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Wind & Water in the Middle Ages

Fluid Technologies from Antiquity to the Renaissance

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Fluid Technologies from Antiquity to the Renaissance

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Contents

Mills in Medieval Ireland: Looking Beyond Design

Niall Brady (The Discovery Programme, Dublin)

The presence of Ireland in any discussion on medieval milling is well established.[1] A substantial body of archaeological and documentary evidence survives and seventh-century examples of both horizontal and vertical wheeled watermills are known from there.[2] Attention has focussed on issues relating to mill design and on celebrating the fact that such early sites survive.[3] There has, however, been little discussion of other issues or on mills during the later medieval period. Yet a study of mill sites in medieval Ireland presents the opportunity to look beyond the essential issues that have captivated previous researchers. The mill also represents a touchstone to wider issues relating to the development of the agrarian economy. In discussing the period before 1100, it is possible to argue for a revision of our common understanding that the economy operated at a subsistence level; the character of early mill sites does not sit comfortably within this context. In considering milling in the greater Dublin area after 1100, it is increasingly possible to describe patterns of mill construction, mill ownership, and mill value in the region that served as the hinterland to the medieval capital city.

Mill Design in Medieval Ireland

The study of medieval mill sites in Ireland has attracted scholars since the 1800s when various discoveries were reported in the national archaeological journals. In 1853, the first volume of what was to become the *Journal of the Royal Society of Antiquaries of Ireland* included an anonymous piece that brought together information from a range of sites that had been uncovered during agricultural works in counties Laois, Kilkenny, and Cork.[4] The paper sought to confirm the contexts of discovery as mill sites and argued that the mills were early medieval in date (*c.*500-1100 AD) on the basis of their proximity to ringforts, enclosed settlements of the period. Such a dating context was supported by the body of

references to mills in the early law tracts from the same period, and this evidence was used to refute an eighteenth-century view that Ireland lacked the apparatus of milling until the arrival of the Anglo-Normans in 1169. Further descriptions of discoveries were made in the 1850s and the early 1900s, but it was not until 1953 that a definitive account on the horizontal watermill in Ireland was presented by A.T. Lucas.[5]

Working from the National Museum of Ireland in Dublin, Lucas wrote a paper that set out the parameters of mill studies for the next five decades. He described the various discoveries of mills up to 1952, and focussed on the discovery of the near-intact basal remains of a watermill in the Irish midlands at Morrett, Co. Laois. His interest was in the complexity of construction, and Lucas argued that it was most important to record each site in detail so that one could appreciate how the mill operated. His work contributed to the study of early medieval milling in general, and his paper is recognized as taking the understanding of watermills further than Curwen's broader essay of 1944.[6] In discussing the larger European progression of watermill design, Barceló has commented that Lucas was the first to be interested in the details of mill construction to the extent that differences in paddle blade shape and form could reveal simple or more complex mill designs. His awareness of the associated features of mill ponds, mill races, and mill dams also drew attention to the larger landscape context of milling.

The application of dendrochronology, or tree-ring dating, in the 1970s transformed the study of milling because it permitted the close dating of individual sites. With a master sequence of oak in Ireland developed at the Palaeoecology Centre of the Queen's University Belfast, supposition and the testing of supporting evidence then allowed clear chronological contexts for these sites. The early date of various mill sites was confirmed.[7] Colin Rynne, in turn, has continued the focus on mill design and has contributed a number of important insights. The recognition in the archaeological record of the vertical watermill as well as the horizontal watermill was perhaps his first important observation. Building on the work of Edward Fahy, who questioned the engineering details of the mill highlighted by Lucas at Morrett, Rynne noted the lack of any obvious mechanism to jet water vertically from a height as might be expected in a horizontal mill.[8] In its place, the penstock was positioned at the same level as the trough where the water could be introduced on a horizontal trajectory to a driving wheel. This arrangement is entirely in keeping with vertical mills, and Rynne has redefined Morrett as the remains of a vertical undershot mill.[9] The site was also securely dated by dendrochronology to 770.[10] Rynne highlighted a still earlier vertical watermill that came to light as part of a rescue excavation in 1977-1978

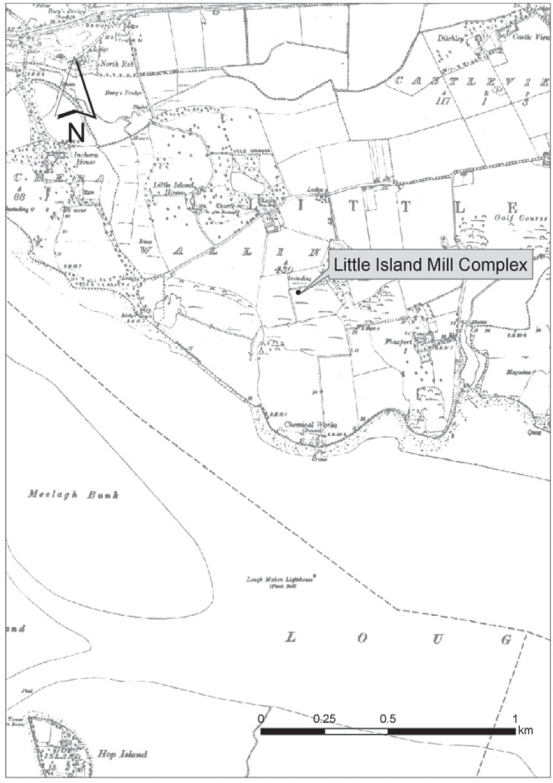

Figure 1: **Little Island, Co. Cork, site location based on Ordnance Survey mapping.** Source: The Discovery Programme.

Note that the location of the mill is some distance inland of the shoreline. This feature is apparent at other tidal mill sites in Ireland, and may suggest a conscious attempt to minimize exposure to storm-filled seas.

in Cork Harbour on reclaimed land at Little Island, and dated to *c.*630.[11] (Fig. 1) The Little Island milling complex was tidal and produced the remains of a horizontal watermill from the same period. It appears that the horizontal mill was designed to power two mill wheels simultaneously, and it is likely that both the vertical and the horizontal watermills were operated at the same time. Such levels of competency are reflected in other watermill sites across the country and suggest the presence of regional variation in milling types at an early date.[12]

Historians have produced further insight, concentrating on the references to mills in the early Irish law tracts—vernacular law codes that have come down to us as "sacred texts"—which were in turn glossed and commented on at a later date. Gearóid Mac Eoin, for example, has highlighted the Old Irish law tract on Distraint, *De ceithri slichtaib Athgabála*—On the four divisions of distraint (also cited as *Di Chetharshlicht Athgabála*)—which lists the parts that served a

horizontal watermill, and has presented them as further evidence for the presence of such mills in the early seventh century and possibly earlier:[13]

Im ocht mbullu ara-fognat muilenn: (1) Topur (2), tuidin (3), tir linde (4), lia (5), mol (6), indeoin (7), ermtiu[d] (8), orcel (9), milaire (10), cup (11), comla (12).	Together with the eight parts that serve a mill: (1) The water source (2), the mill race (3), the land of the pond (4), the upper stone (5), the shaft (6), the lower stone (7), the point of the shaft (8), the chute (9), the pivot stone (10), the hopper (11), the sluicegate (12).

The casual discovery of mill sites by archaeologists across the country continues to build on these essential foundations and to confirm the presence of both horizontal wheeled watermills and vertical undershot watermills throughout the early medieval period.

In 1999, archaeologists studying the intertidal foreshore of Strangford Lough, Co. Down, at the opposite end of the country from Cork, made another early discovery.[14] What began as the excavation of a kelp-strewn stone embankment thought to be a fish trap on the foreshore below the monastic site of Nendrum quickly turned into the excavation of a tidal mill complex. A series of sea walls defining a series of mill ponds emerged. At the head of the primary embankment, excavators focussed their attention on the ruins of up to three consecutive mills. The mills were all horizontal types, and the latest design included a stone wheelhouse. Dating of the large collection of timbers from the various mills and associated features indicates that the mill pond for the first mill was built in 619-621 and enclosed a surface area of 6500m^2. The third and final mill retained timbers dated to 788 and a large intact sandstone flume measuring 3.41m long and 98cm wide. A preliminary account of the excavation suggests an energy output of 1,750-2,250 kWh per annum. It is hoped that the quality of information which survives at Nendrum will in time allow the excavators to consider the volumes of grain that could be processed at the mill site during its period of use.

There have been two other recent discoveries, and both are currently in the process of being analyzed. The first new discovery is another series of horizontal mills associated with a monastic complex.[15] The discovery was made at Raystown, Co. Meath, as part of a national roads scheme project. The excavator has uncovered the remains of six horizontal watermills and associated mill races within a site that includes five corn-drying kilns, bowl furnaces, and the remains of other work activity, as well as burials. It is thought that a pair of mills was in continuous use and that a new watermill was built when the existing mill went

out of use. The date range may extend from the sixth to the twelfth centuries. Without doubt, the nature of the evidence at Raystown bespeaks an elaborate and long-term commitment to the processing of cereal grains in early medieval Ireland. The second recent discovery is that of a vertical undershot watermill that appears to have been a tidal mill as well. The mill was identified during another road-building scheme, this time at Killoteran, Co. Waterford.[16] The interest attached to the site is heightened by the dates that are emerging. Carbon-14 determinations indicate that the mill was used between the fourth and seventh centuries, which makes it the earliest mill site discovered so far in Ireland.[17] The present finding calls to mind a useful essay on early Irish agriculture written in 1944, which noted that the Old Irish word for watermill—*muilenn*—was a Latin borrowing from *molina*.[18] In noting this, Michael Duignan highlighted the Romano-British world in the third-fourth centuries as the obvious source area for milling practices in medieval Ireland. Sixty years on, if the radiocarbon dating proves to be accurate, it appears that archaeologists have been able to discover substantial supporting evidence, and in doing so have dramatically exposed what has been a rather invisible period in the country's archaeological record.

