Illus 1 *A stone-filled field drain.*

Agricultural drainage exposed: observations recorded during a watching brief on the construction of a water pipeline in Angus

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There is nothing connected with the land that has paid for the investment of capital, or ever will pay, so well as the drainage of the soil we cultivate for supplying our needs. (Henry Hutchinson, 1844)

Introduction

Between June 2002 and April 2003, SUAT Ltd undertook a watching brief on the construction by Farrans (Construction) Ltd, of a water pipeline from Loch of Lintrathen reservoir, Angus, to the Clatto Reservoir and water treatment works, Dundee, for the North of Scotland Water Authority (NoSWA), now incorporated into Scottish Water. The pipeline extended for 26 km, passing through Angus, to the E of both Meigle and Newtyle, and areas within Perth & Kinross and Dundee City. The laying of the pipeline was preceded by the stripping of topsoil using 360 degree mechanical excavators equipped with smooth-bladed buckets, down to the first archaeological horizon. This work was subject to continual archaeological monitoring, and all archaeological features were recorded. In accordance with the scheme utilised by NoSWA, individual fields on the pipeline route were numbered as F1, F2, F3, etc, with the field numbers ascending from Lintrathen in the N to Clatto in the S.

As might be expected, given the location and length of the pipeline route, a complex variety of features was recorded and investigated. The full results are described in a report prepared for Scottish Water (Fyles 2003). This paper focuses on the agricultural drainage features recorded during the project.

During the watching brief, a large number of field drains, relating to improvement of the land for agricultural use, were recorded. Some of these were investigated in detail, partly to establish their identification as drainage features and to provide a record of the different methods of construction used in the past. Most examples are likely to date from the 18th and 19th centuries, although some of the evidence could be earlier.

A number of different types of construction (using stone, ceramic tile and wood) and layout were observed, and, although field drains are of limited archaeological value individually, the opportunity to examine a very large number, of different types and over a wide area, is rare. Presented here is an account of how agricultural drainage has developed over time and how past practices relate to the evidence revealed during this project.

The need for drainage systems

The purpose of drainage systems is to remove surplus water from the land, making otherwise wet and boggy ground into viable and productive agricultural and pasture land.

After rain there is a tendency for clay soils in particular to remain wet. This is because the rate of water movement in poorly structured clays is very low, and in the absence of natural cracking and fissures, surface ponding occurs. There are numerous disadvantages to un-drained land which is prone to flooding. If it is used for growing crops, these can be destroyed by surface water, and agricultural machinery can be bogged down and damaged. On pasture land, the movement of animals can exacerbate the effects of saturated soil, and animals and people alike are endangered by boggy conditions. When the soil is frequently wet, good quality grasses and clovers tend to be lost as their roots are damaged, and only unproductive grasses survive. Wet land also harbours disease, and weeds multiply.

Drainage controls the free (gravitational) water in the soil. After rainfall, this water moves downwards through the soil profile until it meets an impervious layer, then collects and builds up. If it reaches the surface, the land becomes waterlogged or, on an incline, it breaks out as a spring. Capillary water, in contrast to gravitational water, is held within the soil structure and cannot be removed by drainage. This water is used by plants and is continually released by evaporation.

Different types of soils have different drainage coefficients (the amount of water that can be removed by drainage). Clay-rich soils retain the moisture they seize, and, after heavy rain, discharge the excess. Peaty soils are more capable of capillary action, and release much of the water by evaporation. The effect of draining is much more active in peaty soils than in clay-rich types.

A brief history of agricultural drainage

The application of field drainage systems can be traced back to an early period, most early eastern civilisations possessing a knowledge of land drainage and irrigation (although the emphasis was mainly on the latter). In around 400 BC, Herodotus mentions drainage in the Nile valley for the removal of surplus water as well as for irrigation. Virgil refers to the use of a variety of materials for the improvement of land through drainage.

During the Roman occupation of Britain, local materials nearest to hand were used for the careful construction of drains or culverts. Roads were vital for the control of the Roman frontier areas in Scotland, and excavation has established that many were flanked by drainage gulleys (Keppie 1986, 40). Further S, Drainage systems were also incorporated into cultivated land around villas. Stone-lined drains similar to those constructed in Roman times continued to be built as recently as the early 19th century, and some are still in good working order today.

