internal report 431

Channel stability in a sand-bed stream in the seasonally wet tropics

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June 2003

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Channel stability in a sand-bed stream in the seasonally wet tropics

Part 1: Channel stability in a sand-bed stream in the seasonally wet tropics, Paper presented at 10th Australia New Zealand Geomorphology Group (ANZGG) conference, Kalgoorlie, Western Australia, 30 September– 4 October 2000

Part 2: Channel morphodynamics of a sand-bed stream in the seasonally wet tropics of Australia, Paper and Poster presented at International Association of Hydrological Sciences (IAHS) conference, Alice Springs, 2–6 September 2002

MJ Saynor

Erosion and Hydrology Program
Environmental Research Institute of the Supervising Scientist

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Part 1 Channel stability in a sand-bed stream in the seasonally wet tropics, Paper presented at 10th Australia New Zealand Geomorphology Group (ANZGG) conference, Kalgoorlie, Western Australia, 30 September – 4 October 2000

Abstract

Channel stability in a sand-bed stream in the seasonally wet tropics

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Swift Creek (Ngarradj) is a sand bed stream in Kakadu National Park, Northern Territory. The stream, located in the seasonally wet tropics, flows for approximately half of the year during and immediately after the wet season. In 1998, 51 permanently marked cross sections were installed to monitor the amount of bed sediment storage and/or large scale erosion at three gauging stations. These cross sections have been surveyed annually during each dry season since installation. These survey data provide information about the changes in sediment storage that have occurred between each dry season. Between 1998 and 1999, aggradation of between 0.1 and 0.2 m occurred at each of the three sites but between 1999 and 2000, this sand level remained constant.

The gauging stations were visited weekly during the wet season when the creeks are flowing to obtain hydrological and sediment load (suspended sediment and bedload) information. A velocity-area gauging is completed at station to construct a discharge rating curve. The gauging cross sectional information is used to investigate the within wet season changes. Scour and fill of up to 0.6 m and a shifting thalweg have been identified. Maximum scour is limited by the exposure of a root mat material or a more resistant bed material layer at the sites.

A total of 36 metal scour chains were installed in the Swift Creek catchment to measure scour and fill during the 1998/1999, 1999/2000 and 2000/2001 Wet seasons. Mean scour ranging from a minimum of 50 $\pm$ 34 mm on Tributary North during the 1999/2000 Wet season to a maximum of 332 $\pm$ 93 mm at the Swift Creek gauge during the 2000/2001 Wet season were recorded. Mean fill ranging from a minimum of 56 $\pm$ 18 mm on Tributary North during the 2000/2001 Wet season to a maximum of 391 $\pm$ 43 mm at Swift Creek during the 1998/1999 Wet season were also recorded.

Three years of erosion pin measurements in the Swift Creek catchment established that substantial bank erosion occurred during the Wet season on the western tributaries by rapid lateral migration (up to 100 $\pm$ 24 mm/yr) and by erosion of gully sidewalls (up to 27 $\pm$ 18 mm/yr) by a combination of within-gully flows and overland flow plunging over the sidewalls. Bank erosion also occurred during the Dry season (up to 26 $\pm$ 14 mm/yr) by desiccation and loss of cohesion of the sandy sediments, by faunal activity and by dry flow processes. Channels with dense riparian vegetation do not generate significant amounts of

sediment by bank erosion (average of 4 ± 4 mm/yr). As found elsewhere by others, deposition (up to $- 28 \pm 14$ mm/yr) was also locally significant, despite the sandy bank sediments.

In general, the between wet season changes are considerably smaller than the within wet season changes. Although there are large amounts of sand movement during the wet season, channel cross sections return to pre-wet season profiles during recessional flow. This indicates that the stream channel cross sections usually reach equilibrium on the flow recession.

PowerPoint presentation

Environment Australia
Department of the Environment and Heritage

Channel stability of a sand-bed stream in the seasonally wet tropics

by

M Saynor, W Erskine,

K Evans & D Moliere

Supervising Scientist Division

Supervising Scientist

Environment Australia
Department of the Environment and Heritage

Channel stability of a sand-bed stream in the seasonally wet tropics

- Swift (Ngarradj) Creek Catchment
  - Headwaters in Arnhem land
  - Flows through Kakadu National Park & The Jabiluka Mineral Lease
  - Debouches into Magela Creek
- Contains Jabiluka Mine

