IAHS Publication 306
ISSN 0144-7815

IAHS ICCE DUNDEE 2006

Sediment Dynamics and the Hydromorphology of Fluvial Systems Dundee, Scotland

2nd - 7th July 2006

PROGRAMME OF EVENTS

DUNDEE UNIVERSITY

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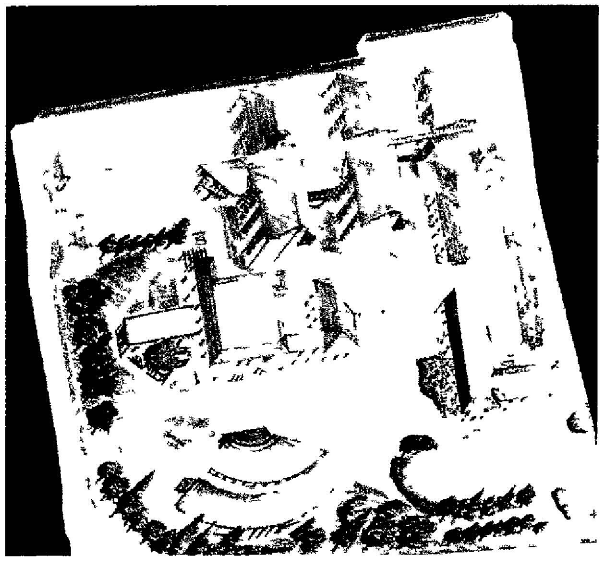

Schematic lay out of West Park Conference Centre

Convenors John S Rowan, Robert W Duck & A Werritty (University of Dundee)

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SUNDAY 2ND JULY 2006-

1400 Registration opens

1830 ICE-BREAKER drinks reception - all delegates and guests invited to attend

2000 Dinner for Residential Delegates in West Park Conference Centre

MONDAY 3RD JULY 2006

FLUVIAL SEDIMENT DYNAMICS AND THE IMPORTANCE OF EXTREME EVENTS

0845 - 0850	**WELCOME AND OPENING COMMENTS**
0850 - 0910	Suspended sediment yield from continents into the world ocean, spatial and temporal changeability *A P DEDKOV & A V GUSAROV (RUSSIA)*
0910 - 0930	Sediment yields in the Exe basin a longer-term perspective *ANNA HARLOW, BRUCE WEBB & DES WALLING (UK)*
0930 - 0950	Influence of different factors on the sediment yield of the Oka basin rivers (Central Russia) *VALENTIN GOLOSOV (RUSSIA)*
0950 - 1010	Glacial erosion and sediment transport in the Mittivakkat Glacier catchment, Ammassalik Island, southeast Greenland, 2005 *BENT HASHOLT & SEBASTIAN H MERNILD (DENMARK)*
1010 - 1030	Sediment transport during a flushing flow in the lower Ebro River *RAMON J BATALLA, DAMIA VERICAT & ANTONI PALAU (SPAIN)*
1030 - 1040	***Questions and Review of Session - Chair Rob Duck***
1040 - 1110	**MORNING COFFEE / REFRESHMENTS**
1110 - 1130	Flood and sediment transport response to hydrometeorological events of diverse magnitude in Vallcebre basin, Eastern Pyrenees *MONTSERRAT SOLER, DAVID REGUES, JERÔME LATRON & FRANCESC GALLART (SPAIN)*
1130 - 1150	Episodic discharge of coarse sediment in a mountain torrent *RICHARD JOHNSON & JEFF WARBURTON (UK)*
1150 - 1210	The life-span of a small high mountain lake, the Vordere Blaue Gumpe in the Bavarian Alps *DAVID MORCHE, CHRISTIAN KATTERFELD SEBASTIAN FUCHS & KARL-HEINZ SCHMIDT (GERMANY)*
1210 - 1230	Output of bed load sediment from a small upland drainage basin in Hong Kong *M R PEART & L FOK (HONG KONG)*
1230 - 1250	Suspended sediment dynamics for June storm events in the urbanized River Tame, UK *D M LAWLER, I DL FOSTER, G E PETTS, S HARPER & I P MORRISSEY (UK)*
1250 - 1300	***Questions and Review of Session – Chair Peter Molnar***
1300 - 1400	**LUNCH**
1400 - 1420	A volumetric approach to estimate bed load transport in a mountain stream (Central Spanish Pyrenees) *N LANA-RENAULT, D REGUES, J LATRON, E NADAL, P SERRANO & C MARTI-BONO (SPAIN)*
1420 - 1440	An underutilized resource historical flood chronologies a valuable resource for determining hydrogeomorphic change *NEIL MACDONALD (UK)*
1440 - 1500	Estimating soil erosion and sediment transport in the drainage basin of the proposed Selova Reservoir, Serbia *STANIMIR KOSTADINOV, NADA DRAGOVIC & MIRJANA TODOSIJEVIC (SERBIA & MONTENEGRO)*
1500 - 1520	The effect of the 'Great Flood of 1993' on suspended sediment concentrations and fluxes in the Mississippi River Basin, USA *ARTHUR J HOROWITZ (USA)*
1520 - 1530	***Questions and Review of Session – Chair Larissa Naylor***
1530 - 1555	**AFTERNOON TEA / REFRESHMENTS**
1555 - 1615	Hydromorphological adjustment in meandering river systems and the role of flood events *JANET HOOKE (UK)*
1615 - 1635	Sediment transport rates of major floods in glacial and non-glacial rivers in Norway in the present and future climate *JIM BOGEN (NORWAY)*
1635 - 1655	Sediment erosion, transport and deposition during the July 2001 Mawddach extreme flood event *GRAHAM HALL & ROGER CRATCHLEY (UK)*
1655 - 1715	Evaluating the impacts of impoundment on sediment transport using short-lived fallout radionuclides *FRANCIS J MAGILLIGAN, NIRA L SALANT, CARL E RENSHAW, KEITH H NILSOW ARJUN HEIMSATH & JAMES M KASTE (USA)*
1715 - 1725	***Questions and Review of Session – Chair Eileen Cashman***
1725	CLOSE OF DAY 1 PAPER SESSIONS
1800	**DINNER FOR RESIDENT DELEGATES**
1910	**CITY OF DUNDEE CIVIC RECEPTION in Dundee City Chambers – open invitation to all delegates and guests. Buses available (one-way) to transport delegates into the city.**

TUESDAY 4TH JULY 2006

THE STRUCTURE, FUNCTIONING AND MANAGEMENT OF FLUVIAL SEDIMENT SYSTEMS

0850 - 0910 Variety is the spice of river life recognising hydraulic diversity as a tool for managing flows in regulated rivers
M C THOMS, M REID K CHRISTIANSON & F MUNRO (AUSTRALIA)

