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Proposed monitoring program to assess bank erosion at Yellow Water, Kakadu National Park, Northern Territory

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1 Introduction

Yellow Water Billabong (Figure 1) is a diverse freshwater wetland situated within the World Heritage listed Kakadu National Park. It is an important habitat for many birds and has become a major tourist attraction within Kakadu National Park. Commercial boat tours allow visitors the opportunity to view the abundant wildlife, especially the birdlife and saltwater crocodiles. Yellow Water is also a popular fishing spot for the both Traditional Owners and recreational fishermen who are chasing the much prized barramundi.

Figure 1 Lilies along the bank of the Main South Alligator Channel Yellow Water 13-11-02

Recently the Traditional Owners and Parks Australia North (PAN) raised concerns about the effects of boat traffic on Yellow Water with regard to erosion of the banks. A report by Cullen and Taylor (1988) was prepared for the Australian National Parks and Wildlife Service (now PAN) on bank erosion on Yellow Water Billabong. As part of the study for the report, a sacred area, Binji Water, was also visited to inspect and identify erosion occurring in a billabong with minimal boat traffic. The Cullen and Taylor (1988) report compiled a map of erosion locations on Yellow Water (Figure 2) and made 10 recommendations to try and reduce bank erosion problems on Yellow Water. It is uncertain how many of these recommendations have been implemented. There is also a concern about possible damage caused by boat motors and propellers when the water levels are low towards the end of the dry season.