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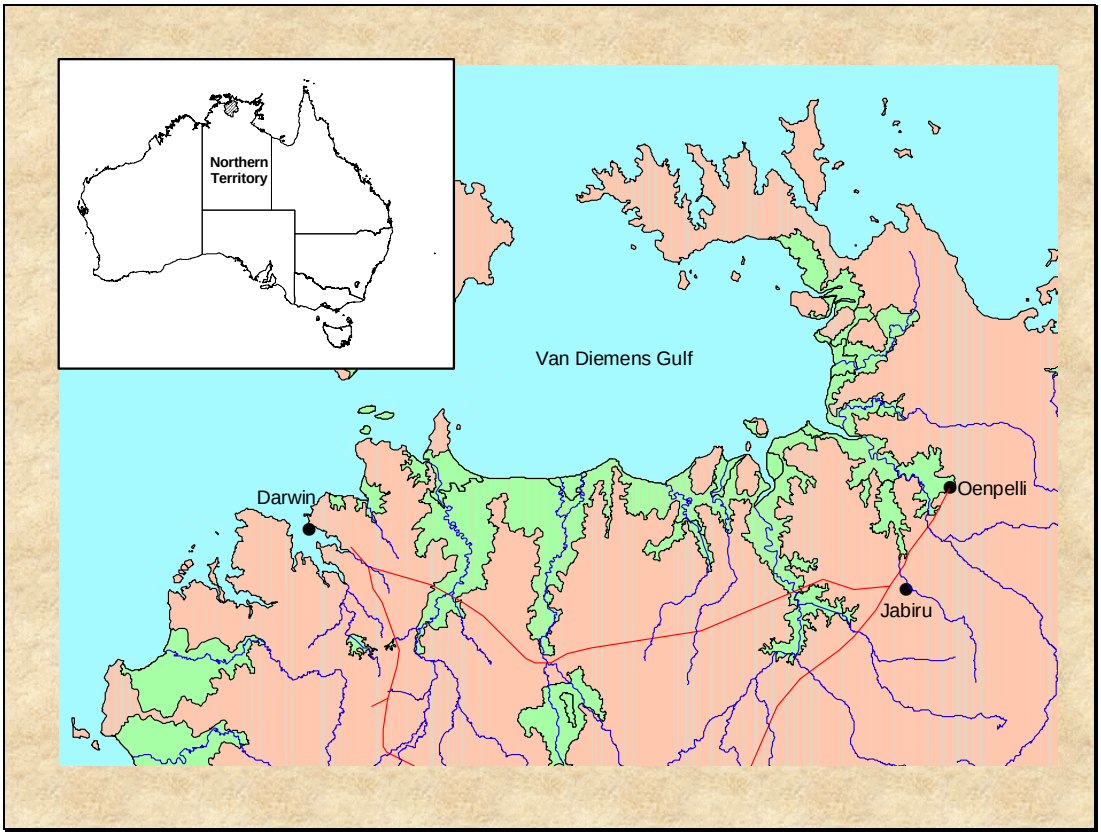

Channel stability of a sand-bed stream in the seasonally wet tropics

- Established gauging station network
  - Upper Swift Creek (UM)
  - Swift Creek (SC)
  - East Tributary (ET)
  - West Tributary

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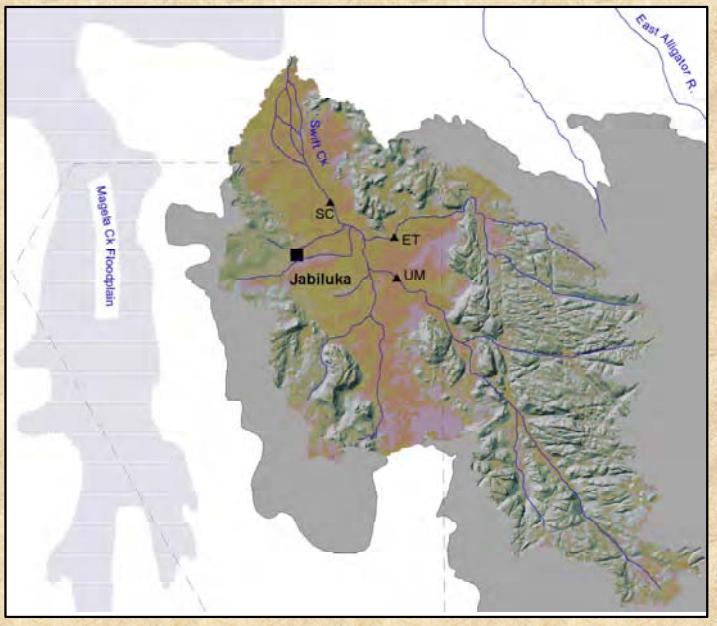
Gauging network established in 1998 to:

- collect discharge and sediment transport data
- determine baseline flow conditions both u/s and d/s of the mine



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Channel stability of a sand-bed stream in the seasonally wet tropics

- Minesite Tributaries
  - Tributary North (TN)
  - Tributary Central (TC)
  - Tributary South (TS)

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Channel stability of a sand-bed stream in the seasonally wet tropics

- Various projects established
  - Hydrology of the catchment
  - Sediment movement
  - Channel Stability
- Baseline Conditions

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Channel stability of a sand-bed stream in the seasonally wet tropics

- To determine channel stability of the creeks the following were established in 1998
  - Permanently marked cross sections (51 cross sections along 5 reaches surveyed annually)
  - Scour chains in bed (36 chains)
  - Erosion pins installed (193)
  - Bed material bulk samples collected (each cross section)

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Channel stability of a sand-bed stream in the seasonally wet tropics

- Scour Chain results for first three years
- Mean Scour for measured reaches
  - Minimum 50 ± 34 mm at Tributary North
  - Maximum 332 ± 93 mm at Swift Creek
- Mean Fill for measured reaches
  - Minimum 56 ± 18 mm at Tributary North
  - Maximum 391 ± 43 mm at Swift Creek

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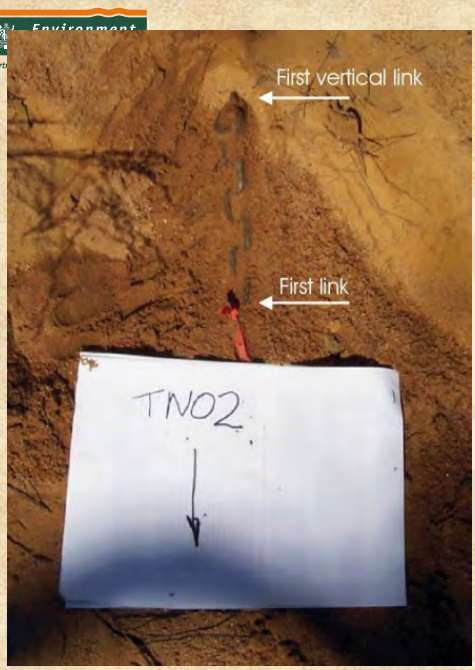

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Channel stability of a sand-bed stream in the seasonally wet tropics

