

**MINUTES OF 2<sup>nd</sup> STEERING GROUP MEETING HELD ON  
WEDNESDAY 6<sup>TH</sup> SEPTEMBER 2006**

**MIRO/MIST PROJECT:  
Water-based quarry restoration: Methodologies, Technologies & Approaches**

**Produced by P Ellis, Hafren Water**

Attendees: P Ellis, Hafren Water  
M Barnett, NYCC  
S Warwick, SUWT  
C Arditto, Tarmac  
M Fuller, Environment Agency  
M Hammond, Consultant Ecologist

Apologies: R Wilson, English Nature  
R Smithyman, Consultant Landscape Architect  
Rob Smith, North Yorkshire County Council (NYCC)  
Jeff Pacey, Environment Agency  
Gary Staddon, Lafarge (now with Dorset CC)

1. Introduction

Hafren Water welcomed the members of the steering group and indicated that the project had been on-going for 13 months and had another 5 months to run. Much of the fieldwork and literature review had been completed and the project was in the final reporting stage. Therefore any input from the steering group should be received in the near future in order to be incorporated in the final research findings. Hafren Water presented the project objectives and progress to date.

For the purposes of the study water-based restoration is taken to include the following:

- Open waterbodies below the watertable
- Perched waterbodies above the regional watertable
- Areas of habitat dependent on wet conditions
- Areas subject to frequent inundation
- The use of groundwater and surface water within a potential restoration

The project objectives are:

- Review methods of water-based restoration
  - Determine physical/practical constraints for each restoration scheme
  - Develop assessment criteria
  - Consider hydrological/hydrogeological implications & engineering requirements
- Inform planning

Potential afteruses for water-based quarry restoration are summarised below:

Water supply/reservoirs/irrigation
Watercourse management/supplement
Flood risk management
Water treatment
Run off management
Amenity Sailing/fishing/diving
Wildlife habitat
Fishery/aquaculture
Industrial process (cooling)
Energy production, Hydropower, biofuels, ground source heating
Lakeshore residential housing
Landfill (hydraulic containment)

Table 1: Potential afteruses for water-based quarry restoration

The study area is located in North Yorkshire primarily around the catchments of the Swale and Ure Rivers and, as discussed previously, comprises 7 case study areas comprising different hydrogeological settings and stages of restoration (see Table 2 and Figure 1).

Name	Map N <sup>o</sup>	Grid Ref
Kiplin Hall Quarry	99	SE 272 973
Marfield Pit	99	SE 215 827
Nosterfield	99	SE 284 807
Dry Rigg Quarry	98	SD 800 695
Scorton	93	NZ 235 007
Wensley	99	SE 065 920
Staveley	99	SE 360 630

Table 2: Case study areas

A combined assessment of each site is in the process of being undertaken involving expert input on ecological, landscape, hydrology, hydrogeology, engineering and quarry operations.

## 2. Progress summary

Much of the literature review has been completed. Ecological (M Hammond, Consultant) and hydrological surveys have been undertaken at all sites. Pro-forma datasheets have been partially completed for each site allowing comparison of attributes between sites and the resulting differences in restoration potential. An assessment of the landscape and engineering options for restoration is to be undertaken in the near future by Pleydell Smithyman Ltd, Consultant Landscape Architects. Landscape Agency (Consultant Landscape Architects) are to produce diagrammatic planning guidance based on the

findings of the work to date and building on the work undertaken for the Swale and Ure Washlands Project. Work on this is scheduled for November and any sketches or other input from project members should be received by that time. Potential sites for application of the project findings outside North Yorkshire are under consideration. One potential site, for a sand and gravel extraction operated by Tarmac, has been identified at Clifton, near Worcester within the Severn Valley. The site has adjacent nature reserves/SSSI, archaeological remains and the landowner has interests utilising the created waterbodies in developing the site for aquaculture purposes.

### 3. Project findings to date

Hafren Water gave a powerpoint presentation on aspects of the project findings to date for discussion.

Basic physical controls on the restoration are listed below:

- Geology
- Watertable
- Topography
- Connection to surface water
- Connection to groundwater
- Habitat potential
- Working method/operational management

An attempt has been made to summarise these controls by the use of a pro-forma datasheet filled in for each site to record information such as:

- Restoration design and habitat type
- Areas of open water
- Water balance
- Thickness of saturated mineral
- Thickness of available overburden

Data is obtained from the operating company and, if possible, historical data from previous operators, at the site or in the locality. Regional data including river levels, rainfall and groundwater levels is obtained from the Environment Agency.

