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BURGH LE MARSH WINDMILL – Design Statement

Building: **Burgh le Marsh Windmill**
73 High Street
Burgh le Marsh
Skegness
Lincolnshire
PE24 5JT

Document: Design Statement

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Contents

1. Introduction

The windmill at Burgh le Marsh, known as Dobson's Mill after the last family of millers to run it, is one of the UK's most outstanding windmills. It became a Grade I listed building on 28th February 1965 as a result of its special character and rare design features. Most prominent of these are the windmill's five sails which, unusually, rotated clockwise when viewed from the front.

Figure 1: A glass plate negative taken circa 1935. The mill stands in a yard with outbuildings, its five sails, 'ogee' cap and eight-bladed fantail clearly visible. From the Mills Archive Rex Wailes Collection.

Following the end of its commercial life in 1965, the mill was purchased for preservation by East Lindsey District Council. In 1974 it passed into the ownership of Lincolnshire County Council. A commitment to regular repairs and maintenance from both Councils ensured the mill remained in full working order throughout its retirement. Since 1984 the windmill has been regularly operated by a team of volunteers to produce flour for demonstration.

A full restoration of the rotating cap roof and sails was commissioned in 2013. This involved the removal of the cap to ground level, renewal of the timber base frame and fan stage, renewal of the sails and a mechanical overhaul of the upper gearing.

Unfortunately, while the eight-bladed fantail was again being repaired shortly after the main restoration works, the windmill became a victim of Storm Ciara on Sunday 9th February 2020, and was extensively damaged. The cap and its five sails were 'tailwinded' and blown clear of the brick tower, which remained virtually unharmed.

Subsequently the wreckage was cleared away and stored off site, allowing the outbuildings on the site to be repaired where they had been crushed by falling debris. A temporary metal-framed roof was installed on top of the windmill tower to protect its floors and internal machinery from damage by the elements.

2. The structure

Apart from a small number of unusual design features, Dobson's Mill represents a typical Lincolnshire tower windmill of medium size. It is taller than the smallest mills in the county, such as the incomplete three-floored example at Stickford, but significantly smaller in height and girth than the larger mills such as Heckington and Moulton with their substantial towers and external balconies set at a high level.

Burgh's circular **brick tower** measures 7.3m in diameter externally at ground floor level and tapers to an external diameter of 4.3m at its apex over a height of 15m. It contains six storeys, with a raised ground floor and five boarded floors above it. The ground, first and second floors are lit by two windows each, while the three floors above have windows to each of the four elevations. The top, or dust floor – as at many Lincolnshire tower mills – is unlit.

Inside the mill, some changes to the layout of the machinery have occurred since the mill was constructed, at an unconfirmed date during the first half of the 19th century. For example, the two opposing windows on the first floor were formerly doors and would have given access to an external **balcony** that once encircled the tower at this level.

The floor height clearances gradually diminish from the ground to the fourth floor, measuring 2.86m (ground), 2.63m (first), 2.61m (second), 2.56m (third) and 2.33m (fourth). The **millstones** are located on the second floor, with two spacious floors for flour mixing and bagging below them and two more congested floors for grain storage above them, plus the unlit dust floor which is located only 1.32m below the tower top.