If it is the case that watermills in early medieval Ireland have attracted considerable attention, it is equally the case that mills in the later medieval period have not. The body of archaeological data for milling in the period after 1100 is less substantial. Although references to specific mills are more plentiful, fewer sites have been identified on the ground, and still fewer excavated. Nevertheless both the horizontal wheeled watermill and the vertical undershot watermill continued in use. The windmill is mentioned from the late thirteenth century, but references are few.[19] The use of fulling mills is recorded at Clones, Co. Monaghan, in 1211-12, and in Youghal, Co. Cork, in the late 1270s.[20] A water-powered forge has been identified in a thirteenth- or fourteenth-century context in Cork city.[21] The sense of a more diversified application of mechanical power is clear, if a little less visible and somewhat later than the pattern in neighbouring Britain. It is not until the more widespread and numerous sources of the seventeenth century that reference to industrial mills, such as fulling mills (also known as Tuck mills at this time in Ireland), becomes in any sense a common occurrence.

The remains of later medieval mills do not survive above ground, and the excavated examples have been exclusively at watermill sites or on mill-races. It is still the case that only the basal working levels of a mill-site survive for examination; namely, the timberworks associated with troughs, sluices, dams, penstocks, and occasionally the wheelhouse. The most recent archaeological work published

is that of Colin Rynne, reporting on a city excavation site at Patrick Street in Dublin which unearthed a vertical undershot waterwheel.[22] Its earliest identified level has been dated to the mid-thirteenth century and it was extensively rebuilt in the later fourteenth century, when it was accompanied by substantial stone revetments to the inlet and outlet channels which were part of a process of canalization on the underlying river. The archaeologists believed that the excavated mill lasted in use until the early seventeenth century when we know Forde's mill occupied the west side of the street, and may well have had a still earlier ancestry on the basis that the millstreams are thought to have been in existence from the late twelfth century.[23]

A sense of the historical development of the mill and its associated water courses is provided by the records that survive for a neighbouring mill associated with St. Patrick's Cathedral which, in their own way, reveal the sometimes intermittent or discontinuous use of such sites in Ireland. In 1326, the Shyreclap Mill generated an annual rent of 70s, and in 1371 Abbot Thomas Minot demised in farm (*i.e.*, leased)

> to John [Pasvaund, citizen of Dublin] the site of the mill … now altogether thrown down and void, to rebuild a mill there at his own expense … to have and to hold the said site and mill when rebuilt, with the ancient mill-course and current, ingress and egress (for all going to the mill and willing to grind there) by a certain bridge over the water-course beside the mill on the south: for 60 years, without rent for two years … in consideration of his outlay; and after …[that] at 20s a year ... Lest the water-course should be impeded the archbishop grants John custody of the pond, stone bridge and "flodrates" during the term.[24]

If the mills on Patrick Street are representative of later medieval milling in general, then the substantive contribution which these sites have to make relates to the context they occupy. The urban location is new, while the upgrading and canalization of watercourses and associated features of an active river channel reveals a scale and organization of production that has not been so apparent previously. There are comparisons to be made with the development of hydro-technology in medieval London, but on a more modest scale.[25] In the third section of this paper, an attempt will be made to look beyond the isolated instance of the later mills to consider the broader patterns they form on a regional scale. In the meantime it is appropriate to consider the wider context of milling in the period before the twelfth century.

The Distribution and Dating of Mills in Early Medieval Ireland

The distribution of archaeologically attested early medieval mill sites is based on a range of sources that includes fifty-five sites identified by the National Museum of Ireland in an unpublished catalogue compiled by A.T. Lucas and Brendán Ó Ríordáin in 1970 (Fig. 2). Many of these sites form the baseline data to Rynne's work, and his survey of milling published in 2000 serves as a check and re-affirmation of this information. The distribution also includes the more recent discoveries. The map represents locations where indisputable structural remains have been identified and reasonably well dated, be they intact mill wheels, base-plates, flumes, paddles, mill races, dams, or parts thereof.[26] The isolated occurrences of millstones have not been included as they are less readily datable and are prone to be more mobile, with the result that the find-place may not necessarily be where the millstone was originally used.[27] Mill sites that are attested to exclusively in the historical record are not included in Figure 2 either, as the problems associated with geo-referencing placenames and dating such notices from early medieval sources represent a significant challenge in their own right, and one that lies beyond the scope of the present paper.

Perhaps the most apparent feature of the distribution is the extent to which the spread of sites is not an even one across the country. The contemporary settlements of the period, the earthen or stone enclosures known as ringforts, are found across the country, and apart from the west and northwest in counties Galway, northern Mayo, and Donegal, it is difficult to identify large areas where such sites are poorly represented.[28] In contrast, the concentration of mills in the east and south of Ireland is quite clear, and this must suggest the primary areas of active arable cultivation in the early medieval period. The distribution of mills is also focussed in areas of the more fertile soil groups which supports this observation.[29] There are locations where mills occur on what is today bogland, but in such instances the wet ground is localized and may be related to the need for access to water sources for the particular mill. It would be incorrect to assume that the mills are located on the only good arable land in the country. There are tracts of cultivable soils in the very southeast and elsewhere where few mills have been identified. It is perhaps more accurate to note that there are few mills located in areas where poor soil cover predominates. To balance this picture, it should be not be forgotten that hand querns are a typical occurrence on any early medieval site across the country, and therefore the distribution of mills is not an indica-

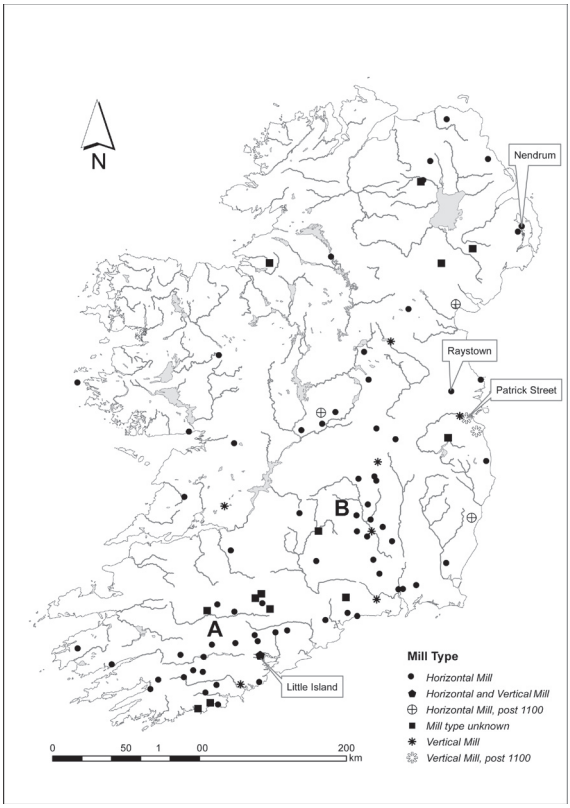

Figure 2: **The Distribution of Early Medieval and Dated Mills in Ireland.** Source: The Discovery Programme. The letters A and B refer to concentrations of mill sites discussed in the text.

tion of the limits of arable cultivation, but rather highlights where cultivation and processing was most intense.[30]

The early mill sites are generally not built on specific river channels. While there are exceptions, most sites were removed from the main channel and are situated on or adjacent to lesser streams that would in turn flow into a larger river. It is also clear that the mill distribution has two focal areas. Twenty-seven sites are located in Co. Cork alone, in the south of the country (Fig. 2, area A). These tend to be situated along the main river valleys oriented east-west, and along the coast. The second focal point occurs along the River Nore to the east, where twelve sites are found within the river's catchment area in Co. Kilkenny (Fig. 2, area B). The majority of the remaining sites lie in the midland counties and the northeast of the country.

The bulk of the sites that survive are horizontal watermills. Vertical wheeled mills are fewer in number (nine out of a total of ninety-seven) but appear to have

become more numerous in the later middle ages. As the example from Patrick Street in Dublin suggests, these mills are associated with more robust and elaborate contexts.

It would be worthwhile to compare the distribution of mills with other aspects of agrarian technology, but this is an aspiration for future study since such work is in its infancy. The case of the plough was addressed several years ago, and while it is possible to generate a distribution of surviving plough irons (iron shares and coulters), the use of the plough proper is witnessed only from the tenth century, before which the evidence suggests that the ard, or scratch plough, predominated.[31] Any comparison with the distribution of mills must also take into account chronological distinctions. Indeed, the distribution of plough irons lies in the northeast and north-central area of the country. It does not echo the southern and southeastern focus of mill sites, and is more in keeping with the distribution of early Viking Age finds and burials.[32] This tends to confirm an origin for the plough in Ireland as a Viking Age phenomenon, but it adds little to the issue of the mill. Further comparative spatial analyses are needed, and at present the mill stands in relative isolation.

