offsite impacts, the concern for the disposal of saline drainage effluent, historically confined to major soluble salts and plant nutrients, now also includes potentially toxic concentrations of several trace elements and pesticides. Downstream water quality needs to be protected and enhanced, and potential damage to plant, animal, aquatic, and wildlife species recognized. Reliable estimates of the time variations in the volume and composition of drainage effluent under alternate drainage designs, possibly obtained from mathematical models, are needed to envisage and plan environmentally acceptable strategies for its disposal or treatment. Public health issues also need to be addressed.

The paper reviews the environmental issues which are likely to arise in drainage projects and identifies the technological options for the management, reuse and disposal of drainage effluent. Improved on-farm water management practices for minimizing the volume and salt load of drainage water, relative merits of different modes of conjunctive use of fresh and salinewater including drainage effluent, and water treatment options are discussed. An example on the application of a two dimensional finite element model of water and solute transport in tile drained lands for evaluating the salt loadings of drainage effluent under alternate drainage designs during reclamation of a 2000 ha highly waterlogged saline area in Haryana in India is presented. Future research and monitoring needs are also discussed.

CHANGES IN FLOW CHARACTERISTICS OF THE RIVER MURRAY IN THE LAST 100 YEARS

*B.L. Maheshwari**, *K.F. Walker*** & *T.A. McMahon****

* University of Western Sydney, Richmond, Australia

** University of Adelaide, Australia

*** University of Melbourne, Parkville, Australia

The River Murray in Australia and its tributaries have been subjected to increasing levels of flow regulations during the last 100 years by construction of storages, locks, weirs and changes in operation strategies. This has resulted in considerable changes in the flow characteristics of the river system with implications on the river ecosystem. The main aim of this study was to examine the effects of the various regulatory structures on the flow characteristics of the River Murray and its tributaries and to investigate the effects of the weirs and locks on the water level fluctuations along the lower Murray (between the South Australian border and the Murray mouth).

The flow characteristics of the river system were studied with reference to eight stages of development, namely, natural (no flow regulation), pre-Lake Victoria, pre Hume, Post-Hume, post-Yarrowonga, post-Hume enlargement, post-Menindee and post-Dartmouth. The flow characteristics of 11 locations, eight on the Murray, one each on the Loddon, Murrumbidgee and Darling Rivers and of the combined flows of the Goulburn, Broken and Campaspe Rivers into the Murray were investigated. Simulated monthly flows were used in the study and the flow for given stages of development were obtained using the 'Monthly Simulation Model' of the Murray-Darling Basin Commission.

The water-level fluctuations along the lower Murray for the upper and lower pools of Locks 1 to 6 were studied. The water level data were analysed, for both pre and post lock periods, by determining the minimum, maximum and average water-level elevations, rates of water-level fluctuations (rises and falls) for different durations.

The study indicates that the average monthly and annual flows are lower under the present conditions than those that existed under the natural conditions,

mainly as result of storages and diversions of river flows for irrigation and other uses. The water-level regime of the lower Murray has also been considerably affected by weir operations, particularly through increases in average water level elevations, decreased fluctuations at upstream pool gauges and increased fluctuations at downstream pool gauges. The implications of these changes, viz. the flow characteristics and water level fluctuations on the river habitats are also discussed in the paper.

APPLICATION OF TRACERS AND DYES TO ASSESS GROUNDWATER CONTAMINATION POTENTIAL FOR GLACIAL-TILL AQUIFERS

R.S. Kanwar

Iowa State University, Ames, U.S.A

Recent studies in the U.S.A. and other parts of the world have shown evidence of the presence of industrial as well as agricultural pollutants in groundwater. Contamination of potable water supplies in the world has raised numerous health related concerns as people are intuitively wary of consuming unwanted chemicals through drinking water, even at low concentrations observed in water supplies. Therefore, a better understanding of groundwater contamination mechanisms is needed to develop techniques for protecting groundwater.

Tracers with different adsorption properties can be very useful in understanding chemical transport to groundwater. Both adsorbed and non-adsorbed tracers provide a means of identifying the leaching potential of chemicals to groundwater. Adsorbed tracers such as fluorescent dyes used in field studies with pesticides can reduce the number of samples required for pesticide analysis or eliminate the use of pesticides to study the transport of pesticides to the ground water. This paper will present the results of three field studies where different tracers were used to understand the contamination of groundwater sources due to nitrates and pesticides.

Field experiments were conducted between 1988 and 1992 at Iowa State University's Research Centres

to evaluate the effectiveness of anions, a cation, and a fluorescent dye as tracers for investigating how agricultural chemicals leach to groundwater. In one tracer experiment, bromide, nitrate, lithium, and Rhodamine WT were applied with irrigation water to the field plot through a sprinkler system. In the second study, bromide, chloride, and Rhodamine WT were mixed with two herbicides (cynazine and alachlor) and were sprayed on the surface of the plot, which received rainfall with a rainfall simulator. In the third study, a 3 m by 3.3m diameter borehole cavity was installed in the field to facilitate collection of water samples from laterally installed suction lysimeters. Suction lysimeters were installed at 5 depths with five replications at each depth. The large borehole cavity was installed to investigate water and chemical transport mechanisms through the vadose zone to groundwater under ambient and simulated rainfall conditions. During and after experiments, groundwater samples were collected from different depths and these samples were analyzed for tracer and chemical concentrations. Based on adsorption tracers (fluorescent dyes) and non-adsorbed tracers (bromide, chloride) have the potential for tracing the movement of water as well as adsorbed and non-adsorbed chemicals (nitrates, pesticides, industrial pollutants) to groundwater

NUTRIENTS RUNOFF MODELLING OF AUSTRALIAN URBAN CATCHMENTS

M.Sivakumar & S.Boroumand-Nasab

University of Wollongong, Wollongong, Australia

The process of urbanisation not only changes the rainfall-runoff processes but also have significant effects on the quality of runoff. Stormwater runoff from urban areas carry pollutants in the form of sediment loads, nutrients, bacteria and toxic substances which have been shown to have long term effects on the receiving waters such as lakes, rivers and ponds. The transport of nutrients in particular can lead to eutrophication of water bodies which is detrimental to the various users of the water source.

