New Opportunities For The Sustainable Management Of Fens: Reed Pelleting, Composting And The Productive Use Of Fen Harvests

Final Report

Undertaken by ELP and Nick Ash On Behalf Of the Broads Authority

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SUMMARY

The aim of this report is to scope options which could deliver sustainable management of the Broadland fens through the productive and eventually the commercial use of vegetation cuttings.

The current Fen Harvester operation is reviewed. The Harvester, 13 years old, has around another 10 years of operating life. One of the main limitations on its operation is the disposal of cut material. Currently this is being composted to form a soil improver which will be incorporated into nearby arable land. Although it is a low-tech and manageable solution, it is also labour intensive, a cost to the operation, and its current ad-hoc nature is of questionable sustainability in the long term.

If the process can be better organised, including processing, licensing and disposal, composting still represents one of the most cost effective options for disposal at the small to medium scale. Fen cuttings could be mixed with peat arisings from turf ponding, woodchips and/or silt from waterways dredgings, all producing a slightly different type of end product. There are two types of product. True compost is a quality-assured horticultural product made from specific feed materials. It has the most diverse range of uses and the highest commercial value. Soil conditioner is a lower grade material used to restore Brownfield sites and other bulk applications. Although both could be produced by a Broads operation, soil conditioner is likely to be the major outcome.

A scaled-up and commercial composting operation could subsidise the harvester operation and would produce the widest range of associated benefits. In particular, it could provide major benefits to private fen owners and secure, for the first time, the full integration of fen management into the agricultural system. The report describes the partnerships and inter-departmental working that would be required to support a composting operation on the scale required.

Other options for disposal of cut material are considered. The main viable ones are:

- **The thatching market**. Commercial reed and sedge cutting are still viewed as core to the sustainable management of the Broads. The Fen Harvester and related disposal operations are complementary to the reed and sedge market.
- **Stock feed**. For a small number of sites of high conservation value, the cutting, baling and sale of marsh hay would be viable. Requiring only modest development or capital investment, it is an option that should be pursued.
- **The products of pyrolysis include biodiesel and biochar.** The latter is an almost pure form of carbon with a wide range of uses. All fen products can be pyrolysed, although the technology is currently at an early stage of development.
- **Combustion fuels.** These include woodchips, bales of scrub, and reed pellets. The first two are well established processes. Consideration of reed pellets forms the much of the rest of the report.

The report describes in detail the process whereby reed is converted to pellets. Feed stocks need to have a moisture content below 16%. Only reed is suitable – mixed fen is too variable in nature and too high in moisture. Reed should be harvested between January and April.

Pellet milling, handling and burning equipment is described. A medium-sized fixed mill is recommended. Material is brought to the Mill, which would have a capacity to process around

3,000 tonnes of reed per year. A wide range of burners based on straw are available to suit a range of different circumstances.

Supply of reed is a constraint. The yield of Broadland reedbeds is around 50 tonnes/ha, requiring 600 ha/year to be cut to feed the above mill, or 1200ha/year if cut on a two year rotation. The report estimates that there would be around 200 ha of reedbed available for harvesting, excluding sites that can be managed commercially for thatching. The gap could be bridged by reed produced from other major sites around East Anglia.

Demand for reed pellets is also reviewed. There are currently no pellet burners in operation in East Anglia, so a pelleting operation would need to stimulate demand and develop user partnerships. It is probable that major power stations could burn reed if they are licensed to burn straw, which has very similar combustion characteristics. The carbon footprint of transport to distant power stations is significant, but despite this, reed pellets have a fraction of the CO_2 Emission Factor that is normally associated with fossil fuels.

The main constraints on a pelleting operation are described in the Conclusion. While there are many, all have possible solutions, which are also described.

The report makes eight recommendations:

1. Composting, with disposal to nearby land, provides the most cost-effective option for accommodating fen arisings at the current scale of operation.
2. Any expansion in fen harvesting, or any move to true sustainability, requires development of a broad range of outlets for fen produce. No single solution can meet all of the needs.
3. An enhanced, commercial composting operation could accommodate a wide range of products including woodchip, peat and dredging silt. It can deal with moisture contents above 35%. It is recommended that this option be pursued vigorously, starting with developing the required partnerships.
4. Reed pelleting for biofuel provides the best use for near-pure stands of reed, cut in winter and with a moisture content of 16% and below, although there are considerable constraints. It is recommended that this option also be pursued.
5. Products of pyrolysis, particularly bio-diesel and biochar, provide the outlet for materials with moisture contents of 16-35%. The technology is at an early stage and therefore it is recommended investigations continue before development is proposed.
6. Smaller scale outlets such as marsh hay and products of scrub clearance would provide a modest but important "niche" outlet for some fen products. They should also be pursued vigorously.
7. The only existing sustainable management technique, traditional commercial sedge and reed cutting, should continue to be supported. Ways in which the above practises can complement and enhance traditional management need to be explored.
8. Because of the potential connections between various options for utilisation, and the synergies that would arise from large-scale development of all of the options, it is recommended that a partnership be formed which can take forward an integrated package of measures for sustainable use of fen products.

1. INTRODUCTION

1.1 Aim of the Report

1.1.1 Origins

Managing the 1650 ha of open fen in the Broads[1] is a considerable challenge for a wide variety of reasons (Stephenson 2004). It has been the subject of ongoing initiatives by the Broads Authority and its partners. The days when fen produce had a significant value, and there was abundant low-cost labour to cut and process the material, are long gone and there are significant consequences for the wildlife value of the fens (ELP 2010a). Only localised areas of high quality thatching reed and sedge are managed commercially and even this arrangement is precarious, threatened by variable quality and cheap foreign imports.

Consequently, there has for at least the last 25 years been a search for a viable solution to the sustainable management of the Broads Fen. This has included mechanisation in the form of the Fen Harvester, sustainable grazing projects involving a wide range of stock types, directly assisting the reed and sedge industries, and extending the financial support available to landowners to manage fens through the ESA and Stewardship schemes. Despite the early hopes of conservationists, none provide a silver bullet and it is likely that a range of management solutions will be needed.

Pelleting was originally considered as a means of dealing with the material that arose from the fen harvester (Andrews 2000 and Section 2 below). It was felt that if the material could be pelletised, it could be used for cattle feed or burned. The latter appears to be the most viable end use, but the technical methods to link harvesting through to making the pellets in a form suitable for delivery to end users requires development. Following further discussions, it was decided to include composting and a broader span of fen product utilisation, in the growing realisation that any initiative would need to consider the productive use of all of the arisings from fen management.

1.1.2 Aims

The aims of the project are:

- To review the main potential end uses for the products of fen management, identifying those which may contribute to long term sustainability of a scaled-up operation.
- To summarise the current composting operation and outline how it may be further developed.
- To specify the technical issues of harvesting and producing reed pellets suitable for combustion, the novel option with most advanced level of development.
- To outline the potential supply of reed pellets from Broads fens.

[1] This area excludes fen meadow and is based on 1999 air photos (Stephenson 2004).

- To provide an overview as to where reed pelleting and other uses for fen arisings fits within a broader strategy for sustainable management of the Broads Fens.

This report is structured around these aims.

1.2 Methods, Sources of Information and the Project Team

There were two main sources of information:

The vast amount of information stored in the heads of the main project team at the Broads Authority – Rob Andrews, Trevor Thorley and Andrea Kelly. Nick Ash has also been working on this theme for many years and for different organisations. Nick was the development engineer for the Fen Harvester and was able to bring this experience to the project too. This undocumented experienced was brought together for this report.

In addition, there were a range of reports summarising previous work that have been essential sources of information for this Report. Key documents are:

Stephenson, S (2004) *A Supplement to the Fen Management Strategy, Incorporating the Fen Audit*. Broads Authority and English Nature
Andrews, R., (2000) *New Wetlands Harvests: Final Technical Report*. LIFE 97 ENV/UK/000511
Ash, NJ (2010) *Reed Biofuel Feasibility Study* RSPB
RPA (2002) *An Investigation Of The Decline of the Broads Reed and Sedge Cutting Industry*. Broads Authority
Hunston Engineering (2002) *Biofuel Energy Plant*. Broads Authority

Finally, miscellaneous guidance on composting and waste disposal regulations were examined along with various test analysis reports undertaken on typical composting material.

2. CURRENT PRACTISE: THE FEN HARVESTER

2.1 Origins of the Fen Harvester Project

Much of the following is drawn from an account of the recent history supplied by Trevor Thorley, supplemented by documents such as Andrews (2000).

Following a Fen Ecological Survey by Jo Parmenter, a Fen Management Strategy was published (Tolhurst 1997). This sought to provide a framework for the environmentally sustainable management of the Broadland fens.

As this Strategy states: "The Broadland fens have developed through centuries of being harvested for a variety of useful products, and are of recognised international importance for nature conservation. However in the past half-century their nature conservation value has been declining as a result of neglect. In spite of considerable efforts in recent years by conservation organisations to reverse this trend, they are continuing to deteriorate."

The Strategy concluded that large scale sustainable solutions to restore and maintain the fens to favourable conservation status are needed, along with a co-ordinated approach amongst the numerous owners and land managers to optimise the use of resources.

As many of the traditional management practices had ceased or greatly declined, a number of management techniques were identified as being required to restore and maintain the fen habitats. The following initiatives have attempted to restore the fens to favourable condition:

- Large scale scrub clearances using various innovative mechanised techniques where it was thought that fen vegetation would return quickly. These tasks have usually been grant funded through Natural England.
- The development of grazing projects which aim to provide long-term management of fen habitats on a variety of sites. The RSPB, NWT, NE, SWT, and BA all use grazing animals (mainly cattle and horses) to manage a number of sites.
- Measures to support, encourage, and develop the declining reed and sedge industry. The BA, with other project partners, undertook a variety of initiatives which included encouraging the Reed Cutters Association to be set up, support with negotiations on reduction or removal of royalty payments, helping to identify "new" sites where cutting had ceased in recent history, setting aside small budgets to give restoration work to cutters in the lean times of the year, and successfully carrying out an HLF-supported training scheme to attract new people into the industry.
- The creation of a new category of fen tier within the ESA scheme to support landowners with the costs of managing fen sites, in addition to EN administered grant schemes.

Whilst these measures and techniques all have an important part to play in achieving fen management, it was also recognised that there needed to be some form of large scale harvesting technique for all of the sites where, for various reasons, the open fen habitats could not be otherwise be managed.

Thus in 1996 – 1997 BA initiated an application to the European Union LIFE programme for a grant to develop a New Wetlands Harvest Project. Match funding was obtained from partner organisations and BA contributed the staff time and practical support.

The main aim of this project was to develop a Fen Harvesting system including the development of machines both to cut large areas of fen vegetation and to enable that cut material to be taken off inaccessible sites and transported to outlets.

The Project lasted from 1st April 1997 for three years and included a number of tasks:

- Dissemination of the information derived from the project;
- Procurement and field testing of the Fen Harvester, transportation system and associated equipment;
- Product and outlet related investigations;
- Environmental benefit assessments including the physical and ecological effects of the harvesting;
- An economic assessment;
- An assessment of potential for technology transfer.

A whole series of reports and outputs charted the development and management of the project culminating in a comprehensive review and analysis of the results (Andrews 2000).

Following the end of the LIFE Funded Project in 2000, EN & BA decided that there were sufficient benefits from what had already been achieved to continue the Fen Harvester Project. Consequently, the costs were included within BA conservation and staff budgets, with financial support annually from Natural England.

The Fen Harvester and the Blower (manufactured in December 1997 and summer 1998 respectively) have enabled a range of fen of sites to be managed by cutting and removal of the arisings.

From the LIFE Project, no firm outlets or uses of the cut material was found. Depending on the circumstances of each site, material was left in piles and left to decompose in non-damaging locations, or taken to a nearby landowner for mixing with manures and turning to compost, then spread on arable land. This landowner ceased farming a number of years ago.

2.2 Operational Method

All the machinery and equipment purchased under the LIFE Project is still in use. The main pieces are:

- One Fen Harvester, which is a low ground pressure, tracked, self propelled machine that cuts, chops and collects the fen material into its own bin.
- A self propelled, tracked Blower machine that is used on some sites to remove the material by blowing down a pipeline either into a tractor-hauled bulk trailer for transport or into a pile.
- A JCB Tractor, a large bulk trailer for transporting cut material.
- A low loader trailer for transporting the machines and equipment.

- A Teleporter which can be used for a variety of tasks including turning composting material.

Within the Conservation Field Team, two officers mainly work with the Harvester, whilst also carrying out other duties, and with support from other Field Officers.

The identification and prioritisation of sites is mainly decided by the Head Officer of Field Conservation (the Team Manager), who negotiates with landowners what should be the appropriate management regime for each site. A number of sites are now in either the ESA or Higher Level Stewardship Scheme.

Ideally sites where the Fen Harvester is the main or only form of management are cut on a long rotation of 4 – 8 years. Within cut blocks, areas of uncut vegetation are retained to benefit invertebrates. This is felt important as the Harvester is able to cut large areas quickly.

Consequently there is a range of sites where this rotational management has now been occurring since 1997. These sites are mainly within the Ant and Bure valleys. Where possible, the Harvester operates from July to March, stopping between April and June for the bird breeding season. A flexible work programme is drawn up each year to ensure work is prioritised and to give options when high water levels alter plans.

There are a number of sites where cutting has been carried out to complement other management techniques such as restoring reedbeds, facilitating the start of grazing on a site, or one-off cuts to enable other forms of management to commence. In many cases, scrub clearance and dyke restoration work follows the Harvester.

Since 2002 the Harvester has managed 18 sites consisting of 56 compartments, with a total area of open fen within these compartments is 148ha. The volume of arisings, based on number of loads cut from July 2008 to April 2009, is estimated at 2000 cubic metres (data from Trevor Thorley).

2.3 The Future for the Fen Harvester

Development work will continue to identify solutions to problems incurred during the cutting and blowing operation. The fen harvester and blower have a long lifespan. Parts can be replaced and repaired as necessary, and the fabric of the machines are maintained by renovation and repair. The project team envisage that the machines could be operational for at least another 10 years.

The ESA and Stewardship schemes will continue to provide income for the work at our management agreement sites for the foreseeable future.

The Harvester has become an essential tool in the range of management techniques for restoring and maintaining favourable condition in many fen sites, for which there is currently no viable alternative. If pelleting is shown to be workable, it will allow the Harvester to focus entirely on mixed fen and more species-rich sites which are unsuitable for pelleting. Hence, reed pelleting for biofuel is seen as complementary to the Fen harvester, rather than a replacement.

The main issues for the harvester are:

- o Removal of arisings from sites where the blower cannot reach the margins or where there are no places to store the cuttings.
- o Once removed from the site, the disposal of the cuttings themselves is problematic. Currently the only known end-use for this material is composting, and even then, a viable and efficient method for making and disposing of the resulting compost has yet to be devised.

Once these issues have been resolved, the harvester will become a mechanised, standard management technique for extensive fen areas.

3. POTENTIAL END USES FOR CUT MATERIAL

3.1 Composting

3.1.1 Current Methods

Composting is currently the only method for disposing of arisings from the Fen Harvester. During the LIFE project, experiments to use the material for cattle feed, making briquettes for burning, or drying for burning loose at Eye power station were all shown not to be viable (Andrews 2000).

The following methods of disposal have therefore been adopted:

- Spreading by neighbouring landowners on arable fields for subsequent incorporation.
- On one landholding, mixing of arisings with manure and subsequent composting and incorporation into arable fields. This landowner is no longer in farming.
- Piling onto an adjacent landowners fields for composting.
- Transport of the arisings to the Fen Harvester base at Buttles Barn for composting in-situ. Currently the piles are being turned to aid the composting process.
- Piled on the fen site of origin to decompose in places where it will not affect the site.

Clearly the last disposal method is not ideal and is not sustainable in the long term. Removal and disposal off-site is the best option. Although compost can be made relatively easily, the Buttles Barn base is not large enough or appropriately set-up for a large scale composting operation. In any case the disposal of the compost itself does not have an agreed outlet, although this is likely to be the least difficult of all the issues to be resolved.

Fen cuttings alone would probably not make compost with commercial outlets, but may make a suitable soil improver. Mixing with other materials could produce horticultural compost but would require a scaled-up operation and possibly partnerships with larger operators such as the County or District Councils who already have green waste disposal operations. Partnerships with the horticultural products industry may also be fruitful.

Composting remains probably the most likely short-medium term prospect for disposal of cut fen material other than reed.

3.1.2 Mixing With Other Materials

Two main products which could be mixed with fen cuttings include:

- Peat from turf-ponding, recent turf pond infill from natural succession and organic scrapings from restoration of fen and reedbed. These materials are currently retained on site following restoration work. This is not sustainable in the long term and may cause flood protection issues. Such material is already half way to becoming compost and would be appropriate for incorporation with fen cuttings.

- Dredging silt. The disposal of arisings from waterways maintenance has long been problematic. This material could be incorporated with fen cuttings to produce more of a soil- or loam-based compost. The challenge is that dredging operations produce vast quantities of material very rapidly, far more than fen management. Considerable planning and coordination would be required.

A third product which could be admixed is woodchips produced from scrub clearance. Woodchips also have an established used as a biofuel for heat and power.

3.1.3 Compost and Soil Conditioner

A fundamental distinction should be made between *Compost* and *Soil Conditioner*. The former is a higher grade product made from a specific range of input materials, manufactured to a high and certified standard. It has the widest range of uses and the highest commercial value. Clearly, it also has significant resource requirements in terms of manufacture. Soil improvers are a lower grade product manufactured to much broader ranges of specifications. It tends to be used for bulk applications such as improving brownfield sites. Both products could be produced with fen cuttings, although the making of true compost is likely to be feasible only with a commercial scale operation.

3.1.4 Regulations

<u>Production of Compost</u>

Making and disposing of fen compost is subject to regulation, among others as a waste product. Its production and disposal to land is therefore controlled by the Environment Agency.

Use of land for the storage and making of compost or soil conditioners comes under the rather complex *Environmental Permitting (England and Wales) Regulations 2010*[2]. The making of compost is usually exempt from permitting, although the requirement to register the activity and obtain EA's agreement that it is exempt (through a U10 submission), still requires submission of forms and a substantial amount of supporting information.

