Proceedings of the

NSW Fisheries

Floodgate Design & Modification Workshop

Ballina, Northern NSW

August 14th 2002

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Executive Summary

NSW Fisheries, with funding support from NSW Agriculture, held a one day workshop at the Richmond Room in Ballina on August 14th 2002, to examine the pros and cons of the different styles of floodgates and associated modifications available to land managers.

The workshop brought together a range of over 50 attendees including agency staff, local government representatives, landholders, industry representatives, researchers, floodgate designers and manufacturers. These included representatives from NSW Fisheries, NSW Agriculture, Department of Land & Water Conservation, National Parks & Wildlife Service, Queensland Department of Primary Industries, Sydney Olympic Park Authority, University of Wollongong, University of New South Wales, Wetland Care Australia, Manly Hydraulics Laboratory, Cane Growers Associations, NSW Sugar Milling Cooperative, Kempsey Shire Council, Nambucca Shire Council, Clarence River County Council, Richmond River County Council, Tweed Shire Council, Macleay Acid Sulfate Soil Local Action Group, Rabbit Plastics, Australian Aqua Services, Waterman Australia, Batescrew and a large number of dedicated landholders.

A range of various floodgate designs were presented by the manufacturers or those land managers that had extensive experience in using a particular style. The advantages and disadvantages of each type was highlighted and then discussed by the workshop participants. This teased out any particular situations where one type of floodgate may be more applicable than others, in addition to providing other relevant details such as the history of operational performance, costings, OH & S and maintenance issues. A general discussion followed the presentations of additional floodgate issues, which were then identified and posed to the workshop participants.

The workshop also provided a tremendous opportunity to 'calibrate' floodgate stakeholders level of knowledge and understanding of floodgated systems. Combined with opportunities for networking with folks from a diverse range of backgrounds, the day was a great success.

Some of the key findings and recommendations from the workshop included the following points:

- Floodgates are a key component in floodplain natural resource management, however a whole-of-system approach incorporating active floodgate management may be of additional benefit,

- There are an increasing number of floodgate styles and modifications available to natural resource managers. The suitability of each type for any particular location needs to be determined on a case-by-case basis.

- There is a need for more integration of stakeholders (farmers, engineers, agency staff, local government) knowledge in selecting the most appropriate style of floodgate and / or modification for a particular system.

- Automatic styles of floodgate (including tidally operated structures) which rely less on manual intervention to operate are being installed in a number of locations. These are able to maximise water flow through the system without compromising landholders agricultural needs, by minimising the time otherwise required in operating floodgates manually.

- Short term funding in natural resource management can lead to focus on short term environmental outcomes, without maximising the potential for on-going solutions.

2. Workshop Introduction

Floodgates traditionally operate passively as 'one-way' structures by draining water from land on the upstream side and excluding tidal ingress from downstream.

When the water level behind the floodgate (upstream) is higher than that of the water in front of it (downstream), the gate opens and upstream water is discharged. Water at the same level either side of the floodgate, or higher on the downstream side, causes the floodgate to close thus restricting the movement of water upstream. Floodgates also prevent backflooding that could otherwise occur as a result of rain induced rises on the main river system.

Floodgates on the north coast of NSW date back to the late 19th century, with a large number installed through flood mitigation works after major floods in the 1950's and again through the 1970's. These were mostly funded by Federal : State : Local Government in the ratio of 2 : 2 : 1.

In the catchments on the north coast, local Council's own and manage (maintain) the majority of floodgates within the flood mitigation systems. Many more privately owned floodgates are located on private drains over the floodplains and are managed by Drainage Unions or individual landholders. The majority of floodgates are designed with a top hinged flap that seals against a vertical face. The flaps are made from various materials including wood, steel, fibreglass and aluminium.

Floodgate structures are a dominant feature of NSW coastal floodplain landscapes. They exclude tidal flows, primarily preventing brackish or saline water inundation of land, and prevent backflooding that could otherwise occur from rises on the main river system. However the negative impacts of floodgate structures on ecosystems have been shown to include:

- Restriction of fish passage,
- Drying out of wetlands,
- Proliferation of weed species,
- Reduction in drought proof pasture refuges,
- Exposure to air of acid sulfate soils,
- Reduced water quality.

This workshop, held on 14th August 2002, was initiated by NSW Fisheries with funding support from NSW Agriculture. Its purpose was to examine and review the available styles of floodgate and associated modifications. The pros and cons of a range of designs were presented, which are further reproduced in this document.

The workshop was conducted as a series of short (ten minute) presentations with an additional ten minutes of question time at the end of each. Each presentation looked at one of the available styles of floodgate / modification or addressed other relevant facets of floodgate management. The workshop concluded with an hour long general discussion of key topics and provoked some thoughtful insights into the floodgate management process. A copy of the day's agenda is shown below:

Time	Presenter	Organisation	Topic
845	All		Arrival / Coffee
900	Simon Walsh	NSW Fisheries	Welcome / Aims / Structure
905	Pat Dwyer	NSW Fisheries	NSW Fisheries Legislation overview
910	Simon Walsh	NSW Fisheries	North Coast Floodgate project
920	Bob Smith	Wetland Care Australia	Floodgate evolution - overview
930	Rob Lloyd	Clarence River County Council	Winches - Clarence
950	Michael Wood	Richmond River County Council	Sluices - Richmond
1010	Ivan Sillitoe	MASSLAG	Macleay ASS Land Action Group
1030	All		Morning tea
1050	Peter Wall	Floodgate designer	Liquid levelling apparatus
1110	Greg Breckell / Alan Cibilic	Floodgate designer / DLWC	Tidal operated floodgates
1130	Steve Posselt	Floodgate designer	Waterman floodgate
1150	Dr Ben McDonald	Uni. of NSW	Saltshaker floodgate
1210	Mathew Johnston	Qld. Dept. of Primary Industries	Side hinged floodgates
1230	William Glamore	Uni. of Wollongong	Automatic Smartgate
1250	All		Lunch
1330	Andrew Bruce	NSW Fisheries	Research - Fish passage
1350	Scott Johnston	Dept. of Agriculture	Hydrology - ASS implications
1410	Peter Haskins	DLWC	OH & S issues / DLWC perspective
1430	Alan Cibilic	DLWC	Hotspot Program

1450	Craig Copeland	NSW Fisheries	Afternoon tea / Discussion
1620	Simon Walsh	NSW Fisheries	Conclusion / Acknowledgements

3. Legislation Overview

Increased Coordination of Floodplain Legislation

Pat Dwyer (NSW Fisheries)

Legislation provides a framework for what we do and how we do it.

Previously contradictory aims of legislation associated with floodplain works limited the ability to:

- Adequately consider impacts of certain works, and
- operate in a coordinated and holistic manner.

In this talk I discuss those pieces of legislation and the legislation that have recently replaced them.

I will highlight how with an improved framework landholders and administrators are better able to work together to achieve sustainable outcomes for the floodplain.

The first piece of fisheries legislation for NSW was gazetted in 1865. It contained a provision that waters not be stalled.

Stalling was a very effective, although inefficient method of fishing whereby a net, brushwood or other structure was placed across a bay, inlet or creek at high tide. At low tide the fisher would collect the stranded fish.

Evidence to a Parliamentary Inquiry that was conducted in the early 1860s and ultimately recommended the preparation of the Fisheries Act 1865 had highlighted that many species of fish moved into wetland habitats to feed or breed. It was felt that a provision that waters not be stalled would protect not so much the fish but the developing fisheries in NSW.

This provision continued to be relevant and made it into the 1935 *Fisheries and Oyster Farms Act*. And in 1979 a penalty of $200 was imposed.

Another provision in the 1935 Act required fishways to be provided in the construction of dams and weirs etc.

While these sections would cover floodplain works s29 - stalling of waters, exempts anyone who is acting under this or any other act.

Several acts:

- the *Water Act* 1912;

- the *Drainage Act* 1939; and
- the *Rivers and Foreshore Improvement Act* 1948

Contradicted the *Fisheries and Oyster Farms Act* and actively encouraged drainage of floodplains.

The *Fisheries Management Act* 1994, which is still in place replaced the *Fisheries and Oyster Farms Act* 1935.

Several sections are relevant to floodplain management.

Section 218 provides the Minister for Fisheries an opportunity to require structures that impede the passage of fish be modified to minimise their impact on fish when they are altered.

A requirement is placed on public authorities to notify the Minister of their intention to undertake such works.

Section 219 is very clear with regard to obligations for those who propose to construct or alter a floodgate. A permit from NSW Fisheries must be sought.

Those acts that 'contradicted' the aims of the *Fisheries Management Act* have been progressively repealed and incorporated into the *Water Management Act* 2000.

Sustainable use of resources and the consideration of those resources in a holistic manner now form a central tenet of both the *Water Management Act* and the *Fisheries Management Act*.

The *Water Management Act* also provides for the development plans that consider drainage and floodplain management issues such as:

- existing and natural hydrological regimes;
- identification of existing drainage works in the area;
- ecological impacts and impacts on water quality, including cumulative impacts, of drainage works in the area.

While I'm sure we'll all wait with interest to see how these plans develop at least we now share a common objective - sustainability and have a framework for improving our management of the floodplain, having considered ecological, economic and social needs of the floodplain.

NSW Fisheries Legislation:

NSW Fisheries has management responsibilities in regard to fish and fish habitat because of the legislative provisions contained in the *Fisheries Management Act 1994, Marine Parks Act 1997* and the *Fisheries Amendment Act 1997*. Activities such as the regulation of water flows, the erection of physical barriers such as dams and weirs, the construction of river and estuary management works, and dredging and reclamation are of particular concern because of the potential loss of fish habitat and resultant decrease in fish for the whole community.

Under the *Fisheries Management Act 1994*, the Minister for Fisheries may require a person or a public authority to provide fish passage, through some form of fishway, if they alter, modify or construct a dam, weir or floodgate. Therefore, any proposal that requires construction, modification or alteration, which requires some approval process by a public authority (including local government) must be referred to NSW Fisheries for determination.

As works associated with floodgates may cover a variety of activities from cleaning to complete replacement, the following guidelines have been developed to guide managers of floodgates:

1. The following activities will require notification to the Minister for Fisheries before any works are carried out:

   1.1 All floodgates which have gradually deteriorated (such that fish are able to pass through them) and are proposed for repair.

   1.2 All floodgates proposed for repair on creeks, rivers or other natural waterway.

   1.3 All floodgates which currently exclude fish but which require major on site works (eg. as might occur with road upgrading).

   1.4 Any new floodgates (or other construction) which impede fish passage.

2. Notification will not be required for:

   2.1 The repair of floodgates affected by acts of vandalism such as gate removal.

   2.2 The repair of floodgates damaged by accident

   2.3 The repair of floodgates that are kept open by other material such as logs or rocks.

   2.4 Floodgates do not involve a waterway (e.g. flood control structures on storage floodways)

   2.5 Minor repairs such as flap, hinge and seal replacement where guidelines 1 and 2 do not apply.

3. Where notification to the Minister for Fisheries is required the relevant floodplain management authority or owner of structure could proceed in two ways.

   3.1 Assessment of environmental issues on a site by site basis. This would include individual site assessment for each work requiring approval.

   3.2 Development of a Best Practice Agreement with NSW Fisheries (already implemented by Richmond River County Council). This agreement will allow an improvement in administration arrangement and easier operation for authorities. The agreement would outline:

   - Assessment procedures

- Approvals for 12 month or 2 year works programs
- Protocols for opening and closing
- Review mechanisms

4. Floodgate Project

NSW Fisheries & the North Coast Floodgate Project

by

Simon Walsh

Floodgate structures are a dominant feature of NSW coastal floodplain landscapes. They exclude tidal flows, primarily preventing brackish or saline water inundation of land, and prevent backflooding that could otherwise occur from rises on the main river system. However the negative impacts of floodgate structures on ecosystems have been shown to include:

- Restriction of fish passage
- Drying out of wetlands
- Proliferation of weed species
- Reduction in drought proof pasture refuges
- Exposure to air of acid sulfate soils
- Reduced water quality

These impacts have been recognised by commercial and recreational fishers and NSW Fisheries for several decades and have often resulted in adverse media due to public disagreements between fishers and landholders with floodgates, the sugar cane industry and floodplain management authorities.

The level of impact was quantified in Williams *et al* (1996). This report provided a complete inventory of all coastal barriers restricting fish passage and tidal inundation in NSW. The report found 4,229 barriers to fish passage and tidal inundation on the NSW Coast. Of these, 1,388 appeared to have some form of mitigation potential. These included 1035 floodgates (99% of the total number of floodgates), with over half of these floodgates (630) occurring on the North Coast of NSW (Tweed, Richmond and Clarence Rivers).

The next step by NSW Fisheries was to organise a workshop entitled *Floodgate Management from a Fisheries Perspective* in 1997. It was seen as an important initiative to discuss the large numbers of floodgate structures in coastal rivers, their impacts upon ecosystems and the ways in which they could be better managed. One technique for achieving this is active floodgate management, which is the controlled opening of a floodgate during non-flood times for the purposes of allowing tidal water to enter the affected waterway.

This three-year project to address the issue was developed by NSW Fisheries based on the positive outcomes of the workshop and the original inventory of tidal barriers by Williams *et al.* (1996). It commenced in early 1999, funded by the Natural Heritage Trust, NSW Fisheries and Kempsey and

Tweed Shire Councils and was project managed by NSW Fisheries on behalf of the proponent, the North Coast Regional Catchment Committee. The aims of the project were to:

- achieve sustainable land management on the coastal floodplains of northern NSW through the development of a model approach to improved floodgate management;

- improve coastal floodplain management practices, based on *in situ* trials of floodgate modifications or removal.

This project identified 1004 floodgates on the north coast, from the Manning River at Taree north to the Tweed River on the Queensland border. Each floodgate was audited and then prioritised in terms of its ease of opening (landholder willingness) and overall environmental benefits in doing so. 220 floodgated sites were assigned to a high priority listing for further action. Of these, 36 sites are currently being actively managed, of which 16 are within the original project area. The high priority list has been provided to each of the six local Council's within the project area, so that Councils can make better informed decisions with regards to actively managing their floodgates.

Each river catchment where possible, has also been provided with two demonstration sites, where active floodgate management and its benefits can be seen by other landholders in the catchment. Interest was initially slow in coming but has now snowballed to the point where landholders from as far afield as Queensland, South Australia and Victoria are expressing interest in the project and changing land practices. New styles of floodgate modification have been developed since the inception of the floodgate project and are represented in some of the demonstration sites. Some of these are tidally operated and are less reliant on human intervention to operate.

NSW Fisheries has also provided teams of researchers to monitor the results of opening floodgates on fish populations. Although the results are still forthcoming, initial trends indicate that active floodgate management has definite benefits for fish populations. The involvement of the Fisheries Development and Research Corporation in conducting a number of research programs looking at the impacts of floodgates has also been facilitated by this project.

Since the initial stages of the project, over 150 kilometres of waterway have now been opened (including Clarence and Hastings catchments) through improved floodgate management. This has provided a whole range of benefits including:

- improved fish passage for feeding, breeding and habitat purposes,

- enhanced water quality conditions,

- better management of acid sulfate soil areas,

- reduced need for landholders to spray or slash weeds in drainage channels, as brackish water kills in-drain weeds without affecting main crop or pasture paddocks,

- allowed landholders greater control in manipulating their drainage systems.

One key result for the project has been the continued support from local Government for active floodgate management. This is shown by in-kind support by Councils in the project area to the value of $ 741, 287 since the project's inception.

Other key results include:

- Over 200 landholders have been involved in floodgate management since the project's inception,

- Out of 1004 sites on the North Coast all were desktop audited and 220 have been fully audited,

- The initial project aim was to achieve 6 demonstration sites. There are currently 16 actively managed sites with several more currently in progress, a further 20 sites are being managed in the Clarence and Hastings catchments,

- The project aimed to improve fish passage and this has exceeded expectations considering the opening of over 80 km of water way that had previously been closed by floodgates within the project area.

Catchments outside the original project area are also actively demonstrating an interest in the goals of floodgate management. Extensive liaison and consultation has taken place between this project and the relevant floodgate management contacts on Clarence River County Council and Hastings Shire Council. The Clarence and Hastings catchments have a total of 236 gates of which 95 have been audited as part of this project. Twenty of these are being actively managed which has opened up over 80 km of water way that was previously closed.

Another project outcome is recognition by the State Government of the importance of this issue. NSW Fisheries has recently sought and gained an additional $522, 950 funding from the Environmental Trust to follow up the success of this initial project by opening 50 floodgates over the next two years. The value of in-kind contributions from Councils and NSW Fisheries will increase this figure to $ 767, 000 within that timeframe. This money will be used to support Councils and landholders who have floodgates on the high priority list and are keen to actively manage them. NSW Fisheries will continue to provide an important advisory and coordination role in the on-going active floodgate management process.

5. Floodgate evolution overview

Presentation by
Bob Smith
Wetland Management Consultant
Wetland Care Australia
bsmith @scu.edu.au
Tel. 02 6628 3472

Notes re page 2:

- WCA is a not-for-profit organisation dedicated to the preservation and rehabilitation of wetlands throughout Australia.
- WCA maintains a team of 6 'wetland specialists' based in Ballina servicing projects in coastal and inland regions of northern Australia, backed up by WCA's head office team of 12 in South Australia.
- WCA sees floodgate and drain redesign, in combination with wetland rehabilitation, as the most cost-effective long-term solution to water quality and habitat problems confronting coastal estuaries in Australia.

Notes re page 3 & 4:

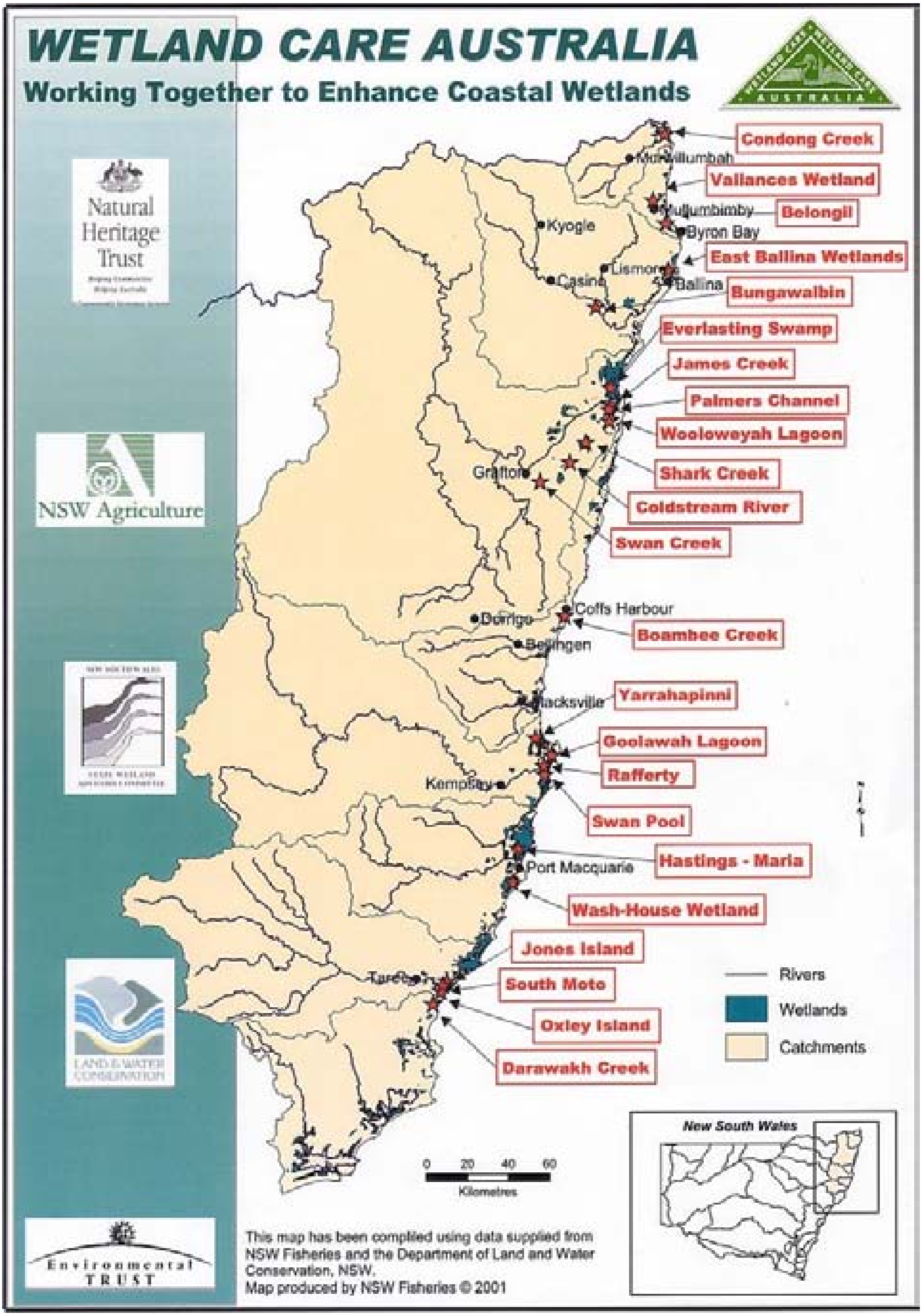
- Floodgates should not be viewed in isolation from the total drainage scheme.
- They impact on fish passage, intensity of drainage, acid export, backswamp groundwater and surface water hydrology, backswamp vegetation, weed growth etc.
- Secondary water control structures are normally required at the edge of the backswamp to achieve certainty in outcomes from floodgate manipulation.
- 'Set and forget' designs are preferred to high-tech or labour-intensive designs.

