



**WATER-BASED QUARRY  
RESTORATION – METHODOLOGIES,  
TECHNOLOGIES AND APPROACHES  
MA/5/2/005**

**APPENDICES 1-9**

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## APPENDIX 1 REGIONAL SCREENING EXERCISE

|    | Name                     | Grid Ref.  | Mineral                                 | Active | SSSI                  | Water restoration           | Company                   | Post code |
|----|--------------------------|------------|---|--------|-----------------------|-----------------------------|---------------------------|-----------|
| 1  | Allerton Quarry          | SE 420 595 |   |        |                       |                             |                           |           |
| 2  | Alne Brickworks          | SE 525 700 |   |        |                       |                             |                           |           |
| 3  | Arcow Quarry             | SD 801 706 | Sst/gritstone, crushed & coated stone   | yes    |                       |                             | Tarmac Ltd                | BD24 0EW  |
| 4  | Asenby                   | SE 389 758 |   | ?      |                       |                             |                           |           |
| 5  | Ballowfield              | SE 003 895 |   | no     |                       |                             |                           |           |
| 6  | Barton Quarry            | NY 230 080 |   |        |                       |                             |                           |           |
| 7  | Brown & Potter Quarry    | SE 240 770 |   |        |                       |                             |                           |           |
| 8  | Brown Moor               | SD 885 905 | Gravel                                  | no     |                       |                             |                           |           |
| 9  | Burton Leonard           | SE 323 630 | Mg Lst                                  | no     | yes                   |                             |                           |           |
| 10 | Carperby                 | SE 003 903 | Sst                                     | no     |                       |                             |                           |           |
| 11 | Castle Bolton Pits       | SE 045 917 | Sst                                     | no     |                       |                             |                           |           |
| 12 | Cleasby Quarry           | NY 255 115 |   |        |                       |                             |                           |           |
| 13 | Corkscrew Pit (Ripon)    | SE 320 732 | Sst?                                    | no     |                       |                             |                           |           |
| 14 | Dry Rigg Quarry          | SD 800 695 | Sst/gritstone, coated stone             | yes    |                       |                             | Larfarge Aggregates Ltd   | BD24 0EL  |
| 15 | Ellerton                 | SE 260969  |   |        |                       |                             |                           |           |
| 16 | Forcett Quarry           | NZ 105 155 |   |        |                       |                             |                           |           |
| 17 | Giggleswick Quarry       | SD 809 651 | Lst, crushed stone, concrete            | yes    |                       |                             | Hanson Aggregates         | BD24 0DH  |
| 18 | Greenhow                 | SE 112 638 | Lst                                     | no     | yes                   |                             |                           |           |
| 19 | Greets Moss              | SE 028 955 |   | no     |                       |                             |                           |           |
| 20 | Grewelthorpe             | SE 239 773 |   | ?      |                       |                             |                           |           |
| 21 | Harmby Quarry            | SE 130 898 | Lst                                     | no     |                       |                             |                           |           |
| 22 | Helwith Bridge           | SD 810 692 |   | no     | adjacent              | lakes                       |                           |           |
| 23 | Hollins Quarry           | SE 152 875 | Lst                                     |        |                       |                             |                           |           |
| 24 | Hollow Banks             | 231997     |   |        |                       |                             |                           |           |
| 25 | Horeton                  | SD 799 721 | Lst, crushed stone, agric lime/stone    | yes    |                       |                             | Hanson Aggregates         | BD24 0HR  |
| 26 | Killerby                 | 265956     |   |        |                       |                             |                           |           |
| 27 | Kinlsey Park             | SD 968 678 |   | no     | yes (malham arcliffe) |                             |                           |           |
| 28 | Kiplin Hall Quarry       | SE 272 973 | sand and gravel                         | yes    |                       |                             | Larfarge Aggregates Ltd   | DL10 6AT  |
| 29 | Leyburn Quarry           | SE 100 912 | Lst, crushed & coated stone             | yes    |                       |                             | RMC Aggregates (Northern) | DLA 5LA   |
| 30 | Leyburn Quarry           | SE 125 903 |   | no     |                       | adjacent lake               |                           |           |
| 31 | Littlethorpe Pottery     | SE 320 685 |   |        |                       |                             |                           |           |
| 32 | Longshaw                 | SD 894 906 | Lst                                     | no     |                       |                             |                           |           |
| 33 | Malham Cove              | SD 898 640 |   | no     |                       |                             |                           |           |
| 34 | Marfield Quarry          | SE 236 823 | Lst, Crushed stone, Agric lime/stone    | yes    |                       |                             | Lightwater quarries Ltd   | HG4 4BT   |
| 35 | Marfield Pit             | SE 215 827 | sand and gravel                         | yes    |                       |                             | Larfarge Aggregates Ltd   | HG4 4NH   |
| 36 | Middleham                | SE 125 888 | Lst                                     | no     |                       |                             |                           |           |
| 37 | North Lees (Ripon)       | SE 310 739 | Lst                                     | no     |                       |                             |                           |           |
| 38 | Nosterfield              | SE 284 807 | sand and gravel                         | yes    |                       |                             | Tarmac Ltd                | DL8 2QZ   |
| 39 | Nr Mile Hse              | SE 215 827 | Gravel pit                              | ?      |                       |                             |                           |           |
| 40 | Pallet Hill Quarry       | SE 234 983 | sand and gravel                         | yes    |                       | adjacent lakes              | RMC Aggregates (Northern) | DL10 7JX  |
| 41 | Pateley Bridge           | SE 125 642 | Lst, crushed & coated stone             | yes    |                       |                             | Hanson Aggregates         | HG3 5JQ   |
| 42 | Potgate Quarry           | SE 275 758 | Lst, crushed stone                      | yes    |                       |                             | Lightwater quarries Ltd   | HG4 3JN   |
| 43 | Preston Pasture          | SE 065 920 | Lst                                     | no     |                       |                             |                           |           |
| 44 | Quarry Moor              | SE 309 692 | Mg Lst                                  | no     | yes                   |                             |                           |           |
| 45 | Ripon                    | SE 315 715 | Gravel and sand                         | no     |                       | floodplain                  |                           |           |
| 46 | Ripon Quarry 2           | SE 285 744 | sand and gravel                         | yes    |                       |                             | Hanson Aggregates         | HG4 3HT   |
| 47 | Scorton                  | 235007     |   |        |                       |                             |                           |           |
| 48 | Skipton Quarry           | SE 009 610 | Lst, crushed & coated stone             | yes    |                       |                             | Tarmac Ltd                | BD23 6BJ  |
| 49 | Spennithorne             | SE 143 893 | Lst                                     | no     |                       |                             |                           |           |
| 50 | Spring Hill Pits (Ripon) | SE 312 736 |   | no     |                       |                             |                           |           |
| 51 | Stainley Mill            | SE 290 773 | Gravel                                  | no     |                       | floodplain                  |                           |           |
| 52 | Staveley                 | SE 360 630 |   | no     |                       | lakes fen/ mire             |                           |           |
| 53 | Stoop House              | SE 146 902 | Lst                                     | no     |                       |                             |                           |           |
| 54 | Swales Lakes             | SE 249 985 | Gravel pit?                             | no     | yes                   | Lakes, feeder system & pond |                           |           |
| 55 | Swallow Pit (Ripon)      | SE 305 725 |   | no     |                       |                             |                           |           |
| 56 | Swindon Quarry           | SD 976 613 | Crushed stone, agric & indust lime/ston | yes    |                       |                             | Tarmac Ltd                | BD23 6BE  |
| 57 | Swinithwaite Pits        | SE 041 885 | Lst                                     | no     |                       |                             |                           |           |
| 58 | Tancred                  | 245005     |   |        |                       |                             |                           |           |
| 59 | Tholthorpe               | SE 465 670 |   |        |                       |                             |                           |           |
| 60 | Threshfield              | SD 975 645 | Lst, crushed stone                      | yes    |                       |                             | Tarmac Ltd                | BD23 5PA  |
| 61 | Ulshaw                   | SE 143 878 | Lst                                     | no     |                       | floodplain                  |                           |           |
| 62 | Ure Valley Quarry        | SE 285 765 |   |        |                       |                             |                           |           |
| 63 | Wensley                  | SE 065 920 | Limestone                               | yes    |                       |                             | Tarmac Ltd                |           |
| 64 | West Tanfield            | SE 268 782 | Lst                                     | no     |                       |                             |                           |           |
| 65 | Westfield (Ripon)        | SE 326 731 | Sst                                     | no     |                       |                             |                           |           |
| 66 | Wooddale                 | SE 074 764 | Lst                                     | no     |                       |                             |                           |           |

## APPENDIX 2

### CASE STUDY DETAILS: MARFIELD

|                       |   |
|-----------------------|---|
| <b>Name:</b>          | <u>Marfield Quarry</u>                      |
| <b>Site location:</b> | 1.2 km north of Masham (Harrogate district) |
| <b>Elevation:</b>     | 83 to 88 mAOD                               |
| <b>Natural Area:</b>  | Pennine Dales Fringe                        |

#### Abiotic characteristics

The site lies approximately 200 m west of the River Ure upstream of the market town of Masham on the fringes of the Yorkshire Dales. Sand and gravel extraction is undertaken by the operator, Lafarge, in the northern area of the site, whilst the southern area has been restored as a nature reserve. The adjacent SSSI comprises base-rich seepage fen at the edge of the river floodplain with wet woodland and swamp within an old river meander. The seepage fen appears to coincide with the point at which groundwater discharges from the base of the sand and gravel river terrace deposit.

Marfield Wetlands Nature Reserve, to the south of the currently active quarry, comprises an area of former sand and gravel workings that have been restored at low level. The site comprises a complex of open waterbodies and wetlands with associated peripheral areas of young plantations and grassland with open bare sandy areas. Marfield holds small but increasing numbers of winter wildfowl, a range of breeding birds and, in addition, can be an excellent site for passage waders. Restoration proposals for the current extraction area include areas of open water and habitat similar to that within the existing nature reserve (**Figures MAR1-3**).

#### Geology

The superficial deposits at Marfield comprise glacial clay deposits generally ranging in thickness from 1 to 4 m (maximum 6 m) overlying a thick (9 to 17.5 m) sequence of glacial-fluvial sand and gravel. Silt-grade material comprises an estimated 15% of the mineral. The sand and gravel is sub-divided into upper, middle and lower divisions by clay interburden of varying thickness and continuity (0-8 m). Groundwater levels in the lower sand and gravel unit are generally slightly higher (0 to 0.73 m) than those in the middle sand and gravel suggesting an upward movement of groundwater. The middle sand and gravel unit is thought to be in partial hydraulic connection with the adjacent River Ure.

Beneath the superficial deposits the solid geology consists of alternating bands of Carboniferous (Millstone Grit) sandstone and shales. The sandstone sequences could potentially act as minor aquifers but are believed to be concealed at depth by clay and will therefore not interact with the site.

#### Hydrology

Drainage of the extraction area is via a gravel-based stream (primarily groundwater-fed) which flows southwards through the nature reserve to a discharge point at the southern end. The site comprises several open waterbodies linked to the surface watercourse, in addition to which several waterbodies are groundwater-supported. Two spring features have been created by localised extraction in the up-gradient area of the site. In areas the watertable is at ground level, creating seepage features over a considerable area. Groundwater levels decrease from ~88 mAOD to ~83 mAOD across the site, with the invert level of the outfall

set as ~80 mAOD. Quantitative information is provided on the accompanying proforma data sheet.

