APPENDIX 6.6.1

FEDERATION OF PILING SPECIALISTS GUIDELINES
Appendix 6.6.1 – Federation of Piling Specialists Guidelines

Introduction

The following notes are intended to provide assistance to those considering the merits of deep foundations for sites located over aquifers, in particular where the aquifer is overlain by contaminated ground. The main concerns with regard to deep foundations affecting aquifers are the following:

- the creation of preferential flow paths, allowing contaminated groundwater and leachates to move downwards
- the transportation downwards of contaminated material during construction / installation
- concrete contamination of the surrounding ground and groundwater.

In the UK deep foundations primarily involve the use of piles or ground improvement by stone columns. Diaphragm walls are used less frequently but can penetrate to significant depths

Piles

Piles can be sub-divided into two main types, depending on the method of installation/ construction:

- displacement piles, which include driven piles
- non-displacement or replacement piles, i.e. bored piles and continuous flight-auger piles

Displacement Piles

Displacement piles are often preferred on sites with contaminated ground, for the simple reason that they produce no waste or spoil. This has obvious practical and economic benefits.

This type of pile is further sub-divided depending on the amount of displacement that takes place during pile installation.

Large displacement piles include driven cast in situ concrete piles and driven pre-cast concrete piles.

Driven cast in situ concrete piles are constructed by driving a closed steel casing, with a sacrificial shoe, to the full depth of the pile. The reinforcing cage is installed and concrete placed as the casing is withdrawn, ensuring that a significant head of concrete remains within the casing at all times.

Driven pre-cast concrete piles are factory manufactured units, usually square, up to about 15 metres in length. They can be extended to greater depths using mechanical joints.

Due to the high stresses induced in the surrounding ground when driving large displacement piles, development of flow paths around the outside of the piles is unlikely. The nature of the concrete soil interface in cast in situ concrete piles further reduces this possibility.

The possibility exists that the piles will push or drag contaminated material downwards, as they penetrate the underlying strata. However, research on driven piles founded in stiff clay has indicated that material from the layers above was dragged down around the shaft for only a short distance.
It is possible that very small amounts of material below the toe could be pushed ahead at the base of a flat ended pile.

Small displacement piles include driven open-ended steel tubular piles and driven steel H section piles. Also included are hybrids such as the screw pile (Omega, CHD, Atlas).

Screw piles are formed using a special thick-stemmed continuous auger. The width of the flights on the auger is small in comparison with the stem. Although there is some movement of the soil upwards and a small amount of spoil is generated, most of the soil is displaced sideways. The auger bores to the full depth of the pile and concrete is placed through the auger stem as it is removed.

With these types of pile, stresses in the ground immediately around the pile are increased, although to a lesser extent than for large displacement piles. The likelihood of flow paths occurring along the surfaces of the pile may be slightly increased.

With open-ended tubular piles the possibility exists for the piles to become ‘plugged’ with soil. This may cause material captured near the surface to be transported downwards, within the tube, towards the founding level. However, experience has shown that ‘plugging’ is rare and only occurs where stiff or dense soils are present.

Replacement piles

This category includes the traditional bored cast in situ concrete and continuous flight auger (CFA) methods of piling.

a) Bored cast in situ concrete piles are usually employed where the ground conditions are primarily cohesive (i.e. clay). This type of pile can be constructed using either augers or the tripod, percussion method. Although the techniques are very different, the basic sequence of construction is the same.

Temporary casing is installed to support the bore through fill, soft clays, granular and other unstable soils or to prevent the ingress of groundwater. Where possible the casing is founded in an underlying clay layer to form a seal, in order to keep the bore dry and to stop material falling in. Providing the clay layer is of sufficient thickness and is present continuously across the site, the temporary casing will prevent the flow of contaminated groundwater or leachates downwards.

The pile bore is then continued to the full depth in open excavation below the temporary casing. Concrete is placed from the surface in dry piles and by tremie pipe to the base of the pile when groundwater is present. The temporary casing is withdrawn only when sufficient concrete has been placed to prevent collapse of the bore and a head of concrete is maintained until the casing is finally removed.