The number of mill sites that now exist, however, have begun to provide a critical mass of information that has uses for dating considerations. Of the ninety-seven mills, forty-three sites can be clearly dated (Table 1). Figure 3 simplifies the raw data of Table 1 by showing the chronological spread of sites between the earliest occurrence in what appears to be a fourth-century context, and the latest closely dated site in the thirteenth century. The picture emphasises the chronological distribution apparent in the initial published list of dendrochronologically-dated mills (1982), but it also fills in several of the blank areas and serves to convey a sense of continual construction throughout much of the early period.[33] The renewed building in the seventh century may be associated with what has been argued from written sources to be an era of great agricultural development during the seventh and eighth centuries, when much of the fertile land began to be partitioned among holders and fenced off for the first time.[34] This is in keeping with other indicators, such as pollen research and the study of animal bone assemblages, which suggest a progressive rise in population and a developing agricultural base from the fifth century, if not earlier, that was sustained throughout the early medieval period.[35] What remains striking is the number of sites that belong to the late eighth and early ninth centuries, and the discoveries since 1982 have tended to emphasise this concentration further. The hundred-year block accounts for nineteen of the forty-three sites, and thirteen mills were constructed in the period 800-849 alone. This is the period when the Anglo-Saxon mill at

Table 1: **Dated watermill sites in Ireland, based on dendrochronology (†), C-14, and other dating methods.** Source: Palaeoecology Centre, QUB (†), *et al.*

Site Name	Estimated Felling Date Date of Construction
Killoteran, Co. Waterford	1530 +/- 60 BP - 2 Sigma, Cal AD 410-650 1510 +/- 60 BP - 2 Sigma, Cal AD 340 to 600
Nendrum, Co. Down, earliest	AD 619 †
Little Island, Co. Cork	AD 630 †
Ballykilleen, Co. Offaly	AD 636 ± 9 years †
Ballygormill South, Co. Laois	AD 719 ± 9 years or later †
Ballinderry, Co. Derry	AD 744 ± 9 years †
Newcastle Upper, Co. Wicklow	AD 744 ± 9 years or later †
Morett, Co. Laois	AD 770 †
Drumard, Co. Derry	AD 782 †
Ardcloyne, Co. Cork	AD 787 ± 9 years or later †
Nendrum, Co. Down, latest	AD 788 †
Ballyrafton, Co. Kilkenny	AD 794 ± 9 years †
Crushyriree, Co. Cork	AD 799 ± 9 years †
Deer Park Farms, Co. Antrim	8th century
Moycraig, Co. Antrim	8th century
Knocknagranshy, Co. Limerick	8th-9th centuries
Cloghbally Upper, Co. Cavan	AD 803 ± 9 years or later †
Mullantine, Co. Kildare	AD 804 ± 9 years or later †
Cloongowna, Co. Clare	AD 808 ± 9 years †
Boherduff, Co. Galway	AD 810 ± 9 years †
Maghnavery, Co. Armagh	AD 810 ± 9 years †
Ballygeardra, Co. Kilkenny	AD 811 ± 9 years †
Ardnagross, Co. Westmeath	AD 812 ± 9 years †
Rasharkin, Co. Antrim	AD 822 †
Killphillibeen, Co. Cork	c. AD 827 †
Ballynoe, Co. Cork	AD 827 ± 9 years †
Cloontycarthy, Co. Cork	AD 833 †
Ballydowne West, Co. Waterford	AD 841 ± 9 years †
Keelaraheen, Co. Cork	AD 843 †
Coolboy, Co. Wexford	AD 873 ± 9 years †
Farranmareen, Co. Cork	AD 873 ± 9 years †
Lowesgreen, Co. Tipperary	AD 890 ± 9 years †
Brabstown, Co. Kilkenny	AD 913 ± 9 years †
Clonlea, Co. Clare	AD 914 ± 9 years †
Newtown, Co. Tipperary	AD 914 ± 9 years or later †
Ballyroe, Co. Wexford	AD 916 ± 9 years †
Rossorry, Co. Fermanagh	AD 926 ± 9 years †
Knocknacarragh, Co. Galway	AD 973 ± 9 years or later †
Carrickmines Great, Co. Dublin	AD 1123 ± 9 years or later †
Clonlonan, Co. Westmeath	AD 1149 ± 9 years or later †
Corcannon, Co. Wexford	AD 1228 ± 9 years †
Ballymascanlan, Co. Louth	AD 1243 ± 9 years †
Patrick Street, Co. Dublin	13th and 14th century

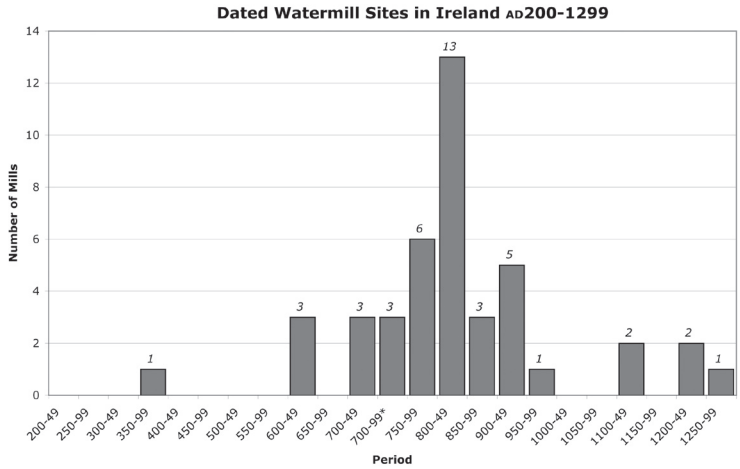

Figure 3: **Chart showing progression of mill construction in medieval Ireland.** Source: Palaeoecology Centre, QUB, et al. Sites that cannot be tied to within a 50-year period are not included. The very early site indicated in the fourth century (Killoteran) may be revised with further analysis of the more fully excavated findings.

Tamworth was built.[36] In Ireland, it is a time of realization for dynastic ambition, be that by secular or monastic interests.[37] It is also the period of the so-called "Golden Age" of largely ecclesiastical art, when the Derrynaflan and Ardagh liturgical chalices were made and other great works produced. It is worth noting that the distribution of mill sites along the Nore valley extends westwards into County Tipperary (Fig. 2, area B), and falls within a regional concentration of high status metalwork in the South Midlands-North Munster zone that has been identified as an especially rich location which could support such prestige work.[38] The mill sites may well inform this discussion by suggesting key areas of production at the local level. In contrast, the absence of construction that follows in the eleventh century is more difficult to understand given the changes then wrought across the island, while the twelfth- and thirteenth-century sites reflect the development sparked first by the coming of the continental orders in 1142 with the establishment of the Cistercian foundation of Mellifont, Co. Louth, and then by the Anglo-Norman colonization from 1169.

The distributional focus on the south and east of the country presents a strong indication of the heartlands of arable husbandry in this period, while the concentration of building in the late eighth and early ninth centuries mirrors broader patterns of social development that are represented widely as the so-called "Golden Age" of early Ireland. There are significant limitations inherent in

this discussion, and at a fundamental level the need for further research on agrarian matters is essential to broaden the scope of enquiry in a manner that retains the focus on the production and processing of food. The degree to which there is a meaningful discussion on the nature of the early Irish economy is also central to this theme. The great historian of the early law tracts, Daniel Binchy, famously characterized early Irish society as "tribal, rural, hierarchical and familiar."[39] It is a view that is largely discarded today, but some individuals still support the thesis.[40] More discrete research reveals that the growth of monastic settlements in the seventh and eighth centuries would have encouraged development, and the trading apparatus of the Hiberno-Norse port towns developing from the mid-ninth century in turn forced a still more significant pace of change.[41] Mainstream historians from the later period, for their part, accept that an important agrarian base had developed in Ireland by the tenth century and that the newcomers of the twelfth century developed the existing situation rather than contributed any revolutionary change.[42] The evidence from the early mill sites indicates the presence of an active and vibrant economic structure much earlier in the early medieval period than the tenth century, and this aspect should prompt us to reconsider our understanding of the economic dynamic at work throughout the early medieval period.

Mills and Economy in Early Medieval Ireland

In 1953, Lucas stated at the outset of his discussion on mills that it was "necessary to avoid falling into the error of overestimating their importance and to remember that… a large proportion of the meal and flour for domestic consumption was produced… by means of querns and mortars of various kinds."[43] Lucas had a great affection for ethnology and this may have influenced his tendency to downplay the contribution of technologically advanced systems of production. His sentiment was echoed by Mike Baillie in 1975 when reporting on the first mill to be securely dated by dendrochronology. In Baillie's view, the horizontal mill was the "simplest possible mechanical adaptation of the hand-operated rotary quern. Its major advantage was not seen as a speeding up of the grinding process but as removal of the drudgery associated with manual operation."[44] In contrast, the contemporary written sources suggest a different view. The Old Irish law tracts, which are concerned with how society should exist, not only include a list of the parts of a mill noted above but also recognized mill ownership as an attribute of status. While a mill could be owned cooperatively, the tract on

status, *Críth Gablach*, observed that not every freeman was entitled to own his own mill; this was a right reserved for the prosperous commoners and the lords above them.[45] There is a sense of mill ownership as something that required significant capital. Fergus Kelly's close study of the law tracts has noted that the watermill was undoubtedly the most complex piece of technology regularly encountered by an early Irish farmer.[46] Colin Rynne has developed this further by highlighting the fact that the millwright was accorded the lowest rank of nobility.[47] Nevertheless, in terms of assessing the productive capacity of the early mill sites in Ireland, Rynne seems reluctant to appreciate their full potential. Writing in 1990, he was content to note that the nature of the milling reflected an ability to process larger amounts of grain more efficiently and, perhaps, a more broad-based distributive network for cereals.[48] Yet he has not developed this important line of enquiry. Three sites will serve to illustrate the presence of an energetic economic dynamic.