The importance of surface drainage is made clear by the widespread use of the rig and furrow technique practised during the medieval period and only discontinued in the second half of the 19th century. In this system of ploughing fields in linear strips, the hollows, up to 10m apart, serve as drainage channels, keeping the rigs free of surface water. This system, however, could not be used effectively to drain marshy areas. Monastic farmers drained an extensive area at Inchaffray in Perthshire in the 13th century by cutting a pow or ditch that ran to the River Earn from the western end of a large expanse of peat (Fenton 1976, 18). On a larger scale, drainage schemes guided by Dutch engineers were carried out from 1544 onwards, to reclaim land from the sea, in Holland and in the Fens of England, using systems of open ditches with embankments.

During the 17th century, fields were drained by series of ditches, narrowing towards the bottom and filled with any permeable material available locally, such as straw, stones, chalk or gravel. Even brushwood was used in woodland areas. These ditches were then covered by a layer of topsoil. Because of clogging by silt, the lifespan of these drains was generally short. Conditions after failures could become worse than they had been before drainage operations began, as failure of the system tended to be localised, and water carried to these areas created localised boggy conditions, some of which could represent a hazard to people and animals. Attempts to replace the rig and furrow technique and level field surfaces were associated with 'furrow drains', which were set along the lines of the furrows (NSA 1845, 590). These played an important role before the development of tile drainage.

Also during the 17th century, a system known as plug drainage was often employed. In this system, wooden blocks around 3 inches (c 75mm) in thickness were placed into excavated trenches and covered by compacted clay, and then the blocks were removed leaving cavities along which water could flow. Holes were bored in the roof of the cavity, and covered with stones or wood, thus preventing silt entering the channel (Livesley 1960, 3).

In the 1760s Joseph Elkington carried out a study of the movement of water through soil, analysing the causes of waterlogging and flooding of land. Prior to undertaking his drainage schemes, generally using stone as a conduit (Gisborne 1852, 14) he spent time on surveying the surrounding countryside for clues to the causes and solutions, and his ideas have been taken into consideration since then. Much draining of marshes and lochs was undertaken during the 18th century, reducing the annual flooding of wet, low-lying areas and the associated hardships of local people. The drainage of marshes also had health implications, for the risk of ague was much reduced.

The 19th century brought new challenges of an increasing population. People moved into the towns in large numbers but remained dependent on the countryside for their food. In terms of agricultural practice, greater production per acre and less waste of available land became the joint aims. An energetic debate between William Smith of Deanston and Josiah Parkes, two leading authorities on drainage systems, focused attention and interest on the topic. Smith, the first acknowledged advocate of systematic draining, favoured shallow drains, with stone used as backfill. Parkes, consulting engineer to the Royal Agricultural Society of England, favoured deep drainage, using ceramic pipes with a one-inch bore (see below).

William Smith's proposals (published in 1831 as his *Remarks on Thorough Drainage and Deep Ploughing*) can be summarised as follows:

a Frequent drains at intervals from 10 to 24 feet (3m to 7.2m).
b Drains should be shallow, not exceeding 30 inches (0.75m) in depth.
c Drains should be parallel and at regular distances, throughout the whole field, 'to promote frequent opportunities for the water rising from below and falling on the surface to pass completely off'.
d The direction of minor drains should be 'down the steep' (following the line of steepest descent), and that of the mains should be along the bottom of the chief hollow; tributary mains being provided for the lesser hollows.
e Stones were preferred to tiles and pipes as backfill.

Josiah Parkes' philosophical essays on the subject of drainage (Parkes 1848) gave a more scientific bearing to it, in parts quite at odds with the more mechanical rules proposed by Smith (above). Parkes' views can be summarised as follows:

a A preference for wide intervals between drains. Twenty-one to 50 feet (6.3m to 15m) was proposed.
b Drains should be a minimum of 4 feet (1.2m) deep, in order to keep the subterranean water at a depth exceeding the power of capillary attraction to elevate it to nearer the surface.
c Drains should be parallel (here, Parkes agreed with Smith).

d Increased depth compensates for the increased width between drains.
e Pipes of a 1-inch (25mm) bore were the most suitable conduit for the parallel drains.

Partly stirred into action by this new interest in drainage, the government passed the Public Money Drainage Act in 1846, authorising the advance of public money to promote the improvement of land through drainage works (Denton 1883, 1).