0910 - 0930 Changing use and hydromorphological adjustment in a coastal lagoon – estuarine system, the Ria de Aveiro, Portugal
JOSE FIGUEIREDO DA SILVA & ROBERT W DUCK (PORTUGAL)

0930 - 0950 Multi-scale analysis of island formation and development in the Middle Loire River, France
EMMANUELE GAUTIER & STEPHANE GRIVEL (FRANCE)

0950 - 1010 Modelling flow, erosion and long term evolution of incising channels managing hydrology and geomorphology for ecology
TIMOTHY NORTON, JULIAN LEYLAND & STEPHEN DARBY (UK)

1010 - 1030 The role of sediments in the dynamics and preservation of the aquatic forest in the Nestos delta (N Greece)
D EMMANOULOUDIS, D MYRONIDIS, S PANILAS & G EFTHIMIOU (GREECE)

1030 - 1040 ***Questions and Review of Session – Chair Dirk De Boer***

1040 - 1110 **MORNING COFFEE / REFRESHMENTS AND FORMAL POSTER SESSION (1)**

1110 - 1130 Evaluating the effectiveness of the Illinois River Conservation Reserve Enhancement Program in reducing sediment delivery
MISGANAW DEMISSIE, LAURA KEEFER, JIM SLOWIKOWSKI & KIP STEVENSON (USA)

1130 - 1150 A practical method for the management of road runoff
INGRID TAKKEN JACKY CROKE, SIMON MOCKLER (AUSTRALIA)

1150 - 1210 The use of buffer features for sediment and phosphorus retention in the landscape implications for sediment delivery and water quality in river basins
P N OWENS, J H DUZANT, L K DEEKS G A WOOD, R P C MORGAN & A J COLLINS (UK)

1210 - 1230 Sediment monitoring and sediment management in the Rhine River
STEFAN VOLLMER & EMIL GOELZ (GERMANY)

1230 - 1250 Are floodplain-wetland plant communities determined by seed bank composition or inundation periods?
MUNIQUE WEBB, MICHAEL REID, SAMANTHA CAPON MARTIN THOMS SCOTT RAYBURG & CASSANDRA JAMES (AUSTRALIA)

1250 - 1300 ***Questions and Review of Session – Chair Andjelka Belic***

1300 - 1400 **LUNCH**

1400 - 1420 Morphometric analysis of UK lake systems as a compliance tool for the European Water Framework Directive
JOHN S ROWAN, IAIN SOUTAR & GEOFF E PHILLIPS (UK)

1420 - 1440 Flows that form the hydromorphology of concave-bank bench formation in the Ovens River, Australia
G J VIETZ, M J STEWARDSON & B L FINLAYSON (AUSTRALIA)

1440 - 1500 Strategies for reducing sediment connectivity and land degradation in desertified areas using vegetation the RECONDES Project
PETER SANDERCOCK & JANET HOOKE (UK)

1500 - 1520 The diversity of inundated areas in semiarid flood plain ecosystems
ORLA MURRAY, MARTIN THOMS & SCOTT RAYBURG (AUSTRALIA)

1520 - 1530 ***Questions and Review of Session – Chair Harriet Orr***

1530 - 1555 **AFTERNOON TEA / REFRESHMENTS**

1555 - 1615 Unravelling the physical template of a terminal flood plain-wetland sediment storage system
SCOTT RAYBURG, MARTIN THOMS & ERIN LENON (AUSTRALA)

1615 - 1635 River sediment/pathogen interactions importance for policy development on safe water practices
IAN G DROPPO, STEVEN N LISS, DECLAN WILLIAMS & GARY G LEPPARD (CANADA)

1635 - 1655 Linking pattern and process. the effects of hydraulic conditions on cobble bio-film metabolism in an Australian upland stream
MICHAEL REID & MARTIN THOMS (AUSTRALIA)

1655 - 1715 Combining biology and hydrology – questions from an integrated study of chalk streams
ROGER S WOTTON & GERALDENE WHARTON (UK)

1715 - 1725 ***Questions and Review of Session - Chair Ellen Petticrew***

1725 CLOSE OF DAY 2 PAPER SESSIONS

1800 DINNER FOR RESIDENT DELEGATES

1930 TASTE OF SCOTLAND – WHISKY & CHEESE RECEPTION (open invitation to all delegates and guests)

TUESDAY 4TH & THURSDAY 6TH JULY 2006

TWO POSTER SESSIONS WITH AUTHORS IN ATTENDANCE (1040 – 1110)

The role of channel storage in controlling the effective particle size characteristics of fine sediments
PAUL A CLARK, DESMOND E WALLING & GRAHAM J L LEEKS (UK)

Erodibility of Quaternary alluvial terraces of the Taleghan drainage basin, Iran
SADAT FEIZNIA & MOHAMMAD-SADEGH ZKIKHANI (IRAN)

Extending flood records using geochemical analysis of palaeochannel sediments
ANNA F JONES, PAUL A BREWER & MARK G MACKLIN (UK)

Erosion and accumulation processes in the Azau Valley in Central Caucasus during the last thousand years
ADAM LAJCZAK (POLAND)

Space and time variability of suspended particulate matter (SPM) transport in 32 French rivers
MANO, V, MOATAR, F COYNEL, A ETCHEBER, H, LUDWIG, W, MEYBECK, M, NEMERY, J, POIREL, A, BLANC, G & SCHAFER J (FRANCE)

Taking stock of lake hydrology in the UK
ANDREW BLACK JOHN ROWAN, OLIVIA BRAGG & ROBERT DUCK (UK)

Spatial and temporal variation of grain size distributions of alluvial deposits in an Alpine river
DAVID MORCHE & MARKUS WITZSCHE (GERMANY)

Identifying scientific questions and tools for delivering WFD monitoring requirements – recent research on managed realignment sites
LARISSA NAYLOR, ELIZA GHITIS, ROBIN ROTMAN & ASHLEY SPRATT (UK)

Hillslope erosion submodel for rainfall-runoff model in GIS
ALEJANDRO DUSSAILLANT (CHILE)

Sediments in one of the drainage canals from the Danube-Tisa-Danube hydro-system
S PANTELIC, A BELIC, PH D, R SAVIC, & S BELIC (SERBIA & MONTENEGRO)

Application of remote sensing data to reconstruct long-term changes in lake water quality parameters across Europe
EIRINI POLITI, MARK CUTLER & JOHN ROWAN (UK)