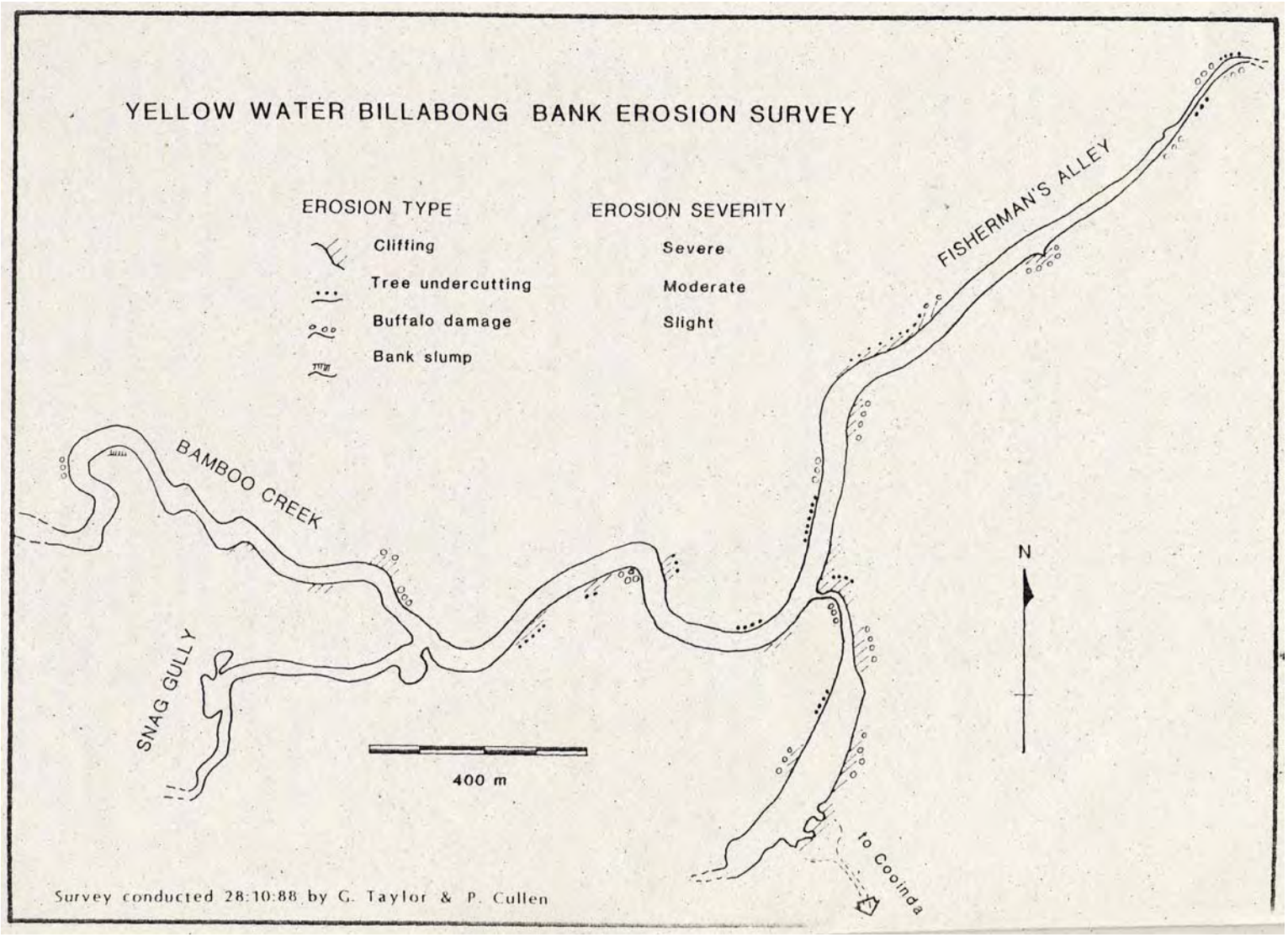

Figure 2 Map showing erosion locations and severity (source – Cullen & Taylor 1988)

At the request of Traditional Owners and PAN, scientists from the Environmental Research Institute of the Supervising Scientist (***eriss***) inspected both sites to suggest a monitoring program to assess the rates of bank erosion at Yellow Water.

This report outlines a monitoring program using photographic records and field measurements to assess erosion rates of the banks.

2 Field inspections

Yellow Water is located on the South Alligator River floodplain and becomes a series of billabongs that are contained within the floodplain (Floodplain Billabong) once the wet season water levels recede. It is used by recreational fisherman and a tour company runs daily tours on the billabong. Binji Water is located on the Nourlangie Creek System (which flows into the South Alligator River) and is more confined by wooded banks. Binji Water is an Aboriginal sacred site with minimal boat traffic on the waterbody. The reason for visiting Binji Water was that it was used by Cullen and Taylor (1988) as a site with minimal boat traffic. They do, however, say that Binji Water is not similar to Yellow Water, since it is not a floodplain billabong but that it is a lagoon with quite steep banks. The catchment area of Nourlangie Creek above Binji Water is approximately 3000 km^2 and the combined area of Jim Jim Creek and the South Alligator above Yellow Water is approximately 6800 km^2.

Field inspections of Yellow Water and Binji Water were conducted on 13 November 2002 and observations and comments are outlined below.

2.1 Yellow Water

A field inspection of Yellow Water was conducted by boat on 13 November 2002 by the author (***eriss***), PAN staff and Traditional Owners. Those present on the field trip were:

Traditional Owners: Violet Lawson, Sandra Mc Gregor, Peter Christopherson

PAN: Kathy Wilson, Rod Kennett

eriss: Mike Saynor

Comments made during the field inspection included:

> Lots of trees are missing with undercutting of the banks
> Here is more vegetation present now that the buffalo have been removed
> Buffalo were removed around 1990 when the B-TEC program was completed. However Jeffrey Lee reckons that there are 5 Buffalos still present
> There are many visible tree roots along the banks
> Sediment plumes are visible along the banks after tour boats have passed by
> Yabbies and file snakes burrow into the banks

During the course of the field inspection, various sites were identified. The observations and discussion at these sites are noted below and where possible a GPS location was recorded (all GPS readings are recorded in WGS84).