Notes re page 5 & 6:

- Drain redesign like floodgate redesign is rapidly evolving, as illustrated at Mays Swamp in Seven Oaks near Kempsey.
- Concepts for redesign of drains has moved from sills in drains to completely filling drains and reinstating natural drainage lines through backswamps to remove floodwaters without mobilising acid groundwater.

Notes re page 7 & 8:

- Floodgate design remained almost unchanged from the 1890s until 2000.
- Top-hinged flapgates have changed mainly in the materials used (copper sheathed timber, zinc coated mild steel, aluminium, composite timber / GRP, plastics), rather than basic design.
- Floodgate lifting devices are popular in cane growing areas as a means of improving floodwater removal – and more recently as a means of flushing drains with salt water.
- Penstocks are used in the Clarence to hold water in backswamps in dry times.
- As outlined by other speakers, many new concepts have been proposed since 2000, but most are still being trialed.


WETLAND CARE AUSTRALIA
Working Together to Enhance Coastal Wetlands
Natural Heritage Trust
NSW Agriculture
Environmental TRUST
Condong Creek
Vallances Wetland
Belongil
East Ballina Wetlands
Bungawalbin
Everlasting Swamp
James Creek
Palmers Channel
Wooloweyah Lagoon
Shark Creek
Coldstream River
Swan Creek
Boambee Creek
Yarrahapinni
Goolawah Lagoon
Rafferty
Swan Pool
Hastings - Maria
Wash-House Wetland
Jones Island
South Moto
Oxley Island
Darawakh Creek
Murwillumbah
Mullumbimby
Byron Bay
Kyogle
Lismore
Casino
Ballina
Grafton
Coffs Harbour
Dorrigo
Bellingen
Macksville
Kempsey
Port Macquarie
Taree
Rivers
Wetlands
Catchments
0 20 40 60
Kilometres
New South Wales
This map has been compiled using data supplied from NSW Fisheries and the Department of Land and Water Conservation, NSW.
Map produced by NSW Fisheries © 2001

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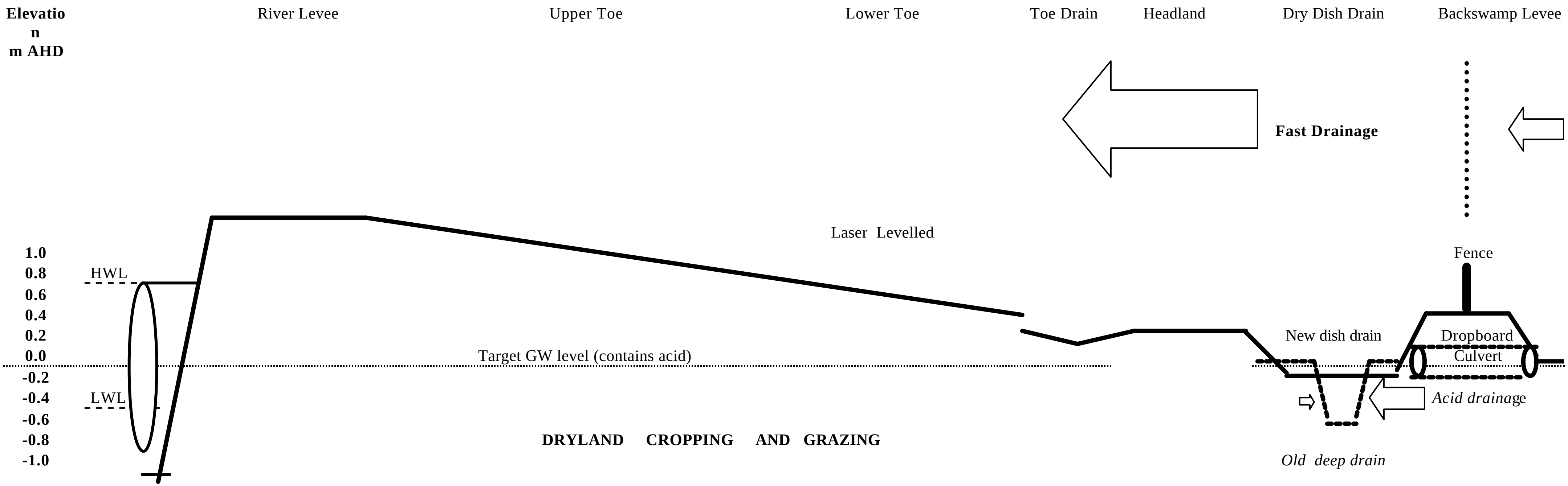
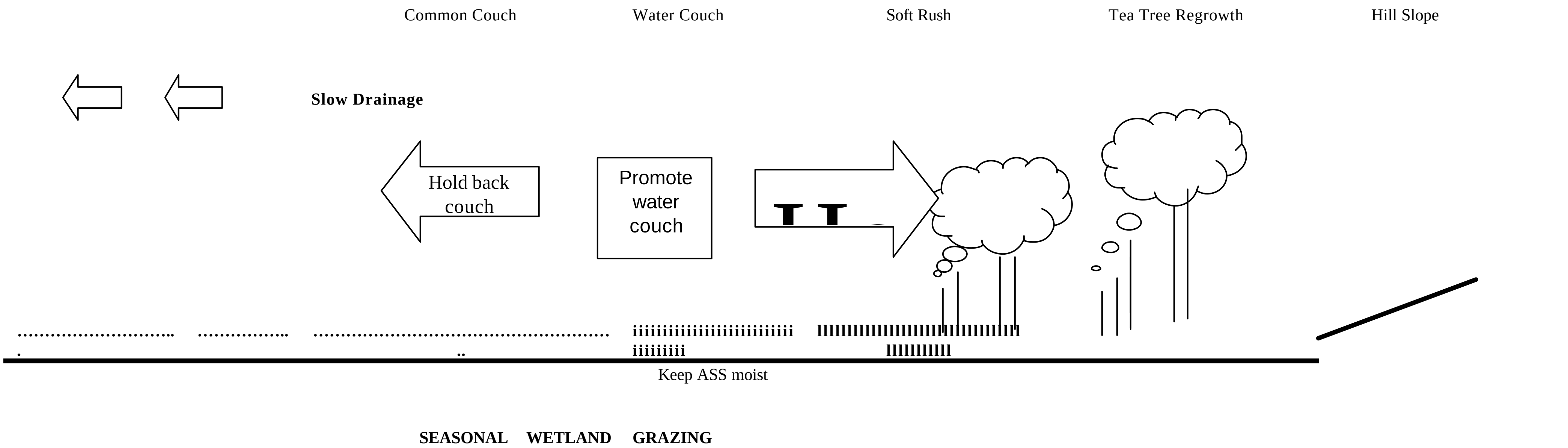
Separating ‘Dryland’ and ‘Wetland’ Production Systems

by Bob Smith





R Smith Shark Creek Project 10/10/00 Acknowledgements D Moloney

NOT TO SCALE

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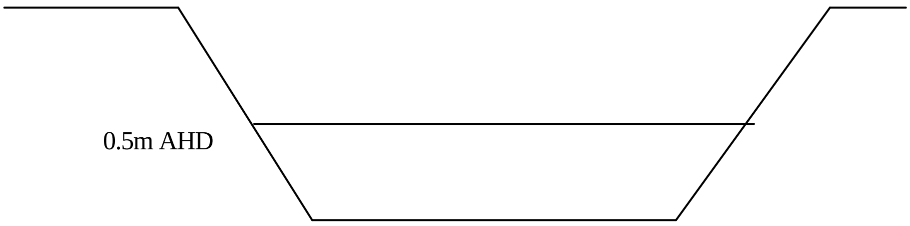
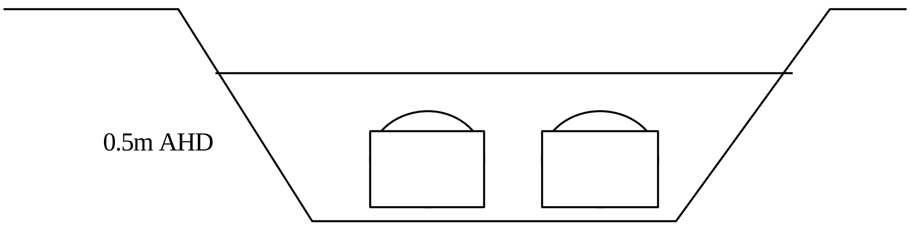
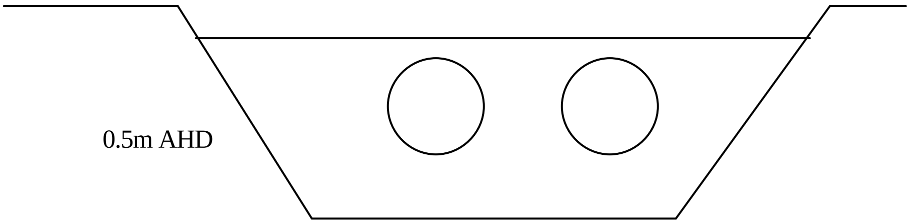
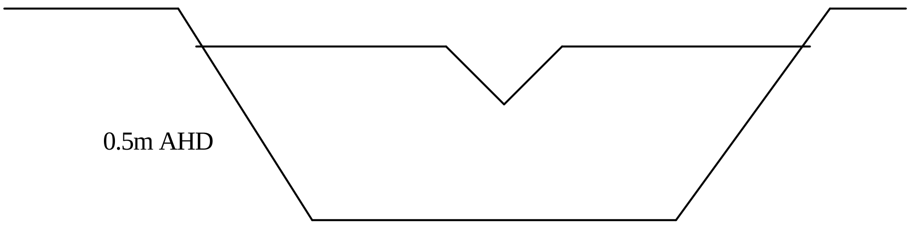
Evolution of In - Drain Water Control Structures at Mays Swamp (Kempsey)

by Bob Smith

	Strengths/ Weaknesses
Concept 1: Earth Sill 	• Low cost • Easy to install • Crest remains wet • Prone to erosion • Cannot raise or lower water levels
Concept 2: Dropboard Culvert 	• Can raise and lower sill to suit season • Moderate cost • Need specialist equipment to install • Difficulty in removing and resealing boards

Concept 3: Elevated Culvert  	• Allows water diversion to backswamps (environmental flows) • High Cost • Can be used for diverting environmental flows
Concept 4: Sill with Spillway  	• Moderate – High Cost
Concept 5: Reinstate ~~Natural Veins & Backfill Drains~~  	• High Cost

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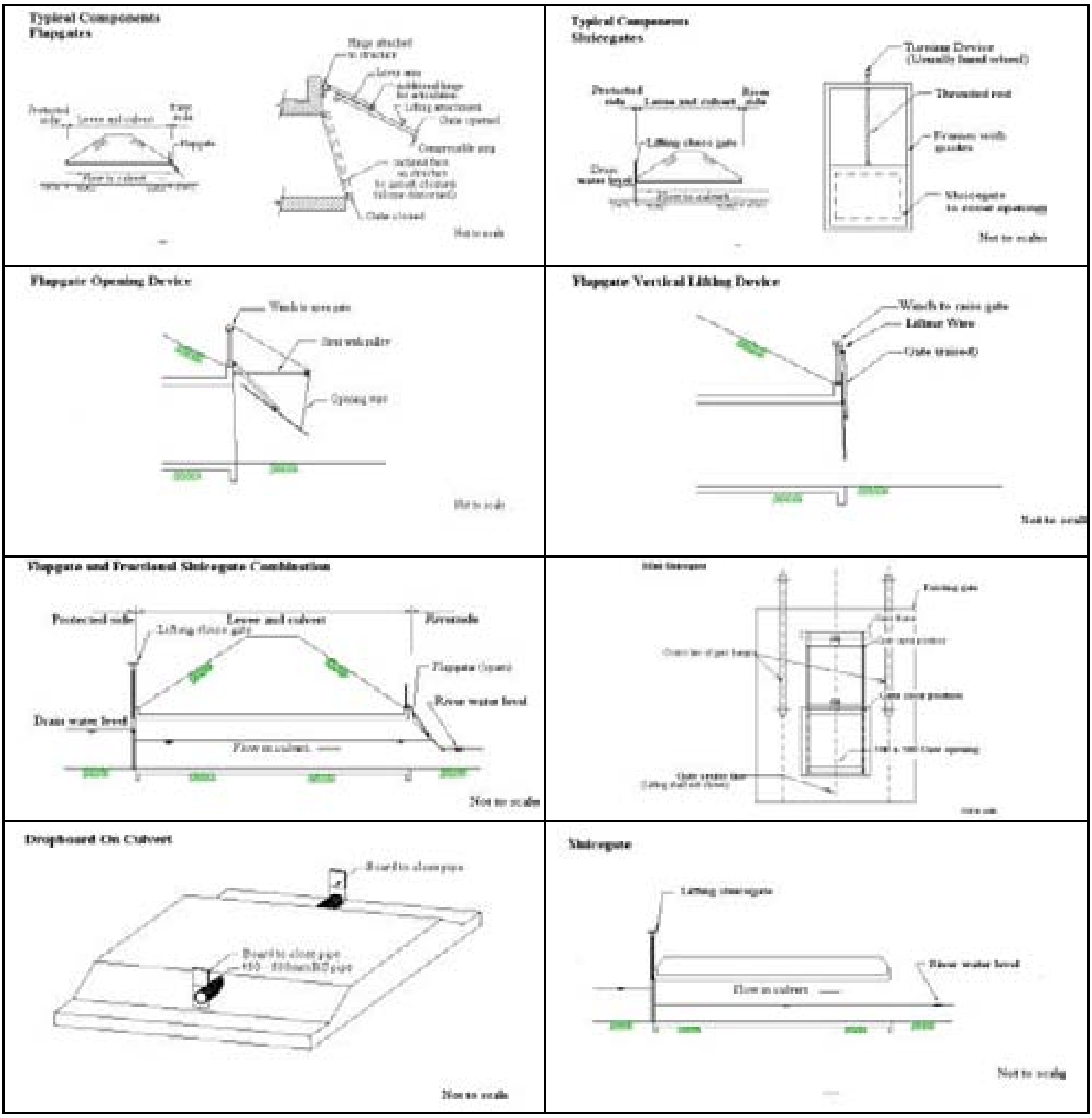
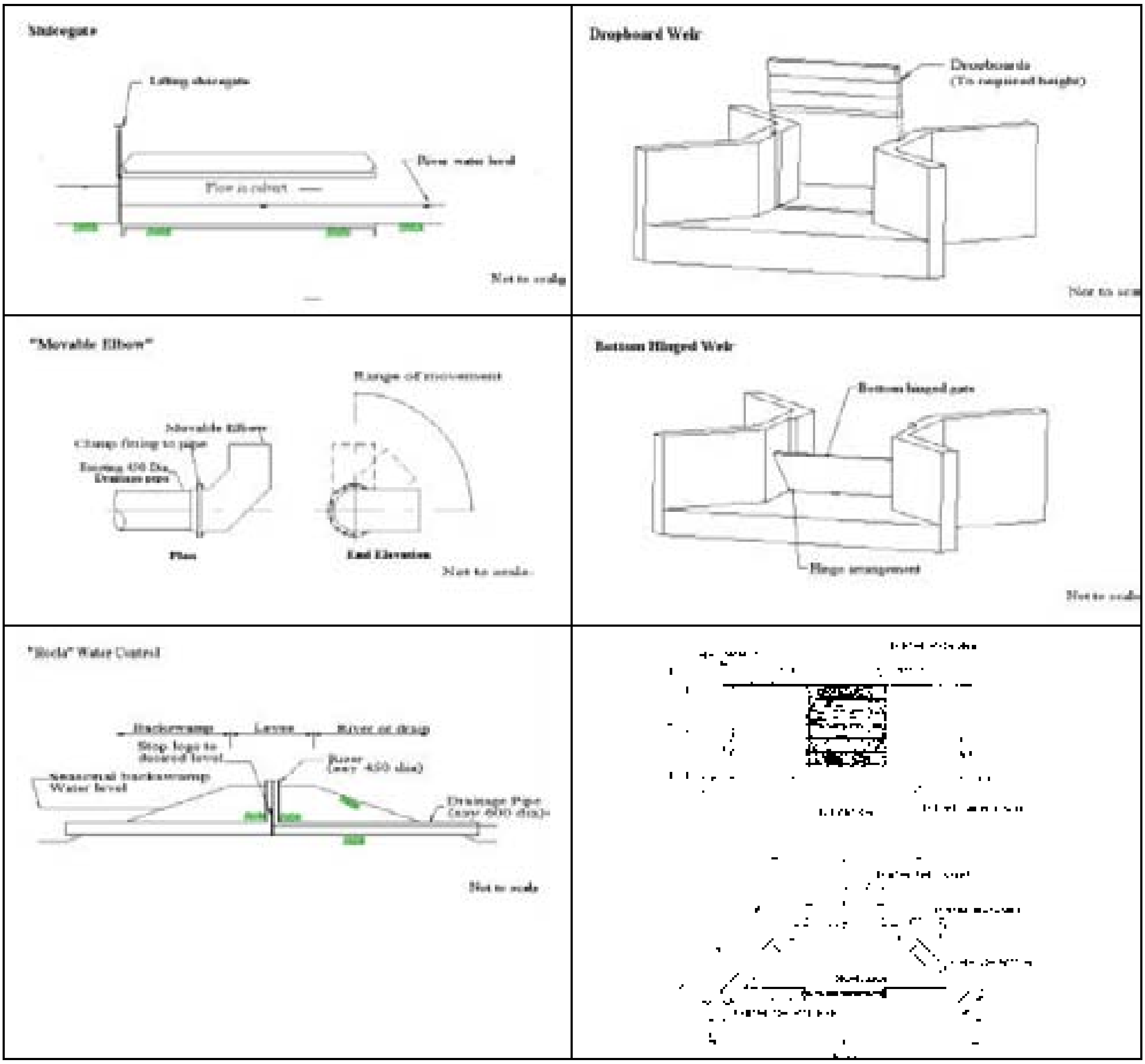




Source: *Patterson W and Smith RJ (2000). Design Improvements – Rural Drainage Schemes. Acid Sulfate Soils Program, NSW Agriculture.*

6. Winches – Clarence

Presented by:
Rob Lloyd
Clarence River County Council

History

Flood mitigation drainage works date back well into the 19th Century, and for almost as long there is evidence of the use of winches to position and open gates. For most of this time, these activities have been haphazard and uncoordinated, however the recent past, since the 1950s was much different. During this time many of the floodgates where fitted with lifting mechanisms around the time they were constructed. In most cases this involved the use of a cane winch mounted to one side, pulleys hug off a log, which rested on the sidewalls of a box culvert and cables attached to the floodgates. These winching mechanisms were usually only fitted to box culverts, there are few instances of floodgates on piped outlets being opened with permanent winching systems before the mid-1990's.

During the early stages of the Clarence Floodplain Project (CFP) the usual mechanism of opening floodgates was still in the traditional horizontal fashion, by use of a gantry structure built out over the top of the gate and a side mounted pulley system. There were also many variations on the log beam approach, with a steel beam sometimes being used instead of a timber pole. Alternatively a gantry system was built out in front of the gates and the person doing the winching would stand out on the gantry and operate one winch per gate.

Although not a new idea, the vertical lifting gantry was not commonly used to open the main gates (those between drain and receiving waters) until fairly recently. This approach involved using a gantry mounted directly over the hinge points of a gate to lift the gate straight up across the front of the pipe. Although this approach does give a greater degree of flexibility with respect to water interchange, it does have a major draw back. Due to the gate always resting against the pipe or headwall, closing or opening the gate when there was more than a slight difference in head pressure is difficult. This is especially so for the closing process where the winching systems used do no provide a positive closing force. One possible suggestion at the conference to alleviate this is to do away with the winch for opening a closing the systems and replace it with a worm drive of screw mechanism. In this way a positive closing force could be applied to over come the pipe to floodgate friction.

