Australian Rivers Institute

Sustainable solutions for rivers, coasts and catchments

Protecting the Great Barrier Reef from sediment pollution

Andrew Brooks, Jeff Shellberg, John Spencer, Jon Olley, Tim Pietsch, Daniel Borombovits, Christina Howley, Graeme Curwen, Fabio Iwashita

Reef & Rainforest





Smart Futures



Major drivers of coral cover decline in the **GBR**

- Climate change:
 - Ocean acidification
 - Bleaching
 - Cyclone (magnitude and frequency)
- Catchment runoff (water quality)
- Of these it is only really catchment runoff that we can do anything about in the short term

Crown of thorns (COTs) outbreaks are known to be driven by poor water quality (fine sediment & nutrients)



Even in the Northern GBR - off Cape York – which hasn't seen the same level of coral cover decline as the rest of the reef - it is likely there is a link between **COTs** outbreaks and catchment runoff







PRINCESS CHARLOTTE BAY REEFS - Feb 2013

Low density of starfish
Some starfish
Outbreak densities



PCB Flood Plume, Jan 2013



эээр июннанру





PRINCESS CHARLOTTE BAY REEFS - Feb 2013

Low density of starfish
Some starfish
Outbreak densities

Alluvial gully erosion like this is the major source of anthropogenic Sediment in Cape York



,1)//1, Griffith

We can now identify erosion hotspots and better prioritise management effort





4 Properties producing ~ 60% of all accelerated erosion;

1 property producing ~ 40% of all Susp. Sediment at catchment scale

50

km

There are two distinct forms of gully: hillslope and alluvial gullies



Hillslope Gullies

(e.g., upper catchments, typical of granitic upland areas)

• Generally found in steeper headwater and low order valleys

in a mix of colluvium & alluvium (significant coarse sediment component)

- Length >> width (due to lateral confinement / topographic control)
- Driven by concentrated overland flow and excess shear stress
- Accelerated by loss of vegetation cover / grazing pressure (direct disturbance + indirect alteration of rainfall/runoff relationship)
- Tend to be self-limiting according to slope/area threshold (+ available sediment on slopes)



Alluvial Gullies

- Gullies that occur exclusively in alluvial sediments (e.g., often > 80% silts and clays)
- Typically along flat floodplains / terraces of main stem channels of large rivers in tropical savannah landscapes
- Typically have well developed deep soil profiles (highly weathered since deposition)
- Highly connected source of suspended sediment
- Width = or > Length.....lack of lateral confinement
- Commonly initiated by cattle pads or roads/tracks across channel banks





Gully Management to date in the GBR

- To date the focus in catchments like the Burdekin has been on small scale management of relatively inactive hillslope gullies
- To date the major problem associated with alluvial gullies has yet to be addressed



Researchers in the Burdekin implementing gully rehabilitation trials in a hillslope gully



Gully expansion rates and initiation dates can be reconstructed from airphoto analysis



• Example from the West Normanby





West Normanby Alluvial Gully



Note the second phase of incision into the main gully (see next slide)

Secondary gully incision West Normanby

50

0

100

200

N

West Normanby



6.5

2.2

19.7

0

1.5

Repeat gully surveys Using LiDAR and GPS show the extent of erosion from year to year. Between 2011 & 2015 this gully extended around 5m per year

25

Ň

50

m ב

Gully Extention 2009-2011 2011-2015

2009 Lidar

Gully erosion acceleration/initiation can be linked to the arrival of cattle into the landscape





How do we reduce sediment from alluvial gullies?

- A characteristic of alluvial gullies is that they are triggered by cattle tracks or other disturbances like farm tracks – but once triggered they can't be stopped by simply removing the cattle or the original disturbance.
- We have to treat the soil to stabilise it.
- It is a process more akin to mine site rehabilitation rather than farm management

Managing highly active incipient (early stage) alluvial gullies is a cost effective way to avoid extensive future erosion – as well as halting current erosion



- This gully producing ~ 400t/yr
- Should be able to treat such a site for ~ \$20K (\$50/t – current erosion + >> future erosion avoided)



Intensive Active Gully Rehabilitation Trials – gully regrading After: Dec 2011

Before: Nov 2011





12-01-2011 15:28:38

(Jeff Shellberg)