- Erosion Pin results for first three years
  - Wet season erosion > dry season erosion by 1 order of magnitude
  - Bank erosion occurs during dry season
  - Net deposition often occurs
  - Bank erosion active on Mine Site Tributaries (up to 285 t/yr)

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Channel stability of a sand-bed stream in the seasonally wet tropics

- Erosion Pin results for first three years
  - Wet season erosion > dry season erosion by 1 order of magnitude
  - Bank erosion occurs during dry season
  - Net deposition often occurs
  - Bank erosion active on Mine Site Tributaries (up to 285 t/yr)
  - Bank erosion inactive in forested meandering reaches (up to 4 t/yr)

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Channel stability of a sand-bed stream in the seasonally wet tropics

- Dry season cross section surveys
  - Conducted once during the Dry season
  - Up to 0.2 m of bed aggradation since 1998 (Sand storage)
  - Show differences from one Wet season to the next

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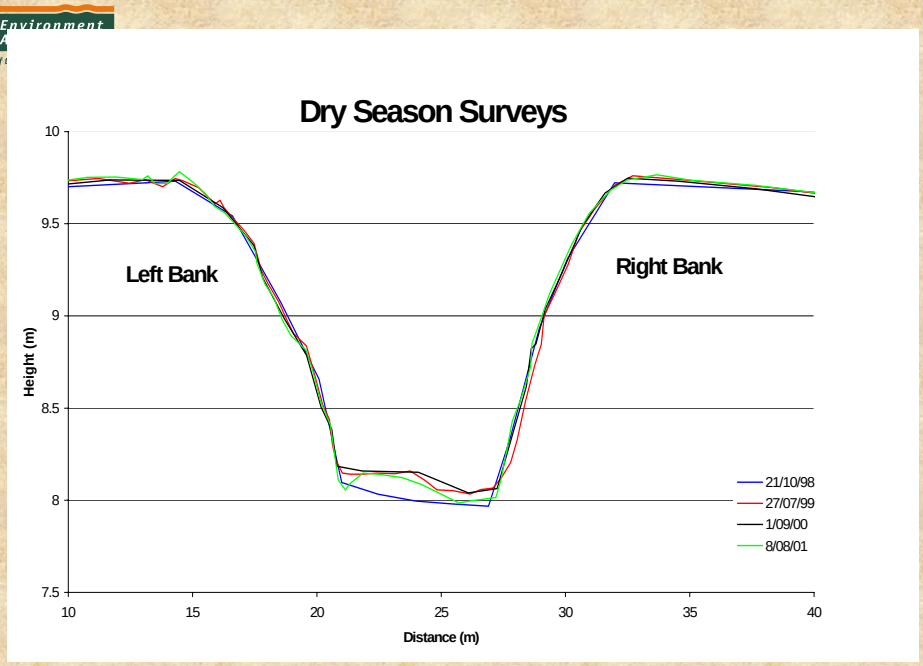

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Channel stability of a sand-bed stream in the seasonally wet tropics

- Wet season cross section surveys
  - Conducted weekly during each velocity-area gauging
  - Indicate scour during rising flood stage
  - Indicate fill during falling flood stage
  - Up to 0.6m variation in bed level