The mill complex at Nendrum, Co. Down, stands out as being different. It is situated on the foreshore below what historians celebrate as one of the most complete examples of an early Irish monastery, where previous excavation, if poorly conducted and reported, has nevertheless shown evidence for occupation and industrial activity and a wide range of locally produced as well as imported artefacts.[49] The more recent excavation programme focussed on the mill site and revealed different phases of mill construction, suggesting the effort expended to construct the associated millponds within the tidal regime. The results further indicate a large-scale and organized construction and maintenance programme that must have satisfied the needs of the large monastic community, if not exceeded them. It remains possible that the mill ponds served a dual function by acting as fish traps as well. The cumulative impression provided by the archaeological data suggests that this was a zone of developed exploitation and production. As noted above, the quality of the information retrieved has also permitted some initial calculations to be made of the potential energy available for milling.[50] When this aspect is developed more fully, it could reveal the extent of milling that was possible over the two centuries of use. Such information may then be used to consider the mill's catchment area. Nendrum lies at the centre of its own small estate whose later boundaries have been charted.[51] It is also within a larger area of good soil cover which would have been suitable for arable cultivation.[52] The sources required to construct the larger context of the Nendrum mill complex therefore appear to exist, and it is hoped that the excavators will be able to develop such lines of enquiry.

The location of Nendrum on the northwest shore of Strangford Lough is in an area that was intensively exploited by large-scale concerns throughout the period. This is evident in the presence of five wooden fish traps that have been discovered close to one another on the eastern shore and dated to between the late seventh and the late twelfth centuries, below what would become in 1193 the Cistercian foundation and fishery of Greyabbey (some 7.2km away, across open water from Nendrum).[53] The early sources are unclear about who operated the fish traps, but it is evident that these lands were part of the monastic estate of Moville, a major concern in the area. Indeed, it may also be that Nendrum was a dependency of the larger bishopric of Armagh and owed her tribute. If this was the case, an argument could be made to suggest that Nendrum served as a specialist centre to provide grain to support the population in Armagh.[54] It is increasingly difficult to see this rural landscape in the northeast of the country as one of quiet dispersed settlement. In contrast, the image is of a busy landscape where large-scale production and therefore trade was dominant.

Charles Doherty has considered the economic context of early Irish society in this period, and in particular that of the Church.[55] He has argued that the larger monasteries exercised control over great estates that are believed to have been organized in a similar way to monastic estates on the continent and to secular estates in Ireland.[56] As secular settlement burgeoned on the fringes of the main enclosures, the monasteries began to act as centres of exchange. The business of feeding and clothing the immediate community as well as those outside the monastery became a busy one, and the adoption by monasteries from the eighth century of the tribal *óenach*, or market, suggests that that level of exchange existed. The *óenach* was a regular feature by the tenth century.[57] Some years ago, John Bradley urged caution against idealizing this early medieval past in terms of the present free market economic paradigm.[58] We should be sensitive to the powerful influence of religion in this society, and therefore cautious not to push the degree of economic maturity too far. Yet it is increasingly difficult to be satisfied with a model of simple exchange, and Bradley now recognizes this in light of the recent archaeological discoveries; the archaeological data are forcing the issue.[59] One of the two new mill sites may represent an outlying production centre that could have serviced a larger monastery. Although its excavation has only been completed, the contexts of the mills at Raystown, Co. Meath, already suggest that this was an elaborate agricultural centre. In addition to the series of six watermills, the remains of five corn-drying kilns, along with bowl furnaces, hearths, and multiple ditches are being exposed within an oblong enclosure measuring approximately 200m by 270m, and which the excavator considers may

have been some form of monastic farm. The sense to which it was a centre for large-scale production is difficult to ignore.

A third site that fits this picture of intensive productive capacity is the watermill complex at Little Island, Co. Cork. What is striking in this case is the fact that both the vertical wheeled mill and the horizontal mill appear to have coexisted in the early seventh century. Bearing in mind that the horizontal mill had two flumes, it was therefore possible that the mill complex could have driven three millstones simultaneously. Such a situation would represent large-scale production, and should be recognized as such.[60] Little Island and Nendrum have another feature in common: both sites were tidal mills. Tidal mills represent construction programmes often in exposed locations where the harsh conditions of the sea would have required sturdy building and constant maintenance. Records that document the costs of mills are not available for this period in Ireland, but a later example from England may serve as illustration from the end of the thirteenth century.[61] Henry of Eastry, Prior of Christ Church, Canterbury, was prepared to invest £143 13s to replace a tidal mill on the Isle of Thanet in Kent that had been destroyed in 1290. The mill achieved an annual rent of 25 quarters of wheat, but was destroyed once again in 1316 by floods. The prior was committed to the mill and spent another £74 13s 4d in its relocation and rebuilding. However, the mill was destroyed once again in 1326 by high tides. At this stage Henry had had enough. He abandoned the tidal location thirty-six years after his first recorded rebuild, and built a windmill as a replacement for a mere £12 19s. The prior's story begs a question of justification that can be applied to other tidal mills: why were patrons willing to invest so heavily in a tidal location? Was it not simpler to divert watercourses on land in a more protected environment where there was no exposure to storms and raging seas, and consequently the risk of destruction was far less?

In an Irish context, the early law tract known as *Coibnes Uisci Thairidne*—The Kinship of Conducted Water—provides some insight. While focussing on milling, the seventh-century tract is concerned with the rules for conducting water across neighbours' lands to power a mill. It states:[62]

> Dligid cach comaithech diarailiu tuididin usci thairidne tara c[h]rich I neoch ma fo-creth(th)er a fhoch[h]raic téchta[i]; ro[-ch] suidiged a fochraic-side for séo(i)t deich screpul dar cach m(b)ru[i]g do-tæt. Neoch mad e(a) t[h]am, ceni gaba acht lethgabail de, di-renar in chruth-so. Mad ainmín immurgu is let[h]sét inna lóg-side. Alailiu is lá cach(a) tire do-tét dlega(i)r aire.

> Each neighbour is entitled from the other to [be allowed to] conduct a mill-race across his land if it be paid for with its proper fee; and the fee for this has been fixed at a sét worth ten scruples for every stead to which it comes. If it be arable land, though it (the mill-race) occupy but half a pace(?), it is paid for in this wise. If, however, it be rough land, a half-sét is the fee for that. Alternatively a day [at the mill] for each parcel of land to which it comes is due for it.

Although the law tracts are notoriously idealistic insofar as they attempt to convey a sense of society as defined by jurists, it is generally accepted that they retain useful indicators of everyday life. In the present context, *Coibnes Uisci Thairidne* is less concerned with the mill per se than it is with the claim that neighbours could have on a mill. While a mill owner had the right to cut a mill-race across a neighbour's lands, he was obliged to pay such landowners an appropriate fee in compensation. This would detract from the profitability of a mill. An ideal solution would be to locate the mill in a location where no one else would be able to claim a part of the mill's profit. Failing access to watercourses on one's own lands, tidal locations would have suited this purpose. The construction of mill ponds along the intertidal foreshore would have used the filling tide to guarantee sufficient headwaters to power a mill on a daily cycle at no "rental" cost to the mill-owner.[63] The presence of the mills at Nendrum and Little Island testify to a commitment to build in these locations. The continued construction of three generations of mill at Nendrum is further testimony to the long-term nature of such a commitment, and echoes the devotion that Henry of Eastry was to give to his tidal mill in Kent. [64]

There are indications of tidal mills elsewhere in Ireland, with seven known sites including Little Island and Nendrum.[65] (Fig. 2) It is perhaps worth noting that not all sites are located on harsh exposed locations. For its part, the Nendrum mill is located in a sheltered part of the Lough, while both of the other excavated mill sites, at Little Island and Killoteran, are situated at a remove from the active shoreline (Fig. 1). This pattern of location suggests the desire to use the tidal waters while at the same time protect the investment in mill structure and components as much as possible. If the decision was informed by a desire to capitalize on the profitability of the mill, as I have suggested, the implications for our understanding of the early Irish economy are significant. Such a rationale does not sit comfortably with the subsistence-based structure prior to the eighth century proposed by Binchy in the 1950s. Nor does it suit the view of a changing economic force during the 700s that was limited to internal or small-scale networks to serve the specific needs of monastic communities. Instead the tidal mill may present a glimpse of a rational economic mind that was concerned with

profit from an early date.[66] There is no problem in recognizing the existence of a market economy in the later medieval period, but the situation is different for the earlier period. Clearly more research is required, both on mill sites and on other aspects of the early economy.[67] Perhaps too, scholars have to be more open-minded about the economic aspirations of the Irish during the first millennium A.D. The purpose here is merely to raise the possibilities associated with watermills, and it is hoped that this will provoke an interest that extends beyond the existing focus which has been exclusively on mill design.

