Appendix 1 Extract from Broads Act

The 1988 Norfolk and Suffolk Broads Act sets out the general functions of the Broads Authority in Section 2(i):

It shall be the general duty of the Authority to manage the Broads for the purpose of

a) Conserving and enhancing the natural beauty, wildlife and cultural heritage of the Broads;

b) Promoting opportunities for the understanding and enjoyment of the special qualities of the Broads by the public; and

c) Protecting the interest of navigation.

In discharging its statutory duty to maintain a safe navigation, and a fundamental part of this provision is the securing of reasonable depth. Section 10 of the Act states that

The Authority shall

a) maintain the navigation area for the purposes of navigation to such standard as appears to it to be reasonably required;

b) take such steps to improve and develop it as it thinks fit

Under Section 2, Schedule 5 (1) The Authority may –

a) deepen, dredge, scour or excavate any part of the navigation area; and

b) sell, or otherwise dispose of as it thinks fit, any material removed from any part of the navigation area in exercise of its powers under this paragraph.

Additionally, under the Port Marine Safety Code the Authority has a duty as a harbour authority to develop a Safety Management System which identifies all hazards related to marine activity and is required to carry out a risk assessment and put in place measures to reduce these risks as far as is reasonably practicable. The risk of grounding due to shallow water has been included in this assessment.

These duties and powers have been exercised to date through the implementation of an annual dredging programme but a Best Value Review of Navigation identified the lack of a strategic approach, which if adopted could bring added value through working with partners towards shared objectives.

Appendix 2 Strategy Steering Group

Terms of reference

1. The principal purposes of the Steering Group are:
   - to facilitate the development of a Sediment Management Strategy for the Broads;
   - to prioritise and steer the research and practical management elements of the Sediment Management Strategy;
   - to monitor and evaluate the development of the Sediment Management Strategy;
   - to coordinate and channel all relevant information and expertise from the catchment, national and organisational levels through the Steering Group; and
   - to informally discuss and debate sediment management issues in the Broads catchment.

2. The Partnership represents key partners (mostly public bodies) but is sufficiently small to be manageable and productive. The agreed Membership is listed below:

   Broads Authority
   British Waterways
   Broadland Environmental Services Ltd
   Natural England
   Jan Brooke - Environmental Consultant
   SEA Environmental Decisions Ltd/SedNet/SedcomUK (Consultant)
   Environment Agency
   National Farmers Union

3. The Steering Group was responsible for overseeing the strategy which should be relevant to the whole Broads catchment and its functioning. This involves using scientific rigour as well as practical achievability, and then subjecting management scenarios to strategic planning and economic assessment. The approach is designed to improve understanding about strategic options and their inherent uncertainties, thereby enabling informed choices to be made. The strategy should take into account navigation requirements, relevant directives, plans, policies and legislation.
4. The Steering Group will meet up to four times a year. Should sub-working groups, to deal with specific strategic issues, need to meet they will have clear terms of reference and meet as necessary.
5. Key recommendations from the steering group and overall progress of the strategy will be reported to the Broads Authority.

Appendix 3 Executive summary of desk based study

Desk based study of the sediment inputs to the Broads catchment, with the identification of key inputs and recommendations for further targeted research and management to minimise inputs, Cranfield University, Silsoe

This study has involved a review of available data relating to sediment sources in the Broads Authority management area. Where possible, sources have been evaluated in a semi-quantitative manner. It has been possible to make estimates of sediment input for headwater catchments, internal catchments, riverbank erosion, sewage treatment works and industrial sources, and for sediment outputs from dredging activity within the Broads area. The major gaps are in quantifying organic inputs from plants and phytoplankton, tidal inputs/outputs, the related dredging carried out by Great Yarmouth Port Authority, and the role of flooding in removing sediment from the river system.

For those sources where it has been possible to make a semi-quantitative assessment, headwater catchments and riverbank erosion are dominant. However, the implications for the future are different for these two as headwater land use and management begins to focus on environmental protection (suggesting a potential reduction in sediment supply) whilst bank erosion is likely to increase over the short to mid-term as setback and pile removal is used as part of the BESL flood alleviation programme. Whilst BESL will be responsible for any additional dredging as a result of this programme it is useful to have quantification of the current system for comparison with future possible conditions, so that their dredging responsibilities can be assessed.

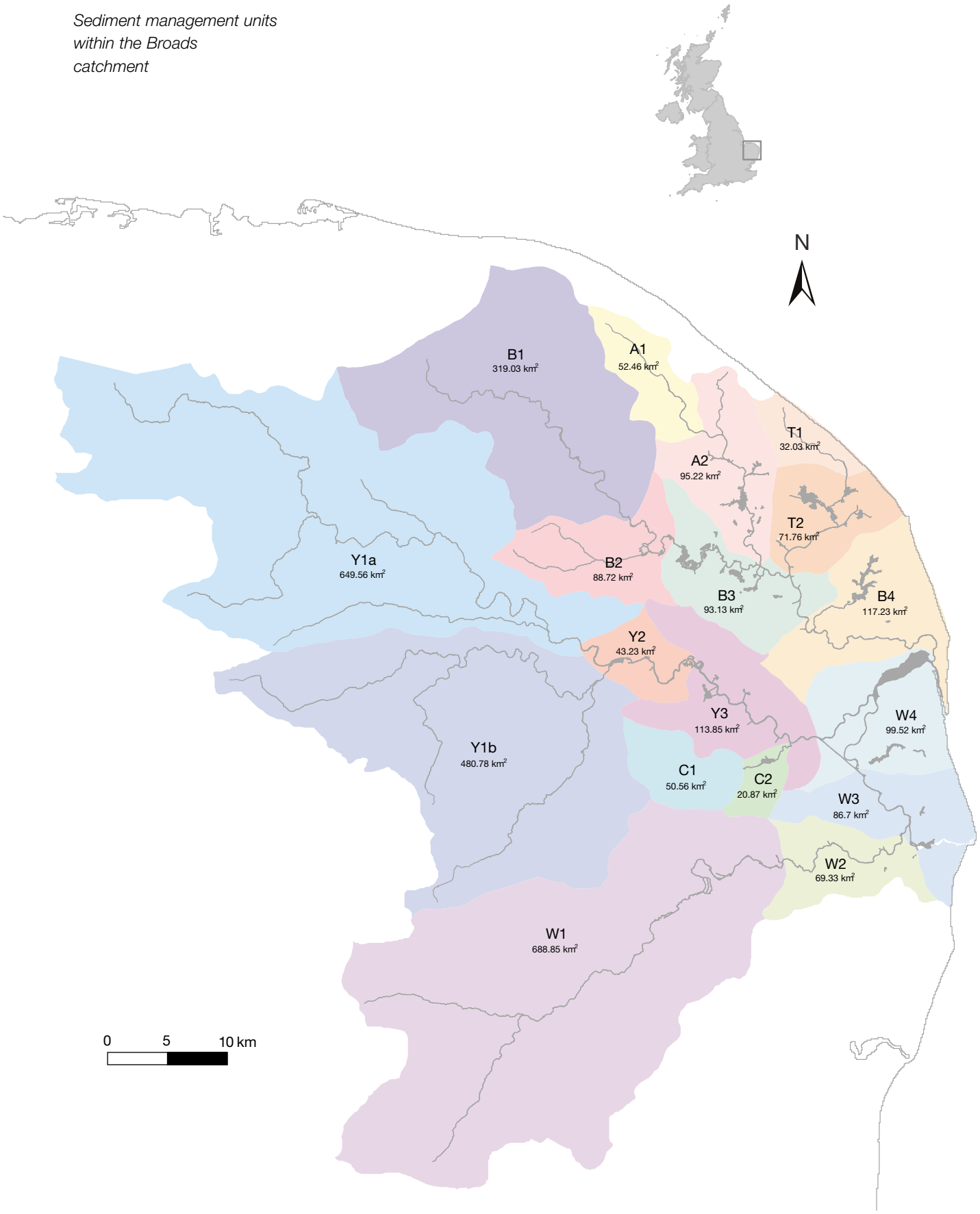
A number of actions have been recommended to allow gaps in data to be filled, thus allowing a complete sediment budget for the region to be made. Much of this data could be collected via short-term field exercises, possibly via student projects. However, it will be much more valuable if the sediment budget could be made spatially explicit, so that sources can be directly related to sedimentation and dredging requirements. This will need organisation of current data and collection of additional data to infill gaps. In support of this it is recommended that the Broads Authority develop a database of sediment related information and a sediment GIS to put information into a spatial context.