The mechanics and significance of debris flows in Scotland a case-study in Glen Ogle
FRASER MILNE, MICHAEL C R DAVIES & ALAN WERRITTY (UK)

River suspended sediment yield investigation by MLP neural network, case study of the Bar River, Neyshaboor, Iran
SEPIDEH ZAKIKHANI, HADI MEMARIAN KHALILABAD & SADAT FEIZNIA (IRAN)

Longitudinal patterns of bed (not bar) material grain size samples in a large, coarse and mixed bedded, navigable river
MICHAEL BLISS SINGER (USA)

The Ayeyarwady River - 125 years on
RUTH ROBINSON, MICHAEL BIRD, NAY WIN OO DAVID HIGGITT, LU XI XI, MAUNG MAUNG AYE & TREVOR HOEY (UK)

Analysis of the relation between "horizontal" flow turbulence and bed deformation
DONATELLA TERMINI & CARLO LO RE (ITALY)

Incorporating climate change in river typologies
ORR, H G, WALSH, C L, LARGE, A R G, NEWSON, M D, KILSBY, C G & WILBY R L (UK)

Riffle-pool morphology, morphodynamics and bed mobility under disturbed und undisturbed sediment supply conditions
THOMAS VETTER (GERMANY)

The observation and quantification of oil migration and binding in sediments using T_2 magnetic resonance imaging
ALISON REEVES & SANDY CHUDEK (UK)

Significance of extreme storm runoff in the delivery of hillslope sediment to upland fluvial systems
JEFF WARBURTON, RICHARD JOHNSON & DAVID MILLEDGE (UK)

The determination of effective sediment yield factors using Principal Component Analysis
MOHAMAD SADEGH ZAKIKHANI, MASOUD NASRI & SADAT FEIZNIA (IRAN)

WEDNESDAY 5TH JULY 2006

FIELD EXCURSION **SEDIMENT DYNAMICS AND THE HYDROMORPHOLOGY OF THE RIVER TAY, SCOTLAND**

All Delegates and guests are invited to journey up the River Tay, from the lower reaches of the estuary to the headwaters and beyond!

0830 DEPART **CONFERENCE CENTRE**

ITINERY

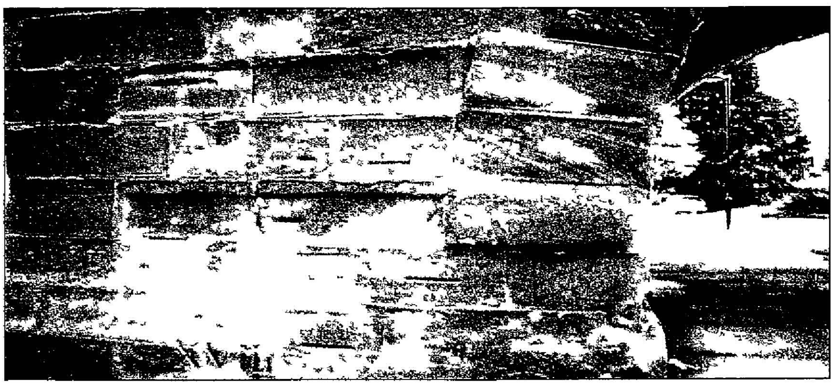
Lower Tay Estuary	Water circulation and sediment provenance
Upper Tay Estuary	Hydromorphological adjustment
City of Perth	Flood risk mitigation strategies in an uncertain climate
Pitlochry	Faskally Dam and Pitlochry salmon ladder

PACKED LUNCH

River Garry	Wandering gravel-bed rivers and conservation constraints
Loch Tummel	Hydropower, hydromorphology and 'The Queen's View'
Allt Dubaig	Sediment transport and downstream fining processes
Distillery Tour	Further research into the *'water of life'*

1800 RETURN **DUNDEE**

1930 Conference Centre Residents Dinner



Epigraphic flood record of River Tay floods inscribed into Smeaton's Bridge, Perth