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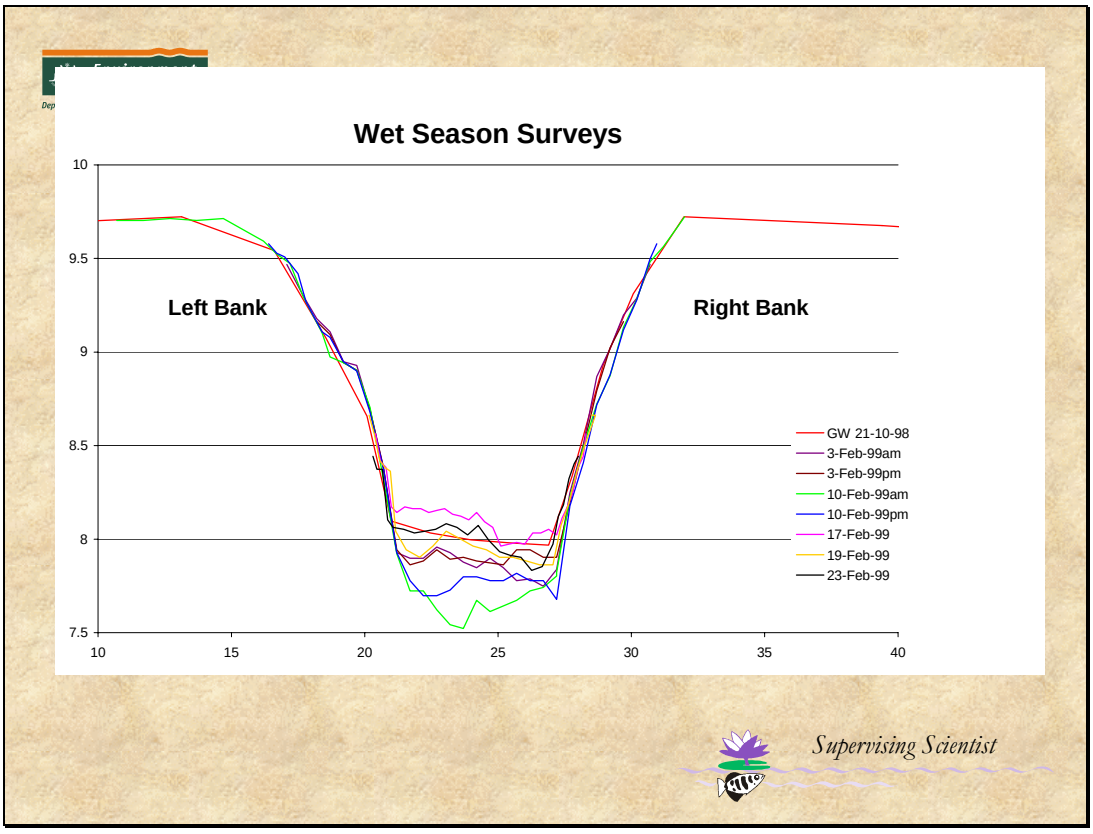
Wet Season Surveys
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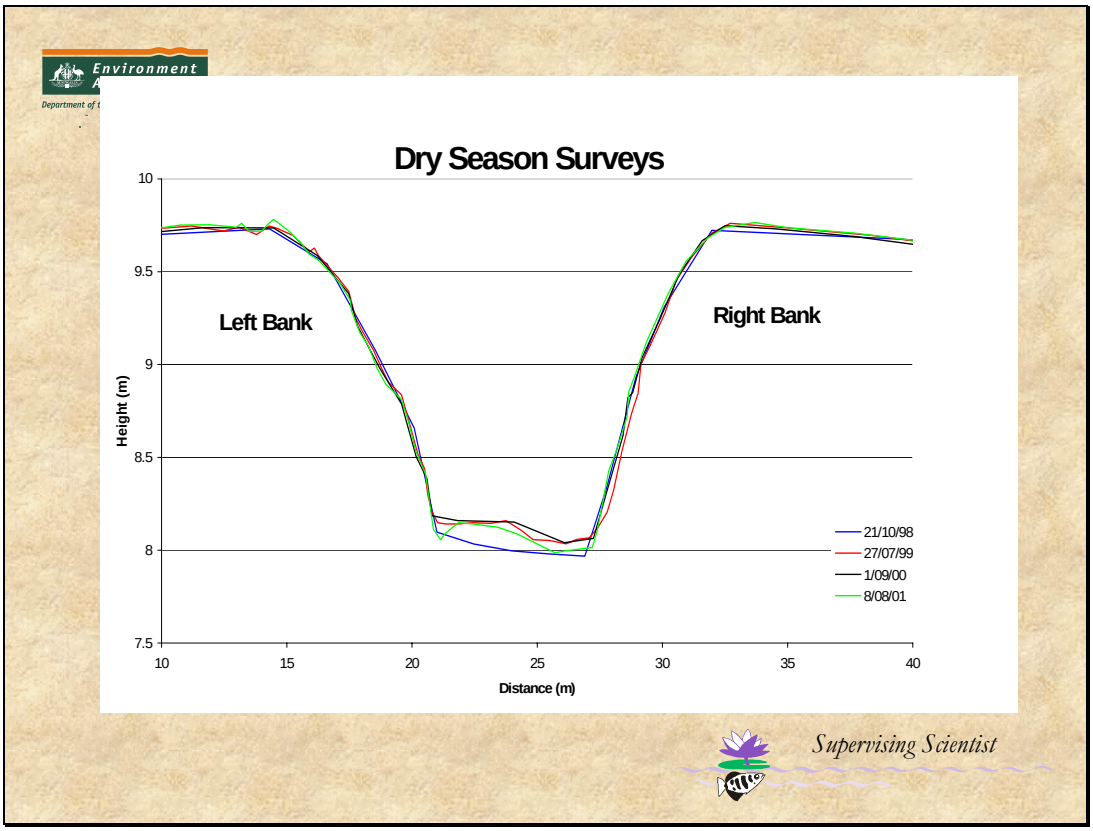
Environment
Dry Season Surveys
10
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Height (m)
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Distance (m)
Left Bank
Right Bank
21/10/98
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1/09/00
8/08/01
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Channel stability of a sand-bed stream in the seasonally wet tropics

- Conclusions
  - Mine site tributaries currently eroding
  - Slight bed aggradation (sand storage) indicated by annual cross section survey over four years
  - Significant scour and fill occur during the Wet season
  - Generally bed levels are similar from year to year (means for each year within 1 SEE of each other)
  - Important for determining sites of storage for mine-derived sediment (sand)

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Trip Report, 10th Australia New Zealand Geomorphology Group (ANZGG) conference, Kalgoorlie, Western Australia, 30 September– 4 October 2000

The Australia & New Zealand Geomorphology Group is an independent organisation that was developed to bring geomorphologists together once every two years. These conferences are held in different geomorphic regions of Australia and New Zealand and the conference field trip is developed around the theme of the region. The main theme of the conference field trip in Kalgoorlie was the mining in the arid zone and also included various stops at a salt lake (Lake Lefroy).

The aim of the conference is to unite the geomorphological community and provide a forum by which people can discuss and demonstrate the type of research that is currently being undertaken. The conference strongly promotes students and recent graduates with the aim of introducing the wider geomorphological community to them. The location of Kalgoorlie limited somewhat the number of students that were able to attend. It also provides the opportunity to meet old friends or develop new contacts in similar fields.

There were 48 papers presented throughout the 5-day conference. Abstracts only a published for this conference. The sessions were grouped where possible into similar themes Glacial, Regolith, Arid Fluvial, Aeolian, Coastal, Big Picture & Karst. Approximately 60-70 people attended each day. I attended each day of seminars as well as the field trip, which was held on the Wednesday. Various sessions were directly relevant to the work being undertaken at ***eriss*** whilst others, although not relevant, were very interesting. No concurrent sessions were held, thus enabling attendance at all presentations. Presenters were mainly from Universities and Government organisations.

The paper that I presented was titled "Channel stability of a sand-bed stream in the seasonally wet tropics" and was co-authored by Wayne Erskine, K Evans D Moliere & I Eliot. The paper discussed cross sectional changes for the annual theodolite surveys and compared the changes in cross section as determined from Velocity area gaugings. The wet season cross sectional changes are 2 to 3 times large than those determined from dry season changes. In general, the between wet season changes are considerably smaller than the within wet season changes. Although there are large amounts of sand movement during the wet season, channel cross sections return to pre-wet season profiles during recessional flow. This indicates that the stream channel cross sections usually reach equilibrium on the flow recession. The presentation was well received and within the allocated time frame.

