PROPOSALS FOR HABITAT COMPENSATION

FOR HAYLE HARBOUR DEVELOPMENT SCHEME

Spalding Associates (Environmental) Ltd

with Appendix by

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(8TH December 2008)

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CONTENTS

1. Rationale

This document is the result of a preliminary desk top style study of various options that are available to provide compensation habitat for intertidal habitat loss resulting from the proposed Hayle Harbour development. The area of intertidal loss that is predicted at the completion of the phases of the development is 3.6 hectares. This figure includes losses at Cockle Bank, Penpol Creek, and small increments such as the slipway.

This study has been compiled in response to the discussions about habitat compensation during the meeting between the consultees and the development design team on 5th November 2008.

2. Background and limitations

The study has been limited by the time available. The consultees have assisted the study by identifying additional site options to add to those identified by the ecology consultants, and Spalding Associates welcomed and thank them for their input. A field meeting was held on 4th December 2008, attended by the design team ecologists and the representatives of the nature conservation consultees, during which the sites were visited and discussed in the light of the information gathered beforehand and the evidence at the site. At the Reskajeage (Red River) site the meeting was joined by Dr Loveday Jenkin, the Chairman of the Red River Working Group, a project set up Kerrier District Council, the local planning authority for the Red River.

We intend that this report should fairly reflect the discussions during the field meeting and the conclusions that were drawn at the end of the meeting. One of the issues that became apparent is that the results of the study cannot be viewed as finalised; all of the options would need further investigation, although to varying levels, and that in any case the mechanism for providing the compensation will need further exploration to deliver any of the options.

3. The principles of the compensation

The following principles have been applied in assessing the sites as potential options. These reflect both the developing evidence for, and philosophy of, providing compensation habitat to offset loss due to development and the discussions with the consultees. They are <u>not in any particular order</u>.

1. There should be a net gain in biodiversity as a result of the compensation.
2. That new habitat be created rather than existing habitat be enhanced
3. Intertidal habitat should be a priority but that in the absence of an acceptable local option (in terms of quality and quantity) other wetland habitat can be considered. Non-wetland habitat, (such as dune grassland) would be considered less valuable in terms of like-for-like compensation.

4. Weight should be given to freshwater sites where long term sea level rise can be reasonably be predicted to become an influence and included as part of the model for natural evolution of the site, possibly toward estuarine/tidal habitat.

5. Habitat creation should avoid proposals which may result in direct or indirect future flooding issues that would conflict with local and national flood strategies.

6. The proposed site should provide enhancement to the local network of nature conservation areas, increasing connectivity between such sites.

7. In selecting the site there should be no duplication of existing projects – the proposal should be for new work to create new, valuable habitat and not to use already planned and funded work.

8. The proposals should be for new valuable additional habitat and not enhancement of existing habitat.

9. There should be generic habitats and species assemblage (eg, wetland, swamp, appropriate bird assemblages) set as minimum targets.

10. Monitoring of development towards these targets must be included as part of the compensation package.

4. Examination and assessment of the options

The following sites were chosen, in discussions with the consultees, to offer a range of options within the locality of Hayle. All have a geographical connection to Hayle, lying within the St Ives Bay and its catchments the Angarrack River, River Hayle and the Red River). The sites are in the order they were visited during the site meeting on the 4th December 2008.

Map showing location of local site options

4.1. Summary of collated information for local site opportunities

4.1.1. River Hayle information summary

Site name	River Hayle – no specific site is identified
Site map/ locations/ definition of boundaries	See GENERAL MAP River Hayle can be split in to 2 main sections based on landscape/habitat character; that above Hayle (narrow semi-natural course largely) and that below (extensively canalised).
Area	Above St Erth 5 km of main river plus over 8km of tributaries. Below St Erth 1 ½ km.
General background summary	
Documented evidence	County Wildlife Sites site sheets
Planning/policy/strategic status	A number of County Wildlife Sites along both sections: Relubbas Ponds, Carbismill to Relubbas, St Erth Pools and Treloweth Woods, see Appendix A
Ownership	Private owners on upper reaches and lower reaches; RSPB at lowest end (Ryan's Field)
GO/NGO involvement	Environment Agency, Cornwall Wildlife Trust, RSPB
Existing management	Agricultural RSPB controlled tidal flooding at Ryan's Field (landward of Causeway) County Wildlife Sites (including Tregembo Marsh) Fish farm at St Erth
General constraints	Small scattered areas with differing ownership
Economic issues	Flood prevention is an important issue for the Environment Agency on this river
Other information	Tregembo Marshes on the upper reaches has been investigated for metal contamination remediation
Ecological summary	
Existing ecology/habitats	A freshwater river site, draining relatively large catchment for the locality. The river uplands drain agricultural areas and significant historical tin mining sites that have left a documented legacy in the river sediments. Low lying ground at Tregembo on the upper river at Relubbas is a valued marshland. There is a network of small woodland areas along the river banks upstream of St Erth. The flood plain at St Erth (St Erth Ponds CWS) is the site of a fish farm. Downstream of St Erth there is a significant woodland area (Treloweth Woods CWS) backing Lelant Sewage treatment works; otherwise the river is canalised but with a controlled brackish lagoon area behind the tidal barrier at the Causeway, created and managed by the RSPB.

Existing nature conservation value	County Wildlife Sites along river (see Appendix A). Potential for nature conservation wetland network action has already been identified but is not available as documented project as yet. Probable Otter habitat and possibly other wetland mammals
Baseline data for site	County Wildlife Sites site sheets
Options for habitat restoration/creation	Varied, due to lack of a specific site to consider. A mitigation scheme could reduce metal loads entering Lelant Water
Time scale for achieving target habitat	To be investigated
Ecological constraints	Known heavy metal contamination of sediments from mining history in upper reaches Effects on hydrology at Sewage Treatment works and RSPB reserve (Ryan’s Field) Partial agricultural history
Sustainability	To be investigated
Sources of information and documentation	County Wildlife Sites site sheets OS map EA (Simon Toms and Mike Williams of EA)
Other available information	Camborne School of Mines have undertaken heavy metal investigations in the upper reaches of the River.
Indications for feasibility	See below

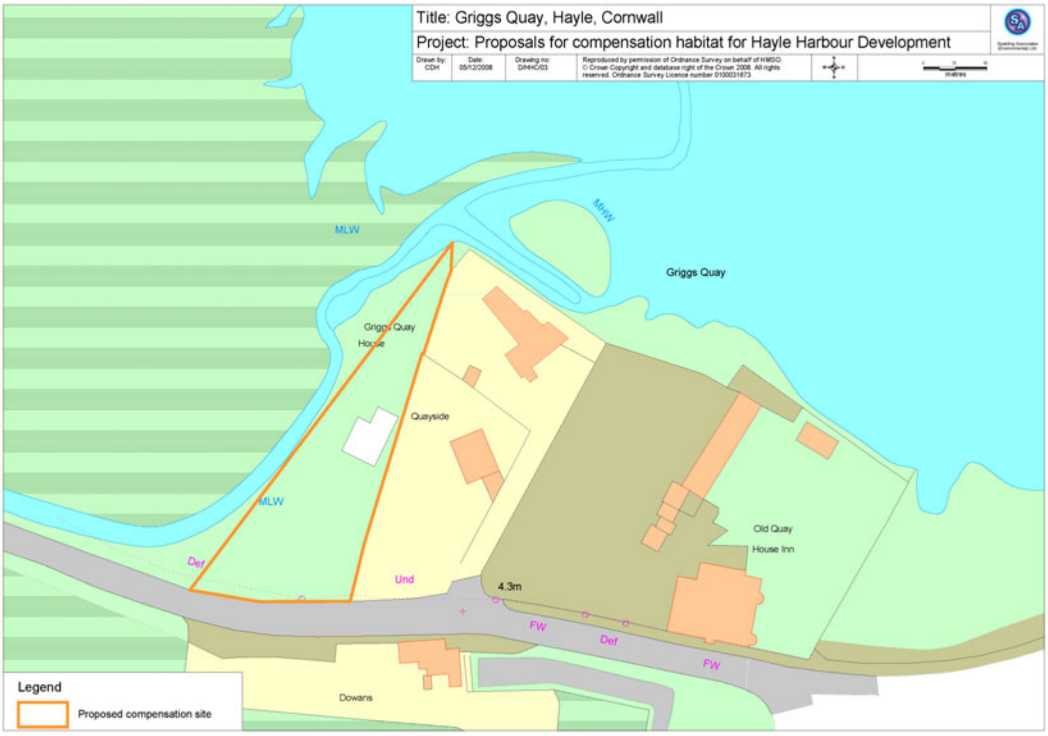
Comments

River Hayle has a good potential for creating wetland habitat network and has been identified as a potential re-introduction site for Water Vole a priority wetland species.

Conclusions

However these plans are well advanced with funding allocated; this and the potential problems of site ownership, complexity of sites, and the probable time delay in delivery indicate that this is not the best opportunity for compensation.