Erosion Control Treatment Plots to test how best to stabilise the soils and address the root cause of the problem

- 1. No Treatment
- 2. Gypsum, Compost, Native Grass
- 3. Gypsum, Compost, Exotic Grass
- 4. Gypsum, Hydromulch, Exotic Grass
- 5. Gypsum Only
- 6. Compost, Native Grass
- 7. Straw, Exotic Grass

Reduce Water Runoff Into Gullies
 Stabilize Gully Head
 Reduce Slope of Gully Channel





Gully treatments - Crocodile Station alluvial gully experimental plots

Gully	Plot #	Treatment	Gypsum	Mulch	Grass			
CRGC1-29	1	Regrade Only	None	None	None			
CRGC1-29	2	Regrade, Gypsum, Compost, Native Grass	80t/ha	25mm surface compost	Native grass: Kangaroo (Themeda triandra), Black spear (Heteropogon contortus), Queensland bluegrass (Dichanthium sericeum) (180 kg/ha or 3.8 kg/210 m ²)			
CRGC1-29	3	Regrade, Gypsum, Compost, Exotic Grass	80t/ha	25mm surface compost	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta) (180 kg/ha or 3.8 kg/210 m ²)			
CRGC1-29	4	Regrade, Gypsum, Hydromulch, Exotic Grass	90t/ha	10mm surface hydromulch	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta), verano stylo (Stylosanthes hamata) (100 kg/ha or 2.1 kg/210 m ²)			
CRGC1-29	5	Regrade, Gypsum	80t/ha	None	None			
CRGC1-29	6	Regrade, Compost, Native Grass	None	25mm surface compost	Native grass: Kangaroo (Themeda triandra), Black spear (Heteropogon contortus), Queenslan bluegrass (Dichanthium sericeum) (180 kg/ha or 3.8 kg/210 m²)			
CRGC1-29	7	Regrade, Straw, Exotic Grass	None	25mm surface straw	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta) (180 kg/ha or 3.8 kg/210 m ²)			
CRGC60/61	8	Regrade Only	None	None	None			
CRGC60/61	9	Regrade, Straw, Exotic Grass	None	25mm surface straw	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta) (180 kg/ha or 1.4 kg/75 m²)			
CRGC60/61	10	Regrade, Gypsum	80t/ha	None	None			
CRGC60/61	11	Regrade, Gypsum, Compost, Exotic Grass	80t/ha	25mm surface straw	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta) (180 kg/ha or 1.4 kg/75 m ²)			
CRGC60/61	12	Regrade, Gypsum, Compost, Native Grass	80t/ha	25mm surface compost	Native grass: Kangaroo (Themeda triandra), Black spear (Heteropogon contortus), Queensl bluegrass (Dichanthium sericeum) (180 kg/ha or 1.4 kg/75 m ²)			
CRGC1-40	CRGC1-40	Regrade Headcut, Gypsum, Hydromulch, Exotic Grass, Wood Grade Control	80t/ha	10mm surface hydromulch	Exotic grass: Indian bluegrass (Bothriochloa pertusa), Saraji Sabi grass (Urochloa mosambicensis), Jap millet (Echinochloa esculenta), verano stylo (Stylosanthes hamata) (100 kg/ha or 2.1 kg/210 m²)			
CRGC1-32	CRGC1-32	No Treatment Control Headcut	None	None	None			
CRGC1-28	CRGC1-28	No Treatment Control Side-Wall	None	None	None			

Vegetation Changes..... After Two (2) Wet Seasons

1) Reduce Water Runoff Into Gullies 2) Stabilize Gully Head 3) Reduce Slope of Gully Channel



Erosion Changes..... After One (1) Wet Season

Reduce Water Runoff Into Gullies
 Stabilize Gully Head
 Reduce Slope of Gully Channel



Exotic Seed

(Jeff Shellberg

Native Seed

Exotic Seed



(Jeff Shellberg

Trial plots - July 2015 dry season (4 years post implementation)





Optimal treatment next to the regraded only treatment – CRGC29 July 2015. Regrade only site erosion rates (LHS) were higher than the control (do nothing). Plot on RHS of image has achieved a 75% reduction in sediment yield



Trial Cattle Exclusion Sites at River Frontage Gullies

- <u>Three (3) cattle exclusion sites (~5 ha each)</u>
 - West Normanby (frontage)
 - Granite Normanby (frontage)
 - Laura River (paddock)