### Water quality

The following water chemistry data were obtained from samples collected on 29/11/2006:

| Variable/<br>Location                          | pH   | Electrical<br>conductivity<br>$\mu\text{S}/\text{cm}^{-1}$ | Ortho-<br>phosphate<br>mg/l P | Nitrate<br>mg/l N | Sulphate<br>mg/l | Magnesium<br>mg/l | Calcium<br>mg/l | Alkalinity<br>mg/l<br>CaCO <sub>3</sub> |
|--|------|--|-------------------------------|-------------------|------------------|-------------------|-----------------|---|
| Spring in<br>SW corner<br>of Nature<br>Reserve | 7.56 | 589  | <0.1                          | 7.18              | 27.1             | 11.3              | 130             | 261                                     |
| Nature<br>Reserve NE<br>lake                   | 8.05 | 470  | <0.1                          | 2.53              | 30.1             | 10.2              | 85.3            | 224                                     |
| Nature<br>Reserve S<br>lake outlet             | 8.08 | 433  | <0.1                          | 4.57              | 29.7             | 9.39              | 78.1            | 168                                     |
| Rivulet<br>below<br>spring,<br>SSSI            | 7.70 | 584  | <0.1                          | 10.3              | 31.5             | 11.5              | 131             | 257                                     |

Table A2.1: Water chemistry data at Marfield Quarry

These data indicate base-rich, moderately alkaline water but with lower concentrations of dissolved minerals than have been recorded from sites adjoining the magnesian limestone. Nitrate levels were high in all the Marfield water samples.

### **Historical and landscape context**

Marfield Quarry is in close proximity to a series of semi-natural wetlands at the edge of the floodplain of the River Ure. Until the mid 1880s, Marfield Pond was "...a natural sheet of water of several acres" comprising a mixture of fluctuating open water and "...a mass of thick reeds occupying the centre of the pond... within which any ordinary number of birds could be perfectly concealed" (Carter, 1886). Interestingly, local botanists recorded from the surrounding wetland a mixture of acidic mire species such as sundews and bog asphodel (*Narthecium ossifragum*) and those more typical of base-rich fens such as early marsh orchid (*Dactylorhiza incarnata*), marsh helleborine (*Epipactis palustris*), globeflower (*Trollius europaeus*), birdseye primrose (*Primula farinosa*) and grass of Parnassus (*Parnassia palustris*). This was probably the same area referred to in botanical records as "Redshank pools near Masham", suggesting an association with breeding waders. Marfield Pond and associated wetland were located in what is now compartment P6. During the historical working of the southern area at Marfield overburden from the initial excavation was used to "reclaim" this area to agriculture.

The relationship between Marfield Pond and the existing Marfield Fen SSSI is unclear. The SSSI is located immediately east of Marfield Nature Reserve (the restored section of Lafarge's aggregate quarry). It supports vegetation characteristic of calcareous seepage fen including black bog-rush mire (NVC M13) and small sedge mire (NVC M10) within a larger area of base-rich fen-meadow (NVC M22). Notable species include common butterwort (*Pinguicula vulgaris*) and broad-leaved cotton-grass (*Eriophorum latifolium*). This habitat appears to have developed where groundwater discharges from the base of the sand and

gravel river terrace deposit at the junction with impermeable clay overlying Carboniferous sandstone and shales. Percolation of water from lake L4 through the intervening sand and gravel is also an important factor in maintaining the seepage lines which occur further up-gradient of the SSI forming small surface water courses flowing down into the SSSI. The markedly calcareous character of the fen requires further investigation of hydrogeological conditions. The SSSI also includes alder carr within an old river course. A smaller area of seepage or floodplain fen occurs to the north of the operative quarry at High Mains.



◀ Black bog-rush, Marfield Fen SSSI

### **Ownership and management arrangements**

Marfield Nature Reserve was restored to nature conservation and amenity after use. It remains in the ownership of Lafarge Aggregates Ltd, who retain responsibility for site management. A nature reserve Management Committee has been established to encourage input from conservation bodies and local people. The Nature Reserve will eventually form part of a larger Marfield Wetlands complex including the currently operational quarry to the north.

Marfield NR is a Site of Importance for Nature Conservation (SINC), a non-statutory nature conservation designation applied by local planning authorities.

### **Ecological objectives of site restoration and management**

The restored area of Marfield Nature Reserve is designed to produce a mosaic of open water, wetland, grassland and scrub with some bare, sandy areas. Restoration proposals for the current extraction area include open water bodies and mosaic habitats similar to the Nature Reserve. The eventual restoration of the whole quarried area is intended to create a significant nature reserve, referred to as Marfield Wetlands.

Within the existing Nature Reserve, surface and ground water flows are managed through a quite complex array of water level controls. This includes the use of former silt lagoons as perched reservoirs, which allows managed inundation of lower-lying areas of tall-herb fen in late winter with the aim of suppressing colonisation by willows. In hydrological terms, the Nature Reserve has been compartmentalised into several more-or-less discrete units.

The main stream, which carries water from the operative quarry through the Nature Reserve and eventually discharges into Hempmill Wood, has been engineered to increase in-stream habitat diversity including the use of rock weirs to create sheltered pools.

Downstream discharge of surface water into Hempmill Wood and maintenance of ground water flow eastwards into the seepage fen are essential to protect the hydrology of Marfield Fen SSSI.

### **Biodiversity interest**

Marfield Nature Reserve is a popular bird watching site, with open water bodies and wetland habitats attracting dabbling and diving ducks and passage waders. The reserve provides a mosaic of standing water, wetland and terrestrial habitats.

Marfield Quarry and Nature Reserve are one of six sites worldwide forming part of the Lafarge Long-term Biodiversity Index: an attempt to monitor the value of quarries for wildlife and track changes over time.

### **Potential for wetland restoration**

The existing Nature Reserve incorporates a range of wetland features including standing waters of varying size and profile, marginal vegetation, flowing water, tall-herb fen and wet grassland managed by sheep grazing.

Marfield Wetlands is one of the few restored mineral sites in North Yorkshire where active use is made of ground and surface water in habitat management. However, it is arguably a weakness of restoration design that wetland habitats do not relate more closely to the adjacent seepage fen SSSI.

#### Nature reserve management plan

A nature reserve management plan has been formulated by Lafarge Aggregates Ltd in consultation with the site management committee. Details relating to water management at the site are discussed below. The wetland consists of a number of management compartments (Figure MAR3), including:

- Compartment L1 - former silt disposal lagoon: the northern part has a raised area of deposited silt whilst the southern part consists of open water that is relatively deep. The water level within the lake is maintained at a higher level than surrounding ground levels (circa 2.5 m above the level in compartment L2 and 1.5 m in compartment P3) by the presence of retaining bund walls. The extent of the exposed silt varies with the rise and fall of the water level: the northern part of the exposed silt supports vegetation. The margins around the lagoon are narrow: the eastern margin slopes steeply down in a stepped fashion to compartment L2.
- Compartment L2 - former silt disposal lagoon with open water in the northern third of the compartment and deposited silt in the southern area. The silt areas are well vegetated. The margins to the silt lagoon are generally sandy and are not well vegetated.
- Compartment L3. The main feature is the stream that carries water from the active quarry workings to the north of the site through the compartment in a northwest to southeast direction for eventual discharge into Hempmill Wood to the southeast of the site. The stream discharges via underground culvert into compartment L4. A system of pools has been created on-stream which imposes a variable flow rate of water through

the compartment. The margins to the stream are relatively wide and are sandy though some parts have been covered with topsoil.

- Compartment L4 - consists of a lake formed by flooding of former quarry workings and represents the largest expanse of open water within the site. The depth of water across the lake is variable ranging from shallow to deep. Water from the lake discharges via underground culvert into compartment L5. The main feature within the lake is the linear island present in the southern part that extends almost across the entire width of the lake. The margins to the lake slope moderately to severely down to the water level and are mostly well vegetated: there are some open sandy areas along the southern margin.
- Compartment L5 - consists of a small lake with relatively wide surrounding margins which are predominantly open and sandy. The margins to the lake slope steeply down to the water surface. Water from the lake discharges via underground culvert into Hempmill Wood.
- Compartment L6 - consists of a lake with margins which slope quite severely down to the water level: this is especially true for the western lake margin. Two islands are present close to the western lake margin. All margins are mostly open with sandy areas.

#### Water distribution system

Water flows along the channel and pools formed in compartment L3 from the culvert in the north to an underground pipe in the south and then into the lake in compartment L4. The water is groundwater that is intercepted in the mineral workings to the north of the site. Water from compartment L4 discharges through an underground pipe into the lake within compartment L5. Overflow from L5 passes through an underground pipe before discharging into Hempmill Wood. The lake in compartment L6 is not on-line with surface water flows and is maintained through groundwater flow.

Three springs occur along the eastern margin of compartment W1, at the base of the sloping ground, which discharge into the lake in compartment L1. Regulating pipes are located along the eastern lake margin, allowing discharge of water into compartment L2, and along the southern lake margin, allowing discharge into compartment P3. Water from L2 permeates through the dividing bank with compartment L3 and then enters into the water system passing through compartment L3.

Water from the lake in compartment L4 percolates through the sand and gravel of the margins and issues within the Marfield Fen Site of Special Scientific Interest.

The maintenance of the water flow from Marfield quarry workings into the site is vital to the long-term development of the nature conservation interest. This importance should be recognised in the management of and any future disposal of the land within the permitted quarry working area on completion of extraction and restoration.

The outward flow of water from compartment L5 into Hempmill Wood is viewed by English Nature to be vital to the well-being of the Marfield Fen Site of Special Scientific Interest. The need to maintain this flow may have consequence to the management of other parts of the site. Percolation of water through the sands and gravel between compartment L4 and Marfield Fen is similarly believed to be important to the well-being of that site. The maintenance of a sufficient water reserve within the lake in compartment L4 will need to be considered in the management regime.

### Wetlands (compartments L1 – L6)

Abundant and diverse wetland plant growth is essential to generate the food-chains on which all aquatic wildlife depends. The direct food resource is provided for many species as well as the creation of the necessary physical structure in which micro-organisms, invertebrates, amphibians and fish find shelter and breeding sites. Many of the lake margins do not, at present, have established marginal and emergent plant communities. In order for the micro-fauna and invertebrate faunas to become established and develop, it will be important to establish the marginal plant communities: some deliberate introduction of plant species has already been undertaken though it may be necessary to extend the plantings.

The management of the marsh areas within compartment L2 will seek to arrest the plant succession to "carr" woodland. Initially, this will be accomplished by control of the water level to inhibit the germination and establishment of willows. Any willows that do become established can be removed individually and the stumps treated with a specific herbicide to prevent re-growth. However, with the build-up of litter, the marsh will become drier as the surface rises and the effectiveness of the water control in preventing willow establishment will decrease. At this stage, assuming that it is still desirable to retain the marsh communities some other form of intervention will be required. Rotational burning may provide the basis for the long-term management of the area. Burning is an emotive management option: obviously it causes damage to plants and kills whatever invertebrates and animals are in the path of the fire. However, recent research has shown that the effects of the fire may not be as severe as once thought: in reed-beds for example, one year after burning, soil invertebrate communities showed no significant changes and only a few families of aerial invertebrates did so. If burning is restricted to small blocks and the periodicity of burning is infrequent, burning may provide the long-term management tool to maintain the marsh communities. The alternative will be for the periodic cutting of the areas and removal of the arisings off-site: cutting will need to be undertaken more frequently than burning. In either case, the management should be undertaken outside of the nesting period. The length of time that inaction (ie burning or cutting) can be tolerated will depend on water supply, litter generation and the speed of carr invasion.

Although the desired state for the silt areas within compartment L1 will be in a bare condition to emulate "mudflats" it is likely that this will not be tenable across the entire silt area. The height of the banks around the margin of the lake determines the depth of water that can be maintained over the silt areas which largely determines the control of vegetation establishing on the silt. However, it is not possible to raise the water level to cover the entire silt area because of the relative height of the "silt-flats" to the banks. Thus it will be inevitable that marsh vegetation will develop over part of the silt areas. The ultimate management of the vegetated areas will follow that described in the preceding section.