4.1.2. Griggs Quay



Griggs Quay information summary

Site name	Griggs Quay
Site map/ locations/ definition of boundaries	See map - The site is a small area of infill on the corner of Grigg's Quay in the Lelant water. The boundary indicated on the map was defined in recent planning correspondence and supplied through Dave Flumm of RSPB
Area	1705 square metres (0.2 hectares)
General background summary	
Documented evidence	OS mapped information, and comments from RSPB and current owner
Planning/policy/strategic status	Subject of planning dispute
Ownership	Private; known to RSPB
GO/NGO involvement	RSPB concern due to the proximity of the development (currently incomplete and non-consented) to the bird feeding habitat
Existing management	Building site currently

General constraints (eg. Ownership)	No feasibility study
Economic issues	The owner may demand a price that would cover his current financial liability on the site
Other information	None
Ecological summary	
Existing ecology/habitats	The site is probable infill, unregulated, at the head of the Lelant water, and likely to represent historic landclaim from the intertidal. The current vegetation, a rough grassland, indicates it is raised to above high water mark.
Existing nature conservation value	Probably minimal
Baseline data for site	None available
Options for habitat restoration/creation	Removal of landfill material with all necessary treatments to return to saltmarsh or leave in place and manage as peripheral habitat to the bird feeding grounds
Time scale for achieving target habitat	Dependant on investigations and requirement for remediation of wastes
Ecological constraints	Probable contamination of infill materials
Sustainability	If infill removed the sustainability of treatment of wastes is questionable but thereafter the habitat would be self-maintaining
Sources of information and documentation list	Dave Flumm, RSPB
Other available information	None
Indications for feasibility	See below

Comments

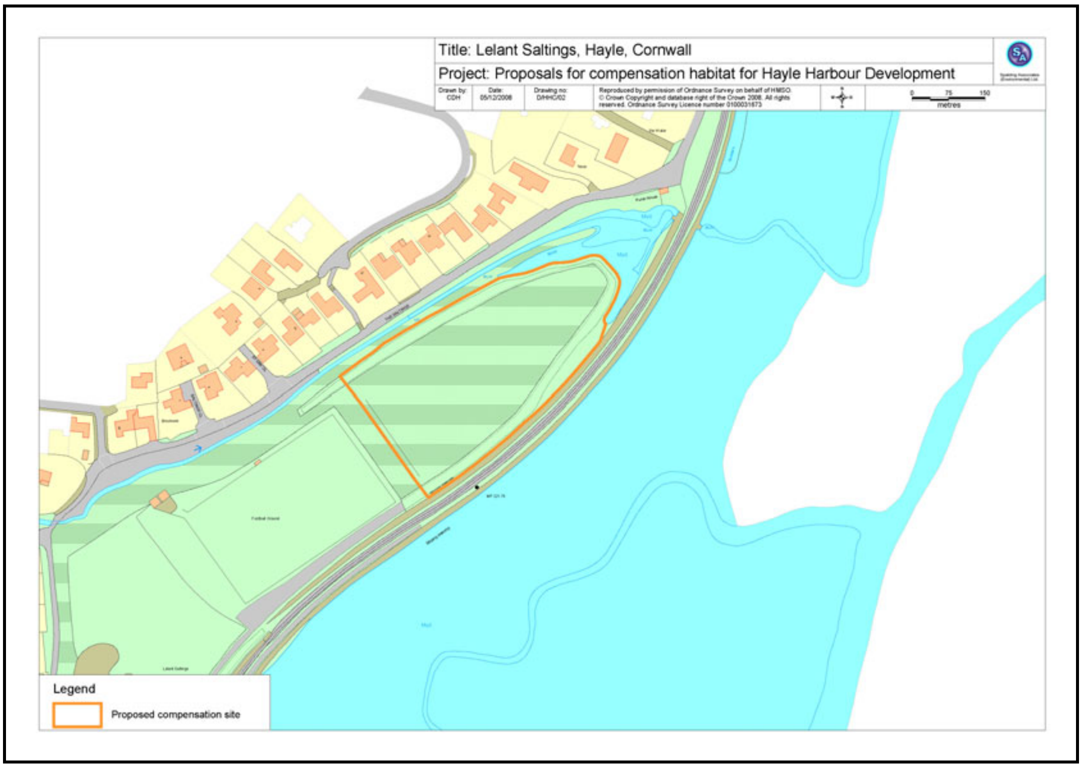
This is a small area claimed from the intertidal on the upper reaches of Lelant water; the ground has been reclaimed for development, without full planning approval, and the development has been stopped. The proposed use of the site also impacts on the important bird feeding habitat at its immediate frontage.

The site would require purchasing, removal of the existing building and removal of infill with the target of returning to intertidal of saltmarsh level, as appropriate to the site. The infill material would require investigation and possible treatment before removal. There is no known data that would inform ecological feasibility of the site as compensation.

Conclusion

The site is a very small area and in need to remediation to restore high quality habitat. It is likely that the cost of purchase and remediation would outweigh the benefit of the small area and habitat quality that would be gained.

4.1.3. Lelant Saltings



Lelant Saltings information summary

Site name	Lelant Saltings
Site map/ locations/ definition of boundaries	See map - The site is a small area of ground adjacent to a sports ground at Lelant Saltings in the Lelant water. The boundary indicated on the map was defined by Paul St Pierre of RSPB
Area	13282 square metres (1.3 hectares)
General background summary	
Documented evidence	OS mapped information
Planning/policy/strategic status	None

Ownership	Unknown
GO/NGO involvement	RSPB concern due to the proximity of the development (currently incomplete and non-consented) to the bird feeding habitat
Existing management	Building site currently
General constraints (eg. Ownership)	Unknown ownership No feasibility study
Economic issues	The site appears to be integral with the railway embankment which could present difficulties.
Other information	None
Ecological summary	
Existing ecology/habitats	The site is probable infill, unregulated, partially retained from estuary water by railway embankment. However a culvert under the railway embankment allows tidal water exchange and there is a low grade mudflat and saltmarsh habitat developing at its northern end. The site may be partially historic landclaim from the intertidal. The current vegetation, is rough and scrubby in part and raised well above high water mark.
Existing nature conservation value	Probably minimal
Baseline data for site	None available
Options for habitat restoration/creation	Removal of landfill material with all necessary treatments to return to saltmarsh or leave in place and manage as peripheral habitat to the bird feeding grounds/saltmarsh.
Time scale for achieving target habitat	Dependant on investigations and requirement for remediation of wastes
Ecological constraints	Possible landfill contaminants; retention of railway line detracts from the quality of the habitat that can be restored.
Sustainability	If infill removed the sustainability of treatment of wastes is questionable but thereafter the habitat would be self-maintaining
Sources of information and documentation list	Paul St Pierre, RSPB
Other available information	None
Indications for feasibility	See below

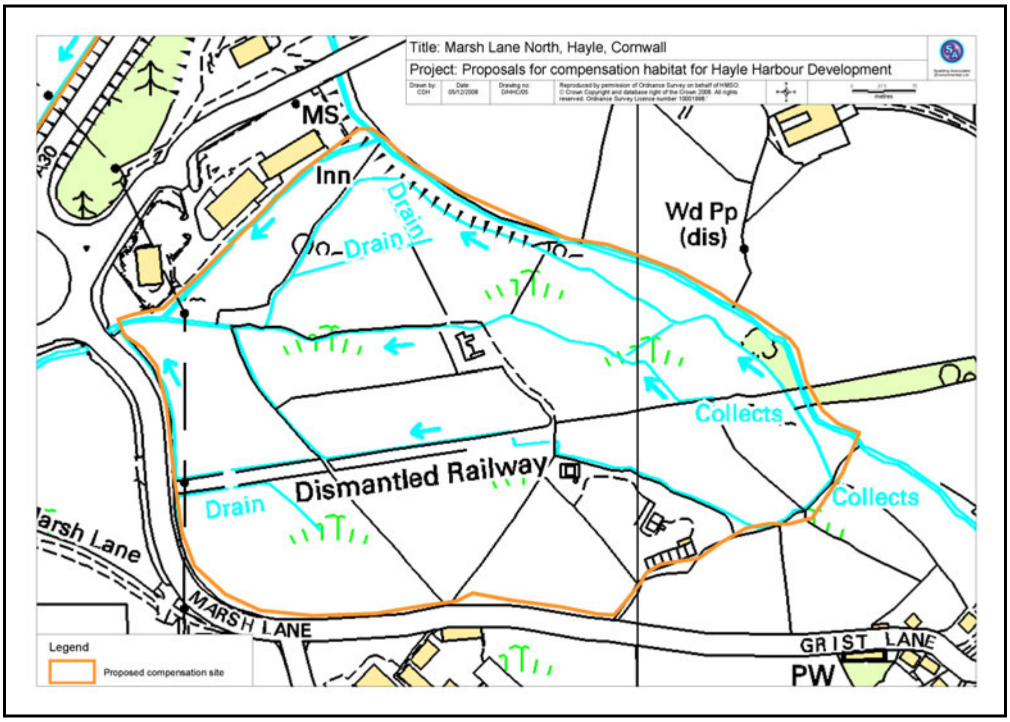
Comments

This is a small area on the north side of the Lelant water, near Lelant Saltings and landward of the St Ives railway branchline. It is believed to be the result of dumped waste and there is certainly abundant non-perishable waste evident on the site. The site is already sopen to tidal influence at its north end, but the existing terrestrial zone is capped and vegetated by mixed scrub/invasive non-natives.