Since the mid-1990's, there has been a rapid expansion in the design, installation and use of winching mechanisms for the opening of floodgates.

Presentation

The presentation is designed to show the different floodgate opening systems, which rely on winches for as part of their opening mechanism.

← This slide shows a large series of box culverts where the original log span has been retained. The original winch has been removed from the site and new horizontal gantries installed on 4 of the 7 gates. A new and safer winch has also been installed to operate the gantries.

↑ The above slides show a box culvert where the original log span has been retained and new pulleys and winch box installed. What this shows is that in many cases the structural longevity of this form of opening device often outlives the moving parts of the system . The reason the gates on this system ceased to be opened was due to a lack of maintenance on the moving parts. In most cases this failure of the operations parts of opening devices can be attributed to the lack of a proper maintenance program, which in turn can be related to insufficient funding.

↑ These slides show a box culvert where a wire cable span has utilised. These systems are especially useful on box culverts in areas with access difficulties such as deep drains or overhanging vegetation.

← This slide shows a winch box and stand. The winch here is a heavy duty 800kg line rated apparatus. Although this is over engineered for its requirements it has been found that with floodgates, using higher rated equipment is important to prevent the failure of winch breaking systems under load. Also of importance is the protective box which is secured over the winch to prevent unauthorized operations and theft of the valuable equipment.

This slide shows a box culvert where the original log span has been replaced by a stainless steel beam and new winch installed →

← This slide shows a box culvert where a gantry system has been installed allowing the operators to walk out and maintain the pulleys and cables. This system has definite advantages from a maintenance perspective.

These three slides show a box culvert where the original log span has been replaced by a horizontal gantry constructed of stainless steel.

This slide shows a piped system where horizontal gantries have been constructed as extensions off the end of the pipes →

← This slide shows a piped system where a vertical lift gantry has been constructed. In this system the vertical gantry is a top pulley system with the potential to create large turning moments around the end of the pipe which can twist or crack the pipe.

← This slide shows a piped system where vertical lift gantry has been constructed. In this system the vertical gantry is a over and under bottom pulley system which greatly reduces the potential to create large turning moments around the end of the pipe. This is a much improved form of vertical lift system

↑ These two slides show a piped system where vertical lift gantry has been constructed on the upstream side of the systems to form a penstock. These systems allow for continual inflow of water while restricting outflows to when the gate is lifted

↑ These slides show a beam lifting device, which operates in a similar manner to the log, and wire systems shown earlier. The difference here is that a tidally operated floodgate has been built into the mechanism. This shows that multiple opening systems can be combined.

Pros and cons

Essentially there are two basic approaches to opening a floodgate, horizontal and vertical. There are strong and weak points to both approaches, and they are suitable to different applications. As it was highlighted at the workshop, perhaps the weakest point is the reliance on a winch design. It was determined that a screw mechanism may be the best option for a vertical gate due to its ability to apply a positive closing force.

Horizontal

The horizontal opening gates are those that use the gates natural method of opening by rotating the gate around the top hinges.

The main benefits with these are:

- Easier to open the gate against a head of water

- Simpler operation
- Positive and dependable closure no matter what the head differential,
- More compatible with tidal gates and mini sluice gates

The main shortfalls with these are:

- Difficulty in leaving the gate partially open on piped systems due to the resultant turning moments around the end of the pipe.

Vertical

The vertical opening gates are those that lift the gate's top hinges retaining the gates natural opening.

The main benefits with these are:

- Ability to leave the gate partially open and act in the same manner as a mini sluice gate
- Able to totally remove the gate from the water column during discharge

The main shortfalls with these are:

- Difficult to open the gate against a head of water
- More complicated operation
- Not as dependable during closure, no matter what the head differential,
- less compatible with tidal gates and mini sluice gates

Workshop Discussion Points

Horizontal gates
- can open at any tide although more difficult at high tide

Vertical gates
- can be caught open or closed particularly on high tides
- this leads to more conservative behaviour from floodgate operators

Recommendation
- combine horizontal or vertical gates with tidally operated modifications to maximise benefits

7. Sluices – Richmond

By Michael Wood of Richmond River County Council

Introduction

Sluices or slide windows are basically a hole cut within the floodgate with a covering plate which can be adjusted to allow for varying amounts of water to pass through. In the Richmond this style of gate is proving successful at a number of sites improving water quality and habitat values without adversely affecting landholders. The gate fits flush within the top hinged flap gates and does not affect the floodgate performance. Aluminium gates reduce maintenance are lighter and not as prone to rust as with the conventional steel gates. Following is listed some of the main points on the use of sluicegates experienced over the past three years.

- Sluicegates can be retro-fitted to existing gates

- The degree to which each sluice gate is opened varies from site to site. A safe operational level is determined over a twelve month trial period in consultation with the key stakeholders and is included in a management plan for that particular drainage system. This approach is conservative but provides for long term tidal exchange. which also reduces the need for floodgate managers to continually adjust the sluice gate opening

- Sluices allow for prolonged fish passage and water quality exchange

- Sluice handles can be removed to prevent vandalism / unauthorised openings and closing

- Threaded screw handles can operate the winding up or down of the sluice window in all conditions / water levels

- As mentioned above sluice gate openings in the Richmond are generally trialed for a 12 month period to allow for seasonal variations in rainfall, flooding etc as well as various stages of the agricultural cycle.

- This type of modification has been installed with success at a number of locations in the Richmond River catchment including Sneesbys Lane, Dungarubba (see figure 1 below), Bagotville Barrage and Thearles Drain at Swan Bay.

Figure 1: Aluminium sluice gate and floodgate Dungarubba Creek

Workshop Discussion Points

- opening and timing of sluice (slide) gates is significant in respect to climatic conditions, agricultural cycles and tidal heights
- can calculate size of gate required
- can be made in Councils workshop or contracted out
- the cost varies depending on the gate size. If fabricated using aluminium the cost ranges from $4,500 for a gate like the one pictured above through to larger gates which cost approx. $10,000
- Small mini-stainless window with brass screw sluice for $2,000
- maintenance of floodgates is an on-going issue for councils and landholders whatever the style of gate although it may well be functional needs to fit within the flood mitigation system and not result in Councils servicing and maintaining an eclectic infrastructure
- Looking at nylon sides to reduce friction for slides
- Pneumatic / air pressure mini-sluice also an option?

8. Macleay ASS Land Action Group

By MASSLAG President - Ivan Sillitoe

The Macleay Acid Sulfate Soils Land Action Group (MASSLAG) is composed of local landholders in the Macleay catchment, in addition to incorporating members from State agencies and local government staff.

The primary role of MASSLAG is to minimise the impacts of acid sulfate soils on agricultural productivity and environmental outputs in the Macleay. Largely through a “hands-on” approach, MASSLAG has targeted and been involved with:

- Active floodgate management,
- Water quality monitoring,
- Installation of drop boards,
- Holding field days to illustrate Best Practice in floodplain management (ie. reed buckets),
- Trials of revegetating scald areas,
- Submitting funding applications and sourcing additional funding to carry out the works outlined above,
- Raising awareness of ASS issues with landholders and Drainage Unions.

MASSLAG has been involved with and made comment on, a number of projects including the Macleay Floodplain Project with the goals of improving acid sulfate soils management, water quality improvements and water level management. Additional involvement has been with:

- Floodplain Risk Management Committee,
- Coastal and Estuarine Management Committee,
- Swan Pool Management Plan,
- Frogmore / Darkwater Water Quality Rehabilitation Project,
- Upper Belmore Floodplain Management Study,
- Lower Macleay Floodplain Management Study.

In the construction and use of floodgate modifications, MASSLAG’s President Ivan Sillitoe has developed plastic moulded gates. These flapgates are extremely light which makes installation on-site much easier. They are also environmentally friendly as they are constructed from recycled plastic and are all Australian made.

The plastic flapgates intended for the Locke at Kinchela Creek are priced at around $1200 for construction, installation and fitting. This particular site also has a stainless steel frame and hinges.

Ivan has also constructed plastic headwalls and pipe culverts which come with all the advantages mentioned above and are priced at around $5,000 for a 4 ft diameter system. .

Other points raised regarding floodgate systems include a recommendation to make any modifications as simple as possible. This would lead to reduced need for wearable, moving parts and so streamline any future maintenance needs.

Another factor was that it is also better to make all floodgate modifications compatible with other such examples on the floodplain. This means that if a component is missing or damaged from one gate, another can be readily sourced without delay.

Workshop Discussion Points

- Can be fitted to recycled plastic pipes
- Would it float? Differential pressure more significant, could add weight to gate if necessary
- Fiberglass gates could flap and increase damage
- Level of lowest low tide AND invert base determine how much the drain drains

9. Auto Flow Gate

By Peter Wall of Australian Aqua Services

- Farmer / User friendly: higher water inside height overrides water outside, at any height
- Reliable – proven performance, trialed for one year on-site, reference letters from Council, land holder, Dept. of Ag.
- Price competitive – check our quotes
- Installation service provided
- Easy to fit, even to uneven surfaces and old gates
- New installation no headworks required, saving major costs
- Quality materials used with guarantees
- No hinges, slides etc to get stuck or jammed with reeds, grass, sticks, etc no pressure edges
- Fully adjustable from full flow to no flow
- Size not a problem from 100mm up
- Different profiles to suit unlimited variations
- Can retrofit to existing gates, flaps, side hinged or sluices

- Water entering gate is taken below surface to avoid debris, rubbish (and mangrove seeds if required)
- Species friendly with flow through same orifice in both directions attracting species moving up stream
- Positioned correctly no need for drop board weirs etc to maintain water level above Acid Sulphate Soil profile
- Translucent and / or light reflective materials used if required
- Easy to fit with monitoring equipment eg. Temp, pH, EC, DO inferred etc
- Adaptable for High Flow Low Head Hydro Electricity Generation

Auto Flow Gate "Plus" Model

Features
All Auto Flow Gate features
"Plus"
Automatic variable ballasts and if needed adjustable from site or remote location with manual and computer controlled system..

- This gives a selection of strata levels of input water
- This gives a variance of tidal range that can be altered for many reasons
- Water can be monitored eg. fresh / salt, EC, pH, DO, temp etc and height
- Top Lid Pipe Ballast optional safety extra

Auto Flow Gate "Dual Plus" Model

Features
All Auto Flow Gate features & "Plus" features
Dual Plus extra features include:

- Water internal mix and match from different strata levels with testing as above on or off site
- Allows to contain or release combinations of regulated flows from various strata's of both inside and outside the Auto Flow Gate
- Many more combinations available, give us your problem to solve.

Workshop Discussion Points

- Impact of accumulated mud etc in pipe? Limited due to air volume in pipe, best in a large diameter pipe

- Cost? $6, 000 for installation of pipe seen in brochure, would be cheaper now.

- Maintenance requirements? None in last 12 months necessary.

- Fish passage? No sampling has been undertaken, however they have been observed freely swimming through the pipe.

- Prawn passage is important and needs to be considered, square pipes would improve fish passage and habitat features could be placed in the pipe.

10. Automatic Tide Floodgate

By Greg Breckell of Rabbit Plastics

- Developed by Greg Breckell after discussions with Thor Aaso (Hastings Shire Council) of a floodgate modification initially developed by a farmer in the Manning catchment

- The float opens and closes the window within the main gate according to a predetermined water level outside the gate raising / lowering the float accordingly

- This level can be adjusted by changing the operational level of the float if desired.

- The window can be secured closed as a failsafe mechanism

- Designs have been tested in a specially constructed test tank at workshop

- Constructed from aluminum components and reinforced plastic float at the Kempsey workshop, this design can be fitted to order

- Costs around $5,000

Workshop Discussion Points

- Maintenance? Gates are self-cleaning due to tidal flushing each side

- Potential for gate slamming as wavelets lift float (and gate) up and down? Can use a larger float to minimise chances of this occurring

- Costs? Plastic headwalls (30 kg) = $165

- Float $12 – if removed gate closes
- 450 mm diameter pipe $350

- Gate itself ~ $800

- 1.5 metre pipe with mini-gate 500 x 800 mm = $5,000

- Limitation – may need drop board in the system to retain water

11. Waterman Floodgate

Stephenson Tide Gate Trial

The test location was on a typical headwall on Palmers Channel which is between the Yamba Lakes and the Clarence River. It is in a sugar cane growing area. There were two existing 66"x66" flap gates that had been in operation for about 30 years. These are zinc sprayed double hung ½" plate sealing direct to the concrete with large J-bulb seals.

The object of the new gate is to allow fish passage and salt water interchange while keeping the upstream level at no more that 100mm above low tide. The salt water interchange is important to keep weeds out of the channel and to reduce impacts of acid from the acid sulphate soils discharging to the river during high rainfall. Tidal range is about 600mm.

Waterman has managed to achieve the goal with a 1675x1675 aluminium flap gate sealing to the wall with small J-bulb backed with 25 thick foam neoprene, a 400x400 smaller flap gate incorporated in the main gate and a 316ss float.

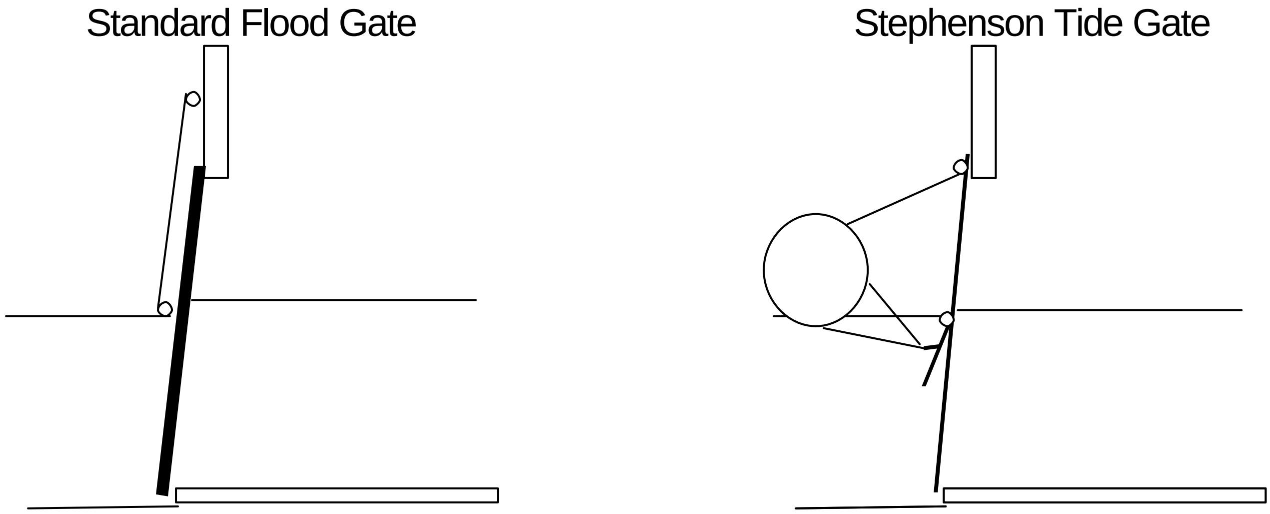
The float has an adjustable hook and is on a much larger radius than the 400mm flap that it picks up. Thus there is a point as the tide comes in, that the hook will not engage the float. In other words, as the tide falls, the float lowers until it latches onto the gate. This is currently set at just above mean low tide but the tide often drops below this. When the tide turns the float will start to pick the small flap up at about mean low tide and hold it until it drops at a point 100mm above this. The flap opens to about 2/3 open but this varies somewhat. Because the main gate is much lighter than the previous mild steel gate, it allows water out of the drain more easily and the net effect on level in the drain after the installation of the Stephenson tide gate was negligible.

Importantly the worst case failure mode is that the gate will operate identically to the gate that was removed. This is a critical design function for the landowners.

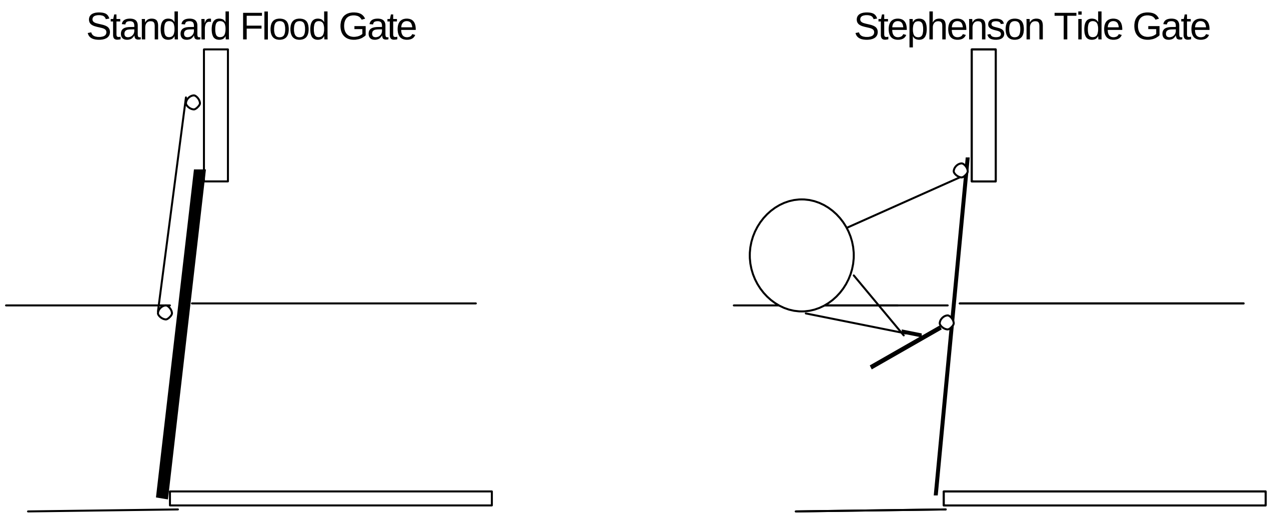
First attempt to operate on an existing gate January 2002

Aluminium bridge with worm drive boat winches

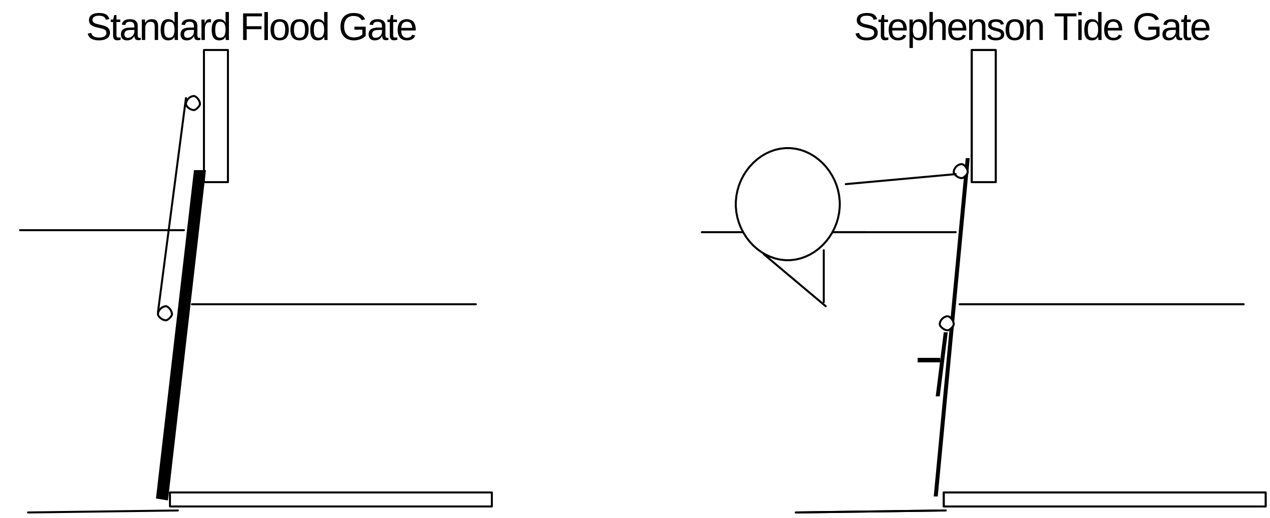
Gate and float lifted up from bridge



Low Tide



Incoming Tide



High Tide

Float after picking up small gate - about half open

Latch rope

Workshop Discussion Points

- Can the float be made cheaper? Yes, can reduce its overall size to do this.
- Cost? 1700 mm gate with float and installation $7,000
- Better to install a new gate than retrofit an existing system
- Clarence River County Council also recommend fitting new gates when adding modifications

12. Saltshaker Floodgate

Ben Macdonald[1], Jodie Smith[1] and Jimmy Dixon[2]

[1] School of Biological, Earth and Environmental Sciences, University of New South Wales. Email: benmacdonald@unsw.edu.au

[2] Marrison Hydraulics Pty Ltd, PO Box 742, Lot 2 Quarry Road, Murwillumbah NSW 2484.