Additional features were added to compartment L3 during the previous plan period to improve and enhance its potential for species of Odonata. Rock weirs were placed across the stream flow to create or enlarge existing in-line pools, to slow the stream flow and increase the warming of the water, and to encourage the development of marginal and emergent vegetation. The benefits of the weirs are now being seen with the establishment of vegetation (aquatic and marginal) and increased animal activity.

The lake in compartment L4 comprises the largest expanse of open water within the reserve. The water supports diverse wildfowl population and management will be directed to enhancing this feature. The area of woodland to be planted along the eastern margin, included for completion during the previous plan period, has been removed to allow larger grassed margins to the lake. Similarly the proposals for woodland along the southern margin have been reduced. Artificial rafts will be established within the lake during this plan period. Encouraged by sightings of otter on the River Ure and within the reserve, an artificial

otter holt was constructed on the northern margin of the lake. The holt will be maintained during the plan period and monitored to determine occupancy.

Within compartment L5 the developing swamp vegetation dominated by common bulrush *Scirpus lacustris* is found along the southeast margin to the water. The extent of expansion into the water is probably now limited by water depth though further expansion laterally along the margins will occur. Management of the vegetation will be required to retain some open margin.

The water contained in compartment L6 is off-line from the other compartments.

The following actions relating to water-based quarry restoration were identified within the management plan for habitat management to maintain and enhance the wildlife interest of the site.

|  |
|--|
| Topographical survey of site/base plan features  |
| Maintain infrastructure such as weirs and control pipes as necessary   |
| Monitor & record water levels all waterbodies  |
| Implement water management scheme by control pipes   |
| Manage habitat (grassland) - FLOODING - control/maintain artificial flooding regime at desired level/review but avoid artificial flooding at nesting period. |
| Manage habitat (swamp/fen) - FLOODING - control of water level   |
| Manage habitat (swamp/fen) – PLANTING - introduce marginal/emergent species from local stock   |
| Manage habitat (swamp/fen, grassland) – FLOODING- control invasive willows   |
| Manage habitat (swamp/fen) – GRADE MARGINS - monitor condition/grade if necessary/required   |
| Manage habitat (open water) – WATER LEVELS - control water levels by operation of control pipes  |
| Manage habitat (open water) – RAFTS - construct/install tern rafts   |

Discussion of water management at the site

Effective use of water inflows from various sources and the head gradient across the site has allowed the creation of a range of habitats, including swamp and seepage fen with an outfall. Water level control (seasonal flooding) is used to control the encroachment of willow on the site. A seepage fen has been established associated with discharge of water through the bund containing the upper lake, and provides evidence that seepage habitats can be created by this method. A Site of Special Scientific Interest (SSSI) supported by groundwater seepage lies down-gradient of the site and potential may exist to create more of this habitat in the future quarry restoration. It appears that the SSSI has formed due to groundwater discharge at the juncture between a relatively impermeable lower clay horizon and the overlying sand and gravel.

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:

- Availability of sufficient inflow volumes to attain the desired water level over the required area for the necessary time period.
- Ability to maintain a gradient in water level across the site, therefore having the potential to raise or lower water levels as required.
- 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.

Of interest at Marfield is the adjacent SSSI which comprises 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 for the current extraction area. This would potentially involve the creation of a series of waterbodies perpendicular to the groundwater flow direction. The intervening bunds would be created from moderately permeable material allowing seepage to occur and associated vegetation to develop at the foot of the bund. A series of long, narrow lakes each at a slightly lower water level than the adjacent would create the maximum potential area of seepage habitat. Whether establishment of local species from the adjacent SSSI will be possible is unknown

### APPENDIX 3

#### CASE STUDY DETAILS: KIPLIN HALL

|                       |   |
|-----------------------|---|
| <b>Name:</b>          | <u>Kiplin Hall</u>                                    |
| <b>Site location:</b> | 3.2 km SE of Bolton-on-Swale (Richmondshire district) |
| <b>Elevation:</b>     | c 35 mAOD   |
| <b>Natural area:</b>  | Vales of York and Mowbray                             |

#### Abiotic characteristics

This site has been quarried for fluvial aggregate deposits and is located amongst relatively low-lying farmland in the northern Vale of Mowbray, close to the River Swale. The site comprises one of several sand and gravel units downstream of Richmond (including Scorton). Restoration of the completed sections of the workings has been partially completed by Lafarge including two open waterbodies. As part of this a fishing lake has been created to complement the landscape setting in the vicinity of Kiplin Hall according to the wishes of the owners (**Figures KIP1 and KIP2**).

#### Geology

The geology at the site comprises Boulder Clay overlying terrace and glacial sands and gravels underlain by clay. The Triassic Sandstone, a Major Aquifer, underlies the site but limited groundwater interaction is anticipated with the superficial deposits due to the intervening clay.

#### Hydrology

The two waterbodies are primarily groundwater-supported. It was decided against a direct connection with the adjacent brook due to turbidity problems. Indirect connection may exist via intervening permeable gravel/cobble material which may help to regulate water levels in the upper lake. Fluctuations in lake levels are observed in response to nearby periodic quarry dewatering.

The upper lake is used as a fishing lake and differences in clarity, flora and fauna were observed from the lower lake which appeared significantly less eutrophic. Also banks were steeper and standing vegetation higher around the lower lake, discouraging geese. Adjacent to the southern lake a small ecologically-rich pond was observed to form in a hollow, fed by surface run-off and by seepage from the adjacent lake. The lower lake contains an overflow channel to prevent overtopping of the bunds.

#### Water quality

The following water chemistry data were obtained (sampled 29/11/2006):

| Variable/<br>Location | pH   | Electrical<br>conductivity<br>$\mu\text{S}/\text{cm}^{-1}$ | Ortho-<br>phosphate<br>mg/l P | Nitrate<br>mg/l N | Sulphate<br>mg/l | Magnesium<br>mg/l | Calcium<br>mg/l | Alkalinity<br>mg/l<br>$\text{CaCO}_3$ |
|-----------------------|------|--|-------------------------------|-------------------|------------------|-------------------|-----------------|---------------------------------------|
| Fishing<br>lake       | 8.01 | 416  | <0.1                          | 2.43              | 50.2             | 18.3              | 54.5            | 133                                   |
| South<br>lake         | 8.09 | 477  | <0.1                          | <0.4              | 85.4             | 23.7              | 60.0            | 162                                   |
| Seepage<br>pond       | 7.67 | 795  | <0.1                          | <0.4              | 102              | 28.9              | 154             | 332                                   |

| Variable/<br>Location | pH   | Electrical<br>conductivity<br>$\mu\text{S}/\text{cm}^{-1}$ | Ortho-<br>phosphate<br>mg/l P | Nitrate<br>mg/l N | Sulphate<br>mg/l | Magnesium<br>mg/l | Calcium<br>mg/l | Alkalinity<br>mg/l<br>$\text{CaCO}_3$ |
|-----------------------|------|--|-------------------------------|-------------------|------------------|-------------------|-----------------|---------------------------------------|
| Kiplin<br>Beck        | 8.03 | 611  | 0.172                         | 12.8              | 53.2             | 21.1              | 103             | 203                                   |

Table A3.1: Water chemistry data at Kiplin Hall

Kiplin Beck is evidently eutrophic but the adjacent lakes appear to be predominantly groundwater-fed. The sample data suggests mesotrophic but mineral-rich, hard water conditions.

### Historical and landscape context

The Kiplin Hall site is one of several aggregate quarries on the banks of the Swale south of Richmond. It is 3 km. south-east of Bolton-on-Swale Lakes SSSI, a complex of former gravel pits designated primarily for their bird interest.

The partially-completed restoration includes a trout-fishing lake incorporated within the Kiplin Hall parkland, and a lower lake which is more isolated. The lakes are primarily groundwater-fed with some lateral input from the eutrophicated Kiplin Beck, which drains an agricultural catchment.

There no historical evidence of pre-existing wetland on this site.

### Ownership and management arrangements

The Kiplin Hall quarries were operated by Lafarge Aggregates Ltd but ownership reverts to the Kiplin Hall estate. There appears to be no formal after-use or site management plan.

### Biodiversity interest

The Kiplin Hall lakes are relatively undisturbed with no formal public access except for use of the upper lake by an angling club. Consequently, the lakes are attractive to waterfowl, especially diving ducks and at times support the largest congregations of Goldeneye in the Swale and Ure Washlands. Bird counts have been undertaken under the auspices of the Swale and Ure Washlands Project but data are not presently available.

The upper lake shows signs of changing trophic status in zones across the lake bed: some parts have turbid water dominated by algal growth but there are also areas of clear water with charophyte (stonewort) beds. The lower lake, not stocked with fish, has a mesotrophic character with species-rich aquatic vegetation including charophytes, various pondweeds and marestalk (*Hippuris vulgaris*).

A small 'accidental' feature of this site is a pond formed inland of the lower lake bund and evidently fed by percolation of lake water through the retaining bund. This is richly-vegetated and was found to support a diverse invertebrate community.

The site supports the following habitats identified as priorities for conservation in the UK and local (Richmondshire) BAPs:

| Feature               | UKBAP Priority | Richmondshire BAP Priority |
|-----------------------|----------------|----------------------------|
| Mesotrophic lakes (?) | •              |                            |
| Standing waters       |                | •                          |

Table A3.2: Habitats supported

### Potential for wetland restoration

This is a partially-completed restoration which has not been focused on habitat creation. The lower lake appears to have mesotrophic conditions and could become a valuable habitat for plants and invertebrates if it can be isolated from inputs of nutrient-enriched surface water. Stocking with coarse fish would be detrimental. Further survey is required to establish the ecological interest of the lakes.

## APPENDIX 4

### CASE STUDY DETAILS: DRY RIGG

|                       |  |
|-----------------------|--|
| <b>Name:</b>          | <u>Dry Rigg Quarry</u>   |
| <b>Site location:</b> | 6 km north of Settle (Craven district/Yorkshire Dales National Park) |
| <b>Elevation:</b>     | c 230 mAOD   |
| <b>Natural area:</b>  | Yorkshire Dales  |

#### Abiotic characteristics

The site lies in the far west of the study area near Horton in Ribblesdale in the Yorkshire Dales National Park (at an altitude of some 224 mAOD). Dry Rigg Quarry is situated at an intermediate elevation in Ribblesdale but within an upland valley landscape in the west of the Yorkshire Dales. Lafarge currently extracts and crushes gritstone to produce a high specification aggregate (**Figures DR1 and DR2**).

#### Geology

The quarry extracts gritstone from the easterly striking Horton Formation, which dips to the south at approximately seventy degrees. The formation is part of the folded sequence of Carboniferous strata which outcrop in the area, including limestone formations with associated karstic features.

#### Hydrology

The gritstone itself has low primary porosity and the quarry receives a very limited input of groundwater from fractures. Superficial deposits comprise thin coverings of soil and glacial Boulder Clay plus an extensive cover of peat to the north east of the quarry. There is no direct hydraulic continuity between the quarry void and any of the surrounding hard rock or superficial deposits. The site receives significant rainfall, measured as some 1,836 mm/yr at the Fountains Fell gauging station (7 km distant). For this reason there is sufficient water to meet the sites evapotranspiration requirements throughout the growing season.

Current pumped discharge rates from the quarry are estimated to average 2 l/s to the Swarth Beck to the south of the site. Following the final development and restoration of the quarry average surface water/rainfall inflows to the entire site after subtraction of ET are estimated to be 12 l/s, which subsequent to the filling of the quarry lake will discharge via an outfall to the Swarth Beck.

A deep pit has been created which will be allowed to flood as part of the restoration to form a ~60 m deep lake. The process of flooding via rainfall run-off (estimated as some 8.4 l/s) may take in the order of 13 years to complete after which water will discharge to an adjacent brook.