Conclusion

The site is a small area and in need of remediation to restore high quality habitat. It is likely that the cost of purchase and remediation would outweigh the benefit of the small area and habitat quality that would be gained.

4.1.4. Marsh Lane /Marsh Lane Meadows



Marsh Lane information summary

Site name	Marsh Lane / Marsh Lane Meadows
Site map/ locations/ definition of boundaries	See map - The site is identified as H31 Marsh Lane North in the Hayle area Action Plan map and as Marsh Lane Meadows County Wildlife Site (P16) in the County Wildlife Sites map (Appendix A)
Area	H31 Marsh Lane North approx 12 hectares Marsh Lane Meadows CWS approx 10 hectares

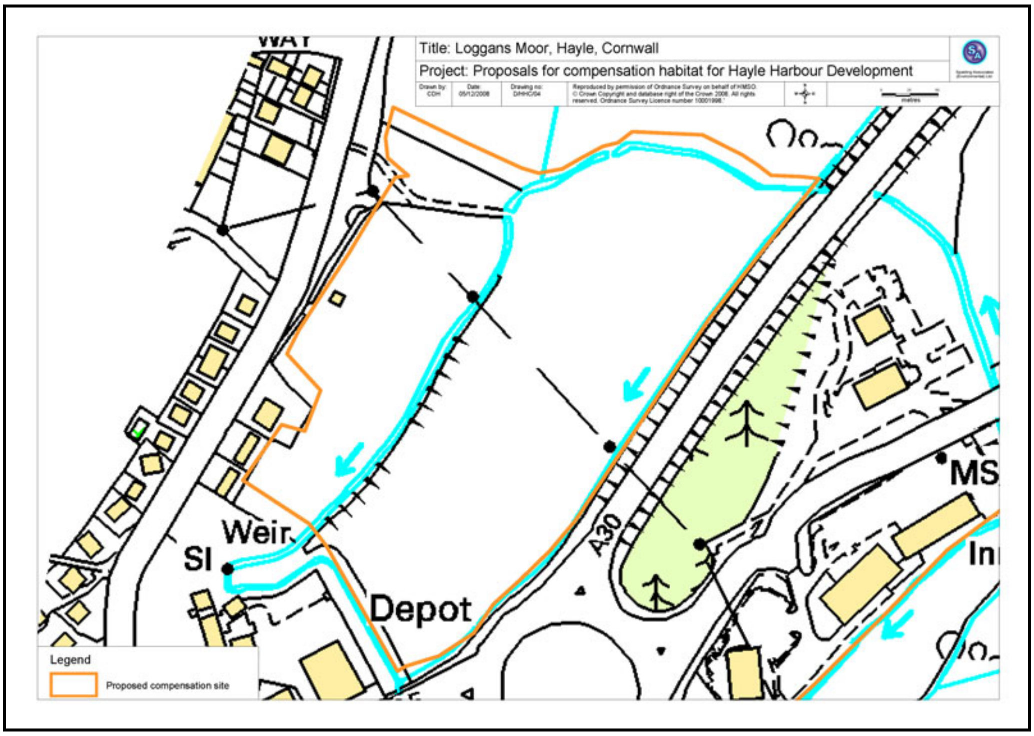
General background summary	
Documented evidence	County Wildlife Site Site Description and file held at ERCCIS
Planning/policy/strategic status	Identified as a County Wildlife Site – site of county importance for wildlife Identified as potential development land extending the Hayle Retail Park and associated development
Ownership	Private
GO/NGO involvement	Environment Agency, Cornwall Wildlife Trust , Penwith District Council, Hayle Town Area partnership
Existing management	None apparent
General constraints (eg. Ownership)	Private ownership and potential as development land; flood alleviation issues. No feasibility study.
Economic issues	Development pressure
Other information	The site has been the subject of discussion for nature conservation acquisition over a number of years. Now acquired for development.
Ecological summary	
Existing ecology/habitats	Mosaic of scrub and grassland habitats. The site is crossed by several channels/streams, hedgelines and railway embankment and is low lying. Presumed to be entirely within freshwater zone but would eventually become partly tidal as sea level rises. Part of the Angarrack river which flows from a historic tin mining area to low lying ground at Angarrack. In 1981 the river was culverted from Marsh Lane to Copperhouse Creek as part of the Angarrack Flood Prevention scheme.
Existing nature conservation value	Marsh Lane Meadows County Wildlife Site. BAP habitats that are recorded as present for the CWS are ancient and/or species rich hedgerows, Fens and wet woodland. Phragmites stands on lowest sections. Probable Otter habitat. Bird importance including four BAP species and wetland species.
Baseline data for site	OS map. EA as managers of the flood alleviation strategy for area. CWS site sheets and probable site management statement for site owner
Options for habitat restoration/creation	Securing future of the site as wetland habitat, with possibility for increased flooding on selected areas
Time scale for achieving target habitat	Partial wetland habitat already exists and can be recreated within 10 years probably
Ecological constraints	Probable heavy metal contamination of sediments from mining history

	Consideration of effects on Copperhouse Pool SSSI hydrology
Sustainability	To be investigated
Sources of information and documentation list	County Wildlife Site files; Environment Agency
Other available information	Local residents have, in the past, produced extensive wildlife reports for the site
Indications for feasibility	No feasibility study undertaken

Comments and conclusion

The site is enclosed by infrastructure including main roads, roundabouts, retail and light industrial units, but is of sufficient size to provide significant contribution to local nature conservation networks. The site has dried and scrubbed up so that there are opportunities for creation of new habitat if the current hydrology can be adjusted/re-aligned without affecting flood prevention targets. It would also secure an existing habitat block which could provide a local resource very close to Hayle town.

4.5. Loggans Moor



Loggans Moor information summary

Site name	Loggans Moor
Site map/ locations/ definition of boundaries	See map Area of ground identified in Hayle area Action Plan map as possible development site

Area	47714.24 sq metres (4.7 hectares)
General background summary	
Documented evidence	Some species information would be available from local experts
Planning/policy/strategic status	Identified as potential development land (H30) in Hayle Area Action Plan map
Ownership	Private owner; targeted as development land with proposals in progress
GO/NGO involvement	None known
Existing management	Possibly grazed occasionally.
General constraints	Already earmarked for development by owner
Economic issues	Development target
Other information	None
Ecological summary	
Existing ecology/habitats	The site is crossed by channels/streams. The site is on partly sloping ground which has been partially improved to tussocky grassland, whilst the lower levels support a tall herb community and are possibly marshy. Presumed to be entirely within freshwater zone. The lower flat ground is partly scrubbed but potentially connected to the central canalised stream by an existing non-functional sluice. The canalised stream along the centre of the site is believed to have been the Mill leat which would have fed the Loggans Mill pond.
Existing nature conservation value	Immediately adjacent, and partly overlapping with the Loggans Moor SSSI and adjacent to Loggans Moor Cornwall Wildlife Trust Reserve . Probable Otter habitat and bird interest
Baseline data for site	Very little available.
Options for habitat restoration/creation	Securing future of the site as wetland habitat, with benefit of extending the Loggans Moor SSSI habitats. The lower flat habitat opportunity for return to wetland is approximately 33853 square metres (3.4 hectares). The southfacing slope grassland, of potentially high value for insects, is approximately 13870 square metres (1.4 hectares). The site appears to be less likely to have contaminated soils since the streams seem to drain the hinterlands of the dune system.
Time scale for achieving target habitat	Possibly wetland habitat present already
Ecological constraints	Effects on Copperhouse Pool SSSI hydrology Partial agricultural history. Recreational pressure from local residents.
Sustainability	To be investigated

Sources of information and documentation list	OS map and EA (Simon Toms and Mike Williams of EA)
Other available information	None found
Indications for feasibility	See below

Comments

The Loggans Moor site has particular potential because of its proximity to an existing designated site (Loggans Moor SSSI) and its management could be incorporated within that scheme. The south facing slope lies on sandy soil and has potential to be returned to a managed species-rich dune grassland habitat with the important benefit of the lower ground which is well placed for occasional flooding (and which has undoubtedly been so in the past). The existence of the sluice gate indicates that the inundation from the leat has been controlled in the fairly recent past but the low lying ground is now being invaded by scrub. There appear to be less flood prevention problems on this section of the Angarrack flood plain than on the Marsh Lane site but there may be flooding issues that relate to the embankment on which the road is located.