Where available the restoration proposals and management plan are also examined. A site visit is made and discussions held with the interested parties including quarry operators, restoration managers and reserve trusts.

A water features survey is undertaken in the vicinity of the site and an assessment of the geology, relative water levels and the key inputs and outputs from the site water balance. An ecological survey is undertaken to assess the habitat present at the site and within the immediate vicinity, plus habitat potential and appropriateness within the regional context.

#### 3.1 Marfield example

The Marfield site was discussed as an example of water management techniques. Active sand and gravel extraction is underway in the northern area of the site whilst the southern area has been restored as a nature reserve. Operational site drainage is via a stream which flows southwards through the nature reserve to a discharge point at the

southern end. Groundwater levels fall from ~88 mAOD to ~83 mAOD across the site with the invert level of the outfall set as ~80 mAOD. Significant inflows from the adjacent gravel deposits allow water levels to be maintained at high levels of ~87.5 mAOD in waterbodies in the western margin of the site. The site is segmented into a series of discrete areas/water features with water control structures between each. Closure of such structures allows periodic flooding and also the creation of reservoirs which can be used to flood adjacent segments at lower elevations. The various segments frequently correspond to previous operational phases and silt lagoons. In general the key requirements in being able to control water levels are:

- i) Availability of sufficient inflow volumes to attain the desired water level over the required area for the necessary time period.
- ii) Ability to maintain a gradient in water level across the site, therefore having the potential to raise or lower water levels as required.
- iii) Topographic detail within each segment designed to allow the desired water coverage, with capacity to incorporate variability of water level and supply.

The outfall from the site is a key factor in allowing successful water management at the site. The adjacent river is at a much lower elevation (<75 mAOD) than the site and the outfall which lies above the river floodplain discharges to an existing stream. This avoids the need for any costly engineering structure which may otherwise be required if discharging directly to the river. Controlled waters such as the River Ure fall under the remit of the Environment Agency and a drainage consent is required before any modification of the watercourse is undertaken.

Water control is an essential management tool in the nature reserve. Maintenance of the watertable at the surface in one area to maintain wet conditions (but not submerged) has allowed the development of a fen/swamp habitat. The encroachment of willow is kept in check by seasonal flooding to a depth of approximately 10 cm during an 8-10 week period in January-February time. The water capacity of the higher 'reservoir' (fed by groundwater) being sufficient for the required area and depth coverage.

Flexibility can be incorporated into the restoration design by sub-dividing the restoration into segments with different surface elevations and design water levels. Each segment should have the potential to accommodate a range of water levels by setting upper maximum limits (eg by an overspill) and having a range of surface elevations to cope with fluctuations below the maximum.

The topography of each restored area should be designed to incorporate water level variations. Uncertainty will be inherent in the design, but having a number of discrete areas within the restoration allows flexibility in future management, potentially including the sacrifice of some areas to maintain others. The creation of scrapes at different basal elevations and the use of shallow slopes can be used to accommodate fluctuations in water level.

Of interest at Marfield is the adjacent SSSI which comprise wet woodland and swamp within an old river meander and also a seepage fen. The latter is located at the edge of the river floodplain at the foot of a steep slope. This appears to coincide with the point at which groundwater discharges from the base of the sand and gravel river terrace deposit. There is potential to re-create parts of these existing habitats within the proposed restoration scheme.

### 3.2 Contributions to the site water balance

Hafren Water presented data comparing open water coverage between sites (Figure 2) and the potential flows of water through each site (Figure 3). Inflows were calculated from direct precipitation to the site, surface water inflows (streams) and predicted groundwater through-flow. This information, along with evapotranspiration estimates, will be incorporated into the final site water balance. Total flows indicate the potential water resources and energy potential of the site. Areas where high flows pertain may be more suitable for wetland creation. Water quality will vary between different sources with consequences for proposed afteruse, in particular habitat creation. Specific habitats have different water quality requirements, often with low nutrient content.

Rainfall has low nutrient and mineral content. Agricultural run-off has high nutrient status, particularly if the suspended solid content is significant. Pesticides and herbicides may also be present.

River and stream courses often receive discharges from industrial sources, sewage treatment works, road drainage and urban run-off, with potentially elevated concentrations of compounds in free phase, dissolved form and sorbed to the surface of particulates.