Mills in Later Medieval Ireland

In contrast to the period before 1100 where documentary references to mills are generalized, there are frequent and direct references to specific mills in the later medieval period, thanks largely to the survival of manorial extents. The identification of these more numerous sites on the ground is problematical, however, as relatively few have been located. It is not clear why this is so, although one possibility is that the sites of later mills were continually developed during the seventeenth and eighteenth centuries, and large industrial mills were built on the same sites as the medieval mills which essentially erased them from view. The excavated watermill at Patrick Street in Dublin does suggest a scale of construction that was not apparent previously, as well as perhaps a tendency for late sites to be positioned closer to active channels than had been the case before. The discovery of further late sites will help to qualify the implications that such structural aspects suggest. Meanwhile it is possible to consider a broader perspective on later mill sites by looking at the references to mills that occur within a 30km study area around Dublin, the medieval capital city.[68]

The landscape of the study area is dominated by the broad, low-lying floodplain of the River Liffey which empties into the Irish Sea at Dublin and extends westwards through north County Kildare before turning south to its point of origin in the Wicklow Mountains. The same rolling flat land occurs to the north, and if the study area was extended in this direction it would encounter the river valley and floodplain of the Boyne. This is rich agricultural land even today, and where the modern metropolis has not already extended onto the good tillage and pasture lands, market gardening and crop husbandry are favoured over stock-rearing and dairying. In contrast, the mountainous south is given over largely to sheep. That this was intensively settled in the later middle ages is not in doubt; the survival of castles, churches, and other standing structures from the period

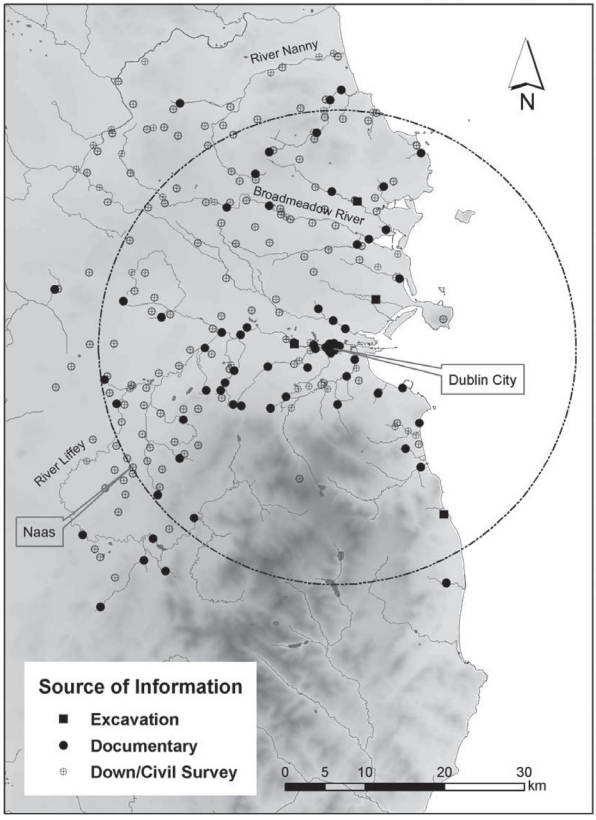

Figure 4: **Distribution of Mills in the Dublin region, *c.*1100-1650.** Source: The Discovery Programme.

form a dense distribution across the area, with the majority of the land held by the Church in its many and diverse estates.[69]

One hundred thirty-five references to mills have been assembled from the body of sources available for the Dublin area between *c.*1180 and 1550, and a further block of information exists in the seventeenth-century Down and Civil Surveys.[70] Documentary references to mills in the earlier period come partly from extents which survive in two groups; those from the period 1250-1350, and those from the period of the Dissolution in 1540. Other references come from a variety of administrative, judicial, and ecclesiastical sources. In common with what Richard Holt has described for England, the sources in the Dublin area do not reveal details of a mill's construction, and this situation reinforces the importance of archaeological discoveries such as those at Patrick Street.[71] More typically, the documentary information refers to the granting of lands for mills;

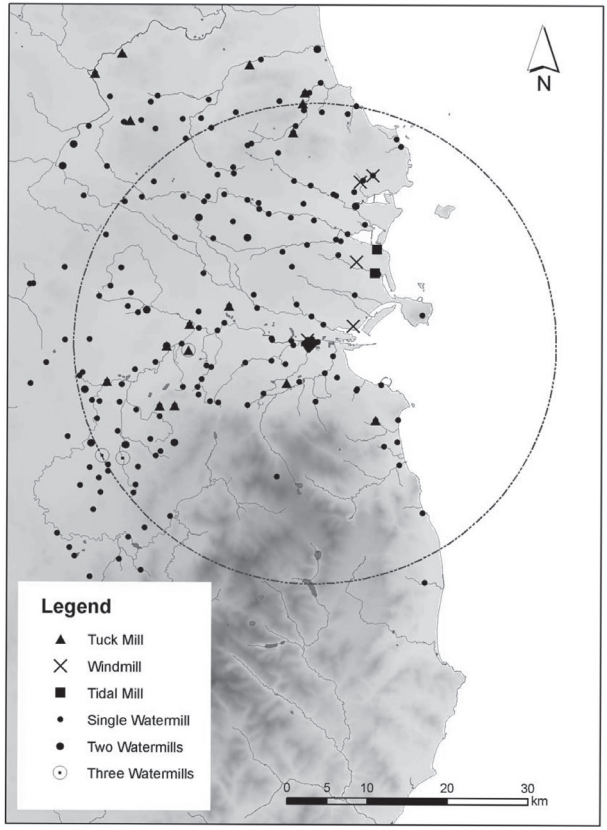

Figure 5: **Types of Mill in the Dublin region, *c*.1100-1650.** Source: The Discovery Programme.

the leasing of mills; the value of a mill as a manorial component or at the time of the miller's death; and the fate wrought on mills by natural elements. Two new mills, for example, were erected for the King in 1248 near Dublin Castle, while in 1302 the King's mills below Dublin Castle were knocked down in a flood.[72] In neither instance do the sources reveal the sums of monies involved in the construction, income, or repair of these mills. In another example, we see something of the property disputes of which mills fell foul: in 1303, a fishing net attached to the bridge in Dublin was removed by the Prior of Kilmainham, and Dubliners destroyed the prior's mill in retaliation.[73] In yet another, we glimpse the interior of a mill: in 1310, at Castlemartin, Co. Kildare, to the southwest of the city, the death of the miller was reported as an accident in the workplace when the upper millstone broke into three parts and one part struck him as he "prepared the mill

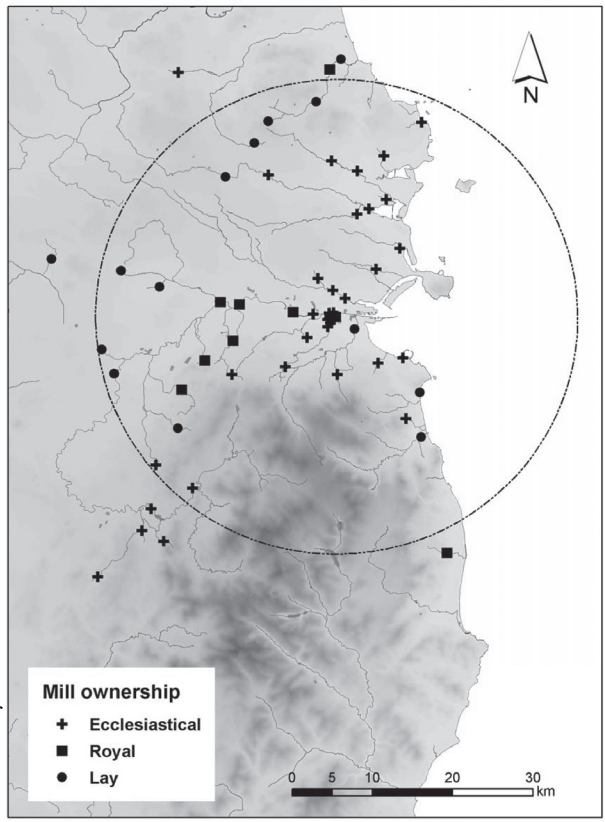

Figure 6: **Ownership of Mills in the Dublin region, c.1250-1540.** Source: The Discovery Programme.

for milling." Value of the upper millstone, the inner and outer wheel and iron of the said mill, was stated as 7s.[74]

The distribution of mills from archaeological and historical sources is indicated on Figure 4, and includes sites recorded in the seventeenth-century surveys. A note should be made on the actual location of these sites. Where a site has not been validated by excavation or field survey (and there have been very few instances where this is possible), the location is based on a combination of attributes that include townland name, reference to the mill being close to or powered by a named stream, and the type of mill where this is recorded. It cannot be stated that the locations are precisely identified, but the approach indicates the general location within a deviation of c. 100m, which is more than adequate for the present level of enquiry. The map shows that mills were not built in any numbers in the Wicklow Mountains to the south, where high altitude and mar-