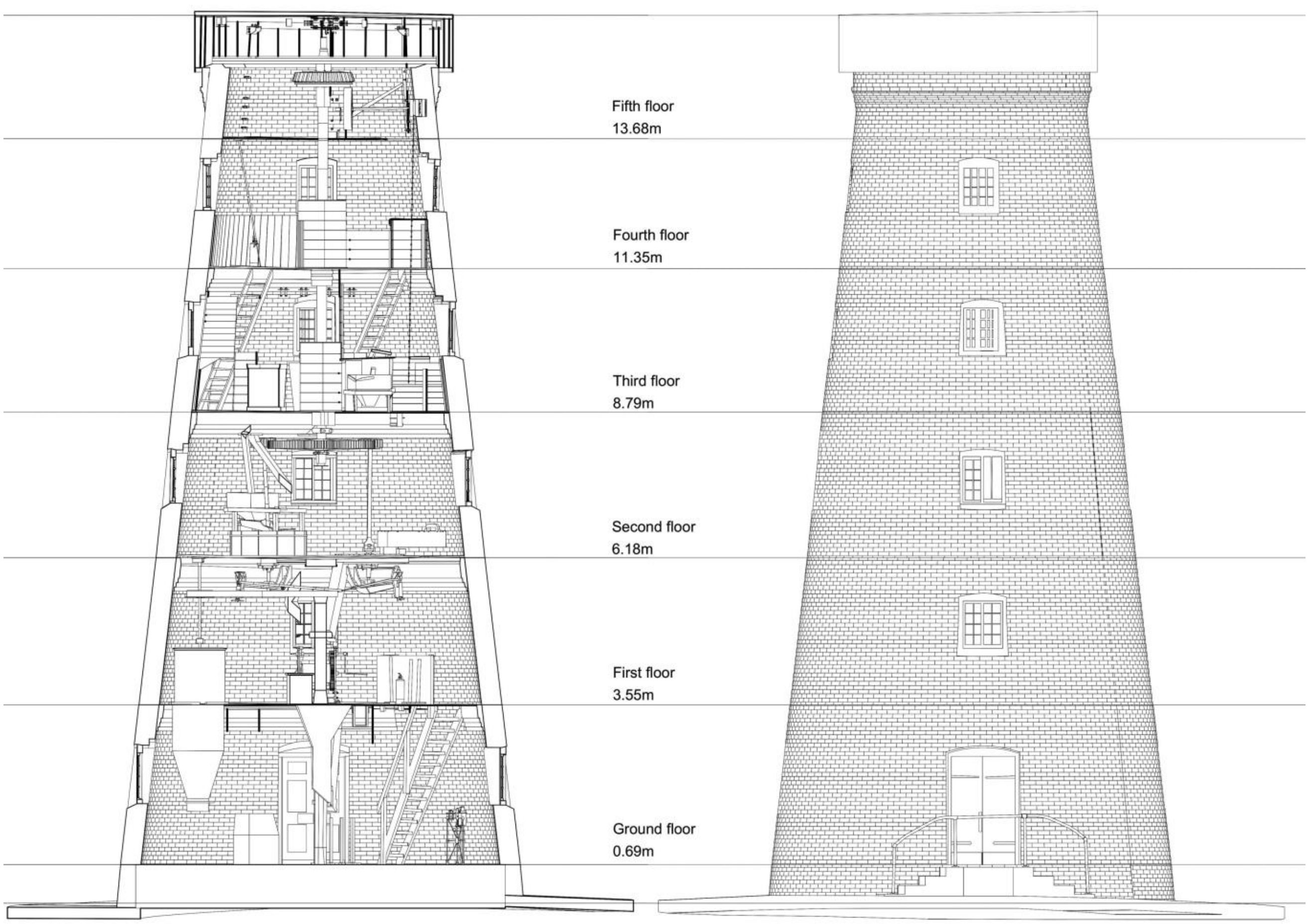


Figure 2: The decapitated tower of Burgh le Marsh Mill: Section through the tower facing north west (left) and external elevation facing south east. Drawings by Surveyline Geomatics Ltd.

3. The curb, cap frame and fan stage

The **cap roof** of the windmill has an onion-shaped or **'ogee'** profile and is circular in plan. It is both a structural and a mechanical element of the windmill. The cap functions to protect the brick tower of the mill from the weather. It also rotates in response to changes in wind direction so that the sails, which are supported by the cap's substantial base frame, face the oncoming wind at all times.

The cap is kept head to wind by the **fantail** (Section 4 below), a set of eight blades positioned above the rear of the cap on a cantilevered external timber framework. A series of shafts and reduction gears convey the movement of the fantail to the **curb** – a segmental cast iron ring fixed securely to the circular brickwork forming the top of the tower. As the wind changes, the fantail rotates one way or the other to steer the cap slowly around so that the front wall of the cap always faces the wind. The fantail is free to operate at all times of the day and night – whenever the wind direction changes.