Recent studies conducted in urban Australian catchment have evaluated nutrients data and concluded that the

land use significantly influences the trend of nutrients runoff process. Modelling these processes involves information and functional relationships on several dynamic variables. For example cumulative runoff volume is the most factor in pollutant runoff estimation in an urban area. Previous laboratory and field experiments in Nakamura in Japan have concluded that roughness and slope of catchment, runoff intensity and cumulative runoff volume are most important factors which influences the removal of soluble pollutants.

A new semi empirical washoff method was developed to predict pollutant washoff loads from urban catchments based on the assumption that transport rate (washoff pollutant rate) is proportional to the distribution and availability of pollutants. In this paper, the newly developed washoff method was tested against two existing washoff algorithms (SWMM4 and Nakamura) using available nutrients field data on nitrogen and phosphorous. The calibration results are shown to be better for the new developed washoff algorithm compared to the existing washoff methods. Implications of the results for future modelling and catchment management strategies are highlighted.

IMPROVED MIXING CELL MODEL OF SOLUTE TRANSPORT IN TWO AND THREE DIMENSIONS WITH NONLINEAR REACTIONS

K. Bajracharya & D.A. Barry

University of Western Australia, Nedlands, Australia

Mixing cell models have been used frequently to model solute transport with reactions. The main advantages of these models are their conceptual simplicity, ease of coding and minimal computational requirements. They are easily coupled with chemical speciation models, and so can predict chemical concentrations in space and time. In this work we discuss in detail the cases of two and three dimensional single species reacting solute during transport. Mixing cell models are simply explicit finite-difference solutions of the governing advection-dispersion equations. The inclusion of reactions in the "standard" mixing cell model degrades its second-order accuracy.

Therefore in this paper an improved model has been used which maintains second-order accuracy regardless of whether reactions are included. In addition, the improved model is unconditionally stable unlike the standard scheme. The improved method is suitable for two or three dimensions where the dispersivities are different in different flow directions. Numerical results obtained from the improved mixing cell model are compared with a standard numerical solution (Crank-Nicolson) for equilibrium transport. The scheme is easily extended to account for time-dependent reactions, or multi-species transport. Our results demonstrate that nonlinear reactions and transport can be modelled very efficiently and quickly by this method.

HEAVY METAL ADSORPTION IN SOIL: COMPARISON OF BISOLUTE ADSORPTION MODELS AND LABORATORY EXPERIMENTS

K. Bajracharya, D.A. Barry*, S. Vigneswaran** & A. Das Gupta****

* *University of Western Australia, Nedlands, Australia*

** *University of Technology, Sydney, Australia*

*** *Asian Institute of Technology, Bangkok, Thailand*

The effect of Zn and NH_4 on the adsorption of Cd has been studied at a pH of 6 for two soils. The experiments were carried out for concentrations of Zn and NH_4 in the ranges present in most industrial wastewaters. The competitive experiments were conducted also with wastewater from a zinc refinery. It was found that both Zn and NH_4 suppressed the ability of Cd to adsorb onto soil. The adsorption of Cd and Zn was determined to be less in the refinery wastewater than that in the single solute batch experiments. Different theories have been proposed to predict the equilibrium concentrations of solutes in the bisolute system using single solute isotherm constants. Four simple mathematical models to predict equilibrium concentrations in the bisolute system have been tested for their applicability, viz., Competitive Freundlich Adsorption Model (CFAM), Modified Competitive Freundlich Adsorption Isotherm Model (MCFAM), Ideal Adsorbed Solution Theory (IAST), and the one given by Sheindorf et al. (1981), (SM). The MCFAM and the SM were found to be satisfactory

in predicting the concentrations in the bisolute system and at the same time more easily incorporated into bisolute transport models.

ENVIRONMENTAL IMPACT ASSESSMENT OF ARTIFICIAL RESERVOIRS

Necdet Alpaslan

Dokuz Eylul University, Bornova, Turkey

There is a general trend in developing countries in the way of selecting "water" as the primary source of energy since it is considered to be "clean" and "harmless" for the environment. Recently however, negative impacts of hydropower generating systems have also been observed so that these countries are faced with a significant paradox. On one hand, water resources must be developed to satisfy the growing energy demand of the country. On the other hand, difficulties are encountered in realization of such projects as different sectors of the society react against the adverse effects of hydropower schemes. In particular, it is not the hydroelectric plant but the associated reservoir that is deemed to produce the adverse impacts. The solution to the above paradox lies in the development of an extensive survey in the form of environmental impact assessment (EIA) to evaluate both the negative and the positive effects of such projects.