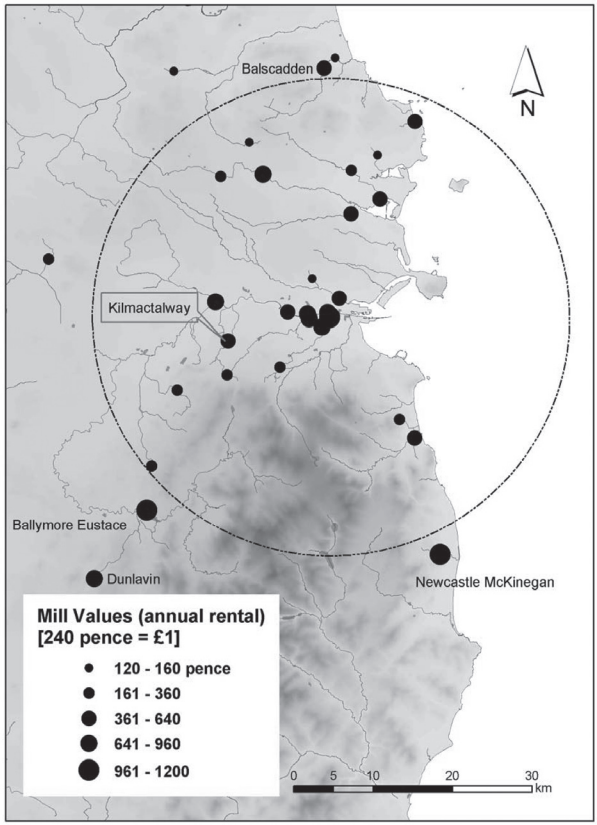

Figure 7: **Value of Mills in the Dublin region, c.1250-1540.** Source: The Discovery Programme.

ginal land predominates.[75] Instead, the distribution follows centres of population. Mills are concentrated on the coastal area, in Dublin city itself, and along the main river valleys which include the Liffey to the west and southwest of the city, and the Broadmeadow, Delvin, and Nanny rivers to the north. The map also suggests a sense of development through time. It will be noted from Figure 2 that few early medieval sites are identified within the study area. This pattern was to change, and by the mid-1200s and on to the mid-1500s significant numbers of mills were constructed. The mills are distributed along the coastal zone particularly to the north of the city, in the city itself, and along the River Liffey valley. By the mid-1600s there were still greater numbers of mills, with an intensification of building in the focal areas, and an extension to the lesser river systems to the north and west of the city itself.

If this is a crude indicator, it nevertheless gives the impression of continuous development throughout the period. Figure 5, in turn, attempts to show the variety of mills in use. The task is often frustrated by the lack of concern to distinguish the type of mill in the sources, other than to indicate whether it was water-powered or not. Consequently, most of the sites are simply referred to as watermills. This is especially frustrating when considering the coastal sites, ten of which could well have operated as tidal mills but only two are identified as such. The records do however distinguish between water power and wind power. The earliest reference to windmills in Ireland is in 1281, and the first example in the Dublin area is in the extent of the lands of William de Vescey at Kildare in 1297, where he had "a windmill worth 26s 8d a year."[76] The next reference occurs in 1330 when Holy Trinity Priory leased land to William de Boseworth in Ostmantown Green, "where Holy Trinity had a windmill."[77] If the Dublin area is representative of the national picture, windmills never became a competitive rival to water power, since there are only six instances identified in our survey. Aside of the two already cited, the other four sites are located close to the coastal zone presumably to avail of the wind off the sea, and they appear as late sites, recorded for the first time in seventeenth-century surveys. Equally, the first reference to tuck (fulling) mills is late, and the distribution of these sites is concentrated on the Liffey valley area and also on the catchments of the rivers Broadmeadow, Delvin, and Nanny in the north of the study area. The distribution may indicate where industrial development was beginning to take hold at the end of the middle ages.

The pattern of mill ownership is shown on Figure 6, and this map is restricted to the period up to 1540. As the dominant landowner, it is little surprise to see the Church as the primary mill owner as well, and the concentration of sites within and immediately surrounding the city reflects the presence of the ecclesiastical houses in the city. The outlying loose concentration in the southwest highlights the town of Naas, where the mills would have serviced that town's needs. For its part, the Crown owned several mills, and with the exception of the King's Mills in Dublin Castle referred to above, the royal mills are located on royal manors at some distance from the city. There is a clear concentration of the royal mills in the middle section of the Liffey valley, in the areas where tuck mills were to become popular somewhat later, and there are two other mills that lie just outside the 30km radius, at Balscadden in the north (which also developed as a tuck mill by the mid-1600s) and Newcastle McKenegan in the southeast. Lay mill sites also developed that were owned by neither institution. There are similar numbers of lay mills and royal mills (ten and nine respectively) and these are also

located away from the city itself. However, the majority of lay mills are situated in an outer belt that lies at a remove far from the central zone. These outer mill sites are also distributed in a relatively even manner which may indicate that the produce was consumed locally rather than in the city and its markets.

The wider project from which this preliminary data is taken will be considering mills in greater detail, as it examines the nature and extent of milling at particular sites within the context of supplying the capital city with its needs for consumption and trade. Figure 7 shows the value of mills as represented in 1250-1350 and at the Dissolution.[78] In general what is being valued in the extent is the yearly profit accruing to the owner from the mill. This would represent the value of sales from grain levied as toll from tenants using the mill (referred to as multure) if the mill is under the lord's direct management. Alternatively it would represent the "farm" or rent of the mill if it is being leased out. The value given therefore represents the productive capacity of the mill rather than the inherent value of the structure, machinery, and other equipment (on occasion, the annual yield of eels from the mill pond is also part of the calculation). Frequently the value of the mill is said to be "less" the cost of repairs and maintenance, and sometimes it is said to be "over and above" the cost of upkeep. When a mill was leased out the lessee was usually in charge of maintenance. On occasion the terms of the lease included a remission of the first year's rent in order to allow the lessee to make necessary repairs and sometimes even rebuild the mill. In 1373 when Archbishop Minot of Dublin granted Thomas FitzEustace the mill of Ballymore Eustace, the lease required FitzEustace to keep the mill "styff and staunch" at his own expense.[79] The value of the mill was obviously lower if it was in bad repair. An extent of 1351 for Kilmactalway values the mill at 4 marks, "and not more because it is old and tumble down and there are not many of the king's tenants to use it."[80]

The variety of ways in which the value of a mill might be calculated as well as the conditional factors such as state of repair and arrangements for maintenance means that caution must be exercised in comparing the value of one mill with another. Nevertheless, some general observations can be made. In the period 1250-1350 the average annual value of a watermill was somewhere between one and two pounds. There were some mills with values significantly greater than this, for example the mills at Dublin Castle and at St. Sepulchre's. More surprising are the valuable mills at Newcastle McKenegan and Dunlavin, Co. Wicklow, in the southeast, said to be worth £5 and £4 respectively, and at Ballymore Eustace, Co. Kildare, where two mills had a combined value of £10 in 1326. In 1540, of the eighteen mills valued not one could match the £5 valuations cited above. How-

ever, the average mill value had risen to between three and four pounds per annum. Two mills were valued at £4, one of which, that belonging to the Hospital at Kilmainham, was a double mill with two pairs of millstones under one roof.

In considering the overall pattern of values depicted in Figure 7, the central importance of the city area is once again clear, but higher values are also apparent at a remove from it. On the edges of the study area, whether to the north, in the southwest in the vicinity of Naas, or in the southeast at Newcastle McKenegan, mill values are noticeably higher than they are in the intervening areas. At Newcastle McKenegan, it is no doubt because the royal mill was the only milling facility in the larger neighbourhood, and it is centrally placed along this narrow coastal belt to service most requirements. Values are available for mills owned by lay lords as well, and these tend to be relatively low, suggesting once again that these mills served local interests only. The evidence for lay mills is nevertheless sufficient to argue that the documentary material within the larger Dublin area is not socially selective. This is an important observation because the received view is that the sources reveal little about people who lived outside the two institutions of Church and Crown. The Dublin study tries to make the common voice heard.

Concluding Remarks

This paper has taken a different approach to the study of medieval mills in Ireland. Instead of focussing on the details of design, as in internalist approaches to the history of technology, the emphasis has been to look beyond the essential construction of mills in an attempt to gauge the degree to which mill sites can inform broader issues that, in this instance, look at the economic bases of the country. The result has perhaps achieved little beyond suggesting future possibilities. Yet I would contend that the early mill sites, and in particular tidal mills, prompt us to reassess the essential economic paradigm that has been formulated to characterise development in Ireland during the early middle ages. In turn, and by isolating references to milling alone, there is sufficient material in Ireland to articulate a discussion on the organization of the later medieval countryside; a discussion that can be carried out within a context that economic historians have developed to understand the growth of the medieval economy in England. Internalist historians of technology can all too easily remain fixated on the detail of the apparatus that is their primary point of reference. Yet it is incumbent on us, as demonstrated by many of the papers in this volume, to reach beyond the par-

ticular to try to place the findings within the broader context, and indeed to see whether the technology can in its own way help to illuminate and modify mainstream paradigms of cultural development.