Whilst this report has focussed on identification and a preliminary quantification of sediment sources to the Broads management area, it must be remembered that sediment fits into a much wider decision making process. Catchment wide management proposals need to consider many aspects other than sediment, eg conservation, navigation, public enjoyment, costs, interactions with other authorities. The Broads Authority operates within a defined set of objectives – the duties to provide public enjoyment, navigation and conservation. Clearly any actions need to work within the law and within budgets. The Broads Authority has restricted control over some processes and therefore its actions in these cases will be limited to influence and persuasion. This is likely to be more powerful if backed up by at least semi-quantitative evidence. Furthermore it is unclear how the implementation of emerging European directives and national policy will affect the prioritisation of Broads objectives and management options in the future.

All recommended actions and sediment sources are evaluated within a management context in the report, in order that any programmes initiated as a result of this study support management decisions rather than purely scientific interest. It is of course to be recommended that where science funding is available this is also sought to enhance actions taken by the Broads Authority.

Appendix 4 Management units

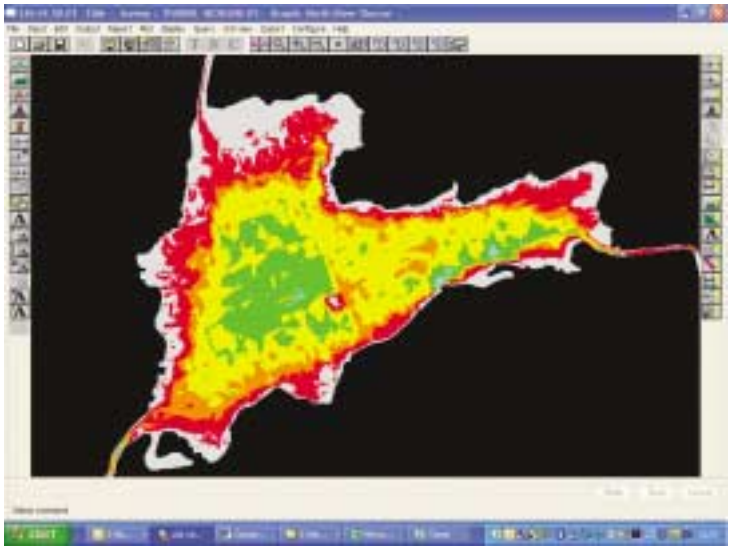
Sediment management units within the Broads catchment



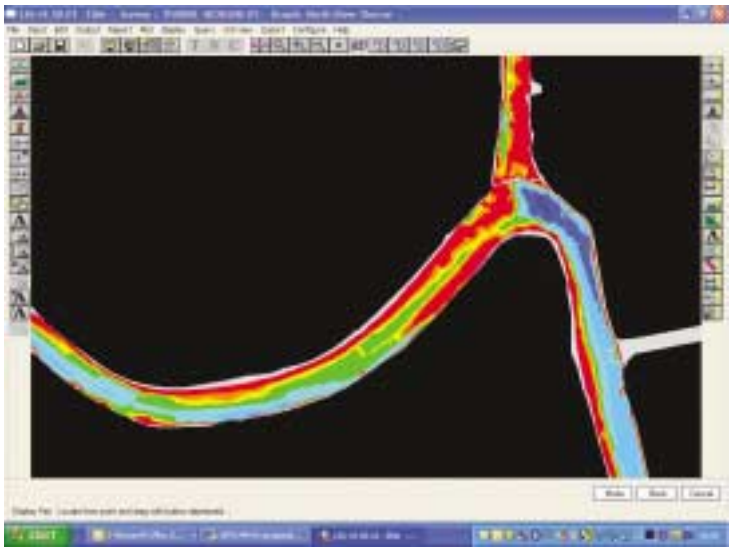
Appendix 5 Hydrographic survey data

The hydrographic survey was undertaken from a vessel equipped with an Ohmex SonarLite echo sounder with Trimble DGPS/RTK positioning equipment, all logged by Trimble HydroPro Software. The Sonarlite echo sounder operates with high frequency transducers at 235 Khz, which will take soundings to the top of soft silt. To define the hard bed, a 30 Khz transducer is required. The transducer has an accuracy of (+/-) 0.01 m, and a range of 0.3 m to 100 m. Real time positioning is achieved with the Trimble DGPS/RKT system, and will locate the position of the receiver in x, y, z coordinates. In combination with the depth soundings this data is then reduced to provide an x, y, z coordinate for each data point, corrected to Ordnance Datum, Newlyn. Data have been provided to the Broads Authority in LSS survey file format from which contour charts can be produced, and with hard copy cross sections at regular intervals.