In developed countries, EIA has become a necessary procedure in the realization of every large scale investment and plan. It is particularly required in the case of artificial reservoirs such as those planned as part of an energy production system. Environmental impacts accruing from an artificial reservoir are numerous with varying degrees of significance. An artificial reservoir has possible impacts on: (a) the hydrologic characteristics of the drainage area; (b) characteristics of the atmospheric system in the form of regional climatic conditions; (c) seismic features of the region; (d) the ecologic, or more specifically the biologic, systems of the water environment as well as those of the surrounding land; and (e) social life within various perspectives. It is often difficult to estimate beforehand the relationships between such

effects and to state whether the eventual impact of the reservoir will be negative or positive. The evaluation basically depends on the question "who does" the EIA from "whose point of view". In any case, it is important that all effects are recognized and accounted for to achieve a realistic EIA.

The presented study investigates a systematic approach for EIA of hydropower systems with special emphasis on effects of artificial reservoirs. Possible effects, negative or positive, of such reservoirs are discussed, and those that particularly relate to water resources engineering are covered in detail. Major points made are demonstrated by examples from different parts of the world as actual evidences of expected impacts of artificial reservoirs. The Southeastern Anatolia Project bears today the first priority in water and land resources development in Turkey. The presented paper discusses the evolution of this large scale project within the last 40 years together with expected modifications to illustrate the dynamic nature of water resources development plans.

GLOBAL WARMING : ITS HYDRO-LOGIC IMPACT IN THE CARIBBEAN

G.S. Shrivastava

University of the West Indies, Trinidad, West Indies

It is now believed, amidst some uncertainty, that the anticipated global warming will cause average temperature to increase by 3 to 5 degrees centegrade, and sea level to rise by about 60 to 70 centimetres over the next century. The characteristics of hydrologic events, such as the magnitude, frequency, temporal and spatial distribution of precipitation, are also expected to change. Furthermore, the sea level rise is likely to cause an increase in the sea water intrusion of critical groundwater resources, and loss of wetlands. It is envisaged that these changes will affect hydraulic engineering design and construction activities in the Caribbean in a number of ways, Sea level rise and altered precipitation patterns, in particular, would significantly impact on the adequacy of the existing and currently proposed hydraulic engineering and water resources systems.

This paper shows, by means of a design example, that the cost of building a bridge today, incorporating the provisions for the anticipated sea level rise, is considerably less compared to the cost of retrofitting the same structure in future. This paper, therefore, concludes that in spite of the uncertainty and the long term nature of global warming, the prudent approach is to recognize the uncertainty but not allow it to forestall action and forward planning.

HYDROCHEMICAL ASPECTS OF RAIN-WATER - A CASE STUDY OF KONKAN REGION OF WESTERN MAHARASHTRA AND WAINGANGA DRAINAGE BASIN OF EASTERN MAHARASHTRA

K.G. Welekar & Smt. R.V. Badve

Groundwater Surveys and Development Agency, Pune, India

Water is a universal solvent due to its molecular structure and distribution of electric charge in the molecule. Atmospheric gases dissolve in amounts which are not proportional to their atmospheric concentrations. Weak acids are formed by dissolution of carbon dioxide in rainwater. The rainwater carries these dissolved materials from the place of origin to long distances and precipitate them in different environments. This hydrochemical cycle of rainwater is very important in recycling various elements and their compounds in nature.

The present paper deals with the hydrochemical aspects of rainwater from Westernly flowing drainage system of Konkan region of Western Maharashtra and Wainganga drainage system of eastern Maharashtra in India. Monthly rainwater samples during monsoon of 1992 were collected at 10 - selected stations to evaluate chemical quality of rainwater. The results obtained indicate that the A - C of the rainwater is positive at Konkan region of Western Maharashtra due to its close proximity of the coast, whereas, in the Wainganga basin of Eastern Maharashtra A - C is negative which can be attributed to alkaline atmospheric dust. The paper advocates the close monitoring of chemical quality of rainwater particularly on the industrial townships which have come up during the last decade.

APPLICATION OF MONTE CARLO ANALYSIS IN GROUNDWATER CONTAMINATION MODELLING

A. Ghosh Bobba

National Water Research Institute, Ontario, Canada

The prediction of the evaluation behaviour of the contamination in subsurface by using contamination transport models, is necessary to plan remedial actions at existing sites and may also be useful in siting and designing new land based waste treatment or disposal facilities. Most models used to take such predictions assume that the system behaves deterministically. A variety of factors, however, introduce uncertainty into the predictions. The factors include model, parameter, and geometry uncertainty. In the present paper the Monte Carlo technique is used to handle this uncertainty by combing this method with three analytical groundwater contamination transport models. The three models involve the transport mechanisms of advection, dispersion, adsorption, hydrolysis, and biodegradation. The uncertainty analysis provides estimates of the statistical reliability in model outputs of concentration and contamination arrival time. Examples are provided which demonstrate that (a) confidence limits around predicted values of concentration and arrival time can be obtained, (b) the selection of probability distributons for input parameters affects the output variables and (c) the probability distribution of the output variables can be different than that of the input variables, even when all input parameters have the same probability distribution.

THE TECHNIQUES FOR ASSESSMENT OF UNCERTAINTY IN NON-POINT SOURCE WATER QUALITY MODELLING

A.Ghosh Bobba & John Carey

National Water Research Institute, Ontario, Canada

In achieving effective environmental control, developing methodologies for dealing with uncertainties in model simulations of contaminant behaviour and effects is important. Several procedures have been proposed to quantify uncertainties in modelling studies.

This paper reviews two methods, First Order Error Analysis and Monte Carlo Simulation, which are the most widely applied and are believed to be most useful.