Introduction

Groundwater discharges from coastal acid sulfate soils are currently polluting many rivers and estuaries (Aström and Björklund 1995; Hooli *et al.* 1993). Artificial drainage of Australia's coastal floodplains has contributed to oxidation of potential acid sulfate soils (PASS) and enhanced the export of oxidation products from the soil profile to the adjacent rivers. The impact of these discharges has been catastrophic on river ecology within acid sulfate soil catchments and have been linked to large scale fish kills (Easton 1989).

Iron monosulfides or monosulfidic black oozes (MBO's) are transitional metal sulphide minerals which form typically in areas with reducing conditions where there is a large supply of soluble iron and sulfate, and available organic matter. Iron monosulfides, not surprisingly form in drains within acid sulfate soil areas. The saltshaker floodgate was designed to reduce the risk of iron monosulfide oxidation, which releases acidity and metals into drain waters.

Scope of the problem

During the dry season (April to November), when evaporation exceeds rainfall, many drains dry out exposing the iron monosulfide basal sediments to the atmosphere. These sediments subsequently dry out, shrink and partially oxidise, and there is also deep cracking into the underlying PASS (Figure 1). Iron monosulfide oxidation can cause a severe decline in downstream water quality (Sullivan and Bush 2000). After an extended dry spell within the Tweed River valley, a rainfall event (43 mm) flooded the dry main drains within a McLeod's Creek sub-catchment (Figure 2), but did not raise the watertable to the surface.

Figure 1 A typical drain at McLeod's Creek during the dry season

During this event 37kg H_2SO_4 was exported from the catchment. It is probable that the bulk of the acidity was generated by partial oxidation of iron monosulfides in the drains and pyrite along cracks within the underlying PASS.

If all of the monosulfides within the main drains of the McLeod's Creek subcatchment oxidised, 100 kg of soluble ferrous iron and 100 kg of H^+ would be produced. This is the worst case scenario and is unlikely to happen under the current climate and management conditions. But nonetheless, iron monosulfides are a major risk to the water quality and downstream ecology.

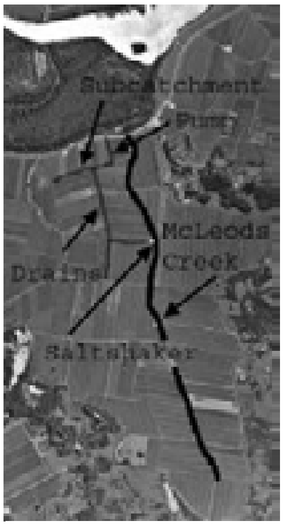


Figure 2. McLeod's Creek subcatchment and saltshaker location.

Current management of iron monosulfides has focused on maintaining a static water level and preventing oxidation within drains during the dry season. The main problem at this site was that the majority of the farm is below mean high tide.

Saltshaker Floodgate

The saltshaker floodgate (Figure 3) is essentially a Teflon disc, which can swivel on a bolt through a new or a pre-existing floodgate. Holes are drilled through the Teflon disc and the floodgate to allow water passage. Figure 4a shows the closed position and Figure 4b shows the open position. The opening and closing of the gate can be manual or dependent on the water level on either side of gate. If the opening mechanism is vandalised the saltshaker will automatically close.

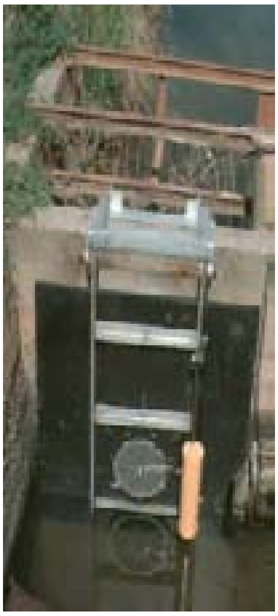


Figure 3. Saltshaker floodgate.

Water Quality Effects

Since installation, the landowner, Mr Robert Quirk, has been able to prevent the drying out of main drains within the sub-catchment. This has reduced the flux of oxidation products from the iron monosulfides. The saltshaker floodgate has also been used to treat acid discharge after larger rainfall events. The main drains within the 100ha sub-catchment quickly become acidic once pumping ceases (i.e. surface waters are removed). When the gate is opened, water quality quickly

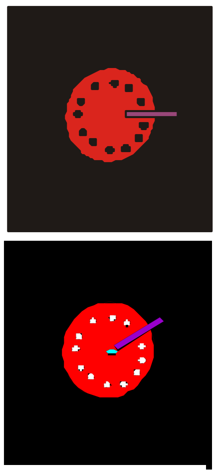


Figure 4 Salt shaker schematic closed and open

improves in the sub-catchment (Figure 5). Figure 5 shows the water quality at the discharge point, the lowest part of the subcatchment.

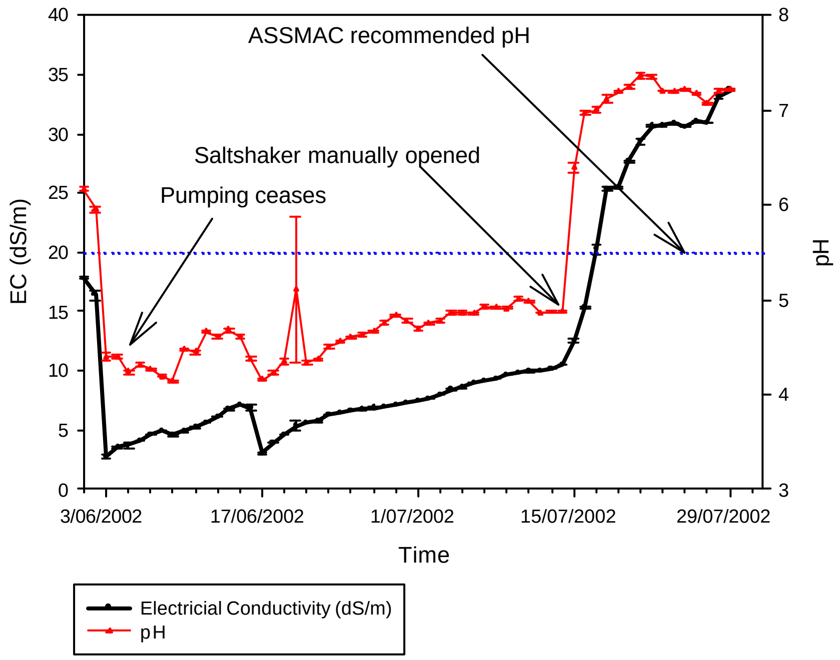


Figure 5 Water quality downstream of the salt

Conclusions

The saltshaker floodgate is an effective and safe way of maintaining drain water levels within flood prone land. It has been successful in preventing the oxidation of iron monosulfides during periods when evaporation exceeds precipitation, and it can also be used to manage and neutralise acid discharge.

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Aström J, Björklund A (1995) Impact of acid sulfate soils on stream water geochemistry in western Finland. *Journal of Geochemical Exploration* **55**, 163-170.

Easton C (1989) The trouble with the Tweed. *Fishing World* **3**, 58-59.

Hooli J, Lakso E, Palko J (1993) Water protection in acid sulphate soils. *Water Sci. Tech.* **28**, 199-203.

Sullivan LA, Bush R (2000) The behaviour of drain sludge in acid sulfate soil areas: Some implications for acidification of waterways and drain maintenance. In 'Proceedings of the Workshop on Remediation and Assessment of Broadacre Acid Sulfate Soils'. (Ed. PG Slavich) pp. 43-48. (ASSMAC: Australia)

<u>Workshop Discussion Points</u>

- mesh gate on the outside of the saltshaker
- 20mm holes limiting for fish passage

- strictly designed for water quality improvements
- Suitable for cane farm drain situations rather than natural creeks
- Presently operated manually, can be operated by upstream / downstream floats
- Cost = $2,000 plus labour

13. Side hinged Floodgate

<u>Investigating the Environmental Benefits of Modifying Floodgates on Cane Farm Drains in the Maroochy River Catchment</u> by Mathew Johnston

Funded by the National Heritage Trust under CASSP

Contributing Members include:

- Department of Natural Resources and Mines,
- Maroochy Shire Council,
- Environmental Protection Agency,
- Maroochy Land Care Group,
- Bureau of Sugar Experiment Stations.

<u>Aims of Project</u>

Document and trial novel floodgate modifications to:

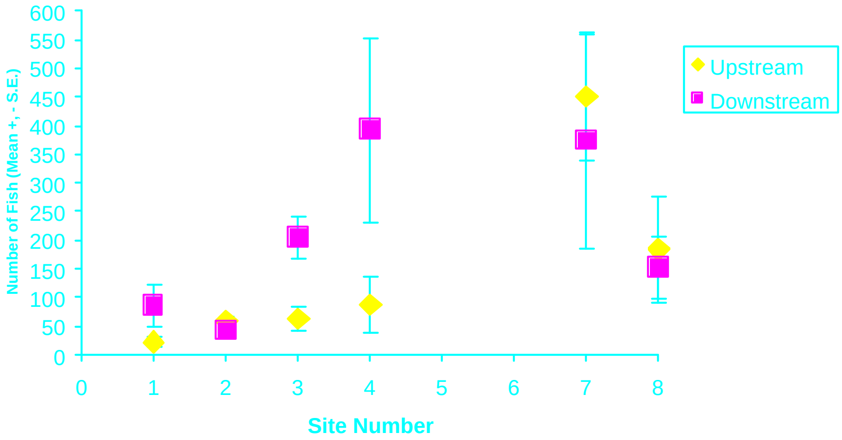
- Increase tidal flushing of drains to improve water quality
- Increase accessibility of drain habitat to fish and crustaceans
- Reduce occurrence of choking fresh water weeds

<u>Sampling Sites in the Maroochy River Catchment</u>

Sites 1, 3, 5, and 7 are the sites that have been modified

Side hinged floodgates

Number of Fish per Seine Tow Upstream and Downstream of Floodgates



Possible Advantages of Side Hinged Floodgates

- Easy to open – requires less water pressure. Once open – stay open until tide turns.
- Doors open wider than top hinged floodgates
- Simple, cheap and no increase in maintenance – good selling points
- Vandal resistant – no obvious modifications or obtrusive structures

Possible Disadvantages of Side Hinged Floodgates

- Problems with debris getting caught in gate
- Not suitable on large rivers – currents, boat wash
- Requires structure to prevent over opening

Conclusions

- Suitable as floodgates on channels set back from main river,

- Possibly requires some sort of retarding device to hold open a little longer,
- Requires a structure to ensure gate doesn't over open.

14. Automatic Smartgate

University of Wollongong

William Glamore
University of Wollongong

Background

- Three year research project examining the impact of floodgate manipulation on water quality.
- Commenced in 1999.
- Located in the Broughton Creek Hotspot.
- 2500ha of high risk acid sulphate soils.

- Stage One: Baseline data and methods for opening gate.
- Stage Two: Modify floodgate and water quality indicators.
- Stage Three: Improved gate design and FEM simulations of acid transport and saline forcing.

Pre-modification-Two Stage Model

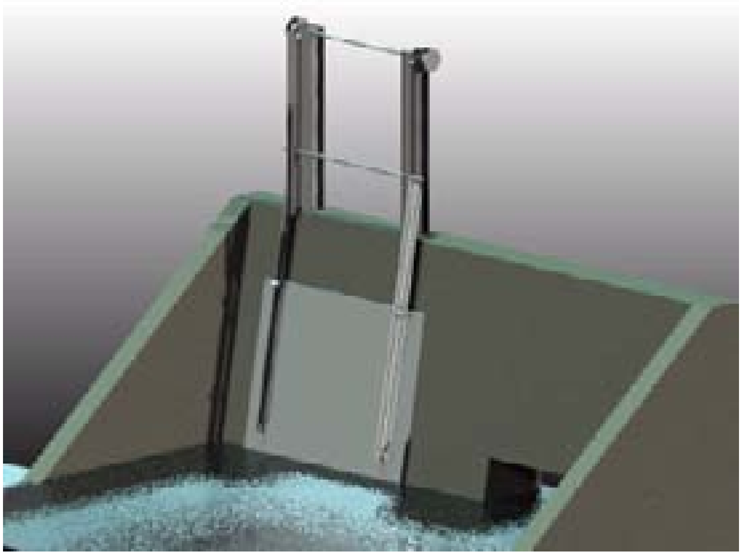
- Stage One involved determining appropriate freeboard levels (tidal heights) within the drain.
- Stage Two involved water quality simulations using an aqueous geo-chemical model, PHREEQC.

Floodgate Modification - (Vertical Lifting gates)

Vertical lifting floodgates were designed to:

- Allow dense saline water to intrude from the bottom.
- Be easily controlled and/or manipulated.
- Restrict tidal flushing if necessary.

Vertical Winch Gates



The smart gate control system was designed to:

- Permit a specific amount of water within the drain based on real-time environmental conditions.
- Multiple triggers.
- Optimise tidal buffering in extreme low-lying conditions.
- Be remotely controlled by offsite managers through dial-up technology.
- Have call-out capabilities in case of emergency.
- Operate on a simple 12V battery with low maintenance.

Typical Operation:
- Gate is open to allow tidal intrusion
- Data logger readings inform system that the tide is rising.
- When trigger level is reached the control system switches on the DC motor and the gate is closed.
- Gate reopens when acceptable levels return.

- Can be modified to allow for larger apertures.
- In future models, a gas bubbler system will replace in-stream data loggers, thereby eliminating fouling.
- Costs range from 9K to 17K plus labour dependent on data loggers, size, GSM modems, motor, etc

Workshop Discussion Points

- Gate monitored / opened by Shoalhaven Council
- Electrical instruments located well above potential flood height
- Winch gate / sluice for $300
- Can regulate a predetermined flow through the gate
- Before gate was opened no fish were seen, minutes within opening fish were observed in the drain

15. Research findings – fish passage

Fish passage issues relevant to estuarine floodgates, and preliminary research results

Andrew Bruce and Fredereike Kroon*
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* CSIRO Land & Water, Long Pocket Laboratories, 120 Meiers Rd, Indooroopilly Qld 4068

Introduction

Natural mangrove creeks and coastal saltmarsh swamps are important nursery areas for many fish and invertebrates. They offer structural complexity, shelter and food sources not readily available in other coastal areas.

It has been estimated that well over half the NSW total commercial fisheries production by weight consists of species that are estuarine dependant at some stage in their life history (Pollard and Hannan 1994).

Much research has been done in Australia into the need for fish passage and fishways since 1985, but it has been mainly focused on barriers in freshwater streams and to a lesser extent tidal barriers.

Structures such as vertical slot fishways and rock ramps can allow successful fish passage, and are being constructed on an increasing number of barriers across the country.

An effective fishway has been defined as being able to pass at least 95% of all fish species and individuals attempting to past the barrier, and operate in at least 95% of the likely flow conditions. However, little research has been done on the impact of floodgates on estuarine fish populations until recently.

Research based in the lower Clarence in the mid 1990's proved what was expected: fish habitat in flood mitigation drains and especially above floodgates had more intensive surrounding land uses, less natural native fringing vegetation, and overall were more highly disturbed than natural creek systems (Pollard and Hannan 1994).

Similarly, higher fish numbers and geater species diversity were found in natural creek systems than in drains above floodgates, and gated drains were dominated by primarily freshwater species such as gudgeons and introduced gambusia.

Fisheries Floodgate and Acid Drainage research project

a) Fieldwork
In 2000, the Fisheries Floodgate and Acid Drainage research project commenced, led by Dr Fredereike Kroon.

Jointly funded by NSW Fisheries and the Fisheries Research and Development Corporation (FRDC), this three year project has as one of its aims, to help develop guidelines for the design and management of floodgates and drainage systems, by opening a number of floodgates and recording changes in invertebrate and juvenile fish populations in the drains above them compared to natural ungated creeks in the same areas.

Water quality and habitat characteristics were recorded, and fish and invertebrates were sampled using seine nets at 13 sites from Brushgrove and the upper Coldstream River to Thorny Island near Yamba. Only fish juveniles were targeted, as these were considered the most important life stage for this project, and can be caught quickly and effectively with small haul seine nets.

Sites consisted of three categories:
- Five control sites at natural ungated creeks,
- Six experimental floodgated sites which were fitted with winches to allow the gates to be lifted,
- two floodgated sites that were left closed.

All eight gated sites were left closed for the first six sampling trips to provide us with a year of data on unmanaged floodgates, after which time it was planned for the six experimental gates to be regularly opened by the landowners as often as they could. This was usually done for an hour or two at the start of the run in tide.

Sites were sampled every two months, the final visit being in May of this year.

Preliminary results

The results presented here are based on the first half of the study data only. The final report is due at the end of this year.

During the first half of the study, on average five times the number of fish and crustaceans were caught at control sites compared with closed sites, with catches at the experimental sites being 50% greater than closed sites (figure 1).

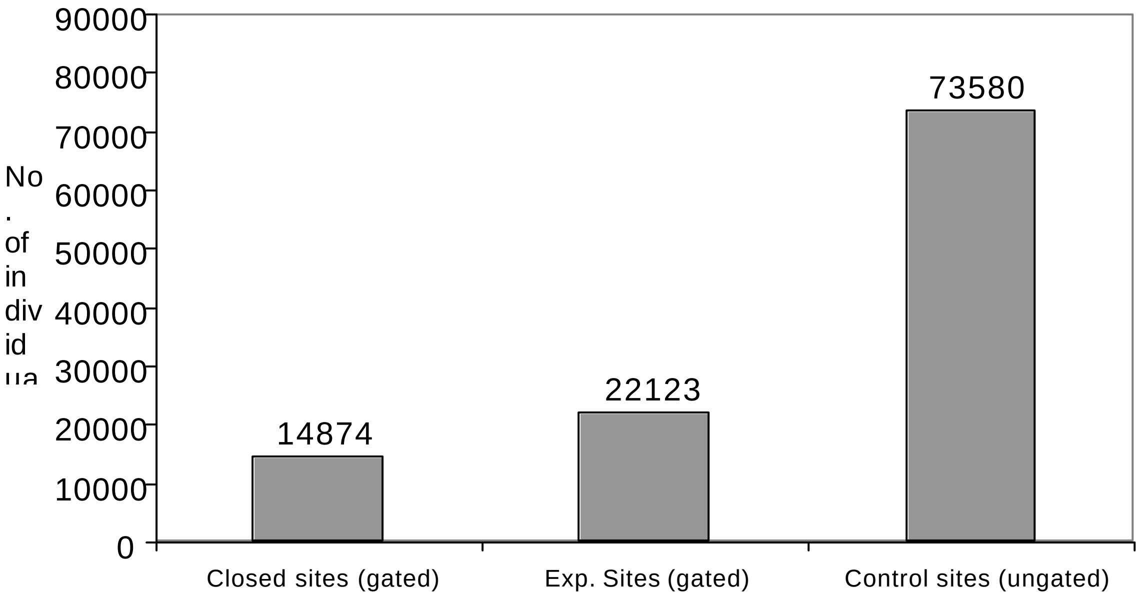


Figure 1. Average number of fish and crustacean individuals caught per site during all trips from July 2000 until September 2001, grouped by site category.

Other invertebrates have been excluded from these figures to highlight the fish and crustacean numbers.

There were delays in getting the winch equipment fitted to several of the experimental gates, so at this stage the catches from these sites still closely resembled the closed site numbers.

