NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Environmental
TRUST

NORTH COAST FLOODGATE PROJECT

Final Report
2002 - 2004

KEMPSEY SHIRE COUNCIL
BOND OF CO-OPERATION

CLARENCE VALLEY floodplain services
A Business Unit of the Clarence Valley Council

RICHMOND RIVER COUNTY COUNCIL

This project has been assisted by the New South Wales Government through its Environmental Trust

Walsh S. and Copeland C. (2004). *North Coast Floodgate Project* - Final Report to the Environmental Trust, NSW Department of Primary Industries, Ballina.

Executive Summary

Major flooding in February and March 2001 resulted in devastating fish kills in the Richmond, Clarence and Macleay rivers. A Technical Workshop was convened to determine the causes, impacts and identify potential solutions to these events. Active floodgate management was identified as one tool to assist in reducing the frequency, severity and duration of fish kills.

Funding was provided by the NSW Government's Environmental Trust to enable the active management of 50 floodgated systems across the Richmond, Clarence and Macleay floodplains. **This objective has been exceeded under this project with a total of 57 systems now under an improved management regime.**

The initial investment from the Environmental Trust program was $522, 000. **Other cash and in-kind contributions from Councils, Industry bodies and individual landholders have totalled an additional $1,567,490 – over triple the initial investment value.**

This project has resulted in both immediate and longer-term benefits to water quality through the continued flushing of previously stagnating waterways. Extensive water quality **monitoring has shown rapid improvements to dissolved oxygen levels, pH values and more moderate fluctuations in water temperature following floodgate openings**. Tidal flushing has also been shown to reduce the accumulation of toxic drain sediments, which were implicated in the de-oxygenation processes that led to the 2001 fish kills.

Fish passage was improved at the same time, with over 606 kilometres restored to a more natural regime. Structural modifications to floodgates have enabled fish to pass these once insurmountable barriers. Landholders have since seen large schools of mullet, prawns and other species in areas previously devoid of fish for decades.

The project's beneficial results for fish populations, was confirmed through the commencement of a PhD study looking at fish usage of actively managed floodgate systems. Although the original proposal required 6 sites for monitoring, a total of 14 sites were sampled and these demonstrated that **actively managed systems had more healthy and diverse fish communities than those with closed floodgates**. Landholders and fishermen alike have been delighted to see these improvements to fish stocks.

A further PhD study facilitated through this project is examining the changes to wetland vegetation communities following active floodgate management trials. Preliminary results have indicated sustained improvements to water quality, **more robust wetland plant communities, as well as agricultural improvements from enhanced pasture grass production**.

Communication of the project's results has been facilitated through media releases, radio interviews, newsletter and magazine articles and presentations at workshops, conferences and natural resource committee meetings, as well as the production of a broadcast quality documentary video. Further communication of the findings is necessary after the project's completion to publicise and maximise the benefits accruing from this work.

Interest from councils and landholders in pursuing active floodgate management goals has significantly increased since the project's inception. Over the last two years, the three local councils in the Richmond, Clarence and Macleay have devoted a greater focus to environmental programs on the floodplain in partnership with the Department of Primary Industries and other organisations. Each catchment now hosts a Floodplain Committee to provide guidance on coastal floodplain issues. Maintaining this focus and building on these successes will be the challenge for the future.

Acknowledgements

The success of this project has depended on collaborative efforts with the following stakeholders, without whom this work would not have been possible.

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Kempsey Shire Council – Ron Kemsley, Tim Morris, Kevin Rosten, Members of the Macleay Floodplain Committee

Clarence Valley Council Floodplain Services (formerly Clarence River County Council) – Jeremy Challacombe, Greg Wilkinson, Peter Wilson, Matt Foley, Rob Lloyd, Members of the Clarence Floodplain Project Committee

Richmond Landholders – Tom Walsh, Laurie Newman, Peter Robinson, John Haynes, David Haynes, Jeff Locke, Pat Buckley, Ken Pursey, Bob O'Connor, Charlie Wade, Barry Elliot

Clarence landholders – Rob Shafer, Alan Byrne, Les Vance, Ed Speirs, Fred Welsh, Geoff Flett, Marie Kelly, Greg Biffin, Therese Biffin, Sharon Gorman, Dave Ewing, Jim Watson, Nerida McClennan, Andrew McClennan, Dick Richards, Roger Maclean, Bob Burges, Dale Vickery, Terry Harrison, Lyle Smythe, Michael Martin, Meg Martin

Macleay Landholders – Peter Ennis, Ivan Sillitoe, Russell Bowen, Howard Lee, Kevin Ball, Charlie Ball, Colin Ball, Mike Hayes

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Clarence River Fishermen's Cooperative – Natasha Keys

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1. Background

Floodgates are essentially a one-way valve system which allow water to flow downstream but not upstream. Most floodgates are designed with a top hinged flap, which seals against a vertical face. Originally designed to prevent flood-waters in main river channels from back-flooding tributaries, floodgates also prevent regular water exchange from entering affected tributaries.

Floodgates were first installed in coastal New South Wales in the late 19th Century and were constructed from timber, with copper sheathing where available, to reduce infestation by borers.

The main installation of floodgates followed massive flooding events on the north coast of NSW particularly in the 1950's and continued until the mid-1970's in a bid to sustain agricultural production. These were mostly funded by Federal, State and Local governments on a 2 : 2 : 1 ratio. On the North Coast, local Councils own and maintain the majority of floodgates within the flood mitigation systems. Drainage Unions or private landholders manage other structures.

Commercial fishers were the first to alert public authorities to the potential for negative impacts of floodgated systems on fish populations and water quality. NSW Fisheries became involved after those concerns were raised and commenced a number of studies into floodgate impacts, which confirmed those early anecdotal reports.

From other research by NSW Fisheries (Pollard & Hannan, 1994) it was observed that most floodgates leaked to some extent and that those which leaked the most had better water quality and fish populations behind them. It was soon realised that opening floodgates in non-flood periods would assist in both improving water quality and also enhancing fish passage and habitat values. This process is known as active floodgate management.

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 1035 floodgates in NSW with over half of those being found on the North Coast.

NSW Fisheries then held a workshop in 1997 entitled *Floodgate Management from a Fisheries Perspective* 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 with relevant stakeholders.

During 1998 – 2001, NSW Fisheries under an NHT funded project, completed an audit of over 700 floodgates on the North Coast (Manning to Tweed) and prioritised those for active floodgate management, based on the naturalness, length and habitat features of the waterway and landholder willingness to trial floodgate openings (Walsh *et al.* 2002). A priority ranking was developed for each catchment and the priority listing was passed on to the relevant councils. Sixteen demonstration sites were developed in four catchments.

During this period Johnston *et al.* (2003) commenced a joint NSW Fisheries/ NSW Agriculture project to examine the management of floodgated drainage systems.

The key impacts of floodgates are:–

- Impacts on juvenile fish and prawn migration;
- Reduced fish passage and recruitment of juvenile fish behind floodgates;
- Increased incidence of 'redspot' disease in fish and other sub-lethal effects upon fish and oysters;
- Fragmentation and loss of fish habitat;
- Increased fish kills from acid or deoxygenation;
- Increased export of acid / toxic metals from acid sulfate soils;
- Enhanced 'black water' impacts and rapid transport of black water to the estuary;
- Increased acid discharge as a result of drain pumping in high permeability acid sulfate soils;
- Nutrient accumulation;
- Increased mono-sulfidic black ooze (MBO) formation in drains and transport to estuary;
- Wetland loss and reduced bird life;
- More fires in back-swamps leading to loss of organic topsoil and scalding.

Water quality and fish monitoring results from this project indicated that the actively managed systems greatly improved dissolved oxygen and pH levels and reduced build-up of iron mono-sulfidic black ooze compared to inactive floodgates.

Active floodgate management controls water levels within drains, increases flushing rates, thereby avoiding the build-up of stagnant acid water and dilutes and neutralises acid discharges during non-flood periods. It also restores fish passage to former important fish habitats.

▼ *Project rationale*

In February and March 2001, severe fish kills occurred following massive flooding events in the Richmond, Clarence and Macleay catchments, with the subsequent closure of two of those rivers to commercial and recreational fishing for a period of seven months. The cause of the fish kill was a dramatic decrease in dissolved oxygen (<1mg/L) along 30 km of river in the Richmond and Macleay floodplains. (Walsh *et al.* 2004).

The drop in dissolved oxygen was attributed to the inundation and subsequent decay of floodplain and riparian vegetation (flood intolerant species) following the flood events increasing the biochemical oxygen demand and suspension of mono-sulfidic black ooze in the base of the flood mitigation drains, which also decreases dissolved oxygen levels, as a result of over-drainage of acid sulfate soil (ASS) back-swamps. The floodplain drainage system and associated floodgates, rapidly exported the “dead” water back into the main river channel as the floodwaters subsided.

In addition, acidic pH levels have been shown to cause other fish kill events and a range of additional sub-lethal impacts if prolonged, such as those identified by Sammut and Lines-Kelly (1996), which include:

- fish disease outbreaks;
- reduced aquatic food resources;
- growth abnormalities;
- reduced growth rates;
- reduced migration potential;
- reduced fish recruitment;
- reduced spawning success;
- increase in damaged and undeveloped eggs;
- altered water-plant communities;
- weed invasion by acid tolerant plants;
- dominance of acid-tolerant plankton species;
- changes in food chain and web;
- secondary water quality changes;
- increased availability of toxic elements;
- reduced availability of nutrients;

This project addressed the causes of the fish kills via the continued implementation of a highly successful trial using active floodgate management techniques (during non-flood periods) to improve water quality from ASS back-swamps and provide opportunities for fish passage into drained creeks and wetlands (former fish habitats). This project focused on the three catchment areas affected by the fish kills; the Richmond, Clarence and Macleay.

▼ *Project Objectives*

The project objectives, as stated in the original proposal submitted to the Environmental Trust, were to:

- reduce the incidence of fish kills on the North Coast of NSW;
- improve the management of 50 North Coast waterways;
- restore fish passage to former fish habitats at 50 sites;
- improve the water quality of the Richmond, Clarence and Macleay rivers during non-flood periods.

2. Methods

Floodgate management process

Site identification

Site identification occured through a combination of processes. Councils in the target valleys were provided with the NSW Fisheries floodgate audit priority rankings to assist in determining suitable locations. In addition, opinions of Council staff were sought as they had a strong local knowledge of floodgate conditions and their suitability for active management. Of particular importance was staff awareness of local issues and the willingness of particular landholders to be involved in floodgate trials. Negotiations with council staff and landholders facilitated the final site selection.

Notification

Correspondence was then sent out to all relevant landholders, including both those with floodgate structures on their propertyand those who managed land that might potentially be affected by controlled floodgate openings. These letters highlighted the aims of the floodgate project, discussed the potential benefits for landholders and outlined the process involved. An example of this correspondence is in Appendix 1.

After 5 – 7 days, a follow up phone call was made to the landholders to further discuss the proposal and answer any questions arising from the letter. If the proposal were of no further interest to the landholder, this would be noted and no further action taken. If the landholders were interested in finding out more about the proposal, an on-site meeting would be arranged at a suitable time for all involved.

On-site meeting

On-site meetings were held between the landholders, NSW Fisheries and Council staff to answer further queries and to outline the process of active floodgate management in more detail. Options for active floodgate management would be presented and the relative merits of each option discussed. If the landholders remained interested in proceeding, a number of actions as outlined below would occur.

Monitoring

Water quality monitoring surveys would commence prior to floodgate openings. Vegetation monitoring through the use of photo-points was initiated. At some systems fish monitoring surveys were also conducted prior to openings. These sites were selected on the basis of a number of variables including the size and suitability of the system for fish habitat, Council and landholder interest and logistical factors such as access for fish sampling equipment.

Trial opening period

Some systems required a trial opening period prior to the full commencement of active management. By allowing the entry of regulated amounts of water over gradually increasing tidal cycles, landholders were able to see for themselves the effects of controlled openings. In addition, this process also clarified if there were any low-lying areas behind the floodgate that may have required additional action to prevent water moving onto productive land.

Floodgate Management Plan development

A Floodgate Management Plan would then be developed, as shown in Appendix 2. Floodgate Management Plans generally specify the following types of information:

- the responsibilities of each party;
- the reasons for actively managing the floodgate (desired outcomes);
- details of the floodgate to be actively managed;
- when it will be opened / closed;
- who will open / close the floodgates;
- contingencies and closure triggers;
- modifications required to make opening / closing safe, simple and effective;
- reporting, monitoring and Management Plan revision;
- training requirements and insurance arrangements;
- legal liability.

Floodgate modifications

Choosing the appropriate floodgate modification for a particular site relied on discussions between all the stakeholders and analysing site-specific requirements. In addition, a workshop was held by NSW Fisheries in August 2002 (Walsh 2002) to identify and examine the various types of floodgate modification and their benefits and limitations (see Appendix 6 for a copy of the Workshop Proceedings). The following provides a summary of the main modification types.

1. Winches (Figure 1) are simple to operate, using a winch and pulley system to physically lift the entire gate. These systems allow for the maximum flushing possible to occur. One limitation is that they rely on landholders to maintain an active presence on a regular basis to raise and lower the gate. Over time, other on-farm tasks can take priority with the gates often remaining closed. In addition, suitable training is required to ensure that gates are not opened at inappropriate times (i.e. high tides) when excessive head pressure can buckle or otherwise damage the infrastructure. The winch handle used is generally detachable and stored off-site to prevent unsupervised manipulation of the floodgate.

Figure 1: Winch mechanism

2. <u>Sluice gates</u> (Figure 2) are comprised of a standard flap gate with a hole removed from the centre of the gate. A sliding panel is fitted over this hole to facilitate the regulation of desired in-flows. A worm drive enables the sluice to be raised or lowered under most conditions. Again a detachable handle is employed to prevent unwanted operations.

Figure 2: Sluice gate with sliding panel

3. <u>Automatic tidally operated gates</u> (Figure 3) have proved to be more useful in areas that are difficult to access or where the floodgate operator is bound by time constraints. A hole in the gate is covered with a rubber sealed panel, which is in turn regulated by a float system. As the float rises on the downstream side due to high tide conditions or a flood event, the panel closes over the hole. When the water level falls again, the panel lifts to reveal the hole again – enabling water exchange and fish passage. The float can be set to a predetermined level, allowing confidence in setting a desired level of water through the gate. This style of modification also has the advantage of reducing the need for Occupational Health and Safety infrastructure such as access platforms as they are self-regulating.

Figure 3: Automatic tidal gate with float

▼ *Floodgate installation*

The selected floodgate modification was then costed and ordered from the manufacturer ready for installation. Finally, the new floodgate would be installed and active management would commence. Generally, the existing floodgate would be replaced with a new marine grade aluminium or stainless steel one – which have a greater degree of corrosion resistance. The lighter aluminium gates also allow for faster drainage of floodwaters than heavier, traditional materials such as steel.

▼ *Monitoring & Review*

Follow up monitoring of water quality, vegetation and fish populations then completed the process, with on-going review of adherence to the Floodgate Management Plan.

3. Monitoring

▼ *Water quality*

Monitoring of water quality involved a number of techniques according to the site-specific requirements. These included:

- Use of in-situ data loggers;
  - useful in measuring 1 – 2 parameters over longer periods of time;
  - data can be remotely accessed through radio telemetry;

- Comprehensive chemical analyses;
  - effective in showing the relative concentrations of selected heavy metals and other chemical compounds;

- ‘Snapshot’ sampling using the Horiba U-10 water quality meter, measuring:
  - pH;
  - dissolved oxygen;
  - electrical conductivity;
  - turbidity;
  - temperature;
  - salinity.

Figure 4: Measuring water quality in the Tuckean system

▼ *Fish monitoring surveys*

Negotiations occurred with Southern Cross University, Lismore in order to secure the services of a PhD candidate for a three-year period to undertake the fish survey work. A detailed report of the fish monitoring component is attached (Appendix 5). The research funded by this project has not only delivered the outputs required by the project but will also provide the first comprehensive data on the impacts of floodgates on fish movement. The objectives of the research are also shown in Appendix 5.

The fish surveys have utilised a number of methods depending on the particular site and environmental conditions experienced. These have included seine netting (Figure 5), fyke netting (Figure 6) and bait trapping (Figures 7 & 8).

1 2 3 4

Figure 5: Seine net sequence at Yaegers, Richmond

Figure 6: Fyke net

Figure 7: Bait trap

Table 1: Fish monitoring sites

SITE	CATCHMENT
Yaegers	Richmond
Bora Creek	Richmond
Dungarubba Creek	Richmond
Tuckean	Richmond
Micalo East	Clarence
Micalo West	Clarence
Little Broadwater floodgate	Clarence
Little Broadwater wetland	Clarence
Frogmore	Macleay
Darkwater	Macleay
Saltwater Inlet	Macleay
Maria # 8	Macleay
Pola Creek	Macleay
Connection Creek	Macleay

Note: A pilot study was undertaken at the Tuckean during August 2004. Due to the seasonally low water temperatures relatively few fish were able to be sampled. A more comprehensive sampling component will be undertaken in Spring / Summer (2004/05).

Figure 8: Setting bait traps behind the Tuckean Swamp floodgates

Vegetation monitoring

Monitoring of changes to vegetation was undertaken through extensive use of photo-points.

Other locations such as the Little Broadwater in the Clarence were monitored more intensively. Funding through this project secured a PhD position focused on monitoring changes to wetland vegetation following active floodgate management, based at the University of New England, Armidale. Appendix 3 contains a comprehensive report on the recent findings of that study.