THURSDAY 6TH JULY 2006
UNLOCKING THE STRATIGRAPHIC RECORD

0850 - 0910	Variation of suspended sediment transport in the Timah Tasoh reservoir catchment, Perlis Malaysia human impacts and the role of tropical storms *ZULLYADINI A RAHAMAN & WAN RUSLAN ISMAIL (MALAYSIA)*
0910 - 0930	Using geochemical stratigraphy to indicate post-fire sediment and nutrient fluxes into a water supply reservoir, Sydney, Australia *WILLIAM H BLAKE, PETER J WALLBRINK STEFAN H DOERR RICHARD A SHAKESBY GEOFFREY S HUMPHREYS, PAULINE ENGLISH & SCOTT WILKINSON (UK)*
0930 - 0950	The role of organic matter on the adsorption of mercury in sediments from Amazon lakes, Brazil *DANIEL MARCOS BONOTTO MARCELO VERGOTTI & ENE GLORIA DA SILVEIRA (BRAZIL)*
0950 - 1010	Dating of reservoir and pond deposits by the ^{137}Cs technique to assess sediment production in small soil catchments of the Hilly Sichuan Basin and the Three Gorges Region, China *ZHANG XINBAO, QI YONGQING HE XIUBIN, WEN ANBANG, FU JIEXIONG (CHINA)*
1010 - 1030	Reservoir sedimentation trends in Ohio, USA sediment delivery and response to land-use change *WILLIAM H RENWICK & ZACHARY D ANDERECK (USA)*
1030 - 1040	***Questions and Review of Session – Des Walling***
1040 - 1110	**MORNING COFFEE / REFRESHMENTS AND FORMAL POSTER SESSION (2)**
1110 - 1130	The use of ^{137}Cs and ^{210}Pb$_{ex}$ to investigate sediment sources and overbank sedimentation rates in the Teesta River basin, Sikkim Himalaya, India *W FROEHLICH & D E WALLING (POLAND)*
1130 - 1150	Sediment storage and transfer in the Mekong generalisations on a large river *AVIJIT GUPTA S C LIEW & ALICE W C HENG (UK)*
1150 - 1210	Holocene sediment budgets of the Rhine Delta (the Netherlands) a record of changing sediment delivery *GILLES ERKENS, KIM M COHEN, MARC J P GOUW, HANS MIDDELKOOP & WIM Z HOEK (NETHERLANDS)*
1210 - 1230	The deposition and storage of sediment-associated phosphorus on the flood plains of two lowland groundwater fed catchments *DEBORAH BALLANTINE, DESMOND E WALLING & GRAHAM J L LEEKS (UK)*
1230 - 1250	Changing fluxes of sediments and salts as recorded in lower River Murray wetlands, Australia *PETER GELL, JENNIE FLUIN JOHN TIBBY DEBORAH HAYNES SYEDA IFTEARA KHANUM, BRENDAN WALSH GARY HANCOCK, JENNIFER HARRISON ATUN ZAWADZKI & FIONA LITTLE (AUSTRALIA)*
1250 - 1300	***Questions and Review of Session – Martin Thoms***
1300 - 1400	**LUNCH**
1400 - 1420	The infilling of a terminal floodplain wetland complex *ROBERT COSSART MARTIN THOMS & SCOTT RAYBURG (AUSTRALIA)*
1420 - 1440	The importance of temporal changes in gravel-stored fine sediment on habitat conditions in a salmon spawning stream *ELLEN L PETTICREW & JOHN F REX (UK)*
1440 - 1500	Investigating the remobilization of fine sediment stored on the channel bed of lowland permeable catchments in the UK *ADRIAN L COLLINS & DESMOND E WALLING (UK)*
1500 - 1520	Unravelling flood history using matrices in fluvial gravel deposits *LYNNE E FROSTICK, BRENDAN MURPHY & RICHARD MIDDLETON (UK)*
1520 - 1530	***Questions and Review of Session – Wojciech Froehlich***
1530 - 1555	**AFTERNOON TEA / REFRESHMENTS**
1555 - 1615	River floodplains as carbon sinks *D E WALLING, D FANG & R J SWEET (UK)*
1615 - 1635	Debris flows in Scotland the role of hillslope-channel coupling on downstream sediment delivery *ALAN WERRITTY, FRASER MILNE, MICHAEL DAVIES TREVOR HOEY & ANDREW BLACK (UK)*
1635 - 1655	The impact of changes in climate, upstream land use and flood plain topography on overbank deposition *IVO THONON, HANS MIDDELKOOP & MARCEL VAN DER PERk (NETHERLANDS)*
1655 - 1715	A gradient or mosaic of patches? The textural character of inset-floodplain surfaces along a dryland river system *MARK SOUTHWELL & MARTIN THOMS (AUSTRALIA)*
1715 - 1725	***Questions and Review of Session – Chair Bill Renwick***
1725 - 1735	CLOSE OF DAY 3 PAPER SESSIONS
1745	**ICCE PLENARY SESSION**
1930	**CONFERENCE BANQUET AT DISCOVERY POINT DUNDEE (OPTIONAL)** **RESIDENTS' DINNER AT CONFERENCE CENTRE**

FRIDAY 7TH JULY 2006

EXPERIMENT-BASED AND MODELLING APPROACHES TO SEDIMENT RESEARCH

0850 - 0910	Sediment phosphorus dynamics in tile-fed drainage ditches *D R SMITH, E A WARNEMUENDE, B E HAGGARD & C HUANG (USA)*
0910 - 0930	A framework for predicting delivery of phosphorus from agricultural land using a decision-tree approach *RICHARD BRAZIER MICHAEL SCHARER, LOUISE HEATHWAITE KEITH BEVEN PAUL SCHOLEFIELD, PHIL HAYGARTH ROBIN HODGKINSON, DES WALLING AND PAUL WITHERS (UK)*
0930 - 0950	Nutrient and contaminant enrichment in rural areas of southwest Germany *MARTIN SCHWARZ & STEPHAN FUCHS (GERMAY)*
0950 - 1010	Salinity and erosion a preliminary investigation of soil erosion on a salinised hillslope *MEL NEAVE & SCOTT RAYBURG (AUSTRALIA)*
1010 - 1030	MOSESS a model for soil erosion prediction at small scales *EDUARDO E DE FIGUEIREDO & HERBETE H R C DAVI (BRAZIL)*
1030 - 1040	***Questions and Review of Session – Chair Art Horowitz***
1040 – 1110	**MORNING COFFEE / REFRESHMENTS**
1110 - 1130	The comparison of numerical and experimental study of dam-break induced mudflow *SZU-HSIEN PENG & SU-CHIN CHEN (TAIWAN)*
1130 - 1150	Predicting erosion patterns using a spatially distributed erosion model with spatially variable and uniform parameters *DIRK H DE BOER (CANADA)*
1150 - 1210	Analysis of local scour downstream of bed sills preliminary results of experimental work *DONATELLA TERMINI (ITALY)*
1210 - 1230	Importance of watershed lag times in IUSG development *KAZIMIERZ BANASIK, MARIUSZ BARSZCZ & LESZEK HEJDUK (POLAND)*
1230 - 1240	***Questions and Review of Session – Chair Lynne Frostick***
1240 - 1345	**LUNCH**
1345 – 1405	Model investigations of the effects of land-use changes and forest damages on erosion in mountainous environments *PETER MOLNAR, PAOLO BURLANDO, JORG KIRSCH & ELKE HINZ (SWITZERLAND)*
1405 - 1425	Modelling the impacts of climate variability on sediment transport *EILEEN CASHMAN & KENNETH POTTER (USA)*
1425 - 1445	Effects of rainfall variability and land use change on simulated sediment yield with SHETRAN *EDUARDO E DE FIGUEIREDO & JAMES C BATHURST (BRAZIL)*
1445 - 1455	***Questions and Review of Session – Chair Emmanuèl Gautier***
1455 - 1505	**Closing Comments**
1505 - 1530	**AFTERNOON TEA / REFRESHMENTS**
1530 -	**END OF CONFERENCE**

Sediment Dynamics and the Hydromorphology of Fluvial Systems

Sediment Dynamics and the Hydromorphology of Fluvial Systems

Edited by

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IAHS Publication 306
in the IAHS Series of Proceedings and Reports

Published by the International Association of Hydrological Sciences 2006

IAHS Publication 306
ISBN 1-901502-68-6

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

The papers included in this volume have been reviewed and some were extensively revised by the editors, in collaboration with the authors, prior to publication.

IAHS is indebted to the employers of the Editors for the invaluable support and services provided that enabled them to carry out their task effectively and efficiently.