#### Water Quality

The following water chemistry data have been recorded from Swarth Moor SSSI, which adjoins the quarry:

| Variable/Location              | Date       | pH  | Electrical conductivity |
|--------------------------------|------------|-----|-------------------------|
| Swarth Moor SSSI (fen)         | 27/03/2006 | 7.2 | 390                     |
| Swarth Moor SSSI (raised mire) | 27/03/2006 | 5.6 | 40                      |

Table A4.1: Water chemistry data at Dry Rigg Quarry

### Historical and landscape context

Dry Rigg Quarry is located on the western flank of Ribblesdale, immediately overlooking the glacial hollow in the valley bottom which supports the complex of raised bog and valley fen designated as Swarth Moor SSSI. An almost intact, ombrotrophic raised mire with a classic dome profile has developed to the north-east of the quarry, characterised by mixtures of hare's-tail cotton-grass (*Eriophorum vaginatum*), purple moor-grass (*Molinia caerulea*), cross-leaved heath (*Erica tetralix*) and *Sphagnum* mosses with associated flora including cranberry (*Vaccinium oxycoccus*), bog rosemary (*Andromeda polifolia*) and bog asphodel (*Nartheicum ossifragum*). Fen areas fed by surface and ground water are more base-rich, being characterised by bottle sedge (*Carex rostrata*), common sedge (*C. nigra*), sharp-flowered rush (*Juncus acutiflorus*) and marsh cinquefoil (*Potentilla palustris*). Within the fen there are open pools and small patches of willow scrub.

A small area immediately west of the quarry access road lies outside of but almost contiguous with the SSSI. This had been used for materials storage in the past and is now being restored as mire habitat.

### Ownership and management arrangements

Dry Rigg Quarry is operated by Lafarge Aggregates. As part of the planning conditions for continued operation, a Restoration and Aftercare Management Scheme was agreed with the LPA in 2004. This provides the framework for the management of the quarry workings and ancillary land and will be supported by a series of more detailed plans covering the different phases of restoration. These plans will be subject to consultation and the approval of a Management Committee including representatives of Lafarge, Yorkshire Dales National Park Authority, Natural England and independent advisors.

### Ecological objectives of site restoration and management

The restoration scheme will incorporate wetland habitats which have been identified as priorities for conservation in the UK or Local (Yorkshire Dales) Biodiversity Action Plans:

| Feature                             | UKBAP Priority | YDNP BAP Priority |
|-------------------------------------|----------------|-------------------|
| Purple moor-grass and rush pastures | •              | •                 |
| Small upland wetlands               |                | •                 |

Table A4.2: Habitats supported

The Restoration and Aftercare Management Scheme emphasises the need to relate restoration objectives to the interests of the adjacent Swarth Moor SSSI and the wider surrounding landscape. Preliminary work, started in 2006, aims to establish mire vegetation on a former stockpiling area outside the quarry void. Eventual restoration within the quarry

will include small areas of upland fen in addition to open water, acidic grassland/heath and moorland-fringe woodland. National Vegetation Classification (NVC) communities have been used to plan habitat creation, with the caveat that establishment of key plant species appropriate to the prevailing edaphic and hydrological conditions is more important than attempting to exactly replicate NVC communities. Habitat creation methods will include landforming, manipulation of substrates and a combination of natural colonisation and seeding/planting using local sources.

### **Biodiversity interest**

Dry Rigg Quarry is still fully operational and work to restore a former stockpiling area to mire has only begun recently. The developing biodiversity interest of this area is being monitored by Lafarge and Natural England.

### **Potential for wetland restoration**

Initial proposals to create acidic bog as part of the restoration scheme had to be revised when it was found that the water supply was more nutrient- and base- rich than originally expected. This may be due to a combination of calcite dissolution from the gritstone matrix, possibly related to the large surface area associated with quarry fines, or percolation from the Carboniferous limestone which outcrops above the Horton gritstone.

A trial is underway involving re-wetting compacted peat in a former stockpiling area adjoining the quarry access road. This is being wetted by overflow from a ditch which carries water discharging from the quarry to Swarth Beck. The discharge pools in the shallow peat basin to provide conditions for the growth of fen vegetation. Initial results have been promising with spontaneous colonization of several rush and sedge species, probably from the soil seed bank. Some introduction of local-provenance seed has also been carried out. It is hoped that this area will develop into mire or poor-fen habitat complementary to the minerotrophic mire components of Swarth Moor SSSI, e.g. NVC S27 bottle sedge and marsh cinquefoil tall-herb fen, M25 purple moor-grass and tormentil mire or M23 sharp-flowered rush and marsh thistle mire.

It had also been intended to create a seepage habitat by distributing some of the outflow water through a permeable bund using a perforated pipe. Discharge from the quarry passes through a manifold which distributes water within a permeable substrate from which it seeps out onto the surface of the peat with the objective of encouraging the development of flush vegetation. Initial results have been disappointing with water tending to drain downwards to the base of the bund, and revised designs are currently under consideration.

The main quarry void will form a slow-filling but ultimately deep upland lake. It is unknown how the water quality of the quarry lake will evolve over time. It is understood that only limited quantities of sulphide minerals are present within the rock and acidification of the lake is unlikely to occur.

Other elements of the restoration scheme will include exposed rock faces, upland ash woodland and acidic grassland.

### **Ecohydrological issues**

Hydrological issues relating to the quarry and Swarth Moor SSSI have been carefully monitored and are discussed by Wardrop et al (2001).

## APPENDIX 5

### CASE STUDY DETAILS: NOSTERFIELD

|                       |  |
|-----------------------|--|
| <b>Name:</b>          | <u>Nosterfield Quarry</u>  |
| <b>Site location:</b> | 6.5 km east of Masham, 7.5 km southeast of Bedale (Hambleton district) |
| <b>Elevation:</b>     | c 40 mAOD  |
| <b>Natural area:</b>  | Southern Magnesian Limestone   |

#### Abiotic characteristics

Nosterfield Quarry is a large operational aggregate quarry on former agricultural land within the Swale and Ure Washlands. The quarry site comprises a partly restored area and active area of sand and gravel extraction operated by Tarmac. Nosterfield Nature Reserve comprises 57 Ha of former sand and gravel workings adjacent to Nosterfield Quarry (**Figure N<sup>os</sup> 1 to 3**). The reserve is managed by the Lower Ure Conservation Trust primarily for birds (see [www.luct.org.uk](http://www.luct.org.uk)).

#### Geology

The landform in the vicinity of the site is of fairly low relief, with a significant slope to the west rising some 40 m. The area is underlain by the Lower Magnesian Limestone to the west and mudstones with interbedded evaporates in the east. Superficial geology comprises fluvioglacial sands and gravels, which forms the economic mineral, glacial lake deposits, clays, till, peat and alluvium. The peat appears to have formed in depressions potentially associated with gypsum dissolution and/or very probably the historical actions of European Beaver (*Castor fiber*). Upper and lower sand and gravel units, each of some 3.5 m thickness, are separated by approximately 1 m of clay interburden.

#### Hydrology

The quarry and nature reserve lie across the groundwater and surface water divide between the catchment of the River Ure to the south and Ings Goit, a canalised watercourse, to the north.

In general groundwater and surface discharge from the nature reserve and quarry is southwards and northwards respectively. The majority of waterbodies in the vicinity of the Application Area are located in areas of current and former mineral extraction which have been worked dry in the shallower areas and via dredging over much of the site.

A floating pontoon is used within Lingham Water to move the discharge point of silt from mineral processing operations. Deposition of material leads to creation of deltas and areas of shallow water. The elevation of Lingham Water is controlled by an adjustable weir which is generally maintained at 39.4 mAOD. Excess water discharges to Ings Goit. There are no outfalls from the other lakes, which are in continuity with the remaining sand and gravel deposits and permeable backfill connecting to Lingham Water. Changes in water levels at Lingham Water have an effect on adjacent lake levels and the surrounding groundwater levels.

Groundwater occurs within two distinct units of the Magnesian Limestones separated by a mudstone unit and within the shallow sand and gravel deposits. Hydraulic connectivity between the aquifers may be restricted by the occurrence of low permeability clay. However, groundwater levels are generally similar and in some areas the limestone is

exposed or in direct continuity with the sand and gravel in which case discharge from the deeper aquifer may occur. The discharge from Lingham Water represents a combination of groundwater and rainfall run-off. Groundwater levels are typically within 4 m of the original ground surface.

Including the quarry discharge, flow in the Ings Goit increases by some 200 to 300% in the 2.4 km reach adjacent to the northern section of the quarry, with downstream discharges recorded in the range 50-300 l/s.

### Water Quality

Groundwater from the magnesian limestone aquifer is an important water source, containing high levels of dissolved minerals. The following water chemistry data has been recorded:

| Variable/Location | Date      | pH  | Electrical conductivity |
|-------------------|-----------|-----|-------------------------|
| Near reedbed      | 20/9/2006 | 7.4 | 810                     |
| Near reedbed      | 2000      | 7.9 | 1350                    |

Table A5.1: Water chemistry data at Nosterfield

### **Historical and landscape context**

Nosterfield Quarry is set within a highly sensitive historic landscape including a nationally-important Mesolithic henge complex to the south-east of the quarry. A current phase of quarrying extends into an area known as the Flasks which had significant peat deposits. In recent decades this had been under improved pasture but was presumably an area of plateau fen or wet grassland in the past. Palaeoenvironmental evidence from a sink-hole within the main quarry indicated the presence of extensive fen with sedges, common reed and reedmace in prehistoric times, along with open calcareous pools containing fen pondweed (*Potamogeton coloratus*).

Fragments of fen vegetation occur in adjoining ditches and in a small woodland (Fox Covert) to the north of the quarry.

Two km. north of Nosterfield Quarry, the magnesian limestone escarpment descends into the low-lying basin of Snape Mires. Although cartographic evidence is contradictory, Snape Mires was probably an extensive wetland site in the Middle Ages with substantial areas of floodable peatland remaining into the 18<sup>th</sup> century, when a major drainage scheme was initiated. There is a clear reference to the extensive 'swamp' that existed in the Medieval era (early 13c.), with references to extensive peat digging and aftermath grazing rights – indicating this was a large and extensive wetland habitat. Nowadays Snape Mires is predominantly improved pasture with some arable, with pump drainage used to lower the water table. Extensive fringes of common reed (*Phragmites australis*) along drainage dykes suggest that reedbeds could have been a feature of the Mires prior to agricultural reclamation. This validates the decision to choose Nosterfield Quarry as a trial site for re-establishing reedbed habitat in the Swale and Ure Washlands.

### **Ownership and management arrangements**

The northern part of Nosterfield Quarry is scheduled for nature conservation afteruse. This will include a combination of open water, reedbed, magnesian limestone grassland and scrub. – ha of reedbed have already been established successfully since 2003.

Staveley Quarry is an operative Tarmac Northern site. The Lower Ure Conservation Trust (LUCT) has played a leading role in managing the reedbed-establishment trial but long-term

management arrangements for the wider nature conservation restoration area have yet to be resolved. North Yorkshire County Council is involved in discussions on a regular basis as this is seen as a leading site for habitat re-creation in the Swale and Ure Washlands. There is a Quarry After-use Committee which includes Tarmac, NYCC, LUCT, and Nosterfield Parish Council.

The original concept restoration was developed in 1996 and has been re-examined on an annual basis by a steering committee including local interest groups and the County Council. A flexible approach has been taken so that over time the design has evolved and opportunities have been taken to enhance the restoration where possible. The restoration is designed to meet a number of end uses including nature conservation, public access and recreation (sailing). The site is owned by a number of landowners who may wish to maintain a long-term interest in the site. The final management mechanism for the site is under review.

### Ecological objectives of site restoration and management

The reedbed has been designed around the needs of Bittern, a UKBAP Priority Species. It is designed around four cells planted with reeds, a central trench and a small lake. The reedbed cells are designed to hold an average of 22.5 cm depth of water in the summer months. A network of 1.2 to 1.5 metre deep dykes runs through the reedbed. The cells are interconnected by 300 mm. pipe sluices. A total of 24,000 *Phragmites* plants were planted in 2003-2004, all grown from local-origin seed.