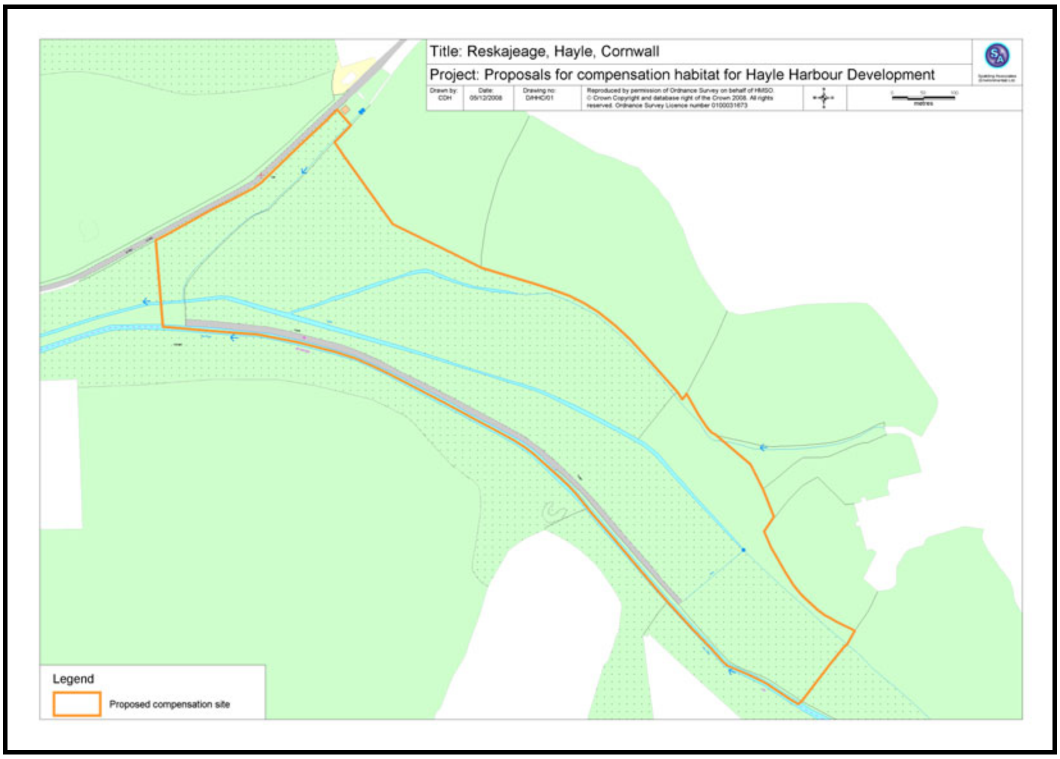
Conclusion

The opportunity for wetland recreation is not extensive but the gain in adding to the extent of a nature conservation site within a wider strategic approach to the network of dune and coastal habitats makes this site of good potential for compensation.

4.1.6. The Reskajeage/Red River site

Site name	Reskajeage/Red River
Site map/ locations/ definition of boundaries	See map Area of flood plain on Red River
Coverage	10.9 hectares
General background summary	
Documented evidence	Extensively studied with some feasibility study documents and land acquisition documents from previous efforts by Kerrier District Council to acquire the site as part of a Red River Management strategy
Planning/policy/strategic status	Area identified by partnership including Kerrier District Council, English Nature, Cornwall County Council as suitable for acquisition as Local Nature Reserve. Lower Red River County Wildlife Site (CWS)
Ownership	Privately owned
GO/NGO involvement	Cornwall County Council (Cycleau Project), Kerrier District Council (Red River working Group), Natural England.
Existing management	Agricultural in part and as part of the Red River management

General constraints	Acquisition and funding; full update to feasibility study
Economic issues	Regular flooding within catchment
Other information	Kerrier District Council are committed to acquiring this site to provide connectivity to an existing wetland network and to allow creation of better quality and more extensive wetland habitat within the Lower Red river. The limiting factor to date has been the current owner's demand for above land value in payment.
Ecological summary	
Existing ecology/habitats	The site is on the banks of the Red River, consisting of areas of damp habitat and improved habitat, with areas of scrub and tall herb fen.
Existing nature conservation value	As part of the ecological functioning of the lower Red River system Part of the Lower Red River CWS
Baseline data for site	Partial ecological information in survey report for wider area of Red River CWS site file
Options for habitat restoration/creation	The habitat opportunities exist over much of the proposed acquisition site, subject to environmental constraints. From vegetation mapping supplied by Cornwall County Council it is possible to estimate that 5.9 hectares of habitat available for wetland habitat creation eg by raising water table and other soft engineering options that minimise adverse operational and constructional impacts.
Time scale for achieving target habitat	To be investigated
Ecological constraints	Known heavy metal contamination of sediments from mining history. Partial agricultural history
Sustainability	To be investigated
Sources of information and documentation list	Existing documentation is extensive
Other available information	There is a well documented history for the site and its landscape history
Indications for feasibility	This site appears to be the best studied with regard to general feasibility



Comments

A number of data studies have been undertaken already which have provided good evidence to support the acquisition of the land for nature conservation, flood alleviation and planning strategy. However further site investigations may be necessary to deliver detailed proposals for biodiversity targets (such as habitat diversification).

Conclusion

There is general consensus amongst the consultees that the Reskajeage site is a viable compensation opportunity, providing clear targets can be agreed on the creation of wetland habitat to offset the losses identified by the Environmental Statement for the development.

4.2. Regional options

Wider, regional or national, options for seeking compensation opportunities have not been examined, and are not recommended at this stage, for several reasons. The limited time available for this study has been used in what is viewed as the priority in ecological and nature conservation terms ie the provision of the compensation habitat within the locality of the loss. Additionally there is no strategic framework for nature conservation creation unlikely to be support from the local population for taking the benefits of the habitat compensation away from the Hayle area.

4.3. Environmental banking options

4.3.1. Habitat banking

Habitat banking as a term has been used in a variety of ways (Morris and Huggett, 2007) but is here used as a means by which strategic land acquisition is undertaken to provide offsetting measures by habitat creation to compensate (but not mitigate) for habitat loss. Compensatory habitat creation can be applied successfully in some wetland and intertidal environments (Morris *et al* , 2006) so that the principle of this compensation proposal, to create wetland, is likely to attract support.

These schemes are relatively new as methods of producing compensation for habitat loss and there is not yet significant support for the principle in the UK. We have found no such schemes within Cornwall that would fulfil the principle of new work or work that already has funding. There remains the option of finding such a scheme at the regional or, failing that, the national level but such an outcome is not likely to be viewed favourably by local stakeholders such as the residents of Hayle and should only be explored in the unlikely event that the options on the top of the list prove unviable.

The Environment Bank

This is a company that has been recently set up to "facilitate the delivery of mitigation and compensation schemes associated with planning development" (The Environment Bank Ltd). The principle that is presented is that financial compensation for habitat loss can be pooled and used to provide large (landscape scale) nature conservation initiatives". Part of the vision that is promoted is the use of the funding as part of strategic nature conservation planning initiatives; this would therefore remain an option but only in the unlikely event that the options on the top of the list prove unviable.

The Environment Bank Ltd may provide a means of handling the financial and ownership issues associated with any of the identified compensation options, but further investigation will be necessary to establish how this mechanism could be put in place and what the advantages and disadvantages are. It must also be acknowledged that the distinctive ecological character of much of the Cornish wetland landscape, with respect to heavy metal contamination, may count against a local project being handled by this organisation.

5. Conclusions

The three sites with the greatest potential appear to be Rekajeage, Loggan's Moor and Marsh Lane. The following table summarises the arguments for and against the sites.

For	Against
Marsh Lane Meadows	
County Wildlife Site – site of designated county importance particularly for BAP habitats and bird habitat	Flood risk to surrounding development
Good potential for sustainable habitat enhancement	Metal contamination
Possible flood alleviation capacity??	Acquired for development??
Good habitat diversity	Small and enclosed by development
Potential green asset for Hayle	Privately owned
Habitat enhancement rather than extensive creation	
Moderate existing data for biota	
Loggans moor	
Extension of the Loggans Moor SSSI and CWT reserve	Privately owned Acquired for development
BAP habitat exist on site already	Small area of wetland potential and possible
High quality additional habitat potential if enhanced (partic. South facing slope)	Limited existing data for biota
Reskajeage	
Extensively studied site	Privately owned
County Wildlife Site includes wetland BAP habitats	Metal contamination
Feasibility study undertaken	Feasibility study probably needing updating with respect to legislation, ownership, value etc.
Naturally flooding site already	
Soft engineering methods are recommended for this site	
Not within development area	
Sufficient habitat is believed to be available to provide net gain in wetland habitat with possible long term tidal influence	

6. Summary

We have concluded that, based on the available information and the comments gathered at the meeting, the following ranking of the local site options reflects the consensus of the consultees, Dr. Phil Smith of Aquatonics and Spalding Associates

The site with the greatest potential to provide ecological compensation has been placed first.

1. Reskajeage, Red River
2. Loggans Moor
3. Marsh Lane Meadows
4. Griggs Quay
5. Lelant intertidal
6. River Hayle wetlands

We are confident that amongst these options, particularly the first three, there is likely to be a suitable site for compensation habitat. Reskajeage has the advantage that it already has a party interested in its purchase and future management as a wetland nature reserve ie KDC or the successor unitary authority.