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IAHS Press, Centre for Ecology and Hydrology, Wallingford, Oxfordshire OX10 8BB, UK
tel.: +44 1491 692442; fax: +44 1491 692448; e-mail: jilly@iahs.demon.co.uk

Printed in The Netherlands by Krips BV, Meppel

Variation of suspended sediment transport in the Timah Tasoh Reservoir catchment, Perlis, Malaysia: human impacts and the role of tropical storms

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Abstract In recent years, soil erosion, sediment transport and deterioration of water quality in many river systems in Malaysia have become major concerns. Headwater streams emanating from forested and agricultural lands supply much of the potable water in this country. The quality, quantity and timing of water from these headwater catchments are strongly influenced by human activities such as deforestation associated with land conversion for agricultural purposes. This study investigates the impact of human activities and the role of tropical storms on the variation of sediment transported into the Timah Tasoh Reservoir, Perlis, Malaysia. The study period was two years, with water samples and gauging carried out bi-weekly and additional intensive sampling conducted during storm events. These samples were integrated with data from two continuous hourly transmitted water-level recording stations located at the major river input of the reservoir. Flow and suspended sediment rating curves were developed and used to estimate the discharge and suspended sediment load. Regression equations were used to estimate the discharge and suspended sediment loading at stations with limited and discontinuous data. The variation of suspended sediment load is significantly affected by the human activities and the rainfall and runoff in the catchment area.

Key words human impact; Malaysia; sediment load; Timah Tasoh Reservoir

INTRODUCTION

In recent years, soil erosion, sediment transport and deterioration of water quality in many river systems in Malaysia have become major concerns. Headwater streams emanating from forested and agricultural lands supply much of the potable water in this country. The quality, quantity and timing of water from these headwater catchments are strongly influenced by human activities such as deforestation associated with land conversion for agricultural purposes (e.g. Douglas *et al.*, 1992; Baharuddin & Abdul Rahim, 1994; Ziegler *et al.*, 2000). The effect of land-use changes and human activities on hydrology and sediment transport are well documented by several researchers (Wan Ruslan & Zullyadini, 1994; Baharuddin, 1998; Steegen *et al.*, 2000; Nelson & Booth, 2002). Under natural conditions, a forest delays runoff and encourages infiltration (Bruijnzeel, 1990), but due to human activity such as urbanization and settlement, construction, agriculture and other human activities, infiltration will be greatly reduced thus increasing total runoff and peak flows.

In tropical regions, storm events play an important role in determining the amount of sediment transported out of a catchment system (Wan Ruslan, 2000). Tropical rainfall is characterized by heavy and intense storms with large rain drops influencing soil erosion and the removal and transport of sediment. Rainfalls with intensities exceeding 200 mm h^{-1} have been reported, while those greater than 100 mm h^{-1} are common (Lal, 1976). In Peninsular Malaysia, about 125 mm h^{-1} is expected in 30-min duration storms occurring approximately once in five years, and 100 mm h^{-1} intensities occur once in two years (Douglas, 1984). Such storms would definitely create a higher erosion rate, and will produce a high amount of suspended sediment transported by river systems. This study investigates the role of tropical storms and the impact of human activities on variations in the amount of sediment transported into a reservoir.

THE STUDY AREA

Timah Tasoh Reservoir (6°36'N, 100°14'E) is located approximately 13 km north of Kangar town near the Thailand border (Fig. 1). The reservoir has a mean surface area of 13.33 km^2 and a storage capacity of about 40 million m^3. The reservoir receives inputs from two main rivers, the Tasoh River and Pelarit River, which have a combined basin area of 191 km^2 and supply approximately 97 million m^3 of water into the reservoir annually. The reservoir is shallow with a maximum depth of 10 m and submerged aquatic plants can be seen along the shoreline and in shallow areas. At present, the main purpose of the reservoir is to supply water for domestic and industrial use as well as for irrigation and flood control.

Three river catchments flowing into the reservoir have been selected as the study area, namely the Jarum River (R1), Upper Pelarit (R2) and Chuchuh River (R3). The location of each study catchment is illustrated in Fig. 1. R1 has a catchment area of 64.4 km^2, R2 42.7 km^2 and R3 14.8 km^2. Table 1 shows the areal proportion of the land use of each of the study catchments. The catchments can be grouped into three categories based on the percentage of forest cover. R3 is nearly 99% covered with forest and very little affected by anthropogenic disturbance. R2 can be categorized as partially disturbed, with almost 91% forest cover. However, this catchment has quarrying which will influence the production of suspended sediment. The third catchment, R1 is considered highly disturbed with anthropogenic activities occurring on 55.1% of the land area. The disturbances are in the form of agriculture activities such as sugar plantation, rubber and paddy.

Table 1 Land use in the study catchments.

Catchments Land-use type	Jarum River (R1) Area (km^2)	 %	Upper Pelarit (R2) Area (km^2)	 %	Chuchuh River (R3) Area (km^2)	 %
Sugarcane	11.58	18.0				
Urban & settlement	0.71	1.1	0.35	0.8	0.19	1.3
Mixed crop	2.22	3.4	0.21	0.5		
Scrub	2.79	4.3	0.33	0.8		
Rubber	12.94	20.1	2.09	4.9		
Paddy	5.23	8.1	0.4	0.9		
Forest	28.9	44.9	38.72	90.6	14.61	98.7
Grass		–	0.13	0.3		
Quarry			0.5	1.2		
Total	64.4	100	42.72	100	14.8	100