Elsewhere within the nature conservation after-use zone, a small fen re-creation trial plot has recently been established.

A small lagoon has recently been infilled with peat transferred from the Flasks, to provide a trial site for establishing fen/sedge swamp vegetation. At the time of writing this trial site is heavily flooded and no further work has been undertaken.

Objectives for nature conservation after-use have changed in recent years, and this has presented challenges for quarry managers. In addition, the sensitive location of the quarry and controversy attached to future expansion plans has meant that restoration schemes are perceived to be under intense scrutiny and need to meet amenity as well as ecological requirements.

### Biodiversity interest

The reedbed contains open pools and trenches which support a range of aquatic species. Flora includes charophytes (stoneworts) and the nationally scarce mudwort (*Limosella aquatica*). Invertebrates recorded from the reedbed include a scarce species of lesser water-boatman and nine species of dragonfly. The reedbed also attracts good numbers of Snipe outside the breeding season.

The following habitats are identified as priorities for conservation in the UK or Local (Hambleton district) Biodiversity Action Plans:

| Feature         | UKBAP Priority | Hambleton BAP Priority |
|-----------------|----------------|------------------------|
| Reedbed         | ●              |                        |
| Lakes and ponds |                | ●                      |

Table A5.2: Habitats supported

The wider quarry site includes several lagoons which attract large numbers of water birds, with waders gathering to roost on spits and shorelines.

### **Potential for wetland restoration**

In addition to the reedbed, a small trial plot has been established as an experiment in re-creating fen habitat. This is a hollow banded off from the main lake in the nature conservation area and backfilled with peat taken from one of the current working areas. However, further plans have yet to be agreed at the time of writing. Lingham Lake currently supports impressive roosts of Lapwing and Golden Plover, however these may be lost once proposed tree planting takes place. Both this waterbody and Flasks Lake support very large roosts of gulls (>40,000 Black-headed Gulls and Nationally Important numbers of Lesser Black-backed Gulls, in season) – although Bird Strike may be an issue. These waterbodies have a few Red Buntings - a BAP and 'Red List' species however they do not provide large amounts of priority habitat from the BAP list. As such the potential of gaining Stewardship income is limited and subsequently the site's sustainability under management for nature conservation is reduced. Potential exists to modify existing plans to increase the long-term scope for nature conservation benefit although this is subject to the interests of the other stakeholders.

### **Nosterfield Nature Reserve**

Separate from the operational quarry, a principal feature of the nature reserve is the frequent inundation of the site during the spring due to winter rainfall and as water levels in the underlying limestone rise.

The average depth of water during inundation is c1 m, in accordance with the High Level Stewardship definition for 'wet grassland' of "up to knee deep". Because of the subdued landform within the reserve, quite a lot of the land above 39.6 mAOD is likely to have grassland that exactly fits this description as the water level rises. Water depths of 2 m or even 3 m may be desirable for some species (ie diving duck); however, not generally as an 'average'. Diving ducks will feed at greater depths but it is generally accepted that they use more energy than they gain, by going to greater depths.

Nosterfield Nature Reserve has been landscaped to provide optimal conditions for wetland birds, with overburden and silt used to create shallows and large water edge lengths around two main waterbodies in the north and south of the site. The LUCT have pioneered the development of seasonally flooded wetland-grassland scrapes. These shallow scrapes are formed in tiers, so that they fill as the water level rises and form valuable muddy areas as the water recedes, before naturally returning to grassland. This practice of using tiered scrapes on inundation sites is now promoted as good practice and the RSPB use the Reserve as a case study in various documents, ie *Habitat Creation Handbook for the Minerals Industry*, RSPB (2003) and *Nature After minerals*, RSPB/MIRO (2006), also on their mineral after-use web site ([www.afterminerals.com](http://www.afterminerals.com)).

Two small historic silt lagoons are located in the southeastern corner of the site and are isolated from the surrounding groundwater system. The main lakes are fed by a combination of surface run-off and groundwater from the underlying limestone and surrounding sand and gravel.

## APPENDIX6 CASE STUDY DETAILS: SCORTON

|                       |   |
|-----------------------|---|
| <b>Name:</b>          | <u>Scorton Quarry</u>   |
| <b>Site location:</b> | 1.7 km northeast of Catterick Bridge (Richmondshire district) |
| <b>Elevation:</b>     | c 55 mAOD   |
| <b>Natural area:</b>  | Vales of York and Mowbray                                     |

### Abiotic characteristics

This site covers a significant area (160 Ha) near the River Swale and Tarmac is still in the initial phase of sand and gravel extraction. Restoration proposals to open waterbodies will include provision to discourage large bird flocks due to the proximity of a major airfield. Potential may exist for the creation of a series of linked waterbodies with an outfall to the Swale. This is dependent on a number of factors including the accurate prediction of final water levels.

The quarry adjoins the River Swale at the southern end and good potential exists for habitat creation keeping in context with the setting of the Swale Valley (**Figures SCR1 and 2**).

### Geology

The area comprises a sequence of relatively coarse glacial sands and gravels with interbedded clay. Much of the sand and gravel may have been deposited at the mouth of a channel which was discharging into a large lake. The base of the workable mineral is predominantly formed by a thick sequence of clay, the depth of which generally increases south-westwards. The underlying bedrock comprises Triassic Sandstone in the east and interbedded mudstone and Dolomite to the west.

The mineral forms a vertically limited but laterally extensive aquifer which is situated above clay. It is assumed that the clay possesses low hydraulic conductivity and forms the base to the shallow surface aquifer system in the vicinity of the quarry. The presence of several large waterbodies in the vicinity of the quarry, which are all situated within former areas of mineral extraction, and the River Swale to the south of the site, are considered highly likely to exert significant control upon the groundwater regime within the sand and gravel aquifer. Interaction between the bedrock aquifers and the overlying sand and gravel is thought to be limited by intervening clay although there is some similarity in water level response (Figure SCR3).

A ridge of clay is observed to outcrop ~200 m to the west of the site and this is considered likely to form a hydraulic barrier between sand and gravel to the west, adjacent to the plant and Scorton Lake, and the mineral to the east within future extraction areas.

The degree of hydraulic connection between the river and the gravels is unknown, but may be limited by the presence of low permeability alluvium in the riverbed. This may explain the relatively large water level difference between piezometer W9 (50.77 mAOD) and the adjacent river level of 52.06 mAOD, which suggests groundwater flow from the river into the gravels.

### Hydrology

Scorton Lake lies immediately to the north of the current plant site within a previously worked area. The lake is used within the current water management system, receiving discharge from the silt settlement lagoons and the quarry void. Water is abstracted from the lake via a gravity feed to a freshwater lagoon which supplies water to the mineral processing plant.

A stream discharges into Scorton Lake which originally discharged into the River Swale, but was diverted to permit landfilling to take place within its valley. The total stream catchment area is c 400 ha. (The landfill is operated by North Yorkshire County Council (NYCC)). The lake does not have a natural outlet and NYCC currently regulates its level by pumping to a drainage ditch running to the east of the site access road. The ditch is estimated to be carrying 75-100 l/s. Water levels within Scorton Lake are generally much higher than in the adjacent workings. The hydraulic connection between Scorton Lake and the groundwater system is thought to be restricted due to the presence of low permeability silt on its base. Scope exists to incorporate discharge from the lake within the final restoration design.

The original approved restoration scheme includes a large lake and two smaller waterbodies which will be naturally regulated, with no outfalls between the lakes or to the River Swale and no inflow from Scorton Lake.

The restored lakes are designed to be in continuity with groundwater within adjacent areas of unworked mineral and their levels will be controlled to some extent by the local watertable. However it is recognised that the hydraulic continuity may decrease over time due to siltation on the lake floor.

The northern lake covers ~2.4 Ha and spans a length of ~1 km perpendicular to the groundwater contours. The prediction of final water levels is therefore complex with a potential range in groundwater levels across the area of 50-54 mAOD.

Observed groundwater levels are lower than the immediately adjacent river levels in the Swale. Should an outfall be considered it would need to operate at a considerable distance downstream to achieve the required elevation. As the site lies within the floodplain of the Swale, inundation of the site will require discharge of flood waters to the groundwater system, if there is no outfall in place.

### Water quality

The following water chemistry data were obtained from samples collected on 29/11/2006.

| Variable/<br>Location | pH   | Electrical<br>conductivity<br>$\mu\text{S}/\text{cm}^{-1}$ | Ortho-<br>phosphate<br>mg/l P | Nitrate<br>mg/l N | Sulphate<br>mg/l | Magnesium<br>mg/l | Calcium<br>mg/l | Alkalinity<br>mg/l<br>CaCO <sub>3</sub> |
|-----------------------|------|--|-------------------------------|-------------------|------------------|-------------------|-----------------|---|
| Quarry<br>lake        | 7.93 | 621  | <0.1                          | 6.38              | 60.3             | 28.5              | 105             | 251                                     |
| North<br>lake         | 8.19 | 498  | <0.1                          | 3.09              | 56.0             | 48.9              | 179             | 159                                     |

Table A6.1: Water chemistry data at Scorton Quarry

This data suggests mildly alkaline, base-rich conditions.

## Historical and landscape context

There do not appear to be any historic wildlife records for this site and it is not associated with any former wetland.

## Ownership and management arrangements

Scorton Quarry is operated by Tarmac. It is a large, operative site being worked in phases. The landowners retain the freehold.

## Ecological objectives of site restoration and management

This site is not currently zoned for nature conservation afteruse. Reduction of bird-strike hazards is a priority due to the proximity of RAF Leeming.

## Biodiversity interest

Scorton Quarry attracts significant numbers of dabbling and diving duck; bird counts have been undertaken under the auspices of the Swale and Ure Washlands Project but data are not presently available.

Standing water is identified as a Priority Habitat for conservation management in the Richmondshire BAP.

## Potential for wetland restoration

The layout of water bodies on this large site is constrained by the need to minimize bird-strike risks due to its proximity to RAF Leeming. Combined with the depth of high quality aggregate deposits, this will result in a series of relatively linear, steep-sided lakes which have limited potential for the creation of adjacent wetland habitats.

However, the southern sector of the quarry (south of Tancred Grange) is within the floodplain of the River Swale. This has been partly quarried for surface deposits in the past and will be re-worked for deeper material in the near future. This area is zoned for nature conservation after-use, although management will eventually revert from Tarmac to the private land owners.

From a landscape ecology perspective, this sector has considerable potential if habitat creation relates strongly to the river corridor. Although this section of the Swale experiences some pollution from waste water inputs, the river corridor contains important habitat features such as permanently- and seasonally- exposed shingle banks, gravel deposits on the floodplain surface and riparian woodland. This reflects the relatively dynamic character of the middle reaches of the Swale.

The middle reaches of the Swale and Ure are amongst the few large rivers in lowland eastern England where dynamic natural processes of erosion and deposition still occur extensively; most lowland rivers have been more intensively canalized and regulated to meet the needs of agriculture, land drainage and urban development.

An important feature of dynamic river systems is the occurrence of exposed riverine sediments such as shingle, gravel and sand banks. These vary from large islands around which the river eventually migrates (known in North Yorkshire as Batts) through to small, transient bars of sand and gravel exposed only during low flows. Recent surveys of exposed riverine sediments on the Ure and Swale have demonstrated their importance for

biodiversity, providing habitats for rare and specialized insects such as the stiletto fly *Spiriverpa lunulata* (a UKBAP Priority Species) and the click beetle *Negastrius sabulicola* (Godfrey, 2006). Exposed sediments are also used as nesting and foraging habitats for birds such as Oystercatcher and Common Sandpiper. They support a range of plant communities from sparse pioneer vegetation to mature riparian scrub. Some Batts on the River Ure have a distinctive woodland flora including plants such as giant bellflower (*Campanula latifolia*) and yellow star-of-Bethlehem (*Gagea lutea*).