Contour plan of Horsey Mere to identify depths. The red shaded area indicates non-compliance with the waterway specification.



Thurne Mouth



Appendix 6 Navigable envelope cross sections

The development of the ideal navigable envelope cross section profile was achieved after considering the following points:

- Depth established by waterway specifications.
- The width of the channel at the agreed depth has been established at $^{2}/_{3}$ the overall width. This profile allows dredged volume to be minimised as well as recognising the need for a sufficient width for all types of boating activity.
- The 1:3 side slopes allow a stable profile for the further encouragement of littoral vegetation, and are appropriate for the nature of bed material, where a steeper slope is likely to result in slumping.

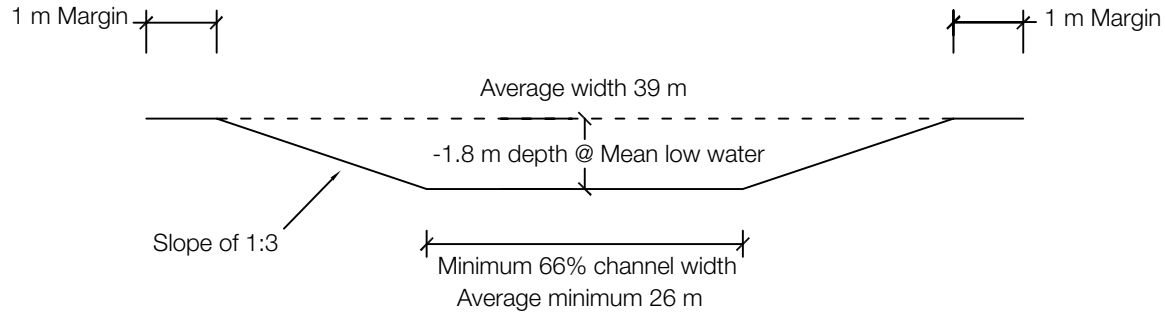
The adopted profile recognises the design of recent flood defence works, through the Broadland Flood Alleviation Project, and establishes a benchmark.
It is anticipated that through the removal of hard defences, the rivers will likely become mobile, and this approach will allow meanders to develop. Intervention will then only be required where the envelope is compromised and the Environment Agency or its contractors will carry out any required channel reinstatement.

Various site-specific profiles shown overleaf have also been developed for each management unit following analysis of the hydrographic survey data. However, it should be noted that for narrower piled river sections the adopted envelope reflects these existing conditions, to protect the navigable width from future developments. Likewise, specifications will be amended alongside Broads Authority moorings to ensure adequate depth alongside the quayheading.

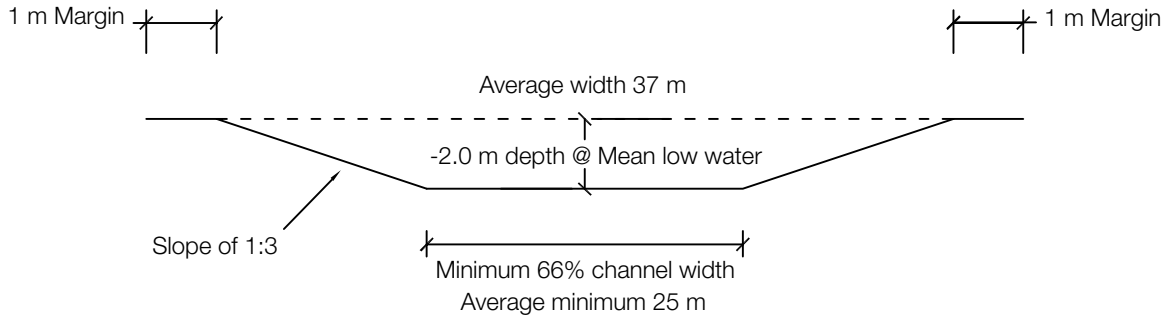
User waterway specifications (not to scale)