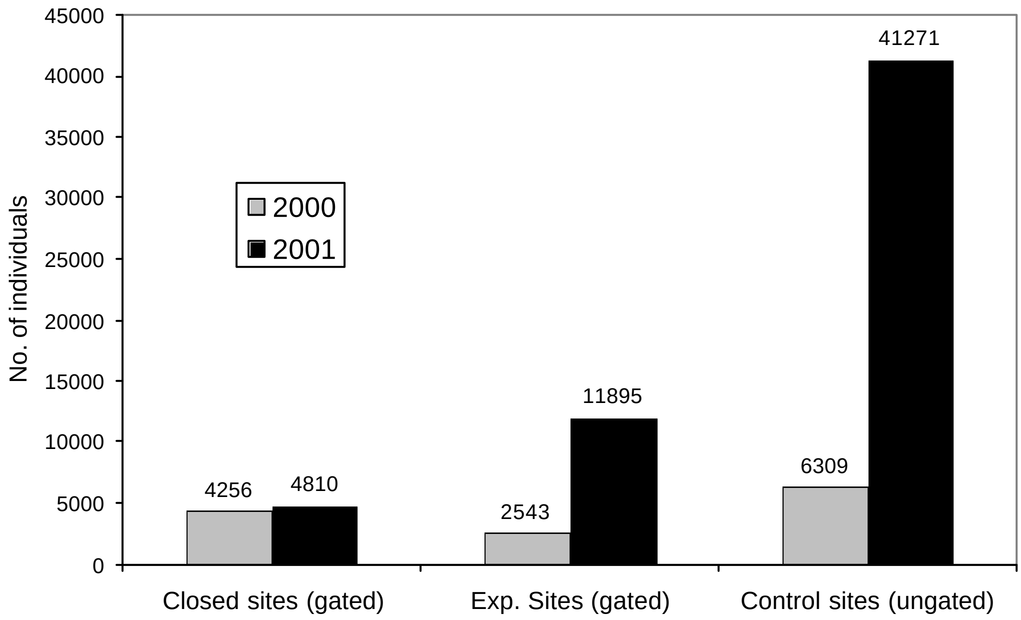


Figure 2. Average number of fish and crustaceans caught per site (July and Sept only, 2000 & 2001), grouped by site category.

Catch numbers were compared between the same two months 12 months apart, as at this stage we only had duplicate data from July and September trips (figure 2). There was a huge difference in the catches at the ungated control sites between the two years, a natural occurrence probably due mainly to increased recruitment following the flood event in early 2001.

The catches at closed sites remained virtually the same during these two months from one year to the next, but the experimental site catches appear to mirror on a smaller scale the control sites, with catches nearly five times greater the second year.

As stated previously, these results are based on preliminary data only, but hopefully show trends that will be validated with the analysis of the full data set.

Individual species catches were also compared between two sites close together, one gated and one ungated (figure 3).

The first paired columns show differences between the catches during the first 6 visits when the gated site remained closed. The natural site had large numbers of juvenile commercial species such as bream, mullet and prawns, as well as huge numbers of small shrimp compared to the gated site, and odd other commercially and recreationally important species such as tailor, trevally, tarwhine and flathead. At the gated site, large numbers of the primarily freshwater species of gudgeons and introduced gambusia mosquitofish were found.

The second paired columns show the catches at the first visit after the gate was opened. This time good numbers of bream and sea mullet were found in the gated site for the first time, as well as a big catch of small shrimp, relatively absent from all previous gated site catches.

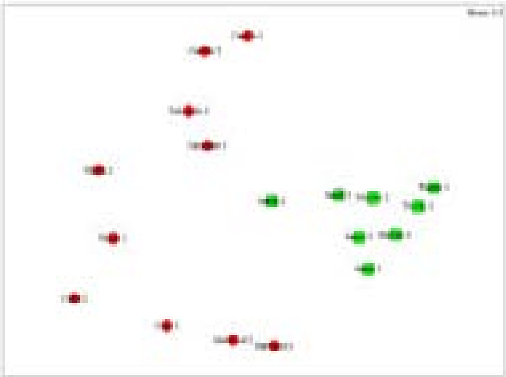
	July 2000 - July 2001 (6 visits)		Sept 2001 (1 visit)	
	Stranges (gated)	**Morroro Ck (ungated)**	**Stranges (gated)**	**Morroro Ck (ungated)**
blackfish			2	
blue-eye	481	708	63	4
bream	4	193	95	4
dumpling squid		4		
eels	4			
flathead		1		
flat-tailed mullet	1	1152		24
flounder		1		
fortescue		3		
gambusia	3834	5	9	
garfish		22		
glassfish		1065	20	8
gobies	2353	1099	560	79
gudgeons	12676	153	4632	47
herrings		7		
leatherjacket			1	
olive perchlet	36	15	5	
other est. fish		109		5
prawns	31	2870	2	389
sea mullet	6	226	210	
shrimp	75	58822	13343	845
tailor		2		
tarwhine		9	1	1
trevally		1		
Total	**19501**	**66467**	**18943**	**1406**

Figure 3. Selected fish and crustacean species changes within a managed gated site. Prawns grouping consists of predominantly school prawns; shrimp grouping is dominated by the common *Acetes* shrimp; gudgeons consist of mainly empirefish, striped and flathead gudgeons; and gobies are mainly blue-spot and Tamar River species.

Final results

Analysis on the full data set has recently commenced, results so far indicating distinct community differences between non-gated, unmanaged gated, and managed gated sites (figure 4.) The four upper catchment gated sites have been omitted from this analysis due to their being dominated by freshwater species.

The closer the symbols are together, the more similar are the communities. Before opening of the gates, the non-gated sites are all very similar to each other, but different from the gated sites. After opening, there is an even greater difference between the non-gated and unmanaged gated sites, with the communities at the managed gated sites falling between the two other groups.



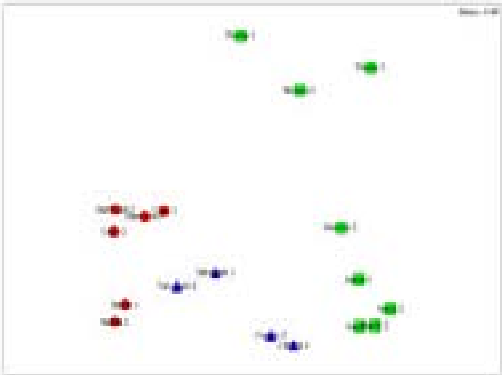


Figure 4. Non-metric multi-dimensional scaling (nMDS) ordinations of species assemblages for 9 sampling locations in the Clarence River floodplain, before (left), and after (right) opening of floodgates. The ordinations are based on log (x+1) transformed abundances and Bray-Curtis similarities. Squares are non-gated drainage systems, circles are floodgated drainage systems (un-managed), and triangles are floodgated drainage systems (managed).

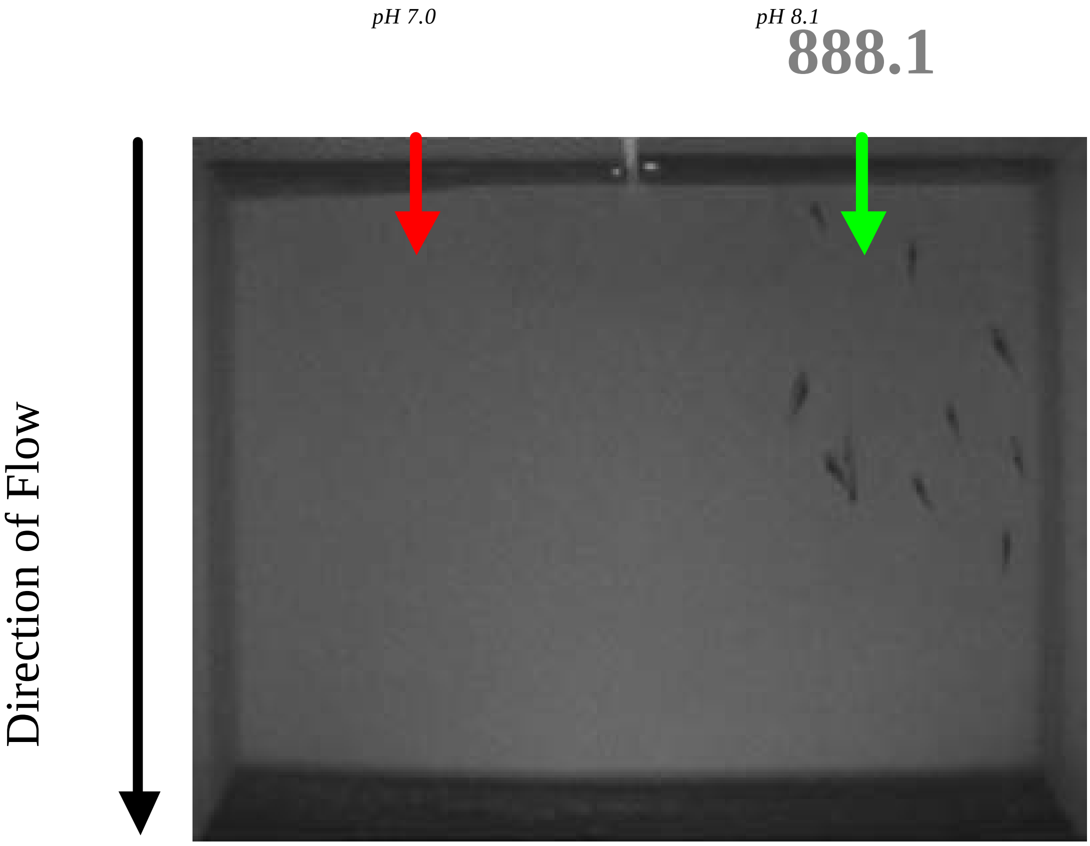
b) Raceway experiments

Experiments are also being run at Port Stephens to see if juvenile fish and prawns avoid low pH water and therefore limit their choice of nursery habitat. Trials of hatchery bred snapper, wild bream, bass and school prawns are continuing.

The raceway was set up with two parallel streams of the same water, one with sulphuric acid added to lower the pH, and the behaviour of the fish and prawns was observed.

Preliminary results for snapper indicate that lowering the pH to only 7 from the natural seawater pH of 8.1 causes them to avoid the lower pH side 95% of the time (figure 5).

Snapper juveniles do not usually venture as far into estuaries from the ocean as the other three species investigated, so it is understandable that they may have less tolerance to minor pH changes. So far it appears that the other two fish species avoid water below pH of about 6.



Summary

Much analysis remains to be performed on the data, but several points are becoming apparent:

- As previously discovered, aquatic communities seem to be very different between unmanaged gated and non-gated systems.
- Floodgates act as an effective barrier to most estuarine fish and crustaceans.
- If floodgates are opened regularly, juveniles of estuarine fish and prawns, including commercial and recreational species, are likely to move into the drains looking for food and shelter.
- Communities within gated systems may quickly revert back to their previous state if gates are not opened regularly.
- Given a choice, juvenile fish may avoid entering water with pH only marginally lower than normal, possibly limiting their choice of nursery habitat.

Preliminary conclusions

Manually operated floodgates can allow fish passage, but need to be opened regularly to be effective, therefore automatic gates need to be investigated further.

As stated earlier, by definition an effective fishway should be able to pass at least 95% of all fish species and individuals attempting to get past the barrier, and operate in at least 95% of the likely flow conditions. Floodgates in tidal situations can allow fish and invertebrates to passively drift through the open gate on an incoming tide, without having to fight a strong current flow, but some species may prefer only to enter against a mild flow, not with it. A large opening speeds water exchange and reduces the velocity of water passing through it, allowing fish with lower swimming ability to negotiate the barrier. The most effective gate design needs to consider the needs of all species likely to be present.

Research from freshwater fishways show that some species prefer to move at night, some during the day, some on the surface and some along the sides and bottom of a channel, so an effective design for floodgates probably needs to address all of these different strategies by being as open as possible to allow in plenty of light, and have an opening that covers as much of the water column as possible.

Higher salinity water is more effective at buffering acid discharges than fresher water. As this water is also more dense and may form a salt wedge at the bottom of the water column, it makes sense for water quality improvement also to have gate openings as close to the channel base as possible.

Tidally operated floodgate modifications of various designs are appearing and being installed in various locations around NSW and across the country. At present, their effectiveness at allowing fish passage is unknown apart from occasional observations of surface fish. It is important that the different designs are investigated now and the most effective design possible is widely utilised before too many gates of inferior design are installed.

The most effective gate for fish passage is of course no gate at all, and in some situations it may be possible to remove the barrier altogether.

Once juvenile fish and crustaceans have got past the floodgate, can they survive and grow to eventually recruit into the adult populations? The answer depends mainly on the two factors of water quality and habitat, which in turn affect the food sources that will be available to the juveniles. Water quality should be improved greatly with the regular opening of the floodgate, but habitat improvement is not so easy. If possible, riparian vegetation especially mangroves should be encouraged to establish in places on at least the northern or western side of a drain to provide shade and habitat.

Although having the potential to supply useful substitute nursery habitat for fish and invertebrates, it is unlikely that many flood mitigation drainage systems in their present form would provide optimal conditions. The number of natural mangrove creeks and estuarine swamp systems in many NSW estuaries have been dramatically reduced, and the possibility of re-establishing large natural wetland reserves probably needs to be investigated closer if major improvements to the fish stocks of NSW estuaries are to happen.

References

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16. Research findings – hydrology

Floodgate and drainage system management: opportunities and limitations. An acid export perspective.

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Abstract

Active floodgate management is being promoted as a means of improving export water quality from coastal floodplain drains. While there are opportunities to improve in-drain water quality through floodgate opening, limitations and complexities exist, particularly in acid sulfate soil (ASS) backswamps. Results from field based short duration floodgate opening experiments are examined in this paper. Opening floodgates can improve in-drain water quality through dilution, exchange and neutralisation, but is often followed by relatively rapid reversion to pre-opening conditions following gate closure. Trials have also demonstrated short duration floodgate opening may, in certain circumstances, increase the export of acidity by recharging the near drain groundwater zone during the opening phase, followed by gate closure and discharge of near-drain ASS groundwater back into the drainage system. Such effects are the result of complex interactions between site specific variables and suggest that meaningful reductions in acid export via short duration floodgate opening may be difficult to achieve without intensive management and a clear, *site specific* understanding of dominant acid export processes and pathways.

Opening floodgates may alter mean longitudinal drain water gradients, reducing net drainage rates or causing net inflow and slowing the rate at which water is removed from floodplain storage basins. Floodgate opening induced tidal overtopping of saline water is a significant agricultural risk in low elevation ASS backswamps and is a major impediment to prolonged floodgate opening in these systems.

In many drained coastal acid sulfate soil backswamps, acid export is dominated by groundwater flows, in turn influenced by local groundwater gradients and the hydraulic conductivity of adjacent ASS soils. Results indicate that in ASS backswamps there is a site specific groundwater elevation range within which most acid groundwater transport occurs. This range can be defined by topography and tidal minima. Reducing groundwater seepage rates when the backswamp water level is in this elevation range via in-drain water retention structures is likely to be far more effective at reducing acid export than floodgate opening alone. Strategic placement of in-drain structures such as weirs, drop-board culverts or penstocks combined with

opportunistic floodgate opening may be an effective means of manipulating groundwater water gradients, containing shallow acidic groundwater and reducing acid export from ASS backswamp systems.

Introduction

Thousands of square kilometres of coastal floodplains in NSW are underlain by acid sulfate soils (ASS) (Naylor *et al*, 1995). In many coastal floodplain backswamps the sulfide layer is close (~1m) to the ground surface (Rossicky, 2001) with relatively thin fluvial capping (Walker, 1972) and large reserves of actual acidity are contained in the upper soil profile and shallow groundwater. There has been extensive alteration of coastal floodplain hydrology through drainage and flood mitigation works since European occupation (White *et al*, 1997; Tulau, 1999). It has been demonstrated that floodplain drainage systems, particularly those in ASS backswamp landscapes, can export large amounts of acidity and other sulfide oxidation products to the estuary (Sammut *et al*, 1996; White *et al*, 1997; Blunden et al, 1999; Cook et al, 2000a; Johnston *et al*, in press). Effective land or drainage management changes aimed at reducing this export of acidity require clear understanding of drainage systems and their role in both receiving and rapidly transporting acidic products to adjacent estuarine systems.

A number of studies have led to the development of management techniques and principles aimed at reducing the drainage export of sulfide oxidation products (White *et al*, 1997; Blunden *et al*, 1999; Cook *et al*, 1999). Strategies for managing existing soil and groundwater acidity can be grouped under four main categories; containment, dilution, neutralisation or transformation (Atkinson and Tulau, 1999). Active floodgate management is essentially an in-drain dilution and neutralisation technique based on allowing periodic tidal exchange back into the drainage system behind what are normally one way tidal exclusion barriers.

While active floodgate management is being promoted as a potential tool for improving drainage system export water quality (Slavich and Chin, 1999; Haskins, 1999) there has been relatively little published field based research into it's effectiveness to date. There is a need to evaluate the effects this strategy may have upon in-drain water quality and the processes responsible for transport of acidic products from the soil and shallow groundwater into drainage systems and estuaries. The effects of active floodgate management upon drain water quality, acid export, shallow groundwater hydrology and floodplain agriculture are being assessed through research on the Clarence River floodplain. Some preliminary results from short duration floodgate openings are examined in this paper.

Methodology

Study Areas

The two study areas are Blanches drain & Maloneys drain, both on the lower Clarence River floodplain (Fig. 1). The Clarence River is the largest coastal catchment in NSW and the floodplain below Grafton is 2,620 km^2 and underlain by an estimated 530 km^2 of high risk acid sulfate soils (Tulau, 1999). Blanches drain is located on Everlasting swamp and Maloneys drain is located on eastern Shark Creek (Fig. 2). Both Everlasting swamp and the Shark Creek floodplain basin are Holocene sub-embayment infills (Sullivan and Lin, 1999) and contain large areas of low elevation (<0.2 m AHD) drained ASS backswamp.

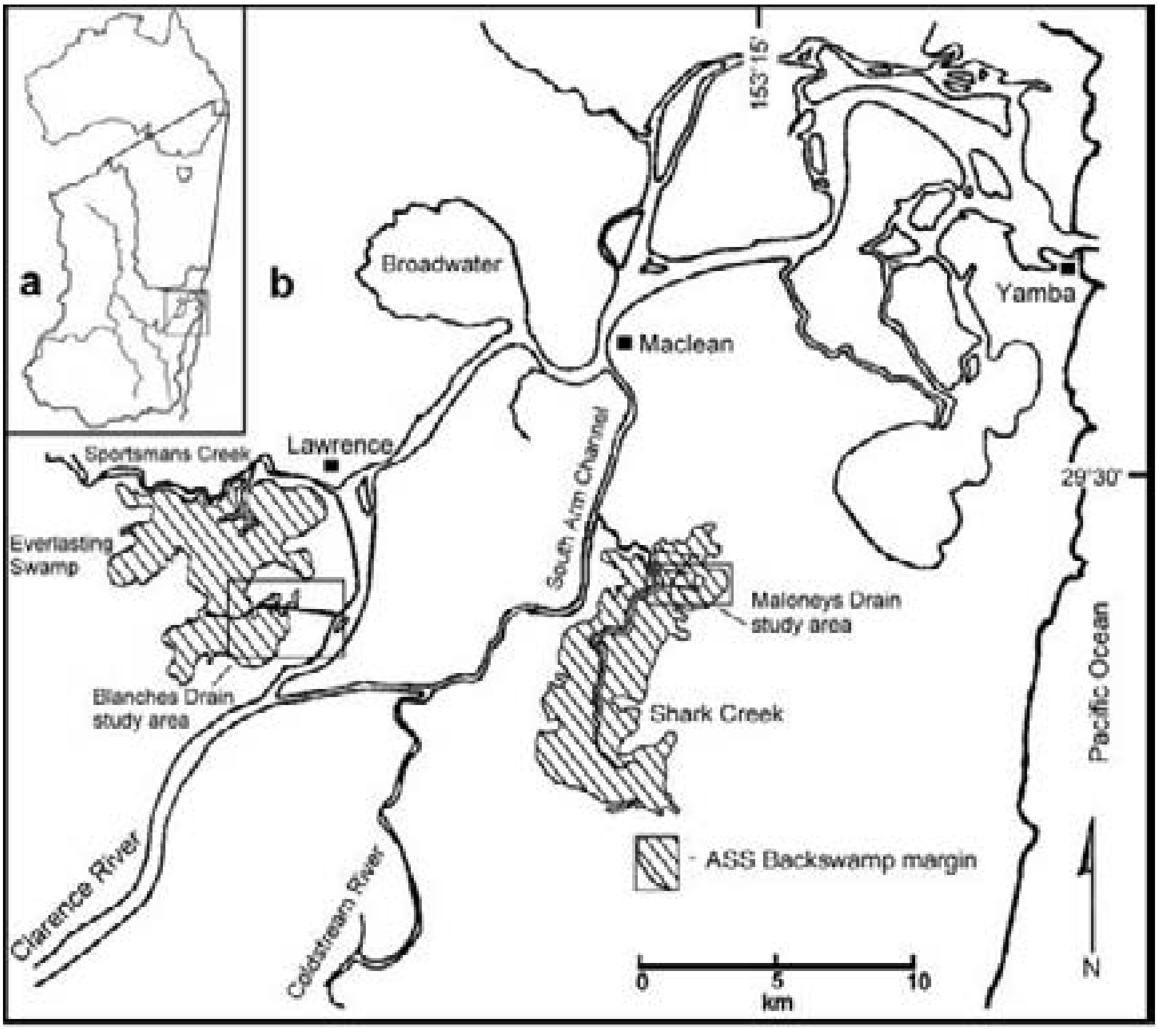

Fig. 1. a) Clarence River catchment and b) lower floodplain study site locations and associated ASS backswamps [A] ([A]Milford 1997).