<u>Disposal</u>

With the current scale of operations, the material is unlikely to find a useful commercial outlet. The most cost effective method of disposal is as a soil improver on local farm land. This also requires an exemption under the Regulations, with submission of forms and the required supporting information. There is likely to be a limit of 50 tonnes/ha for such disposal[3]. BA would also need to demonstrate that the material would result in agricultural improvement of the land.

While the information required by the regulations is quite onerous, if composting sites and disposal sites are used repeatedly, much of this information can be re-used.

[2] These update the 2007 Regulations.

[3] The other factor which could limit application rates could be nitrogen. However, analysis of 5 samples of compost suggested that nitrogen levels are low, and that the 50 tonnes/ha limit would be reached before the 250kgN/ha limit. (Analysis by NRM Labs, March 2010).

Benefits of Local Composting and Disposal

Small-scale composting and disposal to nearby land provides the most effective and economic solution to the needs of the fen harvester as it currently operates. It requires no special infrastructure and can be managed by the current team. If the disposal sites and the licensing can be resolved, this option could ensure the sustainability of the current operation.

Integrated Land Management

Many land owners around the Broads have fen and arable highland in the same holding. They may also have their fen entered into Stewardship. Developing an integrated land management operation, whereby their fen management arisings are composted and then incorporated all within the same land ownership may provide benefits to the landowner as well as to the fen. In addition, it may provide a mechanism whereby the landowner takes some ownership of the harvesting and composting process, with the managers of the fen harvester simply providing a cutting service. The benefits to landowners with difficult to manage fens entered into Stewardship are clear, and such an initiative would once again integrate fens back into the commercial rural economy. It could also reduce the burden on BA for at least some sites. The possibility of including such schemes as a specific, grantable prescription within Stewardship should also be considered, both for capital "set-up" costs such as improving access to the fen and establishing composting areas, and for annual payments. Defra might also consider fostering local land owner partnerships where fen owners team up with arable farmers to the same effect. If the scale of operation was sufficient, landowner cooperatives that jointly owned the harvesting equipment might even evolve, a step which finally integrates fen management with the farming economy. The scheme could be piloted with one or two progressive estates.

3.1.5 Scaling Up

If conservation aspirations are to be met for the fens, and other catchments outside of the Bure and Ant are to be brought within the fen management scheme, the fen harvesting operation needs to be scaled up significantly. Other arisings such as wood chips, peat and perhaps silt dredgings should also be brought within the ambit of composting.

Composting could be made more commercial and operated on an industrial scale with a usable and perhaps saleable end-product. This would be wholly sustainable, as long as the market is buoyant, and could provide a revenue to sustain the fen harvesting operation. The infrastructure and technical know-how required would be substantial, and such a scheme might need significant start-up funding and commercial partnerships. If the technical and commercial challenges were met, this could be a major component of a truly sustainable and long-term solution for fen management.

3.1.6 Partnerships and Inter-Departmental Working

Developing a more advanced and scaled-up composting operation would require significant partnerships and inter-departmental working. The principal partnerships are summarised as:

- **Technical:** Input to develop the product and the process. Partnerships could include the Incrops Project managed by the University of East Anglia, which aims to find alternative, commercial uses for derivatives of crops and green materials. Also required would be engineering input to develop the required machinery for pre-composting treatment. Ideally the harvesting, processing and composting should be engineered as a single process so that all the machinery is designed to be complimentary. Engineers with experience of both the process and working in similar landscapes should be considered as well as agricultural engineers and suppliers of standard equipment. Agronomy and soil science are additional technical requirements either through a partner such as the John Innes Centre or as a bought-in service.

- **Commercial;** If the operation is to be economically sustainable, partnerships with commercial horticultural product companies, land remediation companies and similar should be included.

- **Agricultural**: Partnerships with land owners, agricultural advisors and grant bodies will be required. Defra/Natural England would be key in such partnerships, as would some cooperative estates that could pilot such initiatives.

- **Regulatory**. A large scale operation will need permissions such as permit exemptions for compost production and disposal, planning permission and land management permissions. Partners would include the Environment Agency, Natural England and the planning authorities.

- **Functions**; In addition to ecological and site management expertise from the Broads Authority and the conservation organisations, such a project would require input from the waterways section of BA. Planning advice would also be helpful. The sedge and reed cutting industry would have a potentially significant role especially in the harvesting part of the operation.

- **Co-ordination**: A complex operation such as this requires careful coordination and planning, ideally by an organisation which has a strategic remit and covers a range of the above functions and specialities. Currently this is best placed with the Broads Authority.

- **Funding**; While it hoped the project will be financially self-sustaining in the long term, the planning and development phase will need independent and probably public funding, as will much of the set-up and infrastructure costs. A funding partnership will be needed which will undoubtedly include central government, local agencies such as Natural England, the Broads Authority and the conservation organisations. All such organisations will have a major stake in making this project work, as it could provide significant reductions in their management burden or costs in the long term, as well as deliver core organisational objectives. External grant makers such as the Heritage Lottery Fund and the EU LIFE fund may also be interested for the exemplar nature of the project. Finally, Section 106 funding or Growth Area funding could also be sourced. The onward revenue costs should be borne by the commercial operation.

3.2 Other Options for the Disposal of Cut Material

3.2.1 The Thatching Market

The use of reed and sedge is an ancient practise in the Broads but suffered great declines in recent decades as markets and the economy declined. The issues of the industry up until around 2000 are described in detail by RPA (2000). This report stimulated BA to coordinate a series of initiatives to revive the industry, which were largely successful. However, while the quality and demand for sedge is buoyant, reed cutters still have to contend with a variable quality reed harvest, and cheap imports from eastern Europe and latterly China. The industry is fragile and is likely to remain so for the foreseeable future. Although there are new initiatives on the horizon, such as increasing the component of thatch in new developments such as Rackheath, it is unlikely the industry will expand to cut greater areas than these described in Section 3 below, at least in the short-medium term.

3.2.2 Stock Feed

Cutting of marsh hay and litter for rough feed and bedding was once a thriving industry but has declined to practically nil. Attempts to pelletise material for cattle feed were not successful (Andrews 2000).

However, development of new low ground-pressure harvesting and baling machinery may make this a viable option which could produce feed and bedding for the burgeoning horse market. This option may be especially valuable for fen meadow sites and could be considered for fens cut on up to a two-year rotation.

3.2.3 On-Site Habitat Piles

Habitat piles used to be acceptable on very small sites with non-fen areas suitable to house the material. However, there are relatively few such sites and as noted above this is not a sustainable solution at any meaningful scale.

3.2.4 In-situ Burning

Burning of reedbeds was apparently commonplace especially where stands required restoration or were out of rotation. However research has shown that burning is damaging to invertebrates, especially where large areas are burned. While burning in small areas within larger fens may be acceptable, the practicalities of small area burns, requiring firebreaks and health and safety provisions, means burning is no longer a viable management tool. It was ruled out by the Fen Management Strategy and its Supplement (Tolhurst 1997, Stephenson 2004).

3.2.5 Biofuels

Biofuels from Pyrolysis

In March 2010, the Carbon Trust announced substantial grants for the development of technologies which could convert green waste (which would include fen arisings) into biofuel by pyrolysis. This is an industrial process whereby application of heat, without additional reagents, breaks down a material into a series of by-products. Manufacture of coke from coal, charcoal from wood and oils and alcohols from vegetable matter are all examples of pyrolysis, and there is a wide variety of techniques depending on the desired end product. The Carbon Trust project aims to develop transport fuel akin to diesel from the green waste. The technology promises small scale and local plants which can produce low volumes economically for local use. If successful, the process could produce fuel for fleet vehicles and could be a long term outlet for disposal of fen arisings in very large quantities.

This is new technology that will not be available in the short to medium term. Nevertheless this is an important technological development which could, along with a successful composting operation, provide a long-term outlet for green fen cuttings.

Biochar

Biochar is made by the combustion of organic matter in the absence of oxygen. It produces an almost pure residue of carbon. The production process is the same as charcoal except that the feedstock can be any vegetable matter, not just wood. It is a specific form of pyrolysis.

The carbon that arises is homogeneous regardless of the raw material, and has a wide range of uses. These include combustion, soil improvers, chemical filters, and in fact any use that carbon itself is put to. The product is much reduced in volume compared to the feedstock and therefore is easier to handle if biochar is made on site using mobile equipment.

Biochar can be made from material with a wide range of wetnesses, but operates best in the range which sits between reed pellets (<15%) and compost (>35%), and therefore could complement these technologies.

The technology and use of this material still appears to be at an early stage. More information is available from UK Biochar Ltd, Kingarth Lodge, Church Road, Binstead, Isle of Wight PO33 3SZ, cainblythe@googlemail.com.

Combustion Fuels for Heat and Power

Another form of biofuel is as a combustible material to fuel boilers for heat or electrical generation. This requires drier material of higher calorific value and with suitable burn characteristics. The latter includes ash content, chemical content of residues and vapours, and handling qualities. Consequently only reed pellets are suitable. Green cuttings from mixed fen are not. The range of potential users is very wide, from large commercial power stations through to local community power and heat schemes and to boilers to service specific buildings. Most end-users require security of supply, which may necessitate mixing with other fuels such as wood chip. However, the market has considerable potential with new developments (such as Rackheath) providing an opportunity for sustainable energy.

Combustion biofuel also provides opportunities for utilisation of other products of habitat management such as scrub or cuttings from heathland. There are now machines available which process scrub arisings as large bales, which can then be handled by machines and trucked to suitably licensed power stations (see Figure 1).

Biofuel from reed pellets has considerable momentum, including known technology and proprietary burners and manufacturing equipment. Hence of all of the potential end-uses, this appeared to have the best long term prospects and has been the main focus of the remainder of this report.

Figure 1 : The Scrub Baler, working on brash arising from scrub clearance on the chalk grasslands in Kent. The first photo shows scrub being loaded into the baler by grab. A bale is beginning to emerge. The lower picture shows finished bales, c.1m tall and weighing around one third of a ton.

4. UTILISING PELLET MILL TECHNOLOGY

4.1 Summary of the Pellet Mill Fuel Conversion Process

Pelleting of vegetable matter is a well tried and tested process, in fact the technology dates back to Victorian times. The reasons for pelleting vary but include:

- densification of otherwise very bulky material;
- homogenisation, for example of a blended animal feedstuff;
- rendering the material into a readily handled form for mechanisation.

All three of these reasons apply in the case of reed pellets for use as a solid bio-fuel but as we shall see later the most important is probably the homogenisation to allow for mechanical handling.

The process of making pellets is essentially one of massive compression. This can be achieved in several ways but the most common is using a cylindrical die, rather like a tumble drier drum but of great robustness and with a large number of small holes in the surface of the drum. Several thousand holes of typically 6 mm, 8 mm, or 11 mm are not uncommon. Inside the drum rotate several rollers which run against the inside surface and push any material inside the drum out through the holes. The wall thickness of the drum is typically 30 to 50 mm so there is great resistance to the material being squeezed out through these long holes. This resistance generates the compression which, combined with heat and sometimes a binding agent forms a solid pellet when the material exits from the die.

Although straight forward in principle, making good pellets is not a simple process. Every raw material has its own characteristics during pellet production, and not all pellet machines can process all materials into pellets. For example making pellets from low-density materials is much easier than producing quality hardwood pellets. Most practitioners in the pellet industry regard pellet production as more of an art than an exact science. To produce pellets from different raw materials requires a thorough understanding of the necessary changes that may need to be made to the raw material and pellet mill to consistently produce quality pellets.

The necessary steps are as follows:

Changes in Raw Material Particle Size

Before pellet compression in the pellet mill can take place, the wood, straw, grass, reed or any other form of biomass must be reduced in size. Only a raw material in a consistent form can produce consistent quality pellets. Part of this consistency is the size of raw material particles used in the pellet mill. Particles which are too small or too large can severally affect pellet quality.

Changes in Raw Material Composition and the Inclusion of Binders and Lubricants

In pellet production every raw material behaves differently, and some materials produce good quality pellets more easily than others. Depending on the equipment used, the composition of the raw material may need to be changed to produce good quality pellets at a reasonable productivity. Changing the composition can include adjusting particle size or moisture content, however it may also include adding binders and lubricants to help produce higher quality fuel pellets.

Changes in Raw Material Pellet Mill Feed Rate

Another adjustment that is critical to pellet production is the rate of feed into the pellet mill. Adjustments on feed rate and maintaining a consistent feed rate can make the key difference on how well the pellet mill operates, even if the raw material is perfect.

Changes in Raw Material Conditioning and Steam addition

Conditioning is the pre-treatment of the raw material before it reaches the pellet mill. Conditioning can include specific mixing techniques and sometimes the introduction of additional water or steam. Steam can be used to pre-anneal the raw material and start the lignin or other binder melting process. Though conditioning can have several benefits, in some cases the benefits are negligible and may simply not be cost effective.

Changes in Pellet Mill Operating Temperatures

Temperature is another key requirement in pellet production. Unless a certain temperature is reached in the pellet mill, natural lignin or starch will not melt or activate, and it is not possible to produce some biomass pellets, for example wood pellets below a temperature threshold. Also if the temperature is too high this can damage the pellet mill, and particular consumables such as the pellet mill die, rollers, bearings and seals.

Changes in Pellet Mill Roller and Die Clearance

Another variable which can impact heavily on how successfully the pellet mill operates is the distance between the rollers and the die. The rollers and die are wearing consumable parts, due to the abrasive nature of the feedstock. The distance set between the roller and die can impact on how much energy the pellet mill uses, the quality of the pellet, pellet mill productivity and the amount of fines produced. Correctly setting up the die on a pellet mill increases the life of the rollers and die, and thus reduces the cost of wearing parts and thus the final product.

Changes in Pellet Mill Die or Roller Rotation Speed

The speed at which the rollers and die turn relative to each other affect the complex relationships during pellet compression. Some materials require a greater time under compression, and therefore require a slower rotation speed. Also, speed and torque requirement of the pellet mill change.

Changes in Pellet Mill Die Design and Metal Used

Many different forms of steel alloy are used to produce pellet mill dies and rollers. Different alloys have specific advantages and disadvantages. Using the correct alloy is critical to reduce wear and increase production. However, as this is a matter for the designer and manufacturer of the equipment all the end user has to do is choose a reputable supplier.

Thus it can be appreciated that making pellets is a very specialised task which should not be undertaken lightly. However the forgoing litany can be reduced to three imperatives;

a) Moisture content of raw materials must be kept below 16%
To produce a quality pellet, the massive mechanical pressure required generates significant heat and if the die temperature exceeds approximately 90^{0}C, moisture will begin to gasify into steam and can effectively explode the pellet before it has solidified. Experience shows that if moisture content exceeds 16%, pellet quality will begin to suffer.

b) Particle size to be reduced to 6 mm
Material for pelleting must be of a consistent particle size. Long straws or reeds will cause blockages in the feed mechanisms and larger bodies can cause mechanical failures. When pelleting *Miscanthus*, straw or reeds, it first needs to be chopped to the point where it will flow into a hammer mill. A particle size of 6 mm has found to be ideal for reed.

c) Material types should not be mixed
Different material types must be pelleted using bespoke die sets, the characteristics for which are found by experimentation. However it is sometimes possible to pellet different types of materials through a single die, by using different levels of additive, but this is a very skilled operation. If the materials being presented to the pellet mill are constantly varying, it is very difficult to control pellet quality. However, if differing materials are presented in a consistent ratio and mix, additives can be adjusted to suit and quality pellets could, in theory, be produced, but this is not an easy matter.

This constraint would of course apply to mixtures of reed, other grasses and fen litter.

4.2 Machinery Available

4.2.1 Pelleting Machinery Available

Many different brands of pellet mill are available on the market. Table 1 summarises suppliers for different scales of machines. Most of these are large industrial scale units for producing mainly animal feedstuffs at rates of typically 5 tonnes per hour. The recent upsurge in interest and utilisation of biomass as a renewable fuel has seen many of these manufacturers offering the same equipment but labelled as Biomass Pellet Mills rather than Animal Feed Mills. With correct and appropriate die sets, as described above, these machines work well with biomass. However many of these are large pieces of equipment and with the necessary ancillary equipment would cost c. £1 million (excluding infrastructure). They are probably too large for our application, especially for a pilot scheme to test the market for reed pellets locally.

Table 1: Example Suppliers of Pellet Mills

Large Mills, c. 5 T / hr
ANDRITZ FEED & BIOFUEL Ltd. Sutton Fields Industrial Estate Hull, HU7 0XL Tel: +44 (1482) 825 119 Fax: +44 (1482) 839 806 E-Mail: **andritz-fb.uk@andritz.com** **CALIFORNIA PELLET MILLS Ltd.** Dryton Field Industrial Estate Daventry Northamptonshire NN11 5RB Tel: 01327-704721
Medium Mills, c. 500 kg / hr
FARM FEED SYSTEMS Ltd, Foxes Bridge Road Forest Vale Industrial Estate Cinderford GL14 2PH Tel: 01594.825106
Micro Mills, c. 100 kg / hr
PELHEAT LTD., Lask Edge Road Lask Edge Leek Staffordshire ST13 8QS

There are also now offered on the market several very small "mobile "pellet mills. Typical of these is the offering from Pelheat Ltd. of Leek, Staffs. By comparison with the commercial mills these are tiny. They are best suited to the DIY user and possibly agricultural small-holder making small quantities of animal feed-stuff but some users are making small quantities of biomass pellets, usually from wood waste / sawdust. The basic process requirements for making good quality pellets are the same with these small mills as for the large commercial ones and enthusiasm on the part of the user is by no means a guarantee of good quality pellets. Most of these tiny presses utilise a Flat-Bed-Die (rather than a Cylindrical Die) which is much easier and cheaper to manufacture but is very difficult to achieve optimal pelleting conditions across its whole area, especially for the casual user. The quality of construction on some of these imported micro pellet presses is also doubtful.