The mill's five **sails** (Section 5 below) are supported by the front of the cap, which is substantially framed in order to bear their weight. An inclined shaft of cast iron – the **windshaft** – is carried by **'neck'** and **'tail' bearings** at the front and rear of the cap respectively. Only the forward end of the windshaft extends into the weather. Here, a heavy five-armed **sail cross** is fitted. Each sail is securely bolted and clamped to one of the five arms of the cross.

The base frame of the cap comprises a heavy oak framework built on a pair of fore-aft timbers known as **sheers**. These are not set parallel to one another, but at a slight angle to the centre line, so they draw closer together from front to rear. The forward ends of the sheers are increased in depth by a pair of thick overlay timbers or **'sheer planks'**.

Spanning between the sheers are five transverse timbers which support the neck and tail bearings, the top bearing of the central upright shaft, the winding gear cluster and the rear striking gear. Two pairs of raking timbers – the **spears** and the **spurns** - rise from the rear of the cap frame and pass out through the roof to support the eight-bladed fantail.

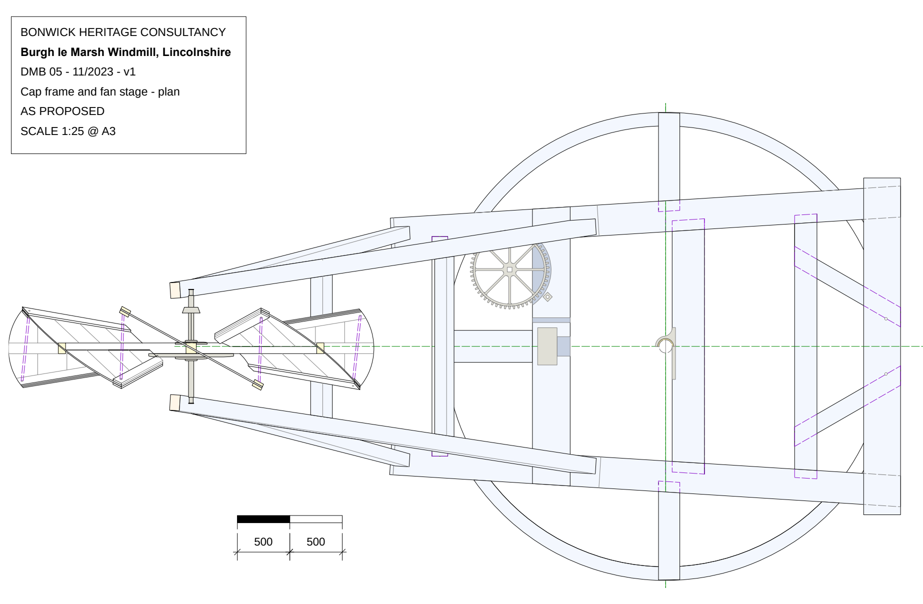


Figure 3: Cap frame and fantail supports, viewed in plan. Scale in millimetres.

4. The fantail and winding gear

The eight-bladed fantail is 3.5m (11’6”) in diameter overall and is set at right angles to the main sails. Each blade consists of a tapering softwood **board** passing through an angled slot in a central oak **stock**, into which the board is securely bolted. Metal stay rods at the periphery of each board connect it to the neighbouring one. The stocks are fastened to an eight-armed hub at the centre. This is keyed onto a short wrought iron shaft, the **fan spindle**, the ends of which are carried on bearings bolted to the upper ends of the spears.

The motion of the fantail is transmitted to the curb via three pairs of bevel gears, a pair of spur gears and a final spur pinion that engages with a ring of inward-facing teeth on the curb. The smaller gear in each pair drives the larger one, resulting in a significant reduction in the number of revolutions between fantail and curb. To rotate the cap through 360 degrees – a situation which would never occur in reality – approximately 790 revolutions of the fantail would be needed. This makes the fantail highly sensitive and thus responsive to small variations in wind direction.