Ideally, habitat creation in the southern sector of Scorton Quarry should incorporate areas of exposed mineral substrate, sandy and gravelly banks and some wet woodland adjoining the Swale. The feasibility of using controlled flooding from the Swale should be considered, since this could replicate natural disturbance associated with fluvial processes.

The creation of a large reedbed taking in part of an adjoining landfill site has been mooted but this would require the commitment of a number of land owners and has not been progressed.



◀ Exposed riverine sediments are an important feature of the Swale corridor

## Restoration Design Options

### Bird strike

The presence of a major airfield in the vicinity with the attendant risk of bird strike is such that the restoration is to be designed to discourage congregation of large flocks of birds. Measures will include:

- Planting of trees right up to the shoreline
- Having a steep (~1:4) gradient to ensure areas of shallow water are not created
- Installing fences between the lake shoreline and the surrounding land

Tree species will be selected which are capable of withstanding short-term inundation and the planting may be adjusted as actual lake levels become apparent. During the first few years after completion of the final restoration it may be prudent to provide pumping capacity in case water levels are not as expected.

### Incorporation of flexibility into the restoration design

Final rest lake levels are difficult to predict due to the current lack of long-term monitoring data. Therefore some flexibility in the design is recommended, particularly if there is to be no outfall from the lake. Based on the available data natural levels in the northern lake are estimated to lie in the range 50-52 mAOD. To avoid the formation of shallows it would

| No | Option  | Advantages  | Disadvantages  |
|----|---|---|--|
| 1  | Three self-regulating lakes (original scheme)                               | Follows approved scheme   | Uncertainty in final lake levels   |
| 2  | Outfall from N Lake to S Lake   | Set maximum level of North Lake   | Requires outfall construction beneath road. Uncertainty in ability of S.Lake to accommodate the additional inflow.   |
| 3  | Outfall from N Lake to S Lake to river                                      | Set maximum levels in each lake   | Lake levels and outfall operations subject to river level and potential flooding. Requires outfall construction beneath road and engineering within the river      |
| 4  | Outfall from N Lake to river  | Set maximum level of N Lake   | Lake levels and outfall operations subject to river level and potential flooding. Requires outfall construction beneath road and engineering within the river bank |
| 5  | As for No 1 but also receives discharge from Scorton Lake to N Lake         | Less drawdown from original surrounding groundwater levels  | Uncertainty as to final N Lake level and whether discharge to groundwater can accommodate inflow without flooding the N lake                                       |
| 6  | As for No 2 but also receives discharge from Scorton Lake to N Lake         | Increased area for discharge to groundwater system. Increased time N Lake is at maximum level with less fluctuation.            | Uncertainty as to final S Lake levels and whether discharge to groundwater can accommodate inflow without flooding the S lakes                                     |
| 7  | As for No 3 but also receives discharge from Scorton Lake to N Lake         | Less drawdown from original surrounding groundwater levels. Increased time N Lake is at maximum level with less fluctuation.    | Lake levels and outfall operations subject to river level and potential flooding. Requires outfall construction beneath road and engineering within the river      |
| 8  | As for No 4 but also receives discharge from Scorton Lake to N Lake         | Increased time N Lake is at maximum level with less fluctuation.  | Lake levels and outfall operations subject to river level and potential flooding. Requires outfall construction beneath road and engineering within the river      |
| 9  | As the above options but N Lake subdivided into a series of cascading cells | Increased confidence in final lake levels. Potential to raise N.Lake level to 53 mAOD and ensure operation of outfall to river. | More construction and material required  |

Table A6.2: Restoration options

be prudent to design the lake shore at a gradient of ~1:4 over this entire range (and potentially  $\pm 1$  m more). This would involve a horizontal width of 8-16 m over which uncertainty on rest water levels exists.

#### Outfall from the lakes

A series of options has been examined should a variation in the original restoration be considered and are presented in the table overleaf. Several of these options will allow the greater control of final water levels via the use of outfalls between the lakes and/or to the River Swale. Based upon the available data it is considered that the average groundwater-supported lake levels are likely to vary between approximately 50 and 52 mAOD in the northern lake and between 48 to 50 mAOD across the southern lakes. Lake levels will be subject to short-term increases due to run-off from rainfall events, and reductions due to relatively high rates of potential evaporation during the summer.

The provision of an outfall from the lakes would allow the maximum level to be set slightly below the predicted natural level. An outfall would limit the uncertainty involved in the design of the upper elevation of the 1:4 slope. Also setting the outfall level close to the natural summer low in groundwater level may reduce the likely fluctuation in Lake levels, although it would also lower the surrounding water table. Flexibility in the restored lake levels could be achieved by installing an adjustable sluice gate (or similar) at the lake outfall.

Accepting discharge from Scorton Lake through the restoration and/or the construction of an outfall to the river may require considerable changes (increases) to the currently proposed restoration levels. For example based on a slight alteration of the original design concept the northern lake level could be regulated to 51 mAOD with an outfall to the southern lakes. Discharge from the southern lakes could then be made via natural groundwater egress (Option 2 in table 3.1). However an outfall over the shortest distance directly from the Northern Lake to the River Swale would require a Northern Lake Level of  $> 52$  mAOD. The implications are considered below.

#### Discharge from Scorton Lake

Routing of outflow from Scorton Lake through the restoration will add further complexities to the system, in terms of flow balancing within the lakes and the required storage capacities. Scorton Lake is fed by a large catchment and it is estimated that average flows in excess of 100 l/s may discharge into the northern lake during the winter months. Whether the outflow from Scorton Lake could be accommodated by natural evaporative losses and discharge to the groundwater system without an unacceptable rise in lake levels is dependent on the hydraulic conductivity of the intervening material between the lake bed and the remaining aquifer. The lakes cover a large area and would likely accommodate this discharge should good connection ( $k > 1$  m/d) be maintained with the sand and gravel. However, siltation of the lake bed is likely to occur and there is considerable uncertainty in the prediction of final rest water levels, plus fluctuations in water levels are anticipated to be significant. Therefore it is likely that an outfall to the Swale will be required. A potential benefit of accepting the inflow from Scorton Lake would be the ability to maintain lake levels at or very close to the outfall level which would then not have to be too far below the natural pre-extraction groundwater level.

#### Impact of the Swale outfall being inoperative

During times of high river level, which are likely to coincide with periods of high rainfall, the river level may be higher than that of the lake and discharge from the lakes will not be possible. Consequently water will accumulate within the lakes and their levels will increase. A 'worst case' scenario may be assumed where maximum rainfall run-off coincides with maximum river stage which could result in some short-term flooding of adjacent land.

### Subdivision of the Northern Lake

Greater confidence in final water levels could be achieved by sub-dividing the Northern Lake so that each segment does not span such a large range in groundwater levels. Out falls between these lakes may be used to effectively fix maximum levels and reduce fluctuations. This approach is also likely to fit well with the progressive nature of the restoration. For example a lake may potentially be created within phase 2 with natural levels of 51 to 53 mAOD. An outfall in combination with inflow from Scorton Lake may be used to maintain lake levels at 53 mAOD giving sufficient head to allow discharge via a ditch running directly to the closest point on the Swale. The outfall to the Swale could be maintained separately to the other lakes with potential to discharge to them if required.

### Sustainable development

Upon completion of extraction at Scorton, several large waterbodies will be created at different elevations, supported by both groundwater and surface water inflows. Restoration proposals include return to agricultural usage, wildlife habitat creation and potentially recreational or residential usage.

A considerable amount of energy is stored within the lakes of the system, both in terms of thermal energy and potential energy (Scorton Lake level lies at 58 m Above Ordnance Datum (mAOD), ~6 m above the River Swale). It may be possible to utilise some of this energy as part of the proposed restoration. Of particular interest may be the use of heat pump system(s) to provide heating for residential, aquaculture or agricultural (greenhouse) purposes and micro hydro-electric generation. The water itself is also a useful resource for agriculture and perhaps residential supply, either for non-potable use or as potable after treatment.

Sufficient land is available for the construction of an ecological waste water treatment system, such as that employed to serve the village of Scaryingham, Yorkshire, which has won several awards. 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. Short rotation willow coppicing to feed a micro power plant might also be considered. This has been discussed in further detail under the section dealing with sustainable energy production within the main report.

## APPENDIX 7 CASE STUDY DETAILS: WENSLEY

|                       |   |
|-----------------------|---|
| <b>Name:</b>          | <u>Wensley Quarry</u>                           |
| <b>Site location:</b> | 4.5 km west of Leyburn (Richmondshire district) |
| <b>Elevation:</b>     | c 280 – 310 mAOD                                |
| <b>Natural area:</b>  | Yorkshire Dales                                 |

### Abiotic characteristics

Tarmac operates a limestone quarry on the northern flank of Wensleydale, above Preston-under-Scar. Wensley Quarry is an active Carboniferous limestone quarry at the edge of the Yorkshire Dales National Park. Wensley limestone quarry comprises the current extraction area plus worked out areas on either side to the east and west. The quarry void has been formed behind the original crags which still form the side of the valley overlooking Wensleydale. Previously worked areas have been restored to produce limestone cliffs and pasture and the restoration scheme is for agricultural afteruse (**Figures WEN1 and 2**).

### Geology

The limestone is generally sub-horizontally bedded, and shallow waterbodies and intermittent streams have formed on a bedding plane above the underlying sandstone with relatively low permeability at the base of the former workings. Limestone has been extracted to form ~15 m faces with the quarry floor formed by a sub-horizontal sandstone dipping gently to the northeast.

### Hydrology

The sandstone has a relatively low permeability compared with the overlying limestone and both surface water and groundwater seepages are channelled along its bedding surface to the lowest point in the quarry. This has led to the formation of a mesotrophic, base-rich body of standing water of high ecological value. Groundwater seepages and a small stream also provide good habitat along the base of the old quarry face. These features appear to be unplanned as the age of the old parts of the quarry is such that detailed habitat creation schemes were unlikely. However there is good potential to incorporate and encourage the development of these features in any future restoration scheme.

### Water Quality

The following water chemistry data have been recorded:

| Variable/Location | Date       | pH  | Electrical conductivity |
|-------------------|------------|-----|-------------------------|
| Quarry pond       | 26/06/2006 | 8.6 | 160                     |
| Pool              | 07/07/2006 | 7.6 | 310                     |

Table A7.1: Water chemistry data at Wensley

### Historical and landscape context

Wensley Quarry is perched on the ridge between Wensleydale and Swaledale, behind the steep limestone outcrops (Scars) overlooking Redmire and Preston-under-Scar. Prior to quarrying the site would have been agricultural land, perhaps including some semi-natural limestone grassland and secondary woodland. There is unlikely to have been any significant

wetland on the site historically, and 'natural' wetlands are scarce on the Carboniferous limestone in Wensleydale.

### Ownership and management arrangements

Wensley Quarry is operated by Tarmac. The disused area is understood to have reverted to the land owner under an agricultural restoration scheme.

### Ecological objectives of site restoration and management

Disused parts of Wensley Quarry have been treated as agricultural restoration. Habitat which has developed has done so incidentally.

### Biodiversity interest

In one of the worked-out quarry voids, a large pond has formed at the base of the quarry walls on top of the relatively impermeable underlying sandstone bed. At the time of the visit this had very clear, alkaline water with submerged vegetation including stoneworts, linear-leaved pondweeds and the non-native Canadian pondweed (*Elodea canadensis*). The shoreline of the pond was a focal point for Oystercatchers and Ringed Plovers, which were probably breeding nearby on the quarry floor. A pair of Wigeon had bred successfully on the pond; this duck is a scarce and very localized breeding bird in Britain, though it does have a small breeding presence in the Yorkshire Dales National Park.

The other disused void has been partly restored to agriculture by replacing soil over the quarry floor. This is set in a mosaic of limestone cliffs, quarry spoil heaps, scrub, secondary woodland and regenerating limestone grassland. A small stream along the edge of the agricultural restoration appears to be fed by a combination of surface run-off and percolation through the restored pasture substrate. There are small areas of seepage mire along the edges of the stream with a series of shallow pools, a semi-permanent pond and a mosaic of bottle sedge (*Carex rostrata*) swamp and willow scrub. These wetland areas are used by Oystercatcher and Reed Bunting.