In between the large commercial mills and the imported micro pellet mills are the old “Lister” style mills. These were developed over 60 years ago by R.A. Lister Co. of Dursley, the company famous for diesel engines and farm equipment both of simple and robust construction. This size and style of pellet mill is still supplied by at least one manufacturer in the UK. Farm Feed Systems Ltd., of Cinderford, Glos., have adapted these old designs and can supply a turn key plant which they have tested successfully on many types of biomass including *Miscanthus*, grass, wood and reed. Again, the same stringent requirements apply for successful pellet production but the company can supply all the machinery and control equipment to ensure consistent production.

4.2.2 Burning Appliances

Obstacles to burning reed pellets

When we come to consider appliances to exploit the potential supply of reed biomass pellets we encounter an unexpected and rather inconvenient obstacle. Research has shown that reed pellets do not burn well in appliances designed for burning wood pellets. In fact in some trials with domestic wood stoves the reed pellets completely extinguished the fire in under 30 minutes and in these and other appliances large amounts of ash and clinker cause severe operational problems. So although there is now a huge range of wood pellets stoves and boilers available and a burgeoning wood pellet supply infrastructure in the UK, this is not a practical route to the adoption of reed biomass fuel.

Reed’s similarity to straw

However, research has also shown that reed biomass has very similar physical and chemical properties to, and behaves in a very similar manner when burnt, to cereal straw biomass. This opens a new range of options, namely straw burning boilers and stoves. Various appliances are available which are specifically designed to run on cereal straw. Many of these have been developed in Denmark where there is a long standing tradition of utilising straw for heat generation.

Chopped, bales or pellets?

Some appliances can burn chopped straw and some are designed to be fed with large straw bales, either “Big Rounds” or “Heston” bales and others are specifically designed to run on pellets.

Chopped straw and reed is a very bulky with a very low bulk density. Handling and storage of any significant amount involves huge volumes. For example, consider a small village school or typical visitor centre of say 1400 m^2. Such a building might have a heat demand of 200 MWhrs per year.

This could be satisfied by 50 tonnes of reed or straw in any format. If the reed were in chopped format the storage needed would be 675 m^3. This would be a very large fuel store and would constitute a significant fire hazard, a possible dust hazard and might be aesthetically unacceptable.

Bales of reed or straw would need less storage space but would need mechanised handling equipment, both to receive the bales into storage and also to feed them to the burning equipment. Typical large straw bales weigh up to 1000 kg. Mechanised handling (tractor and front-end loader for example) requires significant capital and skilled personnel.

Pellets

Pellet burning appliances are the best option on grounds of storage, mechanised handling and ease of operation. Our same example building of a 1400 m^2 using 50 tonnes of straw or reed if in pellet form would only need some 75 m^3. Also the pellet format enables fully automated mechanical handling of the fuel.

Many straw burning appliances claim to be able to handle pellets but trials are essential to confirm this. Pellets burn much hotter than loose fuel and this can lead to problems with the parts of the appliance in contact with the burning fuel.

Table 2 summarises some of the available equipment. Of these, we only have direct reed burning experience with the Carborobot. Other boilers and stoves may perform perfectly well with reed pellets but we have no direct experience with them as yet.

A ten day trial was successfully carried out burning exclusively reed pellets in a Carborobot boiler. The pellets were made by Farm Feed Systems Ltd., of reed sourced from the Tay estuary. The Carborobot F60 Model ran unattended other than for manual stoking every third day and ash removal every fifth day. Control of combustion was under both timer and thermostatic control and connected to a domestic supply heating two average size dwellings. A brief video of this trial can be seen on Youtube at www.youtube.com/watch?v=smxVm2INIRY

Figure 2 : A Carborobot Straw pellet Boiler

Table 2 : Some Brands Of Straw Burning Boiler With UK Suppliers

Straw Boiler Brand	Origin	UK Supplier
CN (Maskinfabrik)	Denmark	**Manco Energy Ltd** Market Weighton Road North Newbald East Yorkshire YO43 4SP Tel; 01430.828660 Fax; 01430.828661 **www.mancoenergy.co.uk**
Carborobot	Hungary	**Straw Pellet Boilers Ltd** Louth Lincs Tel; 01507.601992 **www.strawpelletboilers.co.uk**
Froelling	Germany	**Enonergy Ltd.** Hatley St. George Sandy, Beds SG19 3SH Tel; 0870.0545 554 **www.econergy.ltd.uk**
Heizomat	Germany	**Mercia Energy Ltd,** 86 Grosvenor Rd, Rugby, Warwickshire, CV21 3LE Tel: 01788 842377 **www.mercia-energy.co.uk/**
Linka	Denmark	**Manco Energy Ltd** As above
Reka	Denmark	**J Riley Beet Harvesters (UK) Ltd.** Church Farm, Attlebridge, Norwich, NR9 5ST 01603 262526 **info@riley-reka.co.uk**

4.2.3 Equipment for Handling Pellets

Although reed pellets do not burn as wood pellets do, they can of course be mechanically handled by the same equipment as wood or any other pellets.

The Carborobot boiler used in recent trials had a hopper capable of holding about three day's supply of pellets running on a typical domestic heat load for two dwellings. Larger models in the Carborobot range and also other commercial scale boilers can be fitted with completely automatic stokers which transfer pellets from bulk store to the appliance hopper and thence to the fire grate under automatic control.

Bulk storage options for pellets include storage bins in adjacent buildings, outdoor silos with conical bases and gravity feed to cross augers for eventual delivery into the appliance and also now even pre-fabricated underground pellet stores. Pellets can also be packaged in small, (20 or 25 kg) polythene bags or paper sacks which are very convenient for the domestic user and can be readily manhandled, stored and transported.

Delivery options for small bags include flat bed truck rather like the traditional coal man's delivery round and also self collection by the end user. Some wood pellets can now be bought at petrol station forecourts.

Delivery options for pellets in bulk include large tipper trucks and also now bulk tankers which load and unload the pellets by pneumatic conveyance, i.e. the pellets are blown down a pipe into the customer's storage facility. Figure 3 illustrates some of this equipment.

Figure 3 : Some Pellet Handling Equipment

Underground pellet store

Pellet Silo

Pellet delivery Tanker

4.3 Technical Requirements of Pellet Mills and Burners

Virtually all our research and experience gained has been with reed, although a very small quantity of mixed fen litter has been made into pellets and trial-burnt in a wood pellet stove. We currently have no direct experience with and have found no data on sedge pelleting.

As discussed in detail in Section 3.1, consistency of biomass feedstock to the pelleting process is critical. Varying mixtures cannot easily be tolerated by the process so if *Cladium* and mixed fen litter are all to be pelleted much development work will be needed.

Pelleting of reed alone has been developed successfully and at least one full-scale plant is known to be currently under construction and scheduled to start producing reed pellets in 2011.

As discussed in Section 3.1, the three essentials for making pellets are consistent feedstock, particle size and moisture content.

Consistency
The requirement for consistent feedstock precludes just cutting any old fen material and feeding into the pellet mill. Reed will have to be cut almost as if it were destined for thatch but of course the normal thatchers' requirements of length, straightness and hardness will not apply. Also the cleaning or dressing as for thatch reed is unnecessary and would only result in loss of valuable biomass.

Particle Size
This is completely taken care of by the Pellet Mill plant. The requirements for the in-feed raw material format are discussed later.

Moisture Content
This is the single most critical aspect of pellet making and especially reed pellet making because the moisture content of the raw reed as cut can vary enormously. The upper limit of moisture content for successful pellet making is about 16%. This is by "wet basis" determination and is derived simply by totally drying a sample of the material and expressing the weight loss as a fraction of the total wet sample weight.

Experience gained from many reed cutting operations over several years reveals some interesting data regarding moisture content of the reed crop. When cut traditionally for thatch, reed has a moisture content of typically c.20%. Any wetter than this and the material is not suitable for thatching anyway and if used will result in premature failure of the roof.

Luckily, reed, when cut and stored in bundles continues to dry, even in the UK climate if simply covered in an open building, by a stack sheet or even casually thatched with reed bundles.

Cut reed exchanges moisture with the atmosphere depending on the relative humidity. Eventually equilibrium is reached where little more exchange takes place.

This level of water content is referred to as the Equilibrium Moisture Content, or EMC. In the UK, the EMC for cut reed is about 15%. In Eastern Europe the EMC for cut reed is about 10 to 12%.

By comparison, if fen litter is cut and collected by forage machine, such as the Fen Harvester the water content can be anything up to 75% depending on factors including time of year, weather on the day and height of cut. This water content and the mixed nature of the material thus foraged make it unsuitable for pellet production.

So it can be appreciate that cutting and binding into bundles is the preferred method if appropriate water content is to be achieved. The bundle method has the added benefit that the reeds continue to dry after cutting until an EMC of c. 15% is reached

If burning reed in bundles or bales or chopped, water content up to around 35 or 40 % is acceptable. If burning pellets, the moisture content of the pellets will be below 10% and as such will be suitable for any straw pellet burning appliances. But again it is worth repeating that even at this appropriate level of moisture content, reed pellets will not burn well in appliances designed for <u>wood</u> pellets. Dry storage of any type of pellet is <u>essential</u> to maintain the pellet form. Pellets are highly absorbent and if not kept dry will rapidly fall apart resulting in a very large pile of dust.

4.4 Assessment of Mobile and Static Operations

A search for mobile pellet making equipment does not reveal much choice. A number of pellet presses or pellet mills as they are sometimes referred to are reviewed here and illustrated in Figure 4. Some of these are mobile and some static plants. Mobile or portable plants tend to be either extremely large or to be very small and not equipped for full processing capability. The Static plants were considered to see if they might lend themselves to mobile operation or modification to a mobile function.

4.4.1 Pelheat Mobile Pellet Mill

Pelheat Ltd is a small father and son business from Leek in Staffordshire offering a very small portable pellet mill. The heart of the system is a tiny “flat-bed” pellet mill of Chinese origin.

This has been trailer mounted and driven by a diesel engine which also powers a hammer mill in series with the pellet press. Their prototype machine has been thoroughly investigated and trials carried out with reed material. Some reed pellets have been made, but of only fair quality, and output was quite low at around 40 to 50 kg per hour.

At this rate, 50 tonnes per annum to heat 1400 m^2 would take about 30 weeks to produce, even if the required quality were achieved consistently which is not at all certain. The machine is clearly too small, of the wrong die type and not provided with all the necessary ancillary equipment for fully mechanised operation.

It might suit a research operation wishing to experiment with pelleting of different materials but is unsuitable for serious production needed to make pellets in a regular, reliable and cost effective manner.

Pelheat are predicting a selling price for this equipment of £20,000, however, this will not be possible and the actual price will be significantly more than this, possibly up to twice as much.

The conclusion is that the Pelheat machine would be unsuitable for our needs.

4.4.2 Pellet Pro Mobile Pellet Mill

This is a very similar offering to that of Pelheat but made in America. This machine was not investigated other than by reference to manufacturer's information. It appears to be based on the same Chinese flat-bed die press and that the system suffers from the same shortcomings as the Pelheat offering. Absolutely no ancillary equipment is provided.

The conclusion is that it would be unsuitable for our needs.

4.4.3 Biojoule Ltd and other Moveable Pellet Plants

Biojoule Ltd. claim to have developed a technology to use less power in producing pellets and also have assembled a plant which can be moved although they are cautious in claiming true "mobility". What they have developed is an integrated pellet plant of some 10,000 tonnes per year capacity that includes drying, pellet manufacture and storage. It needs no mains connections, and is fully automated with control via a web link. All an on-site operator needs to do is to fill the bins with wood chip once a day.

The plant is built as a series of linked ISO transport containers, so needs no buildings or foundations. All it needs is a secure flat and level area about 40m by 20m with access and manoeuvring room for a front-end loader and access for heavy haulage vehicles. Mobile phone reception or a telephone line is also important. The plant can be moved from one location to another in a matter of days making it possible to follow harvesting or woodland management operations, and also to use biomass resources that might only be available for a short season.

However, discussions with Biojoule Ltd. suggest that for a move to be worthwhile a minimum feedstock quantity of around 5,000 tonnes is considered necessary.
The conclusion is that this equipment per se is probably too large for our needs; but could we make use of it if it were working nearby to one of our sites; say by feeding our reed material into the supply chain? Unfortunately the answer is probably not. There is a fundamental problem with mixing biomass types in boilers of small domestic and commercial scale. There are similar fundamental problems, as discussed previously, with trying to mix feed-stocks into pellet mills. Different biomass materials require different operation regimes both in boilers and pellet mills so randomly adding reed into wood or other biomass feed streams is a non-starter.

Other moveable pellet mills, such as one currently operating around Thetford Forest and requiring 50,000 tonne lots to make a move viable will also be unsuitable for our needs for similar reasons of scale.

4.4.4 Farm Feed Systems Ltd fixed installation pellet mill

Farm Feed Systems Ltd (FFS) of Cinderford, Gloucestershire is a manufacturer and supplier of small pellet production plants although they do not currently offer mobile equipment. This company has demonstrated that their standard small fixed installation mill can make good hard pellets from 100 % reed material in as-received condition. Several tonnes of reed have been pelleted using FFS equipment. However early success with their bench scale machine was difficult to repeat and significant development work was necessary to resolve the problems of consistent pellet production.

This experience highlights the complexity of reed pellet manufacture. The compression of biomass through the die to create the bonded pellets is only one small part of the overall operation. Material preparation; chopping; grinding; dust control; feeding of water, oil and binder additives; cooling and pellet transfer all need to work in concert to effect successful pellet production. This factor is often overlooked or underestimated in attempts to develop mobile pellet plants so we must beware.

The binder used to produce the reed pellets was lignin. Lignin is a harmless, biodegradable bi-product of paper pulp manufacture and is available commercially for use as a pellet binder, usually for animal feed.

Based partly on these trials and experience and data from other pellet making exercises a specification for Mobile Reed Pellet Plant has been drawn up to investigate possible costs of such a plant. Discussions with Farm Feed Systems Ltd. has established that they could be interested in supplying equipment based on such a specification and have given an order of cost in the region of £125,000. This excludes the base vehicle on which to mount the mobile equipment so we should add to this an element of say £30,000 including adaptations which assumes say a 7.5 tonne flat bed truck. Special machine development can be an uncertain process and adequate budget contingency is essential.

Development projects often run over budget and always run over schedule. A significant contingency must be budgeted and 10% may be on the low side but we will assume this figure as a starting point. Thus a cost in the order of £170,000 should be anticipated from Farm Feed Systems Ltd.

An interesting potential innovation which came out of these discussions with Farm Feed Systems Ltd was the possibility to use the pellet storage facility as a cooler. Pellets are very hot and friable immediately after manufacture and must be cooled to harden off. Coolers are essentially just large containers through which air is blown to cool the pellets. These coolers tend to be very large due to the required residence time for the pellets. Such large volumes would be difficult to accommodate in a mobile plant so the concept was conceived whereby a pellet silo, at the point of use, might double up as the cooling facility. The air mover and suitable connections would travel with the mobile pellet mill. This concept has the advantage of reducing the size of the mobile plant but would also require more costly, bespoke storage silos at the point of use. This concept would be inappropriate if the pellets were to be sold rather than used in house.

Discussion with another potential supplier, Cornwell Heat Ltd of Bury St Edmunds, Suffolk who currently supply wood pellet burning stoves and who have tested some reed pellets also expressed interest in supply of a mobile pellet making system. Their order of cost for budgetary purposes is £183,500 or £201,850 if we use a similar 10% contingency.

These figures are budgetary only at the moment but are useful in order to examine possible production costs for "home-grown" reed fuel pellets.

Figure 4 : Pellet Mills

Farm Feed System's Machine

Pellet Pro Mobile Pellet Mill

An example of a Mobile Feed Rolling Mill.
A Mobile Pellet Mill might look like this.

Pelheat's mobile Pellet Mill

5. SUPPLY ISSUES

5.1 The Resource of Reed-dominated Vegetation in the Broads

5.1.1 The Basis of Any Pelleting Operation

The viability of the reed pelleting operation described above depends on a reliable supply of fuel material. Key aspects of "reliability" are:

- Volume available each year.
- Distribution and patch size of the sites which provide this volume.
- Practicality of harvest and transport of this resource.

The process is essentially mechanised and neo-industrial. The bulk nature of the raw material, its low value per tonne and the high volumes required to make it viable suggest that site and supply issues are likely to be critical to success of the operation, just as they are for other extractive industries. Obtaining a clear understanding of the resource is therefore key to the project.

Note that the reed currently cut for the thatching industry may not be available for pelleting. Maintaining a viable thatching industry is desirable for a variety of reasons (RPA 2002) and therefore only reed unsuitable for thatching would be available for pelleting.

5.1.2 The Fen Management Strategy

The Fen Management Strategy (Stephenson 2004) included a Fen Audit. Between February 2002 and February 2003, BA staff visited all of the open fen sites and assessed each against a checklist of practical requirements if the site were to be managed by either the Fen Harvester or fen grazing. In the following it is assumed that attributes for the fen harvester also apply to harvesting for a reed pelleting operation although this assumes harvesting would be based on large machinery and mechanisation, an assumption revisited later.

Stephenson (2004) notes that the assessment focused purely on practical, not ecological, needs of the site and does not imply either technique is the correct management strategy for a particular place, and this applies equally to harvesting of reed for pelleting. Because of the energetics of reed pellet burning, only sites suitable for winter management of reed could be considered.

The summary data from Stephenson (2004) are:

Area suitable for Fen Harvester:	172ha
Area suitable for Commercial reed management	265 ha

The sites that are suitable for the Fen Harvester are currently restricted by distance from composting sites (the current method of disposal of arisings) and the length of blow pipe that moves material off-site. The report notes that the machine is suitable in practical terms to cut an additional 343ha if the disposal of arisings issue were solved. However, the resulting total of 515ha that could be tackled by the Fen Harvester includes an unspecified area of mixed fen, which would not be suitable for pelleting.

The area assigned as potentially available for commercial reed cutting may provide a better assessment of potential for pelleting. It includes areas currently cut for reed (85ha) and areas that could be if the reed were brought back into commercial condition (an additional 180 ha). Figures 5-9 are taken from the Fen Audit and show for each river valley which sites are in commercial reed production and which could be.