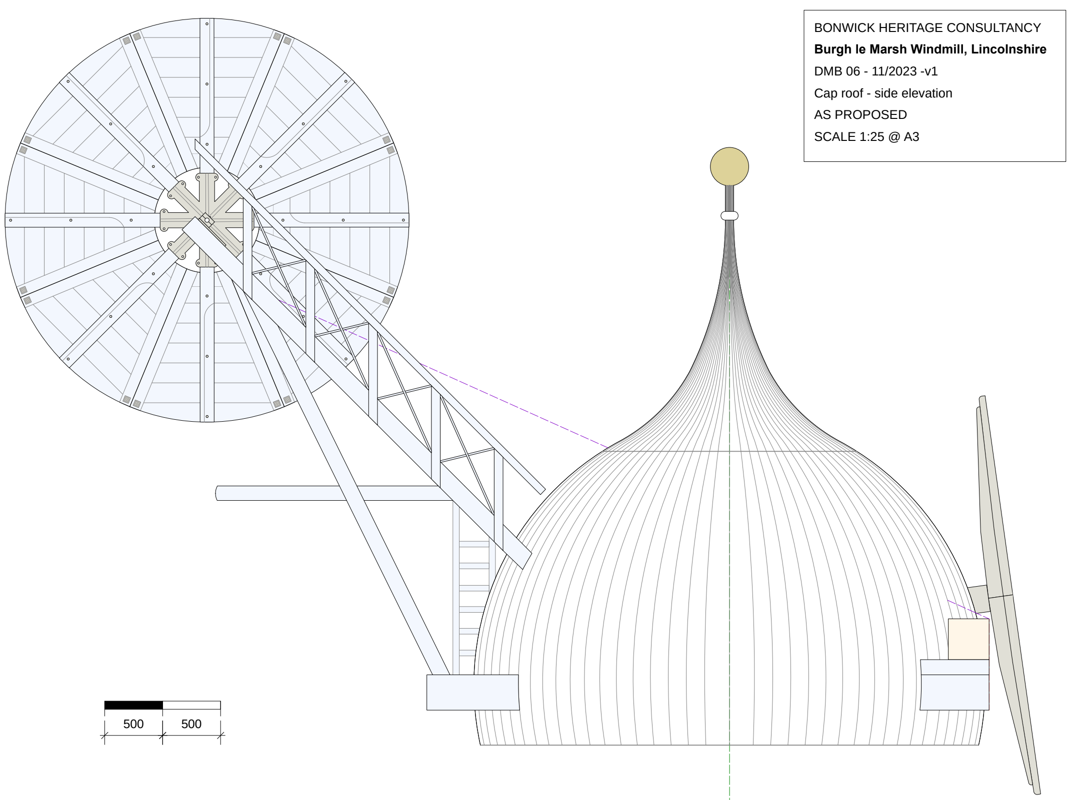


Figure 4: The ogee-shaped cap roof and fan stage in side elevation, showing the sail cross at the front of the cap and the fantail at the rear. Scale in millimetres.

5. The sails

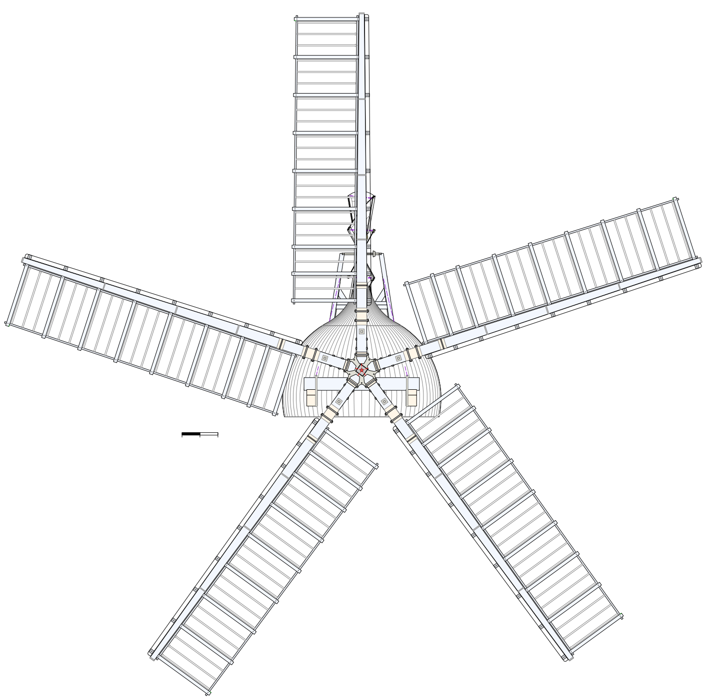
Each of the five sail frames is built around a timber backbone, the **whip**, which is 9.75m (32ft) in length. The whip tapers from the inner or **heel end**, where its maximum section is 280mm wide and 314mm deep, to the outer or **point end** which is 140mm square.