2.1.1 Site 1 – Junction of Jim Jim Creek and South Alligator

This site is where Jim Jim Creek joins the main South Alligator River channel and there is evidence of bank disturbance on the right bank.[1] Figure 3 shows logs that have been placed

[1] By convention, river or stream channels are named left and right bank when looking down stream.

along the bank to try and reduce erosion. The logs on the right of the image were installed during the mid 1980s and those nearer the middle of the image (showing signs of falling into the river) were installed in 1994. Peter Christopherson said that the area behind the logs that were falling over had been left empty of material when it was installed because it was hoped that sediment from the wet seasons would gradually fill in this areas. This has not been the case. All boats accessing the main part of Yellow Water pass this point because the loading point for the boat tours and the boat ramp is just upstream. The GPS location of this site is 12° 53.535' S and 132° 31.076' E.

Figure 3 Site 1 - Junction of Jim Jim Creek and the South Alligator River

2.1.2 Site 2 – End of Fisherman's Alley – South Alligator River Channel

This site is located at the end of Fisherman's Alley as boat traffic is limited by water depth. There was a discussion about the state of the left bank where bare earth and a visible steep slope could be seen towards the top of the bank (Figure 4).The opposite bank (right bank) was well vegetated and there was a discussion about the wet season water flows flowing over the left bank. The GPS location of this site is 12° 52.970' S and 132° 31.525' E.

It was decided to install a star picket at this location for photographic monitoring. A star picket was driven into the top of the left bank and a tag placed on it called EMP1 (for Erosion Monitoring Pin 1). Figure 4 shows the erosion pin at the top of the bank and Figure 4 shows a close up of the installed star picket.

2.1.3 Site 3 – Freshwater mangroves on left bank of Fisherman's Alley

On the way back along the main South Alligator Channel a comment was made that the freshwater mangroves are being washed away form the left bank and that more root material was being exposed. There were several freshwater mangroves present along the top of the bank and the bank below the trees was bare earth. These observations were made as the boat was passing the site and no photographs or GPS locations were taken. It is recommended that this site be one of the photograph points described below in section 3.3.

Figure 4 Star Picket EMP1

Figure 5 Close up of Star Picket EMP1

2.1.4 Site 4 – Right Bank Fisherman's Alley near junction with Jim Jim Creek

Several sites closer to the junction with Jim Jim Creek was also identified as possibly eroding and had a stump on the floodplain not far from the top of the bank. This stump was placed in the floodplain by Dave Lindner and would also serve as a good photograph point. Approximately 50 m upstream towards the junction the boat was nosed in towards the ban to look at a small steep area. A bent rusty star picket was noticed in the bed of the river and it was suggested that it was part of an old fence. Figure 6 shows the bank and also the star picket at this site. The GPS location of this site is 12° 53.493' S and 132° 31.083' E.

Figure 6 Bank and star picket on right bank near junction with Jim Jim Creek

2.1.5 Site 5 – Lunch spot on South Alligator River

Further up the main South Alligator channel, and just past what Cullen and Taylor (1988), called Snag Gully (Figure 2), we stopped and had lunch under trees. As the boat was nosed

into the bank, a sediment plume could be seen in the middle of the channel (Figure 7). During lunch many magpie geese were observed foraging in the shallows of the opposite bank and disturbing the water and creating small sediment plumes (Figure 8). Figure 8 also shows the wake behind the boat that we were travelling in at a relatively slow speed. The GPS location of this site is 12° 53.480' S and 132° 30.674' E.

Figure 7 Sediment plume in the channel near the lunch spot

Figure 8 Magpie geese foraging in the shallows and waves from the boat that we were travelling in at slow speed

2.1.6 Site 6 – Upper part of the South Alligator Channel at Yellow Water

After lunch we travelled up the main part of the channel (called Bamboo Gully by Cullen & Taylor [1988]) and observed several buffalo beside the shore (GPS location 12° 53.293' S & 132° 30.339' E). The banks were generally more vegetated than the sections that had previously been travelled along. On the inside of several bends (point bars) magpie geese

could be seen foraging in the shallows and there were a visible sediment plumes. An example of this is shown in Figure 8.