Figure 5 : Commercial Reed in the Ant Valley. From Stephenson (2004), Courtesy of the Broads Authority

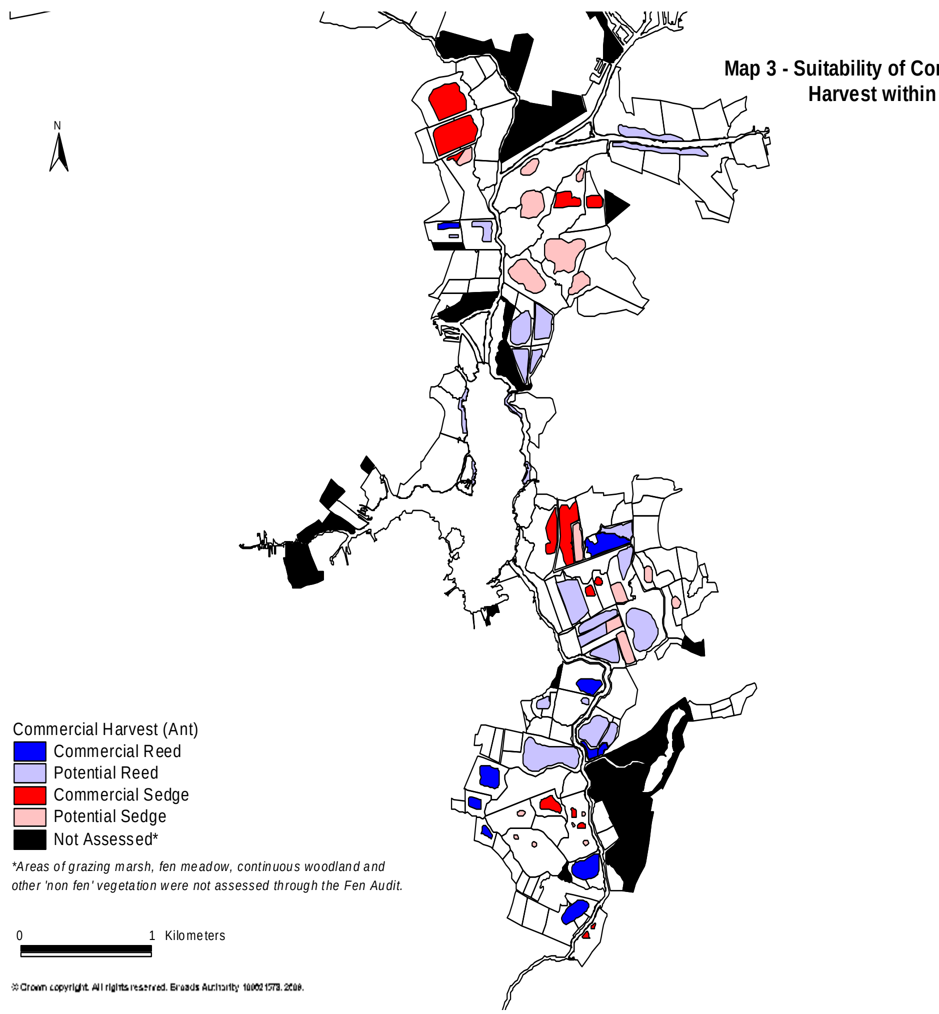


Figure 6 : Commercial Reed in the Bure Valley. From Stephenson (2004), Courtesy of the Broads Authority

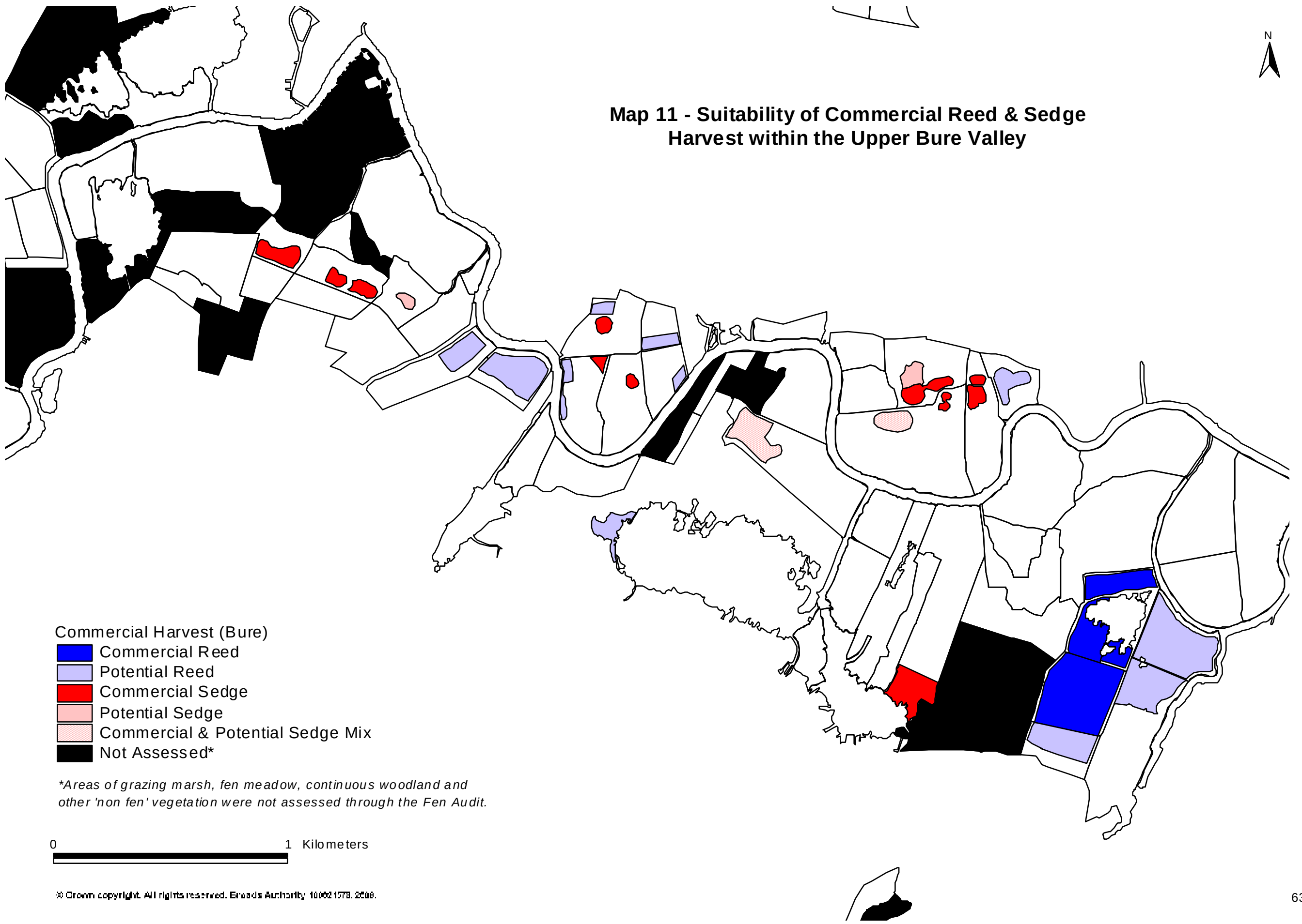


Figure 7 : Commercial Reed in the Upper Yare Valley. From Stephenson (2004), Courtesy of the Broads Authority

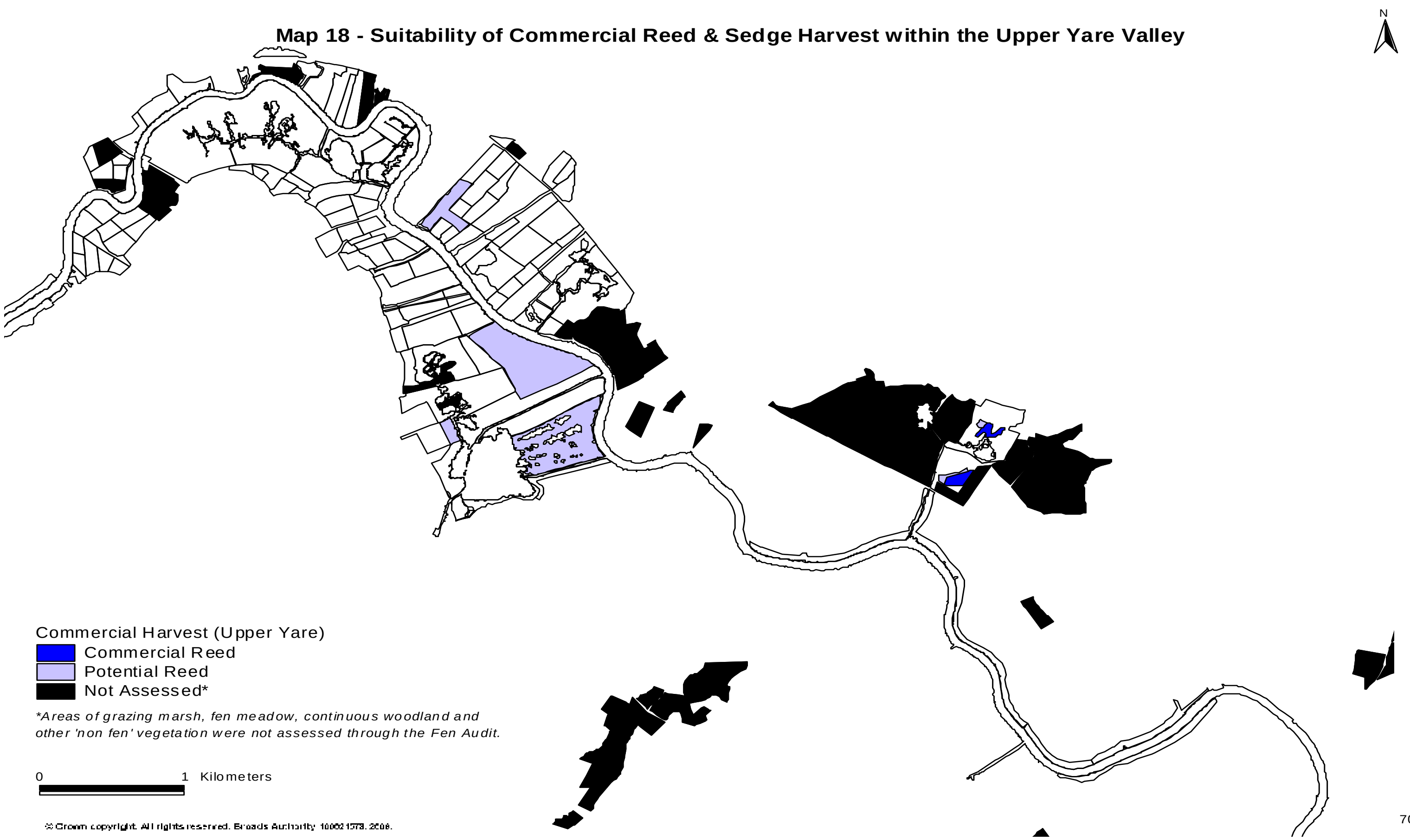


Figure 8 : Commercial Reed in the Lower Yare Valley. From Stephenson (2004), Courtesy of the Broads Authority

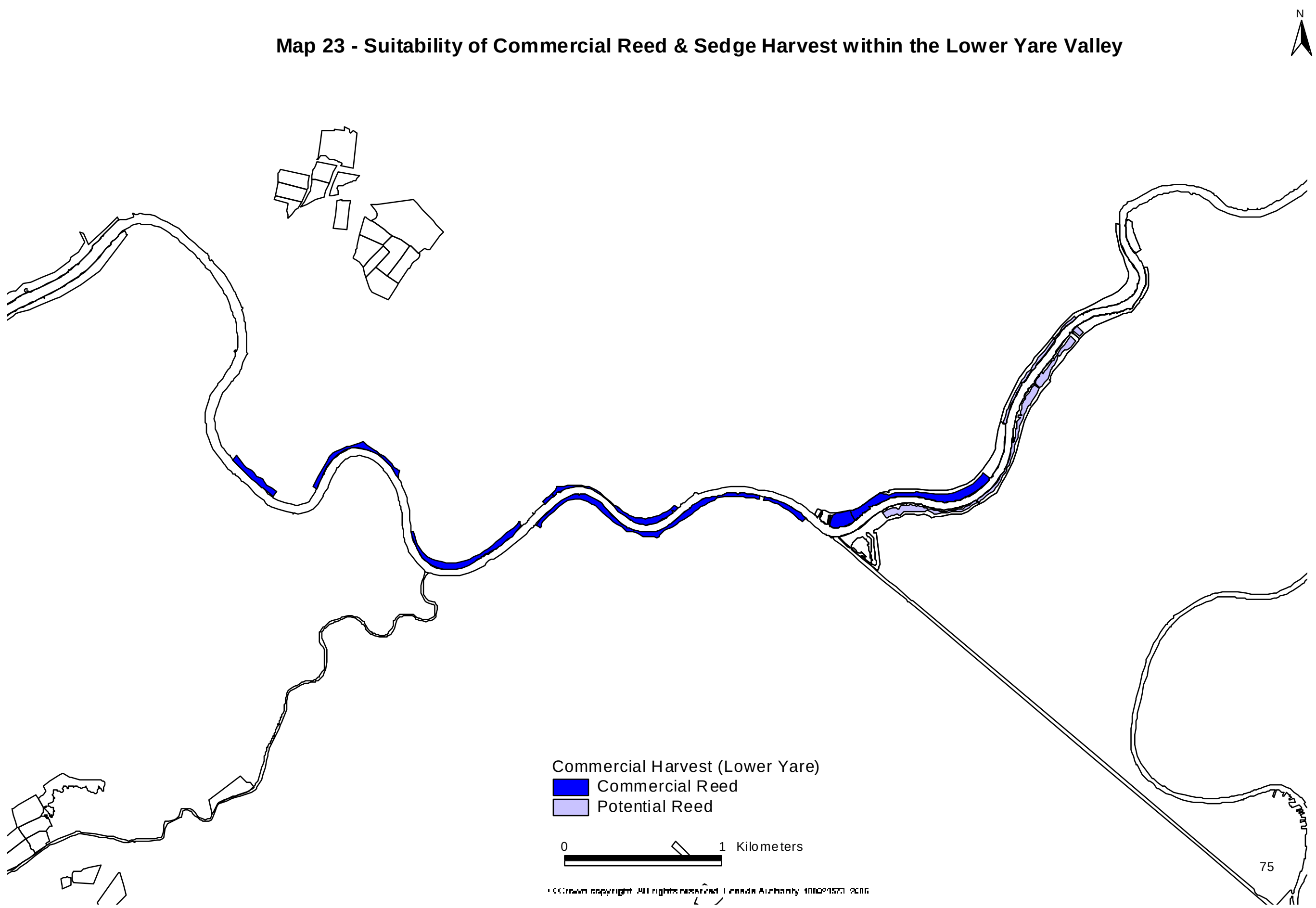


Figure 9a : Commercial Reed in the Thurne Valley. From Stephenson (2004), Courtesy of the Broads Authority