Several questions were asked which provided prompted later discussion with John Chappell, David Dunkerly and also Martin Williams who have all worked in the Alligator Rivers Region.

- John Chappell (ANU) asked how the recent wet season rainfall discussed in the presentation compared to the average rainfall and was it a representative sample.

  I replied that 3 of the 4 wet seasons in question were much higher than the 1480 mm average and although this was the length of the study the hydrology would be continued for the foreseeable future.
- Paul Williams (University of Auckland) asked in there had been any impact from the mine on the Ngarradj catchment.

Replied that the Jabiluka mine had not had any significant on the Ngarradj catchment and that the actual area of the mine was relatively small only 19 hectares.

- Prompted another question from the audience about the incidence of cyclones and what effect they might have on the mine site.

  Replied that the Jabiluka mine site was 50-60km as the crow flies from the coast and that generally any cyclone had lost much of its energy (wind strength) when it crossed the coast. I did say that there would certainly still be significant rainfall that many caused increase erosion within the catchments.

- John Jansen (University of Wollongong) made a comment that he had studied the hydrological record for gauging station 009 on the Magela and that there had not been any cyclones in the period of record. He also asked me about the root mat that I mentioned in the abstract and the organic layer associated with this layer.

  Firstly I was able to mention that the Jabiru area had been affected by the aftermath of Cyclone Max in 1981. I also said that the root mat appeared after large events which scoured out the bed but provided a protection for the material underneath. This root mat was generally covered by sand by the end of the wet season on the falling part of the hydrograph.

I have attended four ANZGG conferences and found them all very interesting, as there are a variety of speakers covering a broad range of geomorphic research. It is also a very good way to network with fellow geomorphologists and to be introduced to recent graduates.

No proceedings are produced from the conference, however, the power point presentation has been stored (paper and electronic) in the library. I will be presenting the presentation as part of the internal seminar series at the Supervising Scientist Division in 2003.

Part 2: Channel morphodynamics of a sand-bed stream in the seasonally wet tropics of Australia, Paper and Poster presented at International Association of Hydrological Sciences (IAHS) conference, Alice Springs, 2–6 September 2002

Abstract

The following is an abstract that was submitted for presentation at the International Association of Hydrological Sciences (IAHS) conference held in Alice Springs September 2002. The conference had a theme of "*The structure, function and management implications of fluvial sedimentary systems.* The paper was not accepted for an oral presentation however it was accepted for a poster session for which a four page paper was required. The paper was published in a supplementary booklet to the main conference proceedings.

Channel stability in a sand bed ephemeral stream in the seasonally wet tropics

MJ Saynor, WD Erskine & KG Evans

Swift Creek (Ngarradj) is a sand bed stream in Kakadu National Park, Northern Territory. The stream, located in the seasonally wet tropics, flows for approximately half of the year during and immediately after the wet season. In 1998, at three gauging stations along the stream, many permanently marked cross sections were installed to monitor the amount of bed sediment storage and/or large scale erosion throughout the channel network. These cross sections have been surveyed annually during each dry season since installation. These survey data provide information about the changes in sediment storage or loss that have occurred between each dry season. Between 1998 and 1999, aggradation of between 0.1 and 0.2 m occurred at each of the three sites but between 1999 and 2000, this sand level remained constant.

The sites are visited weekly during the wet season when the creeks are flowing to obtain hydrological and sediment load (suspended sediment and bedload) information. A velocity area gauging is completed at each of the reaches to construct a rating curve. The gauging cross sectional information is used to investigate the within wet season changes. Scour and fill of up to 0.6 m and a shifting thalweg have been identified. Maximum scour is limited by the exposure of a root mat material or a more resistant bed material layer at the sites.

In general, the between wet season changes are considerably smaller than the within wet season changes. Although there are large amounts of sand movement during the wet season, the stream system's channel cross sections return to pre-wet season profiles during recessional flow. This indicates that the stream channel cross sections usually reaches equilibrium on the flow recession.

Poster Paper: Channel morphodynamics of a sand-bed stream in the seasonally wet tropics of Australia

The following is a copy of the published poster paper for the IAHS conference in Alice Springs. The Bibliographic details are: Saynor MJ, Erskine WD, Evans KJ & Eliot I 2002. Channel morphodynamics of a sand-bed stream in the seasonally wet tropics of Australia. In *The Structure, Function and Management Implications of Fluvial Sedimentary Systems.* Compilers FJ Dyer, JM Olley & J Olley, Poster Report Booklet, International Association of Hydrological Sciences, Wallingford, 39–43.

Channel morphodynamics of a sand-bed stream in the seasonally wet tropics of Australia

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Introduction

Ngarradj is a sand-bed stream that flows through Kakadu National Park and the Jabiluka Mineral Lease, Northern Territory, Australia and debouches into the Magela Creek wetlands. Streamflows are seasonal during and immediately after the wet season from early December until about May. The Jabiluka uranium mine occupies approximately 19 hectares of the catchment and construction commenced in mid-1998. Mineral production has not started and the mine is currently in a care and maintenance phase. Erskine et al (2001) proposed a series of projects that the Environmental Research Institute of the Supervising Scientist should complete to not only determine baseline conditions but also any impacts that the mine might cause. An integral part of the various projects involved the establishment of three river gauging stations within the Ngarradj catchment both upstream and downstream of the mine late in 1998. This paper presents the results of weekly and annual channel cross section surveys and annual measurements of scour chains for the reach near the Swift Creek gauging station (catchment area of 44 km^2) which is downstream of the mine.