The framing of the sail comprises two longitudinal **rules**, an inner and an outer one, and nine **bars** which are positioned perpendicular to the whip and rules. The bars are arranged to form six large and two smaller gaps, known as **bays**. A series of 22 adjustable shutters, or **shades**, are distributed among the bays, three in the larger ones and two in the smaller ones. The shutters are set parallel to the sail bars, their hinges being carried by the inner and the outer rules.

Each sail bar passes through the sail whip at a particular angle, which varies from 22 degrees at the heel to 12 degrees at the point. This gives the sail an aerodynamic twist, known as the **angle of weather**. At Burgh le Marsh Mill, there is only one row of shutters per sail, positioned on the trailing or **driving** side of the whip. A longitudinal **weatherboard**, 115mm wide, connects the shorter, protruding ends of the bars on the **leading** side of the whip.

As the sails of Burgh Mill turn clockwise when viewed from the front, the set-out of the sail is reversed when compared with most other windmills in the county. When standing outside the mill, facing the sails, the shutters on the lowest sail are on the right hand side of the whip. When standing inside the cap, facing the front, the brake mechanism that controls the sails is located on the left hand side. It is probably the location of the brake lever which causes this to be termed a **'left-handed mill'.**

Another unusual feature of the sails at Burgh le Marsh is the position of the shutter hinges relative to the sail bars. On the mill's lowest sail, the nearest shutters are set so their hinges are placed immediately above the sail bar, rather than immediately below it, as is more usual. In effect, each shutter is fitted to the sail 'upside down' when compared with most other mills. Burgh Mill shares the **'above bar'** arrangement with Alford and Heckington mills. Ellis' Mill at Lincoln, by contrast, has the more common arrangement of 'below bar' shutters. At Lincoln, the sails are double sided, with two rows of shutters – a narrower set on the leading side and a wider set on the driving side.



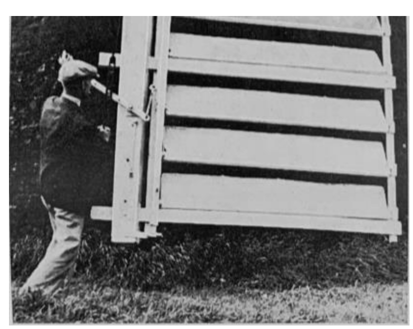


Figure 5: Front elevation of the cap and five sails, showing their clockwise direction of rotation and (photo) 'above bar' shades.

6. The internal gearing

Although there is some confusion as to the construction date of the mill, an inspection of the interior woodwork provides evidence of alteration to the as-built arrangement. This was relatively common practice, as many windmills were periodically updated with new technology as it became available – provided the mill owner could afford it.