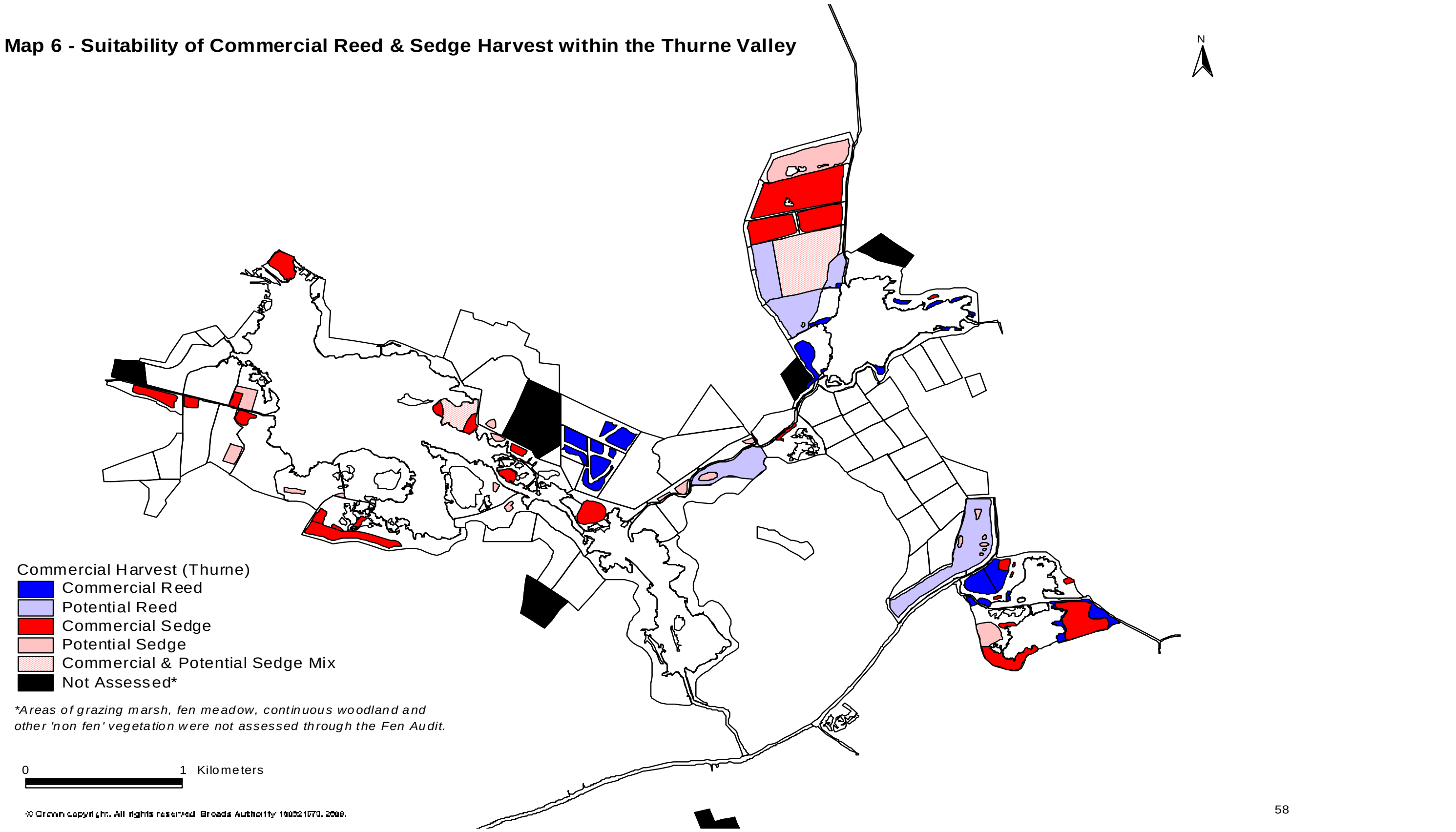
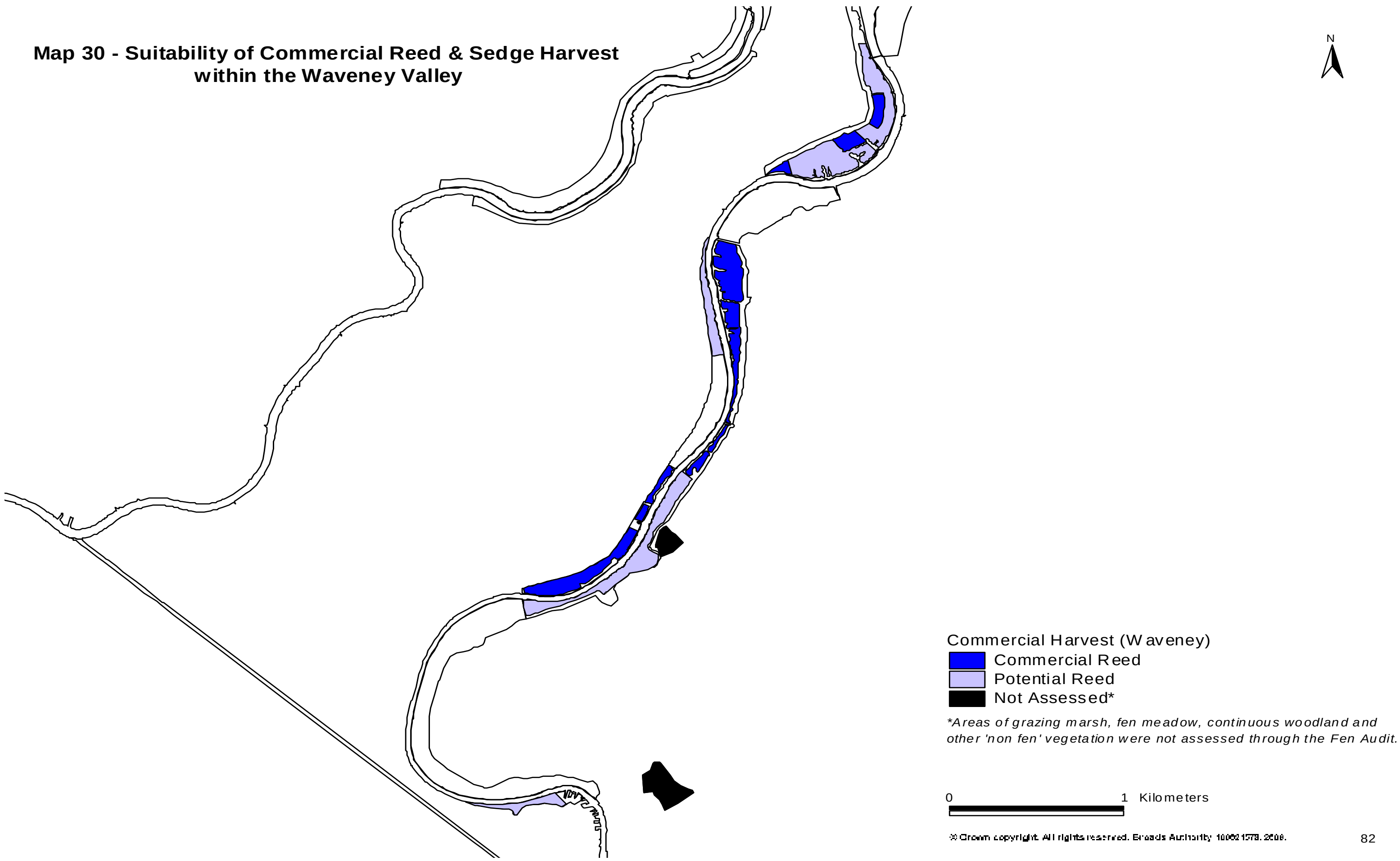


Figure 9b : Commercial Reed In The Waveney Valley. From Stephenson (2004), Courtesy of the Broads Authority



However, the maps are based on returns from reed cutters and may include sites that are unsuitable for large machinery. They do not include new sites that have been developed for reedbed such as additional parts of the Hickling nature reserve.

The map indicates that the reed resource is relatively dispersed among the five valleys and with some exceptions, occurs in relatively small and inaccessible patches. This distribution does not lend itself to mechanised harvest and transport. Much if not all of the sites coloured dark blue may in fact be unavailable for pelleting, being reserved largely for the thatching industry.

Around one third of the fen resource (628ha) was deemed by the Fen Audit to be unsuitable for any of the sustainable techniques at that time, because of site difficulties. It is not clear to what extent the sites could be made suitable for reed production with, for instance, different machinery, preparation works such as scrub clearance or improvements to access and infrastructure.

5.1.3 The 2007-9 Fen Survey

The fen survey conducted by ELP between 2007 and 2009 recorded the species composition of the fens of Broadland. A total of 7,038 samples across around 1750ha of fen were taken, equating to 0.24865 ha per sample[4]. From this data set, all samples where reed has an abundance of greater than 75% cover and where other species were sparse, were extracted and mapped. This gives an accurate and up to date assessment of the distribution and amount of reed dominated vegetation suitable for pelleting.

Maps showing the distribution of dense reed-dominated vegetation are shown in Figures 10-16. The total area derived from the 1151 reed samples for the Broads is 287 ha. This is a little higher than that of the Fen Audit (which estimated 265ha), perhaps because it includes a wide variety of small patches which the Audit may not have deemed viable for commercial cutting. The survey maps also include sites in the Thurne and Bure which have been managed to develop wet reedbed in the last ten years reflecting the conservation effort expended to develop this habitat. Nevertheless, there is good coincidence between the two estimates.

5.1.4 Investigation Into The Reed Industry (RPA 2002)

This report mostly examined the current economics and future prospects of the reed industry. In terms of the reed resource, it reports the area under productive management to be around 100-150ha, but this includes sedge and was in any case based on verbal estimates. From the above more objective sources, it appears to underestimate available reed.

[4] The area covered was larger than the fen audit data as it included fen meadow and other marginal fen habitats.

Figure 10 : Stands of Dense Reed in the Ant Valley. From the 2007-2009 Fen Survey

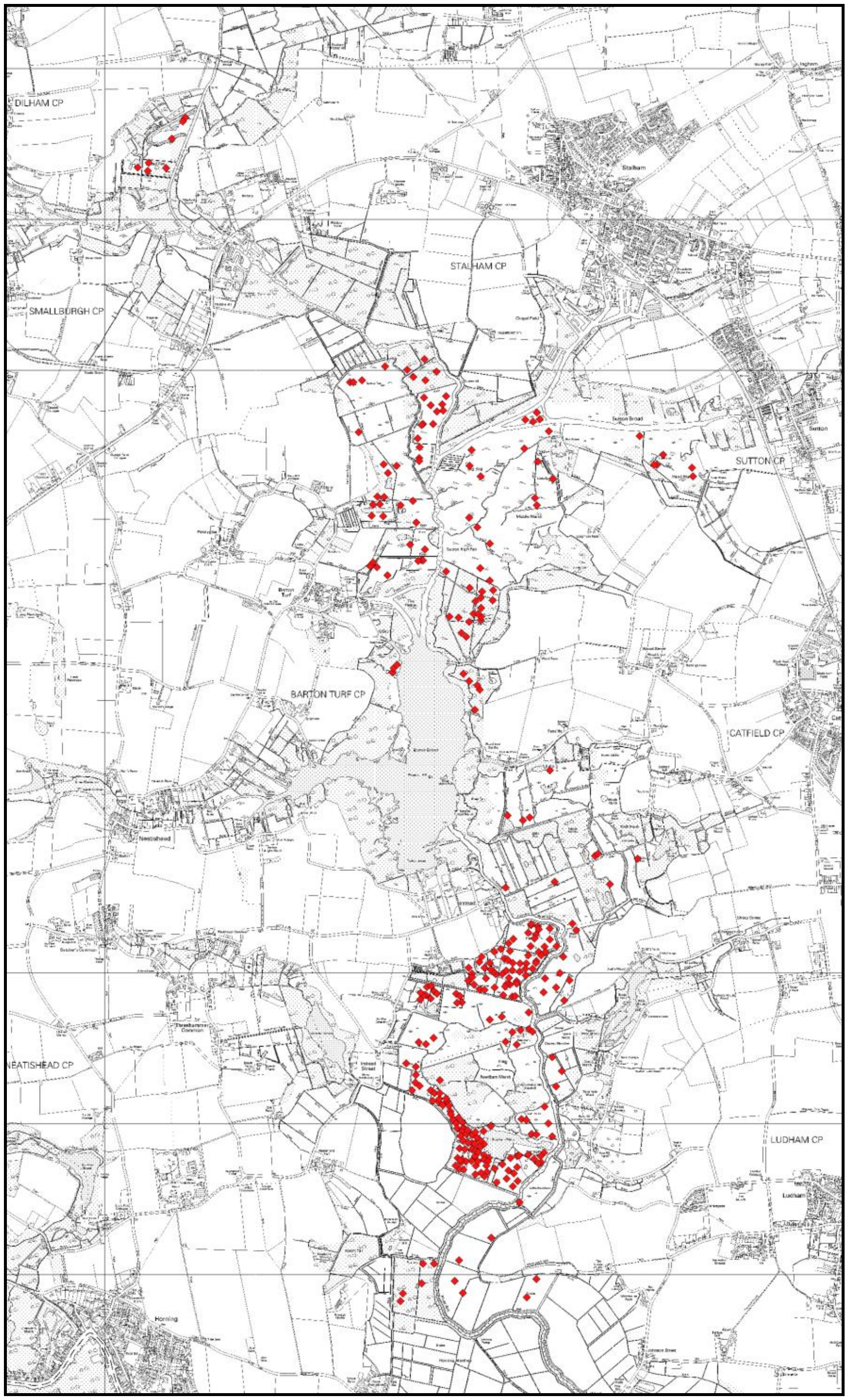


Figure 11 : Stands of Dense Reed in the Bure Valley. From the 2007-2009 Fen Survey

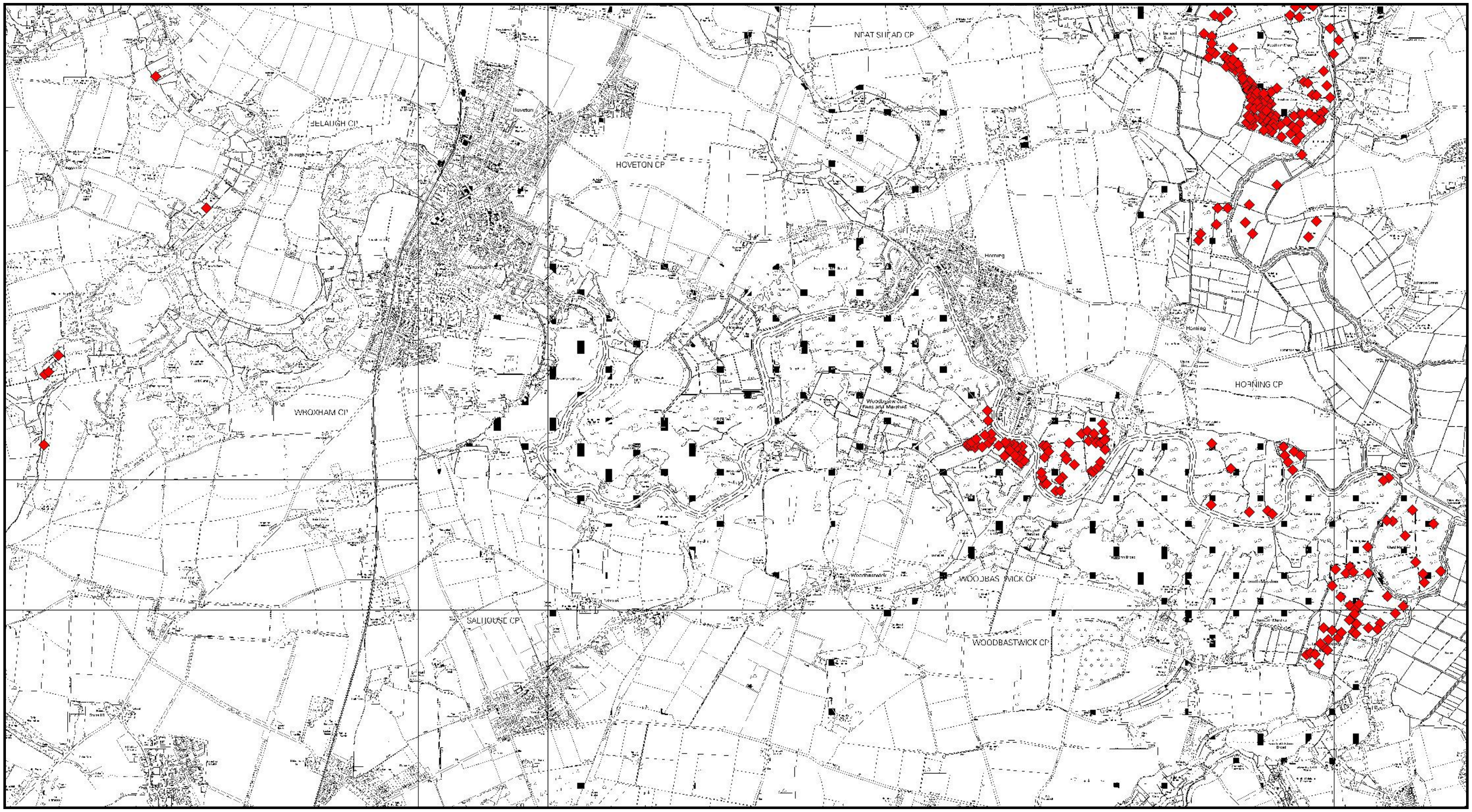


Figure 12 : Stands of Dense Reed in the Lower Bure Valley. From the 2007-2009 Fen Survey

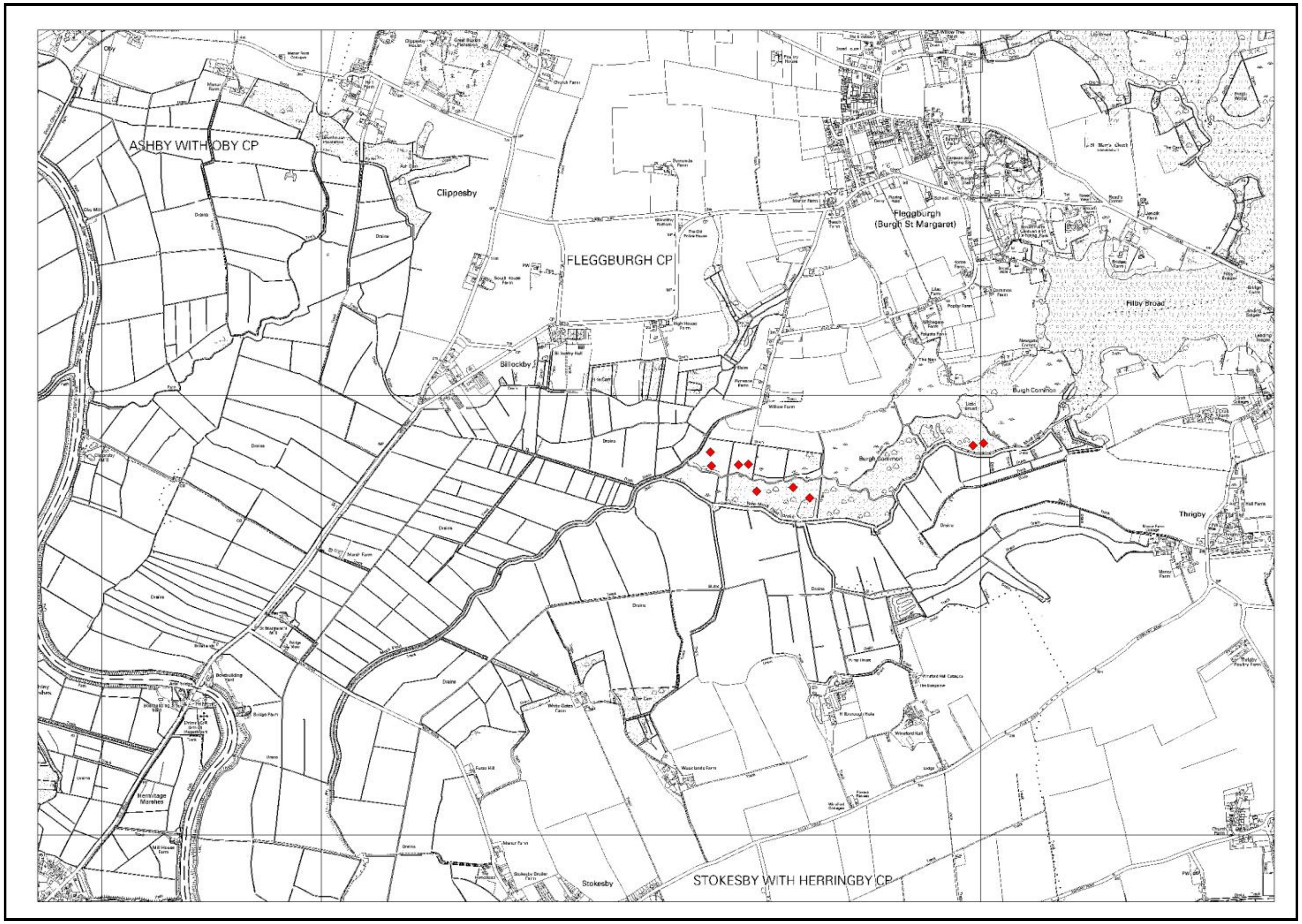


Figure 13: Stands of Dense Reed in the Upper Yare Valley. From the 2007-2009 Fen Survey