Some examples of vegetation photo-points include:

- Bora Creek – Richmond

Fig 9. November 2001
(immediately upstream of floodgate)
before management

Fig 10. February 2003
(immediately upstream of floodgate)
after management

Fig 11. November 2001
(upstream river bend)
before management

Fig 12. February 2003
(upstream river bend)
after management

- Alipou Creek – Clarence

Fig 13. December 2002
before management

Fig 14. April 2004
after management

Tidal surveys

Prior to opening floodgates, it was advantageous to know the relative elevation of land to determine the potential for unwanted water intrusion in areas of lower elevation. Where required, this was achieved through examination of survey plans, conducting theodolite based surveys, employing laser levelling techniques or performing surveys of tidal heights in front of, and behind, floodgate structures using tide gauges.

An example of this is the hydrological survey conducted by consultants Fish Fore Shore at a number of sites on Micalo Island, Clarence. Results of this survey are detailed in Appendix 4.

Figure 15: Measuring relative elevation using a laser guided theodolite and ranging staff system

4. Results

▼ *Richmond Summary*

Table 2: Actively managed floodgate sites in the Richmond catchment

NUMBER	SITE	AREA	MODIFICATION	FISH PASSAGE (km)
1	Thearles	Swan Bay	Sluice	11.73
2	Reardons	Swan Bay	Sluice	13.21
3	Skinners	Swan Bay	Sluice	2.50
4	Bungawalbyn Hall	Swan Bay	Sluice	5.90
5	Haughwoods	Bungawalbyn Creek	Winch	2.00
6	Bora Creek	Bungawalbyn Creek	Winch	2.00
7	Bagotville	Tuckean	Sluice (x 3)	206.58
8	Yaegers	Buckendoon	Sluice	13.82
9	Kilgin	Dungarubba	Sluice	1.61
10	Sandy #1	Sandy Creek	Sluice	10.14
11	Duck Creek	South Ballina	Sluice	6.23
TOTAL				**275.72km**

The Richmond catchment has had a total of 11 floodgates actively managed over the previous two years as shown in Table 2. Over 275 kilometres of waterway are now better managed to improve water quality and fish passage. In addition, large areas of the drained Tuckean Swamp have now been rewetted through the floodgate modifications. Appendix 9 contains images, location maps, photographs and monitoring results for all these sites.

Most of the floodgate modifications in the Richmond are in the form of sluice gates (9) with 2 additional winches. Richmond River County Council has found sluice gates to be effective for their needs and prefer to utilise this system to reduce maintenance of a wide range of structural modifications.

Individual site locations are shown in Figure 16, with the waterways now open to fish passage highlighted in red.

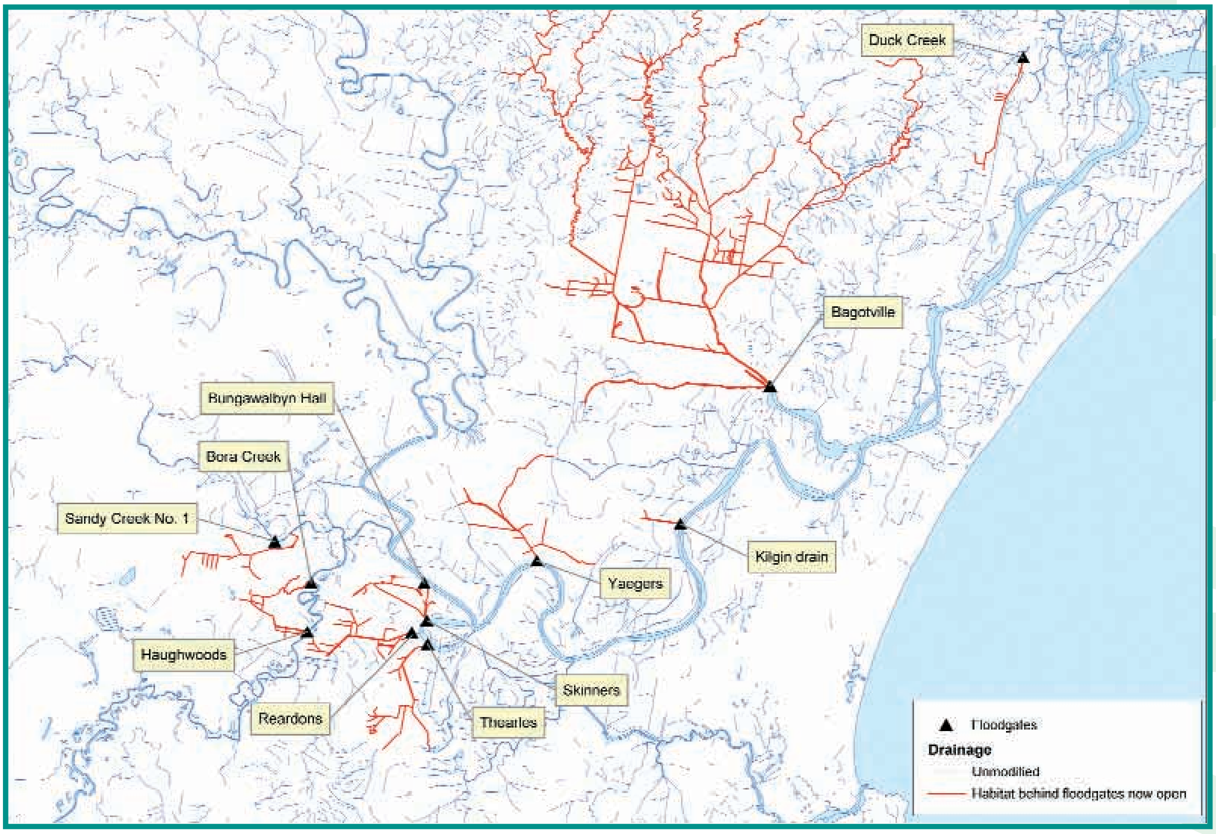

Figure 16: Actively managed floodgates in the Richmond catchment

Clarence Summary

Table 3: Actively managed floodgate sites in the Clarence catchment

NUMBER	SITE	AREA	MODIFICATION	FISH PASSAGE (km)
1	Alipou	South Grafton	Tidal gate	6.59
2	Little Broadwater	Sportsmans Creek	Tidal gate	0.26 + 170 HECTARES
3	Alumy Creek	Southgate	Fish flaps	40.56
4	West Ulmarra	Ulmarra	Sluice	1.75
5	Middle Road	Palmers Island	Tidal gate	5.10
6	McKenzie/Castle	Palmers Island	Automatic (waterman) gate	7.90
7	Notts	Palmers Island	Tidal gate	6.10
8	Clarenza	Clarenza	Winch	0.83
9	Ensbys	Sportsmans Creek	Horizontal gantry	0.48
10	Micalo #1	Yamba	Winch	1.10
11	Coldstream East #5	Coldstream	Tidal gate	2.09
12	North levee	Everlasting Swamp	Horizontal gantry	1.00
13	South Levee	Everlasting Swamp	Horizontal gantry	1.00
14	Reedy Creek	Everlasting Swamp	Horizontal gantry	0.28
15	Woody Creek	Everlasting Swamp	Horizontal gantry	1.60
16	Sportsmans Creek # 35/1	Everlasting Swamp	Horizontal gantry	0.66
17	Sportsmans Creek # 33	Everlasting Swamp	Horizontal gantry	0.39
18	Freemans	Waterview	Horizontal gantry	1.88
19	Denny's Gully	Lower Coldstream	Tidal gate	1.23
20	Swan Creek	Swan Creek	Fish flaps	35.70
21	Blanches	Everlasting Swamp	Tidal gate	3.12
22	Chatsworth West	Chatsworth Island	Tidal gate	36,15
23	Chatsworth Kratz	Chatsworth Island	Tidal gate	1.25
24	Woombah	Woombah	Tidal gate	1.41
25	Ashby Mainland	Ashby	Tidal gate	2.87
26	Tucabia Bloomers	Lower Coldstream	Tidal gate	0.34
27	Broadmouth Creek Block	Lower Coldstream	Tidal gate	4.48
28	Oregon Creek	Lower Coldstream	Tidal gate	10.88
29	Micalo # 2	Yamba	Tidal gate & winch	8.63
30	Arndilly	Broadwater Creek	Tidal gate	2.77 + 304 HECTARES
31	Quayles	Woodford Island	Winch	2.04
32	Ashby Murrayville	Ashby	Winch	3.00
33	Bayldons	Southgate	Winch	1.00
TOTALS				194.44 km

The Clarence catchment has had a total of 33 floodgates actively managed over the previous two years as shown in Table 3. The larger number of systems managed in the Clarence compared to the Richmond and Macleay, can be attributed in part to the physically bigger floodplain with correspondingly larger numbers of floodgates. Over 194 kilometres of waterway are actively managed to improve water quality and fish passage. In addition, wetland complexes at Little Broadwater (170 hectares), Arndilly (304 hectares) and the Everlasting Swamp (1930 hectares) are now able to be rewetted through floodgate modifications installed under this project. Appendix 9 contains images, location maps, photographs and monitoring results for all these sites.

The predominant floodgate modification used in the Clarence is tidal gates. Their automated nature reduces the on-going need for Council staff to visit each floodgate site prior to a flood event in order to manually close the gate. This is particularly useful for a catchment with as many floodgates to operate during flood events as the Clarence. At other locations winches, gantries and sluices have been installed at sites where landholders are willing to operate them on an on-going basis.

Individual site locations are shown in Figure 17, with the waterways now open to fish passage highlighted in red.

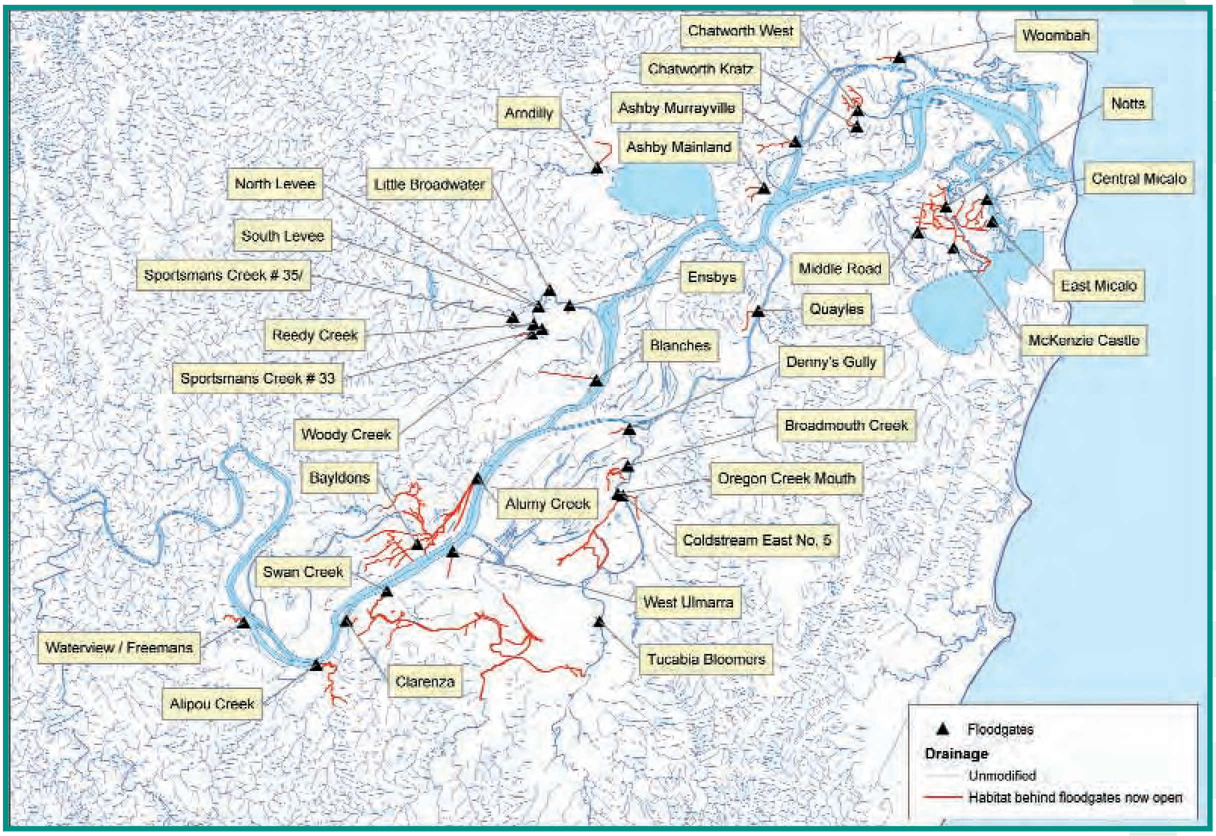

Figure 17: Actively managed floodgate sites in the Clarence catchment

FLOODGATES

Macleay Summary

Table 4: Actively managed floodgate sites in the Macleay catchment

NUMBER	SITE	AREA	MODIFICATION	FISH PASSAGE (km)
1	Christmas Creek	Frederickton	Winch	40.75
2	Euroka Creek	Euroka	Winch	32.39
3	McCuddens	Belmore	Winch	1.08
4	Scotts	Belmore	Winch	4.47
5	The Locke	Swan Pool	Sluice	1.21
6	Irwins	Kinchela	Sluice/Winch	1.00
7	Connection Creek	Maria River	Tidal gate	8.04
8	Saltwater Inlet ("The Lag")	Jerseyville	Tidal gate	2.20
9	Pola Creek	Kempsey	Winch	26.15
10	Maria # 2	Maria River	Tidal gate	2.03
11	Maria # 3	Maria River	Tidal gate	1.23
12	Maria # 8	Maria River	Tidal gate	0.74
13	Union	Frogmore/Darkwater	Winch	15.35
TOTAL				**136.64km**

The Macleay catchment has had a total of 13 floodgates actively managed over the previous two years as shown in Table 4. Over 136 kilometres of waterway are now better managed for improved water quality and fish passage. Appendix 9 contains location maps, photographs and monitoring results for all sites.

The predominant floodgate styles used in the Macleay are winches and tidal gates. Winches are used to enable continual flushing of large volumes of water in non-flood periods, particularly in areas that are reasonably accessible. Tidal floodgates have been used particularly in the Maria River area where continual flushing of the smaller waterways is required to manage ASS. In addition, because they operate on an automatic basis, Council resources are not required to manually close the gates.

Individual site locations are shown in Figure 18, with the waterways now open to fish passage highlighted in red.

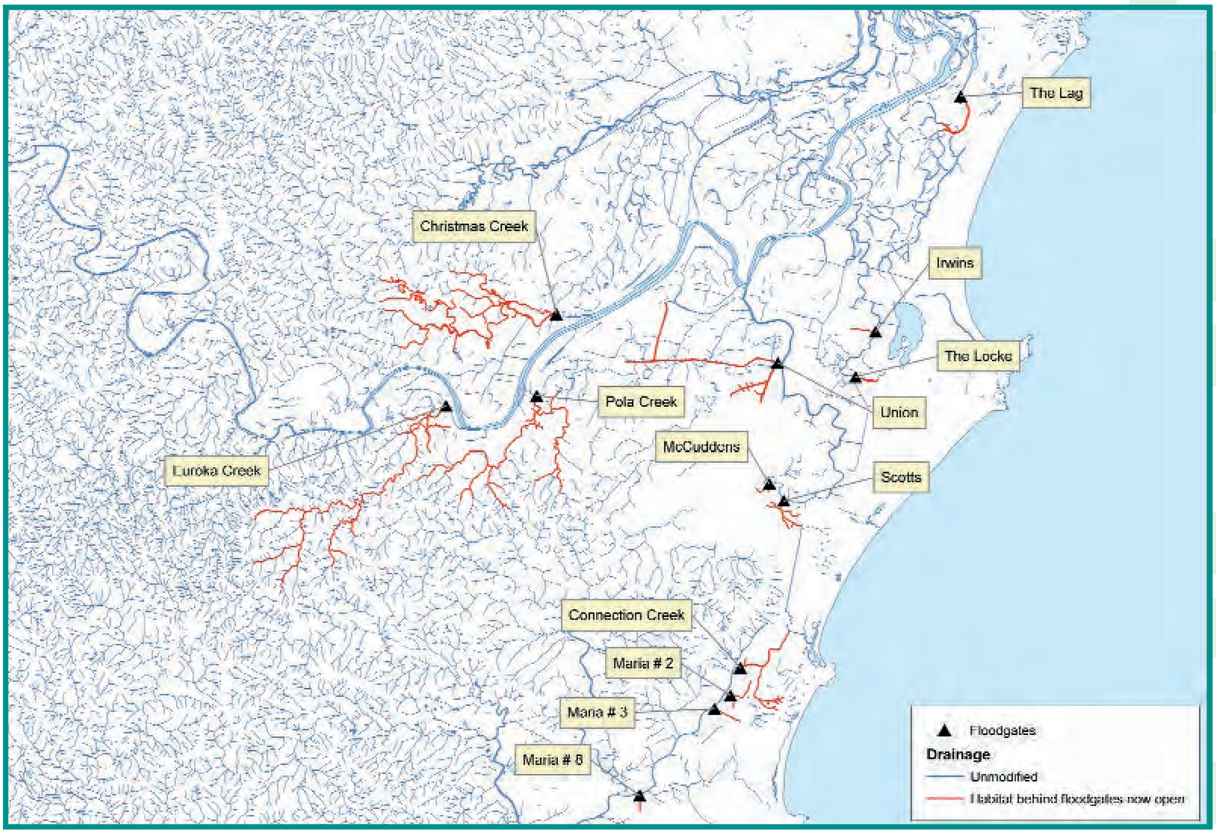

Figure 18: Actively managed floodgate sites in the Macleay catchment

▼ *Data analyses*

Figures 16 -18 highlight (in red) those areas behind managed floodgates which are now potentially open to fish passage – a total of 606.8 kilometres. The extent of waterways open to fish passage was calculated using maps derived from the Department of Infrastructure, Planning and Natural Resources GIS data layers. First and second order streams were removed from the calculations due to their largely intermittent nature. An automatic tally feature within the GIS software was used to derive individual system lengths for each managed floodgate, which are shown in Tables 2 – 4.