£3 million was made available, as loans to landowners, for use on drainage schemes. Although William Smith's 'shallow' system was widely adopted throughout Britain (as the object was simple: getting rid of the surface water), adoption of Parkes' more scientific''deep' system was recommended by the Inclosure Commission when disposing of public money.

At this time, various types of ceramic pipes or tiles were being used in drainage systems. The earliest types were horseshoe-shaped and open at the base. These tiles, known as saddle-back or mug tiles, were laid on top of separate soles of wood, slate or tile. The joins between the soles were placed so as not to coincide with those between the tiles above. Mug tiles were made by forming rectangles of clay in a wooden mould and then pressing these over wooden semi-cylinders of the desired size. Although cylindrical tiles began to be used soon afterwards, their narrow, one-inch (25mm) bore proved too small for effective long-term use, and mug tiles continued to be made and successfully used for some time. They remain in place in many thousands of fields throughout Scotland.

Cone-shaped and hexagonal pipes were also experimented with, although some designs proved unsuitable and had only a short life. The mid-19th century proved to be a period of great innovation in agricultural drainage. In 1843, John Reade had invented a machine for the manufacture of cylindrical tiles, and in 1845 Thomas Scragg improved on the process, developing a more economical method of production. Progress in establishing drainage systems was speeded up by the widespread establishment of tile works. The first tile works in Scotland is thought to have been that established by the Duke of Portland at Cessnock in Ayrshire, in 1826 (Taylor 1839). By the 1840s, there were at least seven tile works in Stirlingshire, and in the same decade a foundry in North Berwick had begun making machines to manufacture drain tiles, according to an invention patented by the Marquis of Tweedale (Fenton 1976, 22). The Scottish tile-making industry, originally restricted to a relatively local scale by the weight and bulk of its products and raw materials, increased in size with the expansion of the railway and canal networks (Douglas and Oglethorpe 1993, 16).

During the second half of the 19th century the drainage principles earlier outlined by Elkington and his successors came into universal use, as government-funded drainage schemes became widespread. This was a period of intense activity on drainage by the agricultural community, and coincided with the adoption of more intensive farming methods. Government loans to landowners resulted in a uniform system of drainage being prescribed. This generally involved the use of two-inch diameter pipes at a depth of between 3 and 4 feet (0.9m–1.2m). Main drains or headers were constructed, and into these were laid laterals at varying distances apart, depending on the type of soil encountered.

Although much unskilled labour was employed on the new drainage work, skilled drainers carried out the pipe-laying in order to avoid costly faults developing. This standardised government drainage, however, sometimes failed to take local conditions into account. Standard patterns designed in estate offices sometimes paid little attention to local variations in the terrain and types of subsoil.

The early part of the 20th century (c 1900–1937) saw an agricultural depression, in which British agriculture suffered from the effects of cheaper overseas imports. Improvements in shipping and transport, along with the development of refrigeration techniques, made importing food more viable. During this period, heavier land was deserted, farms became derelict, and whole systems of tile drains became silted up and lost. Very little new drainage, or maintenance of existing systems, was carried out between the end of the 1920s and 1935 (Livesley 1960, 8).

The outbreak of the Second World War heralded new activity with regard to home-based agricultural production. In 1940, grants for arterial drainage were increased, and for the first time extended to field drainage carried out by owners and occupiers. By this time, however, many experienced drainers had died or retired, and the new generation of farmers had little practical experience of laying drainage systems. This prompted the development of new methods as part of a general revival of interest in drainage works in the 1940s.

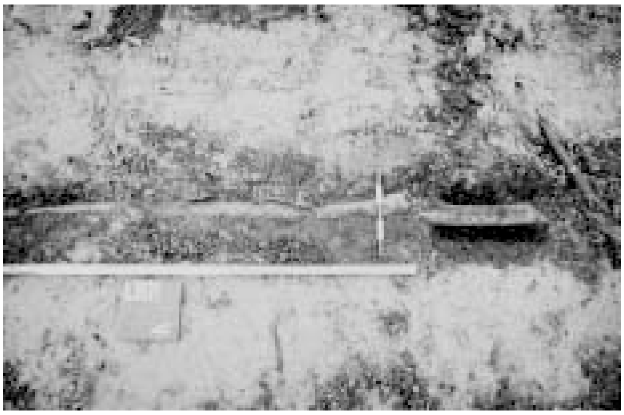
The development of new machinery and types of drainage tiles had a positive impact, and mole drainage, a technique using a system of cylindrical channels formed in the soil by using a tractor to pull a ball or bullet-shaped device through the soil (MAFF 1980, 1) was developed. The Scottish drain-tile industry has, however, declined during the 20th century at a similar pace to that of Scottish heavy ceramics as a whole, with demand for ceramic drains drastically reduced by the development of plastic drainage pipes (Douglas and Oglethorpe 1993, 16). In recent years, work on the technical side of drainage has been carried out by universities and researchers, providing more information on which to base the most efficient and economical methods of draining the various types of soil encountered.