The First Order Error Analysis (FOEA) method basically provides a measure of uncertainties in dependent variables in terms of uncertainties in independent variables. The procedure is based on first order terms in the Taylor series expansion of the dependent variable about its mean value with respect to one or more independent variables. The major assumption in this procedure is that all independent and dependent variables are the Second Moment Variables (SMV), which means that the behaviour of any SMV is completely described by its mean and standard deviation. The mathematically simple nature of the procedure allows its application to simple input - output models with little difficulty. Consequently, it has been applied by many investigators to environmental simulators, for example, lake phosphorous loading models, BOD-DO models in a single reach river system, and groundwater contamination modelling.

The Monte Carlo Simulation (MCS) method uses a large number of repeated trials or simulations with the values for stochastic inputs or uncertain variables selected at random from their assumed parent probability distributions. Each simulation can yield either a single or a set of output values depending on the model structure. When all these outputs are taken together, the forecasts can be obtained in terms of frequency distribution is dependent on the number of simulations. This method is conceptually simple and theoretically sound. The Monte Carlo simulation has been applied to water quality modelling by several investigators.

The paper discusses both FOEA and MCS and their applications to multi reach river system. The outputs have been compared to demonstrate the utility of the methods.

IMPACT OF AGRICULTURE ON NUTRIENT CONTAMINATION OF WATER RESOURCES

M. L. Sharma

CSIRO, Division of Water Resources, Wembley, Western Australia

In the pursuit of meeting increasing demands for food and fibre, modernisation of agriculture around the world has involved a rapid increase in the use of agro chemicals (fertilisers and pesticides) and mechanisation of farm operations. This has occurred without any serious regard to the adverse environmental consequences. The major impact of modern agriculture is that over 70% of the surface waters and a large proportion of groundwaters around the point source pollution from agriculture as a very high priority problem. However, in the developing countries such priority has not yet been recognised, partly because of other pressing demands on resources.

This paper provides an overview of the pollution of water resources, through the discharge of two major nutrients, nitrogen and phosphorus. The discussion on contamination is considered from the view of drinking water for humans as well as eutrophication of surface water resources. Nitrate is the most ubiquitous agricultural pollutant in shallow groundwaters around the world. From the eutrophication view point, phosphorus is the prime limiting element but nitrogen can also limit algal and aquatic growth under certain circumstances.

The magnitude of the pollution is a complex function of many physical, chemical and biological interactions in relation to soil type, management practices and climatic conditions. We consider the mechanisms of nutrient discharge to surface waters as well as to groundwaters. The factors which affect the retention and transport of various forms of nitrogen and phosphorus in the landscape are discussed. Included is discussion on experimental as well as modelling techniques being developed and used for quantifying and predicting nutrient contamination. Finally, a brief discussion on the remediation/abatement/prevention methods to minimise the impact of pollution is included with some suggestions for future research.

INFLUENCE OF SOIL HYDROLOGICAL PROPERTIES ON ALLELO-CHEMICAL FACTS UNDER AGROFORESTRY SYSTEM

R.M. Singhal & S.Srinivas

Forest Research Institute, Dehradun, India

The soil water, accompanying dissolved organic compound through foliar leachates can be treated in a physical soil system to be governed by the same principal of fluid mechanics, more so by the virtue of viscosity of the fluid mass. It has been established that the viscosity of the fluids/liquid is strongly temperature dependant, decreasing with the temperature varies with the organic constituents concentration. The specific viscosity although, independent of concentration, is determined by the nature of the solute and solvent, since the solutions usually have higher viscosities than the pure solvent.

In agroforestry systems, various exotic and indigenous fast growing tree species are planted along boundaries, in blocks or alleys with the agricultural crops. Amidst controversies with eucalyptus, it has been reported that the growth and germination of agricultural crops, (wheat and paddy in particular) are effected adversely to yield comparatively less. An experiment therefore, was conducted to corroborate the above allegations through exsitu and potculture experiments so as to see the allelopathic effects of certain tree species growing with agriculture crops and to ascertain whether hydrological properties of the soil have any influence on the movement of the foliar leachates carrying these allelochemicals, and their retentivity in the soil pores for the uptake by the plant.

An experiment was laid out by raising pot culture of wheat in the soil of different textures (by adding different proportions of sand in the soil).

For this purpose the water leachates were obtained from the litters of five different forest tree species viz., Eucalyptus, Poplar, Leucaena, Morus and bamboo in the laboratory and applied to the seedlings of wheat raised separately in pot culture to simulate rain water. Germination and growth behaviour of the wheat seedlings following application of the leachates were recorded for a period of 30 days from

the date of germination in pot culture under glass house conditions. It was observed that the effects of allelochemicals on germination and growth was more pronounced in the soils having heavy texture as compared to light ones. The results so obtained were then correlated with the different hydrological properties of soil in the pots and attributed infiltration percolation and water holding capacity at field capacity etc.

Effects of allelochemicals on the germination of seeds alone was also studied separately in petri-dish to ascertain the adverse effects, if any they have on the germination. The observations indicated that it had more adverse effect than in the pot culture and was in the order of leucaena, eucalyptus Morus, bamboo and poplar. The experiment brought about the conclusion of the significant role of the soil and its hydrological behaviour towards reducing the intensity of allelopathy in agroforestry more to the advantage of farmers.