Methods

Fifty six permanently marked cross sections were installed throughout the Ngarradj channel network during the 1998 dry season both upstream and downstream of the mine and have been surveyed annually during each subsequent dry season. Eight of these cross sections were located in the Swift Creek gauging station reach and scour chains were also installed in the channel bed on three of these sections (Emmett 1965). The rationale for the scour chains is that they will show the maximum net scour and fill during each wet season (possible storage site for coarse-grained mine-derived contaminants) but do not provide any information on the timing of the events that cause the scour and fill. As part of weekly visits to download stream height data and to collect pumped water samples during the wet season, a velocity-area gauging was completed to construct rating curves. The gaugings are conducted at the same section each week and provide detailed information on short-term scour and fill.

Results

Mean bankfull discharge at eight cross sections between 1998 and 2001 in the gauge reach was 14.3 m^3/s and mean bankfull specific stream power was 8 W/m^2 (Saynor et al 2002). The average graphic mean size at the same sections between 1998 and 2001 was 0.91 ϕ or 0.53 mm (coarse sand on the Wentworth scale). The annual dry season surveys only detect changes in sediment storage between successive wet seasons. Figure 1 shows the changes in bed level for two cross sections for the period 1998 to 2001 at the Swift Creek gauge. All eight cross sections recorded a decrease in area since 1998 and mean depth decreased at six cross sections with the other two remaining stable (Saynor et al 2002). The net sand storage between 1998 and 2001 within the 150 m long gauge reach was 154 m^3 (51.3 m^3/y). This is much less than measured sand fluxes with a Helley-Smith pressure difference bedload sampler during each wet season.

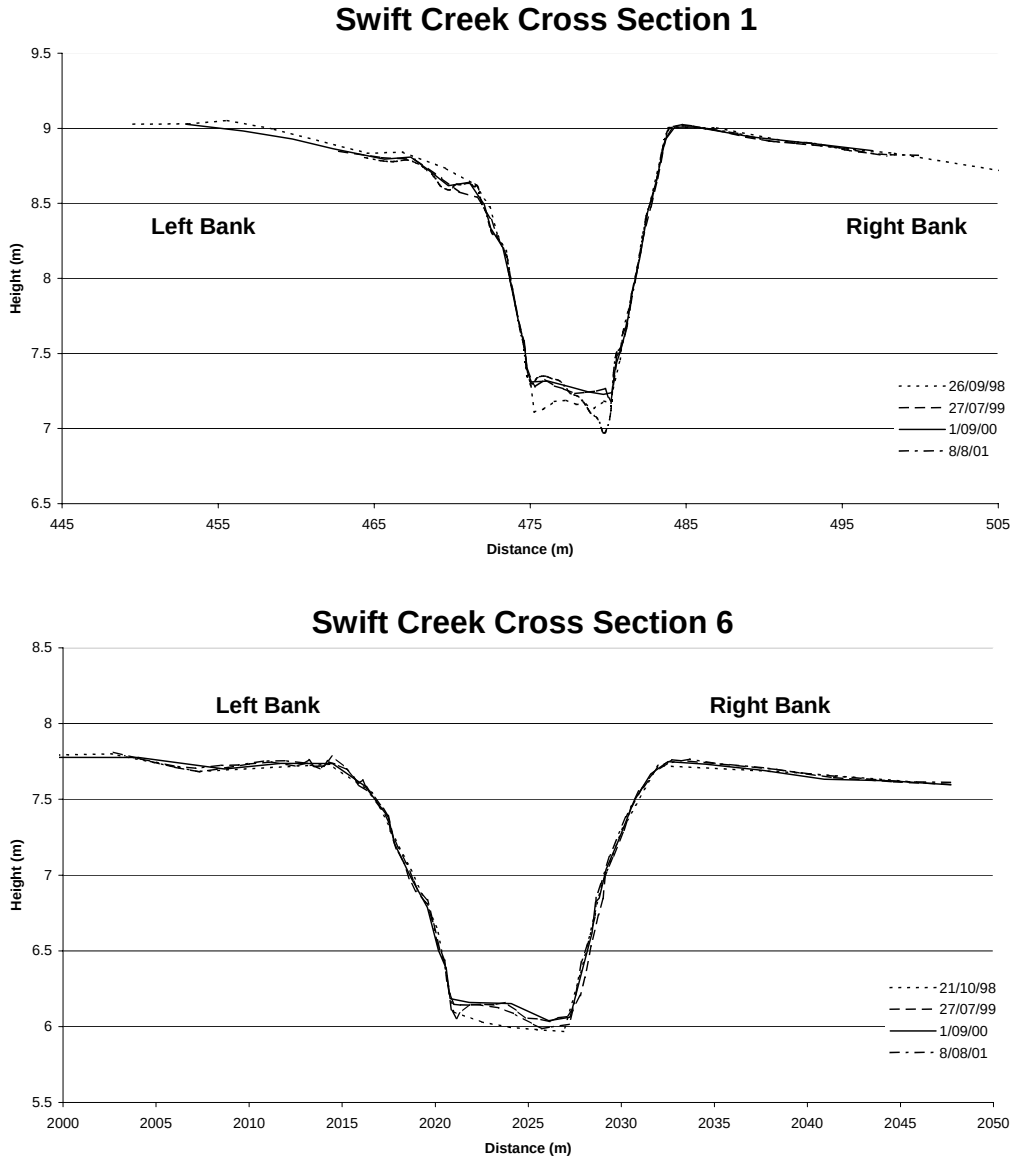

Figure 1. Channel changes between successive dry seasons at selected cross sections at the Swift Creek gauge

During the 1998/1999, 1999/2000 and 2000/2001 wet seasons the average scour was 311 ± 51mm, 272 ± 56 mm and 332 ± 93 mm, respectively. The average fill for the same wet seasons was 391 ± 43 mm, 295 ± 67 mm and 331 ± 102 mm. During the 1998/1999 wet season there was net fill of 80 mm and net fill of 27 mm during the 1999/2000 wet season. The 2000/2001 wet season exhibited no net change. These data confirm the cross section survey results that net aggradation occurred between 1998 and 2001. However, despite this net sand storage, the bed scoured to maximum depths of between 295 and 391 mm below the dry season bed level during each wet season. The net sand storage between 1998 and 2001 within the 150 m long gauge reach determined from the scour chains was 153 m^3 (51 m^3/y) and agrees closely with the cross section surveys.