Depth below average water varies according to waterway specifications

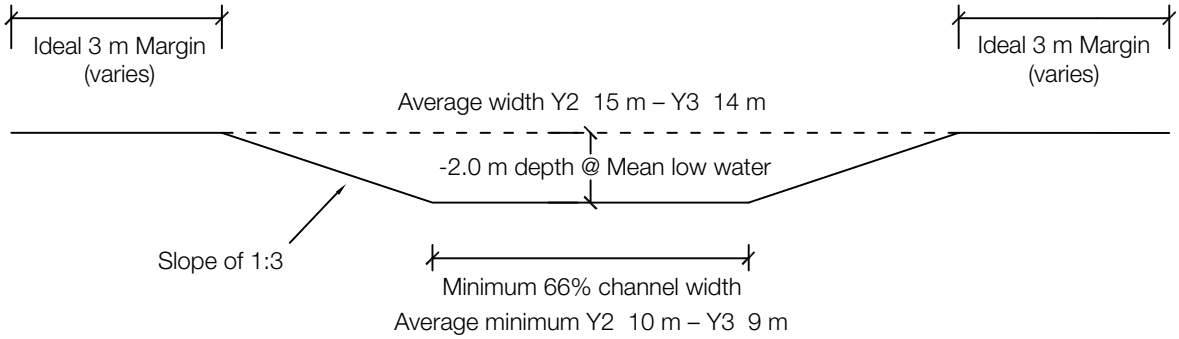
Burgh St Peter to St Olaves – Area W3



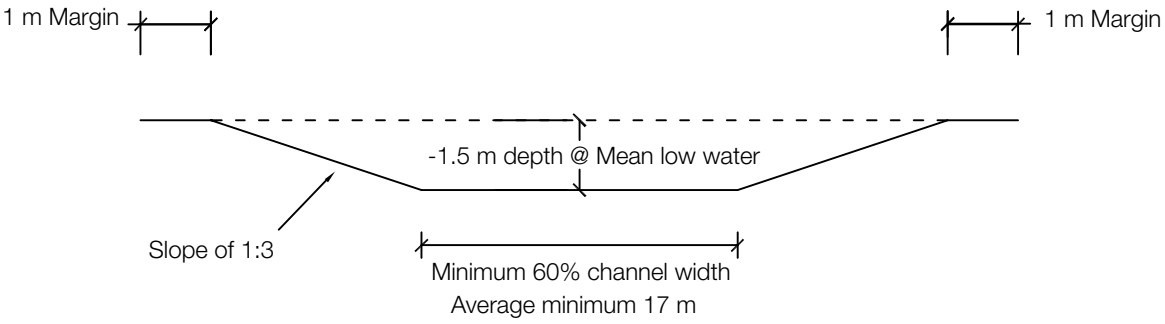
St Olaves to Breydon Water – Area W4



Bargate Dykes – Area Y2
Rockland Dykes – Area Y3

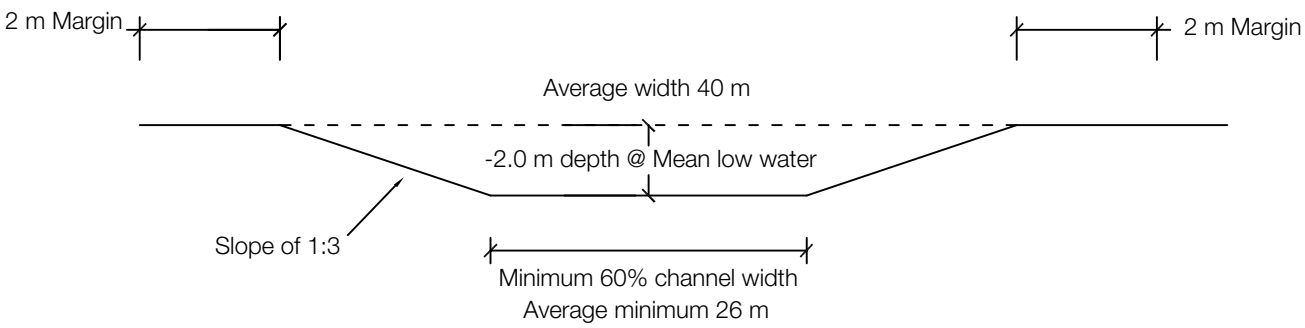


Horstead to Wroxham – Area B2

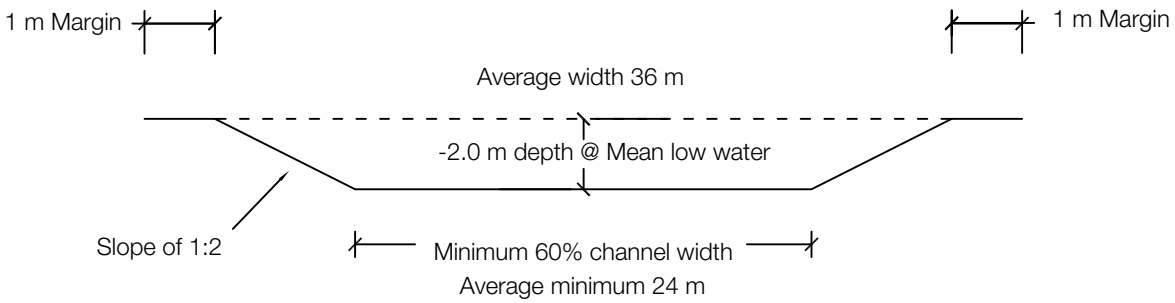


User waterway specifications (not to scale)

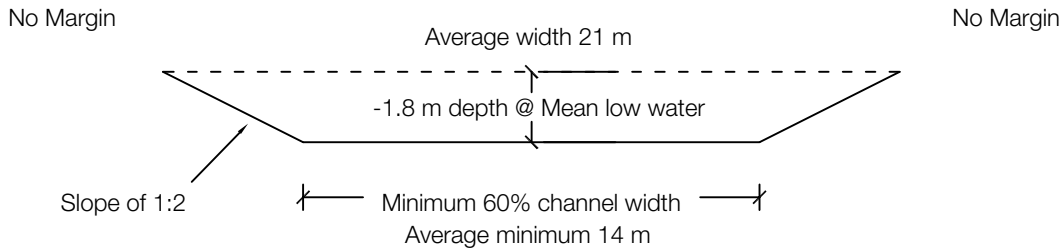
Wroxham to Acle – Area B3



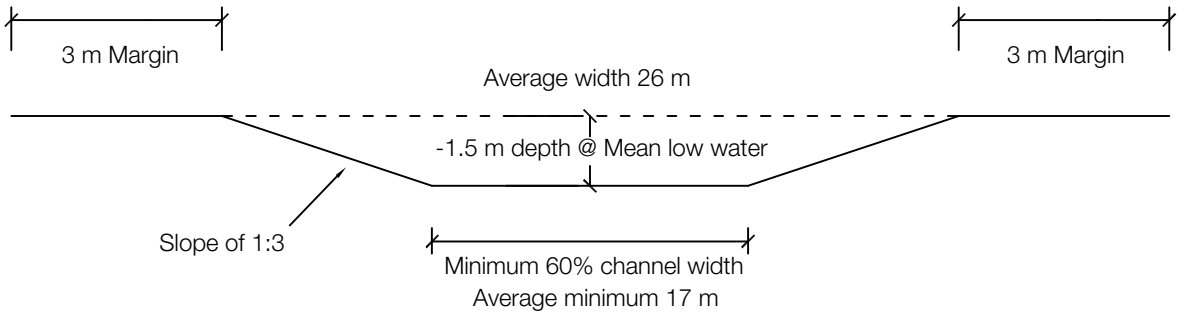
Downstream of Acle – Area B4



Downstream of Barton Broad to Ant Mouth – Area A2

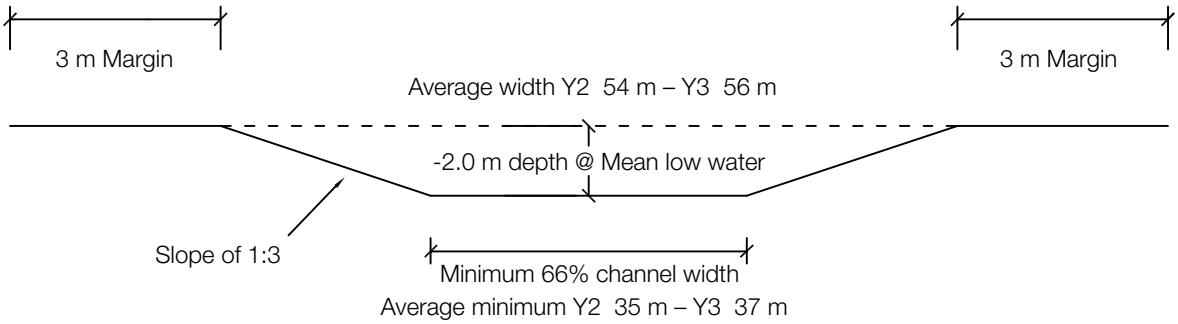


Brograve Mill to Thurne Mouth – Area T2

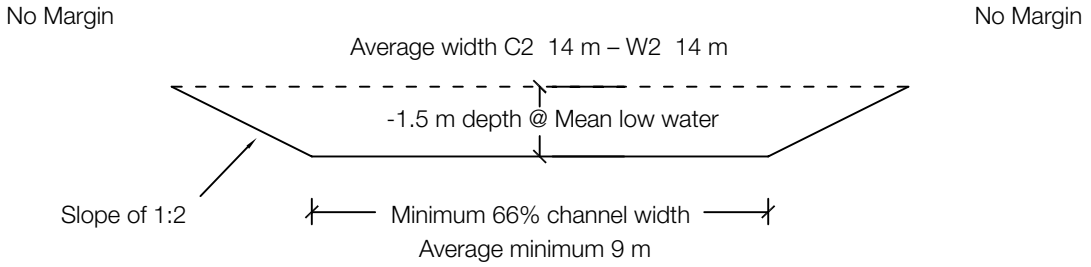


User waterway specifications (not to scale)