HYDROGEOCHEMISTRY OF GROUND-WATER FROM BASALT-A QUIFERS - A CASE STUDY OF BARAMATI TALUKA, PUNE DISTRICT

R.V. Badve & K.G. Welekar

Groundwater Surveys & Development Agency, Pune, India

The present study is focussed on the ground water quality in a typical region of Maharashtra in India. Basalt constitute the most important groundwater reservoirs in the study area. The area under investigation is provided with surface irrigation as well as groundwater irrigation. Recycled water from surface irrigation has greatly influenced the chemical quality of groundwater from shallow aquifers. Sixty seven samples of groundwater were analysed to evaluate hydrogeochemical cycle of groundwater in the study area. Various process of dissolution and precipitation, mixing of groundwater, cation exchange which have influenced the chemistry of groundwater along its flow path have been studied. Hydrochemical facies along the groundwater flow path have been established. The recharge zone facie is predominatly dominated by

HCO₃ - Cl - SO₄ anion and Ca - Mg - Na cation facie. Along the flow path it gets changed to Cl - SO₄ - HCO₃ anion facie and Na - Ca - Mg cation facie. However, due to mixing of surface recycled water with groundwater anomolous facies have been developed, resulting in deterioration of chemical quality of groundwater particularly for drinking water purposes.

FAST PREDICTION OF RUNOFF REMOVAL OF POLLUTANTS UNIFORMLY DISPERSED IN A DRAINAGE BASIN

S.R. Joshi

National Water Research Institute, Burlington, Canada

It is a well-known fact that chemical pollutants dispersed in a drainage basin are slowly released to the receiving surface waters. Such releases are usually predicted by standard confirmation and validation modelling techniques. This approach requires monitoring of pollutant levels in thereceiving waters over long periods of time, usually several years, and thus is of limited use in cases (such as the Chernobyl nuclear accident) where such information is needed immediately to assess the impact on populations consuming such waters.

In this study an alternative approach to such predictions, showing that the mean residence time of a pollutant niformly dispersed in a watershed is propotional to its dimensionless solid/solution distribution coefficient (K_d) in the system has been developed. The proportionality constant, B, is defined as theratio of the volume of precipitation-impacaated soil and the volume of annual precipitation in the watershed; it can also be expressed as the ratio between the water penetration depth in soil and the annual thickness of water above the soil surface. The value of B is established using a naturally occurriing radionuclide such as ²¹⁰Pb (half-life 22.3 years). Both K_d and B can be estimated in amatter of weeks if no such information already exists for the system. For chemically conservative

pollutants, the approach can be suitably modified to account for the fraction migrating deeper into the soil and thus unavailable for removal with the surface runoff. The fluxes to thereceiving surface waters can then be predicted using atmospheric input fluxes and hydrological parameters.

Two nuclear fallout radionuclides, the chemically reactive ¹³⁷Cs and conservative ⁹⁰Sr, were used to evaluate the model as, of all types of pollutants, most reliable historical atmospheric flux estimates are available only for nuclear pollutants. The two radioisotopes have similar half lives, 30.1 and 29 years, respectively. The results for the Ottawa River and Winnipeg River systems in Canada show that the predicted fluxes of the two radionuclides compare favourably with those measured in these two major Canadian watersheds.

BREAK UP MODE AND BINDING FORCE OF FLOC

Md. Delwar Hossain

BUET, Dhaka, Bangladesh

Many surface waters are characterised by low turbidity and are highly coloured due to the presence of organic matter. The coagulation of coloured waters generally produces flocs which are weaker than those formed waters containing higher concentration of suspended solids. To judge the weakness, the important property of flocs is their strength i.e the ability of floc structure to resist deaggregation. The way in which this strength is conferred on floc is not well understood.

This paper describes an experimental investigation into the break-up character of flocs formed by additions of aluminium sulphate as a coagulant in a coloured raw water flocs were placed in a vibrating column and were monitored at the time of disintegration using a CCTV camera attached to a microscope. nature of flocs are elastic. Floc strength was assessed by analysing the rapture behavior in a turbulent flow.

WATER QUALITY MODELS FOR WATERSHED MANAGEMENT

J.R. Williams & J.G. Arnold

USDA-Agricultural Research Service, Texas, USA

Several water quality models are available for use in assessing the effects of agricultural management on the environment. Since these models are being used to solve a variety of water quality problems, they vary considerably in structure and complexity. For example, simple screening models may be adequate and appropriate for identifying potential pollutant sources. However, more comprehensive models are needed in comparing agricultural management effects on chemical transport by runoff and sediment. Model requirements may also vary depending upon temporal and spatial scales, cost, and risk associated with proposed projects.

Some of the most widely used water quality models, particularly those most useful in agricultural management are described briefly. Two of the models, the Erosion-Productivity Impact Calculator (EPIC) and the Simulator for Water Resources in Rural Basins (SWRRB), are presented in more detail to serve as examples of field and watershed scale water quality models. These models were selected because they feature convenient and comprehensive agricultural and soil management components. For example, EPIC is useful in solving management problems involving crop varieties and rotations, tillage, furrow diking, irrigation, drainage, fertilization, pest control, weather variation, atmospheric CO₂ concentration, erosion (wind and water), water quality (nutrients and grazing). The model operates on a daily time step and is capable of simulating hundreds of years if necessary. It is also useful in solving short term (within growing season) management problems operating in a real time mode. The SWRRB model was designed for solving watershed scale problems like water supply and quality (nutrients and pesticides), pond and reservoir design, groundwater flow contributions, irrigation water transfer, and stream channel routing of sediment and agrichemicals. SWRRB also operates on a daily time step and allows watershed subdivision. Subdivisions are made to account for spatial variability of soils, land use, weather, and topography. This gives SWRRB the capability to

estimate off-site impacts including channel and reservoir deposition and total water supplies. Example applications of EPIC and SWRRB to water quality problems are also described.