The scour and fill throughout the 1998/1999 Wet season recorded at the gauge wire (cross section 6) is shown in Figure 2. Although the cross section variations are complex, there have been substantial short-term changes in bed level by individual flood events during the wet season. The maximum bed level during the weekly gaugings was 8.278 m on 26 January 1999. The minimum bed level of 7.523 m occurred during the morning of 3 February 1999. Interestingly, a second gauging was conducted in the afternoon of 3 February 1999 (Figure 3) and the minimum bed level had risen to 7.678 m or 0.155 m higher than in the morning. Both gaugings were completed on the recession after a large event (peak discharge of 20 .4 cumecs) and the rise in bed level later on the flood recession indicates that the bed material was probably scoured during the rising limb and peak of the hydrograph but substantial fill occurred on the recession. The maximum difference in bed level of 0.6 m during the 1998/1999 wet season at the gauge wire is nearly double the mean maximum scour.

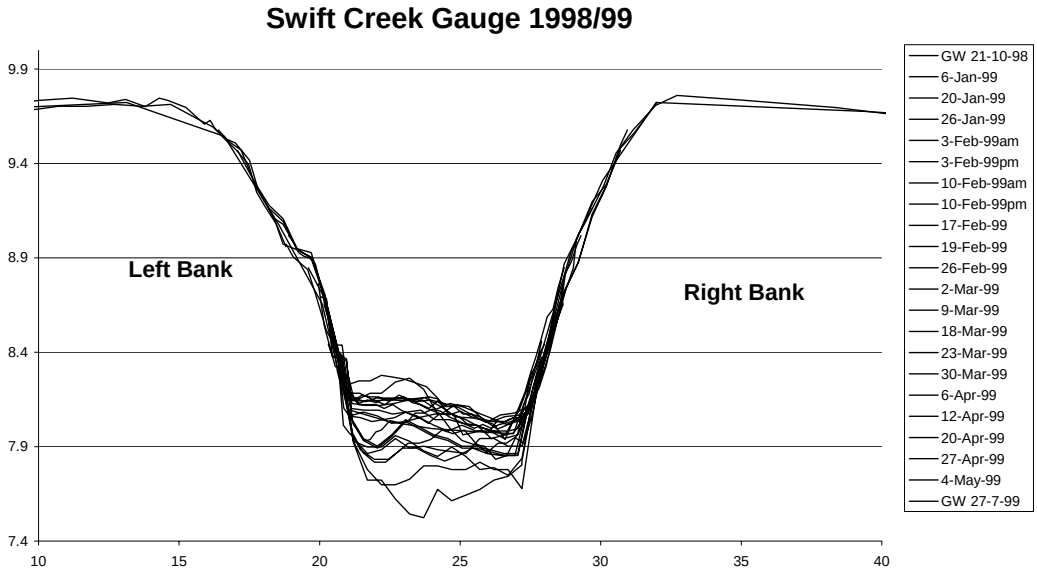

Figure 2 Scour and fill at cross section 6 at the Swift Creek gauge during the 1998/1999 wet season

With each individual flood event sand is scoured from the bed during the rising flood stage and transported in suspension. Then as the event recedes, the bed starts to fill by deposition of the temporarily suspended bed material.

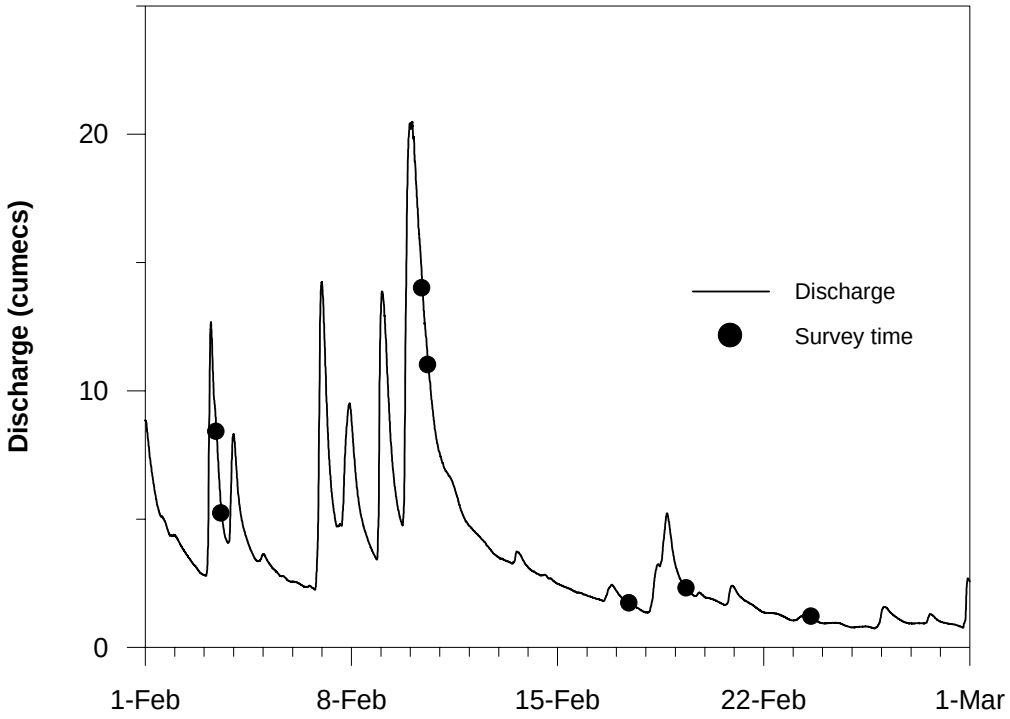

Figure 3 Hydrograph at the Swift Creek gauge during February 1999. The survey times refer to the velocity-area gaugings at the gauging wire (cross section 6).