References

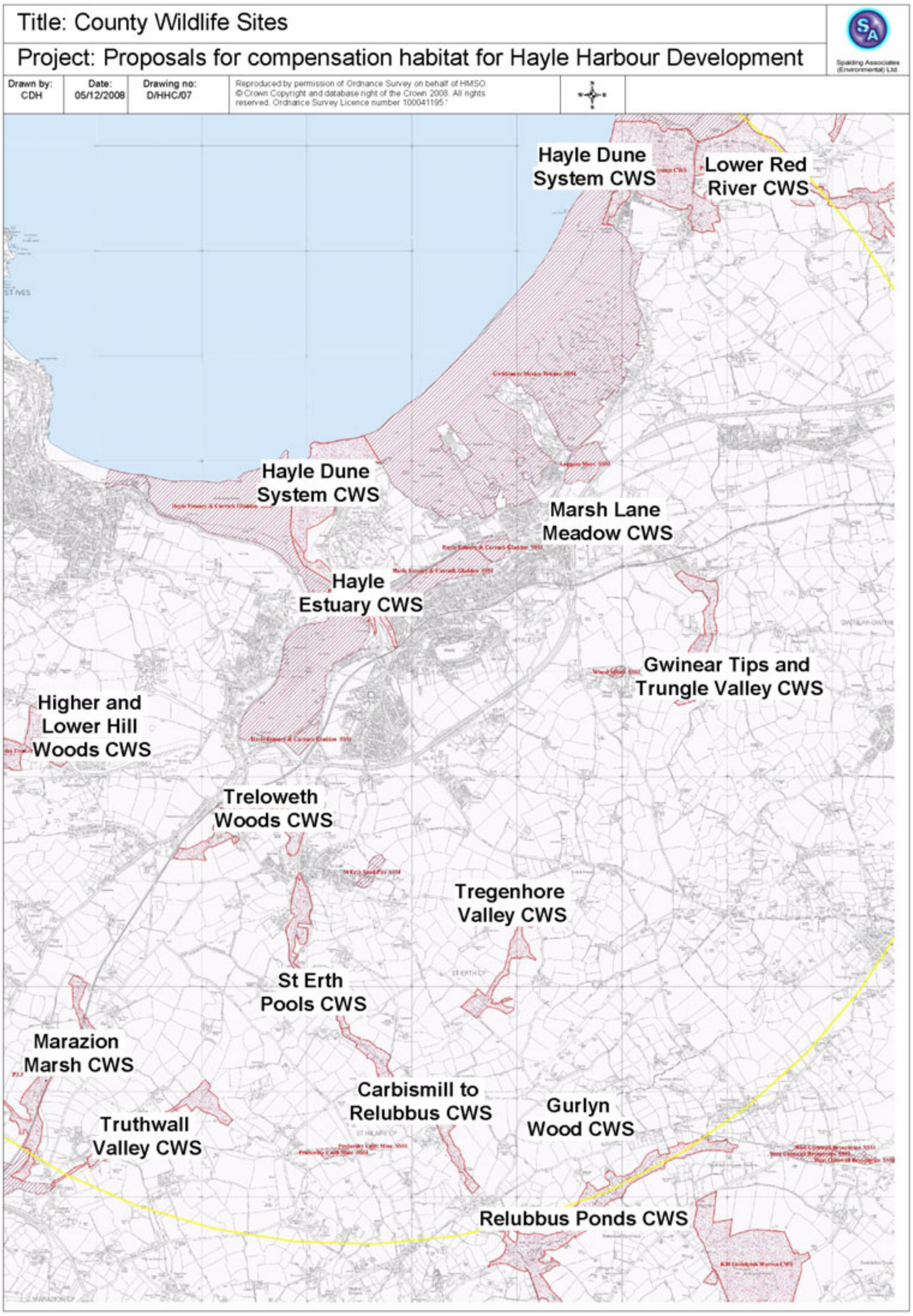
Environmental Records Centre for cornwall and The Isles of Scilly. County Wildlife Site system site files. Cornwall Wildlife Trust, Truro.

Morris, R. And Huggett, D., 2007. Mitigation banking – practical reality or Trojan horse. *Town and Country Planning* December 2007.

Morris, R.K.A., Alonso, I., Jefferson, R.G., & Kirby, K.J., 2006. The creation of compensatory habitat can it secure sustainable development? *Journal for Nature Conservation* 14. 106 – 116.

APPENDICES

APPENDIX A
Location of County Wildlife Sites (CWS) within Hayle area



APPENDIX B.

CREATING WETLANDS IN AREAS CONTAMINATED WITH METALS IN SOILS AND WATERCOURSES.

1. BACKGROUND

It has been estimated that in SW England there are approximately 1700 abandoned metalliferous mine workings (National Rivers Authority, 1994), which result in a minimum of 212 km of streams and rivers being affected by elevated metal concentrations. In addition, there are numerous smaller watercourses that are not monitored and not included in the 212 km figure. Most of the problems are in Cornwall and west Devon, and Penwith District Council and Kerrier District Council both have many affected watercourses within their boundaries.

Watercourses affected by minewaters are often stained by a variety of minerals, which form as the effluent is neutralised. Table 1 gives the common and chemical names for some of the most common oxides, oxyhydroxides and sulphates.

TABLE 1. COLOURED STAINS IN WATERCOURSES AFFECTED BY MINING (source Younger, 2002)

Colour	**Common name**	**Chemical name**	**Mineral name**
Red	Ochre	Ferric hydroxide $Fe(OH)_3.nH_2O$	Ferrihydrite
Orange	Ochre	Ferric oxyhydroxide (FeOOH)	Geothite
Yellow	Yellowboy	Ferric hydroxysulphates eg $FeOHSO_4$ $KFe_3(SO_4)_2(OH)_6$	Schwartmanite and Potassium jarosite
Black	Wad	Manganese dioxide (MnO_2)	Pyrolusite
White	Alum	Aluminium hydroxide $Al(OH)_3$ Aluminium sulphate $Al_2(SO_4)_3$ Aluminium hydroxysulphate $AlOHSO_4$	Gibbsite, boehmite Aluminite Alunogen

2. LEGAL FRAMEWORK

Several pieces of legislation are relevant to the proposed wetland creation. Some of the most important are considered below.

2.1 Environmental Protection Act 1990

Soils at the site may be 'contaminated land' as defined by Part 2A of the Environmental Protection Act 1990, ie land that is contaminated to such an extent that it poses an unacceptable risk or threat to human health or the environment. The Environment Agency have recently produced a ecological risk assessment (ERA) framework for contaminated soils (Environment Agency, 2008).

The ERA framework provides a structured approach for assessing the risks to ecology from chemical contamination in soils. This is a requirement under Part 2A (Contaminated Land) of the Environmental Protection Act 1990. The ERA framework consists of a three-tiered risk assessment process:

- **Tier 1** of the risk assessment is a screening step based on a comparison of chemical analyses of site soils with a soil screening value (SSV) for the contaminants of potential concern.
- **Tier 2** uses a choice of tools (ecological surveys and biological testing) to gather evidence for any harm to ecological receptors (plant and animal species) present at the site.
- **Tier 3** seeks to attribute the harm to the chemical contamination.

It has been designed to

- establish whether pollutant linkages are likely to exist between the contamination and the designated ecological receptors; and
- gather sufficient information for making decisions regarding whether harm to these receptors is occurring or could occur in the future.

This guidance appears to be very relevant to the creation of wetland that aims to be of high conservation value. It could result in a considerable increase in costs and time associated with the wetland creation. For example, it will probably be necessary to determine whether contaminants in sediments can be taken up in the food chain (eg plants, invertebrates and fish) and whether these body burdens could be harmful to wildlife. A study in Montana, USA showed that cadmium was the most consistently accumulated metal in the food web, with the order of bioavailability of the metals studies being Cd, Zn > Cu > As, Ni (Moore et al, 1991).

2.2 Water Resources Act 1991

Any work at the chosen site needs to be carried out very carefully to avoid exposing sulphidic particles to air, resulting in oxidation to sulphates with consequent reductions in pH and enhanced release of metals to watercourses. This has occurred at Bwlch and Cwmsymlog lead mines in mid Wales (Johnstone and Rolley, 2008). In addition, site works could cause the release of high concentrations of sediments to the watercourse downstream. Any pollution incidents from the site could result in a prosecution by the Environment Agency under the Water Resources Act 1991.

2.3 Water Framework Directive (WFD) 2003

The Water Framework Directive (WFD) is the most significant European Community legislation on water quality to date. It is designed to improve the way water bodies are managed throughout Europe. It came into force on 22 December 2000, and was transposed into UK law in 2003 by The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003.

Member States must aim to reach “good” chemical and ecological status in inland and coastal waters by 2015. Each member state has defined the various categories of chemical and ecological status for groundwaters, freshwaters, estuaries (called transitional waters), and coastal waters. The system is complex and the classification system varies between different types of water body. For example, groundwaters can be classified as either “good” or “bad”, but rivers have five categories (high, good, moderate, poor and bad).

Several methods are used to determine the status of a river. The water body is placed in the lowest of the various categories that have been determined for it. This has been described by the Environment Agency as the principle of ‘one out, all out’. The poorest individual result therefore drives the overall ecological and chemical classification.