Acknowledgements

I am grateful to Donald Murphy and Matthew Seaver for allowing me to report on their current excavations in advance of their completion; to Mike Baillie and David Brown at the Palaeoecology Centre, Queen's University Belfast, for sending me a current list of dendrochonologically-dated sites; and to Colin Rynne for ensuring that my reading of his work was up to date. The paper has been read by Charles Doherty, Adam Lucas, Finbar McCormick, and the volume's editor. I greatly appreciate their insight and comments which have helped to tighten up the presentation. Errors and inadequacies remain my responsibility. My colleagues within the Discovery Programme's Medieval Rural Settlement project have also contributed assistance in various ways, especially Michael Potterton who prepared Figures 4-7, Anne Connon who carried out some searches of the earlier sources, and Margaret Murphy who prepared the later sources and commented on a draft of the paper. To each I owe my thanks and appreciation.

Notes

[1] A short list of recent work will suffice: P.A. Rahtz, "Medieval Milling," *Council for British Archaeology Reports* 40 (1981); Örjan Wikander, "Archaeological Evidence for Early Water-mills—an interim report," *History of Technology* 10 (1985): 151-79; Richard Holt, *The Mills of Medieval England* (Oxford: Blackwell, 1988); Miquel Barceló, "The Missing Watermill: a question of technological diffusion in the High Middle Ages," in Miquel Barceló and François Sigaut (eds.), *The Making of Feudal Agricultures?* (Leiden: Brill, 2004), pp. 255-314; John Langdon, *Mills in the Medieval Economy. England 1300-1540* (Oxford: Oxford University Press, 2004).

[2] A.T. Lucas, "The Horizontal Mill in Ireland," *Journal of the Royal Society of Antiquaries of Ireland* 83 (1953): 1-37; E.M. Fahy, "A Horizontal Mill at Mashanaglass, Co. Cork," *Journal of the Cork Historical and Archaeological Society* 61 (1956): 13-57; Colin Rynne, "The Introduction of the Vertical Watermill into Ireland: some recent archaeological evidence," *Medieval Archaeology* 33 (1989): 21-31; Colin Rynne, *Technological Change in Anglo-Norman Munster,* Barryscourt Lectures 3 (Cork, 1998; rpt. in *Medieval Ireland. The Barryscourt Lectures I-X* [Kinsale: Barryscourt Trust, 2004]), pp. 65-95; Colin Rynne, "Waterpower in Medieval Ireland," in P. Squatriti (ed.), *Working with Water in Medieval Europe. Technology and Resource-Use* (Leiden: Brill, 2000), pp. 1-50; T. McErlean and N. Crothers, "The Early Medieval Tide Mills at Nendrum: an interim statement," in Thomas McErlean, Rosemary McConkey, and Wes Forsythe (eds.), *Strangford Lough: an archaeological survey of the maritime cultural landscape* (Belfast: Blackstaff Press, 2002), pp. 200-211.

[3] Research in England indicates the potential of addressing milling in broader contexts; see especially Holt, *The Mills of Medieval England* and Langdon, *Mills in the Medieval Economy*.

[4] "Ancient Irish water-mills," *Transactions of the Kilkenny Archaeological Society* 1 (1849-51): 154-64.

[5] R. MacAdam, "Ancient Water-mills," *Ulster Journal of Archaeology* 4 (1856): 6-15; H.T. Knox, "Notes on Gig-mills and Drying Kilns near Ballyhaunis, Co. Mayo," *Proceedings of the Royal Irish Academy* 26C (1906-07): 265-73; Lucas, "The Horizontal Mill in Ireland."

[6] E.C. Curwen, "The Problem of Early Water-mills," *Antiquity* 18 (1944): 130-46; Miquel Barceló, "The Missing Water-mill," pp. 260-61.

[7] M.G.L. Baillie, "A Horizontal Mill of the Eighth Century A.D. at Drumard, Co. Derry," *Ulster Journal of Archaeology* 38 (1975): 25-32; M.G.L. Baillie, *Tree-Ring Dating and Archaeology* (London: Croom Helm, 1982), p. 182.

[8] Rynne, "The Introduction of the Vertical Watermill" (note 2), pp. 24-26; see also Fahy, "A Horizontal Mill" (note 2).

[9] However, not everyone agrees that Rynne has offered a convincing argument: see Dáibhí Ó Cróinín, *Early Medieval Ireland 400–1200* (London: Longman, 1995), p. 96, n. 77.

[10] Baillie, *Tree-Ring Dating and Archaeology*, p. 182.

[11] Rynne, "The Introduction of the Vertical Watermill" (note 2), p. 26; Denis Power (ed.), *Archaeological Inventory of County Cork. Volume 2: East and South Cork* (Dublin: Stationary Office, 1994), p. 165.

[12] Rynne, "Waterpower in Medieval Ireland" (note 2), pp. 9, 19-40.

[13] Gearóid Mac Eoin (ed. and trans.), "The early Irish vocabulary of mills and milling," in B.G. Scott (ed.), *Studies of Early Ireland: Essays in honour of M. V. Duignan* (Belfast: Association of Young Irish Archaeologists, 1982), pp. 13-19, at pp. 14-15. For a similar survey of slightly later Anglo-Saxon references to water mills, see Philip Rahtz and Donald Bullough, "The Parts of an Anglo-Saxon Mill," *Anglo-Saxon England* 6 (1977): 15-37. It is of interest that the Laws do not consider the presence of vertical wheeled mills, and this gap is perhaps worth exploring further on another occasion. I am grateful to Adam Lucas for pointing out this matter.

[14] McErlean and Crothers, "The Early Medieval Tide Mills at Nendrum" (note 2), pp. 201-11.

[15] I am grateful to Matthew Seaver, site director, for this information ahead of publication, and to Cultural Resources Development Services Ltd. for permission to bring attention to the site at this early stage of its post-excavation work on behalf of Meath County Council and the National Roads Authority. See Matthew Seaver, "Run of the mill? Excavation of an early medieval site at Raystown, Co. Meath," *Archaeology Ireland* 19.4 (2006): 9-12.

[16] I am grateful to Donald Murphy for this information ahead of publication, and to his company Archaeological Consultancy Services Ltd. for permission to bring attention to the site at this early stage of its excavation on behalf of Waterford County Council and the National Roads Authority. He has also supplied the following detail: two samples from planks on the site have returned calibrated dates of 1530±60 BP - 2 Sigma Calibration Cal (AD 410 to 650), and 1510±60 BP - 2 Sigma Calibration Cal (AD 340 to 600) respectively.

[17] It should be noted that the dates returned have a wide standard deviation, and further analysis of the site data may refine this view.

[18] Michael Duignan, "Irish Agriculture in Early Historic Times," *Journal of the Royal Society of Antiquaries of Ireland* 74 (1944): 124-45, at p. 144.

[19] The earliest reference appears to be at Kilscanlan, near Old Ross, Co. Wexford, dated 1281, and cited in Rynne, *Technological Change* (note 2), p. 79.

[20] Rynne, *Technological Change*, p. 86.

[21] Maurice Hurley, *Excavations at the North Gate, Cork, 1994* (Cork: Cork Corporation, 1997), pp. 45-49; and cited in Rynne, "Waterpower in Medieval Ireland" (note 2), p. 45.

[22] Colin Rynne, "The Patrick Street Watermills," in Claire Walsh (ed.), *Archaeological Excavations at Patrick, Nicholas and Winetavern Streets, Dublin* (Dingle: Brandon, 1997), pp. 81-89.

[23] Howard Clarke, *Dublin Part I, to 1610*, Irish Historic Towns Atlas no. 11 (Dublin: Royal Irish Academy, 2002), p. 26.

[24] Charles McNeill (ed.), *Calendar of Archbishop Alen's Register, c.1172-1534* (Dublin: Royal Society of Antiquaries of Ireland, 1950), pp. 171, 220.

[25] See Clarke, *Dublin to 1610*, p. 9; and Roberta Magnusson, "Public and Private Urban Hydrology: Water Management in Medieval London," ch. 8 in this volume.

[26] Certain later sites, highlighted on the map as outline symbols, are included because dates exist for them, although strictly speaking they fall outside the time-frame under review.

[27] To take the millstones home would guard against illegal use of the mill, an abuse that is noted in the laws: D.A. Binchy (ed.), *Corpus iuris hibernici* (Dublin: Institute for Advanced Studies, 1978): 383.32-33; W.N. Hancock, *et al.* (eds.), *Ancient Laws of Ireland* (Dublin: HMSO, 1865-1901), I:162.23-24.

[28] Matthew Stout, *The Irish Ringfort* (Dublin: Four Courts Press, 1997), p. 54.

[29] Comparison has been made with the *General Soil Map of Ireland*, 1:575,000, 2[d] ed. (Dublin: National Soil Survey, 1980).

[30] The distribution of hand querns has not been plotted in recent years but they remain a common occurrence, and a survey of finds from ringforts published in 1961 serves as a background study: V. Proudfoot, "The Economy of the Irish Rath," *Medieval Archaeology* 5 (1961): 94-122.

[31] Niall Brady, "Reconstructing a Medieval Irish Plough," in *Primeras Jornadas sobre Tecnologia Agraria Tradicional*, (Madrid: Direccion Gral. De Bellas Artes y Archivos, 1993), pp. 31-44.