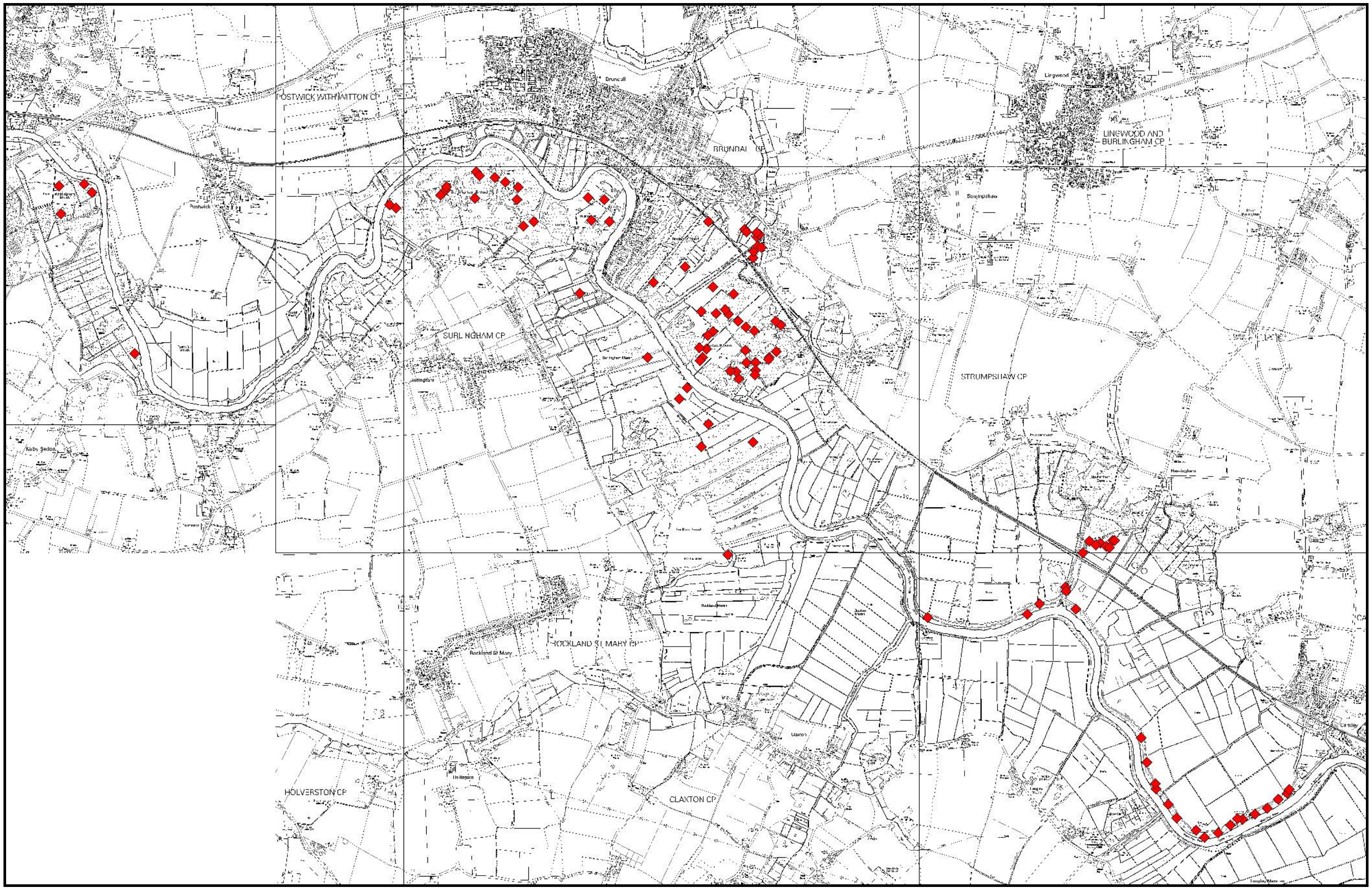


Figure 14 : Stands of Dense Reed in the Lower Yare Valley. From the 2007-2009 Fen Survey

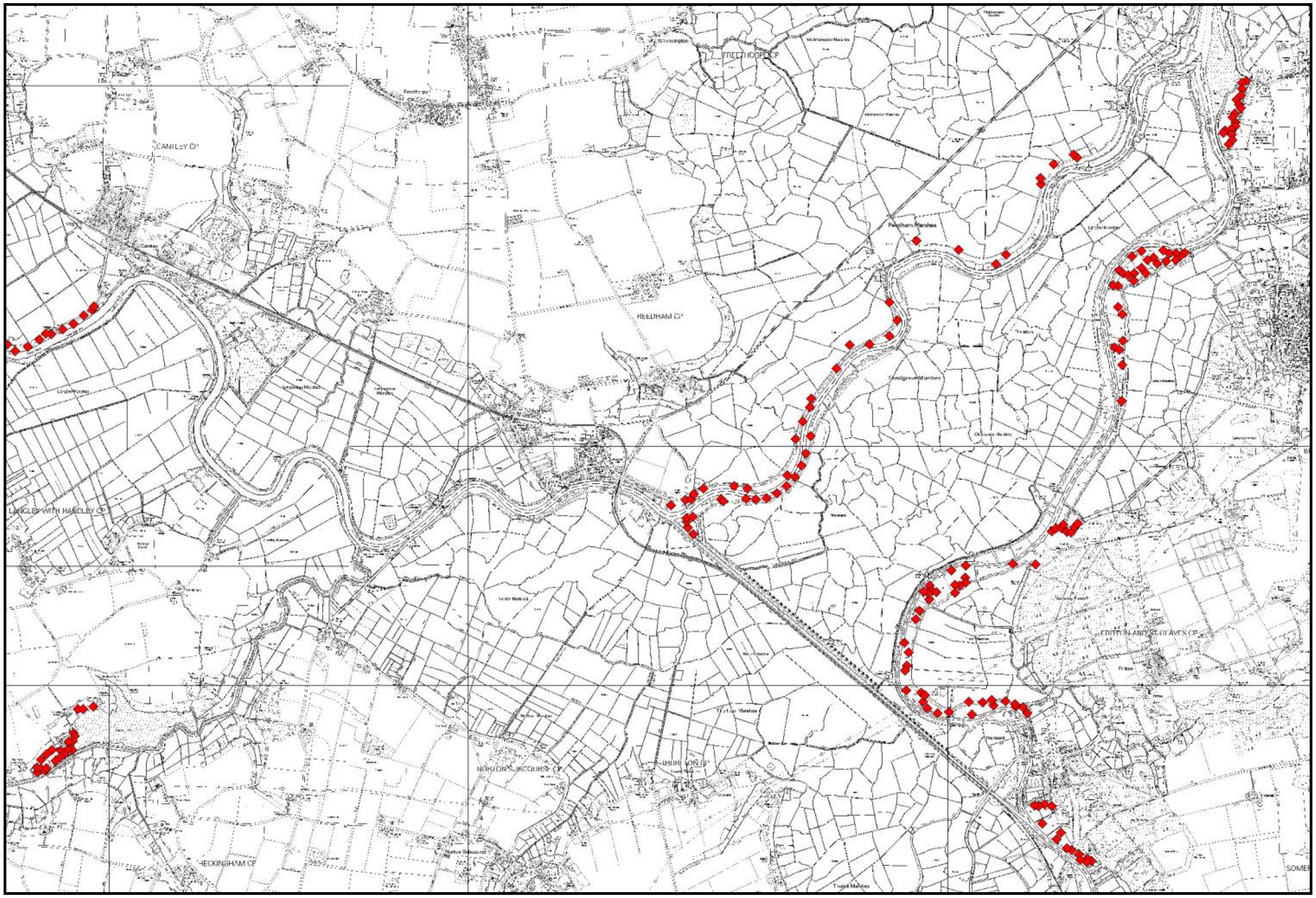


Figure 15 : Stands of Dense Reed in the Thurne Valley. From the 2007-2009 Fen Survey

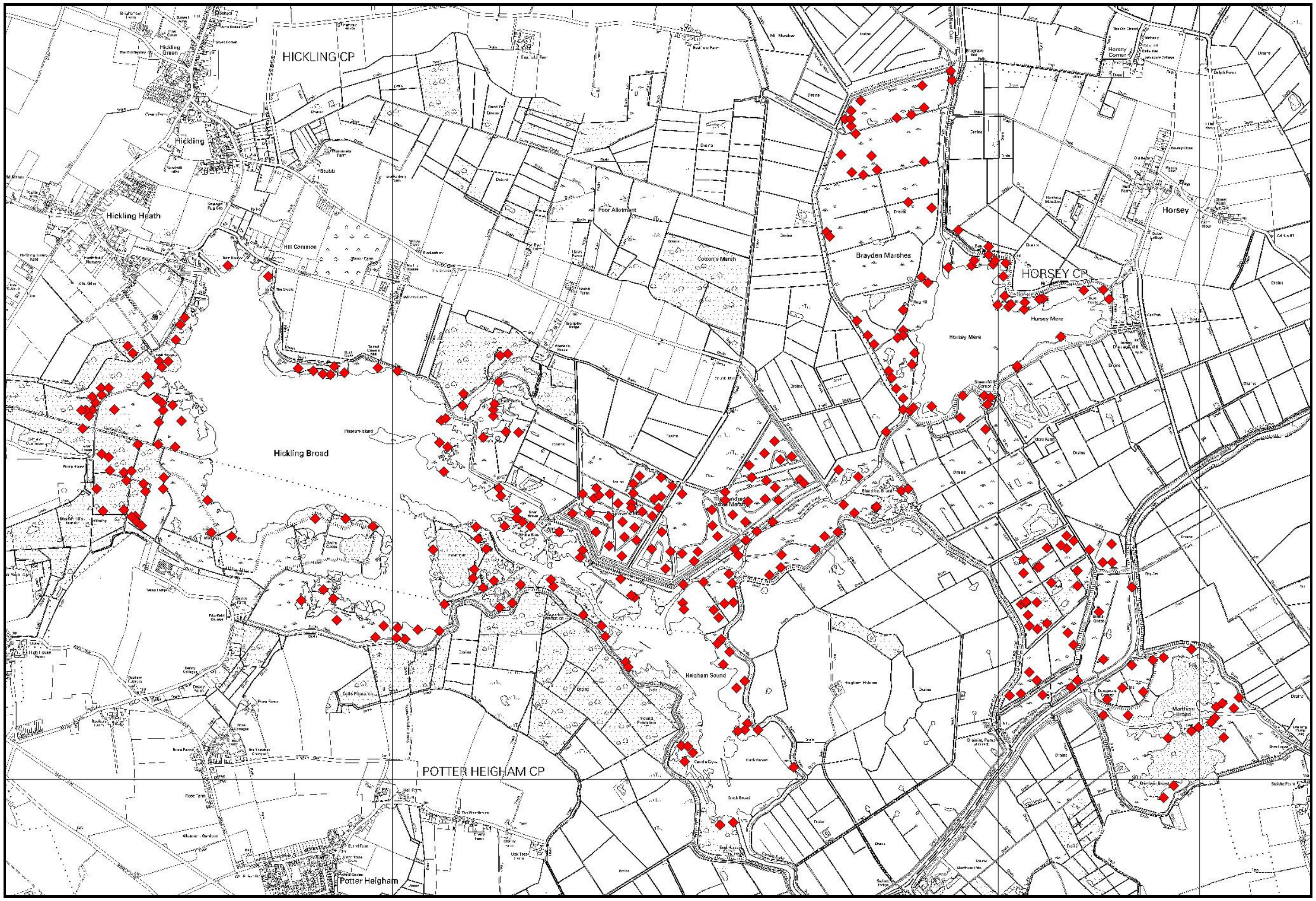
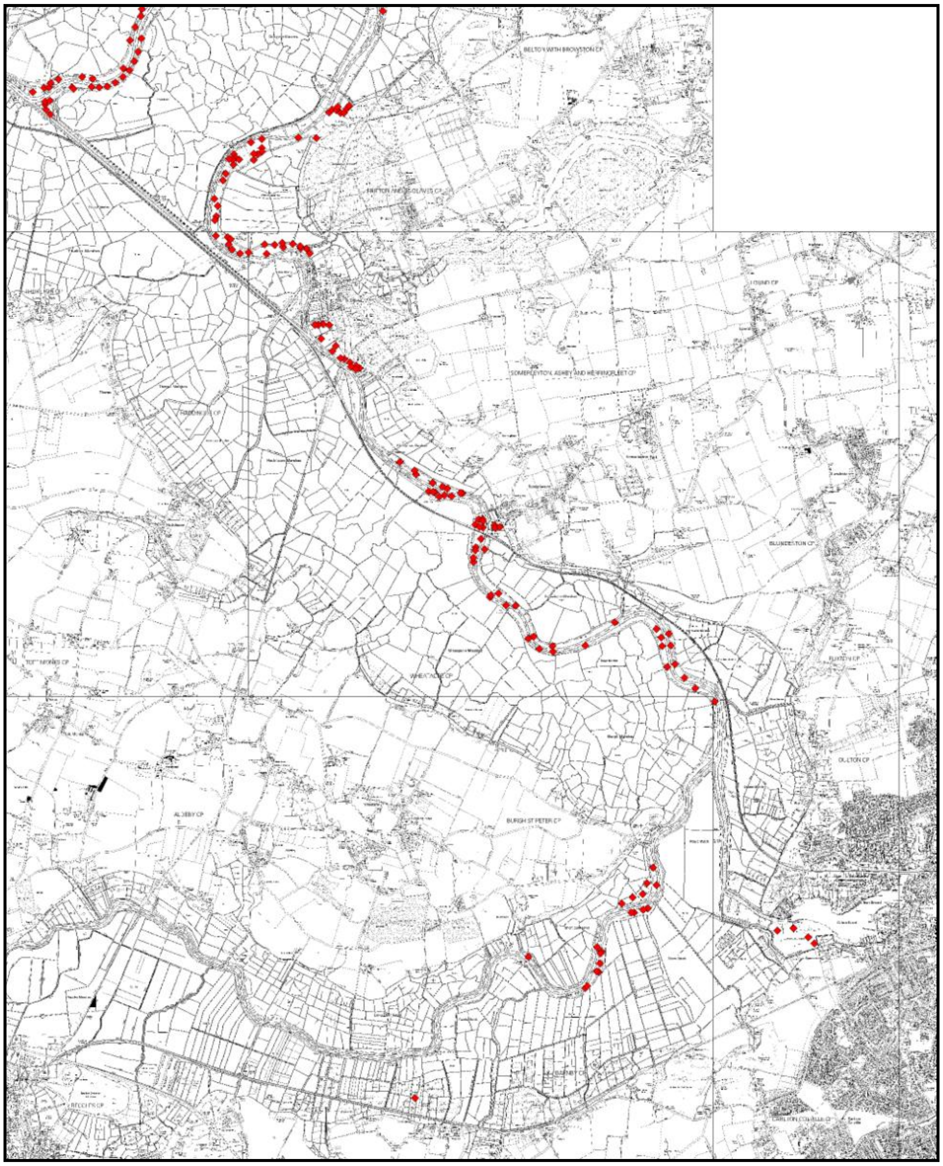


Figure 16 : Stands of Dense Reed in the Yare-Waveney Valley. From the 2007-2009 Fen Survey



5.1.5 Conclusion

Using the data from both the Fen Audit and the Fen Survey suggests there is around 275ha of reed vegetation suitable for reed pelleting, of which around 100ha is reserved for commercial reed thatching. Not all of this reserved area may be required for thatching because in some years the quality may not be appropriate. Indeed there is some benefit in having an alternative market for poor quality reed in order to maintain the beds in rotation and in condition. The thatching and pelleting markets should therefore be complementary, and not competitive. In any given year the amount available to pelleting from thatching reed could be 25% providing a working figure of 200ha of reed resource.

Obtaining a more accurate estimate than this requires a specific exercise similar to the original Fen Audit (even a fully mechanised process is likely to be different to the Fen Harvester operation), but accounting for the particular practical requirements of the pelleting process. Harvesting could include traditional hand-cutting and bundling as an alternative to the thatching market or to address sites unsuitable for large scale machinery management. Any pelleting audit should not therefore be limited to a single harvesting process. The total could be increased if a proportion of the 628ha deemed unsuitable for management by the Fen Audit were prepared for reed management with suitable capital works.

Any estimate of sustainable yield of reed derived from such an audit must take account of the conservation objectives of the site, because these will determine the cutting rotations which themselves determine yield.

In conclusion, a total resource of around 200ha, dispersed among a wide range of small sites, often embedded within ecologically sensitive mixed fen, on wet and soft substrates and with difficult access issues, does not bode well for a process based on large quantities of low value material that needs to be cut, extracted and transported at low cost.