Groundwater may be mineral-rich with varying base content, alkalinity and pH. Temperature will also vary significantly between the water sources: groundwater typically remaining fairly stable around the annual average air temperature at between 9-12°C. Surface water exhibits much greater seasonal temperature variations dependent on the depth/channel, lake geometry and mixing characteristics.

Potential exists to isolate the different inputs and utilise them for different purposes within the restoration.

## 4. Target habitats

Hafren Water and M Hammond presented a list of potential target 'wet' habitats achievable through water-based quarry restoration.

- Mesotrophic standing water
- Seepage fens
- Fen meadow
- Topogenous fens
- Wet grassland
- Reedbed
- Wet woodland

The habitat types represent broad definitions with further site variations within each, dependent on a wide range of variables including water quality, climate, etc. Within the literature many classification schemes have been developed based on various aspects of the habitat investigated and often related to specific regional studies.

Wetland habitats are successional and require a degree of management including grazing, mowing, harvesting, water level control and scrub clearance to sustain them in the desired state. Fen will produce peat which over time may develop into bog. Marginal reedbeds may gradually encroach from lake margins, forming organic rich substrates and peat for successional vegetation. The climax habitat will generally be wet

woodland although on the timescale considered for quarry restoration, which appears to be generally less than 30 years, this is unlikely to occur. Given the dynamic nature of the wetland environment a mosaic of different habitat types often develops and represents a desirable restoration target. However, each habitat created should be of sufficient size to be viable to sustain itself and the associated ecology. This said some habitats, particularly some fen types, are now so rare in the UK that creation of even small amounts will add significantly to the national resource.

The habitat created needs to be suitable and appropriate for the local area. Information on what to consider may be derived from the regional or local Biodiversity Action Plan. English Nature and the RSPB are in the process of constructing guidance on regional/local habitat potential based on a GIS system.

Peat forming vegetation such as fens and reedbeds can form a net carbon sink and suggestions have been made by English Nature that creation of certain habitat types could be promoted with industry for use as CO<sub>2</sub> emission offset.

Key hydro-ecological controls or habitat creation include:

- Watertable elevation and fluctuation relative to ground level
- The composition and hydraulic characteristics of the substrate material and the underlying geology
- Water quality and source
- Site water balance and soil moisture availability

Some habitats can tolerate a greater range in these factors than others which may be rare as a result of very specific requirements. Should a target habitat exist within the vicinity of the site then this provides an indication of a potential successful restoration option that may be pursued. However, significant spatial variability in the local hydrogeology is common, even over distances of <1 km and careful assessment is necessary of the required hydro-ecological controls. During the case study assessments the presence of an ecologist and hydrogeologist on-site at the same time proved highly beneficial to understanding the functioning of the habitat.

#### Seepage habitats

Of particular interest was the development of unplanned groundwater seepage habitats. This was observed at both Marfield and Kiplin Hall. At Marfield water levels were maintained via a bund approximately 1-2 m higher than the adjacent ground level. The hydraulic gradient induced flow of lake water through the sediments of the bund, which discharged forming a seepage face. Seepage was observed to be greater in some places than others, potentially as a result of rabbit activity. The seepage collected causing visible surface flow/flushes to occur. A varied flora characteristic of seepage fen habitat was observed to have developed.

At Kiplin Hall a similar situation was observed where seepage through the perimeter bund of the southern lake collected at a low point to form a species-rich, seepage-fed pond. Also of interest at Kiplin Hall was the apparent difference in water quality between the northern and southern lakes. The northern lake is stocked for fishing, is located within open surrounds and consequently has a population of geese. Nutrient inputs are therefore likely to be high. In addition there is understood to be a hydraulic connection, via permeable material (cobbles) with the adjacent stream, which flows through

agricultural land. This may filter out suspended solids within the stream but dissolved nutrients are likely to be present.

By contrast the southern lake has steep banks and adjacent tree cover reducing the goose presence. The water in the lake was very clear with flora, such as stonewort, indicative of low nutrient conditions. The lake had no observable outfall and a limited catchment area, indicating it was primarily groundwater-supported. It is likely that groundwater inflow occurs through the northern and western margins and discharges through the eastern and southern margins. This has implications for the water quality (nutrient status, temperature, etc) and therefore the ecology within the lake bed at different points around the lake. A similar situation may also occur in the northern lake with zones of potentially nutrient-poor groundwater discharge through the lake bed sediments in some areas and penetration of nutrient-rich surface water in others.