Results from the watching brief (Illus 1–5)

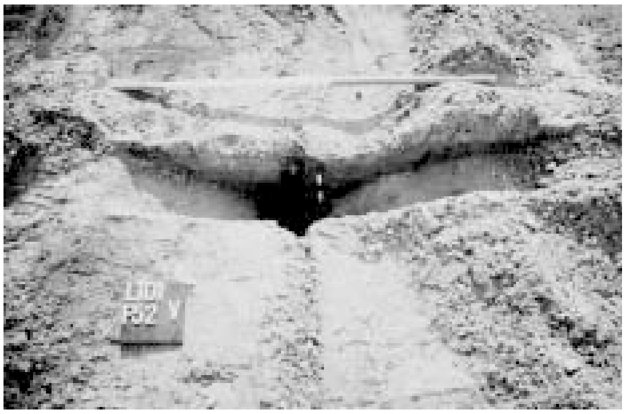
The abundance of field drains recorded during the watching brief illustrates the amount of investment made in draining the land to ensure that it continues to

Illus 2 *Wood-filled main drain or header, in Field 80 (Pitnappie Moss).*

Illus 4 *Three ceramic drains in close proximity, in Field 53 (near Kirkinch).*



Illus 3 *Close-up of wood-filled drain in Field 80 (Pitnappie Moss).*



Illus 5 *A modern field drain in Field 52 (near Kirkinch), backfilled with gravel.*

be viable and effective for agricultural use. It also serves to demonstrate the impact of agricultural improvement in this area. Most of the fields are now large and divided by neat, rectilinear boundaries, enabling the most economic planting and harvesting of a variety of crops.

Almost all the types of field drains referred to above were recorded during the archaeological work, and almost all the fields contained at least some evidence of systematic drainage. In some fields, particularly in Strathmore, NE of Meigle, different systems of field drains were superimposed, with later types constructed across pre-existing drainage systems.

Among the simplest drainage systems recorded were those in the form of open ditches. Many examples were noted, but not all had continued in use; some revealed by the soil-stripping were infilled with topsoil and had become invisible on the ground surface. Most examples were between 1m and 1.5m in width and between 0.8m and 1.2m in depth, narrowing near the bottom. Fenton (1976, 19) refers to the digging of ditches of approximately this form and size during the 18th century.

Stone-lined box drains or culverts, in various states of completeness, were recorded in six fields along the pipeline route. An example recorded in Field 48 (S of

Dean Water, near Harryhill), had been disturbed by later drain construction. Stone-lined drains, which have been in use in Britain since the Roman period (see above) were made by laying flat stones in the bottom of an excavated ditch to form a square or rectangular cross-sectioned drain. A layer of stones, turf, straw, brushwood, rushes or heather was sometimes laid above the box to keep it clean and to provide a permeable layer through which excess water in the ploughsoil could percolate. In Field 48, the stone-lined drain had rounded cobbles loosely packed around and above it.

Distinct from the stone-lined drains, stone-filled drainage channels (larger examples of which were sometimes known as *rumbling syvers*) were narrow, and loosely filled with rounded cobbles or other types of stones (Illus 1). Many examples were recorded archaeologically during this project. Some were filled with angular rubble (eg one recorded SW of Denend), and others with cobbles, probably reflecting what was available in the immediate vicinity. These drains were widespread, not only in Angus but throughout the country, and were being constructed for most of the first half of the 19th century. This method of drainage corresponds with William Smith's preference for shallow, stone-filled drains (see above).

In areas where stones were scarce, woody plants were used instead. The bottoms of wood-filled drains were made narrower, to prevent choking, by means of special draining spades ('dibes'). Wood-filled drains were recorded only in Field 80, a particularly low-lying field in the Pitnappie Moss area with a dark, loamy topsoil and a sandy subsoil. A main wood-filled drain or header was recorded along the eastern edge the field, and a series of wood-filled laterals ran towards this.