2.17 Site 7 – Exposed tree roots on Main Channel

During the fieldwork there were trees with exposed roots in the banks. Although non of these were examined closely an example of one of these trees is shown in Figure 9. The GPS location of this site is 12° 53.501’ S and 132° 30.901’ E.

Figure 9 Tree with exposed roots in the bank

Observations from the trip suggest that areas of bare bank might be susceptible to erosion from boat wakes and that the presence of vegetation helps to reduce the effects of waves caused by boats. In general, when there was a bank on one side of the channel devoid of any vegetation, the bank on the other side of the channel appeared to have vegetation. This suggests that boat wakes are not the sole cause of any bank erosion because they were erosion should be present on both banks. In some areas, cattle (owned by the Traditional Owners) were grazing on the adjacent floodplains.

2.2 Binji Water – Lagoon

A field inspection of Binji Water was conducted on the same afternoon by the author (***eriss***), PAN staff and Traditional Owners. Those present on the field trip were:

Traditional Owners: Violet Lawson

PAN: Kathy Wilson, Rod Kennett

eriss: Mike Saynor

It was originally planned to inspect the billabong by boat, however, the water level was too low to allow the safe launching of a boat. Observations were made from the bank and also a discussion was held regarding the usefulness of Binji Water as a comparison site. Cullen and Taylor (1988) inspected the Binji Water site and suggested that the steep banks, similar to Yellow Water, were exhibiting similar processes of erosion, tree fall and root exposure, despite minimal boat traffic. They also suggested that Binji Water was not similar to Yellow

Water as it was not a floodplain billabong and it did not support the birds, buffalo and crocodiles that were evident in Yellow Water during the survey.

Observations from the boat ramp at Binji Water indicate that the waterbody is virtually all tree lined (Figure 10) with much larger melaleuca trees than at Yellow Water. There is no visible clear areas or grasslands as there were at Yellow Water. The form of the banks cannot be commented on as the boat could not be launched. There was, however, root material from the trees on the banks near the boat ramp that could be helping bind and stabilise the banks. Salvinia was present against the bank near the boat ramp; it is not present at Yellow Water. The trees near the boat ramp had recently (within the last month) been affected by fire.

Figure 10 Binji Water Billabong

A discussion was held and it was suggested that Binji Water would not be a comparison site to Yellow Water, for the following reasons:

- The billabongs are located on different parts of the South Alligator River system, which means that the billabongs don't necessarily experience the same wet season flood flows. Nearby stream gauging stations could provide information on flow conditions and discharge, however, although there is a stream gauge on the Nourlangie System at the Kakadu Highway, there is not a gauging station near to Yellow Water on either the South Alligator or Jim Jim system;
- The catchment areas of the billabongs are different sizes;
- The type of fringing vegetation is different – larger melaleucas are present at Binji Water;
- Binji Water is a channel billabong (surrounded by a well defined forested channel boundary) and Yellow Water is a floodplain billabong (surrounded by floodplain);
- It is unknown if bank soils have similar characteristics.

These differences make it difficult to attribute changes in the banks in the billabongs to the influence of boat traffic alone. A short discussion was held about suitability of other billabongs on the South Alligator System such as Leichhardt Billabong, however, they all get some form of boat traffic at some stage of the year.

3 Monitoring program

To understand present erosion rates there is a need to assess historical changes, the current condition and how it changes on an annual basis. This program is recommended to achieve such an understanding. Suggested studies are:

- An analysis of historical data and an assessment of temporal change,
- Commence a program of measurement of current change using field measurements and photographic record, and
- Determine water level fluctuations and their influence on bank stability.

3.1 Historical sources of information

In the 1998 Cullen and Taylor report, a map (Figure 2) was produced showing locations along the banks where erosion was occurring. It was recommended that an extensive review of Yellow Water be undertaken every three years and the map of erosion updated every three years. To my knowledge this map has not been reviewed; if possible, it would be good to repeat this map to determine what changes have taken place since 1988.

Another good source of historical information are photographs where the date and location are known. The same location should be re photographed and then the photographs compared to see what changes might or might not have occurred. It is important to try and repeat the photographs when the water levels are similar to water levels at the time of the original photograph.