Vegetation Monitoring

- 50 plots (4 m²) at each exclusion area
- Control plots outside, treatment inside
- % cover, species, biomass, tussocks, weeds

Erosion Monitoring

- LiDAR Topography 2009, 2011...2020?
- Plot scale erosion depth
- Plot soil condition

• <u>Timeline</u>

- Before Fence: Nov 2011, April 2012
- After Fence: Nov 2012, April 2013
- Repeat yearly or in 2020

(Jeff Shellberg

<u>Reduce Water Runoff Into Gullies</u>
 <u>Stabilize Gully Head</u>
 Reduce Slope of Gully Channel

West Normanby River Frontage





Alluvial gully management: passive approach – cattle exclusion: How long will it take to see a significant sediment reduction (return on investment)?

Inside exclusion after 4 years

Inside exclusion after 4 years

outside exclusion

Cattle Exclusion Trials

Will Grass Vegetation Recover and Reduce Erosion if Cattle Are Excluded for 10-20 Years? 1) Reduce Water Runoff Into Gullies 2) Stabilize Gully Head

3) Reduce Slope of Gully Channel



- Fence Cattle from River Frontage
- Rely on Natural Resilience of Vegetation
- Monitor Erosion Reduction Over Time?







The Bowen River

- The Bowen River is a major tributary to the Burdekin River which enters downstream of the Burdekin Falls dam
- It has been identified via sediment tracing and loads monitoring as contributing the greatest sediment load to the GBR.
- The Bowen River is dominated by Alluvial Gullies
- If sediment loads to the GBR are to be reduced sediment yields from alluvial gully erosion have to be significantly reduced

Proportion of the Sediment to the GBR from the Bowen & Bogie Rivers

Burdekin Sediment Budget 2005-2009	load % breakdown by particle size				av loads (Mt/yr: 2005-2009)				
	clay	silt	sand	total	clay	silt	sand	total	% of total at outlet
Burdekin R (below dam)	52%	41%	6%	100%	1.32	1.05	0.15	2.52	30%
Bowen R (@ Myuna)	27%	49%	24%	100%	1.02	1.84	0.90	3.76	45%
Lower Bowen/Burdekin ungauged tribs include: Oaky Ck, Pelican Ck, Lower Bowen R; Bogie R) Lower Burdekin @	36%	38%	25%	100%	0.79	0.83	0.55	2.16	26%
Inkerman (catchment	37%	11%	10%	100%	3 10	3 71	1.60	8 //	100%
ouner	5770	4470	1770	10070	5.12	5.71	1.00	0.44	100 %
Bowen + Lwr Bowen & tribs +BogieR	30%	45%	25%	100%	1.80	2.67	1.45	5.92	70%
% of total at outlet				$\boldsymbol{\zeta}$	58%	72%	91%	70%	
Data agunag. Daimhridea at al ((2014) 14	latar Daar							

Data source: Bainbridge et al., (2014) Water Resources Research

Burdekin River TSS loads is estimated to represent 47% of input to whole GBR (Water et al. 2013); hence – Bowen/Bogie inputs represent ~ 30% of the silt/clay input to the entire GBR The alluvial floodplain/terrace system (blue/pink area) on the lower part of the Bowen River contains extensive alluvial gully complexes.





Examples of Bowen River Alluvial Gullies





Preliminary mapping along the lower Bowen R shows there are ~ 2000 ha of highly active gullies



Highly concentrated area of large alluvial gullies along Parrot Creek



Note yellow scale bar is 1km – mapped gullies in this image range in size from a ~1 to 30 ha

Highly Active Alluvial Gullies in the Bowen Catchment

Attempted regrading of gully head without any additional soil treatment; this has been shown to increase erosion rates above background rates in erosion trials

Active alluvial gully complex showing remnant pedestals with trees atop. Gravel like lag on the gully floor are predominantly calcrete nodules which accrete from within the soil profile as part of the gully erosion process

> Arrow indicates approx. photo location

Arrow indicates approx. photo location Ann Fab. 1 70: 1 Nexues the Balance biologic biologic and be growed Hop propin Stationers and Stationers United Station Hosping Balance Stationers

> Early stage alluvial gully erosion – Terrible Creek area Bowen River

Highly active early stage alluvial gully erosion – Terrible Creek area Bowen River Depression in foreground is a sinkhole connected to the main gully via funnel erosion

Highly active early stage alluvial gully erosion – Terrible Creek area Bowen River.