Drainage System Water Quality

Hourly measurements of dissolved oxygen, pH, Electrical Conductivity (EC) and temperature were made with Greenspan CS304 submersible data loggers (SDL). Two SDL's were installed in each drain about 0.3m below minimum low tide level, one near the floodgates and one near the backswamp margin (Fig. 2). SDL's were cleaned, maintained and calibrated every 28-32 days. Spot measurements of in situ drain water dissolved oxygen, pH, EC, Temperature and Eh were recorded at the time and location of sample collection using freshly calibrated portable field equipment. Drain water samples were collected immediately upstream from the floodgate culverts and at the backswamp SDL on a regular basis during export events with higher sampling frequency according to outflow volumes. Sampling was timed to coincide with tidally influenced outflow periods where possible to ensure accurate representation of outflow water. Samples were analysed for a number of parameters including titratable acidity, total and dissolved Fe and Al, Chloride and Sulfate (APHA, 1995).

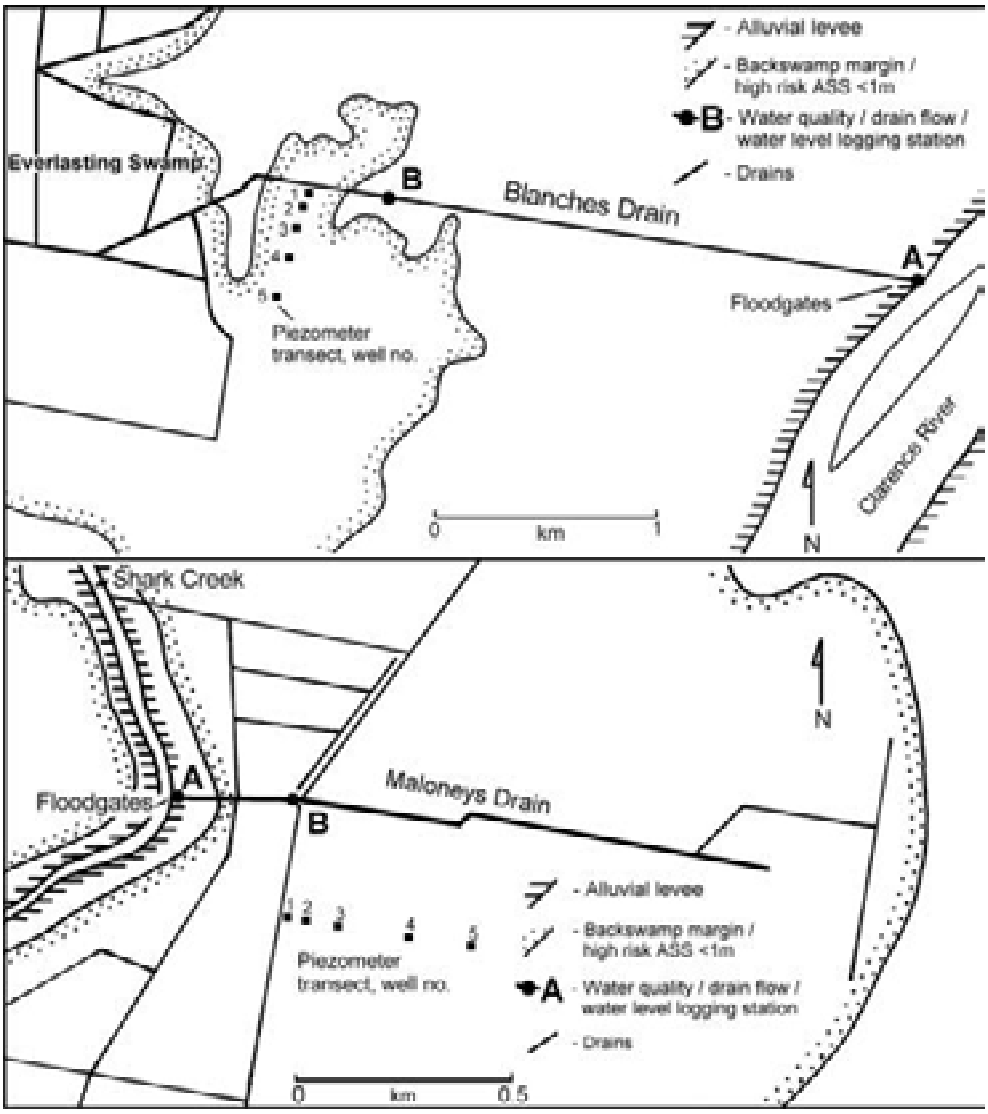

Fig. 2. Blanches and Maloneys study sites, showing the location of submersible data loggers / flow / drain water level monitoring stations (A-B), piezometers, drains, floodgates and ASS backswamp[A] margin ([A]Milford 1997).

Discharge and Flux estimates

Drain flow velocity was measured using a Starflow Doppler sensor (located at the drain floodgate culvert) with a velocity range of 0.021 $msec^{-1}$ to 4.5 $msec^{-1}$ and a factory reported accuracy 2% of measured velocity. Drain culvert dimensions and Starflow sensor location were surveyed to AHD. Cross checks undertaken using a calibrated current meter in the Doppler field of view under a range of flow conditions (>1 to ~0.1$msec^{-1}$) yielded flow velocities within +/- 10% of Doppler sensor. Daily drain discharge (Q_d) was calculated using $\Sigma Q_h = V_h * A_h$; where V_h = mean hourly flow velocity,

A_h = mean hourly cross-sectional area of water in culvert. Daily estimates of acid and other sulfide oxidation product export were made using discharge and drain water chemistry data.

Drain and groundwater levels

Drain water level measurements were logged every hour immediately inside and outside the floodgates and near the backswamp margin using a Dataflow capacitance probe and 392 logger (accuracy +/- 0.01 m) housed within a 0.05 slotted PVC pipe and surveyed to AHD. Groundwater levels were monitored on an hourly basis using identical equipment in a series of 5 piezometer wells located in the ASS backswamp perpendicular to the drain (Fig. 2). Full calibration and maintenance of probes was undertaken every 60 to 90 days.

Soils

A detailed morphological description (McDonald *et al*, 1998) of the backswamp soils to a depth of at least 1.5 m below ground surface was undertaken at each piezometer well site, which was surveyed to AHD. Samples taken at 0.2 m depth increments from representative profiles (Everlasting swamp n=8, Shark Creek n=3) were analysed for Total Actual Acidity (TAA) (Ahern *et al*, 1998; Lin *et al*, 1999) and reduced inorganic sulfur species (S_{Cr}) (Sullivan *et al*, 2000), pH, EC, Chloride and Sulfate (Rayment and Higginson, 1992).

Results and Discussion

Soils and backswamp surface morphology

The soils at both sites are ASS, with a 20-30cm organic rich surface horizon underlain by sulfuric horizons with iron and jarosite mottling. The ground surface elevation at both piezometer transects ranged from ~0.2 to 0 m AHD and the sulfide layer at both sites was approximately 0.8-1.0 m below ground surface. The reduced inorganic sulfur content in the upper 0.6m of the sulfide layer at both sites was around 2% (S_{Cr}). Both sites showed low soil pH (3-4) in the oxidised sulfuric horizons above the sulfide layer. Mean profile TAA results were depth integrated to yield an estimate of total actual acidity per hectare, with Maloneys about three higher at 81 tons $H_2SO_4^{2-}$ ha^{-1} compared to 25 at tons $H_2SO_4^{2-}$ ha^{-1} at Blanches.

Dilution, Neutralisation and Exchange

The primary initial effect of opening floodgates is to allow influx of estuarine water and the processes of dilution, neutralisation and exchange to take place. Seawater has a neutralising capacity in the vicinity of 2 mmol l^{1} and estuarine water is often much less depending on the degree of dilution with upper catchment water and catchment geology. This influx may result in raising of drain pH via acid neutralisation and dilution (Fig. 3), raising dissolved oxygen levels (Fig. 4) or moderating extreme diurnal fluctuations in dissolved oxygen resulting from in-drain photosynthesis / respiration cycles. Other effects include alteration of salinity regime to more closely reflect temporal estuarine dynamics and moderation of daily temperature extremes.

Analysis of over 17 individual floodgate opening events ranging from 1 to 7 days duration shows a number of emerging patterns;

1. Generally an improvement in logged in-drain water quality (pH, DO) during the opening event.

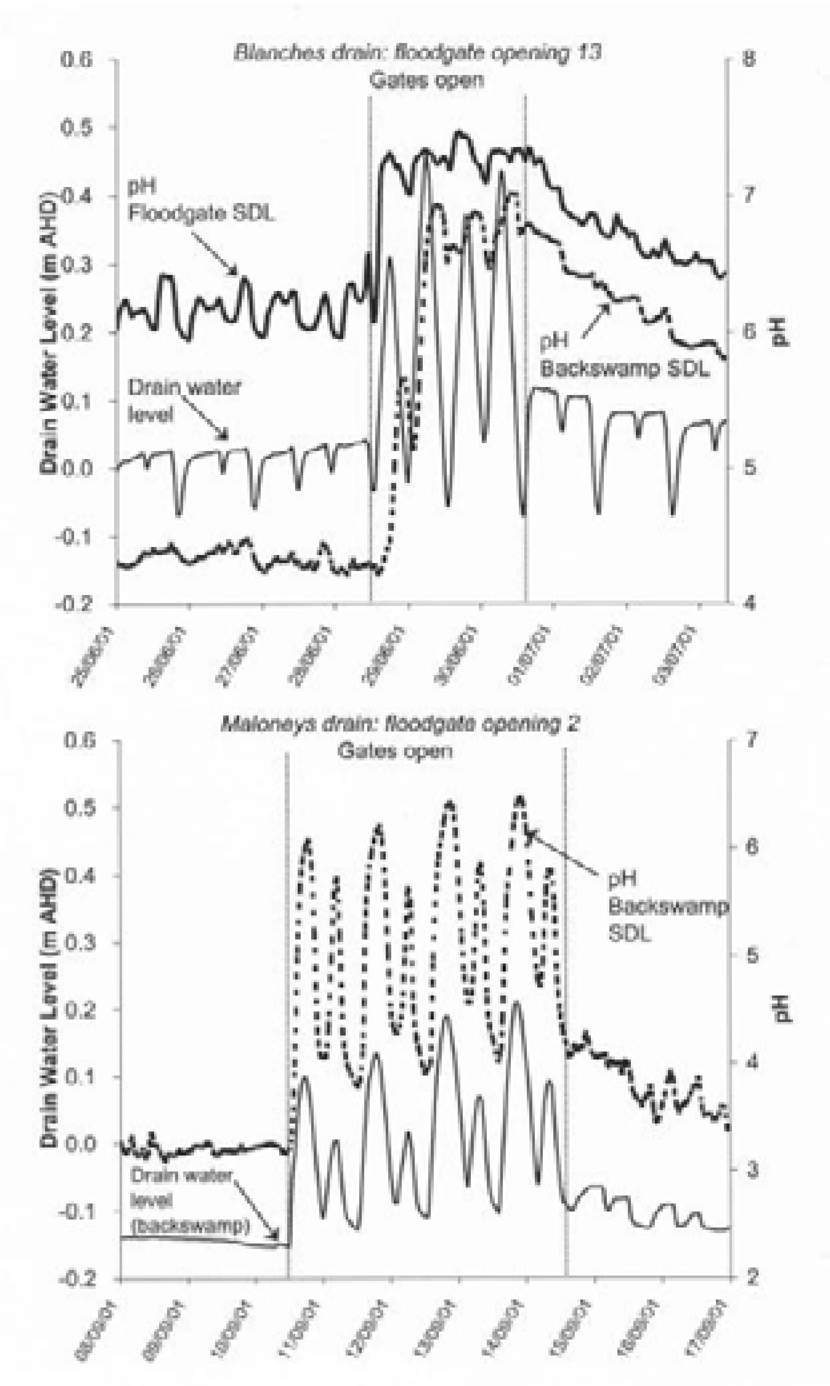

Fig. 3. Changes in drain water pH and drain water level associated with floodgate opening events. Blanches gate opening 13 and Maloneys gate opening 2.

2. The magnitude and spatial extent of improvement due to opening is largely dependent on the interaction between both the volume and quality of drainage outflow water and in-flowing estuarine water.

Increasing lag times and attenuated extent of improvement with increasing distance from the estuary are common features as are partial mixing and ‘slug’ displacement.

3. There is relatively rapid (hrs to several days) reversion of in-drain water quality to pre-opening conditions following gate closure (Figs. 3 and 4).
4. Changes occur within the context of highly dynamic and variable systems and opening induced improvements are not always clearly evident.

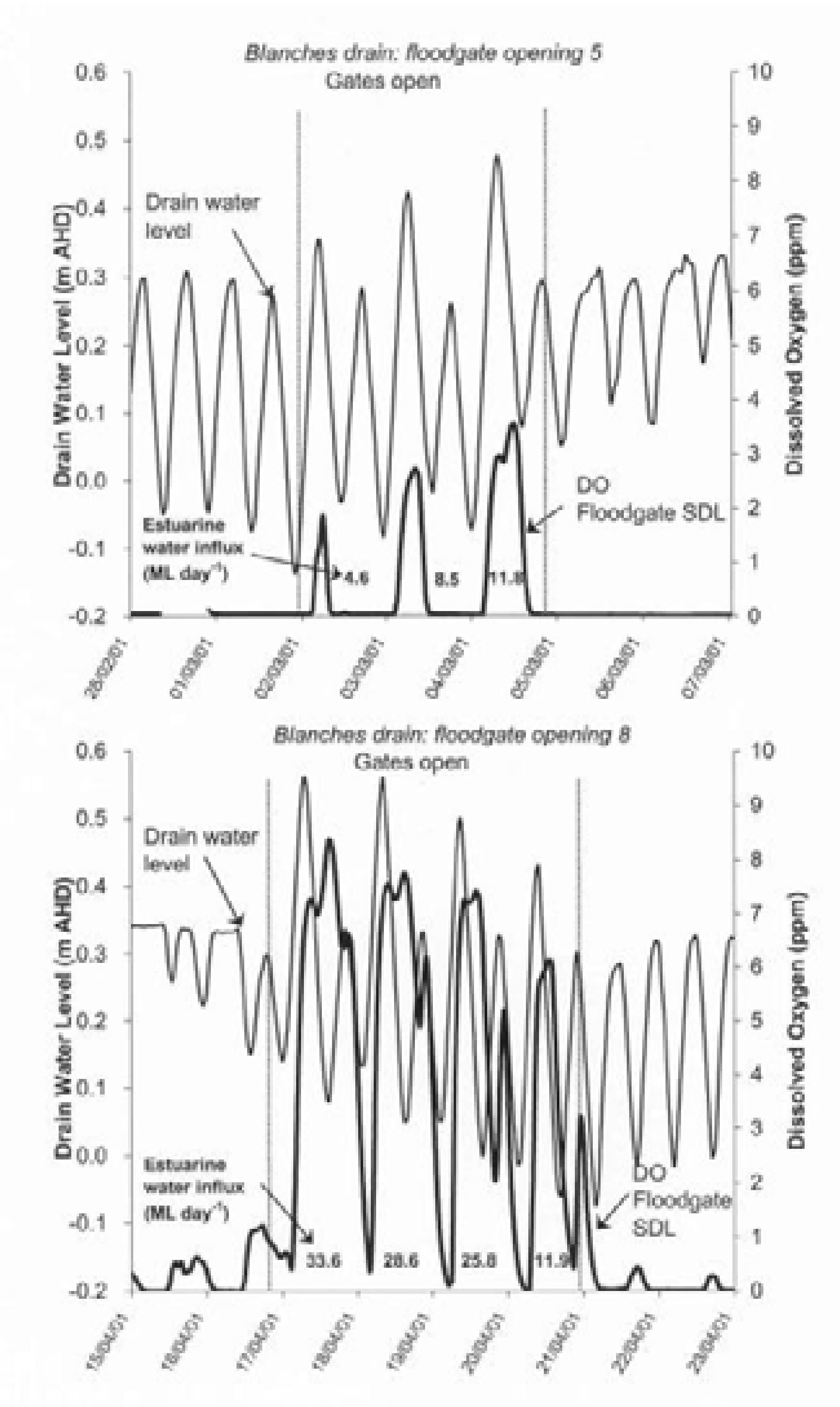

Fig. 4.Changes in drain water DO and drain water level in relation to influx volume of estuarine water (ML day^{-1}) during floodgate opening phase. Blanches drain opening 5 and Blanches drain opening 8.

Many chemical, biological and seasonal factors influence key water quality parameters such as pH and dissolved oxygen (Stumm and Morgan, 1970) and in a number of instances the observed change that may be attributable to short duration floodgate opening is statistically indistinguishable from background variation. Broadly speaking, the extent and persistence of improved in-drain water quality will be largely dependant upon the frequency, magnitude and duration of floodgate opening. Short duration openings, even with large influx volumes (Fig 4), often appear to bring about relatively short lived effects. Research into the effects of smaller volume, but longer duration openings is in progress.

Enhancing Acid Export

While improvements to in-drain water quality may occur during the floodgate opening period, under certain circumstances short duration floodgate opening has the potential to enhance the export of acidity from the drainage system. Detailed monitoring during a floodgate opening event in Maloneys drainage system demonstrated this can occur. The following outlines the sequence of events and key features associated with this opening enhanced export. Figures in brackets are derived directly from the Maloneys system.

1. Groundwater in backswamp ASS close to the minimum ebb tide influenced drain water level [-0.2m AHD]. Limited opportunity for effluent groundwater gradient to develop and minimal seepage of groundwater to drainage system occurring.

2. High hydraulic conductivity (K) soils in upper 1m of backswamp ASS profile [~19m day^{-1}]. Shallow acidic groundwater rich in sulfide oxidation products.

3. Development of influent groundwater gradient during flood tide cycles of the floodgate opening phase. Recharge of groundwater in near drain zone [by ~0.12m at 10m] (Fig. 5) to a point *above* minimum ebb tide drain water level. Dilution of shallow groundwater with influx water occurring in the first few meters adjacent to the drain, alteration of shallow groundwater chemistry (Fig. 6).

4. Gate closure and development of effluent groundwater gradients and groundwater seepage into the drainage system on ebb tide cycles. Transport of sulfide oxidation products with this seepage water and relatively rapid (several days) reversion of near drain shallow groundwater chemistry (Fig. 6).

During this opening event there was a net influx of about 28 ML of estuarine water and groundwater levels rose in relation to tidal influence across the backswamp, up to ~300 m from the drain, even though there was no direct surface overtopping. While much of this rise may be attributable to pressure transmission (tidal forcing) across the aquifer (Sun, 1997; Hughes, 1999), altered shallow groundwater chemistry (Fig. 6) show there was appreciable dilution of shallow groundwater with estuarine influx water in at least the first few meters adjacent to the drain.