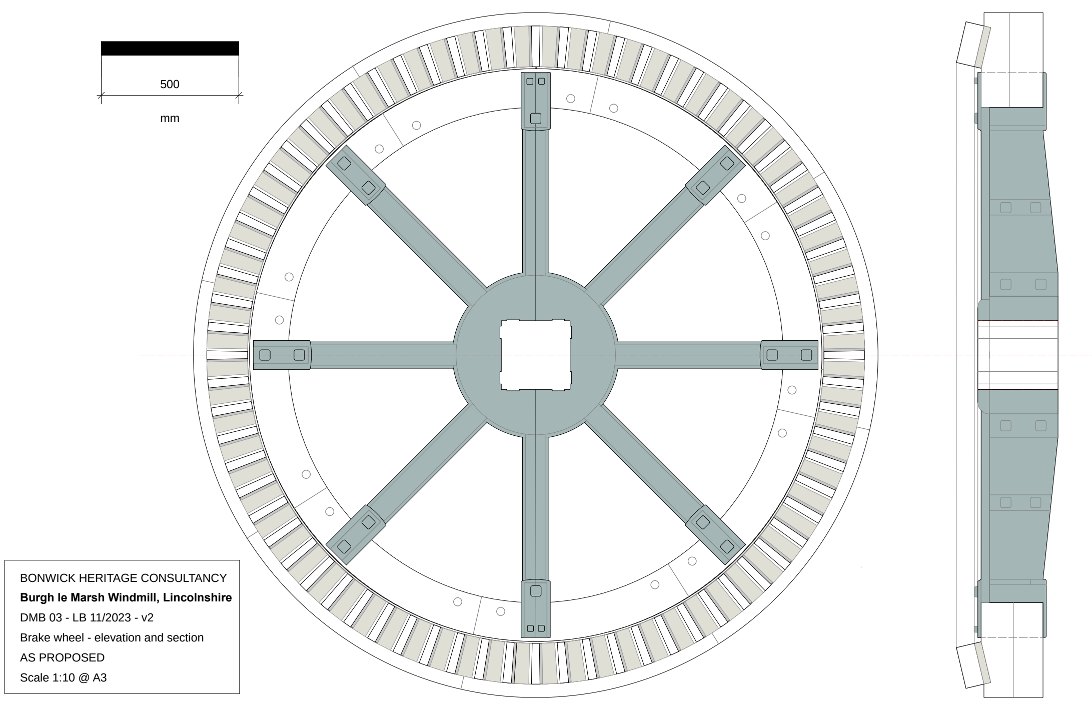
What is clear is that a tower mill was standing on this site by 1810, and an early painting shows a four-sailed mill with an ogee cap but no fantail. The windows at first floor level were originally opposing doorways, giving access to an external reefing stage or balcony.

At some time during its working life, the mill was updated with five patent sails, a fantail and – very probably – a replacement set of internal machinery. James Waterfield, the last of a long line of professional Lincolnshire windmillers, has identified parallels in the design of the gearing at Burgh with that of Alford Mill. Here, the great spur wheel bears the name of its maker, Tuxford of Boston. This ironworks commenced trading in 1828, and Waterfield therefore estimates that the gearing at Burgh, if it is the work of Tuxford, was installed between circa 1835-45. This aligns with a much-quoted construction date for the mill of 1844 - which is clearly incorrect, but could indicate the date of a major refit.

The principal gearing inside the mill, as now existing, largely follows standard Lincolnshire tower mill practice. The arrangement of the gearing and machinery over five floors is conducive to highly efficient operation of the windmill. This is unsurprising, as Lincolnshire tower mills of the 19th century – including those in adjoining counties such as East Yorkshire - were superior in design to their counterparts in most other regions of the UK.

Certain components of Burgh Mill are particularly refined in terms of their construction. The **brake wheel**, for example, is both substantial and elegant, comprising an eight-armed hub cast in halves carrying a hardwood ring which is fitted with sectional iron teeth. The segmental wooden ring forms the braking surface; it is made in two layers dowelled together. The overall diameter of the wheel is 2.49m (8ft 2in).

The brake wheel was severely damaged in the tailwinding episode of February 2020 (see Section 7 below).



The teeth of the brake wheel engaged the wooden cogs of the **crown wheel**, a bevelled gear wheel fitted to the top of the mill's central **upright shaft**, and visually prominent at the top of the mill tower. The gear ratio between brake wheel and crown wheel is 72:32, meaning that the upright shaft rotated 2.25 times for every revolution of the sails.

The lower face of the crown wheel transmitted power to the **sack hoist** by way of a friction ring driving a flat pulley of large diameter mounted on a slim horizontal shaft. A control cord passing down through the floors allowed the sack hoist to be operated from anywhere in the mill.

The upright shaft itself is of cast iron and formed in three sections, with heavy **'dog clutch'** couplings positioned at third and fourth floor levels.

Three pairs of millstones – one of French Burr and two of Derbyshire grey - are located on the second floor of the mill. As is usual in the county, the **great spur wheel** that drives them is positioned over the millstones, above head height on the second floor – an arrangement known as **'overdrift'**. The great spur wheel, a single-piece iron casting, has eight radial arms and a pitch circle diameter of 1.880m (6ft 2in).