5.2 Timing of Reed Harvesting

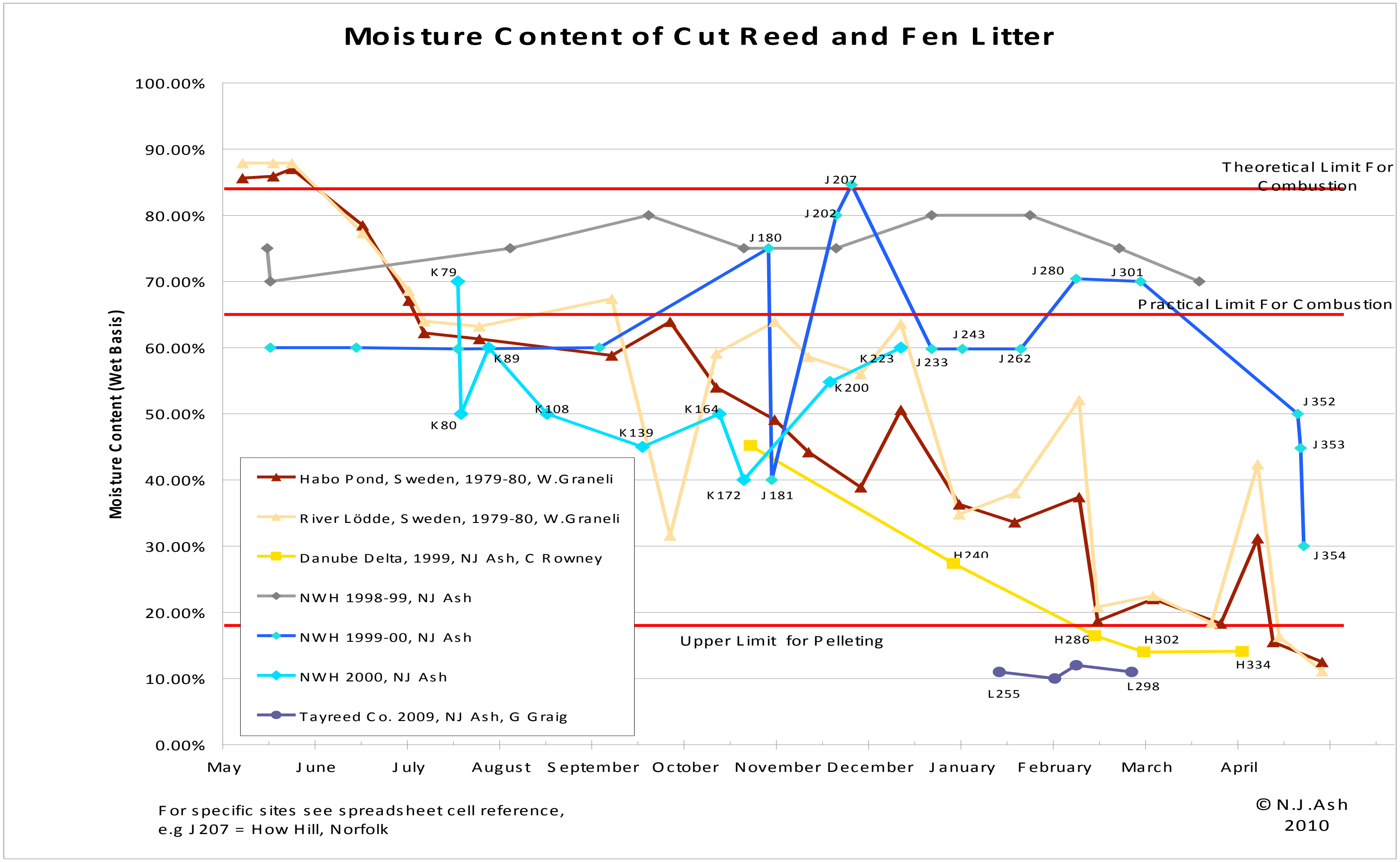
Records from many reed cutting operations over several years reveals some interesting data regarding moisture content of the reed biomass. This data is summarised in Figure 17.

The results from Sweden, the Danube delta and from the Tay estuary all show a steady decline in the moisture content as the season progresses from May through to April. These reed cutting operations are all either for thatch or biomass for burning and involve harvesting of the culms only (with panicles). The moisture content of the material harvested in this way during January to April is almost at a level suitable for pellet manufacture. These results are for as-cut material, i.e. with drying. Further research, (specific data not included here) shows that the bundled material continues to dry in-store to a moisture content of typically 15 %, providing some simple measures are taken to keep off precipitation. This is acceptable for pellet making.

The New Wetland Harvest Project (NWH) results for the three seasons from 1998 to 2000 show reasonably steady moisture content throughout the season. The Wetland Harvester cuts and chops the whole crop including green leaves. It also can cut very low to the ground and is used in this manner to clear fen for restoration. It is assumed that this low cutting and collecting of the total vegetation is the reason for high and sustained moisture content levels throughout the season. Furthermore, results from the New Wetland Harvest Project showed that the cut material does not dry readily or passively in store and can in fact rapidly start to ferment. This material is not suitable for pellet making.

In conclusion, the optimum time to cut and achieve acceptable moisture content levels for pelleting is January to April. Harvesting of the culms only is required. Bundling is necessary to ensure dryness. Cutting too much understory when harvesting results in an excessive moisture content.

Figure 17: Moisture Content Profiles for Reed. NWH = New Wetland Harvest



5.3 Yield of Reed

Yields from reedbeds are very variable not only geographically but also spatially and temporally in specific locations. Also the reasons for cutting the material must be taken into account when considering yields due to different cutting heights.

Thatch harvesting tends to be well managed and yields are optimised for that purpose. Reliable data can be found and is summarised in Table 3.

Litter harvesting is no longer practised in the Broads but it may be assumed that the objective was to obtain dry animal bedding. This would need to be quite dry for purpose and may have been cut and collected in the autumn. No data has been found on yields for fen litter or fodder.

Ecological cutting is relatively new. Some data is available from the New Wetland Harvest project but as discussed above cutting tends to be of total vegetation present and can be very wet as harvested. Correction for this moisture content suggests a dry matter yield of c. 10 tonnes / ha

Reed harvesting for biomass is currently carried out in Sweden, the Baltic States, Denmark and Ukraine amongst other locations. Cutting tends to be carried out in winter and yields of 10 tonnes / ha are not untypical.

It is essential when reviewing and comparing yields to compare like with like. Because of the very variable moisture content it is normally the practise to reduce figures to total dry matter content. The accepted unit is the Oven Dried Tonne, (ODT). To illustrate; one tonne of material with a moisture content of 20% will only yield 800 kg of dry matter and so on.

Table 3 : Some Typical Yield from Reedbeds. The yields from outside the UK are included for interest.

REEDBED LOCATION	**YIELD**		**REFERENCE**	**REMARKS**
	Raw T/ha	***Oven Dry T/ha**		
South Sweden	10	n/a	Graneli, Swedish Inst. of Limnology '83	Aug harvest
Volga Delta	9	n/a	Papchenkov, 1999	
Estonia	10 – 11	n/a	Ulo Kask, Tallinn University, Bio-energy Seminar 24/1/06	Kask observes c. 3 T yield in practise!
Ukraine	10	9	C. Rowney & NJA, FIED Ltd, 1999	Lit. survey
UK				
N. Norfolk Coast (Cley)	**6**	**5.4**	Cut by SJ Eyles & NJA Jan 2000	10% MC
Norfolk Broads	3.4	n/a	Report by RPA Ltd, 2002	750 bundles /ha

Woodwalton Fen	3.6	3.2	Cut by SJ Eyles Mar 2009	12% MC
RSPB Fowlmere	3.74	3.3	Cut by SJ Eyles Mar 2009	12% MC
RSPB Tay Estuary	**5.0** to**7.4**	**4.4**to **6.5**	G. Craig, RSPB / Tayreed Co.	12% MC
ASSUMED YIELD RANGE		**4.4** to **6.5**		
1. * ODT Oven Dry Tonnes, sometimes referred to as DM, Dry Matter 2. These figures are adjusted from the wet or raw yield figures.				

The UK figures are quite consistent if we consider the sources. The Norfolk Broads yield comes from a desk study carried out to review the reed and sedge cutting industry's future (RPA 2002) and may suffer from under-reporting of actual yields for commercial reasons.

The recent cutting at Woodwalton and Fowlmere seem rather low but are consistent with occasional cutting of the sites for access purposes only.

The North Norfolk and Tay Estuary sites are both active commercial reedbeds, maintained and cut regularly for thatch quality material and well managed for that purpose and it is interesting to note the close correlation. The Norfolk figures were derived by weighing actual samples of the crop straight off the cutting machinery and the Tay Estuary yields come from records kept over many years of commercial operation.

Both are considered to be highly reliable and thus are taken here as the yield which might be reasonably expected from established reedbeds well managed.

We can assume a potential yield range of 4.4 to 6.5 ODT per hectare, say 5 ODT / ha for simplicity.

5.4 Sites Which Lend Themselves To Reed Pellet Harvesting

The same problem is encountered with a site-by-site assessment of suitable pelleting sites as was found with the evaluation of the resource in Section 4.1. The information collected and presented in the Fen Audit (Stephenson 2004) is not directly transferable to reed pelleting. Once the process for pelleting is confirmed, a new audit which identifies particular sites and their suitability for particular types of harvesting should be undertaken. The broad approach and format of the original Audit should be utilised and the pelleting exercise produced as a supplement.

The case for developing an interactive, digital and GIS-based Fen Audit format, is strengthening. The advantages of such a system are that:

- It would not need to be printed and would not be subjected to being lost.
- It could be updated on a site by site basis as circumstances and opportunity change. It would therefore never be out of date.
- Everyone could have access to it for management planning, project development and strategy work.
- Achieving all three of the above will raise the profile of fen management and encourage partnership working.

Developing this system would require some partnership working from those organisations and landowners directly involved in managing the Broads. Because the Broads Authority originally developed the Fen Audit, and because it would be a core system assisting the management of a major part of the Broadland natural resource, BA remains the best option for hosting such a system.

5.5 Annual Supply

The foregoing analysis provides the following key points in relation to reed supply:

- A viable reed pelleting operation requires a medium sized fixed plant which would process up to 3000 T / yr. The Broads reedbeds yield on average 5T/ha, producing a requirement of 600ha/yr if cut annually, 1200ha if cut every two years and more if long rotation and non-intervention areas are to be maintained.
- There are currently around 200ha of reed likely to be available, yielding a maximum of 1000T/yr. if cut annually.
- This hectarage is dispersed among the river valleys in often small sites with significant practical challenges to efficient harvesting.
- An unknown hectarage could be added to this figure if the funds were available to restore potentially productive reedbed elsewhere in the Broads.
- However, even then this will provide a substantial deficit in available reed.
- To address these supply issues, one or preferably both of the following need to be undertaken:
    1. A substantial hectarage of new reedbed needs to be developed in the Broads, preferably with good access and controllable water and ground conditions, to provide a core availability of reed.
    2. A partnership approach is required, utilising reedbeds on the Norfolk and Suffolk Coasts and the Cambridgeshire Fens, in order to develop a critical mass of reedbed.

6. DEMAND FOR THE PRODUCT

6.1 Types of Potential User of Reed Pellet

Potential users of reed pellets.

Theoretically, any energy purchaser with ambitions to use renewable energy for heating is a potential customer for reed pellets. Any industrial, commercial or domestic user could install readably available boiler plant with which to use biomass including reed pellets. Many office buildings especially councils, schools and domestic houses are now heated by wood chip or pellets and the numbers are increasing daily.

Constraints

However there are some practical issues to take into account and additional constraints when considering reed pellets.

Any energy user needs security of energy supply. Users of oil for example have a large number of alternative oil suppliers within a short distance. They only need to pick up the yellow pages for another price or if their regular supplier cannot deliver.
Wood pellet supply chain and infrastructure is developing rapidly across the UK including East Anglia. Potential users of wood pellets can be assured of regular deliveries from a range of alternative suppliers, although as yet not with such a wide choice of suppliers as oil.

When we consider reed pellets, there is no such existing supply industry. So the first user to adopt reed pellets will be in a very exposed, single-supply position.

However, although wood pellet burning appliances cannot cope with reed and straw, appliances designed to burn reed and straw can cope with wood pellets. This wood pellet fall-back position will be key for the early adopters of reed pellets.

Parameters of supplying pellet market.

The supply of biomass pellets, although currently unregulated, tends to follow the British Biogen Code of Practice for biomass pellets. This CoP stipulates certain properties for the pellets including minimum calorific value, maximum ash content and various chemical contents. Research has shown that reed pellets will almost certainly not be able to comply with this CoP (ash and chlorine content will both be too high) and thus retailing of the pellets will be very problematic.

Very large biomass users such as power stations are less fussy about the fuel. This is not due to a cavalier attitude to environment issues but because their burners can cope with the less perfect fuels with higher ash, chlorine and sulphur. However there are obstacles to selling the pellets to a large power generator. It is very likely that the power generator's planning permission will stipulate particular fuels and extending permits to burn other fuels is very costly and likely to involve a test burn of at least 500 tonnes.

Power generators need to guarantee security of supply of their electrical energy to their customers and therefore need guarantees from their fuel suppliers. This takes the form of fixed quantity and date supply contracts with very heavy penalties for non compliance. Such contracts are expensive to manage and as such favour large suppliers (several hundred thousand tonnes).

Brokerage

One option is to sell reed pellets to or via a broker. Biomass brokerage is already established and further developing in the UK. Brokers can consolidate smaller lots of biomass and thus enable smaller producers to sell relatively small lots of biomass.
One such broker is Manco Energy Ltd of East Yorkshire YO43 4SP

In house use

Could the Broads Authority use their own reed pellets? This would be technically possible but quite a complex project. Apart from the very high capital cost there is a major issue of balancing the internal supply and demand. Also most of the constraints above would apply except for the retailing of the pellets. A practical option might be to choose a suitably sized heat load, depending on likely amount of reed harvested per year. Then to install straw pellet burning equipment and identify a supplier of straw pellets. These initial steps ensure energy security. Reed pellets, either made in a fixed or mobile plant would then be delivered into the installation as and when available and required. Any shortfall in fuel supply could be met by purchasing reed pellets from the straw pellet supplier. Any surplus might be sold to the straw pellet supplier.

6.2 Practical Range of Market From Broadland

Contrary to widespread belief, road transport is highly efficient and also modern engines have much lower emissions than earlier models. Reed, as bales or pellets is readily transported. However, just because it is easy and less polluting than formerly we should not be profligate in any use of energy. So how to quantity the transport costs in terms of energy and emissions?

Energetics

The energy contained in reed pellets has been established as over **4 kWhr / kg** or 4 MWhr / Tonne[5]. The energy consumed in making the pellets, including cutting the reed is about 0.28 kWhr / kg leaving a net energy content of about **3.72 kW/kg**.

Energy consumption for transport by road can be estimated at **1.4 kWhr/kg /1000** miles. (2009 Guidelines to Defra / DECC's Conversion Factors). This assumes a 10 T load, >17 T truck, 53% load factor and is an average for all HGV's. Specific figures are available for all sizes of truck at different load factors.

[5] Actual net heat content depends on moisture content, 4.7 kWhr / kg is typical but we will use 4 kWhr/kg as a very conservative and convenient figure.

Thus the reed pellet net energy content of 3.72 kWhr/kg could be transported over 2650 miles before we have a net loss of energy. This distance is of course absurd but serves to illustrate the high energy density of the reed fuel pellets .

For comparison it is interesting to note that diesel fuel, to the point of delivery costs about 112 kWhrs for every 100 kWhrs delivered. This includes the whole supply chain from sourcing, through refining to delivery.

If we adopt as "acceptable" a similar 12% energy "cost" of delivery we could spend 0.48 kWhrs / kg on transporting the finished reed pellets . This equates to a round trip distance of 342 miles or 171 radial miles from say Statham in the Broads. This brings into range for example Dixon Brothers Straw Pellets at Rickinghall near Diss (48 miles) , R A Foster-Clarke, Straw Pellets at Harleton (40 miles) and even Manco Energy Ltd, biomass brokers at North Newbald in Yorkshire (168 miles)

Carbon Footprint of transport

The energy cost of transport derived above can be readily converted into an equivalent carbon emission by reference to Defra's "Guidelines to GHG Conversion Factors for Company Reporting". The transport energy cost of 1.4 kWhrs/kg/1000 miles equates to a CO_2e emission of 0.369 kg CO_2e / kg / 1000 miles (assuming the transport is diesel powered and running on fossil fuel).

Thus our "range" of say 171 radial miles would have a footprint of 0.063 kg CO_2e / kg of reed pellets or 63 kg per Tonne.

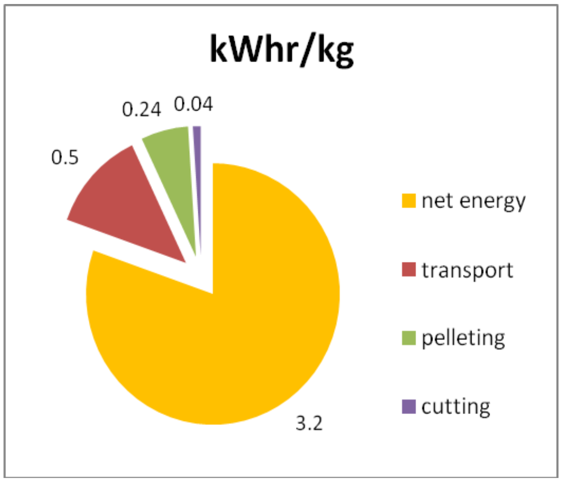
Is this good? As a stand alone figure this probably does not mean much. How does it compare with say the fossil heating fuels which the reed pellets might displace? Published figures for fossil fuels show that Burning Oil, LPG and Natural Gas emit 255, 225 and 203 kg CO_2e / MWhr respectively.

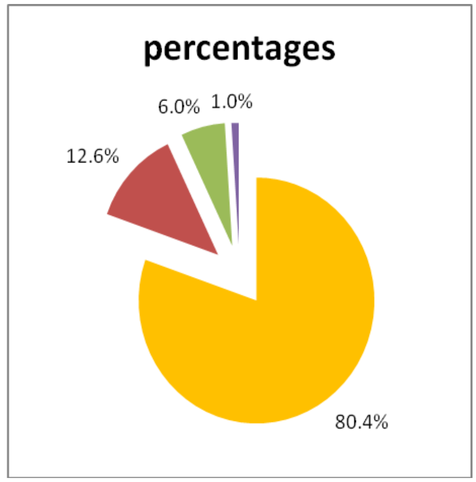
Our reed pellets, delivered within the 171 mile radius would cause emissions of about 45 kg CO_2e / MWhr. This is quite respectable. The comparison is flawed however in that the published government figures for the fossil fuels are direct emissions only and do not account for full life cycle.

Our derived factor for reed pellets on the other hand do account for full life cycle. Thus the CO_2e savings will be even greater than suggested here.