In many cases restorations were observed to have evolved from original designs and produce some interesting habitats, some of which were unplanned. The factors causing the creation of these habitats could perhaps be duplicated, expanded and implemented at other sites. However, it is observed that creation of the desired water environment does not necessarily result in successful habitat creation because other factors such as soil type, aspect, etc are equally important, not to mention having an adequate rooting stock/seed bank and preventing competition by undesirable species.

#### 5. Design water levels

Once a desired habitat has been selected and its hydro-ecological controls understood, landforming and control structures may be emplaced in an attempt to achieve the desired result. However this should not be undertaken without a detailed understanding of the water environment at the site. Current planning application procedures require a hydrological assessment but older permissions and historical sites may have no formal assessment. Monitoring of water levels and inflows/outflows from a site provide essential data for restoration design. In many cases there is a relatively limited monitoring period of data available before restoration designs are undertaken. Regional water level data may be available from the Environment Agency monitoring network, although this is primarily associated with water resources, large aquifers and public abstractions. The Agency also holds data on water quality and river flows and stage. Information may be available from other operators of the site or surrounding operations. However, data is not always easily accessible. It was suggested that a central electronic archive of water level data would be extremely useful, perhaps developed from the on-going monitoring at most sites required by the MPA.

On-going monitoring during quarry operations and subsequent to restoration is a key part of developing and adjusting a water management plan for the site. Monitoring points such as piezometers are assets, expensive to install, which should be preserved if possible and 'handed over' along with any historical data and borehole logs to the subsequent management of the restored site. Variability is inherent in the natural system and the longer the run of available data, the better the indication of the likely variation. Predicting accurately the post-restoration watertable across a site is uncertain and past variations in water levels are no guarantee of future levels.

Final predicted water levels based on a short run of data, eg less than 5-10 years, are likely to have a lower level of confidence than longer monitoring periods.

## 6. Influences of water level fluctuation

The magnitude of watertable fluctuation is dependent on the variation in recharge and local and regional control 'boundary' conditions. Nosterfield Nature Reserve was used as an example to illustrate the various factors involved in water level fluctuations.

Boundary conditions which control groundwater levels and flows through the site include:

- recharge
- regional groundwater system
- groundwater – surface water interactions between rivers, streams, drains and lakes
- abstractions

## 7. Recharge and water levels

Recharge to the local groundwater system depends on the incident rainfall, modified to account for losses due to run-off and evapotranspiration. Estimation of recharge is complex, requiring climatic data including solar radiation, temperature, wind speed, humidity and soil and vegetation characteristics. Using data from a weather station 8 km north of the site, recharge has been calculated for Nosterfield Nature Reserve according to the method outlined in (Allen et al, 1998)<sup>1</sup>. Precipitation over the period 1985-2004 (Figure 4) ranged from 458 mm in 1989 to 938 mm in 2000 and calculated recharge from 70 mm to 544 mm (Figure 5). Water levels at Nosterfield Nature Reserve are available for the period 1997 to date (Figure 6) and show a close relationship with the predicted recharge. Levels recorded in the main lake range from approximately ~38.8 mAOD in the drought period of 2003 (recharge 99 mm) to a maximum of ~42 mAOD during the very wet period in winter 2000-2001.

The site occupies former sand and gravel workings and is in hydraulic continuity with the underlying Magnesian Limestone. The site is separated from the underlying Magnesian Limestone by variable thicknesses of soil, sub-soil, sand and gravel and silt from mineral processing. Transfer of water from the limestone to the nature reserve occurs across this interface. Complexity in the local groundwater flow regime results from groundwater exchange between the sand and gravel and the underlying limestone.

Lower permeability formations will restrict the seepage of groundwater into the reserve and conversely limit seepage from surface water to ground. The deeper sections of the main lake are likely to be closest to the limestone bedrock, however the build-up of sediments within the lake over time will reduce the hydraulic connectivity in this zone.

Nosterfield Nature Reserve is designed to provide a large expanse of open, seasonally inundated grassland for breeding birds. Water level control systems or outfalls are not present at the site which is, consequently, reliant on natural variations in groundwater levels and surface water inputs. Similar variations in water level trends are observed between the underlying limestone and the main lake. However, the range in level fluctuation appears greater in the lake, probably due to the input of surface water run-off in addition to groundwater seepage.

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<sup>1</sup> R G Allen et al, 1998. Crop evapotranspiration – Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56.

Two extremes in annual water level fluctuations are present within the data, and the reserve needs to be viable under both sets of conditions. In order for this to occur shelves and scrapes have been created at different elevations. Based on the precipitation and recharge data the most representative average year in which site monitoring data is available appears to be 1999. Lake water levels range from ~39.3 to ~40.7 mAOD during this period.