Well developed alluvial gully complex -Strathmore – note extensive tunnel erosion



Incipient alluvial gully in the adjacent palaeo-swale to the gully shown in the previous slide

ian | yap | yau | Maasar ba kalanin korani sa putu a Bryanat Majangti 30,20 <mark>anim binantangti 50,20 anim maggi 10,20 binat</mark>

Incipient alluvial gully - Blue Valley area; gully is eroding into the margins of the alluvial terrace (assumed to be Pleistocene age)

Arrow indicates approx. photo location



The solution for the Reef

- Sediment loads to the reef will only be reduced if there is a major investment in the management of alluvial gullies
- Most other sources pale into insignificance compared to this issue.
- The good news though is that with the appropriate expertise, resources and focused effort – significant results can be achieved on relatively short timeframes (e.g. < 10 years) within the existing resources



Further work

- There is a diversity of alluvial gully forms, and more research is required to identify the key characteristics of the soil chemistry and other drivers which lead to such diversity of form, and hence rehabilitation requirements.
- In the Bowen catchment, the initial evidence is compelling that alluvial gullies are indeed the dominant source of sediment to the Bowen River and the whole GBR lagoon. However, precision mapping along the lines of that undertaken in the Normanby is required in this catchment to confirm this.
- Given this, it should be a priority to collect high resolution LiDAR data in the Burdekin catchment to enable us to quantify the relative distribution of hillslope and alluvial gullies and their respective sediment contribution, and to help prioritize rehabilitation.



Guily empior into active river fixedplains and tensors indict floodplains) in roothern Austania effects inter health and equats the industries, infrastructure, and indigenous cultural activities. As they words notes and sergerc galles are made the last annuality for particul and agricultural cas. They also are yubilized and noticets from for default interact, work, given, gargenes, estanders and access calleding a quick filled and their lasted.

TRACK has studied the causes and impacts of gally motion from alterial sols, which is widespread across northern Australia, and recommends changes to land management. Options for reliabilitating and protecting affected land an provided in this sum many and an associated report.

Anot allowed gallies their directly into sea to cherry.

shiftenses and eventually settle in mens astwarter, and coastal waters, forme altorial galles drain away

from main overs and deposit sediment into local

connects and lagoons.

which can delives and investigated and publicity long

Key findings

- Allegal gally emport represents a rules threat to oparise and equality benciscapes in northern Antidia
- Butchean land use practices have accelerated the instation and providi of allivial guilles.
- Pervalorginative grace regulation analysisting self surface defaultance are the mod important defences against shares guily-excelon.
- Charges to cattle grazing practices can prevent allovial gally forwatton and epitote average rates.
- In areas of strategic and caltural importance. rehabilitation tools need to be further developed to determine the best parallel or direct laphagical chemical, and physical methods for reducing results made it has begun

What is allustal gully ecosional

NETH SCHERCE PROCEEDING AND UNKER DRVF Jarti Sol. Phi an Landboom (2015 Convente & 1011 Infor Witte & Inst. Uni Published orders in Miles Collins Like section/department (COP, 10, 1000Acop, 1719)

Modelling suspended sediment concentration and load in a transport-limited alluvial gully in northern Queensland, Australia

Calvin H. Roon," Jolley C. Meilling and Antone P. Rennin

and is deal 120 in Recent of Ashengia (2012) Ashend Probusing 2015 managements (1991) 40 Nov. Rose 218, Bulling VII, 177 Januar, Raal, Yuman Queenslum, 1111, Aurula, Fringl. 1 worksy 494-00