The wood filling the drains in Field 80 mainly consisted of single branches, trimmed of their offshoots, and appeared to be ash or a similar wood (Illus 2 and 3). Ash was noted growing nearby, on the marshy ground to the E of the field, around the disused Newtyle to Dundee railway. The branches were laid in the centre or at the sides of the drain cuts, the longest single branch measuring 2.2m and the diameters of the branches varying from 30mm to 110mm. Small, irregular stone slabs had also been placed alongside the cut for the main drain, possibly in an attempt to prevent silting. Possible stake holes were also recorded along the eastern edge of the main drain cut, perhaps representing evidence of an earlier fence alongside the drain. Unfortunately, no dating evidence was recovered from these wood-filled drains, but they may have been early examples, perhaps of 17th- or 18th-century date or possibly even earlier, as they were cut by later, ceramic drains, and by modern plastic drains.

Field 80 was particularly wet, and the stripped area flooded to a depth of up to 0.5m during the archaeological work, following a spell of heavy rain. Clearly, despite the many drains constructed in this field, even in recent times, flooding remains a severe problem.

Examples of ceramic drains using a modified form of mug tile were also recorded during the archaeological work. Mug tiles were among the earliest types of ceramic drains, and had a horseshoe-shaped cross-section, open at the base. Except in the firmest kinds of soils, these open-bottomed tiles were vulnerable to being filled by sand or clay from below, and so they were often laid on top of separate soles of wood or tile, until modified to include an integral ceramic base. With a wider diameter than some of the cylindrical drainage tiles, the mug tiles sometimes proved more successful and remained in use for longer. As with other types of ceramic tiles, minor faults in laying, or subsequent movement, led to them silting up.

A great deal of evidence was also recorded for drainage using cylindrical tiles, dating from the 19th century. These were frequently parts of symmetrical systems, sometimes laid out in a herring-bone pattern, with side drains or laterals running into a main drain or header. Spacing between laterals varied widely, but 5m to around 15m was common. Many of the recorded examples had silted up, particularly in fields where the subsoil was sandy. Silting is also more rapid where the flow of water is variable and in small quantities at times. Silting up is not, however, the only cause of blockages in such pipes. In other parts of Britain, iron-rich mineral deposits have been blamed for causing blockages, especially in the mining areas of Wales, Cornwall, Lancashire and Yorkshire. Blockages can even be caused by animals (eg frogs).

It was clear from the nature and number of drains recorded that several attempts had been made to construct effective drainage systems in some fields. These, logically, tended to be the lowest-lying fields, most prone to saturation and flooding. In Field 53, a particularly wet field to the W of Kirkinch, three sets of ceramic drains of the same type were recorded running in slightly different directions, at depths of 0.18m, 0.3m and 0.45m below the sandy subsoil (Illlus 4). The subsoil here was particularly fine sand, and it is possible that the drains had only had a short effective life. In the adjacent field, a large number of recent field drains was recorded (Illus 5).

Conclusions

Agricultural field drains were the commonest type of feature recorded during this project, and a surprising number of different types were represented. Drainage features were encountered in almost every field, whether used for arable land or as pasture. It was clear that some of the drainage systems were still functioning, at least in part, as water flowed through them towards ditches and burns following heavy rain. Drains that had entirely silted up were also noted.

The majority of the field drains observed probably date from the 18th and 19th centuries, when extensive drainage work was carried out, converting unproductive land into good quality agricultural land. Although the evidence points to their use in large numbers during this period, the construction of stone-filled drains eventually became inefficient, not only because of changing technology but also due to rising labour costs. Twentieth-century systems, such as mole drainage, overcame the need for a large workforce to be employed on drainage projects and made efficient use of the new types of technology available.

This project has provided opportunities to examine and assess the impact of recent improvements to the land, and to gain insights into their relative levels of success or failure. The investigation has demonstrated that agricultural drainage systems vary widely and reflect changing economic circumstances and technologies, even within a limited geographical area.

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Abstract

A watching brief on the construction of a water pipeline in Angus provided an opportunity to examine the evidence for the construction, use and replacement of a variety of types of agricultural drainage systems. This paper discusses the evidence against the background of changing economic circumstances and technologies, and illustrates the wide variation of systems employed, even within a limited geographical area.

Keywords
Angus
drainage
field drains
land improvement

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