The maps were further refined through consultation with the relevant Council staff to increase their accuracy. It should be recognised that some areas highlighted in red may flow intermittently on occasion. Detailed groundtruthing would be required to identify those areas, particularly during extended drought conditions.

Financial summary

Cash and in-kind contributions from the three catchments in the project area over the last two years are shown below in Table 5.

Table 5: Financial contributions to the North Coast Floodgate Project.

PROJECT PARTNER	CATCHMENT	CASH AND IN-KIND CONTRIBUTION
Clarence Floodplain Services	Clarence	$990, 000
Richmond River County Council	Richmond	$311, 090
Kempsey Shire Council	Macleay	$100, 000
DPI – Fisheries	All	$23, 000
Landholders	All	$64, 800
Industry	All	$75, 000
TOTAL		**$1,567,490**

The table shows that contributions totalled over $1.5 million for the two year project – over three times the initial investment ($522,000) from the Environmental Trust. When combined, this gives a total project value of **$2,089,490.** The relatively large contribution from the Clarence catchment reflects the high proportion of actively managed systems in that catchment.

Industry bodies involved in the project included the NSW Sugar Milling Cooperative, Richmond Cane Growers Association, Clarence Cane Growers Association, Evans Head Fishermen's Cooperative, Richmond Fishermen's Cooperative, Clarence Fishermen's Cooperative, Macleay Oystergrower's Association, Macleay Acid Sulfate Soils Land Action Group, Southern Cross University and the University of New England.

Water Quality Summary

Detailed water quality results for actively managed sites are compiled in Appendix 7 which contains the monitoring results, images, maps, environmental assessments and other information for each site.

Overall the results indicate that prior to floodgate openings in unmanaged systems, the water quality was generally poor. Sites with closed floodgates were characterised by water with low dissolved oxygen levels, which reduce the suitability of the water body for aquatic life. These conditions also proved suitable for the growth of in-stream weeds and algal blooms. Following active management, water quality parameters tended to improve with increased oxygen levels, reduced acidity, moderated temperature fluctuations and improved weed management.

*Figure 19: McKenzie – Castle system **before** opening, Clarence*

*Figure 20: McKenzie - Castle System **after** opening, Clarence*

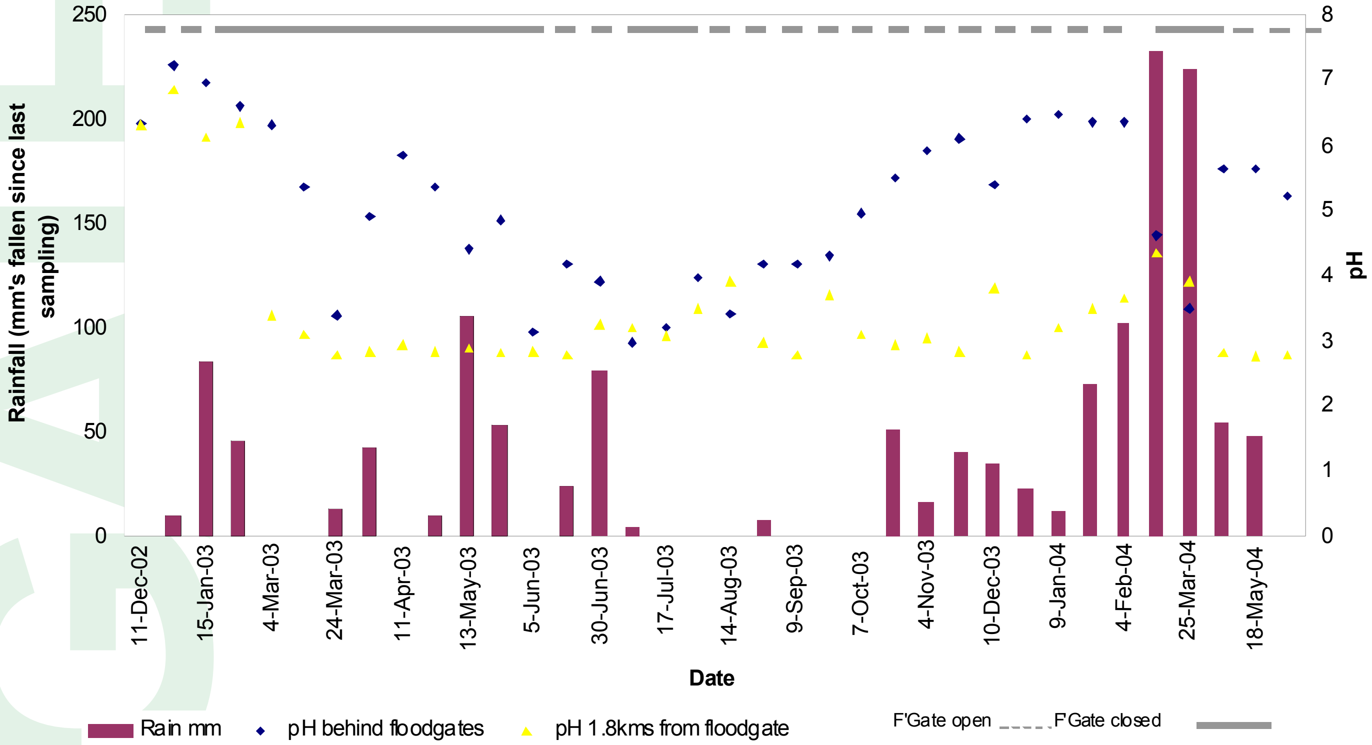

Figure 21: Water quality monitoring results for Haughwoods, Richmond.
(Data courtesy of Chrisy Clay, NSW DPI)

As an example, Figure 21 shows the response of pH at Haughwoods to active floodgate management. At the top of the graph, dashed lines indicate periods when the floodgates were winched open and bold lines show when they were closed. Floodgates were closed on occasions over this period largely due to concerns for potential inundation following rain events.

Floodgate closure shows a clear correlation to falling pH levels (increased acidity). This is particularly the case for the site nearest the floodgate itself. The reduced amount of flushing and dilution would serve to accentuate the acid levels.

Overall, the site that was furthest upstream from the floodgate (and so further from the flushing effects) displayed more acidic conditions, on occasion below pH 3.

Around midway through the study period shown, the open floodgate allows more flushing and pH levels steadily begin to improve. A rain event in March forced the closure of the floodgate and pH levels again rapidly deteriorated.

Additional water quality improvements were demonstrated for the sites at the Little Broadwater in the Clarence and Thearles floodgate in the Richmond. Thes can be seen in Appendix 7.

It should be recognised that not all systems were able to be comprehensively sampled for water quality both before and after floodgate modifications took place. At some sites the landholders were already aware of the benefits of keeping floodgates open and had been using 'informal' means such as placing logs or bricks under the flap-gate to provide for water exchange. In these instances, there was no clear 'before' regime to monitor.

Figure 22: Floodgate with stake preventing total floodgate closure

Other limitations to water quality sampling included the following:

• It was often not known in advance which sites were to be actively managed. As a result 'before' data has been collected at sites that are not currently being actively managed.

• Once landholders decided to actively manage a floodgate, they tended to want it open immediately, restricting the time available for 'before' monitoring.

• Some gates had modifications recently installed but remain partially closed pending resolution of minor issues associated with trialling floodgate management.

• Other gates have been installed, for example six at Everlasting Swamp, but are awaiting resolution of land acquisition issues by the Department of Environment and Conservation at this important wetland complex.

• Clarence Valley Floodplain Services are in the process of collecting additional data from a number of systems with modifications recently installed. These data will be collated into a full report and forwarded onto the Environmental Trust upon completion.

CASE STUDY 1: THEARLES, SWAN BAY IN THE RICHMOND

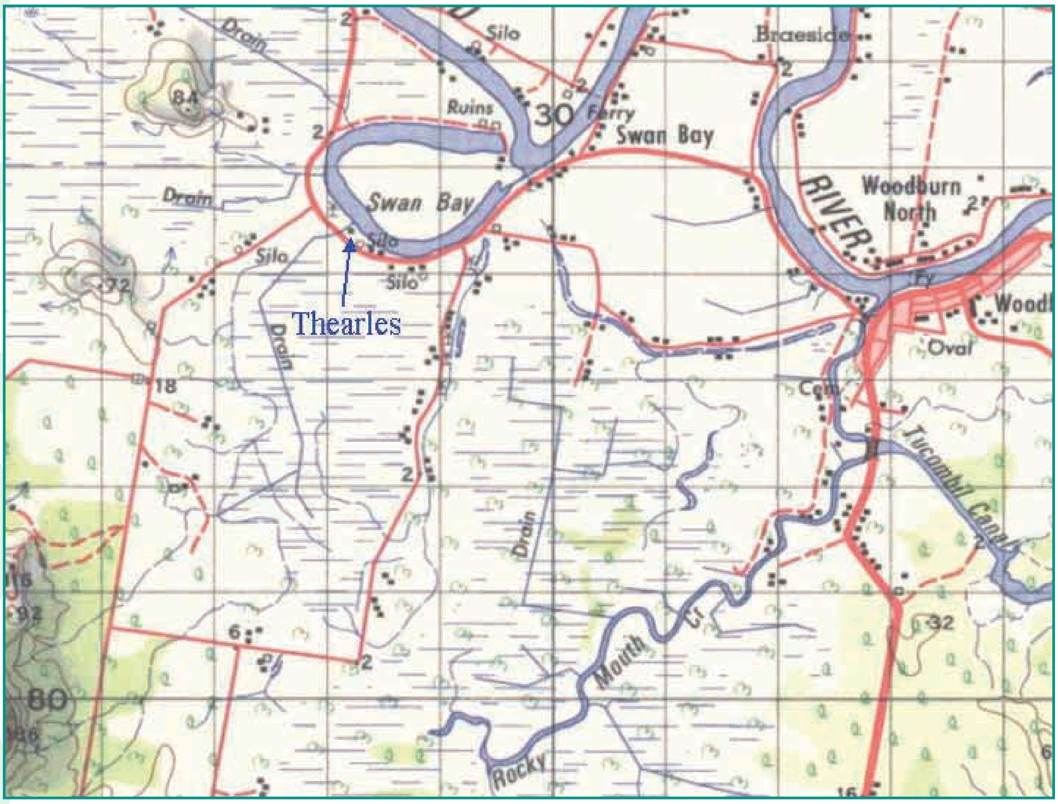

Figure 23: Location of Thearles floodgate at Swan Bay, Richmond

Swan Bay is located in northeastern New South Wales to the west of the town of Woodburn (see Figure 23). The Swan Bay sub-catchment that flows into the Richmond River is a site known for its poor water quality and fish kills. Prior to drainage and installation of floodgates, the area was historically an important habitat for recreationally and commercially targeted fish in the Richmond catchment.

Thearles is one of four floodgates that discharges into Swan Bay; two others (Skinners and Reardon's) are also being actively managed under this project and the final gate at Campbell's is to be opened in the near future.

Surrounding land use is predominantly sugar cane with some beef cattle grazing. Following concerns from fishermen over poor water quality discharging into Swan Bay and from landholders keen to maximize on-farm water quality and agricultural production, the floodgate modification process commenced. A Management Plan was drawn up detailing the roles and responsibilities of the various stakeholders in managing the floodgate. An aluminum sluice gate was then fabricated and installed to allow regulation of water flows.

*Figure 24: **Before** opening, 17/7/02*

*Figure 25: **After** opening, 8/1/03*

Figure 24 shows the clear, low turbidity conditions caused by an acidic dominated environment. Metals such as aluminium bind to any particulate matter in the water resulting in an unnaturally transparent water column.

Figure 25 illustrates the improvement resulting from the open floodgate flushing the system with better quality river water. The visual results are reinforced by the chemical analyses results detailed below.

Figure 26: Operating the Thearles winch mechanism to open the sluice

Water quality - results of chemical analyses

(Data courtesy of Michael Wood, Richmond River County Council)

30/09/02 Pre opening

	pH	EC (us/cm)	Al (mg/L)	Fe (mg/L)	SO_4 (mg/L)
Site 1	8.22	573	0.1	0.09	27.0
Site 2	3.76	925	2.4	0.3	193.0
Site 3	3.39	2200	26.0	3.1	650.0
Site 4	3.01	3070	54.0	12.4	1200.0

04/10/02 Post opening

	pH	EC (us/cm)	Al (mg/L)	Fe (mg/L)	SO_4 (mg/L)
Site 1	7.81	662	0.027	0.03	32.0
Site 2	6.56	661	0.055	0.24	69.0
Site 3	5.64	790	0.140	0.50	150.0
Site 4	3.43	1400	6.800	0.93	325.0

Sites 1 (closest to floodgate) to site 4 (furthest upstream) are located along Thearles Canal.

PH levels during both surveys displayed a similar pattern of being more acidic further upstream. Acidity levels were moderated in the lower to mid reaches soon after the floodgate opening through a combination of brackish water buffering and dilution.

Electrical conductivity levels were again higher further upstream over both sampling runs, indicating the effects of evaporation in concentrating the available salts. Following the opening, these concentrations were halved upstream through the improved flushing regime.

Concentrations of sulfates and the heavy metals, aluminium and iron, were also more concentrated upstream. Once again, improved tidal flushing was able to reduce concentrations of these potentially toxic compounds by a factor of 10.

Figure 27: Garfish schooling in front of the now actively managed Thearles sluice gate

Although the main reason for actively managing this particular floodgate was to address the poor water quality arising from the system, there have also been other direct benefits for aquatic life. Figure 27 shows a school of garfish schooling near the open sluice, either preparing to move up into the system or awaiting food to flow downstream.

Case Study 2: Little Broadwater, Clarence

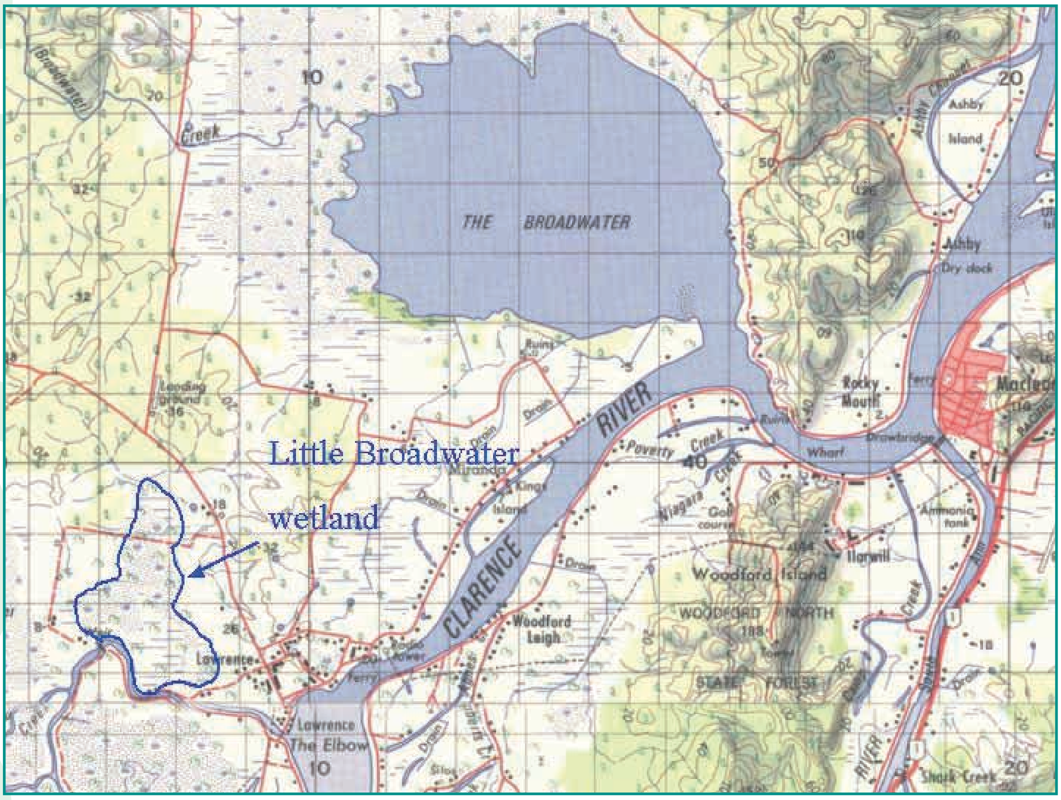

Figure 28: Little Broadwater location map

Little Broadwater is situated in the Clarence catchment on the north side of Sportsman's Creek, approximately 3 km west of the township of Lawrence.

Little Broadwater is a SEPP 14 (Coastal Wetland) and is identified as SEPP 14 No. 231. The sub-catchment area is approximately 670ha with the core wetland area of 170 ha.

▼ *Brief history*

The original survey plans (dated 1898 -1905) show that this area was originally fringed with mangroves on both the eastern and western banks (Wilkinson, 2003). Swamp Oak dominated the slightly higher elevations on the natural levee adjacent to the mangroves. The reedy swamps behind the Swamp Oaks were recorded as being good pasture, although subject to inundation during spring tides.

The Little Broadwater Swamp was traditionally regarded as an important habitat for adult and juvenile fish species and made an important contribution to the Clarence River fishery. The site was open to the main body of Sportsman's Creek for over 200 metres and was an open water embayment.

Between 1911 and 1927, the Little Broadwater Drainage Trust reclaimed 235 ha for agricultural purposes through construction of a 200-metre levee bank across the mouth of the embayment with one small floodgated 900mm discharge pipe.

During the late 1920s, the Drainage Trust constructed a three-celled spillway to provide extra drainage.