The following habitats and species have been identified as priorities for conservation in the UK and local (Richmondshire) Biodiversity Action Plans:

| Feature         | UKBAP Priority | Richmondshire BAP Priority |
|-----------------|----------------|----------------------------|
| Fen             | •              | •                          |
| Standing waters |                | •                          |
| Reed Bunting    | •              |                            |

Table A7.2: Habitats supported

Wensley Quarry is just outside the Yorkshire Dales National Park, so it is also appropriate to consider conservation priorities identified in the National Park's Biodiversity Action Plan, *Nature in the Dales*. These include 'small base-rich wetlands' and Wigeon.

### Potential for wetland restoration

The area restored to agricultural use includes a small-scale but diverse base-rich upland wetland including seepages, pool complexes, a pond, sedge swamp and willow carr. This has developed accidentally and there is little means of ensuring appropriate habitat management as the site is under an agricultural restoration agreement. Under sympathetic

management such as low-intensity sheep grazing, it is likely that the seepage habitats could develop a rich flora analogous to a base-rich small sedge mire (NVC M10). However, there are few wetlands on the Carboniferous limestone in Wensleydale, which could impede natural colonization of rarer species.

The large pond in the west quarry provides an important if unplanned habitat in its own right. It is a markedly alkaline but nutrient-poor water body formed by drainage of ground water through the quarry walls into a hollow in the underlying bedding plane. This could be considered a small mesotrophic lake (a UKBAP Priority Habitat) and it already has distinct wildlife interest including breeding Wigeon (at least in 2006), breeding waders using the shoreline and submerged vegetation including stonewort communities. Little active management is required to maintain this water body as a valuable wildlife habitat but it is important that adjacent parts of the disused quarry are kept free from disturbance during the bird breeding season to protect nesting waders.

## APPENDIX 8 CASE STUDY DETAILS: STAVELEY

|                       |  |
|-----------------------|--|
| <b>Name:</b>          | <u>Staveley Nature Reserve</u>   |
| <b>Site location:</b> | 3 km southeast of Boroughbridge (Harrogate district)   |
| <b>Elevation:</b>     | c 22 mAOD  |
| <b>Natural area:</b>  | On the border of the South Magnesian Limestone Natural Area and the Vales of York & Mowbray Natural Area |

### Abiotic characteristics

The site is managed by Yorkshire Wildlife Trust and is located in a low-lying area in the south of the study region southwest of Boroughbridge. Staveley is observed to have a diverse range of habitat, including fen meadow open water and reedbed. This is the result of an initial unplanned restoration (simply bulldozed flat) and subsequent regeneration over a 30-year period. Former sand, gravel and clay workings were allowed to naturally regenerate and, after several decades, a complex ecology has developed reminiscent of the original wetlands, Staveley Carrs, which were drained for agriculture in the early 1800s. The geological map indicates extraction occurred over the western half of the site leaving intact peat over the eastern half. Plans are being assessed to re-wet adjacent agricultural fields underlain by peat.

Of key importance appears to have been:

- Avoidance of spreading nutrient-rich topsoil over the entire site
- Availability of a suitable seed bank within the area, which was allowed to re-colonise rather than sowing/planting of agricultural grass seed mix which would prevent establishment of other species
- A continuous supply of surface water (and groundwater discharge) to the site throughout the year with watertables within 1 m of the surface and superficial deposits of fine (clay) material and peat causing significant capillary rise and providing damp surface conditions.

### Geology

The geology at Staveley is complex with a range of superficial deposits underlying the site including glacial till, peat, silty and clay, glacial lake deposits, fluvio-glacial terrace deposits, alluvium and backfilled quarry workings. The solid geology beneath the site incorporates the Sherwood Sandstone, a major aquifer, beneath the northern section of the site.

The Upper Permian Marl with evaporites underlies the central portion of the site and the Upper Magnesian Limestone, also a major aquifer, underlies the southern section of the site (**Figures ST1 and ST2**). A fault is identified on the geological map running in a northeasterly direction immediately to the south of the site.

Potentially water discharging from the limestone and draining from the area to the southwest of the site will be alkaline and base-rich. Evaporites within the upper marl have potential to dissolve within groundwater to produce elevated levels of sulphate and chloride.

The hydraulic connection of the bedrock and the surface water system is limited by the intervening cover of superficial deposits.

Groundwater flow is expected to follow the topography in a generally northeasterly direction. There is potential for groundwater discharge to the superficial deposits (eg a buried spring line) along the contact between the permeable limestone and the low permeability marl.

Results of hand augering indicated:

- At ST1: 0 – 0.3 m dry brown clay-rich soil and 0.3 – 1.2 m dark brown clay, occasional orange/grey patches, organic-rich silty clay
- At ST2: 0 – 0.5 m silty brown clay and 0.5 – 1.64 m of grey black silty organic-rich clay

#### Monitoring

No groundwater monitoring data was available for the site; therefore two shallow piezometers (ST1 and ST2) were installed to determine groundwater levels at the site. Data loggers were installed within these and the main lake to investigate the interaction between the groundwater and surface water system.

#### Hydrology and landform

The site is relatively flat-lying, falling from 23 mAOD at the stream inlet on the western margin to ~21.3 mAOD on the lake margins (average ~21.8 mAOD). Flowing eastwards along the northern margin of the site is the River Tuft with a potential catchment area of some 1,000 Ha. Embankments along the Tuft are at some 23 mAOD with an invert level of ~21.3 mAOD.

The main lake is fed by a stream from the west which drains a catchment area of some 117 Ha. A drain with an invert level of ~21.15 mAOD forms the outlet from the lake. The channel dimensions are 3 m wide by 2 m deep with a water depth of some 40 cm. At the time of the site visit (27<sup>th</sup> June 2006) flow was too slow to measure with a float.

The results of weekly lake stage monitoring between 1995 and 2000 indicate levels ranging from a minimum of 21.11 mAOD to a maximum of 21.54 mAOD, with a mean of 21.30 mAOD. Note that the readings are calibrated assuming a stage reading of 4" is equivalent to 21.3 mAOD taken from the site survey (23<sup>rd</sup> April 2003). Logging at 10 minute intervals between June and September 2006 indicated lake levels to range between 21.68 and 21.32 mAOD with an average of 21.25 mAOD (**Figures ST3 and ST4**). Piezometer data from ST1 for the same period shows water levels to vary between 21.15 and 21.43 mAOD with an average of 21.27 mAOD. Variations in lake and groundwater levels show similar trends with several significant recharge events occurring on 2<sup>nd</sup> August 2006, 18<sup>th</sup> August 2006 and 2<sup>nd</sup> September 2006. Water levels in the piezometer are observed to rise by up to 10 cm and in the lake by 5 cm during these events. It is apparent that the lake and the adjacent River Tuft have a significant influence on water levels across the reserve, maintaining groundwater levels at around 21.3 mAOD. This maintains the watertable approximately 0.5 m below surface and with capillary rise associated with the significant clay content of the soil, moist conditions are generally maintained within the soil profile.

The data loggers also recorded temperature variations at the site. Air temperature varied between 5.55°C and 26.05°C, lake temperatures between 15.6°C and 19.9°C and groundwater showed a steady increase from 10.4°C to 12.7°C.

#### Water Quality

The following water chemistry data was obtained from samples collected on 30/11/2006:

| Variable/<br>Location | pH   | Electrical<br>conductivity<br>$\mu\text{S}/\text{cm}^{-1}$ | Ortho-<br>phosphate<br>Mg/l P | Nitrate<br>mg/l N | Sulphate<br>mg/l | Magnesium<br>mg/l | Calcium<br>mg/l | Alkalinity<br>mg/l<br>CaCO <sub>3</sub> |
|-----------------------|------|--|-------------------------------|-------------------|------------------|-------------------|-----------------|---|
| Inflow<br>channel     | 7.59 | 1010   | <0.1                          | 0.763             | 436              | 45.8              | 196             | 253                                     |
| Lake<br>outflow       | 8.27 | 710  | <0.1                          | <0.4              | 199              | 39.1              | 111             | 180                                     |

Table A8.1: Water chemistry data at Staveley

### Historical and landscape context

Staveley NR is located on part of the historic Staveley Carrs, a once extensive area of wetland formed within an ancient course of the River Nidd between the villages of Staveley and Minksip. The Carrs were probably used historically as rough grazing and were investigated by the clergyman-botanists William Gawthrop and James Dalton in the mid to late 18<sup>th</sup> century. Their records suggest base-rich standing water habitats such as grazing-marsh ditches but also areas with acidic peat and *Sphagnum* moss.

Staveley Carrs were reported to have been thoroughly drained and enclosed by the mid 19<sup>th</sup> Century (Slater, 1886). However, it is possible that remnants of wetland flora survived in agricultural drainage ditches or along the banks of the River Tutt. This may explain how the Nature Reserve has developed a markedly richer fen flora than any other minerals site in the Swale and Ure washlands.

### Ownership and management arrangements

The Nature Reserve is owned and managed by the Yorkshire Wildlife Trust, having been acquired from RMC in December 2002. The Trust has a Reserve Management Plan but this is currently being revised. A very active group of local volunteers works with the Trust in managing, recording and monitoring the reserve and its wildlife. The Management Committee produces a comprehensive Annual Report.

### Ecological objectives of site restoration and management

The present landform of the site results from backfilling the steep edges of a single flooded gravel pit in the early 1970s. On-site overburden was used plus some washings from a neighbouring aggregate quarry. The lack of a more formal restoration scheme has, in this case, allowed a rich diversity of wetland habitats to form naturally along a hydrological gradient. Current management includes selective mowing of drier grassland / fen-meadow areas to encourage botanical diversity, scrub removal from lake-edge swamps and excavation of small ponds around the lake edge. An area of former improved pasture on peat soils on the east side of the reserve has recently been acquired with the intention of re-creating wet grassland (this area had not been quarried).

## Biodiversity interest



◀ Fen meadow at Staveley NR

Staveley NR is best known for its ornithological interest associated with the open water of the main lagoon and its fringing reedswamp (mainly *Phragmites*). Regular wintering species include , Jack Snipe, Goldeneye and Pochard. Regular breeding birds include Water Rail, Reed Warbler, Sedge Warbler, Grasshopper Warbler and Reed Bunting. The site is also important for wetland invertebrates: it is the richest site for Odonata (dragonflies and damselflies) in Harrogate district and

supports species-rich water beetle communities including some scarce lowland fenland species close to the northern edge of their British range.

Of particular botanical interest is the presence of several nationally uncommon wetland plants (e.g. water violet *Hottonia palustris*, lesser water-plantain *Baldellia ranunculoides*, marsh helleborine *Epipactis palustris*) and several more widespread species associated with infertile habitats and therefore scarce in lowland Yorkshire (e.g. common cotton-grass *Eriophorum angustifolium*, hare's-tail cotton-grass *E. vaginatum*).

From a wetland restoration perspective, Staveley NR is important as an example of the spontaneous development of fen communities on raw mineral substrates.

The site supports the following species and habitats identified as priorities for conservation in the UK and local (Harrogate) Biodiversity Action Plans:

| Feature        | UKBAP Priority | Harrogate BAP Priority |
|----------------|----------------|------------------------|
| Fen            | •              | •                      |
| Reedbed        | •              |                        |
| Standing water |                | •                      |
| Reed Bunting   | •              |                        |

Table A8.2: Habitats supported

Staveley NR is a Site of Importance for Nature Conservation (SINC), a non-statutory nature conservation designation applied by local planning authorities.

### Potential for wetland restoration

This site supports a well-established and well-managed mosaic of wetland habitats and can be seen as a very successful example of habitat creation which complements the historic character of the site. It is possible that more extensive areas of fen-meadow could be established by extending annual or rotational mowing. Maintenance of open waterside habitats will require ongoing management to prevent succession to willow scrub.