Aerial photographs and satellite imagery could be used to determine changes. However, the photographs need to be of sufficiently high resolution to identify bank change. Aerial photographs might be more useful in determining changes in tree numbers, but a limiting factor is the regularity of the coverage. The most recent images of Yellow Water were flown in 1991 and 2004 at a scale of 1:25000. Satellite imagery such as Quickbird etc may also have the resolution to monitor bank changes, however, the costs may prove prohibitive

3.2 Bank measurement

To establish a monitoring program for the banks of Yellow Water it is important to monitor various locations along the banks of Yellow Water. One way of doing this would be to establish photograph points (10–15) along the banks of Yellow Water choosing a variety of locations. These points would be photographed regularly during the year from the water (by boat) so that changes from year to year can be determined. The use of a standard camera (SLR) as well as a digital camera is recommended until digital camera technology catches up and supersedes standard camera picture quality. Where possible sites should be chosen where there is a historical record.

3.2.1 Method

It is important to identify an easily recognisable feature such as a well-marked post, tree or group of trees. Where there is no identifiable stable feature, install a star picket. These features should be identified by a mark on the tree, painted cross, flagging tape (this could easily be removed) and also a GPS location recorded. Where a star picket is installed, it should be marked with a tag (Figure 5). The sites should be labelled with a unique number and are called photo-points subsequently in this report.

When taking the photographs, position the boat in the middle of the channel and take a photograph towards the photo-point, taking care to include the water surface, the bank and the identifiable stable feature. Also take a photograph of the opposite bank by physically turning 180 degrees. As the water level of Yellow Water changes throughout the year it is recommended to take photographs four times during the year.

- During the middle of the wet season (when water levels are at there highest Jan–Feb);
- After the wet season and during the peak fishing times when fishing pressure will be at its highest (Mar–Apr);
- During the middle of the dry season (July August);
- At the end of the dry season (Oct–Dec) when the water levels are at there lowest.

As well as taking photographs, where possible (ie when the water level is low enough) simple physical measurements should also be recorded. These should include:

- Where a star picket is installed, the height of the picket, from ground level to the top of the star picket;
- Horizontal distance from the feature (tree, post, star picket) to the top of the bank;
- Height of erosion scar if present.

The observations and measurements should be recorded on a pre-prepared data sheet that should include:

- A photograph of the feature and site (black and white would be fine), with name and number of the site;
- Date and time of the new photographs;
- Number of photographs taken and also type, eg two photographs and two digital images;
- Distance and height measurements, when it is possible to make them, noting that during the wet season it will not be possible to measure these;
- Any other important comments or observations, eg tree fallen into channel, etc.

It is important that all data are recorded and stored properly to enable easy retrieval for analysis. Photographs and digital images should be labelled and stored correctly.

The photographs will provide qualitative estimates of change through time, (based on comparison of photos). The measurements will provide limited information on bank erosion as they won't always be in exactly the same spot and will really only identify large scale changes. More quantitative erosion rates can be measured using exposed tree roots.

Several cable ties could be placed around a number of the exposed roots, hard up against the bank. If the bank is retreating then the distance between the cable tie and the bank should increase as the bank retreats. This distance should be recorded on the data sheets at the time of photographing. This is more likely to be possible during the mid-and late-dry due to lower water levels and in time will provide information on rates of bank retreat.

Regular photography and simple physical measurements at the photographic points (once they have been installed) should take no more than a day to complete. This will enable the work to be planned for by PAN staff in the Jim Jim District and ensure it doesn't become an unduly arduous task.