The adoption of the ‘one out, all out’ principle has had an important effect on classification of water bodies. In 2007, 72% of English rivers and 87% of Welsh rivers were classed as good or better under the general quality assessment (GQA) of biology. However, draft results for WFD classification of ecological status of assessed rivers in England and Wales showed that 19% of rivers by length were good, 52% moderate, 21% poor and 7% bad (www.environment-agency.gov.uk/commondata/acrobat/081013_nlpe_item_2__2149581.pdf).

The WFD and daughter directives will cover all aspects of protection of groundwaters, inland waters and coastal waters. It will rationalise the EC’s water legislation by replacing seven of the "first wave" directives: those on surface water and two related directives on measurement methods and sampling frequencies and exchanges of information on fresh water quality; the fish water, shellfish water, and groundwater directives; and the directive on discharges of dangerous substances. The provisions of these directives will be taken over in the WFD, allowing them to be repealed (ec.europa.eu/environment/water/water-framework/info/intro_en.htm).

Many rivers and coastal waters in the UK will not “good” ecological status by 2015. Rivers contaminated by mines and run-off from mine spoil heaps are of particular difficulty, as no-one is liable for their clean-up. The UK government, presumably with other EC member states, will ask for extra time to meet the “good” status. The WFD stipulates that the river basin planning cycle should be 6 years. The UK has adopted a position that it will aim to achieve “good” status within three sets of river basin planning cycles (ie 18 years, from 2009 to 2027). Even this timetable will be demanding for rivers that are affected by historical mining, due to the lack of a co-ordinating body to implement clean-up. Table 2 shows the WFD timetable up to March 2010.

TABLE 2. ENVIRONMENT AGENCY TIMETABLE FOR WFD 2008/09
www.environment-agency.gov.uk/commondata/acrobat/081013_nlpe_item_2__2149581.pdf)

ACTIVITY	DEADLINE
Press release on 2007 water quality and new WFD classification scheme	6 October 2008
Classification results included in Draft River Basin Plans	End Dec 2008
Incorporate 2008 data into classification scheme	March 2009
Local offices audit the classification results and use the data to predict biological outcomes	May 2009
Classifications included in V0.1 First River Basin Management Plans	End July 2009
Final classifications published in V0.4 First River Basin Management Plans	Dec 2009
Final classification results sent to the European Commission	March 2010

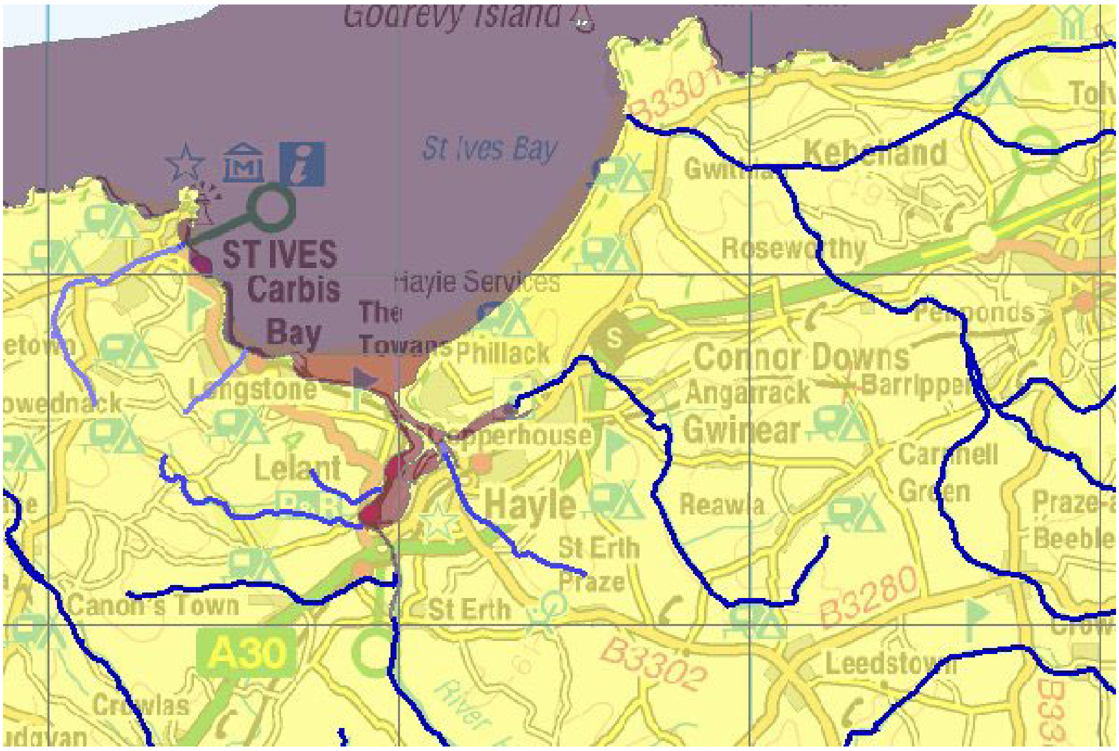


Figure 1. Assessment of Watercourses under the Water Framework Directive. All the sites being considered are “at risk” of failing to meet good ecological status by 2015.

Detailed results of the classification of rivers under the WFD will be available on the Environment Agency web site on 22 December 2008 (pers. comm. Ben Bunting, River Basin Programme Manager, EA, Exeter). These results will give us a better insight into the contamination issues that occur in the watercourses at the candidate sites. We already know that all of the candidate watercourses are "at risk" of failing to meet the 2015 deadline (see Figure 1).

One potential problem with the creation of wetland at a contaminated site is that the landowner may in the future be expected to ensure that any water on the site meets "good" chemical and ecological status. This is most likely if new habitat is created that has a poorer water quality than the watercourse that feeds it, for example due to increased oxidation of sulphidic minerals resulting in decreased pH (increased acidity) and higher concentrations of dissolved metals.

3. RIVER QUALITY AT POTENTIAL SITES FOR WETLAND CREATION

The chemical and biological classification of UK watercourses affected by mine drainage can be very variable, as until recently metal (copper and zinc) concentrations in the water were not included in the chemical assessment of water quality. However, both copper and zinc regularly exceed their Environmental Quality Standards (EQS) (source www.cycleaucornwall.org.uk/catprofiles/Red/quality/water.htm). Table 3 shows that the biological assessment of water quality gives a lower classification in the Red River catchment in the 1995 and 2000 assessments.

TABLE 3. WATER QUALITY IN THE RED RIVER CATCHMENT

Chemical (in red) and biological classification (blue) of water quality in the Red River catchment (source www.cycleaucornwall.org.uk/catprofiles/Red/quality/water.htm)

Reach	From:	To:	1995	2000
Praze River	Cargenwen Reservoir	Praze	C / B	B / A
Praze River	Praze	Barripper	C / A	C / A
Reen Stream	Source	Wheal Pendarves	D / A	D / A
Reen Stream	Wheal Pendarves	Ramsgate	No Data / A	No Data / A
Reen Stream	Ramsgate	Roseworthy Confluence	D / A	D / A
Roseworthy	Botetoe Bridge	Penponds	B / A	B / A
Roseworthy	Penponds	Nancemellin	C / A	B / A
Tehidy Stream	Tolvaddon Bridge	Old Merrose	B / A	B / A
Tehidy Stream	Old Merrose	Coombe	B / A	B / A
Red River	Brea Works	South Crofty	F / A	F / A
Red River	South Crofty	Roscroggan Bridge	F / D	F / B
Red River	Roscroggan Bridge	Kieve Bridge	F / C	D / A
Red River	Kieve Bridge	Gwithian Towans	E / B	No Data / A

Several rivers in Cornwall and West Devon have difficulty in meeting the water quality requirements under the Freshwater Fish Directive. Table 4 shows examples of rivers in south-west England that failed to meet the mandatory standards of the freshwater fish directive.

TABLE 4. FRESHWATER FISH DIRECTIVE. EXAMPLES OF SITES IN SOUTH WEST ENGLAND THAT FAILED MANDATORY STANDARDS IN 2007.
Source: Environment Agency (2008)

Sample Point Name	Parameter	Class of Fishery
Calenick Stream at Calenick Bridge	Zinc	Salmonid
River Carnon downstream of County & Wellington Adits	pH & Zinc	Cyprinid
River Coper at Loe Pool Bar Outfall	pH	Salmonid
River Hayle at St Erth Gauging Station	Zinc	Salmonid
River Hayle at Godolphin Bridge	Zinc	Salmonid
Portreath Stream at Bridge downstream of Cambrose	Zinc	Salmonid
Bolingey Stream at Bolingey	Zinc	Salmonid
River Tamar at Buses Bridge	Total ammonium	Salmonid
Fivehead River Fivehead Road	Dissolved Oxygen	Salmonid

Data are available on metals in waters, sediments and invertebrates in the River Hayle (Brown, 1977). Total zinc concentrations in the water were approximately 10 times higher than total copper, but in the sediments copper exceeded zinc by a factor of three (Brown, 1977). This finding is in agreement with studies by Aquatonics Ltd which showed that clays take up more copper than zinc (Aquatonics Ltd, 2003).