WATER QUALITY OF BANDALAMOTTU Cu-Pb-Zn MINE AREA, GUNTUR DISTRICT, ANDHRA PRADESH

M.N. Babu & P. Sankara Pitchaiah

Nagarjuna University, Nagarjunanagar, India

Bandalamottu mine exists 103 km away from the Guntur town in India where copper, lead and zinc minerals are explored. The area receives 500 mm annual average rainfall and is normally dry in summer. The country rocks are Chlorite Phyllite, Carbonaceous Phyllite, Dolomitic Limestone, Calcareous Argillite and Phyllite. Galena, Chalcopyrite and Pyrite are the important ore minerals within the mineralized belt. Mining disturbs the hydrological system and results in physical and chemical environmental changes often leading to water pollution. Hence, an attempt is made in this study to present the quality of water from the bandalamottu mine area.

Twenty three water samples were collected from the bandalamottu mine and the surrounding villages-Bandalamottu, Malapadu, Bollapalle, Gangulapalem and Mugachintalapalem which were subjected to the standard chemical analysis. pH of the water samples vary from 6.6 to 7.9 and TDS 372.71 to 1204.56 mg/l. Total alkalinity ranges from 168 to 484, total hardness, 136 to 1092, chlorides 32 to 174, sulphates 19.34 to 405.9, nitrates 1.95 to 158.15, fluorides 0.6 to 2.7, sodium 60.3 to 219.4 and potassium 1.33 to 16.83 (all in mg/l). It is observed that various parameters are decreasing downslope. The study indicates the possible movement of the mine drainage further downward in near future, which is already affecting the Bandalamottu village. It is also found that 60% of the village waters have higher concentrations of total hardness, fluorides and nitrates and the water is not suitable for drinking.

ENVIRONMENTAL IMPACT AND ECONOMIC ASPECT OF GREATER DHAKA FLOOD PROTECTION STRUCTURE

M.H. Rahman

Bangladesh University of Engineering & Technology,
Dhaka, Bangladesh.

Bangladesh suffered two serious floods during monsoon period of the years 1987 and 1988. During that time Dhaka, the Capital City of Bangladesh experienced an unprecedented degree of flood level, 1.5 m higher than normal level for a period of about four weeks. At that time 2.5 million, i.e. 60% of total population of the city was directly affected. In this situation, the Government of Bangladesh decided to construct flood protection structures to surround the Greater Dhaka Area. The first phase of this work has already been completed. The construction of the flood protection structures was so hurriedly done that there was serious deficiency in planning, design and construction processes. Due to construction of two types of protection structures, namely brick wall and embankment, the facility cannot be used as roadway. The construction of conventional earth embankment without proper soil investigation may cause several types of embankment failures. The embankment breach followed by flooding is likely to cause greater damage to lives and properties.

In this study above mentioned aspects have been clearly identified with recommendations for proper remedial measures. The cost analysis of project indicates that the reinforced earth embankment is much more cost-effective and serviceable compared to the present structure. This study also focuses on the environmental degradation of Greater Dhaka City area due to pollution created by domestic wastes, industrial wastes and to some extent agricultural wastes are not handled in organized way. Only 40% of total population of the city is being served by Water and Sewerage Authority. Rest of the population either has its own sanitation facilities or nothing at all. The surface drains aiming to carry storm water, also carry human excreta from slum areas thereby causing environmental degradation. It is expected that these environmental problems will be amplified with the construction of flood protection structures. A comprehensive guide line to improve waste management system in Greater

Dhaka City, proper environmental impact analysis of the project with the solution of major salient environmental issues and a cost-effective solution of flood protection structure with better serviceability is recommended in this paper.

SALT WATER INTRUSION IN CENTRAL GODAVARI DELTA

T. Thomas, T. Vijay & P.V. Seethapathi

National Institute of Hydrology, Kakinada, India

Intrusion of salt water into the aquifer system in coastal areas depends on the utilisation and exploitation of groundwater. The quality of ground water in coastal areas will be effected by indiscriminate pumping. The aquifer system once gets polluted due to salt water intrusion is rather difficult to reclaim. In order that the aquifer system is maintained and preserved without getting polluted, proper management strategies are to be adopted. For evolving suitable management strategies, it is necessary to understand the hydrological behaviour in the coastal areas. The Central Godavari Delta region forming a part of very fertile, highly irrigated, East Godavari area in Andhra Pradesh. Though no groundwater exploitation is adopted in this region on a large scale, the borewells in this part are being used for drinking water purposes. In spite of less pumpage from these wells, the quality of water is getting deteriorated over a period of time. If this trend continues, the situation may arise where the wells can not be used even for drinking water purposes. The assertion of reasons for the deterioration of quality of groundwater is therefore imperative. The pertinent data were collected and analysed for identification of the reasons for the deterioration of groundwater quality. The data analysis indicated that reduction of flows in various arms of the River Godavari through the barrage constructed at Dowleswaran has tended for the sea water to intrude into the arms of the river stretching distances even upto around 50 kms. This has led to the infiltration of salt water through these river arms into the aquifer system, thereby causing the quality problems. The paper indicates the critical analysis carried out on the information collected. Though no remedial measures have been suggested, logical conclusions have been drawn to

avoid furtherance of quality problems by maintaining certain minimum flow in the arms of River Godavari.

APPLICATION OF GIS IN EROSION ESTIMATION - A CASE STUDY IN NAYER SUBWATERSHED OF RAMGANGA RIVER(W) BASIN USING UNIVERSAL SOIL LOSS EQUATION

D.S. Rathore

National Institute of Hydrology, Roorkee, India

Universal Soil Loss Equation (USLE) is used in estimation of soil erosion from a subwatershed. For estimation of erosion caused by storms, rainfall erosion index is used in this equation.