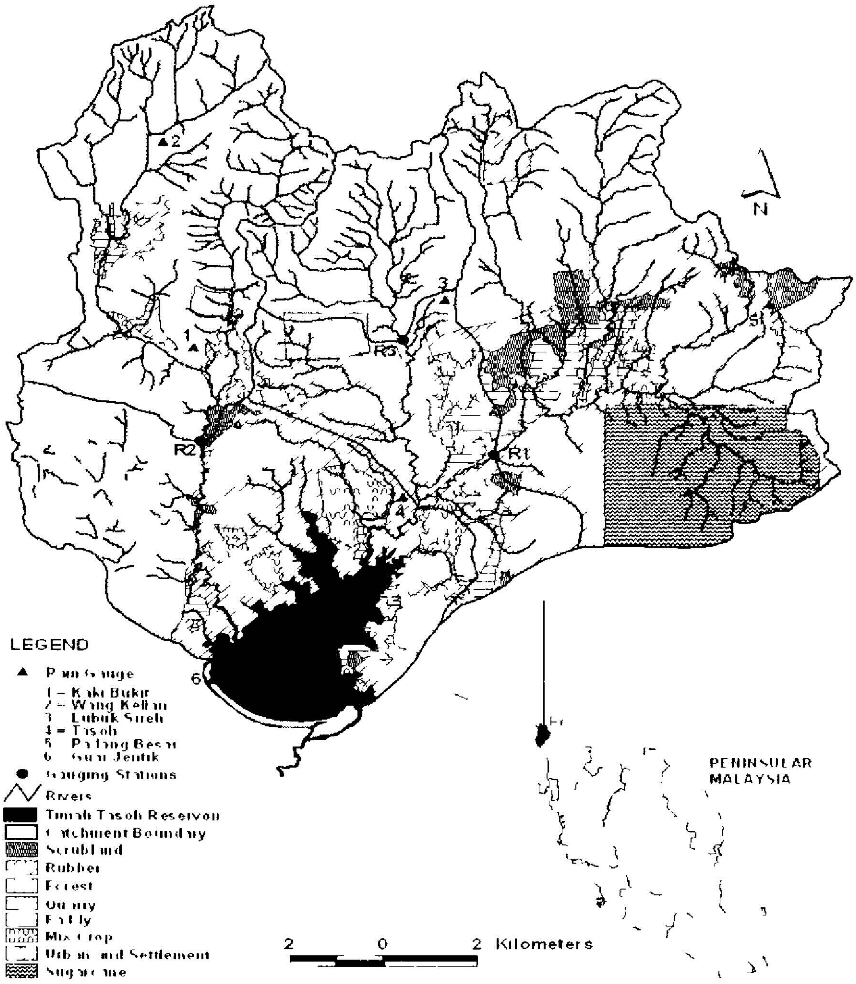

Fig 1 The study catchments

METHODOLOGY

Rainfall data were obtained from the six raingauges maintained by the Drainage and Irrigation Department (DID) of Perlis (Fig 1) Streamflow gauging and water sampling were carried out every two weeks, integrated with frequent intensive sampling during storm events Sampling was carried out from January 2001 to December 2002

Continuous telemetrically-transmitted hourly water level records for R1 and R2 were obtained from the DID Channel cross-sections, velocities and depths were measured to obtain discharge data and three replicates were taken for water sample analyses The water samples were then filtered using Whatman GFC 47-mm filter paper and oven dried for 24 hours to obtain the suspended sediment concentration The suspended sediment concentration was computed by applying the suspended sediment concentration rating curve equations summarized in Table 2 The suspended sediment load for each station was determined by multiplying water discharge and sediment concentration

Table 2 Suspended sediment rating curve equations used to compute the suspended sediment concentration (SSC) for each study catchment

	Regression equation (Year 2001)	r^2	n	Sig. level	Regression equation (Year 2002)	r	n	Sig. level
Jarum River (R1)								
All Data	$SSC = 0.126Q^{1.327}$	0.50	207	0.01	$SSC = 0.063Q^{0.434}$	0.67	110	0.01
Baseflow	$SSC = 0.139Q^{1.468}$	0.79	65	0.01	$SSC = 0.061Q^{[illegible]}$	0.34	22	0.01
Highflow	$SSC = 0.201Q^{0.167}$	0.51	43	0.01	$SSC = 0.03Q^{[illegible]}$	0.12	32	0.01
Rising limb	$SSC = 0.417Q^{1.388}$	0.47	51	0.01	$SSC = 1.352Q^{[illegible]}$	0.27	23	0.01
Falling limb	$SSC = 0.074Q^{[illegible]}$	0.28	48	0.01	$SSC = 0.057Q^{[illegible]}$	0.34	27	0.01
Upper Pelarit (R2)								
All Data	$SSC = 0.065Q^{1.607}$	0.28	107	0.01	$SSC = 0.032Q^{0.777}$	0.66	183	0.01
Baseflow	$SSC = 0.004Q^{1.848}$	0.45	46	0.01	$SSC = 0.017Q^{[illegible]}$	0.44	49	0.01
Highflow	$SSC = 0.189Q^{0.780}$	0.20	36	0.01	$SSC = 0.024Q^{1.815}$	0.63	54	0.01
Rising limb	$SSC = 0.197Q^{0.472}$	0.46	44	0.01	$SSC = 0.081Q^{[illegible]}$	0.38	43	0.01
Falling limb	$SSC = 0.012Q^{0.883}$	0.45	46	0.01	$SSC = 0.034Q^{[illegible]}$	0.38	36	0.01
Chuchuh River (R3)								
All Data	$SSC = 0.122Q^{1.334}$	0.28	133	0.01	$SSC = 0.125Q^{[illegible]}$	0.41	195	0.01
Baseflow	$SSC = 0.644Q^{1.348}$	0.42	48	0.01	$SSC = 0.049Q^{1.803}$	0.36	97	0.01
Highflow	$SSC = 0.196Q^{[illegible]}$	0.23	37	0.01	$SSC = 0.245Q^{[illegible]}$	0.35	46	0.01
Rising limb	$SSC = 0.438Q^{1.567}$	0.63	17	0.01	$SSC = 0.438Q^{[illegible]}$	0.63	17	0.01
Falling limb	$SSC = 0.089Q^{[illegible]}$	0.82	31	0.01	$SSC = 0.095Q^{1}$	0.72	35	0.01

RESULTS AND DISCUSSION

Total runoff

Upper Pelarit (R2) had the highest runoff during the study period at 2122.8 mm, while Chuchuh River (R3) and Jarum River (R1) recorded 1215.9 and 1159.4 mm, respectively (Table 3). When compared to the rainfall runoff coefficients, the same trend remains. The runoff for R2 is 61% of total rainfall. For R3 this drops to 34.7% of total rainfall and for R1 the runoff is 33.1% of total rainfall (not very much lower than R3).

The mean monthly runoff coefficients for each study area are 35.9%, 59.8% and 38.34% for R1, R2 and R3, respectively (Table 3), closely resembling the total runoff coefficients. For R1 the monthly runoff coefficients ranged between a minimum of 11.7% and a maximum of 86.72%. The maximum and minimum runoff coefficients were 8.2–165.4% for R2 and 12.5–92.6% for R3. The runoff exceeded rainfall twice at R2, during December 2001 and October 2002. This was due to delayed runoff because of the high rainfall in the previous month (239.4 and 259.3 mm in October and November 2001, respectively).