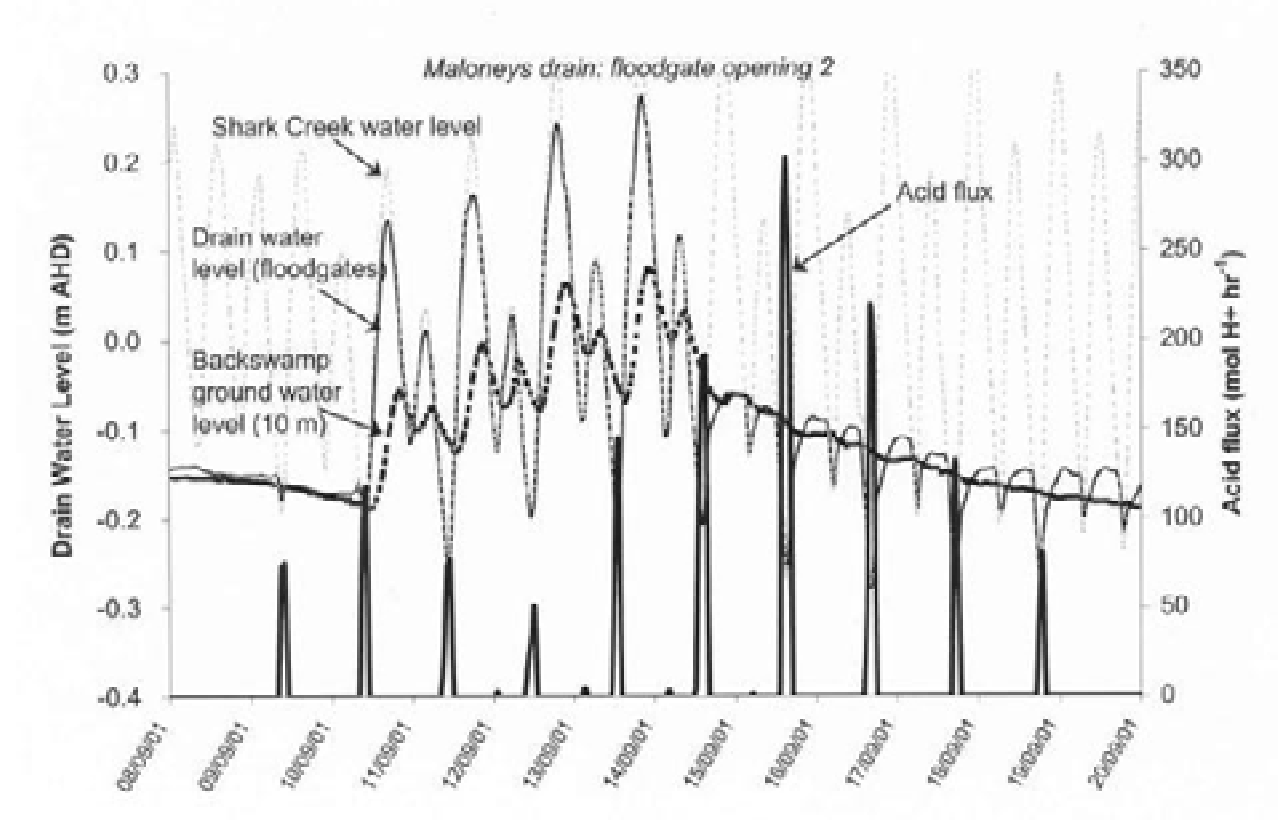

Fig. 5. Changes in estuary water level (outside floodgates), drain water level (inside floodgates), ground water level (backswamp – 10m from drain) and acid flux associated with Maloneys floodgate opening 2. Note recharge in near drain ground water during opening phase followed by draw down and enhanced acid export after floodgate closure.

While the actual amounts of acidic products exported following this opening event were quite small (max ~770 mol H+ day^{-1}) it demonstrates the *principle* of near drain zone recharge followed by seepage of ASS groundwater back into the drainage system associated with a short duration floodgate opening event. The potential for such an interaction to occur in any given system will depend on a number of factors including;

a) The chemistry of both the shallow groundwater and estuarine influx water.

b) The degree to which the near drain water table is raised *above* the minimum low tide level experienced in the backswamp ASS section of the drainage network.

c) The hydraulic conductivity (K) of the adjacent ASS soils, particularly in the sulfuric horizons.

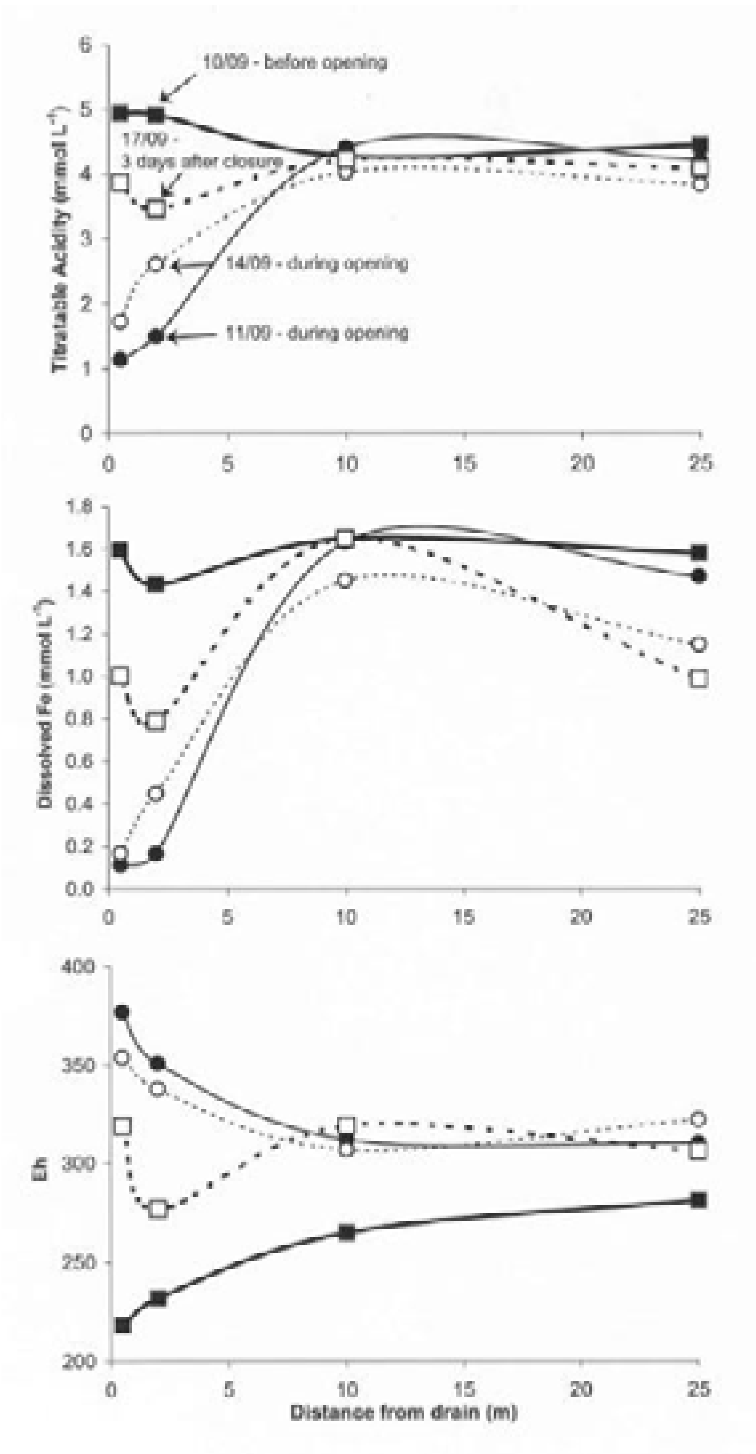

Fig. 6. Changes in shallow[A] ground water chemistry (Titratable acidity, dissolved Fe and Eh) in near drain zone (0-25m) associated with Maloneys floodgate opening 2. Note dilution in first few meters during opening phase and recovery soon after floodgate closure. [[A] <0.6 m below ground surface].

The hydraulic conductivity of ASS is a particularly important factor influencing the dynamics and rates of groundwater seepage into adjacent drainage systems (Cook *et al*, 1999). While the texture of the backswamp ASS at this site is predominantly silty clay and would be expected to have quite low hydraulic conductivity (Boulding, 1995), the existence of a significant macropore network (dominated by relic root channels and bio-pores) means this site has relatively high K soils. Observations made during pit and bore hole excavations revealed large numbers of macro-pores (some >20mm diameter) extending down into the sulfide layer. The macropore network displays high connectivity in the horizontal plan and is capable of transmitting large volumes of groundwater to the drain under relatively small head pressures. Pore count surveys at this site revealed >120 per m^2 of readily visible (>2mm diameter) tubular macro-pores on drain side seepage faces in the 0 to -0.2 elevation range, with approximately 25% of these >10mm diameter. Pores were coated in ferric iron and direct seepage rate measurements on large (~20mm diameter) pores showed them capable of continuously discharging groundwater at around 0.03 L sec^{-1} under approximately 0.1m head pressure. Pore discharge rates were maintained even after yielding many tens of litres of water in seepage rate experiments and individual pore water chemistry showed little variation over the duration of measured discharge. Both these results suggest high pore network connectivity.

An identical opening event at a similar site, but one with low hydraulic conductivity ASS, and / or a relatively high and stable drain water level with low tidal amplitude *after* floodgate closure would likely result in far less acid groundwater seepage into the drainage system. The principles in operation are only transferable within context of the individual site characteristics.

Reducing Net Discharge

Opening floodgates can also reduce the net drainage rate or cause net influx of estuarine water by reducing and potentially reversing mean the longitudinal drain water gradient. This is demonstrated at Blanches drain (Fig.7) with large openings clearly capable of causing significant influx and alteration of the mean longitudinal drain water gradient. Slower drainage rates will enhance the retention time of water in floodplain storage basins increasing the potential for evaporative efflux rather than drainage. However, this effect will largely be confined to the floodgate opening period and may be of limited overall significance in context of short duration floodgate opening events.

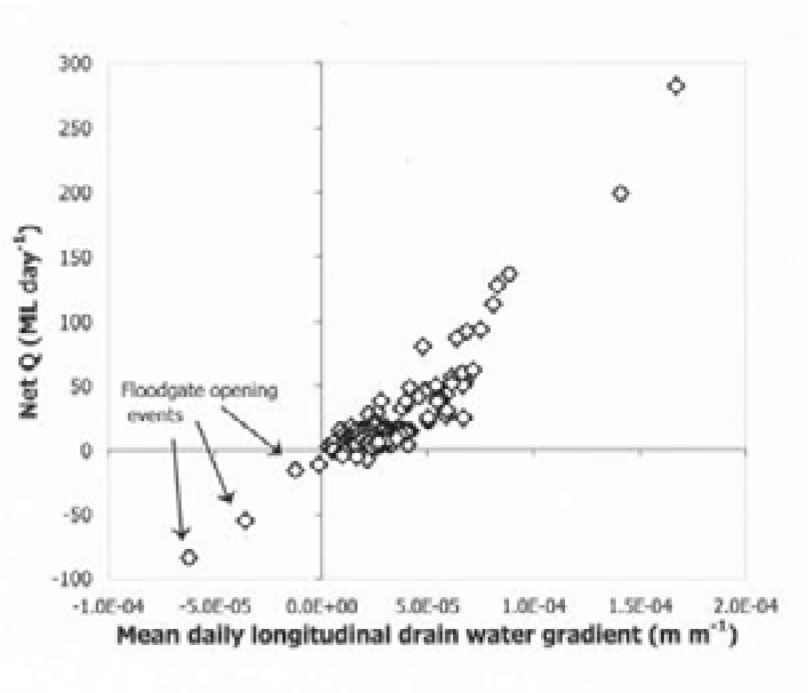

Fig. 7. Relationship between net daily discharge (Q) and mean daily longitudinal drain water gradient, Blanches drain. Note; negative values of Q associated with net influx due to floodgate opening events.

Impediments to floodgate opening

One of the key impediments to a higher frequency, magnitude and duration of floodgate opening events is the risk of saline overtopping in adjacent land used for Agriculture. This is most relevant to low elevation ASS backswamps, which represent some of the most significant acid exporting landscapes on NSW floodplains. Low elevation ASS backswamps such as Blanches and Maloneys are up to >0.6 m *below* spring tide maxima experienced at their floodgates. Thus there is ample opportunity for tidal overtopping to occur. Estuarine water with high marine salt concentrations is relatively common at both study sites. Many low elevation ASS backswamps in NSW are in a similar relative topographic/tidal maxima context, depending on their location and local estuarine tidal dynamics. Extensive periodic migration of the salt wedge is a common feature on all Northern NSW estuaries due to the highly seasonal rainfall distribution. Tidal forecast charts are one of the main management tools currently used by land holders to manage the risk of overtopping ie; by opening gates during neap tide phases only. However, tidal anomalies are a relatively common feature on the NSW coastline and may lead to ocean tides in excess of >0.5m above predicted. This combination of features has significant implications for floodgate management. Higher frequency and duration of floodgate opening within the current Agricultural land use context on low elevation ASS backswamps is only likely to occur when there is a high degree of surety in water level control. This can be partly achieved through types of opening device such as sluice gates and mini-tidal gates plus also secondary retention / exclusion structures that may allow saline tidal water to be confined to sections of the drainage system with high sides.

Acid export prevention: Containment in profile

While the in-drain dilution and neutralisation associated with floodgate opening may provide water quality benefits, it is unlikely to cause a significant reduction in acid export loads from chronically discharging ASS backswamps. This is because *by itself* it is unlikely to prevent shallow groundwater seepage, which is the most significant pathway via which acidity is transported to drains. In many ASS backswamps, most export of acidic products is occurring via groundwater directly seepage directly into drainage systems (Sammut *et al*, 1996; Blunden *et al*, 1999; Cook *et al*, 2000b; Johnston *et al*, in prep). While this generally represents a small component of the overall water balance, the concentration of acidic cations in this groundwater, particularly ferrous iron and aluminium, is often very high (Cook *et al*, 2000b). For example at Maloneys in 2001, more than 80% of the total acid export discharged with only 13% of the total outflow volume. Most of this export took place *after* surface water had preferentially drained from the site. A more effective strategy for minimising acid export would involve containing the shallow acid groundwater within the backswamp landscape, preventing it from being transported to drainage systems in the first place.

The rate at which shallow ASS groundwater is transported to the drainage system per unit area of drain bank depends largely upon the hydraulic conductivity of the adjacent ASS and magnitude of the effluent groundwater gradients. In sites with high K, such as Maloneys drain, the rates of lateral seepage to the drain, particularly via macro-pores, can be quite significant even with small gradients. The magnitude of the effluent groundwater gradient at this site is strongly affected by the water level in the drain adjacent to the ASS. In turn, this is influenced by the local estuarine tidal dynamics and the magnitude of tidally related drain water level draw down during the ebb tide phase (Johnston *et al*, in prep).

Acid flux estimates from the Maloneys drainage system suggest there is a relatively narrow elevation range within which most of the acid flux is occurring (Table 1). Data shows ~80% of the total export flux of acidity occurred while the backswamp water level was within a 0.4m 'window' which can be defined by topography and tidal minima. The upper boundary of this 'acid export window' (0.3m AHD) corresponds to the upper levels of the ASS backswamp plain plus about 0.1m, while the lower boundary (-0.1m AHD) corresponds to the approximate mean minimum low tide level experienced in the backswamp section of the drainage network. The concentration of acid export while the groundwater is in a narrow elevation range is directly related to the main pathway of acid export being groundwater seepage. Significantly, this provides a clear target window on which to focus management efforts.

Table 1: Percentage of total acid flux yr^{-1} in relation to backswamp water level elevation range at time of flux. Maloneys drain, 2001.

Backswamp water level elevation range[A] (m AHD)	Acid flux[B] (% of total export[C] for 2001)
>0.7	3.0
0.7 - 0.6	1.5
0.6 - 0.5	2.0
0.5 - 0.4	5.9
0.4 - 0.3	6.2
0.3 - 0.2	15.5
0.2 - 0.1	37.7
0.1 - 0.0	21.2
0.0 - *-0.1*	6.9
-0.1 - -0.2	0.2

[A] Mean daily water level measured at piezometer well 10m from drain in ASS backswamp.
[B] Based on daily estimates.
[C] Total acid flux for 2001 ~$1.08*10^6$ mol H^+.

While soil ripening and structural development may enhance the K of near surface horizons over time (Dent, 1986), the hydraulic properties of the soil are a relative constant. Water levels in this ASS backswamp will periodically fluctuate through this 'acid export window' elevation range (0.3 to –0.1 m AHD) depending on seasonal rainfall, inflows and evapotranspiration. Extensive drain shallowing and infilling would reduce the area over which groundwater seepage could occur and would be quite effective at reducing acid export. However, this is unlikely to be socially or economically palatable without some incentives. An alternative approach would be to place a water retention structure in the drainage system, allowing controlled maintenance of *high* and *stable* drain water levels while the backswamp water level is in this 'acid export window' (Fig 8).

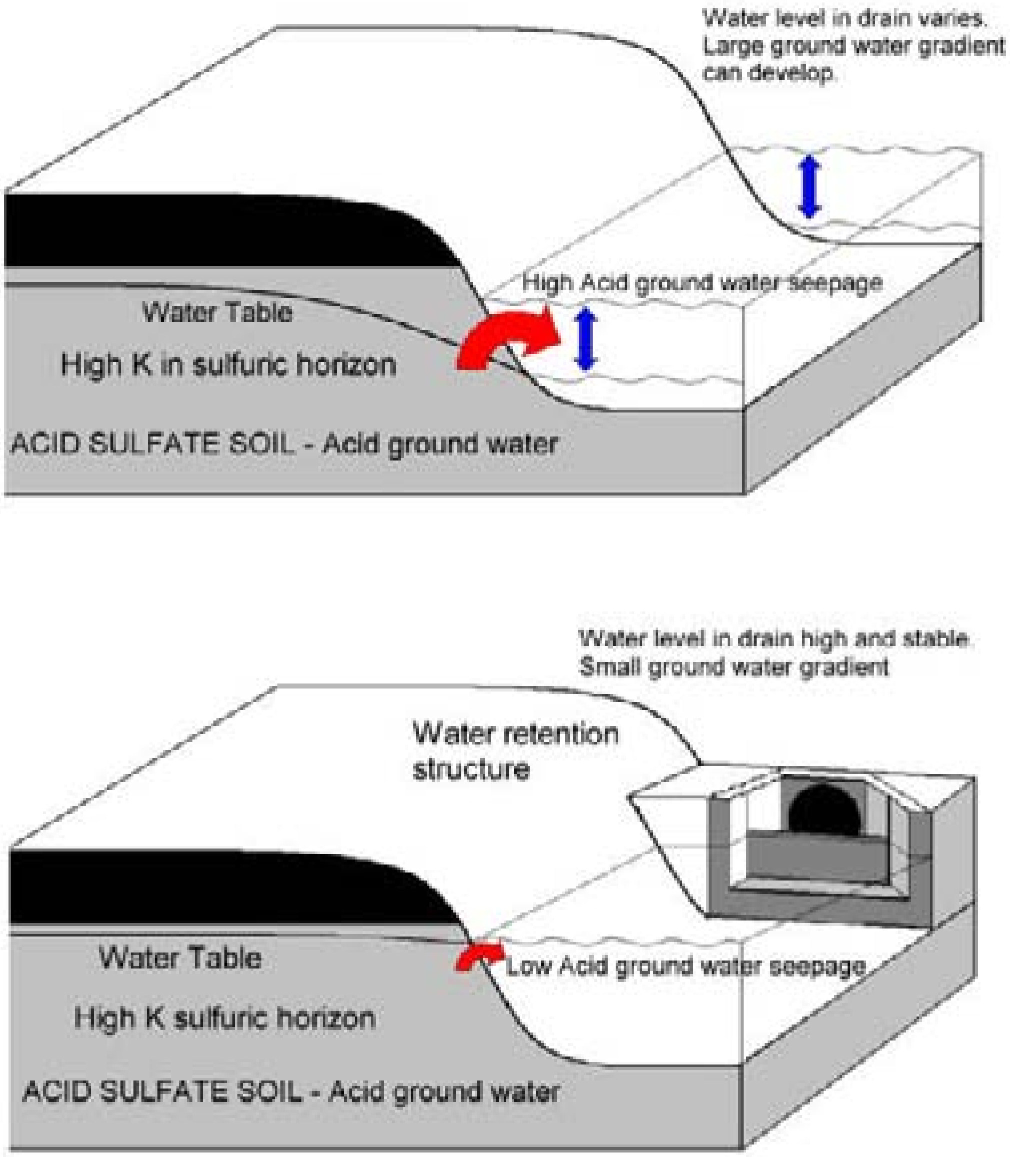

Fig. 8. Schematic representation of groundwater seepage in high K ASS and effects of retention structure on reducing seepage rates.

This strategy would decrease the magnitude of the effluent groundwater gradient, thus reducing groundwater seepage to the drainage system, in a similar fashion to that reported by Blunden *et al*, 1999. While it may *not* prevent low pH drain water developing behind the retention structure, it will reduce *seepage rates*. This will effectively act as a 'brake' on the system, increasing shallow groundwater losses via evapotranspiration. This is essentially a form of containment strategy and is likely to be a far more effective method of reducing acid export than floodgate opening alone, particularly in an ASS backswamp with high K soils. This strategy is obviously most applicable to grazing landuses and poorly suited to cane given it's greater requirement for subsurface drainage. The potential may exist in some systems to combine this strategy with strategic floodgate opening to yield greater in-drain water level control during non-flood periods and further enhance water quality outcomes.