ARTAICT . Allocid galles are ober formed to dispective outs along steep hashs of rectord two charents. Pedd data collected by Shilling of al abort Sacker Process and Andrews III. 1761–1776, 2015. Inter a guly called in undere standals physical little humanic between scales discharge and free

inited rather than expression bed conditions. The major a manys, and the coarses trained unsequent was been ed by cite, a new method who developed for conducting the set extensis the average witting velocity of the total aspendic siletied during fload conditions. These setting selects Book (Make Amounty Research 20, 217-218, 315-218, At a cross-section, signifies of the complexity of transpor-tanic and bed section, offse distanted amou. The acceptor preser (F = 1.32% that is effective in ai-aimsining solition basis from other allocked gallon in the region with and

factors for sequenced site Δ_{a} or three and shall β_{a} concernations. Only basic field data on setting vehicle characteristications of samples, if were taken and durings, and associated areas margins an marked for transport limit theory predictions of economical or old and. This Benny is might than that sequend is an an infinited strations. Caparight \$2,3175 (sho billing & bern, 12)

Bracks at al. 2009. Skelling and Reeds, 2022; prints and

with the highest eccipion once need to be targeted for initial actions. Guile distribution data (Renée et al., 2009) Brooks

at al. 2022), ampleto al galla sension and sufficient hast that

Hardbarg et al., 2011a, 2010g and net gally motion from spear 12048 light detection and ranging data division et al. 2010, can help observe agent seein, but an ability to result

editions pields have the weighty distillated galline reads also

Viciefling poly evolutions, prevenue and metabors have

Schenchole, 1999; Kittley et al., 2003; Kittley and Boatkee

and Malley 1948. Econols, 1950, Eugendal, 1966, 1968.

ophind and Harsen, 1967: Still amager motion aller he

ers developed to describe retains rate and processes, the

upping distribution of unit evolver, and waterlashingst yield is g. Hairstw. and Rose, 1992a. 1992b; Hensel and vari Auch.

2007b latter of al. 2003b Table of al. 2007b Mergan and

in cases channed from piecessing respect long, taken

ord substantial attention mig. Bull and Minister, 1989

ant instagent mobile have been developed

and management decisions.

NETO MANY MORE

BYWERDS allocatight search making convolution/metric provided to provide the setting which, must provide the set

Introduction

Shaid polity interpret incoments and of the land place or twince for more decades once initized on men tor hado Reolo et al. 2009, Stelling, 2011; Sofberg unul. 2015a. 2019bi Land and Instants with an other general out determine and mathems constantion have represent the estation of all acid gallies and according their safe, of erates is nothern Austalia Shellberg at al. 2010. Shelberg 211 Dellerg and Burls, 2013, Altared publing tax or ert and active vipulation will little a non-productive wateriant at propriated to the task specie, so has been appreciated on the set of instituted performal of the basis cape, degrades natural does and awa, and delivery large quartities of suffront to their systems ori mantal analmentariti dinatia et al. 2009 Routoriti at a Catcheory et al., 2012; Shelling and Imagin, 1012; Shellberg at al. 2011a, 2017a.

Provening puts to the start of additional parts in product by school guides are bey load manapered priorities -Disilipart and Boscie, 2011). Measured the Wilmond building

IAETH SURFACE PROCEEDIS AND LANDFORMS Earth Saint, Process, Landkovek (2013) Copyright @ 2013 July: Wiley A how, 141 Published rolling in Wiley Chilling Library belimenhashing core DOV 10 http://www.bala

Sediment production and yield from an alluvial gully in northern Queensland, Australia

Jeffrey G. Shelberg,* Andrew P. Breoks and Cabin W. Rose Austalian Shers Indhes Grifith University Nation Owersland, Austalia

Research 11 Memory 2012 Reveal # February 2010 Account 21 February 2013

Composition to select building Scint 1 No. Soling X11. Yill Insult Real Yorkey, (Secondard, 277). Autoria: Local John Deepley Real and



ABSTRACT: Sediment production, transport and yield were quantified over various threader in response to sainfall and name within an allowial gally (2: 8 hat, which repoles into dispendite soils, soils of a small fixedpiters calcherent (33 hat along the Mitchell Riser, earliers Australia. Historical air photographs and recent global proliforing system (CPS) surveys and UDAR data documented linear increases in gally area and volume, indicating that addiment supply has been relatively consistent over the historic period Daily time base photography of scarp reteat rate and internal environ processes also demonstrated that environ terminal and rurol8 consideritly applied fine workload is, 63 µm underent is additor to count lags of send but material. Empirical measurements of asspended andment yields (89 to 363 ybayd) were high to both Australian and world data. Total sediment yield entimated from empirical washiowf and theoretical bed material load was dominated by the workload (-c.h.) and. A lack of hyderesis in sugrended sedment ruling curves, scarp retreat and rediment yield considered to - Anited conditions unerseled thread