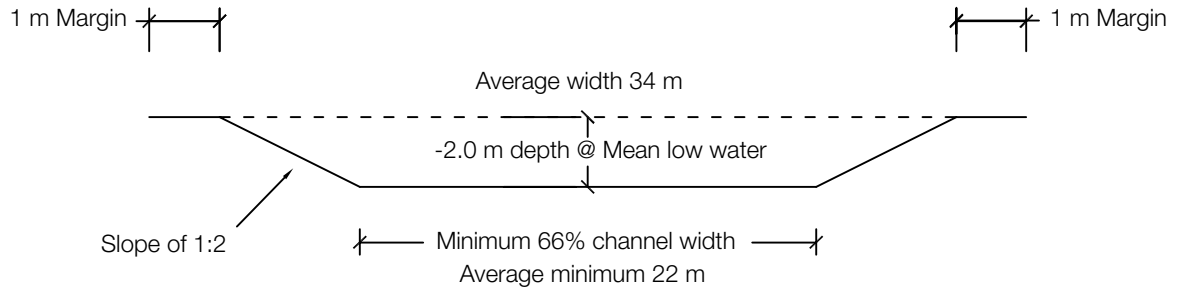
New Mills to Brundall – Area Y2
Brundall to Cantley – Area Y3



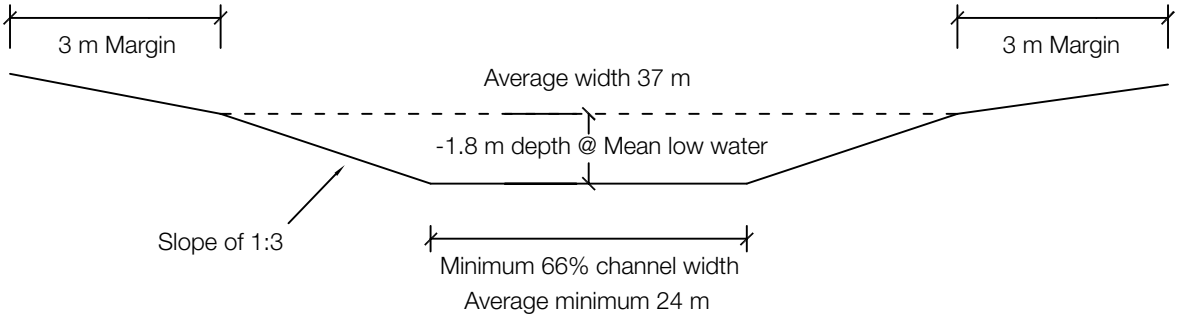
Loddon to River Yare – Area C2
Geldeston Boat Dyke – Area W2



Geldeston to Burgh St Peter – Area W2

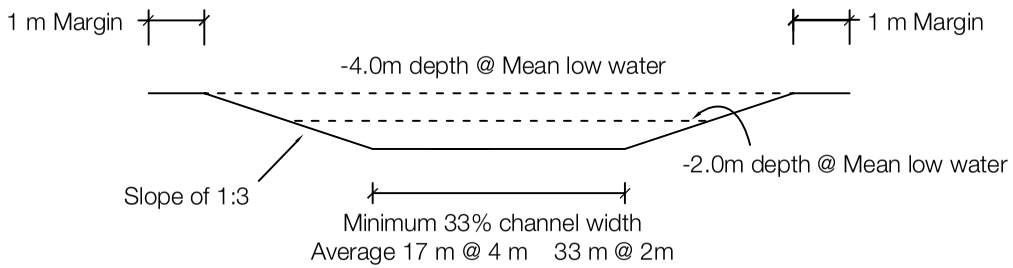


Oulton Dyke to Oulton Broad – Area W3

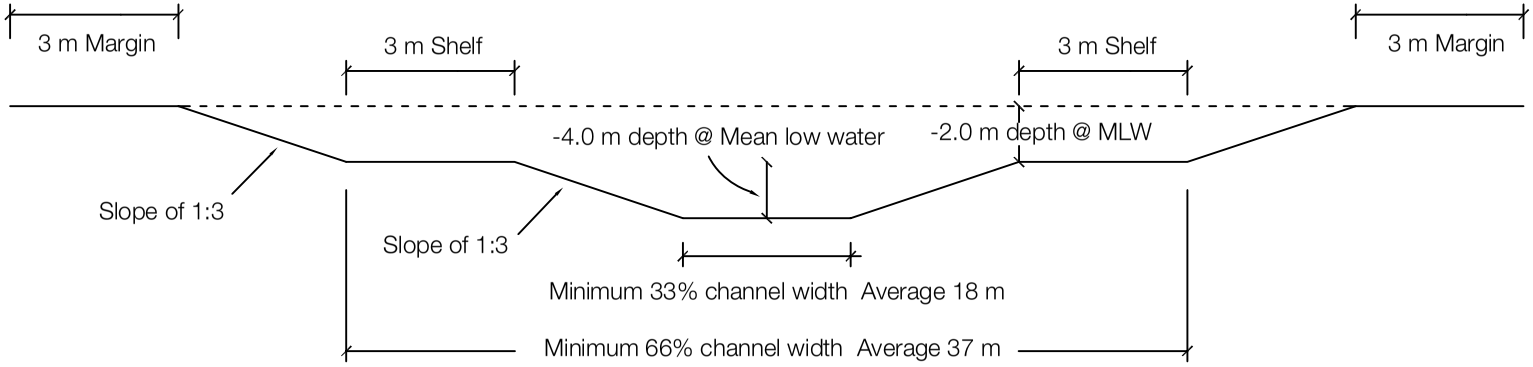


User waterway specifications (not to scale)