## Ecohydrological issues

The main water supply to the reserve is an inflow ditch channeling water from the nearby Staveley West Lagoons (a more recently-restored aggregate site). A sequence of fen communities has developed around the inflow drain, although the extent and importance of lateral percolation is unclear.

This system makes the reserve vulnerable to changes in the hydrological management of the West Lagoons, and to extraneous sources of pollution or nutrient enrichment. The rarer plants and plant communities, along with their associated invertebrates, are mainly characteristic of base-rich but relatively nutrient-poor conditions (the occurrence of a few species usually found in acidic mires is anomalous). To maintain these communities, soil and water conditions in the fen areas and lakeside pools must be low in nitrate and plant-available P.

The limited data available indicate that water in the inflow ditch has high electrical conductivity (a measure of the concentration of dissolved ions), with measurements in excess of  $1000 \mu\text{S}/\text{cm}^{-1}$ . This is also reflected in high measurements of alkalinity, sulphate, calcium and magnesium.

Sulphate was more than double the level recorded at the outlet channel, and more than four times that recorded at any other site in the study. The magnesium concentration recorded from the Staveley NR inlet channel was higher than for any other sample except one (Scorton North Lake).

The source of dissolved minerals is likely to be the evaporite deposits in the Permian marl outcropping to the west of Staveley. Gypsum is an important component of evaporite deposits associated with the Magnesian Limestone in North Yorkshire, and high sulphate levels can be expected where groundwater comes into contact with gypsum ( $\text{CaSO}_4$ ) beds.

Nitrate was recorded at a low level in the inlet sample (0.763 mg/l) and reduced further at the lake outlet (<0.4 mg/l). If this is at all typical of water chemistry on the site, it suggests that the lake and associated wetlands function as a nitrate sink.

The Yorkshire Wildlife Trust has recently acquired a buffer zone between the reserve boundary and intensive arable land to the west. This will be managed as a perennial grass strip and will provide some measure of protection against agricultural nutrient-enrichment via fertilizer drift, soil erosion and surface run-off. It will not, however, protect against more diffuse forms of groundwater or atmospheric enrichment.

There is no effective means of isolating the reserve hydrologically in the event of pollution of the inflow drain.

## Potential Water Management Options

Adjacent land elevations are such that a drop-board sluice would allow lake levels to be increased to ~21.7 mAOD if required although neighbouring fields to the east of the nature reserve are at 21.4 mAOD. Based on surrounding ground elevations a sluice installed at the inlet to the nature reserve has the potential to generate surface water with a head of 23 mAOD for uses such as re-wetting the adjacent peat land and seasonal flooding of wet pasture.

High nutrient content may be unsuitable for the development of certain habitat and the water quality of the influent water will require analysis due to the surrounding agricultural landuse. However, flora observed in the reserve is not indicative of eutrophic conditions and as the influent water has passed through several large ponds and wetland areas a certain amount of 'natural' water treatment (settlement and degradation) may already have taken place.

Compartmentalisation of sections of the reserve using low bunds with inlet and outlet sluices, and a series of shallow drains, to distribute water from the inlet would facilitate management. A boundary drain along the eastern margin of the site would ensure neighbouring land does not become flooded.

The water requirements of the site are likely to be readily met from the current influent surface water. However, potential exists to increase the supply if required by engineering an inlet from the River Tuft, although it is anticipated that water from this will be considerably more eutrophic.

## APPENDIX 9 AQUACULTURE

Characteristics of the ideal pond for cage culture include the following (Swann *et al*, 1994):

1. Be at least one surface acre (4,000 m<sup>2</sup>) with larger ponds preferred.
2. The pond should have a depth of eight feet in at least  $\frac{1}{3}$  to  $\frac{1}{2}$  of the pond area. The remainder of the pond should be at least 1.2 m deep.
3. Water levels should not fluctuate more than 30-60 cm during the summer.

| Species           | Tolerable extremes<br>°C | Optimum growth<br>°C | Growth period to<br>market size (months) |
|-------------------|--------------------------|----------------------|--|
| Trout             | 0 – 31.7                 | 17.2                 | 6 – 8                                    |
| Salmon (Pacific)  | 4.4 – 25                 | 15                   | 6 – 12                                   |
| Freshwater prawns | 23.9 – 32.2              | 28.3 – 30.6          | 6 - 12                                   |

Table A9.1: Enhancement of fish growth

| Description     | Hardness in mg/l<br>as calcium | Hardness in mg/l<br>as calcium carbonate |
|-----------------|--------------------------------|--|
| Soft            | 0 - 20                         | 0 - 50                                   |
| Moderately soft | 20 - 40                        | 50 - 100                                 |
| Slightly hard   | 40 - 60                        | 100 - 150                                |
| Moderately hard | 60 - 80                        | 150 - 200                                |
| Hard            | 80 - 120                       | 200 - 300                                |
| Very hard       | Over 120                       | Over 300                                 |

Table A9.2: Ranges in water hardness

### Pond size

The main factors affecting pond size are, species cultured, management requirements, and cost considerations. The expected level of production is important in determining pond size. Most production guidelines suggest completing the drain harvest of individual ponds in one day to reduce the possibility of deterioration or loss of the crop.

Construction cost per unit area declines with increasing pond size as the area occupied by bund walls and channels declines in proportion to pond area. Building five 10 Ha ponds will require half the number of water control structures than ten 5 Ha ponds. Orientating the ponds so the long sides are parallel to the contour of the land, reducing cut and fill may also cover construction costs. Although small ponds are relatively more costly to construct, they are amenable to more intensive management efforts, and some culture systems (eg bait fish) require small ponds.

### Pond wall characteristics

Wave height, a function of pond size, must be considered in estimating bund height and freeboard. Freeboard is the vertical distance from the pond surface at its design depth to the top of the dike after settlement. Freeboard varies from 0.3 m to 0.6 m, depending on the length of the pond, and the amount of traffic the dike is to bear and dike soil characteristics will modify this estimate. The bund crown must be well above the level of soil saturation

under normal pond water levels to prevent sinking and damage to the bund from passing traffic.

Bund top widths vary with the height of the bund. Minimum width for a dike 3 m high or less should be 2.5 m or more. If the dike top is to be used as a roadway, top width should be at least 3.7 m, and preferably 4.0 to 4.5 m (*MSU, 2006*). At least one side of each pond should be made wide enough for vehicles. The centre line of the dike crest should be elevated about 15-20 cm higher than the shoulders to drain rain water more effectively. Bund side slopes are a function of the type of soil used. The most commonly used slope is 3:1 (horizontal to vertical).

Ponds larger than 0.5 Ha should incorporate erosion control in bund designs. Upstream slopes are exposed to the erosive forces of wave action; downstream slopes are exposed to erosion during heavy rains. In general, upstream slopes should be flatter than downstream slopes to handle erosion better in a saturated state.

### **Water control structures**

Design specifications of water-control structure should anticipate future changes in bund height, height of pond bottom over initial levels, and changes in particle size of bottom soils. Inlets and outlets must be separate and located to prevent any mixing of incoming and discharge. Locating the inlet and outlet far apart within the pond avoids 'short circuiting' water flow within the pond and allows freshwater to be added to the pond during harvest operations. The size of inlets and outlets is determined by the time needed to fill or drain the pond.

Two water-control structure designs – a drop inlet structure and a movable standpipe or riser – are commonly encountered. Drop inlets can either replace a section of the dike (a weir) or can be a structure within the pond.

In drop inlets, crest height maintains a constant water level in the pond. Incorporating adequate freeboard in weirs allows the structure to handle expected storm run-off. Spillways channel the water discharged over the weir crest. The main consideration is that the spillways pass the projected harvest or overflow volumes without damage. The most common spillway type is lined for some distance upstream and downstream with reinforced concrete. Fish screens may be required to prevent losses.

The second type of water-control structure consists of a horizontal conduit through the dike connected to a movable standpipe or riser within the pond. Anti-seep collars around the conduit will prevent leaks and possible bund failure. Swivelling the riser up or down controls the water level.

The downstream ends of any discharge pipes should incorporate an energy dissipator or some form of protection against scouring. The banks of drainage ditches opposite discharge conduits are especially vulnerable to scour at full discharge flows.

Water distribution and drainage canals may supply water to and from the ponds, and must be sized to handle maximum projected flows, including storm water. Internal pond drains are sometimes used to carry water from undrained depressions to the pond outlet.

## Revenue streams

Intensive farmed trout retail at £2,000-£3,000/t

Ecological farmed trout retail at £12,000-£15,000/t.

Ecological aquaculture is viable with lower production rates of fish because it is designed to produce multiple products from the same system all at the same time. Substantial grant aid is available for sustainable and innovative aquaculture systems, and aquatic plant nurseries will provide a local commercial enterprise and provide an extensive resource for future local conservation schemes.

Viable products and services:

1. Brown trout
2. Rainbow trout
3. Brook trout- (*Artic Char sp.*)
4. Grayling
5. Tench
6. Perch
7. Freshwater molluscs
8. Crustaceans
9. Aquarium freshwater fish sp.
10. Edible aquatic plants
11. Ornamental aquatic plants
12. Live food for the aquarium industry
13. Live invertebrates for scientific research
14. Ecological aquaculture training programmes.
15. Educational (school) training programs
16. Aquatic field study centres
17. Public amenities/visitor centre
18. Commercial processing/packaging
19. Trout fisheries
20. Coarse fisheries
21. Aquatic plant nurseries
22. A Centre for the National Freshwater Fish Collection (gene-pool bank)
23. Professional consultation

## Intensive Trout Production

Wholesale price: £1.70-£2.20/kg (Trout harvested at about 300g-400g although larger fish are required for smoking and re-stocking of fisheries). Retail price: >£3.00/kg. An example of gross margin expected per tonne of trout (extracted from SAC's Farm Management Handbook) is given in the tables below:

|  |
|--|
| Costs (SAC, 2006)                                |
| Fry: £60/1,000 fry purchased at 6-8 cm (100/lb). |
| Feed: £600-£800/t (depending on size of fish).   |
| Vet & medicine: £30/t trout.                     |
| Haulage, sales commission, etc ~£300/t           |
| SEPA inspection ~£1,000/y.                       |

|                             |                             |
|-----------------------------|-----------------------------|
| Returns                     |                             |
| Output                      | Per tonne of production (£) |
| Wholesale value @ £1.9/kg   | £1,900                      |
| Less fry: 3,330 @ £60/1,000 | £200                        |
| Subtotal                    | £1,700                      |

|   |                             |
|---|-----------------------------|
| Variable Costs                            | Per tonne of production (£) |
| Feed 1.03t @ £670/t                       | £690                        |
| Vet & medicine                            | £30                         |
| Other costs (marketing, packing, haulage) | £250                        |
| Subtotal                                  | £970                        |
| Gross Margin                              | £730                        |

|                              |                              |
|------------------------------|------------------------------|
| Sensitivity-Change +/-       | Change in gross margin/t (£) |
| 10p/kg wholesale             | £100                         |
| £10/t feed                   | £10                          |
| 0.1 in feed conversion ratio | £66                          |

### Ecological trout production

|   |
|---|
| Cost (Hutchinson, 2005.)  |
| Fry: (Rainbow trout): £120/1,000 fry purchased at 10 cm-12 cm (100/lb). |
| Fry: (Brown trout): £160/1,000 fry purchased at 10cm-12cm (100/lb)      |
| Feed: Natural live food   |
| Vet & medicine: £30/t trout.  |
| Haulage, sales commission, etc ~£300/t                                  |
| SEPA inspection ~£1,000/y.  |

### Returns

From direct niche market sales to the restaurant trade a retail price: >£12.00/kg, a gross margin achieved per tonne of trout (*Freshwater Solutions, 2007*)

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*Freshwater Solutions, 2007*

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## FIGURES