Nayer subwatershed is a hilly subwatershed of Ramganga River (W). Ramganga River (W) is a tributary of Ganga River and it originates in Himalayas. For other subwatersheds of Ramganga River (W), Bino and Gagas, parameters are available (Chandra, S. et al, 1987). In estimating erosion from Nayer subwatershed, length-slope factor and management practice factor values are taken from Chaukhutia subwatershed. Values of soil erodibility factor and cover factor are taken from Bino and Gagas subwatersheds respectively. The soil erodibility factor are available for Bino subwatershed, defined for different landuse/cover.

A landuse/cover map of the subwatershed is prepared using IRS LISS-II scene 27-47 A1 of date March 23, 1989. Ground control is done using SOI topographic map number 530 of scale 1:250000. To landuse/cover, soil erodibility factor and cover factor are assigned. Soil erosion is computed using 'calculation' and 'table calculation' options in ILWIS (Integrated Land and Water Information System) for different storms in the catchment.

The subwatershed area is 70.06 sq.kms. The basin falls in Almora district of Uttar Pradesh, India. Area of landuse/cover of forest, agricultural land, waste lands are respectively 11.49, 49.13, 9.44 sq.kms. Average erosion computed for the subwatershed for 1.820 t.m.cm/ha-hr rainfall erosion index is 0.2161 tonnes/hectare. The average erosion for the subwa-

tershed is computed for erosion indices of 7.512, 2.786, 2.244 t.m.cm/ha-hr for different storms. Various commands used in computation in batch files, command line are given. Computation of yearly erosion rate for agricultural land is done for the subwatershed.

HYDROLOGIC IMPACTS OF PARTIAL FOREST CUTTING ON WATER YIELD

S.V.N. Rao & Jack King***

* National Institute of Hydrology, WHRC, Jammu, India

** Intermountain Forest Research Stn, Boise, USA

Traditionally forest management studies involving single and multiple watersheds have been reported since early 1960's. Here linear regression models are generally used to relate flow from a treatment watershed to that of a control (hydrologically same) for a certain calibration period. The regression equations so obtained are used to estimate flows during the post calibration periods assuming no cutting. A high degree of correlation with significant increase in flows during post calibration indicate impacts of forest cutting on water yield. Most studies infer an increase in water yield as a result of forest cutting followed by a gradual decrease in yield arising out of regrowth. The increase in yield is largely attributed to reduction in interception and transpiration losses. A second approach becoming popular in the recent times involve modelling (simulation) of land use change. Efforts to replace control watershed with that of a calibrated model have not been very successful, but have been giving encouraging results.

Leavesley's model was used in the present study to evaluate impacts of partial forest removal in two small watersheds in the Silver Creek study area, south west of Idaho (USA). Data of about 6 - 8 years (approx) was obtained from the USDA forest service, Intermountain forest research station, Boise. The watersheds were selected for study on the basis of similar hydrologic and topographic characteristics with reference to a control watershed. All the watersheds were completely forested with Ponderosa pine and Douglas Fir during the calibration period. Treatments involved patch clearcutting (helicopter logging) in the two watersheds (33% and 23% cut). In the first

case the trees were cut and scattered while in the second case it was broad cast and burnt.

The Leavesley's model is a deterministic, modular design, physical process based, distributed model. Distributed parameter capabilities are provided by partitioning the watershed into HRU's (hydrologic response units) sing characteristics such as shape, aspect, elevation, land use, soil type etc. To evaluate the impact of clearcutting the calibrated model was rerunduring the post calibration period without changing any parameters. This estimate was compared with measured flows in arriving at increase in water yield. A water balance and an energy balance are computered daily for each HRU. The sum of the responses of all HRU's weighted on a unit basis produces the daily watershed response.

The paper illustrates the application of Leavesley's model in arriving at increased water yields due to partial forest cutting. The results of paired watershed analysis are however not presented due to inadequate length of a calibration data.

The model also serves as a tool to the forest manager in the management of water resources in forested catchments.

AN ASSESSMENT OF THE ENVIRONMENTAL IMPACT OF TUNGABHADRA PROJECT

S.A.Abbasi & K.K.S.Bhatia***

* Pondicherry University, Pondicherry, India

** National Institute of Hydrology, Roorkee, India

Tungabhadra project near Shimoga (Karnataka) is one of the largest water resources projects in the Krishna river basin. It is based on a man-made reservoir of gross storage capacity 3767 million m³, and serves the dual purpose of power generation and irrigation.

The paper presents findings of a study on the environmental impact of Tungabhadra project. The study is based on an extensive 3-year survey with reference to 75 environmental indicators encompassing all biotic and abiotic factors relating to reservoir catchment, feeder streams, impounded water, and downstream

(including the command area). Over 400 sources of information were explored comprising of a) universities and autonomous research institutions, b) governmental agencies including pollution control boards, electricity boards, hydropower corporations, public works departments, irrigation departments, and command area development authorities, c) research institutions, d) non-governmental agencies, and e) books and journals.

The study reveals that the biggest adverse environmental impact of Tungabhadra project has been in terms of water-logging and harm to groundwater quality. The main causative factors are cropping pattern, improper land development, low efficiency of water use, and unchecked sub-surface drainage. These aspects are quantified and analysed in the paper in adequate detail.

GEOCHEMISTRY OF SOIL SODICITY AND GROUND WATER SALINITY IN THE WATER LOGGED AREAS OF U.P.