Natural variability is potentially set to increase with climate change predictions of wetter winters and drier summers. Water-based restorations should therefore incorporate a range of scenarios under which the site will operate successfully. There is likely to be increasing emphasis on water level control to achieve the desired range in water level despite natural variability.

Without accurate knowledge or control of water levels designs could lead to wet grassland that can't be flooded or conversely proposed grassland that becomes a lake.

Aside from direct precipitation Nosterfield Nature Reserve may also receive recharge from a wider catchment via surface run-off, particularly from the high ground to the west. Water from drainage systems could potentially be utilised within the reserve.

#### 8. Seasonal inundation

The maximum water level in the main lake at Nosterfield Nature Reserve and the duration and range in water levels fluctuation has been lowered over recent years than previously. The primary reason for this is thought to be the recent dry weather, particularly during 2003, with a gradual recovery in levels observed since this time.

Flooded areas were calculated at different water levels using survey data for the western section of the site (Figure 7). Areas increase from <10,000 m<sup>2</sup> at a water level of 39 mAOD to ~75,000 m<sup>2</sup> and ~140,000 m<sup>2</sup> at 40 and 41 mAOD respectively. Site water level variation and the time period over which inundation occurs has a significant impact on the habitat created at the site.

#### 9. Water management plans

On-going management of the water environment within a quarry restoration is considered key to the successful operation of a site. A water management plan should be formulated containing pertinent data and it is envisaged that the site pro forma datasheet could form the basis of this. Target water levels (and durations) related to habitat goals would be included within the plan, together with water level control options related to the potential variations within local conditions. Items of income or expenditure related to variations in water level would be calculated and optimised. These may include maintenance of habitat hectareage under a funding scheme, such as HLS, or reduction in maintenance costs for willow scrub removal.

The cost and long-term importance of engineered control structures needs to be included in a management plan. It may be that the initial capital outlay may be recouped over an acceptable period. The cost benefit of the water management system and plan will frequently pass to the management of the restored area rather than to the quarry operator.

## 10. Long-term revenue and costs

Restored sites have potential to be entered into the High Level Stewardship Scheme sponsored by DEFRA to promote the creation/restoration of certain priority habitats. The scheme is competitive and sites must demonstrate the potential to create and maintain worthwhile contributions to biodiversity. Income is generated on a per hectare basis for qualifying habitat, and income for the western section of Nosterfield Nature Reserve was calculated for wet grassland (Figure 8) (requiring annual inundation) at a rate of £360 per ha, without flooding payments reduce to £80 per ha. The revenue derived from wet grassland was observed to increase from <£500 at 39 mAOD to ~£5,000 at 41 mAOD.

Failure to obtain desired water levels may lead to a decrease in revenue. Landowners may be unaware of the potential revenue to be derived from habitat creation which could, under certain circumstances, exceed what they could otherwise obtain from low-grade agricultural land.

There was considered to be some doubt over the current available level of funding for the HLS scheme due to funding issues.

## 11. Regional groundwater heads

The restoration design will influence water levels locally, eg installation of an outfall but regional aquifers of sufficient size are likely to control water levels within the wider vicinity of the site. Conversely small aquifers of limited lateral extent (eg some isolated sand and gravel deposits) are likely to be more sensitive to local influences on water levels.

Regional groundwater flow at Nosterfield is from the high ground in the west, either northeastwards, where groundwater discharges to Ings Goit stream, or southeastwards for eventual groundwater discharge to the River Ure.

The radius of influence of a quarry operation or restoration is proportional to its size and the degree to which original/natural water levels have been lowered. The greatest influence will occur down-gradient (within the regional groundwater flow system) of the site. In the case of Nosterfield Nature Reserve (Figure 9) the active quarry lies parallel and down-gradient to the site. There was discussion as to whether the influence of the current quarry operations and restoration extended as far south as the main lake on the nature reserve.

## 12. The influence of the restoration design on water levels

The restoration design will have an impact on the surrounding water environment due to:

- changes in aquifer characteristics eg emplacement of low permeable material or 'infinite permeability' lakes
- Increase in groundwater loss/discharge from the system, eg installation of an outfall or drain
- change in recharge to system, eg increased evapotranspiration or evaporation from vegetation or open water
- change in landform, increased/decreased run-off
- change in storage of the system, eg removal of unsaturated zone, 100% storativity in lake

### 13. Adjacent quarry operations

Quarry restoration is generally undertaken progressively and often quarries are laterally extended over time. Sites frequently have other operations present in the vicinity. The combined effect of water level control during working and subsequent to restoration will have an impact on the surrounding water environment (quality, levels and flowpaths).