Conclusions

Floodgate opening in ASS backswamps can lead to improved in-drain water quality, but there are also substantial limitations and complexities, particularly in relation to short duration opening events. While dilution, neutralisation and exchange can improve in-drain water quality, this is often followed by relatively rapid reversion to pre-opening conditions upon floodgate closure. The extent of improvement will be largely dependant upon the frequency, magnitude and duration of floodgate opening and the relative interaction between both the volume and quality of drainage outflow water and in-flowing estuarine water. Field trials have demonstrated the potential for short duration floodgate opening to enhance acid export by causing recharge of near drain groundwater during the opening phase and enhanced seepage of acidic shallow groundwater to the drainage system after floodgate closure. This is more likely to be an issue in ASS soils with high K and very poor groundwater quality.

Floodgate opening can lead to reduced net floodplain drainage rates for the duration of opening by altering longitudinal drain water gradients and may lead to significant net inflow in dry periods. Overtopping of saline tidal water represents a significant risk to agricultural land in low elevation ASS backswamps and is a major impediment to high frequency and duration floodgate opening in such systems. This has the potential to be managed with water exchange device designs that allow greater surety of water level control.

A containment strategy to reduce acid groundwater seepage rates based on decreasing effluent groundwater gradients via maintenance of high and stable drain water levels, is likely to prove far more effective at reducing acid export than floodgate opening alone.

Acknowledgments

We thank the Blanches and Maloneys landowners for their assistance and cooperation. We thank CRCC for assistance and access to data. This study was funded by Land and Water Australia, Sugar Research and Development Cooperation, Acid Soil Action and NSW Agriculture.

17. DLWC perspective / OH & S

Speech notes for:

A DLWC PERSPECTIVE

Peter Haskins

BACKGROUND

DLWC has a long association with the work surrounding the design, maintenance and modification of Council-operated floodgate structures. This derives primarily from the Council access funding available under the State-only Floodplain Management Program.

Since 1992 the Program has allowed for significant improvements in the design and operation of floodgates to enhance environmental outcomes and has more recently been expanded to include provision of OH&S modifications as more floodgates become actively operated by non-Council personnel. Prior to this time, the emphasis in works primarily addressed outcomes relating to engineering issues of operational efficiency, routine maintenance and structural integrity.

ORIGINS

The Department of Land and Water Conservation (DLWC) is an organisation developed from the merger of the former Department of Water Resources, the former Department of Conservation and Land Management, and the Water Services Policy Division of the former NSW Public Works.

It can trace its links back further to the former NSW Lands Department, the former Soil Conservation Service of NSW and other bodies. As such, it is a composite entity with a history of specific responsibilities for administering a range of Acts, Regulations and policies. The bringing together of these responsibilities, while it has removed significant overlaps and duplication of functions, has also resulted in what may appear to be potentially opposing management priorities.

PRIORITIES

The priority goals of DLWC have been summed up in the phrase "*Clean, healthy and productive catchments*". This recognises the community expectations of the condition and values of various landscapes within the catchments. Achieving those expectations is a balancing task sometimes made difficult when productivity, in social and economic terms, is viewed against the concept of pristine environments implied by measures of cleanliness and health.

NSW floodplains, and particularly the northern coastal floodplains, have been developed as productive resources for more than 150 years. The backswamp environments of the floodplain landscape have been increasingly developed over this time with the transition from timber getting to dairy and mixed farming. Cropping of sugarcane in the lower parts of the floodplain represents perhaps the most intensive and, at the same time, the most productive rural activity. It is an activity dependent on drainage works to produce a suitable cropping environment and for flood mitigation.

Severe flooding in the 1870s (Williams and Porter in Tulau, 1999) prompted government participation in coordinated drainage works in the early 1900s and laid the foundations of a relationship between government and the rural community that continues to this day.

The relatively smaller scale initial drainage works that were carried out up to the 1940s were followed by deeper and larger drainage works as more funds and horsepower became available. These took place mainly in the 1960s and continued into the 1970s, in the wake of major flood episodes in the 1940s and 1950s, allowing further development of even the most low lying areas as swamps became pasture land and, in many cases, ultimately crop land.

The environmental awareness of the day was considerably lower then, and swamps were generally perceived as far from clean and certainly as unhealthy. The immediate productivity goals were achieved by the drainage works, with permanent access, reduced post-flood inundation periods and the apparent creation of wealth, employment and a sustainable resource.

WARNING SIGNALS

Notwithstanding the hopes and aspirations of all concerned with the promotion of drainage, and the fact that drainage had been first officially sanctioned and encouraged by an Act of Parliament in 1865, cautionary voices had warned of the need for care in the development of the floodplain soils. The subsequent Water and Drainage Act 1902, in the overriding spirit of the day, none the less encouraged both flood mitigation works to protect existing assets and drainage works to create further assets on the floodplains.

Mackay, as early as 1885, reported the analysis and adverse presence of 'reduced iron' in the clay soils of the floodplains. He was to be followed in 1910 by Jensen. The latter's monumental '*Soils of New South Wales*' records no less than 72 references which, with the wisdom of hindsight, establish the presence of acid sulfate soils in the floodplain. Equally importantly, Jensen identified the aquatic weed issues that were also affecting the drainage systems of the day, and graphically supported them with commentary and photographs.

Remarkably, perhaps because of prevailing climatic patterns, World Wars and increasing rural prosperity, almost no further record of specific concern with acid drainage can be found for the next 50 years. The rapid loss of wetland and estuarine habitats raised clusters of concern but failed to achieve widespread recognition in either government or the community.

By 1960, Walker was addressing the potential impact of drainage and exposure of 'cat clays' on water quality and production in the lower Macleay. Walker's clear recognition of the potential for damage by the draining of what we now refer to as acid sulfate soils went unheeded in the push for drainage.

In 1976, when most of the deep drainage projects had been completed, the then Department of Public Works N.S.W. issued staff with Manual No. T~01. '*Design of Flood Mitigation Structures*'. This carried the very clear caution not to drain coastal floodplain soils too deep:

'Artificial drainage of low lying areas requires a knowledge of the soils of these areas. Certain strata in back swamps may produce salt and acid on exposure to the atmosphere and hence excessive drainage to depth of these areas could bring about large increases in salinity and acidity by aerating significant thicknesses of these strata. ***The lowest allowable limit for the drainage of these areas would be the upper limit of these strata****.'*

Fish kill events plagued coastal estuaries throughout the 1970s and into the 1980s, drawing community attention with their high visual impacts. Speculation was rife in the media, with blame being largely laid on illegal dumping in creeks and farm chemical usage despite the familiar recognition of 'summer flood' conditions by many farmers in the more northern coastal floodplains. The spectacular clarification of the Tweed River that followed a major rainfall event in March 1987, with a coincident kill of a wide range of aquatic organisms, was recognised and documented by Easton (1989) as an acid sulfate runoff event.

This latter event and its causal connotations triggered the wider recognition of the potential downside of deep drainage in the coastal floodplains and with it the search for compromise between productivity and the protection of the environment.

MIXED CONCEPTS

Floodplains and backswamps aren't necessarily what the whole community thinks of as clean healthy or productive, even if their virtues are extolled in these terms by some. Just as the community is divided into various sectors, so is the opinion and knowledge about the floodplains and backswamps.

The undeniable agricultural productivity has been achieved at a cost of lost habitat, virtually irreversible change in ground conditions and the interruption of the floodplain cycle of renewal and replenishment. Their natural environmental range of functions has been almost wholly replaced by predominantly social and economic functions. Adverse impacts, such as acid drainage discharges, largely impact on receiving waters and have limited direct effect on sites from which they emanate.

Three principal State policies – the Flood Policy, the Estuary Policy and the Weirs Policy – recognise the inherent conceptual conflicts in management of the floodplain resource. The former is primarily focused on reducing the impact of flooding on the individual while the two latter expressly address the protection of the environment. Reconciling the outcomes is a demanding task, particularly when an action under one policy is potentially contradictory for an objective of another.

FUNDING

The Floodplain Management Program (FMP) administered by DLWC provides funding for a range of flood mitigation works that has increasingly broadened in scope to include environmental enhancements to existing schemes. Nonetheless, the funding available comes with a limiting control in the form of a priority-setting mechanism and the further restraint of requiring a contribution from local government.

While other sources of funding outside the immediate control of DLWC do exist and, over time, represent very substantial expenditures, the commitment of FMP funds over the last decade to specifically remedy adverse environmental outcomes of past drainage and flood mitigation works is very significant. Expenditures have been approved for works from the most basic studies, to comprehensive management plan development, water quality monitoring, structural modifications (with appropriate Occupational Health and Safety standard compliance) and ongoing community involvement at all levels.

For major projects, such as the Tuckean Swamp (Bagotville Barrage) where the floodgates have been modified and a trial is currently in progress, costs are approaching seven figures and the process has required more than eight years of commitment by local government, State agencies and, most importantly, the cane growing industry. Other projects of a similar scale have required equally large sums to be invested.

The development of the Acid Sulfate Soils “Hot Spots” Program has the potential to build on the investment created by FMP funding. Currently in Stage 1, this Program foresees an averaged investment of some $500,000 in each project, and while the Program is administered by DLWC the ongoing funding into Stage 2 is dependent on real achievement in the present Stage.

KEY ISSUES

The trend in environmental modifications to existing structures and drains is to achieve a compromise between retained productivity values and improved environmental values. The two are not mutually exclusive, however they cannot be addressed in isolation from each other, or from the considerations that the local government must have in respect of the burden of responsibility for the maintenance of existing levels of flood protection.

For DLWC, the issues of retaining the integrity of the flood mitigation scheme, its essential simplicity and the maintenance systems have to be balanced against the functionality of the system with proposed changes. For instance, will it replicate the pre-works system effectively, are the skills necessary to make the changes work truly in place (ie will saltwater enter former freshwater areas, can operators be trained in safe opening skills, is the modification practical and reliable in engineering terms?)?

To these issues must be added wider considerations of the repair of degraded land itself associated with past practices, integrated planning for long term future land use and the avoidance of unintentional future damage.

THE FUTURE

The protection of the State’s floodplain resources is one now affecting effecting a very wide range of the community at large, industry, academia, State government agencies and local government. The more closely all parties can work together, the more quickly effective, timely and wearable solutions can and will be found.

It is more than simply a matter of lifting the floodgates or shallowing the drains.

DLWC supports the composite model of research, assessment, trial, monitoring and modification of existing (and future) drainage and flood mitigation works. Experience has taught us all at all levels that there is no simple UNDO button when an unexpected factor enters the environmental equation.

18. NSW ASS Hotspot program overview

OBJECTIVES

To reduce the duration, frequency & intensity of acid discharges from the nominated hot spots, by:

- working cooperatively with stakeholders to make incremental gains in reducing acid discharges to meet agreed environmental goals
- developing site specific solutions
- monitoring results, assess strategies, refine future strategies for short & long term management
- promoting community awareness

Stage 1 projects

- Cudgen Lake (Tweed catchment)
- Everlasting Swamp (Clarence catchment)
- Collombatti-Clybucca (Macleay catchment)
- Upper Maria - Connection Ck (Hastings catchment)
- Partridge Creek (Hastings catchment)
- Moto-Ghinni Ghinni Creek (Manning catchment)
- Broughton Creek (Shoalhaven catchment)

Stage 1 time line

- 2000/01 - $3.4 million announced, local government site managers identified & contracts developed
- 2001/02 - NSW Technical Committee established, initial contact made with property owners, concept plans developed, additional studies completed (eg elevation surveys, soil assessments, groundtruthing) draft management plans under development, monitoring commenced
- 2002/03 - management plans completed, development approval obtained, EIS's completed where required, works designed & constructed, monitoring continues, projects completed

Role of site managers

- manage day to day progress
- establish, support & host community reference group
- lead community consultation & negotiations with property owners

- prepare management plans
- manage consultants
- seek development approvals
- supervise implementation of works

Role of DLWC

- project manager
- final decision maker on strategies and implementation
- support site managers
- provides planning and technical advice
- supports Technical Review Committee
- monitoring
- communications
- liaises with Environmental Trust, ASSMAC, Water Management Committees, Catchment Management Boards, Water CEO's

Role of Technical Review Committee

- review initial options & endorse concept plan
- review draft management plan & provide comment
- endorse final management plan
- report to DLWC

Role of Community Reference Group

- indicate community wishes
- review draft plans & recommend preferences
- provide opportunity for informal stakeholder liaison
- report to site manager

Cudgen Lake, Tweed Shire - Eastern area showing discontinued golf course

CHARACTERISTICS

- 800 ha, high drainage density (90m/ha)
- ~ 25 mm average tidal range at Cudgen Lake
- 1 discharge point, no major floodgates
- persistent scalds, major fish kills at Cudgen Lake
- motorway construction provided capping & dewatering at site
- high value land use

Sample, showing drain in-filling & lasergrading

MANAGEMENT

- 14 management units: grazing, cropping, nature reserve, roads and recreation open space
- main options: drainage redesign (eg 13 km drain in-filling), scald reclamation, strategic liming, best practice cropping (eg laser grading, BP drain maintenance.)
- Strategic liming by mobile rock lime crusher, for drainage applications to polish discharges

Everlasting Swamp - Teal Lagoon, March 2002

CHARACTERISTICS

- 3,000 ha, most high value wetland
- average land elevation ~ -0.1m AHD
- extremely poor groundwater, little discharge
- post-flood scalds
- 14 discharge points

Little Broadwater, May 2002

MANAGEMENT

- 9 management units, grazing and cropping
- main option: water discharge management by bunds and weirs to enhance wetland vegetation & minimise scald development and duration
- floodgate modifications to allow backflooding

Collambatti – Clybucca

New scald at Seven Oaks drain

CHARACTERISTICS

- 2,981 ha
- protracted low pH drain discharge
- 1 primary discharge headworks
- 1.6m tidal range
- persistent scalds
- land elevation ~1.0m AHD
- mostly grazing land

Stratified acid water at Eastern Drain

MANAGEMENT

- 4 management units
- main options: tidal exchange at primary headworks, scald remediation via surface water & stock management, increase drain water levels to reduce groundwater in-flows
- largely cooperative landowners
- some drainage redesign is likely

Partridge Creek

Drain in-filling

CHARACTERISTICS
- 542 ha, ~ 90% Council-owned
- average land elevation ~ 0.1m AHD
- repeated acid discharges
- post-flood scalds
- 1 major discharge outlet
- proposed effluent treatment site
- identified threatened species

Discharge from Partridge Creek

MANAGEMENT
- 2 management units
- main option: establish 70 ha effluent treatment pond (re-establish pre-drainage hydrology) & neutralise with lime as required
- review and redesign drainage system at other problem sites, including dropboard weirs
- construct 1.85 km levee with water control weirs
- contain groundwater

Moto- Ghinni Ghinni

CHARACTERISTICS
- 3,882 ha
- 55 discharge points, 78 landowners
- cumulative acid discharge from tidal pumping at 52 headworks
- persistent scalds
- 55 drainage systems

Scald at south Moto

Moto Coopernook swamp April 2001

MANAGEMENT

- 52 management units:
- 15 km drainage redesign
- surface & groundwater containment via in-drain weirs
- tidal exchange at some floodgates
- scald reclamation

Upper Maria

CHARACTERISTICS

- 4,496 ha, large areas native vegetation
- average land elevation ~ -0.1m AHD
- protracted low pH discharge
- minor scald development
- 13 discharge points

Anderson's drain, trial sandbag weir

MANAGEMENT

- acid containment is main technique
- tidal exchange at floodgates for neutralisation and dilution
- raise drain water levels to reduce groundwater inflows
- trade-offs required for landowners where agricultural productivity is compromised

Broughton Creek

Smart gate site visit

CHARACTERISTICS

- 2,500 ha, inc. high value agric & commercial
- land elevation -0.5 to +1.0 m AHD
- continual low pH drainage
- severe fish kills
- 19 main floodgated drains

Self tilting weir, prototype

MANAGEMENT

- 12 main management units
- ~2 km drain in-filling
- tidal exchange at automated floodgates
- self-tilting weirs for water level management
- BMP drain management
- property owners willing to participate

Comparison of hot spot project sites

Hotspot	Site Manager	Area (ha)	Average Elevation	Land Use	Other Site Characteristics	Management Techniques
Cudgen Lake	Tweed Shire Council	800	~ +1.5 m AHD	Sugar Cane, Grazing, Tea tree, Recreation	25 mm tidal range; drains without floodgates; severe fish kills; high drainage density (90 m/ ha); no centralised drainage planning;	drain in-filling; land use changes; plantation forestry proposals; laser grading; strategic liming; 5 key property owners; compensatory wetland (Reserve).
Everlasting Swamp	Clarence River County Council	2900	~ - 0.1 m AHD	Wetland grazing, Sugar cane, Tea tree, Wetland lagoons	estuarine tidal pre-1927 (salt exclusion weir construction); mostly SEPP 14 coastal wetland; low density drainage (11m/ha); 14 discharge headworks;	acid containment; scald remediation by water management - bund construction & dropboards; tidal floodgates & floodgate winches; fish passage significant; BPM.
Collambatti / Clybucca	Kempsey Shire Council	2981	~ +1.0 m AHD or 0.3	Grazing / Dairy, Improved pasture	1 primary discharge headworks; protracted low pH drain discharge; scald development; 1.6m tidal range;	tidal exchange at primary headworks; increased drain water levels to reduce groundwater in-flows;
Partridge Creek	Hastings Council	542	~ +0.8 m AHD	10% grazing, Council owned,	repeated acid discharges from one major outlet;	construct 1.85 km levee and water control

				proposed effluent treatment	threatened species occurrence; 90% Council owned land;	weirs; re-create 70 ha wetland for effluent treatment; contain groundwater; strategic liming as required.
Moto / Ghinni Ghinni	Greater Taree City Council	3882	~ +0.5 m AHD	Grazing	55 discharge points; 78 landowners; cumulative acid discharge from tidal pumping at 52 headworks; persistent acid scalds	Tidal exchange at some floodgates; surface and groundwater containment; scald remediation; ~ 15kn drainage redesign
Upper Maria River	Kempsey Shire Council	4496	~ +1.0 m AHD	Grazing, Native vegetation	13 drain discharge points; some with protracted low pH discharge; minor scald development; previous aquatic life kills	tidal (inc automatic) exchange at floodgates; acid containment; increased drain water levels to > groundwater level
Broughton Creek	Shoalhaven Shire Council	2500	~ +0.7 m AHD	Improved pasture, Dairy & grazing, Industrial effluent	19 main floodgate structures; high value agricultural and commercial areas; severe fish kills; continual low pH drain discharges	tidal exchange at automated floodgates; water level management via self-tilting weirs; ~ 2km drain in-filling; BPM.

Implementation

- These large scale projects demonstrate that the economic imperatives of property owners influence their willingness to implement ASS remediation techniques developed from site-specific studies.

- Site managers are required to match technical solutions to the needs of property owners in order to gain the best environmental outcomes.

- Trade-offs and other incentives assist site managers to secure optimal environmental gains on private property.

19. General discussion / conclusions

Manual vs. Automatic gates

- Suitability for any particular style needs to be determined on a case-by-case basis
- If manual style is used, to be effective it needs to be almost always open – benefits rapidly deteriorate once gate is closed again
- Need to consider the requirements of the floodgate manager, don't want to be constantly attending floodgates with other on-farm priorities
- Influence of potential flood risk
  - low risk for manual
  - higher risk for automatic (use manual backup at these times)
- All gates need a manual override system
- Whatever the management regime of the gate, it needs an 'owner' for maintenance, operation etc.
- Landowners like to have the ability to manage open gates
- Even standard flap gates have bugs
- Preferable to have small openings for long periods than big openings for short periods
- Need to investigate system of phone call back up to warn landholders of impending rain, floods etc.
- Automatic gates reduce the workload for landholders
- When replacing gates need to consider advice from Fisheries, engineers, and landholders etc for their input

- Some landuses and landscapes are more sensitive than others to saline intrusion and this too should be a consideration

Holistic System Management

- Need to consider the whole subcatchment of the drain, what will happen further upstream?
- Consider exchange in drain
- Porosity of soils
- Landscape features – habitat values
- Because some drains are over-engineered the establishment of mangroves (where shallow sides exist) may not be detrimental
- Investigate the redesign of whole drainage sub-catchments rather than just installing a gate
- Difficulty is that infrastructure is established around an existing drainage network
- Drains designed to remove flood flows
- Natural creek systems to connect / drain backswamps
- Modelling sub-catchments
- Consider landuse change and possibilities to return to more natural drainage patterns
- Potential impacts of sea level change
- Short term funding cycle reduces long term potential for on-going success, doesn't fit natural resource management
- Management plans for gates are not always benchmarked
- What effort is being put into maintaining landholder agreements for the continued management of gates
- Partnerships to manage floodplains / gates