INDECLOCICAL PROCESSES Model Frances (2012) Published on feas in Wiley Online Littrary Information Instrument DOC 18 (1823);p35300

The hydrogeomorphic influences on alluvial gully erosion along the Mitchell River fluvial megafan

J. G. Shellberg,* A. P. Brooks, J. Sponcer and D. Ward Associate Rivers Section, Griffith Electronic, Nathan, Questialand 4117, Aurosta

Abstract

Hydrogenetrytic processes influencing allocid guby enroise were evolueted as indigite spatial and temperatively and and temperatively and and temperatively and temperative influtation-cocces randil, soli-scare integral, river backware and southack flood interfactors. The frequency of river flood institution of allocal paths, shared to pay dependently, according to true motion and confinement. New the true of the regulars, flood scare scare, contained writers for scare dependent and scale according to the flood scare scare. insubated adjusted galline ending into Perspective adversars, he determiness blobs are floodplates, manufaction of adversal pather summed beyond the 5-to 5-pare ensemble and an environment applications are seen and ensines. However, note pathe scarge enseme at all converses down by above tradidly and addresso-records mucht, with the 34-bit entitled tradit bring the root productive variable. The remaining variability can be explosited by seasonal segurative conditions, complex spects of soft working and dying, tension stuck development, new surface permosate pressure, and black softenancing, from specifier and evolution Row, and not property hetergeneity, lequinations for granting management impacts on out surface and processing grant methodes include effects on device raisfull environ, water includings, raiseff volume, water concentration along tacks, and the nisance of highly dispersible soils to golly initiation or propagation under intense impical rateful. Oppright © 2012 John Wiley & Sons, 1 to

ner winen allorid gally arning. Rodging conscients randal insise, iallrable-crass multi-arnite science phaling wataperent

Received 13 July 2003: Accepted 2 February 2012

Alluvial Gully Erosion: A Dominant Erosion Process Across Tropical Coastal Knowledge Northern Australia Shellberg¹, A. firnoks² lovember, 2012

¹Griffith University, Australian Rivers Institute



CARTIN NUMPACE DROCKSING AND LANDPORE Jash Saf, Prent Lardovet 14, 1922 - 1903 (2008 opengis in anim julie whey a non, usi abilitied online in Wiley premichence (where stamptoten adaption) (SCE '7) 2000aug 1000

Special Issue

ict suspended and

2) Seber quintfy

Engyright @ 2011

of allocal rulls al, 2008, 2009,

Calcheon et al.

ets and theoretical

these gallies lives

t height for the

to where alloyid

pully enouble tates

chevent along the

breen for detailed

this remeatch were

er nanoff, (2) set-

and (I) technical

tines devenuales in

located in remote

167, 143-46365

ational data.

(Index)

Alluvial gully erosion: an example from the Mitchell fluvial megafan, Queensland, Australia A. P. Brooks,* J. G. Shellberg, J. Kright and J. Spencer

petallan Ryon Iratium, Orlinh Uniternity, Nathari Oceaniand, Apenilia

Rentand 17 July 1000 Barried 19 December 2006 Accessed 2 July 2005

Companies of Native Roads, Native Vent Vents, Cellin University Native Discovery (11), Autoral Annual Native Wildow, p.



ABVIOCT: Considerable amongsture has been becaused on the role of gallon as a contributor to concorrepting underset back of rives to Australia. In southere Australia rapid acceleration of Mildops gally ensuine has here withly deconterent in the post-functional partial (+-last 200 point). In the northern Australian seques, however, gally ensuin-processe operating along allucial plans have not been well decomposed and can alifer submarkable lever from pullars making into rollwaran on bubliques. New recompliances surveys in 2004 along 13.500 km of the main new new that men into the Call of Carpuntata (CaC), sterrified mersion amas til allasial tarati cha favos favos impacted by a personio fore of golfy enviros. Atom detailed enviros serving haved reagging within the 31000 km² Mitchell River favolal regular has identified that active galfying into allovium exceptio