In cases where there are substantial depths of unstable soil, and it is not possible to install temporary casings to the full depth necessary, some other form of support is required in order to advance the pile. In these circumstances large diameter bored piles are constructed using a support fluid such as bentonite, in conjunction with temporary casing in the top part of the bore.

Bentonite powder mixed with water forms a slurry to provide the necessary support. This method is usually used in sands and gravels, but has also been used in chalk and other weak rocks.

The main concern regarding bentonite is the possibility of flow into the surrounding ground and contamination of groundwater. However, in sands and well graded gravels the slurry forms a filter cake around the extremities of the
b) Continuous flight auger (CFA) piles have become the most common type of pile in use in the UK. The piles are constructed by boring to the full depth, using a long auger in one continuous downward movement. Soil travels upwards as the auger rotates, keeping the flight full of spoil.

Once the required depth is achieved, concrete is pumped under pressure through the hollow stem of the auger to the top of the pile, as the auger is slowly withdrawn.

With this type of pile there is no open bore at any time. Although it is possible that water could flow down the auger, this is minimised by the upward movement of soil at all times and the advance of the rising concrete which prevents the development of preferential flow paths or downward transportation of contaminants.

c) Cased flight-auger piles are also now possible. With this system, temporary casing can be installed to seal into a clay layer, as with traditional bored piles. The casing advances at the same time as the auger to the depth required to form a seal. The auger then continues to the design depth and the pile is concreted as normal. The casing can be withdrawn with the auger or afterwards, if necessary.

One concern that may arise from both bored and CFA piles, as well as other types of cast-in-situ pile, is that of concrete contamination of the surrounding ground and groundwater. This is thought unlikely to occur even in soils of high permeability or fissured and jointed rocks unless very wide fissures or joints are present. Piling in the immediate vicinity of pumping stations or other extraction points should be carefully considered.

Diaphragm Walls

The construction of diaphragm walls involves the excavation of a deep trench, between 0.5 and 1.5 metres wide, using 'grabs' or rotary cutters to construct panels varying in length between 4 and 8 metres.

Concrete guide walls are used at the top of the trenches to increase the accuracy of construction. These may be extended downwards slightly, to provide additional support in unstable ground. Excavation is carried out using a support fluid, usually bentonite, to maintain the stability of the trenches until the concrete is placed.

Comments made previously about bored cast in situ concrete piles constructed under bentonite also apply to diaphragm walls.

Ground Improvement

a) Vibro-replacement
The main form of ground improvement used in the UK is vibro-replacement. This involves the construction of stone columns, using a vibrating poker. The ground is displaced laterally as the poker penetrates. The stone can either be placed from the surface or by a bottom-feed system in which the stone passes through the stem of the poker.

This form of ground improvement is normally used only to shallow depths, typically between 2 and 5 metres, and cannot generally penetrate stiff clay soils or dense granular soils.
The main concern with this type of foundation is that it creates preferential flow paths down the stone columns, through which contaminated groundwater might flow. Recent developments have included the use of a concrete or bentonite plug to seal the base of the column. Grouting of columns is also possible.

b) Vibrated concrete columns (VCC)
This form of ground improvement is carried out using similar equipment to vibro-replacement. Instead of forming a stone column, a concrete column is constructed, using bottom-feed (tremie) equipment. The method is usually used in very soft clays or other weak soils and has similar depth and penetration limitations to vibro-replacement. Since the columns are constructed with concrete pumped under pressure, the likelihood of a preferential flow path developing is very slight.

Conclusion

The above guidance notes cover a wide variety of deep foundation systems which need to be considered in the context of the individual site conditions. In particular, the following main considerations apply:

- The type of foundation and construction technique proposed
- The geology in relation to the founding level
- The groundwater regime and whether static, flowing or artesian conditions are present. Under artesian conditions there will be a tendency of upwards flow away from the aquifer.