Baseflow and stormflow

The monthly average stormflow contribution in the Jarum River (R1) is 31.9%, varying from zero to 69.7% (Fig. 2). Maximum stormflow occurred in September 2002 reflecting high rainfall. As illustrated in Fig. 2, much of the runoff at R1 is dominated by baseflow, except during the wet season. In Upper Pelarit (R2), the monthly average of stormflow was 26.5%, with a maximum of 67.8%. As illustrated in Fig. 2, much of

Table 3 Summary of runoff coefficients for the study catchments during the study period

Year	R1 Runoff (mm)	R1 Rainfall (mm)	R1 % Runoff	R2 Runoff (mm)	R2 Rainfall (mm)	R2 % Runoff	R3 Runoff (mm)	R3 Rainfall (mm)	R3 % Runoff
Total 2001	573.8	1697.4	33.8	1093.3	1812	60.3	604.3	1697.4	35.6
Total 2002	585.7	1808.6	32.4	1029.4	1669.5	61.7	611.6	1808.6	33.8
Total	1159.4	3506.0	33.1	2122.8	3481.5	61.0	1215.9	3506.0	34.7
Annual mean	292.8	904.3		514.7	834.8		305.8	904.3	
Month									
Mean	48.3	146.1	35.9	88.5	145.1	59.8	50.7	146.1	38.3
Max	139.9	295.3	86.7	226.5	308.3	165.4	145.5	295.3	92.6
Min	8.0	0.0	11.7	5.3	0.0	8.2	8.7	0.0	12.5
Std Dev	38.9	94.9	20.4	72.0	91.1	34.9	39.7	94.9	21.6

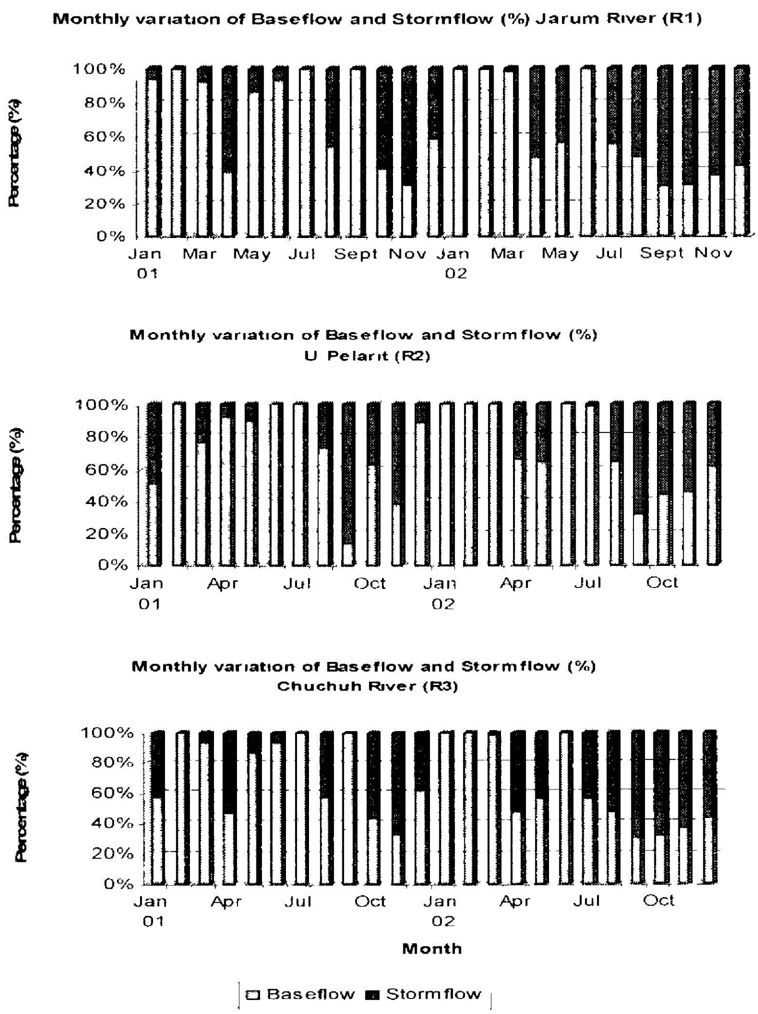

Fig. 2 Monthly variation of baseflow and stormflow (%)each of the study catchments during the study period

the runoff in R2 is dominated by baseflow. Stormflow produces a monthly average of 35.3% of runoff in Chuchuh River (R3), with a maximum of 69.6%. Baseflow also dominates the monthly runoff at R3, except during the wet months of April, May and September–November. It is clear that stormflow plays a significant role in shaping the runoff patterns of each catchment during the study period.

Suspended sediment concentration

Generally, the suspended sediment concentrations closely follow anthropogenic activities in the catchments (Table 4). The Upper Pelarit (R2) has the highest mean concentration of suspended sediment compared to the other two catchments. Based on all the data for 2001, the maximum concentration at R2 was 1544 mg L^{-1} with a minimum of 1.2 mg L^{-1} and a mean of 202.2 mg L^{-1}. These are generally higher values than those recorded at the Jarum River (R1) and the Chuchuh River (R3). The maximum concentration at R1 was 1118.1 mg L^{-1}, with a minimum of 6.8 mg L^{-1} and a mean of 143.7 mg L^{-1}. Lower values were obtained at R3, with a maximum concentration of 702.4 mg L^{-1}, a minimum of 1.2 mg L^{-1} and a mean of 121.1 mg L^{-1}.

Based on the whole data set, suspended sediment concentrations for 2002 showed only slight differences from those of 2001. R1 reported a maximum of 864.8 mg L^{-1}, a mean of 117.9 mg L^{-1} and a minimum of 2.3 mg L^{-1}. Comparable values for R2 were 784.8, 147.2 and 1.6 mg L^{-1}, respectively. There was no difference in the maximum and minimum suspended sediment concentrations observed at R3 in 2001 and 2002 (Table 4).

When the suspended sediment concentration data were divided into baseflow and stormflow, a distinct contrast was apparent between the study catchments. During baseflow, mean concentrations at R2 and R3 were much lower than at R1. By contrast, at R2 the low sediment concentrations during baseflow give way to very much higher values during stormflow, which clearly contributes most of the suspended sediment. This is due to human activities around the catchment area. Quarrying and former tin mining in the catchment are the major sources of suspended sediment production during storm events. Quarrying activities clearly influence the suspended sediment concentration transported into a river system. Wan Ruslan & Zullyadini (1994) show that, during a single storm, the maximum suspended sediment concentration was 63 200 mg L^{-1} and the lowest concentration 1100 mg L^{-1}.

Table 4 Descriptive statistic of SSC (mg L^{-1}) at the gauging stations (all data).