There are other more accurate methods of measuring bank retreat. However, they are more time consuming, can be dangerous (crocodiles) or even be destructive to the bank itself. These include:

- **Theodolite survey**: More accurate surveys could be obtained by a theodolite and staff survey which could be used to provide a surveyed bank profile at the site. This requires specialised equipment and training. Surveys are more time consuming and expose field workers to the threat of crocodiles.
- **Erosion pins**: These have been suggested, but are not believed suitable by the author for the bank profiles that are present at Yellow Water. They are more suited to steep banks not the gentle sloping banks that are present at Yellow Water. They can at times be destructive to banks (usually more coherent banks when they are hammered in). Also there would be exposed ends of steel (30–50 mm) which can catch inhabitants (crocodiles birds) and on rare occasions present a boat hazard. Therefore erosion pins are not recommended for monitoring erosion at Yellow Water.

3.3 Water level

The water level of Yellow Water gradually falls during the dry season and is dependent on when the early wet season rains supply sufficient water to start filling up the billabongs. Some form of depth gauge or gauge plate should be installed and water level readings made at approximately the same time each day. This could perhaps be done by the operators/drivers of the tour boats. These staff posts should be on the pontoon near the boat ramp. It should be possible to attach a narrow gauge plate to both of the poles/pylons at the landward side of the pontoon between the rollers to allow the rise and fall of the pontoon with changes in water level. The height of the water is determined by reading the height of the top of the pontoon and subtracting the height of the pontoon to obtain water level. If this is not possible then a post should be installed in a place that can be easily seen through out the year and gauge plates attached to the post.

3.3.1 Measurement of water depth

Water depths at areas of concern can be measured from a boat using a metre rule or a 3 m staff (used when surveying). The location that the measurement is made is recorded by GPS and later marked on a map or an enlarged aerial photograph. Several close measurements should be made around monitoring points to determine water depths. These water depths are related back to the water level at the pontoon. Initially it is important to determine the minimum depth that the propellers from tour boats and recreational boats require to not churn up and disturb the bed of the channel. This can be done be taking a boat through shallow water and observing when sediment is disturbed and can be seen discolouring the water. When sediment is disturbed the depth of water should be measured. An average depth of disturbance will be determined and from this a minimum water depth can be established below which propellers will have an impact.

Water depth measurements from various parts of Yellow Water can then be used to suggest when boats shouldn't travel into these areas as there will be considerable disturbance to be sediments. Different parts of Yellow Water will become inaccessible during the late dry as the water levels drop. The junction of Jim Jim Creek with the main South Alligator is the most important area as it allows access to the main channel for the tour boats and the recreational boats. This location gets reasonably shallow towards the end of the wet season and there might be times when boat access is restricted due to insufficient depth of water. After the first year or two the depth at which this junction becomes impassable will be known and with the

daily recording of water level it should be possible to predict when the water level will drop to a level low enough to prevent boat passage. This prediction would allow the boat operators to plan ahead with regard to staffing etc.

The measurement of water depth in Yellow Water would provide valuable and interesting information on the yearly hydrologic cycles of Yellow Water, in the context of biological events such as water lily flowering or arrival of the magpie geese.

4 Summary

It is recommended that between 10–15 photographic points be established. These locations should be photographed and measured four times each year by PAN staff and Traditional Owners. It is also important to install a depth gauge comprising of staff plates that can be easily read. Depth measurements should be made at various places throughout Yellow Water. Yellow water is a natural system and there will always be some change occurring naturally in the environment from year to year and from wet season to dry season.

After several years it will be possible to determine the relationship between water level on the staff post to water levels at various places throughout the billabong. These should then be used to determine when the photographic survey and measurements are carried out. Monitoring program data can be used to assess what changes are occurring and if there are other influences rather than natural changes to the system. This program should continue for at least 5 years, as gradual small scale change may not be evident in the shorter term and then reassessed.

Sources of historical photographs should be investigated and, if date and location can be identified, they could be re photographed and comparisons made. Figure 11 is a photograph taken of a section on Fisherman's Gully on October 1993.

Figure 11 Looking downstream along Fisherman's Gully in October 1993 (Photo M Saynor)

References

Cullen P & Taylor G 1988. *Report on bank erosion Yellow Water Billabong – Kakadu National Park*. Water Research Centre, Canberra College of Advanced Education, Canberra ACT.