In the 1960's, Clarence River County Council constructed a flood mitigation levee, 1.22m high (AHD) along the banks of Sportsman's Creek, over the three-celled weir. A floodgated mitigation drain was also constructed at that time (Lawrence / Whalans Drain).

The average land elevation is below sea level at around -0.1m AHD, with the natural channels from -0.2m to -0.4m AHD. ASS are present at an average depth of 400 mm below the surface. Previous over-drainage has oxidised the ASS resulting in poor water quality and reduced agricultural production.

The area continued to suffer from acid scalds, with the majority of the management area largely devoid of vegetation following the March 2001 flood.

Figure 29: In the 'wetland', prior to floodgate opening - November 2001

▼ *Current works – aims*

The management of Little Broadwater has involved a funding partnership of the Department of Infrastructure, Planning and Natural Resources ASS Hotspot program, NSW Recreational Fishing Trust and the Environmental Trust program. This project funded the installation of two automatic tidal floodgate modifications, and the placement of drop board structures aimed at raising drainage invert levels. The core area of wetland has also been fenced to exclude stock from key areas.

Figure 30: Tidal floodgates

Figure 31: Drop boards and tide gauge

One of the project partners, Wetland Care Australia, negotiated with the landowners to provide greater fish passage and greater water exchange with Sportsman's Creek through providing stewardship payments.

These stewardship payments provide financial incentives to three landholders for inundation of 170 ha of property with brackish water as part of an innovative three-year trial. Some of these funds were provided by the NSW Recreational Fishing Trust, which has allocated partial funds from the recreational fishing licence for fish habitat rehabilitation.

Figure 32: Water flowing into the wetland

Other project partners include:

Clarence Valley Council;
Department of Infrastructure, Planning and Natural Resources;
Clarence River Fishermen's Cooperative;
University of New England;
Southern Cross University.

Water Quality

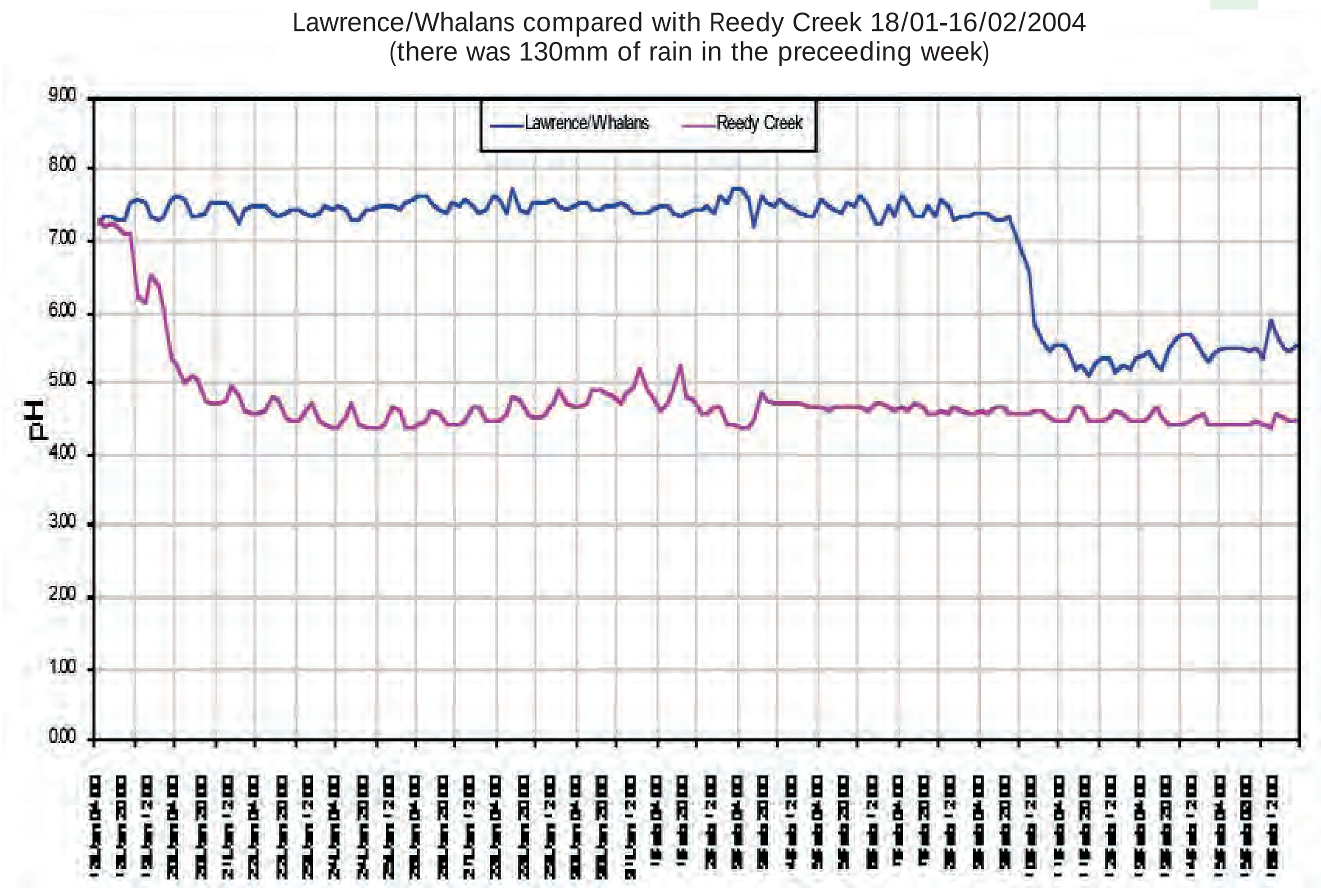

Figure 33: Comparison of acidity at Little Broadwater and an unmanaged site (data courtesy of Clarence Valley Floodplain Services)

The figure above shows a comparison of acidity at Little Broadwater through Lawrence / Whalan's drain (top line) and a nearby unmanaged site at Reedy Creek (bottom line), after some months of active management and a recent rainfall event. Both sites are recognised as problem areas for acid sulfate soils under the "Hotspot" program. Normally following rain events acid products are flushed out of the system and can lead to fish kills.

The pH levels in the unmanaged system were always lower (i.e. more acidic) throughout the period than at the managed site. After two days at Reedy Creek, pH levels fall significantly and remain around pH 4 – 5 for at least the next month. At Little Broadwater however, levels remained above neutral (7 – 8) for a period of three weeks before dropping. This drop eventually occurred with acidic inputs from the upstream Reedy Creek! The 10-fold difference in pH shows how all ASS Hotspot sites could be managed in the future.

Fish monitoring

The floodgate fish monitoring concentrated on two main areas at Little Broadwater. The first was at the modified floodgates themselves, to examine fish passage through the structure. The second monitoring component took place at a number of locations upstream of the floodgates, to examine the habitat usage by fish in the four main vegetation communities within the wetland.

Prior to the commencement of the floodgate openings, the 'wetland' was largely comprised of dry, bare earth (see Figure 30). Following the re-wetting of the wetland, a whole range of fish species have been recorded, including an abundance of school prawns, yellowfin bream, sea mullet, long finned eels, catfish and numerous species of gudgeons and gobies.

Figure 34: Fish and prawns caught swimming below the floodgate from the wetland

Figure 35: Fish monitoring in the wetland Phragmites community

Vegetation monitoring

The vegetation monitoring program focused on assessing the effects of the reintroduction of brackish water inundation on vegetation in the Little Broadwater wetland. Twenty two sites were selected for six replicate surveys to determine vegetation change over 12 months.

In addition, high resolution multi-spectral imagery was captured by the University of New England's airborne video system during the October 2003 and March 2004 sampling periods. The data has been used to map the distribution and condition of each vegetation community to gain an understanding of the spatial changes in the vegetation communities over the study period. The final report will also provide an assessment of the changes to wetland pasture productivity including a seasonal feed analysis report.

The studies undertaken to date by the University of New England have shown a largely positive change in vegetation health over the summer period. During this time, rainfall combined with floodgate openings has resulted in previously dry areas becoming inundated with brackish water. Most plant communities have coped with increased water levels and fluctuating salinities. Some areas have thrived since the floodgate openings.

Figure 36: 7th February 2003 – Before opening

Figure 37: 2nd April 2003 – After opening

Figure 38: 4th June 2003 – After opening

Case Study 3: Saltwater Inlet, Macleay

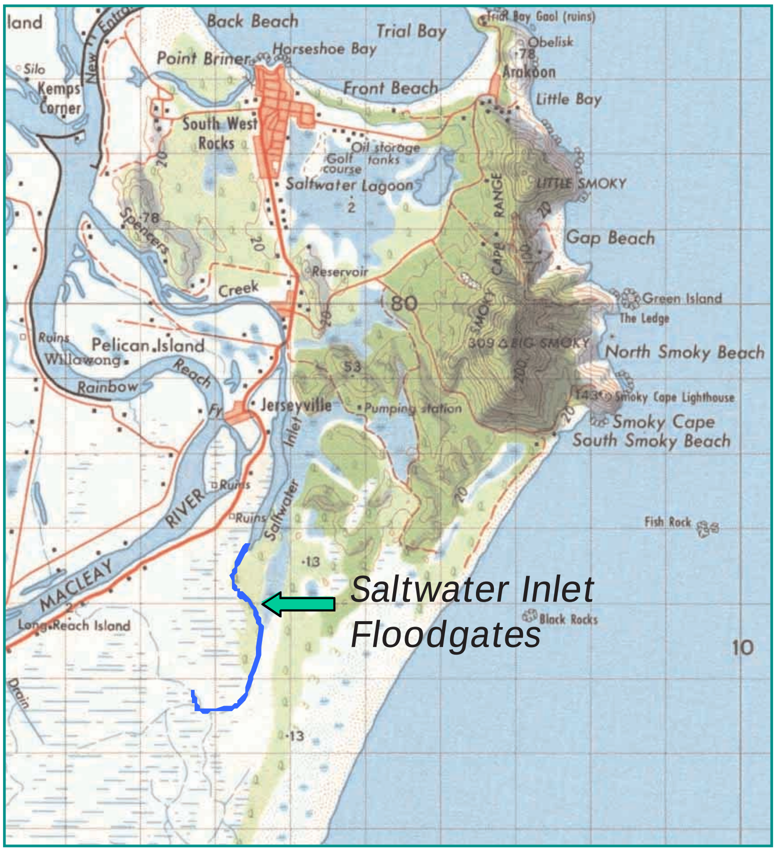

Figure 39: Location map of Saltwater Inlet (or "the Lag")

The Saltwater Inlet site was identified as part of the video documentary process in August 2003. One floodgate was found to be in a state of disrepair and was allowing the passage of some water behind the system. The Department of Primary Industries then contacted Kempsey Shire Council and the landholders to discuss options for improved management of the waterway. The landholders were keen to pursue the tidal gate option at this site.

Figure 40: Before modification

Figure 41: Installing the new tidal gate

Figure 42: Downstream of the floodgates

Figure 43: Upstream of the floodgates

Figures 42 and 43 highlight the difference in vegetation communities on either side of the floodgate. Downstream the riparian vegetation is comprised exclusively of mature mangroves, which provide excellent fish habitat. Upstream there were no mangroves – one bank was lined with casuarinas and the other with pasture grass and reeds.

Following the positive vegetation community response to tidal inundation, the landholders agreed that allowing controlled amounts of saltwater into the creek would assist in providing natural weed control. They also advised that two existing earthen weirs upstream would prevent the ingress of brackish water into areas where it would be unsuitable for agricultural purposes.

Figure 44: Filming the Saltwater Inlet floodgate

The entire waterway is fronted by properties belonging to two brothers, Kevin and Charlie Ball. The Balls have traditionally managed their property to retain local rainfall on their paddocks through a system of earthen weirs. These farmers have also voluntarily fenced large sections of the creek to prevent unwanted cattle intrusion. Increased in-stream salinity assists the Balls in natural weed control, reducing on-farm costs for chemical sprays.

Collecting accurate before and after water quality results proved to be difficult given the state of disrepair of the original gate (see Figure 40). The gate had been leaking for some time, which meant that water quality sampling would not indicate a true ‘before’ value.

Fish sampling

A preliminary fish survey was undertaken on the 4th and 5th March 2004 to establish fish usage of the system. Three sites were sampled along the system – 2 kilometres upstream and 50 metres either side of the floodgate. A combination of fyke nets and bait traps were set overnight and recovered the following day.
At the two upstream sites prior to modification, the species were dominated by freshwater assemblages including long finned eel, freshwater shrimp, empire gudgeon, striped gudgeon and flathead gudgeon. Due to the existing state of disrepair of the floodgate, some estuarine species were also recorded including a few school prawns and a single, juvenile mud crab.

Downstream of the floodgate amongst the mangroves (see Figure 42) a different assemblage was encountered. An abundance of commercially and recreationally valuable large school prawns dominated the catches, with long-armed prawns and mud crab also present. An unusual find was a juvenile silver batfish, normally seen on tropical reefs.

These results show that commercially and recreationally important species of fish are found downstream rather than upstream of the unmanaged floodgates. The fact that the floodgate was leaking accounts for those saltwater species found upstream as they too would normally be excluded.

Figure 45: School prawns

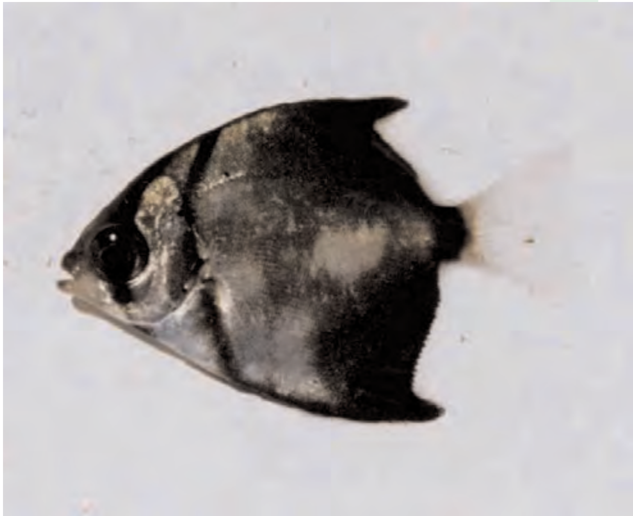

Figure 46: Silver batfish

The new floodgate structure was installed during Winter 2004. It is planned to undertake further follow up surveys at Saltwater Inlet during the forthcoming Spring/Summer period in 2004/05, when water temperatures are as close as possible to those of the original survey discussed above.

Figure 47: Installation sequence of a tidal floodgate at Saltwater Inlet (The Lag), Macleay – *images courtesy of Ron Kemsley, Kempsey Shire Council.*

***1.** Attach old gate to crane wire*

***2.** Old gate removed*

***3.** New tidal gate on truck*

***4.** Lifting the gate from the truck*

***5.** Swinging across to the site*

***6.** Lowering into position*

***7.** Fixing into the final position*

***8.** Installation successfully completed*

5. Communications

▼ *Media, promotions and publicity (see Appendix 7 for copies)*

The following communications and promotions have been achieved as part of the project:

Media release regarding the allocation of funds from the Environmental Trust to the NSW Fisheries North Coast Floodgate Project – 20 June 2002;

ABC Mid-North Coast Radio News – 20th June 2002 – Interview with Paul O'Connor (NSW Fisheries) regarding water quality improvements from floodgate management;

Tweed Heads 97AM Radio News – 21st June 2002 – Interview with Minister Bob Debus re: funds from NSW Environmental Trust to reduce devastating fish kills;

Floodgate Workshop held on 14th August 2002 to highlight the potential modifications available to land managers to facilitate active floodgate management and its associated benefits;

Proceedings of Floodgate Workshop were published, hard copies were distributed to all stakeholders and the document was also placed on the NSW Fisheries website;

ASSAY – the Acid Sulfate Soil Awareness Newsletter contained details of the NSW Fisheries Floodgate Workshop – September 2002 and September 2004;

Media release 10th February 2003 – *"Minister opens floodgate project to improve water quality in the Tuckean Broadwater"*;

May 2003 Edition of the NSW Fish Passage Update newsletter *"Here, There & Every Weir"*;

Contributed articles and funding assistance for the June, September, December 2003 and March 2004 issues of the *Clarence Floodplain News*;

September 2003 Edition of the NSW Fish Passage Update newsletter *"Here, There & Every Weir"*;

Lower Clarence Review 19th September 2003 *"Finding Nemo in our flood drains"*

Richmond Floodplain Newsletter – October 2003;

Lower Clarence Review 10th October 2003 - *"Riches talk entertains"*;

Provided an update for the *Commercial Fishers Newsletter* – Northern Region, December 2003;

Floodgate Project baseline details available on NSW Fisheries website [http://www.fisheries.nsw.gov.au/pub/aquahab.htm]

"In Rehab" NSW Fish Passage Update – March 2004 – provided details of developments with the North Coast Floodgate Project;

NSW Fisheries FishNote *"Oysters & Acid Sulfate Soil Production"*;

Production of a broadcast quality video discussing the issues and benefits associated with active floodgate management.

Conferences & Workshops

Attendance at various conferences and workshops also enabled closer linkages to be made with others in the field, both formally through presentations and informally during breaks. These have included:

5th International Acid Sulfate Soils Conference, Tweed Heads, August 25th – 30th 2002;

De-oxygenation processes in the Richmond catchment, Southern Cross University, 10th December 2002;

NSW Sugar Industry Water Quality Project, Ballina RSL Club, 21st March 2003;

Achieving Sustainable Production in Backswamps, Coraki Youth Hall, 19th March 2004;

Hydrologic effects of floodgate management on coastal agriculture and Coastal floodplain management in eastern Australia: Barriers to fish and invertebrate recruitment in acid sulfate soil catchments, South Grafton ex-Servicemen's Club, 15th October 2003;

North Coast Wetland Assessment Techniques, Broken Head, 29-30th April 2003.