[32] See Raghnall Ó Flóinn, "The Archaeology of the Early Viking Age in Ireland," in Howard Clarke, Máire N´Mhaonaigh, and Raghnall Ó Flóinn (eds.), *Ireland and Scandinavia in the Early Viking Age* (Dublin: Four Courts Press, 1998), pp. 131-65, at p. 151. The distribution of plough irons is presented in Niall Brady, *The Plough in Early Historic and Medieval Ireland,* M.A. thesis, University College Dublin, 1986.

[33] On the original pattern of construction, see Baillie, *Tree-Ring Dating and Archaeology* (note 7). I am particularly grateful to Mike Baillie and David Brown at the Palaeoecology Centre of the Queen's University Belfast for supplying a revised list of tree-ring-dated sites.

[34] Eoin MacNeill, "Ancient Irish Law: the law of status or franchise," *Proceedings of the Royal Irish Academy* 36C (1921-24): 265-316, at p. 286, n. 2.

[35] Michael Ryan, "Furrows and Browse: some archaeological thoughts on agriculture and population in early medieval Ireland," in Alfred P. Smyth (ed.), *Seanchas. Studies in Early and Medieval Irish Archaeology, History and Literature in Honour of Francis J. Byrne* (Dublin: Four Courts Press, 1999), pp. 30-36.

[36] P.A. Rahtz, "Medieval Milling," in D. W. Crossley (ed.), *Medieval Industry*, CBA Research Report 40 (London: Council of British Archaeology, 1981), pp. 13-14.

[37] Donnchadh Ó Corráin, "Viking Ireland—afterthoughts," in Clarke *et al.*, *Ireland and Scandinavia* (note 32), pp. 421-52, at pp. 428-31.

[38] Michael Ryan, "The Significance of the Hoard," in Michael Ryan (ed.), *The Derrynaflan Hoard, volume 1, a preliminary account* (Dublin: National Museum of Ireland, 1983), pp. 36-41, at pp. 40-41.

[39] D. Binchy, "Secular Institutions," in Myles Dillon (ed.), *Early Irish Society* (Dublin: Colm O Lochlainn for the Cultural Relations Committee of Ireland, 1954), pp. 52-65, at p. 54.

[40] See for instance, Nerys Patterson, *Cattle-Lords and Clansmen: Kinship and rank in early Ireland* (New York: Garland, 1991), pp. 67-68.

[41] See for example, Charles Doherty, "Exchange and Trade in Early Medieval Ireland," *Journal of the Royal Society of Antiquaries* 110 (1980): 67-89; John Bradley, "Urbanization in Early Medieval Ireland," in Catherine E. Karkov, Kelly M. Wickham-Crowley, and Bailey K. Young (eds.), *Spaces of the Living and the Dead: An Archaeological Dialogue*, American Early Medieval Studies 3 (1999): 133-47.

[42] Kevin Down, "Colonial Society and Economy," in Art Cosgrove (ed.), *A New History of Ireland. II. Medieval Ireland 1169-1534* (1987; rpt. Oxford: Oxford University Press, 2001), pp. 439-91, at p. 481.

[43] Lucas, "The Horizontal Mill in Ireland" (note 2), p. 3.

[44] Baillie, "A Horizontal Mill" (note 7), p. 25.

[45] Fergus Kelly, *Early Irish Farming* (Dublin: Dublin Institute for Advanced Studies, 1997), p. 482.

[46] *Ibid.*, p. 484.

[47] Rynne, "Waterpower in Medieval Ireland" (note 2), pp. 6, 18-19.

[48] Colin Rynne, "Some Observations on the Production of Flour and Meal in the Early Historic Period," *Journal of the Cork Historical and Archaeological Society* 95 (1990): 20-29, at p. 21.

[49] H.C. Lawlor, *The Monastery of Saint Mochaoi of Nendrum* (Belfast: Belfast Natural History and Philosophical Club, 1925).

[50] McErlean and Crothers, "The Early Medieval Tide Mills at Nendrum" (note 2), p. 211.

[51] McErlean *et al.*, *Strangford Lough* (note 2), p. 76.

[52] *General Soil Map of Ireland* (note 29).

[53] T. McErlean and A. O'Sullivan, "Foreshore Tidal Fishtraps," in McErlean *et al.*, *Strangford Lough* (note 2), pp. 144-85, at pp. 182-83.

[54] I am especially grateful to Charles Doherty for this comment, in advance of his note on the historical evidence for Nendrum's connections with Armagh: Charles Doherty, "Nendrum: a note," forthcoming.

[55] Doherty, "Exchange and Trade"; see also Charles Doherty, "Some Aspects of Hagiography as a Source for Irish Economic History," *Peritia* 1 (1982): 300-23; Charles Doherty, "Settlement in Early Ireland: a review," in Terry Barry (ed.), *A History of Settlement in Ireland* (London: Routledge, 2000), pp. 50-80.

[56] Doherty, "Some aspects of hagiography," p. 320.

[57] *Ibid.*, p. 302.

[58] Bradley, "Urbanization in early medieval Ireland" (note 41), pp. 142-43.

[59] John Bradley (pers. comm., December 2004).

[60] Unfortunately historical references to Little Island in the early period are few and unclear; it is currently not possible to indicate who owned the mill site. I am grateful to Anne Connon for looking into the possibilities for me.

[61] Holt, *The Mills of Medieval England* (note 1), pp. 88-89.

[62] D. A. Binchy, "Irish Law Tracts Re-edited i. *coibnes uisci thairidne,*" *Ériu* 17 (1955): 52-85, at pp. 68-71.

[63] I am not aware of a law tract that requires payment of compensation in the construction of an intertidal millpond, while the laws take the view that the issues of the sea belong to either the owner of the adjacent land or to the finder: Fergus Kelly, *A Guide to Early Irish Law* (Dublin: Dublin Institute for Advanced Studies, 1988), pp. 107-8.

[64] In the absence of rivers and streams in the immediate vicinity, the tidal mill at Nendrum capitalized on the presence of a tidal regime. On other aspects of tidal mills, see Langdon, *Mills in the Medieval Economy* (note 1), pp. 78-79.

[65] The sites are Knocknacarragh, Co. Galway; Tahilla, Co. Kerry; Donaghmore, Co. Cork; Little Island, Wallingstown, Co. Cork; Killoteran, Co. Waterford; Great Island, Co. Wexford; Ballymascanlan, Co. Louth.

[66] Indeed, John Langdon argues that later medieval tidal mills in England needed to be located close to areas of high population density to ensure that sufficient profits would be forthcoming from milling to support the long-term maintenance costs: Langdon, *Mills in the Medieval Economy*, p. 79. This line of enquiry is worth following up with further research in Ireland.

[67] The possibility of broadening the spectrum of research into agrarian practices in Ireland is suggested by a short note on corn-drying kilns: Muiris O'Sullivan and Liam Downey, "Corn-drying Kilns," *Archaeology Ireland* 19.3 (2005): 32-35.

[68] The following data is drawn from the Discovery Programme's Medieval Rural Settlement project, which is examining archaeological and historical sources to describe patterns of land use, land ownership, and land value within the hinterland of Dublin: Niall Brady, *Exploring Irish Medieval Landscapes* (Dublin: Discovery Programme, 2003).

[69] *Ibid.*, p. 29; A.J. Otway-Ruthven, "The Medieval Church Lands of Co. Dublin," in J.A. Watt, J.B. Morrall, and F.X. Martin (eds.), *Medieval Studies Presented to Aubrey Gwynn* (Dublin: O'Lochlainn, 1961), pp. 54-73.

[70] The references up to 1550 have been collated by Margaret Murphy, while those for the seventeenth century have been collated by Michael Potterton.

[71] The recent excavation of a mill in the Liffey valley at Chapelizod by Claire Walsh has yet to be published, as has the site of Carrickmines to the southeast of the city excavated by Mark Clinton for Valerie J Keeley Ltd., archaeological consultancy.

[72] *Calendar of Documents Relating to Ireland, 1171-1251* [etc.] (hereafter *CDI*) (London: Public Record Office, 1875-86), I:438; *CDI,* V:4.

[73] *CDI,* V:81-83.

[74] James Mills (ed.), *Calendar of the Justiciary Rolls, or proceedings in the court of the justiciar of Ireland preserved in the Public Record Office of Ireland 1295-1303* [etc.], (Dublin: HMSO, 1905, 1914), III:156.

[75] It would however be wrong to assume that no mills were built in the mountains. The *Annals of Tigernach* for 1177 record a great bursting forth of water through the centre of Glendalough, which is located within the Wicklow mountains, and this flood swept away bridges and mills of the town and left some fish in the town. Whitley Stokes, *The Annals of Tigernach* [rpt. from *Revue Celtique* 1896/97] (Llanerch: Felinfach, 1993), p. 298. I am grateful to Charles Doherty for this reference.

[76] *CDI*, IV: 225.

[77] M.J. McEnery and Raymond Refaussé (eds.), *Christ Church Deeds* (Dublin: Four Courts Press, 2001), no. 578.

[78] I am grateful to Margaret Murphy for the following.

[79] *Calendar of Archbishop Alen's Register* (note 24), p. 222.

[80] London, The National Archives [Public Records Office], C47/10/22/7.