### 14. Quarry lakes

Where excavation of sand and gravel has taken place to a depth below the watertable, the cessation of dewatering will lead to a gradual filling of the pit until the water level equals that of the surrounding aquifer, forming a 'pit lake'. In theory, the water level will attain a level midway between the groundwater levels that existed at the upstream and downstream ends of the pit before the gravel was extracted. To satisfy this condition, groundwater levels must fall up-gradient of the pit and rise down-gradient of it when compared with the pre-mining watertable. Many of these pit lakes are 'through flow' lakes since all the water entering the lakes (by lateral groundwater inflow or precipitation/surface run-off) at their up-gradient margins is delivered back to the sub-surface by lateral groundwater outflow at their down-gradient margins.

The lake levels at Nosterfield Quarry are controlled by an outfall structure to Ings Goit. It is understood that there is some flexibility in setting the outfall level. Discussions were held as to what effect an increase in lake levels at the quarry site would have on water levels at the main lake area of the nature reserve some 1 km distant. Any increase realised at the reserve would be proportional to the permeability and thickness of the intervening material and inversely proportional to the distance. A rise in water levels of 0.5 m in the quarry lakes would produce a smaller rise in groundwater levels at the nature reserve. There would also be problems and liabilities associated with flooding of agricultural land adjacent to the quarry lakes if water levels were increased. Connection between the groundwater and surface water systems will allow fluctuations in one system to be transmitted to the other. However, the hydraulic connection will also tend to dampen the fluctuations observed. For example, summer lake levels will be maintained by groundwater inflow. Static lake levels, such as those controlled by an outfall, will dampen fluctuations in the adjacent watertable.

### 15. Rivers

Another potentially significant influence on water levels at Nosterfield Nature Reserve is the River Ure, which lies less than 500 m to the southwest of the main lake. Interaction between groundwater and river will be greater the more permeable the intervening strata. Given the sediments in the Ure are understood to be fairly permeable, with exposed bedrock in some places, the watertable is likely to be similar to the river level in the vicinity of the Ure. Changes in river level will therefore result in variations in adjacent groundwater levels. In cases where a river is dredged or levels controlled artificially, changes may impact on an adjacent reserve. River level data was presented from the gauging station at Ripon for 1998 to 2003 (Figure 10). River levels were observed to vary by approximately 3 m with falls of ~0.5 m between winter and summer baseflow conditions. Baseflows were observed to be considerably lower in 2003 than 2000.

Many quarry restorations have potential to be connected to rivers which may fulfil a number of needs:

River water may be abstracted via a gravity inlet, or less sustainably, via a pump system. This may be to raise water levels for seasonal inundation, for specific habitat types (eg wet grasslands) to meet habitat water consumption demand or to provide water during periods of high winter river levels in reservoirs to support sites during summer. Maximum water levels within a site may be regulated by installing an outfall to a river. River water quality needs to be assessed and an abstraction licence is potentially required.

River inlet and outfall systems both require a detailed understanding of potential seasonal river level variations to indicate the range of conditions over which the system may operate. This may be assessed by undertaking frequency analyses of the stage data (Figure 11). For example an inlet from the river may be designed to operate and flood an area of land and knowledge will be required of:

Maximum water levels obtainable for use in the restoration

- The reliability of obtaining these levels each year, ie a 1% probability of occurrence has a higher risk of not being attained than say a 20% probability
- The time and duration over which inflow may be obtained and whether this is sufficient
- Water quality often varies with the flow rate in the river

#### 16. Groundwater abstractions

In some locations, for example Scorton and Kiplin Hall (Figure 12), regional groundwater levels are influenced by high rates of abstraction from public supply wells. Watertable levels are subject to changes in abstraction rates and even failure over the long-term (eg contamination of supply, borehole collapse, alternative supply) with an associated rebound in groundwater levels. In some extreme cases this could lead to the inundation of parts of a site and the formation of waterbodies. Similar impacts have also been observed in the vicinity of old underground mine workings when pumps have been switched off and the regional watertable has risen.