Floodgate workshop

In August 2002, NSW Fisheries through the North Coast Floodgate Project, convened a one-day workshop to examine the different styles of floodgate and modifications available to floodplain managers. The workshop brought together over 50 attendees including a range of 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 interested landholders.

Figure 48: Presentation and attendees at the Floodgate Workshop

A range of 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 were highlighted and 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.

The workshop also provided a tremendous opportunity to ‘calibrate’ floodgate stakeholder’s level of knowledge and understanding of floodgated systems. Combined with opportunities for networking with people from a diverse range of backgrounds, the day was a great success. The key findings of the workshop have been compiled into a proceedings document for all participants (presented in Appendix 6).

Figure 49: Tea break discussions at the Floodgate Workshop

▼ *Documentary video*

A key component of the communications side of the project has been the production of a broadcast quality video covering all aspects of active floodgate management (copies provided in Appendix 10). A professional film making company *Filmstream* was contracted to assist in its production.

Figure 50: Video production underway in the Macleay at the McCuddens site

The video aims to portray the story behind floodgates and the path to their improved management through on-site interviews with farmers, fishers, oyster-growers, land managers and researchers. By combining these viewpoints with aerial footage, time-lapse photography, historic imagery and digital animations, an intriguing and educational production has emerged.

Discussions have commenced with the Department of School Education for the distribution of the video to high schools along the North Coast.

Use of 3-chip cameras and quality sound booms has produced footage to be of a suitable quality for use on national television.

6. Project evaluation

Table 6: Issues encountered and measures taken to resolve them

Description of difficulties / delays encountered with an outline of modifications / variations to deal with these problems or which led to improvement in the project's outcomes.

ISSUE	RESOLUTION
Conflict with elements of agricultural industry and DPI due to historic disagreements over floodgate management.	Closer liaison and support for agricultural interests. Eg. Co-development of a plan to improve environmental and agricultural values at Rocky Mouth Creek in the Richmond has seen an improvement in relations.
Lack of staff at Councils to pursue active floodgate management.	Assistance was provided in preparing funding applications to enable the provision of additional Council staff and other resources.
NPWS concern for potential impacts of floodgate openings on threatened bird species, the Comb-crested Jacana.	Following negotiations with NPWS Regional and Directorate staff, they are satisfied that the benefits of active floodgate management outweigh the potential for displacement of the Comb-crested Jacana given the amount of existing alternative habitat.
Planning NSW (now DIPNR) issue with undertaking wetland rewetting in artificially drained SEPP 14 area, possibly requiring an EIS.	Negotiations with Planning NSW and local government highlighted that the Council were the determining authority and they in turn determine that there was no requirement to undertake an EIS.
Ongoing maintenance costs of new floodgate modifications, local Councils concerned who is responsible?	Infrastructure belongs to Councils. The new modifications generally require the replacement of the old gate with one constructed from corrosion resistant and durable marine grade aluminium or stainless steel. Future funding applications for floodgate modifications would seek to incorporate this requirement.
Difficulty in 'selling' 50 media releases for each floodgate opening in local papers.	Production of a broadcast quality video documentary in addition to communications through stakeholder magazines, radio interviews and presentations.
Inability to add new floodgate sites to Weirs database as it is now defunct.	The relevant information has been added to the new Aquatic Habitat Rehabilitation database which has superseded the old model.

▼ *An evaluation of the actual project as compared with the proposal outlined in your application*

The original proposal included the following seven deliverables:

Floodgate Management Plans at 50 sites signed off by all surrounding landholders

Achieved
Floodgate Management Plans have been completed for 54 of the 57 sites being actively managed. Three sites in the Macleay Valley (Maria #2, Maria #3, Maria #8) have had tidal floodgates installed, which negate the need for Floodgate Management Plans at these particular sites.

The Management Plans are dynamic documents, which reflect the changing landholder needs over time. They require constant review and updating as situations alter. For example as land ownership adjacent to a floodgate structure changes hands, those new owners need to be incorporated into the management structure.

Operating structures built at 50 sites

Achieved
Structures have been constructed at all sites where necessary. Pre-existing structures at some previously unmanaged sites allowed for extra funding to be provided for additional monitoring, negotiation and liaison costs.

Water quality monitoring results from 50 sites

Achieved
Water quality results are available for all sites (Appendix 9). As highlighted elsewhere in this report, some sites and circumstances lead to more complete monitoring regimes than others. Some gates have been partially opened by landholders in the past, leading to difficulties in determining a true 'before' site assessment. Other floodgates, particularly in the Clarence, have had modifications recently installed and are undergoing an 'after' monitoring regime in the near future.

Fish monitoring results from 5 sites

Achieved
Fish monitoring results are available for a total of 14 sites. A PhD candidate based at Southern Cross University has been engaged to conduct this work. Appendix 5 contains a detailed report of the results of this work.

Data stored on the State Weirs Database (GIS) and available to the public

Achieved
Data was originally to have been stored on the State Weirs Database. However, a series of operational issues for the team constructing this system meant that the data is now being held on the more functional and accessible Aquatic Habitat Rehabilitation Database, which will be made available to the public.

An interim and a final report

Achieved
A total of three Interim Reports, in addition to this Final Report have been provided.

Media releases for all 50 actions

Not achieved
As discussed previously, securing media releases for each individual floodgate opening proved problematic due to the unforeseen potential for media saturation in a relatively small project area. Media and communications coverage produced includes various publications for key stakeholders and the production of a broadcast quality documentary video. These are included in Appendix 7.

▼ *Critiques or evaluations of the project and its achievements by people involved in the project or otherwise qualified to provide comment*

The critiques / evaluations were received from the key staff at each of the three local government partners. Copies of these are provided in Appendix 8.

In essence, these critiques highlighted the important role of both the Environmental Trust and NSW Fisheries (now Department of Primary Industries – Fisheries) in securing the large number of actively managed systems. The partnerships developed through this project have led to an anticipation of similar successful programs progressing onground-works.

▼ *Overall assessment of the project's value and effectiveness including an appraisal of its successes and failures*

The project aimed to actively manage 50 floodgates in the Richmond, Clarence and Macleay catchments within two years. At the time many observers in the field commented on the ambitious nature of this target.

However, this target has been not only met but also exceeded, with 57 gates now being actively managed.

Since the inception of the project two years previously, there has been a massive change in the status quo on the floodplain. Increasing numbers of farmers have now seen the benefits of active floodgate management and are keen to trial such initiatives for themselves. Industry bodies such as the Sugar Cane Co-operatives have incorporated active floodgate management into their Codes of Best Practice.

Building partnerships with Councils has also been an extremely successful aspect of the project, with increased respect and awareness of each other's roles and responsibilities. The Floodplain Committees in each of the three catchments are a key tool in promoting and consolidating positive environmental outcomes on the North Coast.

Significant progress has been made towards reducing the likelihood of fish kills on the scale that devastated the Richmond, Clarence and Macleay river systems in early 2001. Improved water quality behind floodgates through increased regular flushing of drain sediments and the water column has reduced the cumulative impact that such materials can have on mobilisation flowing a flood event

▼ *A statement about the future (long term impacts or implications of the project; and any further work or follow up required)*

Although an additional 57 floodgates are now being better managed compared to two years previously, the real successes however are still being realised. Knowledge of the environmental and agricultural benefits of active floodgate management is becoming increasingly widespread, particularly amongst the key target audience of local councils and the farming community both in NSW and other jurisdictions (eg. Queensland).

Farmers are increasingly aware of the project and interested in trying floodgate management for themselves. Perhaps one of the key methods for 'spreading the word' appears to be farmers looking at the positive results on a neighbour's property.

The increasing interest needs to be serviced to maintain the tremendous impetus created. Many farmers are often keen to proceed rapidly once they are comfortable with a proposal and interest can wane should that need remain unmet.

There are still large numbers of floodgates in coastal NSW, which have great potential for better management. The Richmond, Clarence and Macleay catchments are now well underway although a number of additional sites in each catchment remain to be achieved. Other catchments also have similar floodplain issues and are becoming increasingly interested in trialling active management. In the Tweed for example, numerous groups of landholders have contacted this Department, keen to install modifications such as tidal gates for themselves.

▼ *Relevant visual documentation (maps, plans, photographs, diagrams etc)*

Please see Appendix 9 for copies of relevant Floodgate Management Plans, photographs, water quality monitoring results, fish monitoring results, vegetation monitoring results and tidal surveys.

7. Conclusions

• The partnerships forged and consolidated through the project with key stakeholders, particularly local government, industry and landholders, were critical to the project's success.

• The project was not only successful in addressing the causes of the fish kills, but provided holistic improvements to a range of other issues.

• Water quality has improved through restoration of more natural flushing regimes; leading to reduced acidity, higher dissolved oxygen levels, more moderate temperature fluctuations, reduced accumulation of potentially toxic drain sediments and fewer algal blooms.

• Active floodgate management under this project has assisted in the remediation of Acid Sulfate Soil "Hotspot" areas such as the Little Broadwater in the Clarence.

• Fish passage has been restored to over 606 kilometres of previously inaccessible waterway and fish populations have been shown to be using these areas.

• Populations of fish species that are commercially and recreationally valuable are found in greater numbers and species diversity in actively managed systems.

• The agricultural community have also noticed benefits from improved on-farm water quality, better pasture production and drought proofing, as well as more natural in-stream weed control.

• The continued promotion of active floodgate management benefits to both stakeholders and to the broader community will assist in improved floodplain management.

• Aiming towards a whole-of-system approach where, in addition to floodgate openings, there is also scope for provision of riparian fencing, off-stream watering points and other agricultural / environmental improvements will maximise the benefits for all concerned.

• The techniques and lessons learned from this project can be applied to other coastal floodplains in NSW and Queensland.

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9. Appendices

Appendix 1:

Correspondence example

Appendix 2:

Floodgate Management Plan example

Appendix 3:

Vegetation Monitoring Report for Little Broadwater, Clarence

Appendix 4:

Hydrological Survey Report for Micalo Island, Clarence

Appendix 5:

Fish Monitoring Report

Appendix 6:

Proceedings of the Floodgate Modification and Design Workshop

Appendix 7:

*Copies of communications, promotions and publicity**

Appendix 8:

*Project evaluations / critiques**

Appendix 9:

Individual Site Summaries, Location maps, Photographs,*

Floodgate Management Plans, Water Quality data

Appendix 10:

*Floodgate Documentary Video**

*NB: Full copies of the Appendices highlighted above are contained separately, as they total a further 200+ pages

APPENDIX 1: LANDHOLDER CORRESPONDENCE EXAMPLE

Mr Smith
Smiths Lane
SMITHTOWN 2440

15 September, 2004

Dear Mr Smith,

RE: ACTIVE FLOODGATE MANAGEMENT

NSW Fisheries is the manager of a project, funded by the Environmental Trust, looking at implementing options for the active management of floodgates within the Macleay River catchment. This involves providing funding for modifications to the existing floodgate structure, which allow for improved water passage in non-flood periods, while still retaining the original flood mitigation function.

Kempsey Shire Council, support the project through the Macleay River Floodplain Project Steering Committee, providing there are no adverse affects to landholders or the immediate environment.

Some benefits of active floodgate management include regular drainage channel flushing, aquatic weed control, increasing fish passage in the drain waterway, habitat improvement, improving water quality and neutralisation of potential acid sulfate soil leachate.

Of the 86 floodgates located in the Macleay River catchment, 20 have been prioritised for further investigation, including the floodgates on Pola Creek. Ron Kemsley from Kempsey Shire Council has developed an information sheet that discusses the proposal in more detail and is attached here for your information.

We are now seeking your views and thoughts about the proposal for retrofitting and actively managing the Pola Creek Floodgates to allow water exchange in the mid to lower reaches of the Pola Creek, in non-flood periods. In the event or likelihood of a pending flood, Kempsey Shire Council staff will close the close the gates and re-open after the flood threat has abated.

If you have any enquiries regarding the above, please do not hesitate contacting me on (02) 6686 2018.

Yours sincerely,

Simon Walsh
CONSERVATION MANAGEMENT OFFICER
NSW FISHERIES

FLOODGATE MANAGEMENT PLAN
SANDY CREEK NO. 1 CANAL

Introduction

This Management Plan sets out the principal tasks and responsibilities for an active floodgate management trial at Sandy Creek No. 1 Canal, Swan Bay.

The aim of the trial is to assess the effects of active floodgate management on water quality, aquatic ecosystem health and aquatic weed control in Sandy Creek No. 1 Canal.

This Plan has been prepared in consultation of all stakeholders. The degree of involvement, methodologies, timing and evaluation is detailed below.

Floodgates

The canal is controlled by a single cell (3.3 * 3.3 m) floodgate structure.
The current floodgate has been fitted to the mouth of Sandy Creek No. 1 Canal.
The floodgate will be opened and closed by means of a winch.

Location

Sandy Creek No. 1 Canal empties into Sandy Creek, about 5 km upstream of the confluence of Sandy Creek and Bungawalbyn Creek (see attached map).

Parties involved in the Development of this Management Plan

Shane Davies (farm manager),
Ken Pursey (landowner),
Richmond River County Council (RRCC),
New South Wales Fisheries (NSWF),
Department of Infrastructure, Planning and Natural Resources (DIPNR).

Floodgates and trial

RRCC will conduct the trial.
All actions to be undertaken are consistent with past and established management practices and in consultation with State Government agencies.
RRCC has fitted lifting gear to the floodgate at the mouth of Sandy Creek No.1 Canal.
A safe working walkway and platform has been installed to allow safe access.

- **Gate Opening and Closure**

Opening

The floodgate will be lifted in order to allow fresh water to be either held back or pushed up the drain, to keep target area's watertables higher, and soil profile moist. Ag NSW will be working with farmers to fence off the canal and install in-drain groundwater control structures.

Closure

As the tidal amplitude in this relatively freshwater section of the estuary is small, a closure will depend on a flood warning, storm surge or localised flooding which would trigger a lowering of the gate.

Timing

The floodgate has been opened on an ad hoc basis in the past. This trial will standardise methodologies and protocols.

Monitoring

Drain water quality - datalogger

- None at this time.

Drain water quality – spatial

- The farm managers/landholders and RRCC will select strategic sites along the drain system for RRCC to conduct regular manual monitoring with a Horiba U-10 water quality meter.

Ground water monitoring

- None planned at this time.

Water levels

Farm managers/landowners and RRCC will monitor water levels along the system.

Vegetation

Farm managers/landowners and RRCC will monitor bank vegetation and in-stream vegetation using photo points and visual assessment.

Measuring and Evaluation of the Trial

RRCC, farm managers/landholders and recognised specialists in vegetation and water quality, will evaluate the trial.

All data collected will be made available to those individuals and organisations listed in Item 4 of this plan.

Measurable outcomes

Over the duration of the trial, the focus will be on the determination of water quality improvements expressed in the following terms:

- decrease in the net store of acid products in the drain,
- improved water quality,
- control of aquatic weeds,
- no deleterious impacts on surrounding land uses,

- fewer fish kills,
- cleaner drains,
- reduced issues with black water.

Contingency Plan

The gates will be shut if there is a risk of:

generalised catchment flooding (major flood warning from the Bureau of Meteorology),
localised sub-catchment flooding (minor flood warning from the Bureau of Meteorology),
risk of bank overtopping,
storm surges and/or
any significant concerns by landholder, after consultation with all stakeholders.

Contacts

Shane Davies ph: 6683 0000 (farm manager)
Ken Pursey ph: 6683 0000 (landowner),
Michael Wood ph: 6621 0000 Richmond River County Council (RRCC)
fax: 6622 0000
Simon Walsh ph: 6686 0000 New South Wales Fisheries (NSWF) fax: 6686 0000

Management Plan Endorsement

The endorsement of key stakeholders involved in the implementation of this plan appear below:

NAME	SIGNATURE	DATE
Shane Davies (property manager)	....	....
Ken Pursey (land owner)	....	....
Michael Wood Richmond River County Council (RRCC)	....	....
Marcus Riches Senior Conservation Officer New South Wales Fisheries (NSWF)	....	....
Wayne Garrard Catchment Manager Dept. Infrastructure Planning and Natural Resources (DIPNR)	....	....

APPENDIX 3: Vegetation responses to tidal inundation of Little Broadwater Wetland.

PROGRESS REPORT: JUNE 2004

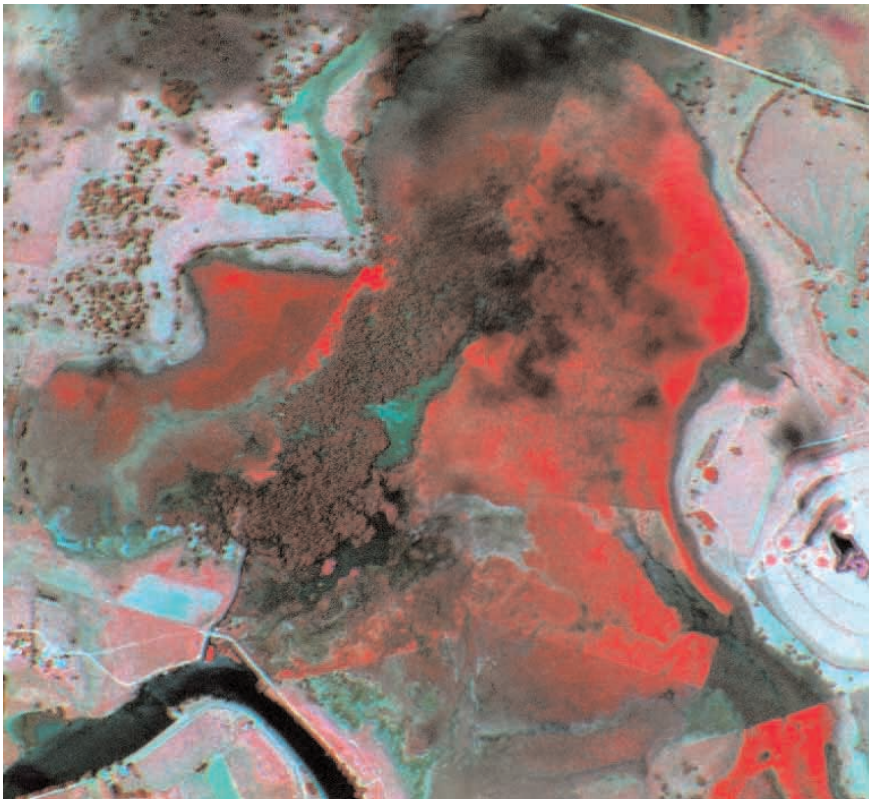


Photo: November 2003 Quickbird Satellite image displayed in the near infrared. Actively growing, healthy vegetation is represented in bright red areas, darker areas are water, bare soil or dead vegetation

Justine Graham, John Duggin and Paul Frazier
Ecosystem Management, University of New England, Armidale.