There is a good dataset for soils along the Red River valley, which is summarised in report by Cornwall County Council (2005). From these data it appears that concentrations of arsenic, copper and cadmium are likely to be the main problems. Fortunately concentrations of metals such as lead, mercury and chromium are not high in comparison to Soil Guideline Values (SGVs). Concentrations of dissolved zinc in St Ives Bay near the mouth of the Red River have failed to meet the saline waters EQS in some years (Cornwall County Council, 2005).

Freshwater flows have a significant impact on metals, as they affect dilution, the sources of contamination and rate of mobilisation. At locations such as SW Spain where flows are closely linked to seasons, iron concentrations in the water were low in the summer due to increased precipitation of ferric oxyhydroxides (Olias et al, 2004). Flows on the Red River are not monitored continuously, but are generally in the range 0.2 to over 5 m^3/second at Gwithian Bridge. The bank full discharge is approximately 2.5 m^3. Regular flooding occurs at

Gwithian Bridge, with the bank full discharge being exceeded 16 times between 1980 and 1998 (Cornwall County Council, 2005).

4. GROUNDWATER QUALITY

Groundwater quality in the Red River catchment is generally good, except where wells penetrate into mine voids.

Groundwater vulnerability is a classification that describes how easily an aquifer can become polluted, should a risk of pollution occur. The vulnerability takes into account the nature of the soil (how permeable and how thick the soil layer is), the depth to the saturated zone (deep water tables being less vulnerable than shallow ones) and the nature of the aquifer (Major, Minor or None). The Red River catchment only has minor aquifers, but the vulnerability does vary, as shown in Figure 2.

The lower Red River Valley comprises alluvial sands and gravels and blown sand deposits which are overlain by Devonian Mylor Slates. Many of the alluvial deposits at the potential wetland site have been variably worked for tin streaming, resulting in the presence of made ground (Cornwall County Council, 2005). The Mylor Slates are classified as a Minor Aquifer by the Environment Agency. This is a locally important aquifer, mainly for private supplies. Recharge of the slate aquifer will typically be less than 20% of the effective rainfall with the majority running off to surface water ditches (Cornwall County Council, 2005). Groundwater seepage from the slates into the alluvial valley bottom deposits will typically reduce in summer months due to the low storage within the slates.

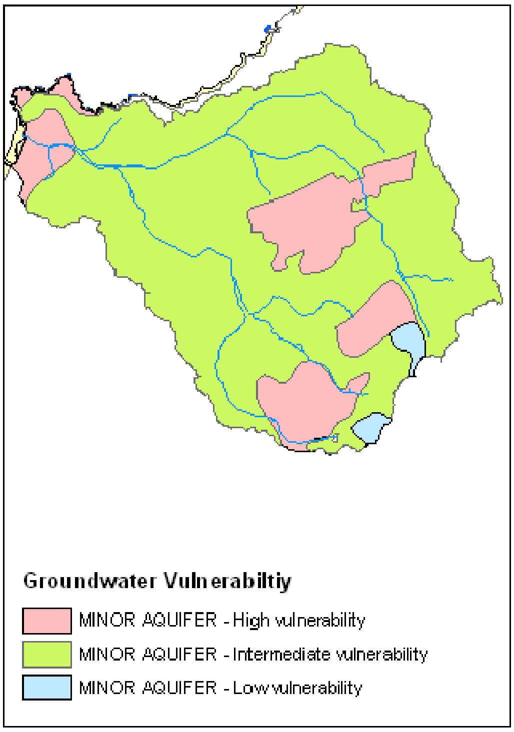


Figure 2. Aquifers and their vulnerability in the Red River catchment.

5. WETLAND CREATION AT SITES WITH HIGH METAL CONCENTRATIONS

Any groundworks at the chosen site need to be carried out very carefully to avoid exposing sulphidic particles (eg pyrite FeS_2, chalcopyrite $CuFeS_2$ and sphalerite ZnS) to air, resulting in oxidation of the sulphides to sulphate with consequent reduction in pH and an increase in soluble and therefore more toxic metals (Batty and Younger, 2004). Bacteria play an important role in the oxidation of sulphides to sulphates (Mayes et al, 2008).

5.1 Sensitive and Tolerant Flora and Fauna

For macroinvertebrates in the UK the main monitoring method for rivers is based on the BMWP method, which assigns scores of 1 to 10 to each invertebrate family, depending upon their sensitivity to organic pollution, for example from sewage. Unfortunately, the invertebrate families that are tolerant of organic pollution are not the same as those that are tolerant of high concentrations of metals and low pH (Chessman and McEvoy, 1998). This means that monitoring the impacts of mining needs an approach that can distinguish between the impacts of reduced pH, deposition of iron hydroxides, metals and other sources of pollution such as sewage. If iron concentrations are high invertebrates that have gills (eg larvae of stoneflies and mayflies) would be expected to prefer low pH that keeps the iron in solution, as an increase in pH will cause precipitation of iron oxides and oxyhydroxides onto gills and other surfaces. Conversely, groups such as molluscs may be intolerant of low pH, especially if copper is present, but more tolerant of the iron precipitates. A study in Spain showed that no molluscs or crustaceans (apart from ostracods) were present in the River Guadiamar downstream of the pollution incident from the collapse of the Aznalcollar tailing pond (Sola et al, 2004). In the same study the most impacted sites were mainly dominated by dipteran larvae (mainly Chironominae). Other metal tolerant groups found in the most impacted reach were Heteroptera, Coleoptera and Odonata (Sola et al, 2004).

The Acid Waters Indicator Community Index (AWCI) has been developed to assess the impacts of acidity on streams and rivers in England and Wales (Davy-Bowker et al, 2005; Ormerod et al, 2006). Ephemeridae and Physidae were among the most acid sensitive taxa (AWIC score of 6), while Chloroperlidae and Nemouridae were the most tolerant of low pH conditions (AWIC score of 1). In the Welsh coalfields one of the most important pollutants is the deposition of iron oxides and oxyhydroxides, rather than low pH (Davies et al, 1997). In the circum-neutral minewater discharges the higher pH resulted in lower dissolution of aluminium, itself an important pollutant for fish (Brown and Waring, 1996; Whitehead and Brown, 1989).

The species present in areas contaminated by mining vary between sites. Some mine waters are very acidic, others almost neutral. The metals present at high concentrations will vary between sites, as will their chemical form and availability. A few aquatic plants can tolerate very high concentrations of metals in waters and sediments. A Polish study showed that

Potamogeton pectinatus and *Myriophyllum spicatum* were tolerant of high concentrations of copper in the water and sediments (Samecka-Cyperman and Kempers, 2004).
Certain mosses and liverworts, including some rare species, thrive on metal contaminated soils. It will therefore be necessary to undertake a survey prior to finalising wetland design to ensure any populations are protected, if necessary.

The flora and fauna of a wetland constructed at a site with a long metal mining history and relatively high concentrations of metals in the soil and in the watercourse feeding the wetland is unlikely to be as diverse as in a natural or semi-natural wetland at an unpolluted site. It will therefore be necessary to have realistic expectations about what can be achieved. Although the flora may be reasonably diverse it is likely that the invertebrate fauna will be restricted. The invertebrate fauna at two wetlands constructed to passively treat effluents from coal mining or coal mining spoil heaps was less diverse than natural wetlands but did sustain a macroinvertebrate community that could support higher organisms (Batty et al, 2005).

5.2 Treating mining effluents in the UK

At present 33 coal mining effluents receive treatment in the UK, with a further 13 treatments plants used to prevent new uncontrolled discharges (Johnstone and Rolley, 2008). By contrast the only full-scale treatment plant for metal mining effluent is at Wheal Jane. The contrast between the coal mining and metal mining sectors does not reflect their relative importance, but instead the fact that coal effluents are the responsibility of a single body, The Coal Authority, which was set up in 1994. Unfortunately most metal mining works are very old and no organisation has the responsibility to clean them up.

Diffuse sources of metals can be very important in mining catchments. A recent study on diffuse pollution from mining (Mayes et al, 2007) identified four main sources of diffuse pollution:

1. diffuse seepages in the immediate vicinity of point discharges
2. direct input of polluted groundwater to surface waters, via the hyporheic zone (eg Gandy et al, 2006)
3. runoff from spoil heaps rich in sulphide minerals (Jarvis et al., 2006)
4. re-suspension of metal-rich river bed and bank sediments

In the coal mining catchment of the River Gaunless in NE England, during low flows diffuse sources account for around 50% of instream iron loading. This increased to 98% in high-flow conditions (Mayes et al, 2007). The low-flow sources appear to be dominated by direct discharge of contaminated groundwater to surface waters in lower reaches of the catchment. In high-flow, resuspended Fe-rich sediments (naturally occurring and also derived from historic mining) become the dominant diffuse source of Fe in the water column.