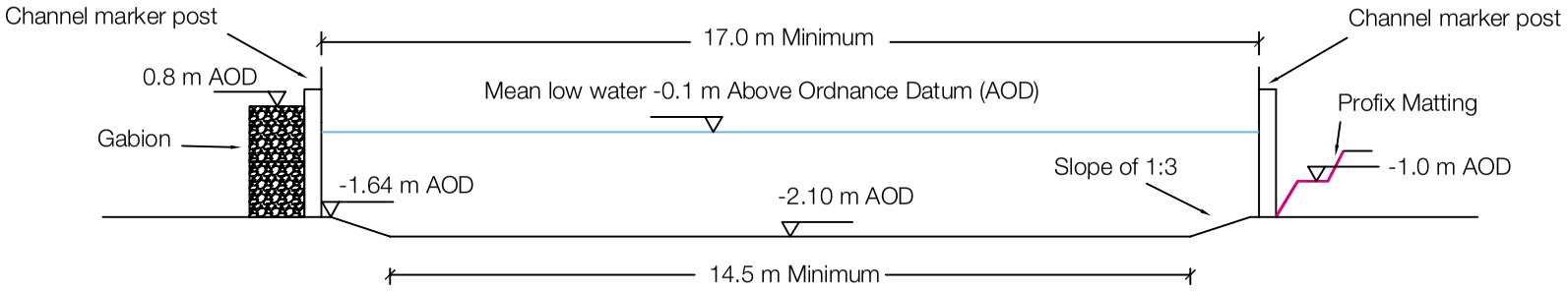
Reedham to Breydon Water and Breydon Main Channel – Area W4



Cantley to Reedham – Area Y3

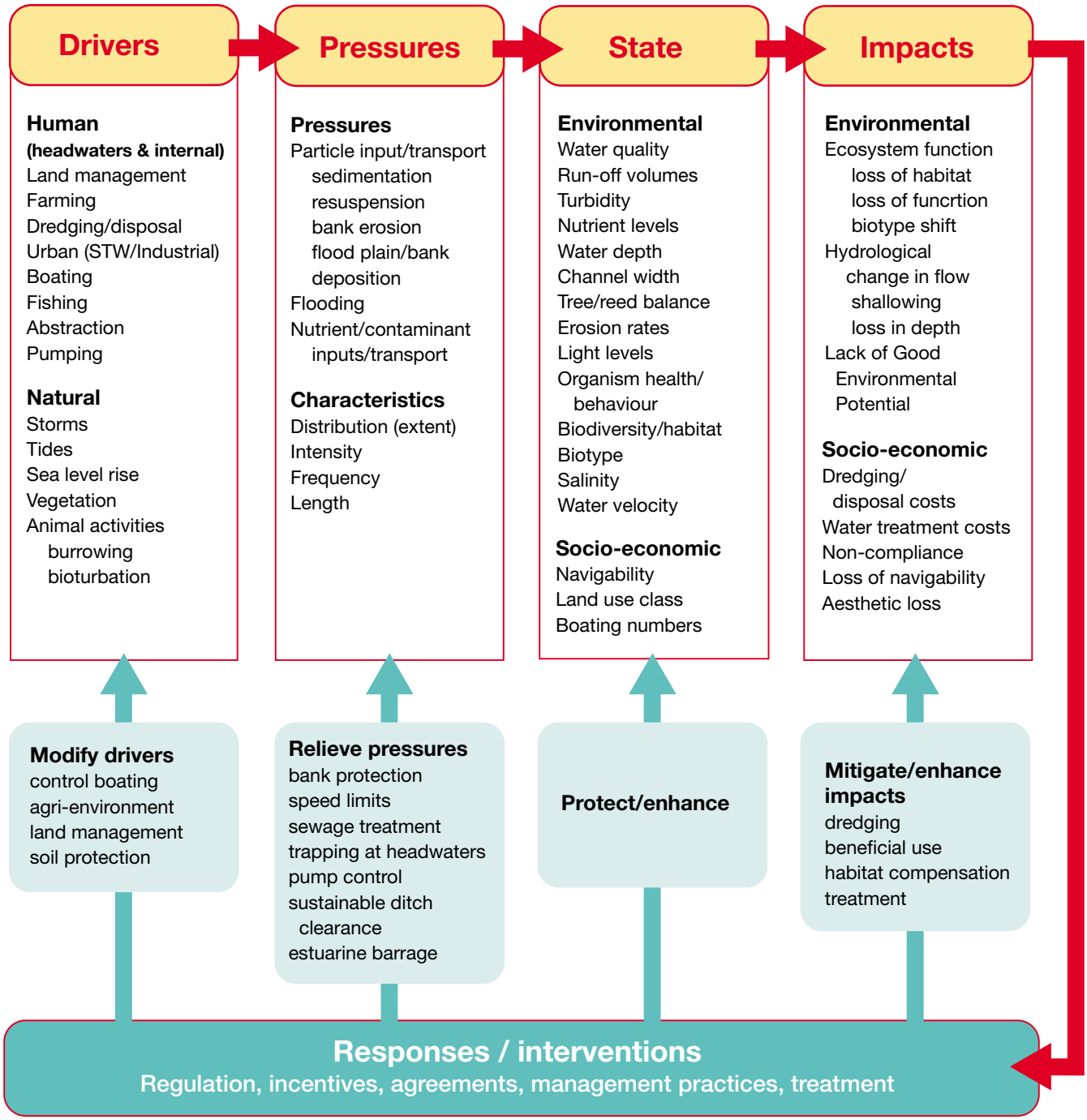


Haddiscoe Cut – Area W4



Appendix 7 DPSIR framework

Figure 6
DPSIR framework for Broads Sediment Management



Appendix 8 Management control techniques

Source control techniques

Mike Page

New Mills sluice

Headwaters

Within the desk based study headwaters were considered as a separate management unit. In themselves, each upriver area is subject to diffuse pollution from agricultural sources, bank erosion and other inputs. However, at the boundary with the Broads area they enter the system as a point source and so could be tackled in alternative ways.

The Environment Agency with DEFRA and Natural England, is currently completing a Pilot Study in the Wensum Valley, working with farmers and agronomists to improve land management methods to reduce diffuse pollution within the sub catchment, and this should eventually result in a reduced input through the New Mills sluice at the head of navigation on the River Wensum as well as improving the water quality within the upriver SSSI. Higher Level Schemes promoted by Natural England also encourage better soil management to farmers within the Broads and wider catchment areas, although the take up cannot be targeted or guaranteed.