Supported by: NSW FISHERIES; UNE The University of NEW ENGLAND

Introduction:

The Division of Ecosystem Management within the University of New England was engaged by NSW Fisheries to conduct research into the impact of tidal inundation on the existing pasture and wetland vegetation communities at Little Broadwater wetland. The initial modification and opening of floodgates occurred in July 2003, and monitoring of vegetation communities began in early August of the same year.

To date existing vegetation communities have been identified and their extent assessed through Aerial Photo Interpretation. Sampling sites have been established across the wetland and four field trips have collected data for the winter 2003 to autumn 2004 periods. Satellite imagery analysis will be undertaken for the May 2004 sample, during which time a Quickbird Image was captured of the site.

Aim:

To assess the impact of reintroducing tidal waters on the habitat and production values of vegetation communities in Little Broadwater Wetland.

Project Timetable:

SAMPLE	DATES	PURPOSE	PROGRESS
Winter 2003	8 – 10th August	• Establish monitoring sites • Condition assessment 1	Complete
Spring 2003	3-5th November	• Condition assessment 2 • Pasture sampling 1	Complete
Summer 2004	5-7th February	• Condition assessment 3 • Pasture sampling 2	Complete
Autumn 2004	6-8th May	• Condition assessment 4 • Pasture sampling 3 • Vegetation ground truthing • Satellite image collection	Complete
Winter 2004	5-7th	• Condition assessment 5 • Pasture sampling 4	Pending
Winter 2004	4-6th November	• Condition assessment 6 (final)	Pending

Methods:

Twenty-two vegetation-monitoring points were established across all the community types (Table 1) at varying distances from the floodgate (Figure 1). Markers are in place at each site and vegetation condition assessment occurs within 8 1x1m quadrats arranged around the marker at each site (Figure 2). A photo point has been established north of each site and a photo is taken with every seasonal sample.

Table 1. Vegetation communities sampled

No	TYPE	No	TYPE
1	Soft rush grazed (*Eleocharis equisetina)*	12	Clubrush south *(Schoenoplectus validus)*
2	Soft rush/water couch grazed *(Paspalum distichum)*	13	Nutgrass south *(Bolboshoenus calwelli)*
3	Soft rush ungrazed	14	Clubrush north
4	Soft rush grazed	15	Common reed north
5	Soft rush ungrazed	16	Nutgrass north
6	Soft rush grazed	17	Swamp oak north *(Casuarina glauca)*
7	Soft rush /couch grazed	18	Swamp oak south
8	Soft rush /couch grazed	19	Soft rush/couch grazed (Smythe's East)
9	Soft rush grazed	20	Soft rush grazed (Smythe's middle)
10	Soft rush ungrazed	21	Soft rush ungrazed (Smythe's east)
11	Common reed south *(Phragmites australis)*	22	Soft rush/Couch grazed (Vickery's middle)

Vegetation condition assessment records the vegetation species present and the percent foliage cover of each for the eight quadrats at each site. The status of each species (dead/alive) is recorded and the percentages of bare ground and litter at each quadrat included. Water depth, salinity and pH are measured in the field for each site.

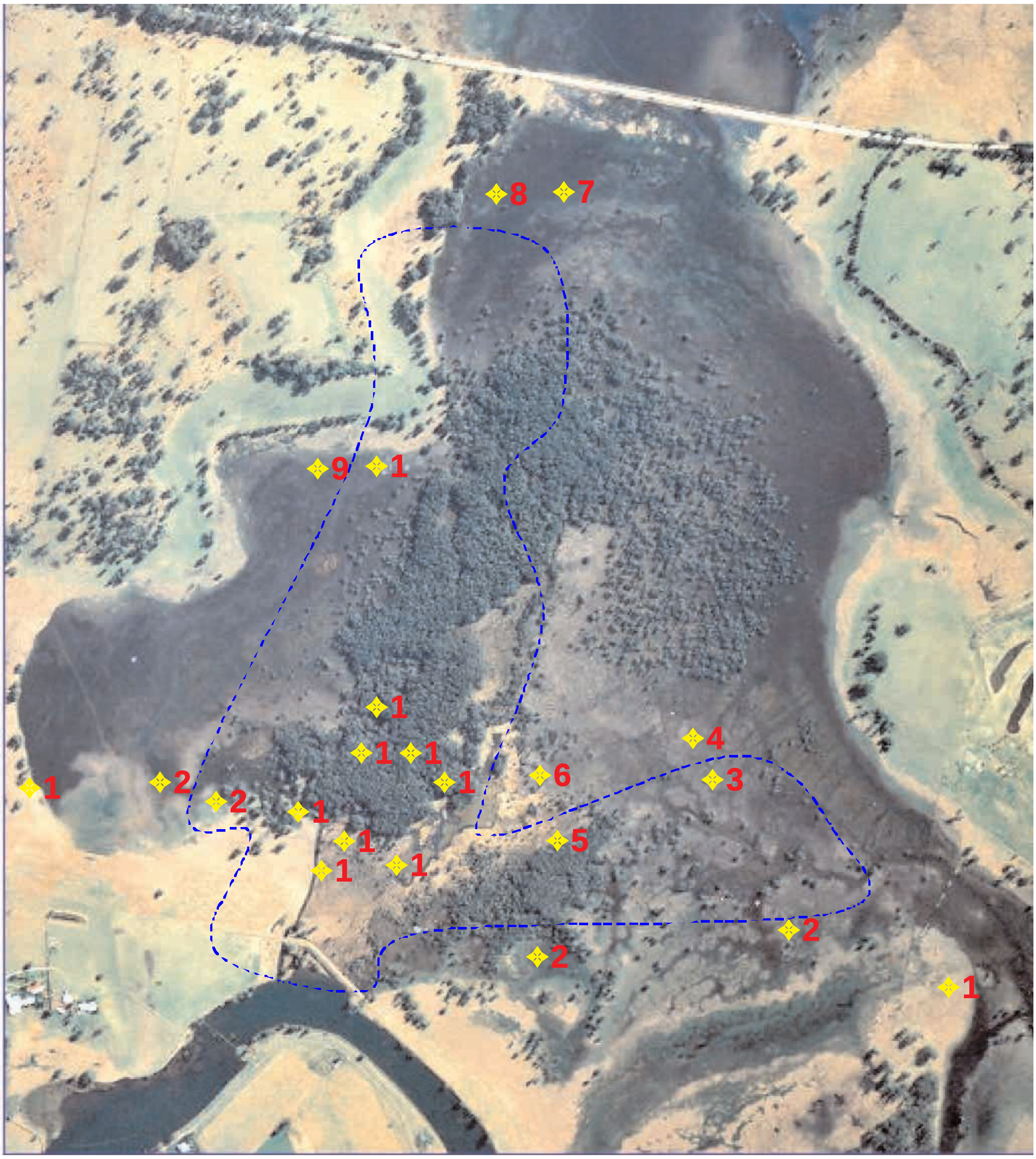


Figure 1. Vegetation monitoring points established August 2003

Approximate grazing exclusion area ---------
Vegetation monitoring point markers ✦

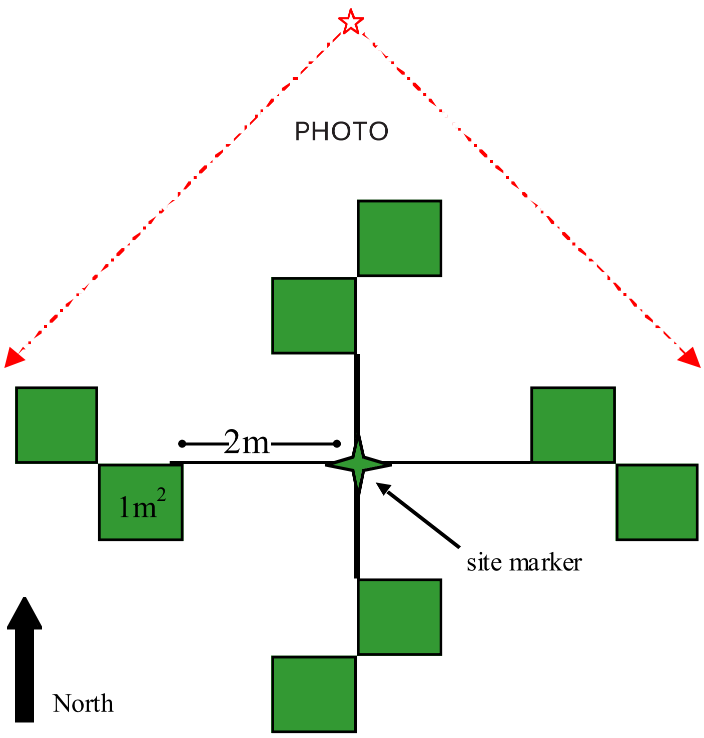


Figure 2. Sampling strategy at vegetation monitoring points

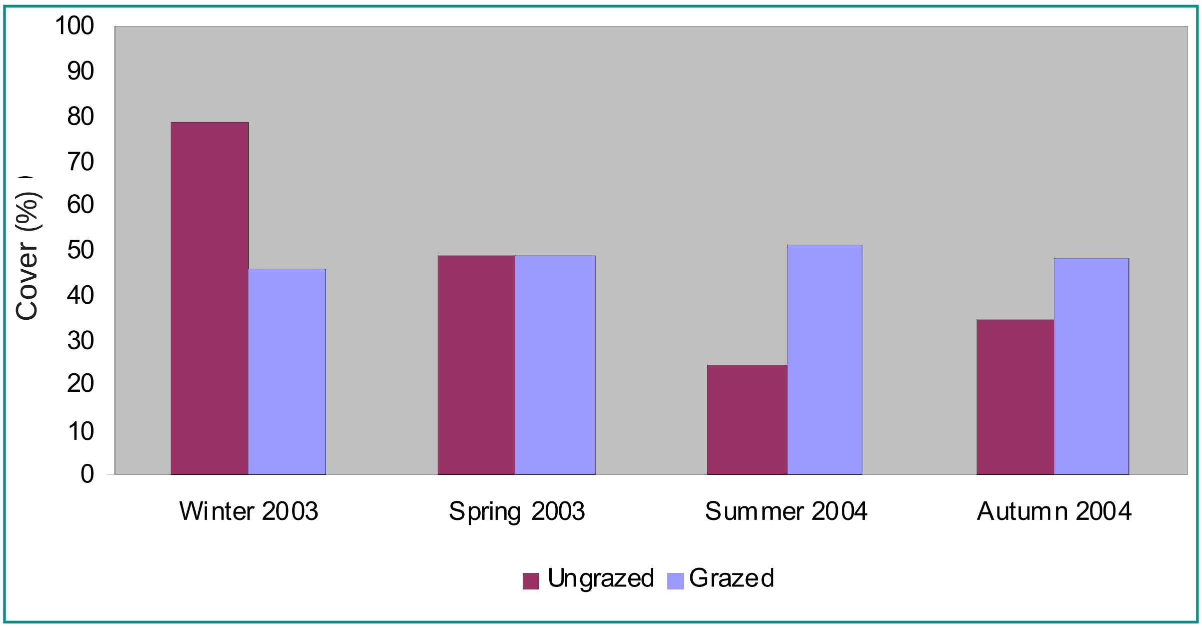
Outcomes so far:

The sampling to date has shown a largely positive change in vegetation health over summer, during which time rainfall, coupled with floodgate opening lead to previously dry areas becoming inundated. These conditions, and the mobilisation of acidic salts from drained acid soils have led to an edge effect of dead vegetation and bare earth that is now visible on most aquatic/terrestrial boundary areas of the wetland (Photo 1). This is exacerbated by the previous domination of these zones by Blue Couch (*Cynadon dactylon)*, a species that is not tolerant of long periods of inundation and has died off as a result of the new conditions. Such an impact is to be expected following water regime changes in a wetland, and is a natural phase in the move towards vegetation species that favour wetter environments.

Photo 1. Edge effect in areas previously dominated by Blue Couch *(Cynadondactylon)* as seen in February 2004

The impacts of reinundation on specific vegetation communities have been picked up through our sampling and are illustrated in the graphs and photos below. All but one of the communities sampled have exhibited tolerance to the new water levels and varied salinity in the wetland. The large tracts of Softrush (*Eleocharis equisetina)* that surround open water and forested areas have remained healthy, and in some areas exhibited a marked improvement in cover of the species, mostly visible in the grazed areas (Graph 1, Photos 2-5).

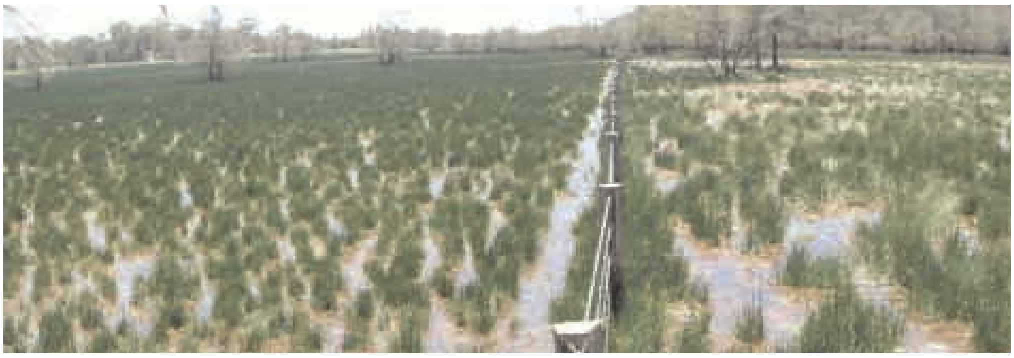
The same species has died off in some of the ungrazed and deeper parts of the wetland, largely as a result of clearing by waterbirds. The black swans have created cleared “flyways” in these areas, as well as pulling up and feeding on the plants. The Softrush that was growing very thickly in some of the ungrazed zones has died off through it’s natural annual lifecycle and, without grazing disturbance, the dead vegetation has remained in place leaving tracts of organic matter on the surface providing a valuable food source for fish and prawns. These changes can be seen clearly in the February and May photos of the eastern photo point (Photos 6 – 9).



Graph 1. Softrush *(Eleocharis equisetina)* cover in grazed and ungrazed sampling areas. Grazed zones have maintained their levels of vegetation throughout the seasons, while ungrazed areas exhibit seasonal die off and the impact of increased feeding pressure from birds.

Photos 2 - 5. Grazing photo point on the western boundary of the exclusion fence showing differences between grazed (left) and non-grazed areas in the Softrush *(Eleocharis equisetina)* community since the opening of the floodgates.

August 2003



November 2003

February 2004

May 2004

Photos 6 - 9. Grazing photo point on the eastern boundary of the exclusion fence showing differences between grazed (left) and non-grazed areas in the Softrush *(Eleocharis equisetina)* community since the opening of the floodgates.

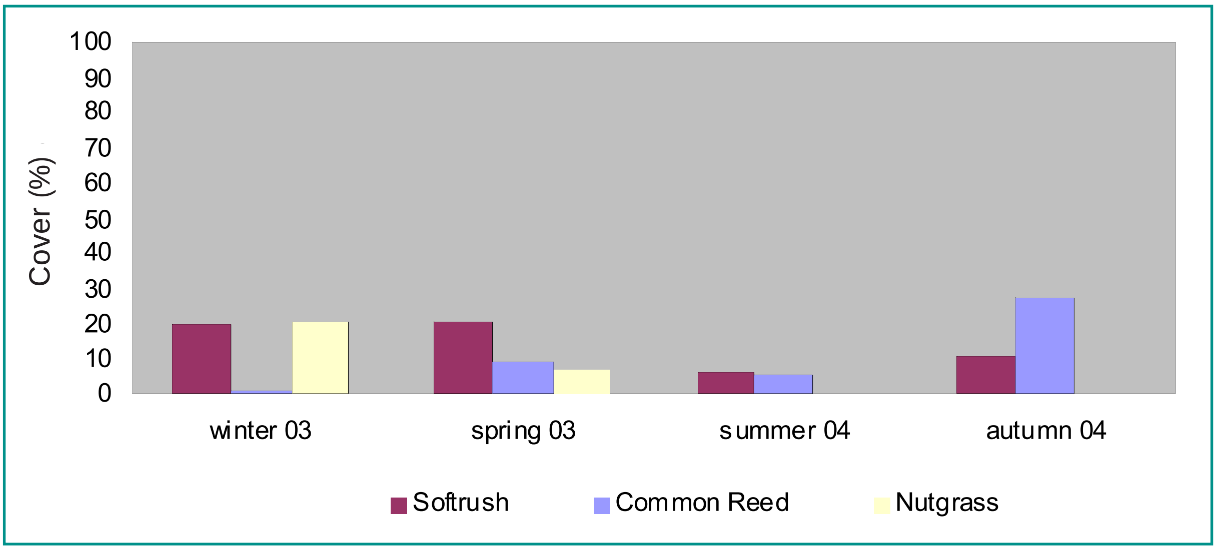
August 2003

November 2003

February 2004

May 2004

Samples taken in the open water and fringing vegetation communities of the top and bottom ponds (sites 11 – 18) have shown a dramatic change in one species, known as Nutgrass (*Bolboshoenus caldwelli)*, and seen other communities maintain or improve their health. The nutgrass species is the most sensitive to salinity changes, exhibiting little or no tolerance to the low levels of salinity that have been recorded in the swamp (Graph 2, Photos 10-11). Other species that have been previously recorded as salt sensitive have maintained their health throughout the sampling periods, illustrating that salt levels have remained within a threshold acceptable to most fringing aquatic communities.