Conclusions

Between wet season channel changes are considerably smaller than within wet season changes. The weekly wet season cross section surveys indicate a dynamic sand bed where large volumes of sand are moved but the annual cross section surveys indicate slow aggradation. The results from the other two gauging stations are currently being investigated but preliminary results indicate similar trends.

Acknowledgments

B Smith, E Crisp, G Fox, D Moliere are thanked for their help with the field work.

References

Emmett WW 1965. The Vigil network: methods of measurement and a sampling of data collected. *Representative and Experimental Areas*, Proceedings of the Budapest Symposium, Publ. No. 66, IAHS, Wallingford, 89–106.

Erskine WD, Saynor MJ, Evans KG & Boggs GS 2001. *Geomorphic research to determine the off-site impacts of the Jabiluka Mine on Swift (Ngarradj) Creek, Northern Territory*. Supervising Scientist Report 158, Supervising Scientist, Darwin.

Saynor MJ, Erskine WD, Smith BL, Fox GJ & Evans KG 2002. Cross sectional data and a preliminary assessment of channel changes in the Swift Creek (Ngarradj) catchment between 1998 and 2001. Internal Report 385, Supervising Scientist, Darwin. Unpublished paper.

A4 size version of the poster

Supervising Scientist

Channel morphodynamics of a sand-bed stream

Figure 1 Swift Creek catchment showing the location of

Swift Creek (Ngarradj) is a sand-bed stream that flows through Kakadu National Park and the Jabiluka Mineral Lease, Northern Territory (Fig 1), Australia and debouches into the Magela Creek wetlands. The Magela Creek and floodplain are listed as Wetlands of International Importance under the RAMSAR Convention and recognised under the World Heritage Convention. Streamflows are strongly seasonal and persist only during and immediately after the wet season from early December until about May (Fig 5). During the wet season, streamflows are highly variable with flood spikes superimposed on high baseflows (Figs 4 & 5). The Jabiluka uranium mine occupies approximately 19 hectares of the catchment and construction commenced in mid-1998. Mineral production has not started and the mine is currently in a care and maintenance phase.

The Environmental Research Institute of the Supervising Scientist (eriss) has initiated 13 projects to not only determine baseline conditions but also any impacts that the mine might cause. An integral part of the various projects involved the establishment of three river gauging stations (Fig 2 & 3) within the Swift Creek catchment both upstream and downstream of the mine late in 1998. This poster presents the results of weekly and annual channel cross section surveys and annual measurements of scour chains for the reach near the Swift Creek gauging station (catchment area of 44 km^2) which is downstream of the mine.

Figure 2 Suspended load and bedload gaugings at the Swift Creek gauging station. Average graphic mean size of bed

Figure 3 Swift Creek gauging station. Flow is at bankfull stage which is 14.3 cumecs and specific stream power is 8 W/m^2

Figure 4 Normal wet season flow (top) and bankfull

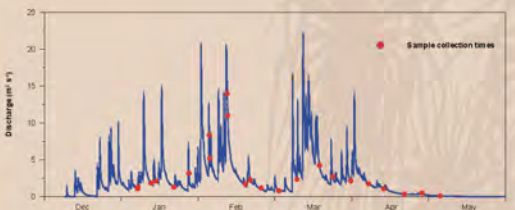

Figure 5 Hydrograph for the 1998-1999 wet season at the Swift Creek gauge. The survey times refer to the velocity-area gaugings at cross section 6. Streamflow has been measured

Figure 6 Scour chain excavated at cross section 8 at the Swift Creek gauge. Flow direction is from right to left. Average wet season scour is 0.30 m and average fill on wet season

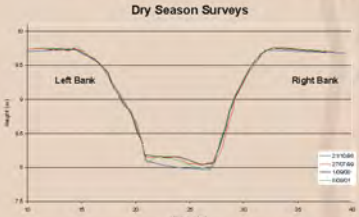

Figure 7 Annual surveys at cross section 6 (one of eight cross sections at each gauging station) showing 0.2 m of aggradation during the 1998/99 wet season. Aggradation was recorded at six of the eight cross sections at the Swift Creek gauge.

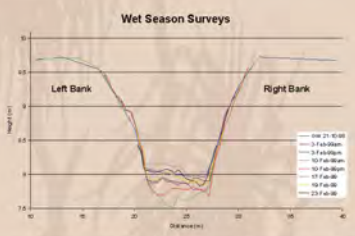

Figure 8 Scour and fill at cross section 6 at the Swift Creek gauge during February 1999. See figure 5 for the corresponding discharges and antecedent streamflow

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4. Division of Geography, School of Geosciences, University of Sydney, NSW 2006

Between wet season channel changes are considerably smaller than within wet season changes at the Swift Creek gauge. The weekly wet season cross section surveys during river gauging indicate a dynamic sand bed where large volumes of sand are moved but the annual cross section surveys and scour chains indicate slow aggradation. The results from the other two gauging stations are currently being investigated but preliminary results

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