Alternatively, silt traps could be established upriver of the sluice, which, if regularly cleaned out could also reduce the amount of sediment coming through the sluice.

Bank erosion

Broads Authority

Martham bank restoration

There are a number of techniques to tackle bank erosion, both locally and strategically.

1. **Erosion protection works**

a. These are set out in detail within the Waterway Bank Protection Reference Manual (Environment Agency 1999), along with a methodology for selecting the appropriate technique for any given situation.

b. Flood defence works currently undertaken by Broadland Environmental Services Ltd on behalf of the Environment Agency involve removing hard defences to promote a more natural and sustainable riverbank edge. Works to agree the monitoring methodology and trigger levels for remedial works are currently in progress, and the risk of accelerated erosion in the short term has been recognised within a Memorandum of Understanding with the Broads Authority.

2. **Vegetation management**

Scrub clearance

Broads Authority

Scrub clearance and promotion of reed growth are effective in providing natural banks, which have the ability to absorb and dissipate wave energy thus reducing erosive forces.

3. **Boat control measures**

a. Numbers – the Broads Authority currently has no power to limit the numbers of boats registered within the area. Using the Boat Census data it is possible to recognise that whilst numbers remain stable there is a change in the composition of the fleet which is reflected by the declining trend of boat movements since the 1980's, primarily due to the declining hire boat industry.

b. Speed – Speed Limit byelaws were introduced in 1992 and the Authority employs Navigation Rangers to patrol the rivers to provide advice and assistance, as well as enforce all navigation byelaws. Speed Limit compliance monitoring recently carried out showed a high incidence of vessels exceeding the speed limit although the majority was exceeding by less than 1 mph. Further measures could include requirements for speed indicators to be provided on board vessels to improve boaters' ability to

Navigation ranger using radar gun

Broads Authority

control the vessel, a greater level of patrolling, more speed limit signs, and well publicised enforcement action/prosecutions. Work is ongoing looking into the effectiveness of each of these techniques, to improve future management.

c. Wash – boat wash could also be reduced through hull design and the Authority is working with the Anglia Boatbuilders Association through grant aid and technical support on the development of an Ecoboat, to be used in promotion of sustainable boating.

Boat travelling with minimal wash

Peter Howe

4. **Wave action**

   It is not possible to reduce tide or weather generated waves/erosive forces, but by promoting reed growth as stated above this energy could be dissipated.

Point sources

There are a number of point sources identified within the Broads area, eg Internal Drainage Boards outfalls, Sewage Treatment Works (STWs) outfalls, highway drain outfalls. These could be tackled physically through silt traps. Imposing conditions regarding level of suspended solids within discharge consents given by the Environment Agency can only be applied to STWs.

Organic material

The amount of siltation within the Broads attributable to organic material is currently unquantified but could include:

1. **Algal deposit** – water quality improvements within the system will hopefully eventually lead to a reduction of algae within the water column.
2. **Leaf matter** – Tree and scrub clearance on riverbanks and ronds will reduce this input, although some areas of vegetation will be preserved as identified in the Tree and Scrub Guidance document, to maintain a mosaic of habitats. Overhanging trees that create a hazard to navigation will be managed.
3. **Aquatic plants** – Material produced through the die back of aquatic plants may be a local issue, but it is believed that where these exist there is a corresponding decrease in algae which have a very rapid turnover thus the comparative volume is lower.

Marine input

Again, this element of source is unquantified but is believed to be a limited issue, confined to lower reaches only. There are no control measures or techniques that could reduce marine inputs other than physical barriers but that would be a disproportionate response to a minor input.

Resuspension

Whilst there continues to be a high level of material already within the system resuspension can provide a recycling of sediment within the system. This could mean sediment moving from areas where it does not pose or create difficulties into more sensitive areas, possibly only moving under storm or flooding events where the energy within the channel is greater than usual. Control measures could include:

- Bed stabilisation by vegetation growth, where plant roots could assist to bind sediments. This can only be achieved where water quality is good, and the level of disturbance is likely to be low, eg within biomanipulation barriers or closed water bodies.
- Deepening to increase under keel clearance by dredging or in-channel techniques would reduce the likelihood of bed disturbance by prop wash in shallow reaches. However, if navigation passage is not impeded by water depth it could be considered that dispersion of the disturbed sediment by vessels may be more sustainable than dredging intervention.

In situ treatments

In-channel techniques exist which can be applied at sediment receptor sites (areas of accumulation) to relocate sediment within the water environment. These include:

(i) **Water injection dredging** – low-pressure water is introduced to the surface sediments in order to create a density plume, which will flow under forces of gravity, tidal flow and differential pressure into low areas. The area of dispersion will depend upon particle size but has been widely used by ports and harbours where the disturbed sediments could not be subsequently identified.

(ii) **Ploughing** – this is a more controlled technique where material is moved physically by dragging the plough from shallow to deeper areas, either for deposit or natural dispersion by tidal or scouring action.

(iii) **Agitation dredging** – bed material is disturbed by blades/chains to put sediment into suspension throughout the water column and again dispersion is achieved by tidal flows.

These techniques have the additional benefit that they do not require disposal of material arising from the works, and so can be a cost effective means of delivering increased water depth.

Dredging techniques

R N Flowers

Grab dredging at Five Mile bends River Yare

Grab

The traditional dredging technique used within the Broads for the last 40 years, grab dredging uses a clam shell bucket suspended from a crane jib and is usually operated by wires to dig material from the bed of the waterbody eg River Yare, shown above.

Due to the difficulty of bank side access the dredger is usually water borne, and towed into position by a tug. This method is relatively controlled, works within a confined area and removes sediment from the water environment. The jib is usually sufficient length to place material ashore if allowed, but otherwise is used in combination with barges to transport the spoil to an agreed disposal site. Disturbance of the sediments can create an increase in suspended solids within the water column locally, although this is relatively low. A more significant source of sediment to the water column can arise from spillages from the bucket, either from over filling, poor seals or premature opening. The clam shell bucket can also result in an uneven bed profile, with 'bites' being seen when examined by divers.

Hydraulic excavator

Broads Authority

In order to try and reduce the risk of spillage of dredging spoil, works have been undertaken to trial hydraulic backacters which are used by other inland waterways and considered by the CIRIA document 'Inland Dredging - guidance on good practice' report 169, to produce low levels of suspended sediment.

Our experience demonstrated that the level of operator skill is a prime factor in the control of spillage, for example an open bucket slewing at an inappropriate speed could cause spillage. Additionally, a smoother channel profile could be achieved, eg Catfield Dyke approach channel. Unless using a long reach excavator, there is a reduced ability to place material directly to the bank side, so the plant must be supported by barges.