Grouped around the great spur wheel are four wooden-geared spur pinions, or **stone nuts,** of cast iron. Three of these drove the millstones while a fourth conveyed power from the engine drive gearing below. Empty bearing positions indicate the locations of two additional nuts, removed many years ago. The gear ratio between spur wheel and stone nuts is 103:22, or 1:4.68. Overall, the ratio between sails and millstones is 1:10.53.

The two floors above the millstones are used for the storage of grain. Partitioned **grain bins** are arranged around the central upright shaft. These are built from softwood and have an aged appearance, contributing significantly to the traditional atmosphere of the mill's interior. A refined feature is the raised **pulpit** over the sack hoist well which enabled the miller to shoulder heavy grain sacks with ease.

On the floor below the millstones, three **meal spouts** converge at the centre of the floor to deliver ground meal from the millstones. These are the originals, showing a well-worn patina. The bridge trees, governors and hand tentering gear are visible at this level.

Also on this floor is a mid-20th century **mixing machine** bearing a maker's name plate of local millwrights Thompsons of Alford. The cylindrical upper part of the mixer narrows to a cone on the floor below. A fourth pair of millstones, located on the first floor, were fed by an **elevator** and driven via the bevelled **engine drive gearing** visible on the ground floor. These are connected to a flat belt pulley which can be seen on the exterior of the mill tower, opposite the main door.

The mill contains numerous other small details and features of interest, including a small miller's desk that could be folded down when not in use; turned wooden handles on the sack hoist operating cord; a hand winch by Wilkinson Wright & Co of Boston; and carefully designed twisted ladders between floors to accommodate the tapering curve of the brick tower.

7. Storm damage in February 2020

A ‘tailwinding’ situation is a windmiller’s worst nightmare. Windmills are designed to withstand winds of considerable strength, but only if these strike the front face of the sail assembly. If the wind veers around and strikes the sails from the rear, the cap will become unbalanced and – as was the case at Burgh le Marsh – the cap and sails may become completely detached from the brick tower.

The tailwinding situation occurred because the eight-bladed fantail, which is designed to automatically keep the sails facing the oncoming wind, was out of action and had been lowered to ground level. During Storm Ciara, the southerly wind struck the cap of the mill from the rear, causing the five sails to rotate backwards against the brake. The strength of the wind forced the shades in the sails to close against the striking gear, increasing the sail area and enabling the sails to rotate faster.

The pressure of the wind on the rear face of the sails forced them forwards, out of the cap, causing the tail journal of the windshaft to attempt to rise out of its bearing. The guide sheaves or centring wheels, attached to the lower face of the cap frame, were initially prevented from rising by the overhang of the teeth on the inside of the curb. Eventually the guide sheaves failed, allowing the tail end of the cap to lift with the windshaft.

The strength of the wind finally overbalanced the rotating sails, drawing the windshaft forwards and outwards. The rotating sails smashed themselves to pieces as they fell on neighbouring buildings, breaking all five arms off the sail cross as they did so and scattering their shades across the yard.

The cap frame and roof followed the brake wheel and windshaft to the ground, landing upside down on top of the remains of the sails and cross. The cast iron arms and wooden rim of the brake wheel were shattered as they parted company with the windshaft.

Soon after the event, a temporary metal roof was constructed on top of the tower to protect the floors and surviving working parts from damage by the elements.

The remains of the cap and sails were removed from the site and subsequently transported to a millwright’s workshop for safe storage. Here, the condition of the surviving components was assessed in detail and accurate dimensions of the broken parts were taken.

Figure 6: The decapitated windmill in February 2020, showing debris from the shattered cap and sails strewn across the yard.

Photograph credit

8. Reconstruction of the cap and sails

Traditional millwrighting techniques, like those used during the original construction of the mill in the 19th century, can be used once again to reconstruct the shattered upper parts of the windmill.

Although all of the large components have been damaged beyond repair, a detailed analysis of their remains has allowed accurate design drawings of each part to be made. This analysis has been aided by numerous photographs of the windmill taken during its working days, and others taken during the process of restoration in 2013, which show exactly how each of the wooden and metal elements fitted together.

Some of the smaller metal gear wheels, brackets, fixings and fittings from the cap and sails survive intact and are capable of being re-used. When the cap and sails are reconstructed, elements of the original fabric will be incorporated wherever it is considered possible and safe to do so.