#### 17. Floating islands

Natural and semi-natural wetlands include a range of raft-forming vegetation types, in which semi-aquatic plants form a floating mat over the surface of open water. These vary from schwingmoors, in which a peat-accumulating raft several metres thick develops over the surface of a deep, steep-sided lake, to carpets of fen vegetation colonising shallow peat cuttings, which move vertically in response to fluctuations in water level. Natural floating islands may occur when vegetation growth extends outward from the shoreline of a wetland area. As the water gets deeper the roots no longer reach the bottom, and oxygen (and potentially other gases such as methane) in the root mass provide buoyancy. Sections may break free from the shore during storm events to form islands which migrate around the lake with the changing winds, eventually either reattaching to a new area of the shore, or breaking up in heavy weather.

The area beneath these floating mats is likely to be rich in aquatic life. The various types of floating mire are of high nature conservation interest, forming a characteristic or component part of several habitats listed in the UK Biodiversity Action Plan and /or the EU Habitats Directive. As well as the conservation interest of the plant communities themselves, floating mires form part of the habitat mosaic used by various wetland birds

and tend to be very rich in invertebrates, allowing terrestrial, semi-terrestrial and aquatic species to exploit different niches within the raft.

As well as the benefit to biodiversity other potential benefits to industry and society include:

1. Improvement of water quality, floating wetlands have been used to reduce nutrient content of eutrophic waters resulting from agricultural run-off and in waste water treatment applications.
2. Reduction of open waterbodies near air fields to reduce the potential for bird strike from flocking birds such as gulls.
3. Peat forming vegetation may provide a carbon sink and a means of offsetting carbon emissions.
4. Protecting and up-grading secondary drinking water supplies through improvements in quality and a potential reduction in the evaporative losses that would otherwise occur from open water.
5. An increase in mineral recovery. In some cases mineral is being sterilised to provide restoration material for habitat creation consequently leading to a greater requirement for land elsewhere. Maximum extraction would utilise all the available mineral resource potentially creating greater areas of open water. The use of floating wetlands could maximise the habitat creation potential in these areas.

Artificial islands have been employed successfully in other locations and the technology would be trialed and applied to a quarry restoration. Generally a floating island comprises a structure and/or natural material or geotextile to provide

1. To provide buoyancy and support growing media, distribution systems and vegetation.
2. A high surface area media for attached-growth (biofilm) and support of diverse biological communities.
3. Potentially distribution systems for aeration and circulation of oxygen and nutrients, this may also include some type of energy generation system.
4. Suitable planting including native wetland plants from which a viable habitat may develop suited to the local environment.

Hafren Water presented several slides showing the available floating island technology.

#### 18. Opportunities for sustainable water-based energy supply through quarry restoration

Often upon completion of mineral extraction large waterbodies will be created at different elevations, supported by both groundwater and surface water inflows. A considerable amount of energy may be stored within the lakes of the system, in terms of both thermal and potential energy. It may be possible to utilise this energy within the proposed restoration schemes, which often include return to agricultural usage, wildlife habitat creation, recreational or residential usage. Of particular interest may be the use of heat pump systems to provide heating for residential, aquaculture or agricultural (greenhouse) purposes and micro hydro-electric generation.

Sufficient land is often available for the construction of required facilities and necessary engineering works may be undertaken during the restoration. The availability of these sustainable resources may complement the creation of an ecologically friendly

development or 'eco park' such as the very successful Cotswold Water Park. The use of sustainable energy will add value to the final restoration, reduce carbon emissions and potentially benefit the surrounding community. Natural water treatment (ie reedbeds), water supply, habitat development and recreation facilities may all be utilised in conjunction at the site.

### 18.1 Ground source heat pumps (GSHP)

Heat pumps have only recently come to the fore in the UK, in part as a result of the increase in gas prices, but have been widely used for decades in mainland Europe and North America. A heat pump works on the reverse principle to a refrigerator, extracting heat from one medium (eg lake water) and transferring it to another, using electrical energy to drive a compressor. Heat extracted is derived from indirect solar energy. The system is reliable and highly efficient; typically the input of 1 kW of electrical energy will produce a 4 kW output of heat (coefficient of performance equals 4). This makes it environmentally friendly and operating costs generally work out cheaper in comparison to other fuel types (see table below).

Fuel	Price (p) per kWh
Gas	1.8 – 2.58
Oil	2.85 – 3.125
Electricity	2.94 – 7.88
Heat pump (COP 4)	0.7 - 2

Table 3: Estimated energy costs

On the downside is the relatively high initial capital cost although the payback period for high energy users is relatively rapid.