Suction dredging

Cutter suction dredging can be used within the Broads, and uses an auger to disturb the sediments, which is then sucked into a pump and can be transported significant distances. This technique is most controllable, does not produce suspended solids at the point of use and provides a very smooth bed profile.

However, to transport the sediments high volumes of water are also taken up through the pump, with a low percentage of solids (usually 10%). The resultant material requires dewatering and probably requires construction of lagoons to manage the process. The excess water can be returned to the waterbody, but suspended solids need to be settled out first to ensure no local pollution at the discharge point. The material may take significant time to dry sufficiently to be rehandled and the area reinstated.

Suction dredger - as used at Barton Broad

Sediment lagoons - constructed to receive pumped silt and clean the return water

Mike Page

Combined dig and pump

In order to increase the opportunities for beneficial reuse of dredged material trials have been undertaken using a concrete pump, which can transport materials without the need for adding water. This means that materials produced through traditional dredging techniques can be transported to an appropriate site and offloaded from the barge and placed over a greater area using a pipe. This decreases the disturbance otherwise incurred using dumpers or other heavy earth moving equipment, which may also be restricted due to the marshy ground conditions eg St Benet's.

Dredgings from Thurne Mouth offloaded from barge and pumped over St Benet's site

Land & Water Services

Disposal of dredgings

As discussed in the Sediment Management Strategy, before reviewing the following methods for disposal, subject to the sediment quality, any dredging project should first consider mechanisms to reduce or minimise material arising from the dredging by considering the specification for works.

Beneficial reuse

Where at all possible projects should aim for beneficial reuse of the dredged material. When designing the project initially sediment quality from the sediment characterisation survey database should be reviewed and a site specific sampling survey should be completed if required to help refine possible options, which will be limited by contamination levels, particle size, organic content etc.

Possible options include:

- Habitat creation eg Bure Loop salt marsh creation, where dredged material was used behind a rock toe to build up a sub tidal mud flat outside the navigation area to develop a salt marsh community.
- Land spreading for agricultural benefit eg Barton Broad lagoons.
- Flood defence works, eg marsh raising in set back areas to create new reeded ronds such as Seven Mile House. Dredgings can also be used to provide backfill to erosion protection measures such as alder pole piling, gabions, or within geobags. Additionally, direct crest raising has been carried out where treatment using mobile plant has been trialled to blend dredgings with other materials eg Land & Water trial at Cantley sugar beet factory, where the resulting material was used within the Langley marshes flood wall.
- Land raising, where low-lying land requires works to improve the amenity of the site. In the case of St Benet's Abbey shown above and below, the works were required to help stabilise the adjacent historic remains of a Scheduled Ancient Monument.

Land & Water Services

Land raising at St Benet's Abbey

The best management projects are those which can deliver multiple benefits eg Bure Loop, St Benet's Abbey, working with partners to ensure added value is achieved in all stages of the project and promoting all of the Broads Authority's statutory duties.

Exemptions from Waste Management Regulations

Traditional Broads dredging has been completed by placing material on adjacent river banks eg River Chet and this activity is still permitted via an exemption within the Waste Management Regulations 1994, Schedule 3, Paragraph 25.
A symbiotic relationship has existed between navigation maintenance and flood defence, with material being used over generations to build up adjacent river walls. However, within the Environment Agency's Broadland Flood Alleviation Project the principle of set back which has been adopted means that the new walls are a significant distance from the river edge, the specification for construction materials is much tighter and the timing of works do not necessarily coincide. Additionally, other consents and permissions are required which can include landowners, conservation agencies and local councils, and these factors combined with practical issues of reach, transportation distance etc can mean that this option is often not possible.

Paragraph 7a of the Waste Management Regulations 1994 allows for land spreading activity where benefit to agriculture or ecological benefit can be demonstrated eg Barton Broad as shown above and also complies with the Code of Good Agricultural Practice. The amounts of material are limited both in terms of volume via a restriction placed on the exemption, but more significantly is dependent upon the level of nitrate within the material. Current legislation does not recognise the benefit of recycling this nutrient following its removal from the waterbody, and is concerned at the possible release to groundwater.

Paragraph 19a of the Regulations allows for dredged material to be used within construction projects, although this is limited to drainage works. Projects such as the provision of material for building up flood walls would fall into this bracket, along with reuse of dredged material for marsh raising within Broadland Flood alleviation Project set back areas.

Paragraph 9a of the Regulations exempts the spreading of waste from dredging any inland waters on any land in connection with the reclamation or improvement of that land, provided that:

- By reason of industrial or other development the land is incapable of beneficial use without treatment
- The spreading is carried out in accordance with a planning permission for the reclamation or improvement of the land and results in benefit to agriculture or ecological improvement
- No more than 20,000 m^3 per hectare of such waste is spread on the land.

Recycle

Where immediate reuse of the material cannot be achieved due to its nature, treatment through dewatering, composting, or chemical stabilisation, could be used to create construction materials.

There are no examples in the Broads other than simple in situ dewatering through lagooning or mobile plant use, but it can be shown that these processes can advance the use of the material by improving its handling characteristics as well as improving other factors such as material shear strength[1].

[1] The strength of a soil depends on its resistance to shearing stresses. Resistance to shear is provided by internal friction (interlocking of soil particles) and/or cohesion ("stickiness" tending to hold soil particles together).

Experiences reported from Belgium have identified that whilst there has been a big push for reuse and recycling of dredged material there are significant difficulties including low customer confidence, variable supply, limited market etc, therefore they have achieved a very limited success.

Landfill

The Broads Authority has a single licensed site, at Postwick Tip. This site had been in use for many years, to receive dredgings form the urban areas of Norwich and suburbs but subsequent to the Waste Management Regulations the licence was suspended pending a Regulation 15 risk assessment needed to determine risk to groundwater. The site was reopened in 2001 and is licensed to receive lightly mercury/copper contaminated materials which can be found within an 18 km stretch of the Rivers Wensum and Yare. Due to the limited capacity of the site disposal of uncontaminated waste is discouraged, to preserve the availability to deal with material which would otherwise have to go to commercial landfill.

There has previously been a network of historic sites around the Broads, usually adjacent to open waterbodies, which have been used to receive dredged material. Due to changes in waste legislation and site designations, all of these sites are now closed, and will require some level of restoration.

A strategic network of new sites will likely be required to be developed, which will have to have waste management licences, although it has been agreed that these sites will fall outside the scope of the Landfill Directive and as such will not require a Pollution Prevention Control permit.

Postwick Tip

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