Dhaneshwar Rai, D.K. Sharma & S.C. Singh

Ground Water Department U.P. ,Lucknow, India

Soil sodicity is the consequent effect of water logging in the major irrigation commands. Ground Water salinity is also increasing in shallow unconfined aquifers. The source of ionic constituents are not well established, but the authors feel it to be derived from the existing clay minerals. Hydrolysis of clay minerals in water logging condition, release several ions, which enrich the soil water and ground water. Ions of low ionic potential such as Na, Ca, Mg release at faster rates and remain in solution during the process of weathering and transportation. Elements with intermediate ionic potential be precipitated and their ions be associated with hydroxyl groups in equeous solution and elements with higher ionic potential form anions containing oxygen which are usually soluble. Hydrogen ion concentration of soil water and oxidation reduction potentials of elements favour the hydroloysis of clay minerals. Colloidal state of particles favour to bind and concentrate certain sub-stances through physical and chemical adsorption. The main ionic constituents of sodic soil and of ground water are : Na⁺, Ca⁺⁺, Mg⁺⁺, SO₄⁻, Cl⁻, CO₃⁻, HCO₃ etc. which in soil

occur in solid state in the form of minerals: Thenordite, Blaedit, gypsum, halite, hexahydrate, mirabilite etc. which be crystallized in the form of evaporites.

GROUND WATER QUALITY IN KUTTIADI RIVER BASIN

S.A.Abbasi, K.K.S.Bhatia***

* Pondicherry University, Pondicherry, India

** National Institute of Hydrology, Roorkee, India

Kuttiadi river basin in Kerala, India, a small basin encompassing a mere 583 Km² but is served by two large storage reservoirs of which one - Kakkayam Reservoir - is used for Hydropower generation and the other - Kuttiadi Reservoir - for irrigation.

In this paper groundwater quality of the basin is described on the basis of sampling of dug wells and bore wells followed by physico-chemical analysis. In general the waters confirm to the acceptability criteria set by Indian and WHO standards for drinking and irrigation but some wells exhibit exceptionally high levels of total dissolved solids, hardness, and heavy metals.

The paper also explores the relationship between the quality of surface water and ground water in the basin and finds them to be closely interrelated.

A PERSPECTIVE ON TIME-CONTINUOUS SPACE-DISCRETIZED SOLUTIONS OF CONVECTION-DISPERSION EQUATION IN VARIABLY SATURATED POROUS MEDIA

Sita Ram Singh & S.K. Kamra***

* Water Technology Centre For Eastern Region, Bhubaneswar, India

** Central Soil Salinity Research Institute, Karnal, India

Three time-continuous space discretized semi-analytic approaches to solve one and two dimensional convection dispersion equations have been critically examined. The methods are: (i) eigen function finite element method, (ii) Laplace transform finite element method, and (iii) Laplace transform finite analytic method. In the first approach the space discretization of convection dispersion equation by Galerkin's finite element method yields a system of time dependent inhomogeneous ordinary differential equations that

is solved by eigenvalue-eigenvector method of Euler. The second approach involves a simple application of Laplace transform to eliminate the temporal derivative before the application of Galerkin's procedure and subdivision of the domain into finite elements. The resulting transformed system of algebraic equations is solved for nodal concentration in Laplace p space, and thereafter the numerical Laplace inversion algorithm is employed to recover the nodal concentration in physical time domain. In the third approach, the temporal derivative is eliminated using Laplace transform, and the resulting steady state like convection-dispersion equation is solved analytically over small subdomains by assigning constant value to the parameters of the differential equation. The solution in the transformed domain is numerically inverted to get concentration as a function of time. Out of the three semi-analytic methods the Laplace transform finite analytic method is most accurate and has the potential of application to other areas as well.

RESERVOIR STRATIFICATION - CASE STUDY OF A TROPICAL RESERVOIR IN KERALA, INDIA

S.A.Abbasi, A.V.M.Kunhi* & K.K.S.Bhatia***

* Pondicherry University, Pondicherry, India

** National Institute of Hydrology, Roorkee, India

Kuttiadi lake is a man-made reservoir situated at Peruvannamuzhi, near Kozhikode, Kerala (11°35N, 79°49E). The temperature and dissolved oxygen (DO) profiles of the lake were studied across its width and depth over a 1-year cycle.

The lake was found to often exhibit the classical pattern of the thermal and DO stratification typical of tropical lakes with well-defined epilimnion, thermocline, and hypolimnion. These patterns were observed in spite of regular withdrawal of the hypolimnetic water for irrigation purposes, and consequent disturbances to the strata.

The DO was seen to fall to very low concentrations in the hypolimnetic layer reaching below the levels of 4 ppm needed to maintain diverse fish community. The stratification of temperature and DO induced sharp changes in the concentrations of trace metals across the depth of the lake.

ENVIRONMENTAL CONSIDERATION IN WATER RESOURCES DEVELOPMENT

S.K. Sinha

Central Water Commission, New Delhi, India

Water Resources Development results in variety of environmental impacts, both beneficial and adverse. One of the objectives of water resources development should be, to the extent found feasible and desirable, to improve the environment by the management, conservation, preservation, creation, moderation of upgradation of quality of certain natural and cultural resources and ecological systems. Experience has shown that many of

the problems result from failure to consider the development and the environment concurrently and from adopting a compartmentalised approach to planning rather than a multi disciplinary integrated approach. The likely effects of water resources development on the environments have been broadly brought out in this paper and a view has been taken that the most of the adverse impacts could either be mitigated or remedied or minimised if sufficient and timely attention is paid to them at planning stage and a multi disciplinary integrated approach is adopted.