A closed loop system is generally used to collect the heat in which an antifreeze mixture is pumped through coils of pipe buried in the ground or submerged in a lake. An open-loop system, which utilises flowing water directly to the heat pump, can have even higher efficiencies (co-efficient of performance typically >5) with an associated reduction in running costs. Assuming a co-efficient of performance of 4 and a temperature drop in the water of say 5°C a flow rate of ~0.036 l/s is required per 1 kW of heat energy required.

Typically hot water output temperatures are 35°C for use with under-floor heating systems, up to a maximum of 55°C, although this becomes less efficient. Potentially the heat generated may be used for space heating in residential buildings and recreational facilities including swimming pools. For some applications the system may be reversed during the summer to provide cooling (either passive or active). Other uses include aquaculture and greenhouse heating.

Serious consideration should be given to the application of heat pump technology at restored quarry sites given the large volumes of water available and the potential to use gravity transfer.

### 18.2 Application to aquaculture and horticulture

Following restoration landowners are often seeking a return to some form of agricultural land with an associated income although often the quality and quantity of land may be

low due to the mineral extraction and waterbodies. Aquaculture and horticulture may potentially produce higher returns than other end uses. Both are energy intensive to provide optimum temperatures for growth.

Potentially some portion of aquaculture or greenhouse heating could be economically supplied using a ground source heat pump with supplementary heating if required via gas or oil during peak loads. As an example for a large 3.2 ha greenhouse heating costs could amount to between £57,000 and £95,000 per year (gas 1.8 – 3 p per kWh). Should a heat pump prove feasible, operating costs could potentially reduce to between £22,000 and £64,000 (0.7-2 p per kWh). The savings could make restored quarry sites very attractive for these applications.

Other agricultural applications of GSHP which have been tried successfully in North America include:

- a) Mushroom farming, which also has a considerable cooling requirement due to the heat from the breakdown of organic material
- b) Soil cooling for certain plants (eg Freesia) which require very close control of soil temperature in order for bulbs to grow properly and produce flowers
- c) Dehydration of soil to reduce the moisture content of potting soil being readied and packaged for shipment (grain drying).
- d) Cold storage facilities

### 18.3 Micro hydroelectric power

Micro hydro power systems which generally produce less than 100 kW are receiving more widespread interest in the UK due to improved technology and less stringent regulation of grid-connected micro hydro generators. Electricity supply companies are now obliged to buy a certain proportion of their electricity from renewable sources, such as hydro power through the Renewable Obligations scheme.

The hydro power in a stream or river can be calculated as follows:

Hydro Power (kW) = Head (m) x Flow (m<sup>3</sup>/s) x 9.81 x Efficiency

The system efficiency for micro hydro plants is typically 50% to 60%

Various types of turbine-generator units have been developed for a wide range of heads and flows and are available in the UK at costs of less than £2,000 per kW. The electricity generated from these units may be used on site or sold to the grid under the Renewables Obligation for ~ 4.5 p per kW.

### 18.4 Case study area

A suitable quarry restoration site has been identified at Scorton in North Yorkshire near the River Swale where Tarmac is still in the initial phase of sand and gravel extraction. Restoration proposals potentially include the creation of a series of linked waterbodies with an outfall to the Swale. The site has good potential for the use of an efficient open-loop ground source heat exchange system with minimal pumping costs due to the available gravity feed. An adequate water supply is available to meet the project requirements and electricity demand may potentially be offset by micro generation on-site (hydroelectric). A flow rate of at least 75 to 100 l/s is available with a drop in head of ~7 m across the site. Peak demand is likely to be during the winter when maximum water flows are likely to occur.

The following opportunities have been identified for the application of heat pump technology at the site:

- Quarry office
- Agricultural (Greenhouses & covered growth sheds. Potential for the Tarmac owned farm adjacent to Scorton lake)
- Aquaculture (Heated fish ponds)
- New build homes (Persimmon to the west)
- Potential industrial units on Hollowbanks
- Existing dwellings around the various lakes (feasibility would need to consider pumping costs, conversion costs and distance to properties from heat sources)

These applications are typical of those found at many sites around the country and the project will have a generic application.

#### 19. Grant applications

Hafren Water proposed to submit a grant application for funding of a more detailed research project into opportunities for sustainable water-based energy supply through quarry restoration. In addition to this funding is sought for trials into the use of floating islands in quarry restoration.

#### 20. Date of next meeting

The date of the next meeting was set for Friday 30<sup>th</sup> November 2006 at 10.00 in City Hall, Northallerton. It is hoped that as many people as possible will be able to attend this meeting.