The first stage of the process of making new cast iron components will involve the manufacture of full size wooden patterns. Some of these, such as the pattern for the five-armed sail cross, will be very large indeed (Figure 7).

A sand mould will be created using the patterns, and molten iron poured in to create metal components of the correct size and shape (Figures 8-11). Once cooled, the castings will be fettled to remove excess material and their working surfaces will be accurately machined to enable them to rotate or pivot smoothly.

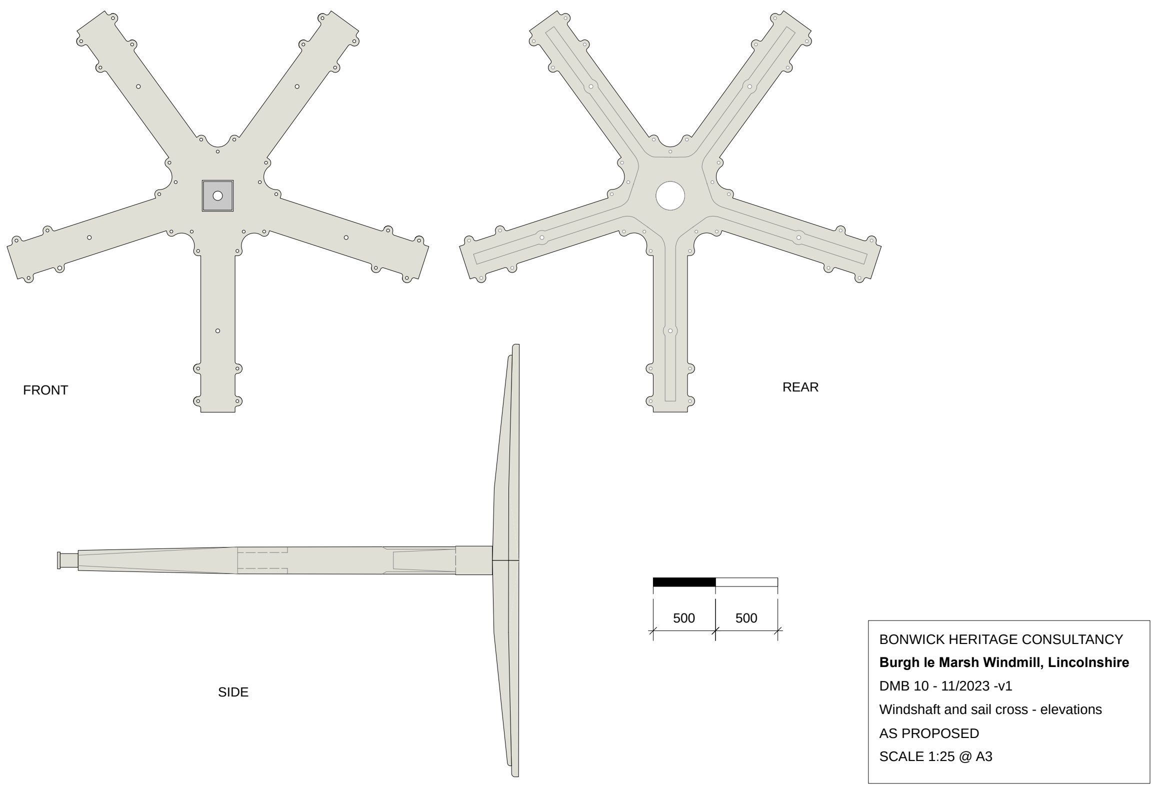


Figure 7: Reconstruction drawing of the five-armed sail cross and windshaft. These large cast iron components have been damaged beyond repair and accurate replacements will be required.

Figures 8-11: The process of making a new sail cross. These examples from a four-sailed mill show the different stages of the process:

Making a full-sized wooden pattern (top left); creating a sand mould (top right); pouring molten iron into a mould (lower left); the finished cross and windshaft loaded on a flatbed lorry for transport to the site (bottom right).

Photographs 8 & 9 courtesy of James Waterfield.
Photographs 10 & 11 courtesy of Adam Marriott.

END OF REPORT