Graph 2. Changes seen in the Nutgrass *(Bolboshoenus caldwelli)* community since gate opening. By Summer 2004 the Nutgrass had completely died off in our sampling areas whilst the Common Reed *(Phragmites australis)* has increased in its place.

Photos 10 – 11. Nutgrass community die off has occurred since gate opening in July 2003.

August 2003

February 2004

▼ ***Future work:***

Further fieldwork will indicate the effects of seasonal changes as well as longer-term alterations to salinity and water levels in the swamp. Results shown here are preliminary and illustrate the main changes we have seen throughout our fieldwork thus far. Satellite imagery analysis and further analysis of the data collected will indicate any statistically significant changes to vegetation communities, and the overall difference between grazed and ungrazed areas.

APPENDIX 4: FISH FORE SHORE

INITIAL HYDRODYNAMIC TIDAL SURVEY FOR FLOODGATE FISH PASSAGE ENHANCEMENT, MICALO ISLAND

Prepared for:

Simon Walsh
Floodgate Project Officer
Office of Conservation
NSW Fisheries – Ballina
Date: April 2004

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Introduction

Saltmarsh wetlands are an important fish habitat that is being lost to agricultural and urban development along the east coast of NSW. Saltmarsh wetland communities are located in the littoral zone of estuaries high in the intertidal zone where they experience short infrequent tidal inundations by only the most extreme of astronomical high tides.Therefore saltmarsh wetland communities are often at threat because they represent prime water front real estate.

Recent PhD research at the Australian National University by Mazumder.,D. (2003) into '*The contribution of saltmarsh to the temperate estuarine fisheries in south east Australia*', found saltmarsh to be as economically and ecologically important as mangroves, while supporting a significantly different fish assemblage to mangroves. The results support the importance of temperate saltmarsh as habitat for economically important fish, including crab larvae and found that saltmarsh export a positive contribution to the estuarine food chain supplementing the nutritional requirements of estuarine fish including commercially and recreationally important species.

The NSW Fisheries 'North Coast Floodgate Project' through the Environmental Trust is currently funding a suite of floodgate modification projects to allow for fish passage. A number of privately owned floodgates have been targeted on Micalo Island towards the mouth of the Clarence River with the potential to provide fish access to in excess of 250 hectares of saltmarsh type fish habitat. Knowledge of the external tidal characteristics from the floodgate drainage network is essential to the design of floodgate fish passage enhancement structures that will provide for the highest astronomical tidal flooding of saltmarsh fish habitat.

Once modifications have taken place to the floodgate structure on Central Micalo Island, follow up surveys will commence to ensure that water is restricted to desired areas, particularly following spring tide conditions.

This work was conducted in conjunction with Green., B. PhD research funded through a NSW Fisheries scholarship at Southern Cross University (SCU) School of Environmental Science and Management, Lismore NSW.

Tidal Characteristics

The upper part of the tidal cycle is most relevant to the design of a hydrological regime that will reinstate the highest astronomical tidal flooding of saltmarsh communities adjacent to an extensive floodgate drainage network on north Micalo Island and thus the height of the high tides are considered as the most important from a design point of view.

MATERIALS AND METHODS

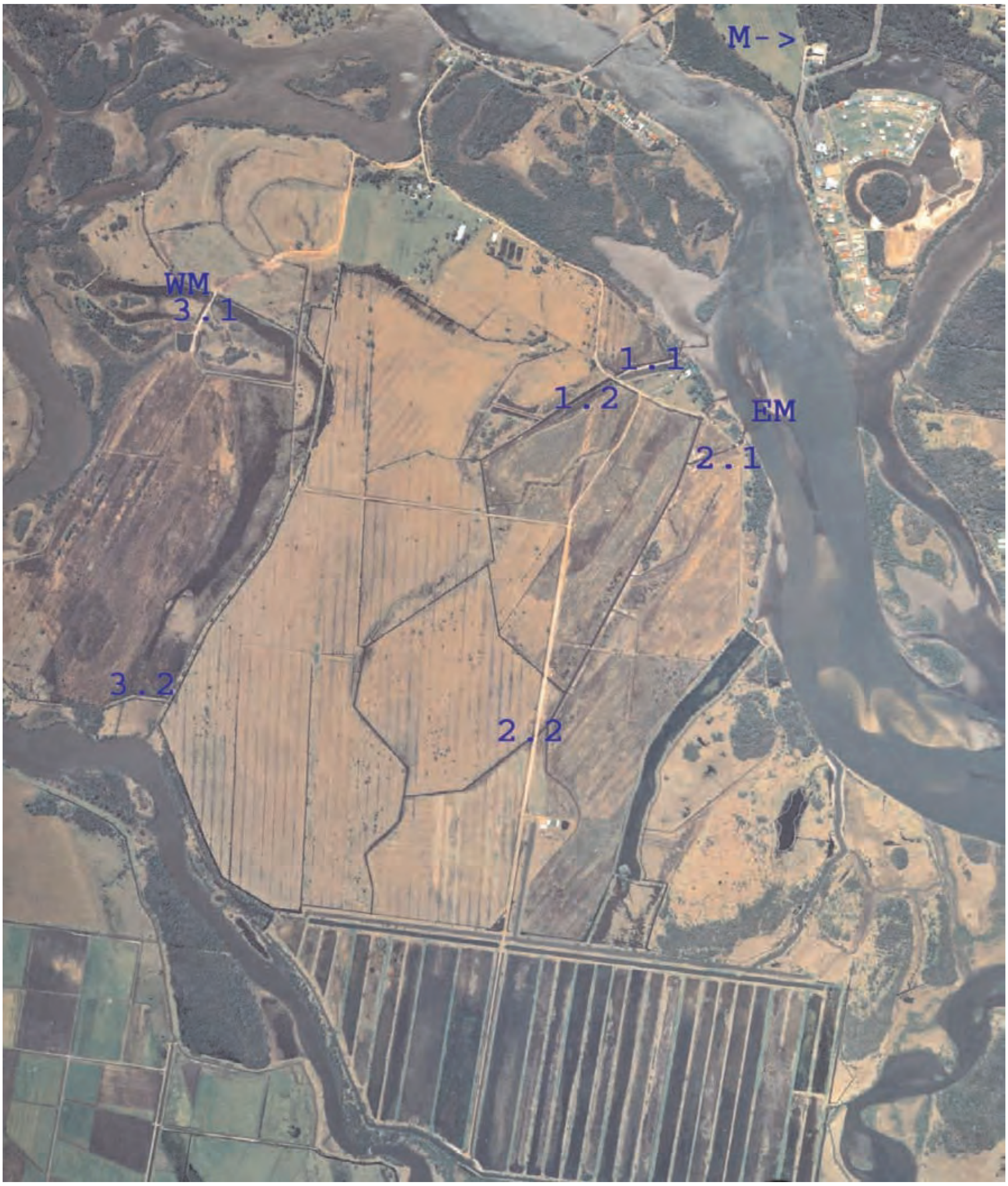

Figure A: Map of study sites on Micalo Island showing the following:

Site M	Clarence River mouth
Site EM	east Micalo Island at the Oyster channel side of floodgate 2 on drain 2
Site WM	west Micalo Island at the road crossing on downstream end of drain 3.
Site 1.1	upstream side of floodgate 1 on drain 1
Site 1.2	upstream point on drain 1
Site 2.1	upstream side of floodgate 2 on drain 2
Site 2.2	upstream point on drain 2
Site 3.1	road crossing on the downstream end of drain 3 @ Site WM
Site 3.2	upstream point on drain 3

Tidal survey

Surveyed the spring high to spring low ebb tidal cycle on the new moon lunar cycle to address the most extreme king tide levels.

Australian Height Datum

Figure 1 sourced from Fort Denison tide time predictions and adjusted to Australian Height Datum (AHD) by applying a conversion of 906mm variation to equate the Iluka Port Datum of Indian Spring Low to 0 on tide chart (Gulaptis and Smith Surveyors, pers. comm.).

Standard Error

When interpreting these results it is important to consider that the accuracy has been compromised by two factors. Firstly, the reference points for AHD were taken from marks on telegraph posts surveyed in several years ago and minor variations may have occurred over that time due to subsidence. Secondly, an inherent error exists with the dumpy level equipment supplied by Southern Cross University (SCU) that was tested to be approximately $\pm$0.05meters. Therefore, any comparison made between two separate survey points may represent a 200 millimetre error range. It is recommended these results be consolidated using laser levelling technology to confirm the AHD points applied.

Results

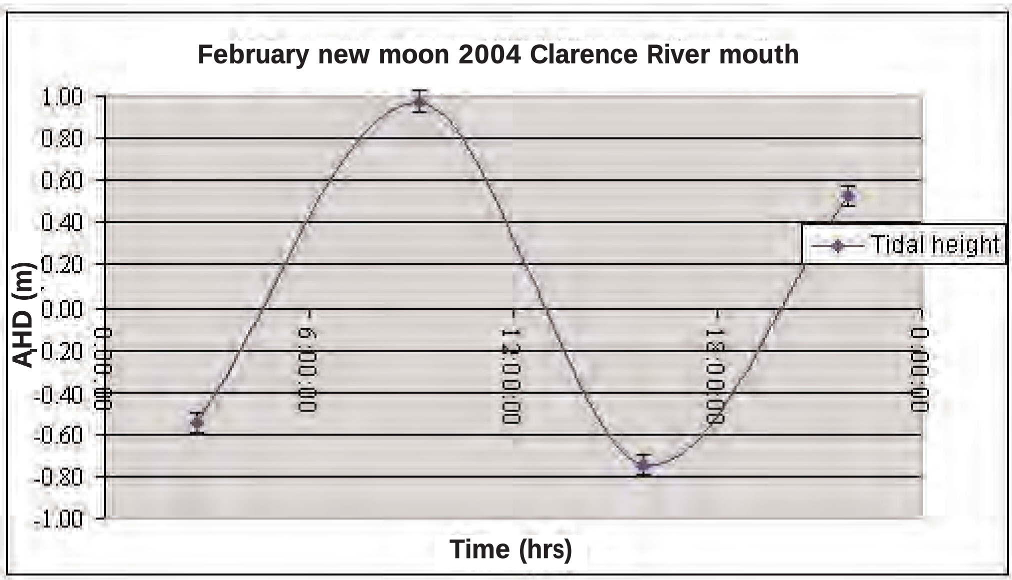

Figure 1: Spring tide height at the Clarence River mouth on 20/02/2004 sourced from Fort Denison tide time predictions and adjusted to AHD using the Iluka Port Datum of Indian Spring Low.

Figure 1 displays the lunar month maximum spring high tide of 0.97m AHD at 09:14hrs and spring low tide of -0.75m AHD at 15:51hrs

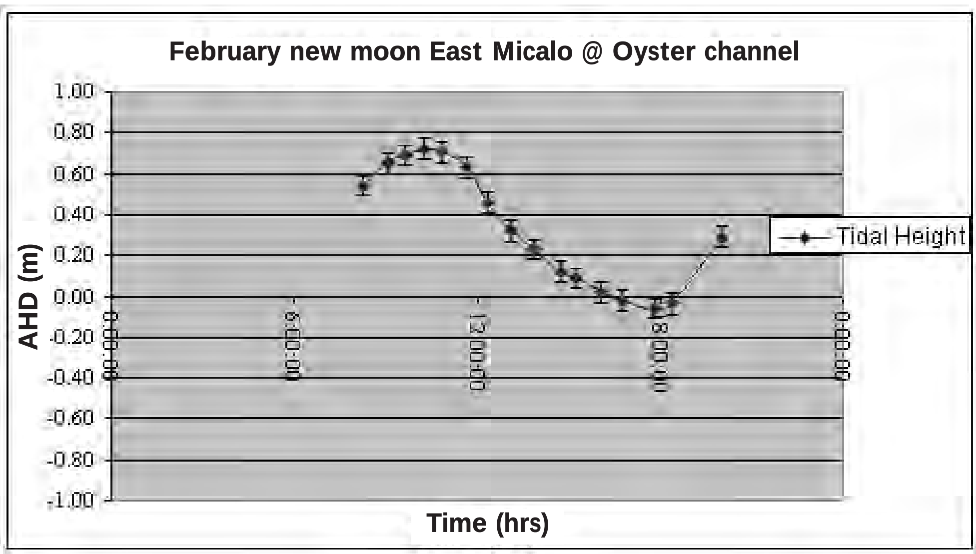

Figure 2: Spring tide height at east Micalo Island in Oyster channel (site EM) 20/02/2004.

Figure 2 displays the lunar month maximum ebbing spring tidal range from a spring high tide of 0.72m AHD at 10:15hrs to a spring low tide of -0.06m AHD at 17:50hrs.

Plate 1: Spring high tide at east Micalo Island in Oyster channel looking down stream from floodgate 2 on drain 2 (site 2.1) 20/02/2004.

Plate 2: Spring low tide at east Micalo Island in Oyster channel looking down stream from floodgate 2 on drain 2 (site 2.1) 20/02/2004.

Plate 3: Spring high tide at east Micalo Island in Oyster channel looking up stream towards floodgate 2 on drain 2 (site 2.1) 20/02/2004

Plate 4: Spring low tide at east Micalo Island in Oyster channel looking up stream towards floodgate 2 on drain 2 (site 2.1) 20/02/2004.

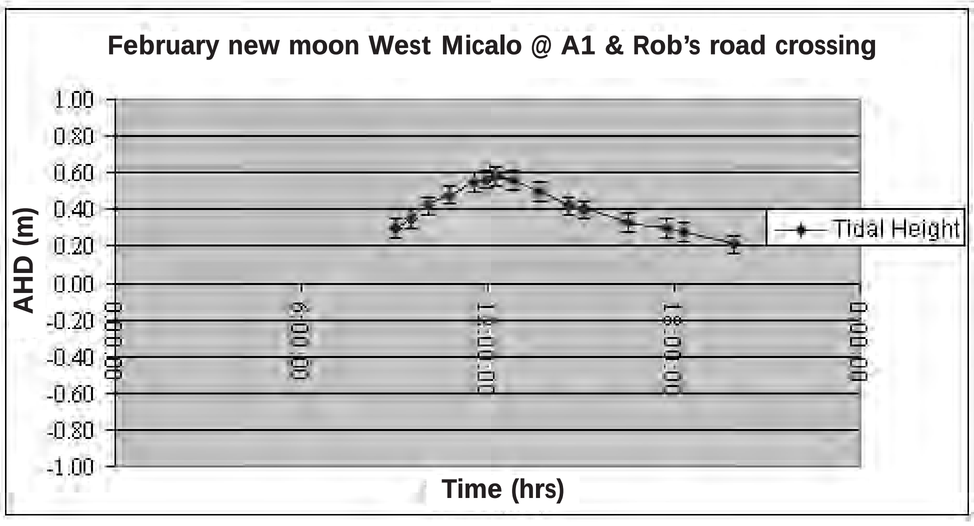

Figure 3: Spring tide height at west Micalo Island road crossing on drain 3 (site 3.1) 20/02/2004.

Figure 3 displays the lunar month maximum ebbing spring tidal range from a spring high tide of 0.58m AHD at 12:15hrs to a spring low tide of 0.21m AHD at 19:55hrs.

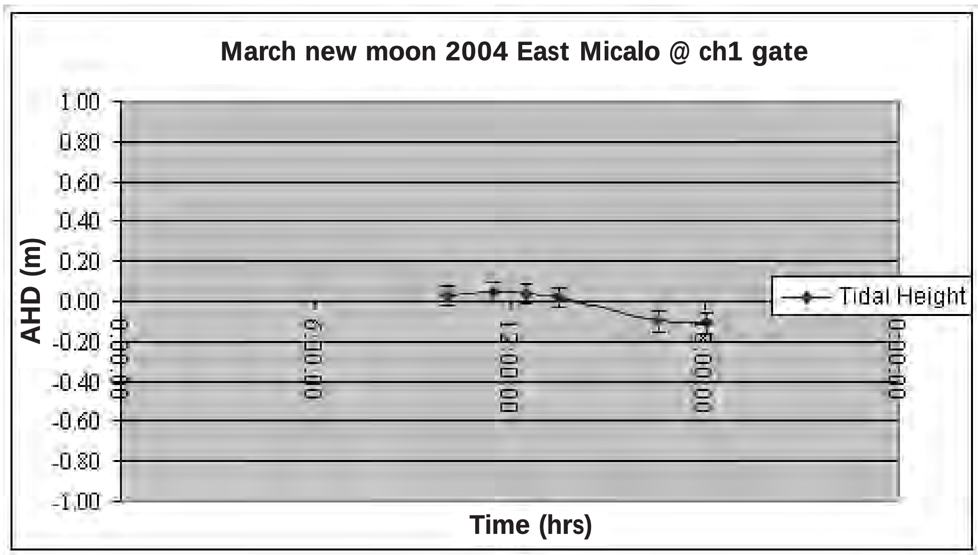

Figure 4: Spring tide height at east Micalo Island up stream side of floodgate 1 on drain 1 (site 1.1) 20/03/2004.