- webtient hadget, where wearing

wild gallies are concentrated along train drainage character and their new disc floodplate and riser shalway. While new incluion into the immula he emilier, inter factory such in floodplate trybology, and colligation. In this paper we present a conceptual model of altavial The parties, in this paper we parent a conceptual model to during their in the community of paper by them that have here discribed in this way this here all advised pallying care only be gained when they are by models and theories. We present evidence of type mamples of it distribution and morphology at different scalar, highlight scree of rams and chicing their expansion. Copyright © 2009 (afm Wiley &

See: http://www.track.org.au/showcase/alluvial-gully-erosion http://www.capeyorkwaterquality.info/

hmakaways from locations amanal the worki (USA: ilitian 1986; Pape et al., 1975; Thomas et al., 2004; Australia Simmon and Doubh, 1977: Condon, 1986: Holson, 1981-Pringle et al., 2006; Bando et al., 2008; 2009, McClosken, 2010; Europe: Porson, 1993; Vandekarokhovor et al., 2008. 2001, 2000; Africa: Ontwood Wijdanes and Bryon, 2001; India: Singh and Datesy 2000, Yadav and Bheehan, 2002). Altorial guily initiation and evolution can spot large spatial and temporal scales in disadplain environments from small arthropogenically enhanced allovial gallies te.g. Vandeken/khove at al., 2001, 2003) to large alloyial

Composition to 1.0. Oxflorg Building 513, 1156, 178 Roosts Real, Nation, Question 4111, Austrilia, E-mult_intelligently (Handware

Capitals 0.202 Main Wite A.Son, Lid.

motion on a 'catchevent controlled' alloved guily but did not antify hydrologic processes at 'han-level controlled pilles along floodplain strum. Allovial 'back gallan' in Spain are driven by nantali-ranoff processes orhanized by agriculture activities (Classwood Wijdenes et al., 2000 Windenes et al., 2000: Vandekeethboor et al., 2009, 2004. 2007). In Tadia, allovial nations and gallies are inflammed by surface watermeno? from spricultural land (Haigh, 1998; Yalay and Bhashan, 2003, tassiel stocket and groundwater epage (Sharma, 1987) and river backwater charing flood (Singh and Dubey, 200): Yades and Blanhan, 2002). Fee allovial golly gravies in northern Australia, preliminary observations by Brooks et col. (2009) suggested that hydrological mechanism influencing gally mittation or propagation could opin the full continuous of surface inc abourface environ rendols (Florion, 1933; Kithby and

Introduction

Considerable immut has been expressed meanth immune land and water metatric development (e.g. impaid agrical-tics, markanic water transfer, winning thereave particular the property severes landscapes of restainty Assesses in p Ossidant, 1965; Wainstein and Diswart, 1987; Yuains, 2007 Carolinist al., 2007 Chapterel and White, 2007). This interest has meetinand slop-lic severe occurring and technical chair impro in g. Davidson, 1963, 1969; Haum, 1978; Baireali in el., 1983; Wolmanik and Davison, 1997), which are a partial mult of the significant limitations reported by the natural climate, hydrology, geometryliology, softe, and location of the regime targ. Diameteon, 1965, 1965. Swelly et al., 1965. Performer set al., 2008. To date, this regime has experienced solatively low levels of agricultural and arban slevelopmen remained with temperaturant sub-terpts al reporter of Assimilia. thrunding the externs land uses Abertytnal land a and exhand management, softle gazing, allorial and hard rock mining, commercial and menation failing, itserver, his-

dischere construction. As a consequence, these has been levind countly ensure to apport both how and make and ensuring appar-by of the lambaups to apport both human and ensuring demands. In readless Aparalia, the extent to which coment and past land any has had an impact on encoder takes and automent hands within the regions instructive their systems has not have fully analysed, article the instructive research or southern Australian sedences loads over little log, gody and valley kill instances typing, 72771 trying and Directory, 1998. Fairing, 1993; Wesser et al., 2007; Diles and Wesser, 2003) to anythere Australia, gully emotion has been telestified as a daminant solverer source in many regions (Oho) and History, 2003. Presser et al., 2001, heatly constraining up to \$7% of the total articles would and demonstrating maps becaused rates of activity lorder of magnitude or most in the prot-Fortproter period to g. Oley and Wossen, 2001. Western adheses laurget modelling in worthern Australia produced a dependence of hithloge softees resolve sources to satures lenderappes Presser et al. 2001; However, field haved instead and monitoring studios suggest telesive coveriantians of sub-