A range of treatment techniques are available for treating discharges from active and abandoned mines and spoil heaps. There are two main categories, passive treatment systems and chemical treatment systems. In chemical treatment systems, limestone or other alkaline materials are used inside a treatment plant to neutralise the acidic effluent and precipitate iron and other metals as their hydroxides. Examples include the chemical treatment plant at Wheal Jane, with a capital cost of £3.5 million and an annual running cost estimated to be £1 million. Chemical treatment systems are outside the scope of this report, as they are not being considered as part of the wetland creation due to their high capital and running costs.

Passive treatment systems have been defined as “the deliberate improvement of water quality using only naturally available energy sources (eg gravity, microbial metabolic energy, photosynthesis), in systems which require only infrequent (albeit regular) maintenance in order to operate effectively over the entire system design life (Batty and Younger, 2004). The main types of passive treatment systems for mine waters are:

- Compost wetlands, using substrates such as spent mushroom compost (Chang et al, 2000), composted conifer bark and manure, organic waste from paper making, horse manure and straw, or composted municipal waste. Any wetland plants that grow naturally or are transplanted will add to the organic matter. These constructed wetlands require a large land area but are generally cheaper in capital and running costs. Examples include a pilot treatment wetland at Lisheen, Ireland (Treacy and Timpson, 1999), Stanley Burn in County Durham (Jarvis and Younger, 1999) and the pilot treatment works at Wheal Jane in Cornwall (Hamilton et al, 1999). Bacteria play an important role in such wetlands, especially where sulphate concentrations are high, as sulphate-reducing bacteria such as *Desulfovibrio and Desulfotomaculum* can grown in anoxic environments where they oxidise organic matter and reduce sulphate to hydrogen sulphide, which reacts with soluble metal ions to form insoluble metal sulphides (Brierley, 1990).

- Use of waste or low value clay beds (Aquatonics Ltd, 2003). So far this idea has only been used in laboratory and pilot studies, but shows considerable potential especially if copper is present at high concentrations.

- Reducing and alkalinity producing systems (RAPS). These are similar to the compost wetlands but in addition they include a limestone gravel bed at the base of the system to maximise alkalinity generation. Potential safety concerns over the low load-bearing capacity of the compost can be overcome by mixing the compost and limestone (Younger et al, 2002).

- Permeable reactive barriers (PRBs). These systems are designed to treat subsurface flows or flows from spoil heaps (Younger et al, 2002). A PRB is a vertical wall of a reactive material, installed in the path of the flow of contaminated groundwater or spoil heap discharge.

Constructed wetlands are of particular interest in the current context, as it would be possible to construct a wetland that has enhancement of biodiversity as the primary purpose, and reduction in metals in the watercourse downstream as a secondary aim. Any constructed wetland is likely to remove metals (provided that it is designed carefully), as the wetland allows for a longer contact time between the contaminated water and fine sediments. Plants in the wetland also take up metals into their tissues. However, to design a sustainable wetland to remove metals so that the ecology of the downstream watercourse benefits is not without difficulties. If flood control is added to the functions of the wetland (as appears to be the case for the Red River site) then design of the wetland is likely to be a compromise, or require different areas to have different primary functions.

In 1999 the costs for constructed wetlands were in the range £41 - £51 per square metre, excluding land purchase costs (Jarvis and Younger, 1999). It is unlikely that within the available budget a large area of constructed wetland could be created, and an approach that combines an area of treatment followed by a more natural (and hence cheaper) area of wetland is the most likely outcome.

Aquatonics Ltd received a SMART award from the DTI in 2000 to undertake a series of studies to examine the effectiveness of waste clays and low value clays to remove metals. The results have been summarised in a report to the DTI (Aquatonics Ltd, 2003). For some metals such as copper and zinc extremely high levels of removal can be achieved, either with clay in suspension or as a clay-lined bed. It is highly likely that a clay-lined area of wetland would be a cost-effective solution to the problem of leaching of metals from the spoils into the water. If combined with treatment of the incoming water in clay lined channels it would be relatively easy to produce an area of wetland that supported a high diversity of plants and invertebrates, and possibly fish such as sticklebacks.

6. POSSIBILITIES FOR WETLAND CREATION NEAR HAYLE

We do not have site-specific contaminant data for all three sites considered in this report. However, due to the mining and smelting history of the Hayle area it is unlikely that we can find a site which does not have relatively high metal concentrations. In addition, any surface waters that can be used to create the wetland are likely to be polluted by metals such as copper, arsenic and zinc. These metals are highly toxic to many plants, invertebrates and fish. For example, copper toxicity is likely to be the greatest problem for molluscs, and a wetland without a reasonable range of molluscs could not be considered normal or of high ecological value. One of the main challenges to overcome is the problem of creating ecologically valuable freshwater wetland on these difficult sites. This section of the report examines the techniques available and the studies that will be needed.

It is too early to propose a suggested design for the wetland, which will be determined by a number of factors such as concentrations of contaminants, pH of inflow water, availability of materials (eg for compost cells) and any likely values for metals in the effluent discharge consent (if one is needed). However, it is possible to consider the possible options, which are outlined below:

- Clay lined wetland and clay lined channel feeding water into the wetland
- Compost cells, eg horse manure and straw, composted municipal waste, spent mushroom compost, or conifer bark and manure (Batty and Younger, 2004). The compost could be mixed with limestone or another source of alkalinity.
- Augment flow with pumped groundwater (if tests show that it is relatively unpolluted). The groundwater could be pumped using wind power.

Some of the metal removal may occur in the hyporheic zone. This is the sediment and porous space adjacent to a stream through which stream water readily exchanges with groundwater. Manganese oxides are likely to be important for metal removal in the hyporheic zone (Gandy et al, 2006). At the proposed wetland site near Hayle arsenic removal is likely to be a requirement. Iron oxides and oxyhydroxides in the hyporheic zone can be important sites for arsenic sorption (Gandy et al, 2006).

These options could be used in combination, to create a mosaic of connected wetland habitats. The first wetland could have primary function of removing contaminants and raising pH. The water with improved quality and lower toxicity could then flow into a second wetland area where the main function would be to provide a wetland with a high conservation value. It would also be possible to have final wetland where the flow was augmented with pumped groundwater to further improve water quality. This final wetland could potentially have a flora and fauna comparable to a wetland constructed at an uncontaminated site. An Australian study found that water quality was more important than sediment quality in determining macroinvertebrate diversity in two rivers affected by mining (Battaglia et al, 2005).

Most wetlands that are designed to remove metals and increase pH have a design lifespan of 15-20 years. If the whole wetland had a removal function then it could be necessary to disturb the wetland at a point where it was well-established and diverse. With the zoning approach outlined above the final, highest diversity wetland could probably be left undisturbed.

In order to design and manage the constructed wetland it will necessary to undertake a range of tests at various stages in the process. Some of the more obvious studies are highlighted below.

Assessment prior to purchase

- Detailed assessment of water quality (eg pH, alkalinity, metals, DO, conductivity etc) in relation to flows. Note that the pH of minewaters can rapidly decline if leachate exhausts the reserves of calcite or dolomite in the rocks that it passes through (Younger, 2002). Predicting whether and when this will occur at a particular site would be extremely difficult.
- Toxicological assessment with sensitive invertebrates, eg molluscs. Determine level of dilution required to provide long-term (> 30 days) survival.

- Invertebrate survey immediately upstream of abstraction point.
- Groundwater quality.
- Metals, sulphides etc in soils at various depths.

Assessment between purchase and first groundworks

- Continued assessment of water quality (eg pH, alkalinity, metals, DO, conductivity etc) in relation to flows.
- Invertebrate survey immediately upstream of abstraction point and downstream of discharge point.
- Invertebrate and plant surveys of any areas on the site that are already wetlands.
- Further assessment of contaminants in soils.

Assessment during groundworks

- Routine surveys of contaminants entering the watercourse and comparison with baseline levels. Cessation of works or amendment of working practices to overcome any water quality problems.

Assessment after commissioning

- Water quality in all distinct areas of the wetland.
- Invertebrate and plant colonisation of new areas.
- Contaminants in flora and fauna (Moore et al, 1991).
- Monitoring of invertebrates and fish downstream from the discharge.

7. THE STUDY TEAM

Designing a wetland that meets expectations and does not cause any pollution incidents requires a team with a range of expertise. The ecological and mine-water remediation members of the team will probably include:

Dr Phil Smith, Aquatonics Ltd. Water quality and macroinvertebrate surveys
Dr Anne Smith, Aquatonics Ltd. Advice on impacts on fish
Spalding Associates. Surveys of wetland plants and overseeing any planting

Advice on wetland creation to remove contaminants will be provided by Dr Lesley Batty of Birmingham University and either Dr Adam Jarvis or Dr Will Mayes of Newcastle University. All have first-hand experience of using wetlands to treat mine waters (eg Batty and Younger, 2004; Batty et al, 2005; Jarvis and Younger, 1999; Jarvis et al, 2006).

We expect that technical assistance will be available from Buro Happold. There is considerable expertise on minewaters and their impacts within the SW Region of the Environment Agency, which will be very useful to the team. It is expected that local knowledge of the Red River and other sites will be available from staff at Cornwall County Council, Natural England, Cornwall Wildlife Trust and the RSPB.

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