Figure 4 displays the lunar month maximum ebbing spring tidal range from a spring high tide of 0.05m AHD at 11:30hrs to a spring low tide of -0.11m AHD at 18:05hrs.

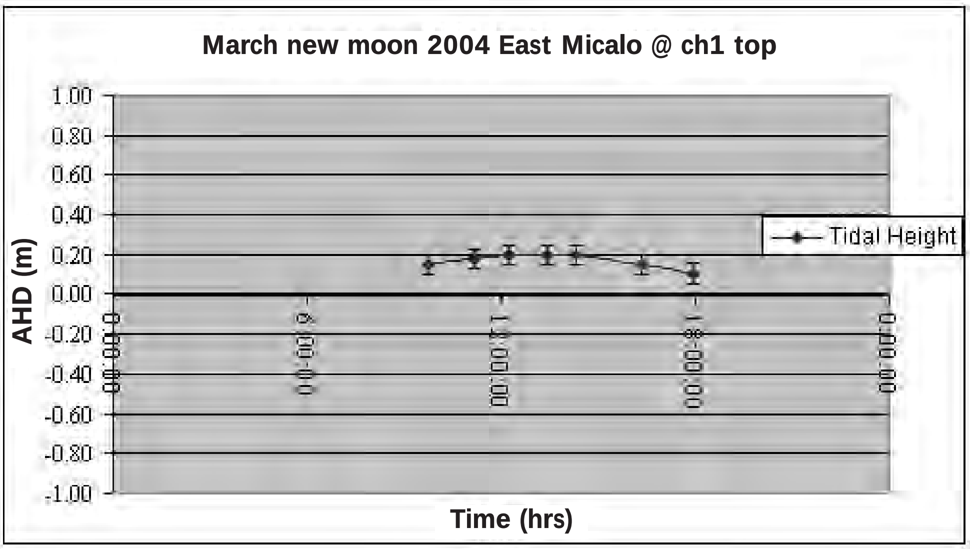

Figure 5: Spring tide height at east Micalo Island upstream on drain 1 (site 1.2) 20/03/2004.

Figure 5 displays the lunar month maximum ebbing spring tidal range from a spring high tide of 0.20m AHD at 13:25hrs to a spring low tide of 0.11m AHD at 17:55hrs.

Plate 5: Spring high tide at east Micalo Island at floodgate 1 on drain 1 (site 1.1) 20/02/2004.Note subsidence of the floodgate levee and topping by spring high tide water level.

Plate 6: Spring low tide at east Micalo Island looking downstream at floodgate 1 on drain 1 (site 1.1) 20/02/2004. Note subsidence of the floodgate levee.

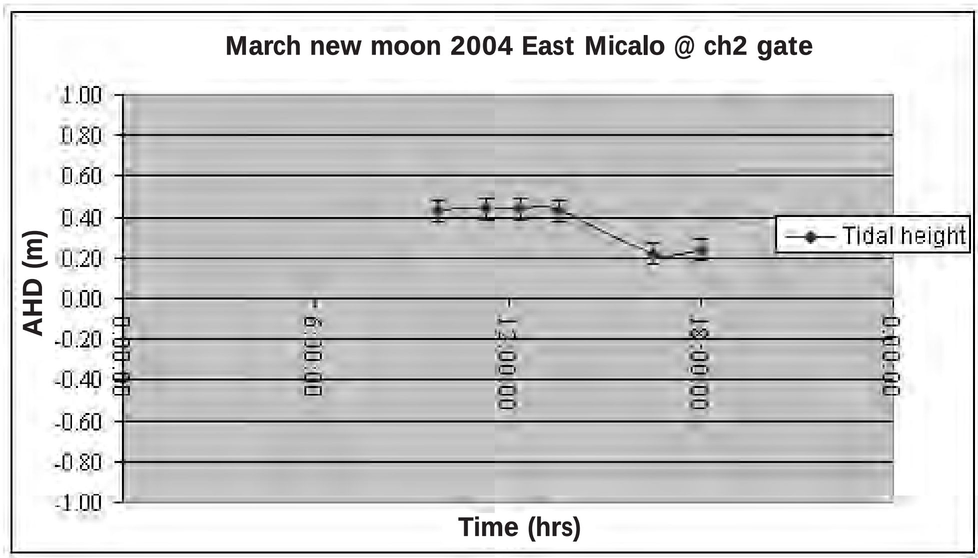

Figure 6: Spring tide height at east Micalo Island up stream side of floodgate 2 on drain 2 (site 2.1) 20/03/2004.

Figure 6 displays the lunar month maximum ebbing spring tidal range from a spring high tide of 0.44m AHD at 11:55hrs to a spring low tide of 0.22m AHD at 16:30hrs.

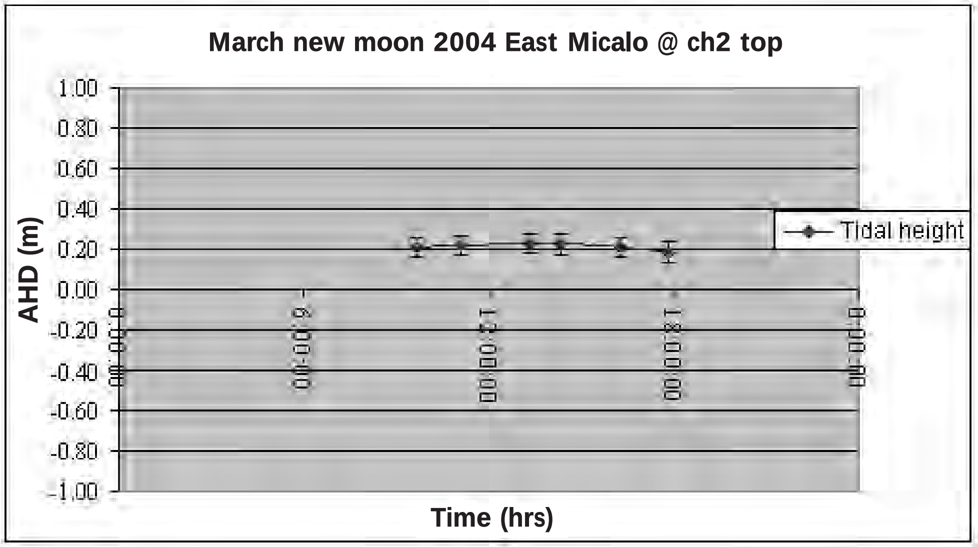

Figure 7: Spring tide height at east Micalo Island up stream on drain 2 (site 2.2) 20/03/2004.

Figure 7 displays the lunar month maximum ebbing spring tidal range from a spring high tide of 0.23m AHD at 13:50hrs to a spring low tide of 0.19m AHD at 17:50hrs.

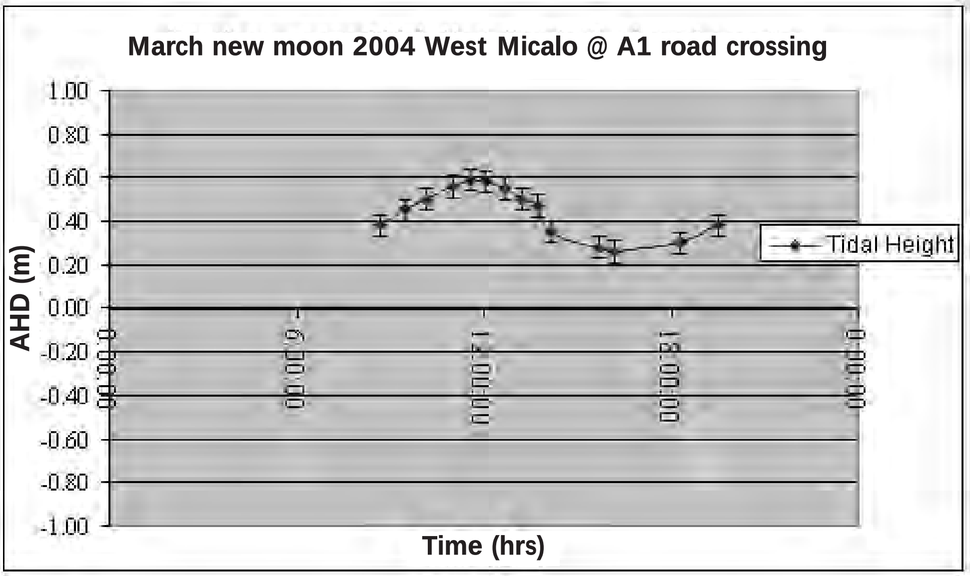

Figure 8: Spring tide height at west Micalo Island at the road crossing on the downstream end of drain 3 (site 3.1) 20/03/2004.

Figure 8 displays the lunar month maximum ebbing spring tidal range from a spring high tide of 0.59m AHD at 11:35hrs to a spring low tide of 0.26m AHD at 16:10hrs.

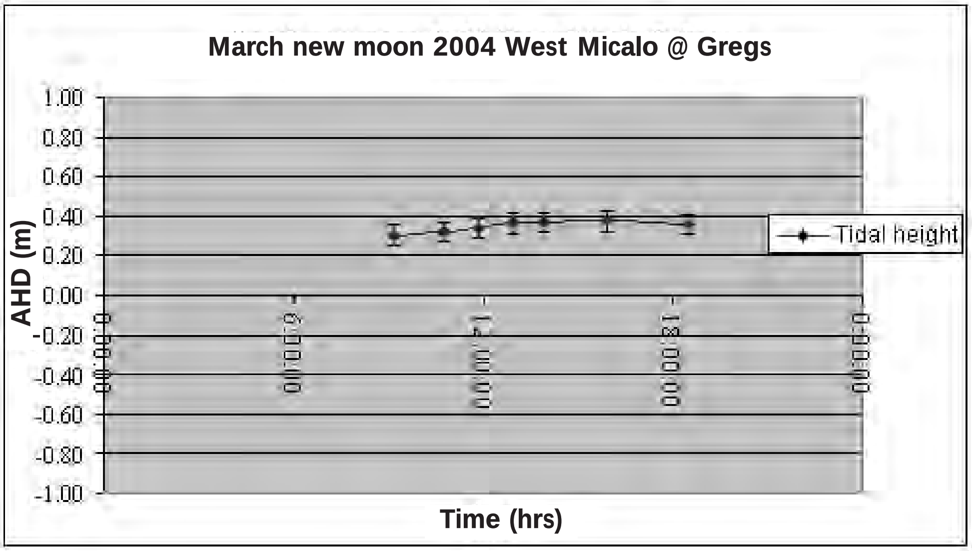

Figure 9: Spring tide height at west Micalo Island upstream point on drain 3 (site 3.2) 20/03/2004.

Figure 9 displays the lunar month maximum ebbing spring tidal range from a spring high tide of 0.37m AHD at 13:25hrs to a spring low tide of <0.36m AHD at >18:30hrs.

Discussion

Tidal lag

Tidal lag in the main channel

Comparison of Figures 1 and 2 displays a tidal lag of approximately 1hr from the mouth at site M to east Micalo Island at site EM with spring high tide peaking at approximately 09:14hrs (Figure 1) at the mouth site M and 10:15hrs (Figure 2) at the Oyster channel site EM.

Comparison of Figures 1 and 3 displays a tidal lag of approximately 3hrs from the mouth at site M to west Micalo Island at site WM with spring high tide peaking at approximately 09:14hrs (Figure 1) at the mouth site M and 12:15hrs (Figure 3) at the west Micalo Island road crossing site WM.

Comparison of Figures 2 and 3 indicates a tidal lag of approximately 2hrs from east Micalo Island at site EM to west Micalo Island at site WM with spring high tide peaking at approximately 10:15hrs (Figure 2) at the Oyster channel site EM and 12:15hrs (Figure 3) at the west Micalo Island road crossing site WM. However, it must be noted that the west Micalo site is within the confines of a non-floodgated drain and not in the open channel and therefore the accuracy of this observation may be compromised. It is recommended an additional site be added at the confluence of drain 3 with Shallow channel in an effort to establish the exact tidal lag.

Tidal lag in the drainage network

Comparison of Figures 4 and 5 displays a tidal lag of approximately 2hrs in an upstream direction of drain 1 with spring high tide peaking at approximately 11:30hrs (Figure 4) downstream at site 1.1 and 13:25hrs (Figure 5) further upstream at site 1.2.

Comparison of Figures 6 and 7 displays a tidal lag of approximately 2hrs in an upstream direction of drain 2 with spring high tide peaking at approximately 11:55hrs (Figure 6) downstream at site 2.1 and 13:50hrs (Figure 7) further upstream at site 2.2.

Comparison of Figures 8 and 9 displays a tidal lag of approximately 2hrs in an upstream direction of drain 3 with spring high tide peaking at approximately 11:35hrs (Figure 8) downstream at site 3.1 and 13:25hrs (Figure 9) further upstream at site 3.2.

Tidal amplitude

Tidal amplitude in the main channel

It is important to note the skew in tidal amplitude towards a reduction in low tide levels that do not extend far below 0.00m AHD (Figure 1,2 and 3).

Comparison of Figures 1 and 2 displays an upstream reduction in tidal amplitude of 0.88m from the mouth (site M) to east Micalo (site EM). This reduction is represented by a variation of 1.66m (Figure 1) at the mouth site M from 0.97m AHD at February spring high tide to -0.69m at February spring low tide to a variation of 0.78m (Figure 2) at site EM from 0.72m AHD at February spring high tide to -0.06m at February spring low tide. This reduction in tidal amplitude equates to a difference in high tide of approximately 0.25m (±0.05m) and a difference in low tide of approximately -0.69m (±0.05m).

Comparison of Figures 1 and 3 displays an upstream reduction in tidal amplitude of 1.29m from the mouth (site M) to west Micalo (site WM). This reduction is represented by a variation of 1.66m (Figure 1) at the mouth site M from 0.97m AHD at February spring high tide to -0.69m at February spring low tide to a variation of 0.37m (Figure 3) at site WM from 0.58m AHD at February spring high tide to 0.21m at February spring low tide. This reduction in tidal amplitude equates to a difference in high tide of approximately 0.39m (±0.05m) and a difference in low tide of approximately -0.90m (±0.05m).

Comparison of Figures 2 and 3 displays an upstream reduction in tidal amplitude of 0.41m (±0.05m) from downstream at east Micalo (site EM) to upstream at west Micalo (site WM). This reduction is represented by a variation of 0.78m (Figure 2) at site EM from 0.72m AHD at February spring high tide to -0.06m at February spring low tide to a variation of 0.37m (Figure 3) at site WM from 0.58m AHD at February spring high tide to 0.21m at February spring low tide. This reduction in tidal amplitude equates to a difference in high tide of approximately 0.14m (±0.05m) and a difference in low tide of approximately -0.27m (±0.05m).

▼ *Tidal amplitude in the drainage network*

Comparison of Figures 4 and 5 displays an upstream reduction in tidal amplitude of 0.07m (±0.05m) from site 1.1 at the upstream side of floodgate 1 on drain 1 to site 1.2 at the upstream point on drain 1. This reduction is represented by a tidal amplitude of 0.16m (Figure 4) at site 1.1 and a tidal amplitude of 0.09m (Figure 5) at site 1.2. This reduction in tidal amplitude equates to a difference in high tide of approximately -0.15m (±0.05m) from 0.05m AHD (Figure 4) at site 1.1 to 0.20m AHD (Figure 5) at site 1.2 and a difference in low tide of approximately -0.22m (±0.05m) from -0.11 AHD (Figure 4) at site 1.1 to 0.11AHD (Figure 5) at site 1.2.

Comparison of Figures 6 and 7 displays an upstream reduction in tidal amplitude of 0.18m (±0.05m) from site 2.1 at the upstream side of floodgate 2 on drain 2 to site 2.2 at the upstream point on drain 2. This reduction is represented by a tidal amplitude of 0.22m (Figure 6) at site 2.1 and a tidal amplitude of 0.04m (Figure 7) at site 2.2. This reduction in tidal amplitude equates to a difference in high tide of approximately 0.21m (±0.05m) from 0.44m AHD (Figure 6) at site 2.1 to 0.23m AHD (Figure 7) at site 2.2 and a difference in low tide of approximately -0.03m (±0.05m) from 0.22 AHD (Figure 6) at site 2.1 to 0.19 AHD (Figure 7) at site 2.2.

Comparison of Figures 8 and 9 displays an upstream reduction in tidal amplitude of 0.27m (±0.05m) from site 3.1 downstream at the road crossing on drain 3 to site 3.2 at the upstream point on drain 3. This reduction is represented by a tidal amplitude of 0.33m (Figure 8) at site 3.1 and a tidal amplitude of 0.06m (Figure 9) at site 3.2. This reduction in tidal amplitude equates to a difference in high tide of approximately 0.22m (±0.05m) from 0.59m AHD (Figure 8) at site 3.1 to 0.37m AHD (Figure 9) at site 3.2 and a difference in low tide of approximately -0.05m (±0.05m) from 0.26 AHD (Figure 8) at site 3.1 to 0.31 AHD (Figure 9) at site 3.2.

▼ *Water Head Gradient*

A water head gradient was observed within the drainage network that appeared to be falling from west to east during the ebbing spring tidal cycle surveys. This phenomenon appeared to be driving an upstream current flowing from west to east persisting well after tidal water levels begin to recede in the west. It may be that a combination of effects is contributing to this process whereby the tidal lag dynamics and the tidal amplitude variation generate a water head gradient falling from west to east within the drainage network during the ebbing spring tidal cycle on north Micalo Island.

▼ *Future Work*

This hydrological survey will be completed following the installation of on-ground works at Micalo Island. Follow up surveys will determine the amount of water able to enter through the modified floodgates without deleterious impacts accompanying the natural tidal variation.