	Upper Pelarit (R2)		Jarum River (R1)		Chuchuh River (R3)	
Year	2001	2002	2001	2002	2001	2002
Mean	202.2	147.2	143.7	117.9	121.1	97.3
Maximum	1544	784.8	1118.1	864.8	702.4	702.4
Minimum	1.2	1.6	6.8	2.3	1.2	1.2
SD	324.2	157.6	125.4	182.3	158.6	140.6
n	172	181	207	109	133	195

Suspended sediment load

As expected, the Upper Pelarit (R2) had a suspended sediment load that is higher than the other study catchments. The total suspended sediment load produced at R2 over both years was 19688 9 t, compared to 15978 7 and 1923 4 t for Jarum River (R1) and Chuchuh River (R3), respectively (Table 5) Storm runoff carried a small proportion of the sediment output of R3 (1360 t) compared to R1 (11 148 1 t) and R2 (13 322 3 t), but the proportion of storm output over total load was the highest at R3 Storms accounted for 70 7% of the sediment output at R3, slightly higher than that at R1 (69 8%) and R2 (67 7%)

Table 5 Summary of suspended sediment load values of each study catchments

	R1	R2	R3
Period (year)	2	2	2
Total load (t)	15 978 72	19 688 88	1923 37
Total yield (t km^{-2})	248 12	490 88	129 96
Annual yield for 2001 (t km^{-2} year^{-1})	92 34	310 15	58 24
Annual yield for 2002 (t km^{-2} year^{-1})	155 78	150 73	71 72
Total storm load (t)	11 148 10	13 322 33	1360 00
Total storm yield (t km^{-2})	173 11	311 85	91 89
Annual storm yield for 2001 (t km^{-2} year^{-1})	34 94	226 32	34 45
Annual storm yield for 2002 (t km^{-2} year^{-1})	138 17	85 53	57 44
Proportion of storm output over total load (%)	69 77	67 66	70 71

The monthly suspended sediment loads varied, reflecting the seasonal rainfall of the study catchments (Table 6) At R1, the highest suspended sediment amount was observed in October 2002 (2732 6 t) During this month, storms contributed as much as 2615 1 t of suspended sediment load, accounting for 95 7% of total load of that month. The lowest suspended sediment load was observed in February 2002 (15 07 t), during which no storm event was recorded

At R2, the highest monthly suspended sediment transported was in November 2001 (3766 9 t), during which 2625 6 t was contributed from storm events The highest percentage of storm contribution was observed in January 2001 which accounted for 97 7% of the total load in that month, although January can usually be considered as a dry month. Nevertheless, the few storms that did occur during this month contributed much of the suspended sediment load This was due to the availability of new sediment sources which had accumulated in the river channel and from the slopes during the previous wet month The lowest monthly suspended sediment load was in March 2002 (1 39 t) reflecting the driest period during the study with no storms recorded since the end of January 2002

At R3, the highest monthly suspended sediment load was recorded in November 2001 (283 1 t), of which 242 t was contributed from storms in this month The highest monthly proportion of storm outputs was recorded in September 2002, reflecting the beginning of the wet season within the study period Most of sediment accumulated

Table 6 Monthly variation of suspended sediment for each study catchment

	Jarum River (R1)			Upper Pelarit (R2)			Chuchuh River (R3)		
	Load (t)	Storm (t)	% storm	Load (t)	Storm (t)	% storm	Load (t)	Storm (t)	% storm
Jan-01	737.76	62.02	8.4	1284.68	1255.61	97.7	85.23	9.65	11.3
Feb-01	93.57	0	0.0	9.04	0	0.0	11.55	0	0.0
Mar-01	188.21	29.95	15.9	288.84	273.14	94.6	20.86	2.84	13.6
Apr-01	278.63	215.02	77.2	338.92	228.6	67.5	32.5	24.63	75.8
May-01	674.93	117.05	17.3	33.14	11.31	34.1	69.54	15.35	22.1
Jun-01	431.82	46.27	10.7	10.12	0	0.0	44.11	5.19	11.8
Jul-01	35.77	0	0.0	10.14	0	0.0	5.72	0	0.0
Aug-01	498.27	240.46	48.3	2520.86	2248.67	89.2	74.72	49.74	66.6
Sep-01	232.2	0	0.0	736.73	427.26	58.0	15.65	0	0.0
Oct-01	1003.93	558.75	55.7	3684.53	2471.81	67.1	145.66	113.46	77.9
Nov-01	1293.53	751.4	58.1	3766.85	2625.61	69.7	283.1	241.95	85.5
Dec-01	477.77	229.04	47.9	565.84	126.41	22.3	73.33	47.12	64.3
Jan-02	19.01	0	0.0	9.33	0	0.0	5.47	0	0.0
Feb-02	15.07	0	0.0	2.01	0	0.0	4.41	0	0.0
Mar-02	28.34	15.84	55.9	1.39	0	0.0	3.88	0.1	2.6
Apr-02	697.43	630.83	90.5	87.98	72.95	82.9	59.48	44.71	75.2
May-02	616.93	467.19	75.7	103.57	87.46	84.4	58.32	39.33	67.4
Jun-02	15.57	0	0.0	3.13	0	0.0	4.53	0	0.0
Jul-02	176.44	162.17	91.9	27.42	0	0.0	18.04	13.89	77.0
Aug-02	960.16	905.73	94.3	591.85	397.42	67.2	97.52	72.7	74.6
Sep-02	2009.89	1857.17	92.4	1950.76	0	0.0	244.57	212.2	86.8
Oct-02	2732.63	2615.05	95.7	1724.59	1461.88	84.8	277.83	234.78	84.5
Nov-02	1638.22	1519.64	92.8	1218.21	1034.54	84.9	175.81	144.08	82.0
Dec-02	1122.65	724.5	64.5	718.95	599.67	83.4	111.52	88.29	79.2
Total	15978.73	11148.08	69.8	19688.9	13322.3	67.7	1923.35	1360.01	70.7
Mean	665.78	464.50		820.37	555.10		80.14	56.67	
Max	2732.63	2615.05	95.7	3766.85	2625.61	97.7	283.1	241.95	86.8
Min	15.07	0	0	1.39	0	0	3.88	0	0

and deposited in the channel was flushed out by the storms in this month. The lowest monthly suspended sediment load was recorded in March 2002 (3.9 t).

CONCLUSIONS

The variations in runoff and suspended sediment transported in the study catchments show the influence of anthropogenic activities in the catchment area as well as the effect of storms. This paper shows that there is a significant difference in suspended sediment concentration during the baseflow period compared to that during storm events. Human disturbance, such as quarrying activity, makes sediment available for transport during a series of storm events. Almost 70% of the suspended sediment load was transported during storms in the study catchments.

Acknowledgement The research project was financed by a research grant from the Ministry of Science and Technology, Malaysia through IRPA Program 08-02-05-0015. The authors wish to thank the Drainage and Irrigation Department of Perlis for providing facilities, rainfall and water level records.

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