The overall energy balance for reed pellets is shown in Figure 18. Figure 19 provides some comparisons with other fuel types.

Figure 18 : Energy Balance for Reed Pellet Manufacture

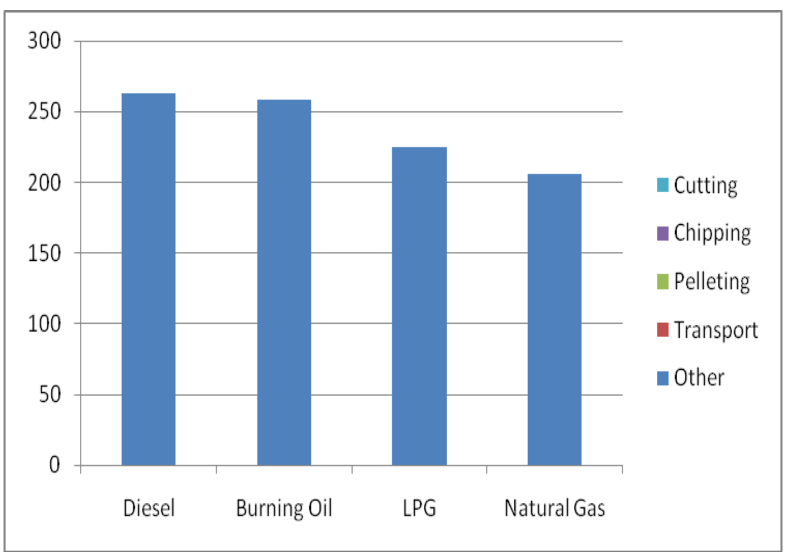




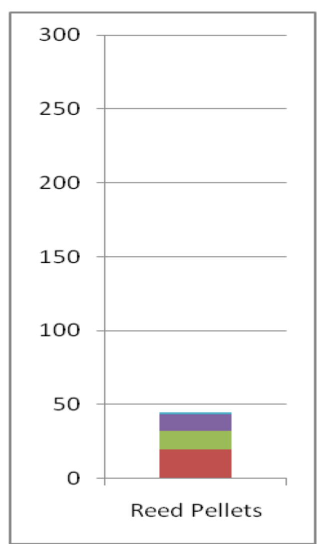
Notes to the Figure:

- "Cutting" and "Pelleting" refers to the actual processes carried out as part of recent research. The transport input refers to hypothetical transport by an average HGV, >17 tonnes, running 342 miles.
- From this specific energy consumption, (kWhr / kg) to make the reed fuel and knowing the energy content of the fuel (kWhr / kg) an emission factor in kg CO_{2e} per kWhr is readily derived using published data for fossil and electrical energy inputs.

Figure 19 : CO_2 Emission Factors from Using Different Fuels. Units are $KgCO_2$/Mwhr



For Fossil fuels (AEA data)



For Reed Pellet (derived)

7. TIME, RESOURCES AND ECONOMICS OF A PELLET MILL OPERATION

7.1 Time and Resources Required For Each Aspect Of The Process

7.1.1 Harvesting Principles

An essential practical implication of the subsequent use of the reed as a fuel is the format in which the reed is produced. Cost effective handling dictates that mechanical handling will be essential. As discussed above, for reed to be useful as a biomass fuel and especially if to be made into pellets, water content is critical. Reed which is cut and bundled and then stored can have acceptably low water content. This can even improve in-store by further passive drying. So the essential element here is the bundling and baling of the reed.

Mechanical cutting is of course essential to achieve meaningful outputs in terms of both habitat maintenance and reed-fuel production. Hand cutting by scythes is a traditional form of reed cutting that predates mechanisation and as such is not appropriate to this study. Not only is the productivity hopelessly inadequate but this method sends out an entirely inappropriate message. If we are to develop reed biomass as a practical present-day renewable fuel and energy source, albeit a niche one, we should not be seen to be returning to days of manual harvesting however cosy the image. This "cottage industry" image could immediately mislead many observers, who may then dismiss the idea of reed biomass energy and by association other renewables.

Mechanical reed-cutting is well developed, at least with regard to thatching reed production. Work elsewhere has shown that the best way to cut reed which is destined for biomass fuel is to cut and bundle. The bundles thus produced have a wonderful ability to stay dry and even to become drier if stacked with some attempt keep off the majority of rain. Reed which is cut and chopped by forage harvester type machinery, such as the Broads Authority's Fen Harvester, tends to be much wetter and does not dry easily in bulk. In fact, there is a great tendency to start decomposing, heating up and composting of the chopped material. This tendency might be an advantage to a composting project but is a severe hindrance in a biomass fuel harvesting operation.

So as a minimum, cutting and binding is essential. Furthermore, manual handling of the bundles which is the traditional method is slow and costly. Currently we have not been able to identify a commercially available reed baler but it will be essential to source such a device, either commercially or by in-house development, to ensure efficient mechanical handling of reed biomass

7.1.2 Reed Cutting Machine Options

Fen Harvester And Other Forage Type Machines

This has been discussed in detail in Section 2 but for reasons stated above is not suitable for reed pelleting.

Fen Harvester

Seiga

The “Seiga” or more correctly the “Tortoise 4 WHD”, made by JSP Seiga Maskinfabrik of Denmark is a purpose built reed cutting machine.
These machines are the workhorse of many commercial reed cutters throughout Europe including one variant with the RSPB Tay Reed Company in Scotland.
Seiga Reed Harvesting Machines are very large, particularly in width and have a very wide turning circle.

Seiga type Reedcutter

Baling device

They cut and bind the reeds into bundles of about 20 cm diameter, weighing typically 4.5 to 6 kg, depending on moisture content.
Graham Craig of RSPB / Tayreed Co has extensively modified and further developed a Seiga type machine to include a baling device. This device bales up and binds 80 bundles resulting in a bale which weighs about 400 kg. These bales are carried on the reed cutting machine until a full load is achieved when the Seiga then drives to a storage area to unload. The baled reed is then readily unloaded and subsequently handled mechanically with standard farm machinery, such as a telehandler. This baling feature is a significant advance in reed handling and dramatically reduces the required manual handling.
The Seiga is well suited to large open areas of reed where they can raster in long straight cuts. They are not very well suited to cutting around intricate reedbed edges. The nominal output of these machines can be up to a quarter of a hectare per hour, on a cut and bind only basis. Allowance has to be made however for travelling time to and from the stacking areas where the reed bundles are to be stored for further processing either for thatch or as an energy crop. Making allowance for this transit time to and from the store can reduce the productivity to perhaps one hectare per day, very dependent on distance of course, but which is typical of output at Tayreed Co.. Road transport of these machines, because their width is 3.1 m, is a serious operation requiring wide load permission and special transport so moving machines between sites needs very careful consideration.

Reed Baler on Telehandler

The current price of Seiga machines is €169,313 for a four wheeler and €202,563 for a six wheeler both complete with the Cut and Bind harvester head. Lead time is currently quoted as six months. A further €15,621 purchases weather protection for the driver and a mechanical conveyor to transfer the reed bundles to the rear load area of the machine and hence dispense with the third operative. A six wheel option requiring a crew of two will cost €218,184.

Seiga type machines could cut Reed Biomass Fuel and deliver in suitable format providing cost and logistical issues were acceptable. It is understood that a Seiga type machine was trialled in the Broads many years ago but only anecdotal evidence has been found. Apparently the trials were not very successful on the Broads' soft peaty reedbeds.

BCS

The most widely used reed cutting machine employed in the UK used to be the *"Olympia"* which has now been superseded by the *"BCS"*, basically the same machine re-branded and still widely used for commercial thatch production. The output format is in bundles, typically 20 cm in diameter which is, by default, the UK standard reed bundle.
The output of these machines in the right hands is quite phenomenal, Outputs of over 1,250 bundles per hour (equivalent to over 5,500 kg) per hour have been observed. These machines are however very heavy and brutal to operate. There is concern in some quarters that vibration transmitted to the operator over prolonged periods might become a health issue. Although tests have shown that levels are within guidelines it cannot be denied that operating one of these machines for extended periods might qualify as an Olympian task!

BCS Machine

The bundles produced by these machines are certainly suitable for storage, self drying and subsequent use as biomass fuel. The major shortcoming is that there is no ability to collect up the bundles. The machine simply deposits bundles onto the ground as it passes. If there is any standing water, the reed which was probably quite dry in the stand immediately gets wet. Collecting and carting the crop of bundles from their position lying all over the reedbed becomes a much greater task than that of the original cutting.

Current price for a BCS Cutter Binder is approximately £14,500 with a lead time of 4 to 8 months depending on the time of year when ordering. These machines are batch built once per year, in Italy and assembled in Holland. It is also interesting to note that the BCS Cutting Head alone, without the self propelled chassis and engine, is used in some "home-build" reed cutter projects, especially in Eastern Europe.

Softrak Reedcutter Binder

Loglogic Company, the builders of the Fen Harvester, went on to develop various other low ground pressure machines targeted at conservation operations. One such machine is their Softrak. With encouragement from the RSPB, Loglogic are already testing one of these Softrak machines fitted with a Cutter Binder head from a BCS machine. The objective

Softrak Reed cutter-binder

is to retain all the desirable properties of the BCS, the cutting and binding ability and yet avoid the drawbacks of heavy manual handling and non-collection of the reed bundles. Trials of this equipment are ongoing (spring 2010) and initial results are very encouraging. When perfected this machine should be able to cut reed and produce bundles as required for good drying. It should also be capable of carrying a payload of bundles straight off the reedbed. Currently there is no baling facility so Loglogic will need to be encouraged to develop this feature. The baling developed at RSPB Tayreed Co or something very similar should be considered. It must be recognised that the Softrak will never have the payload capability of the Seiga type machines and hence the transit to and from the reed stack will be very critical. It may be worth considering a second machine for transport off the reedbed.

The productivity of this Softrak Reed Cutter Binder machine is of course as yet unknown. It may be reasonable to assume that a similar instantaneous cutting and binding rate to that of a BCS or Seiga will be achieved. The operation of both of these other machines relies to a great extend on forward speed to maintain momentum of the reeds into the binding mechanism. A much slower forward speed results in reed falling out of the mechanism rather than being driven into it. A much faster forward speed results in an overloaded mechanism and consequent blockage. So an instantaneous throughout of between 500 and 1000 bundles per hour might be expected. But as always the overall productivity will depend on transit times and the material handling.

Productivity similar to the Seiga might reasonably be expected of say one hectare per day subject to reedbed geometry, distance to reed stack, density of material and period of cutting rotation. The projected price for the Softrak Reed Cutter Binder is expected to be about £60,000 with a lead time of 4 months.

This machine combination has been designed with road transportation in mind so easy machine transport between sites will be possible. The cutting head is also demountable, so a number of other reserve management tasks could be undertaken by the base Softrak machine. Loglogic also offer a Cut and Collect Forage implement for Softrak mounting. This might be used on dense, long rotation areas where cut and bind is not possible to restore the reedbed for harvesting in the next season.

<u>Other Reed cutter-binder machines</u>

Many reed cutting operations in Eastern Europe make up their own machinery. Several examples can be reviewed, for example on Youtube. Building of "self-build" reed cutting machinery might be an option for adventurous and innovative entrepreneurs but is not recommended for the Broads Authority. The focus is all wrong, management burden disproportionate to benefit and lack of product support will only lead to still further dilution of conservation core activity.

7.1.3 Bailing of Reed Bundles

Even though the reed is ultimately chopped, the initial harvested bundles should be baled to enable mechanical handling. This can be done in a device such as that devised by Graham Craig of the RSPB Tayreed Co. or something similar. Further development may be needed to change the bale bindings from steel banding if this presents an issue to the further processing such as the chopping. It is understood that some Norfolk reed cutters also bale their bundles but no specific machinery has yet been identified.

7.1.4 Processing

The area needed to receive reed bales, some buffer storage prior to pelleting, and marshalling of materials with adequate space to manoeuvre vehicles and handling equipment will be in the order of 5000 m^2. Some undercover space is desirable to keep raw reed feedstock dry.

7.1.5 Pelletising

For a fixed pellet manufacturing plant, an area of at least say 600 m^2 will be needed. This must be secure and fully serviced. Three phase electrical supply of at least 100 kW will be needed and of course suitable welfare facilities. In addition to this covered area, outside secure storage and materials handling area will be required of say 5000 m^2 as above

For a mobile plant an area at each site to be visited of say, 1200 m^2 will be needed to accommodate the plant and allow safe manoeuvring of mechanical handling machinery.
It must be appreciated that no suitable mobile pellet plant has yet been identified. These figures are hypothetical.

Finished pellet dry storage facilities will be required. It is essential that pellets are kept dry as they have a great potential to absorb moisture and if so rapidly fall apart. The density of reed pellets is about 600 kg /m^3. Thus 1000 T needs about 2000 m^3 bulk storage. There is no limit to the depth at which pellets can be bulk stored, however the angle of repose of reed pelts is about 45 degrees which needs taking into account. Hopper or silo storage is a practical option. If the pellets are in "dumpy" bags of 1 m^3, then 2000 m^2 of floor space is needed.

It is however possible to sell the pellets as they are produced, so only around one month storage capacity may be needed. This would equate to say 200 m^3 of hopper or silo volume or 200 m^2 of floor space.

7.1.6 Loading and Transport

Transport of finished pellets to the end user or intermediate buyer is best left to local specialists with the appropriate vehicles, maintenance facilities and transport operator licence. Contracting out the transport ensures very high utilisation of transport vehicles. Loading to the road transport can be by the mechanical handling kit used for the reed feeding and the pellet manufacture, i.e. fork-tuck, agtrac with loader or telehandler.

7.1.7 Storage Space Needed For Raw Reed Biomass.

If reed biomass is to be used as fuel it will need to be stored after harvesting and before further processing whatever route is eventually adopted. Outdoor storage is acceptable providing some effort is made to keep off the worst of the weather. Simple stack sheets or crude thatch with reed bundles is adequate.

The required space will depend on the format of the material, but as already discussed the format will have to be in bales so we will need space(s) to store reed bales of say 2.4 m long x 1.2 m diameter. 100 tonnes of such bales if stacked 4 wide x 4 high x 30 bales long need a space of 5 m x 60 m, or 300 m^2. Storage space for other amounts can be estimated pro rata. Such stacks could be located adjacent to the source reedbed, subject to ground conditions and access for mechanical handling.

7.2 Health and Safety Considerations

7.2.1 Mobile Pelleting Operations

If mobile pelleting machinery is to visit reedbed sites to process reed into pellets then an adequate working area will be needed. An area of at least 20 m by 60 m is considered necessary. This area will need to accommodate the mobile truck and also any tractor movements to load the machine. This area is in addition to any reed bale storage area. This will essentially be an industrial operation, albeit only temporarily in site. As such full safety provision will need to be provided, especially access restrictions and exclusion of the public. Noise may also be an issue. Regarding noise level legislation, machinery working out of doors is allowed to emit higher levels than indoor machinery and as such may create a nuisance.

7.2.2 Safe Use Of Machinery

As with all machinery, safe working practises must be followed. CE marking of all machinery used is essential as is observance of the *Provision and Use of Work Equipment (PUWER) Regulations*. 1992, SI 1992/2932. Any mobile pellet mill developed or sponsored by the Broads Authority would need to comply with these regulations.

Full and appropriate risk assessments will have to be made at the time for all activities. Training of personnel in use of the machinery and equipment may be required, certainly for any new machinery developed to make reed pellets.

7.2.3 Dust

The amount of dust created from chopping and handling the dry reed is significant. This applies to both static and mobile operations. This dust is certainly a nuisance and may present a health hazard.

The dust contains silica, up to 15% by weight. Silica is known to be hazardous to health when "fused and respirable" and as such is covered by the COSHH Regulations. Workplace exposure limits for silica are set out in EH40 / 2005 "*Workplace exposure limits"* for use with the "*Control of Substances Hazardous to Health Regulations 2002"* q.v.

Whether reed dust constitutes an actual health hazard needs further attention. The fact that it is present is not conclusive; tests must be carried out to determine how much of the silica is actually breathed in by an operative under actual working conditions. This cannot be done on a hypothetical basis but must be a practical test, collecting air samples from the area adjacent to the operator's face for typical exposure periods during the actual operation when the dust exposure occurs. Such testing is offered by commercial test houses who can also advise on the consequences of the results and appropriate personal protection equipment (PPE) if appropriate

7.3 Scale Issues

7.3.1 Considering The Best Scale Of Operation

As discussed above, typical commercial pellet mills (5Tonnes + / hr) are probably too large in this application. The small portable or Micro Mills are definitely too small.

The 500 kg / hr plant from Farm Feed Systems could be an appropriate size. Such a plant could produce about 1000 T per year based on 20 T / 5 day wk, or 4 T / 10 hour day, or 0.5 T / hr

This 1000 tonnes of reed could be harvested from say 200ha of reed on annual rotation or c.1400 ha on a 7 year rotation or pro-rata for other cutting regimes at 5 ODT reed / ha / yr. (see 4.3 above for discussion on Expected Yields)

Such a 1000 T/annum plant might cost about £200,000 excluding provision of buildings, services and infrastructure.

In terms of scaling up production it might be preferable to use several medium scale plants in preference to one very large plant to give better security of production (one plant can back up the other in case of breakdown) and also to reduce transport and vehicle movements locally.

Initial increase in scale can be readily achieved by adopting double and then triple shift work patterns. Pellet mills actually perform better if run continuously, the start up and shut down procedures to achieve steady and consistent pellet production are time consuming and 24 hour operations are preferable if financial constraints permit.

Further increases in scale might best be achieved by replicating the 1000 Tonne plant in other locations.

7.3.2 Developing Partnerships

There are possible benefits from partnership with an existing straw pellet producer. In such a partnership the Broads Authority could benefit from an existing plant, infrastructure, sale network and customer base. The existing straw pellet producer might benefit from improved green credentials by association with the Broads Authority.

In its most basic form, the relationship might simply be one of selling reed to the pellet maker, with possible option of buying back the pellets. No contact has been made with potential partners at this stage. Such negotiations would be outside the scope and remit of this initial study. Later it may be appropriate to consider these two existing local straw pellet makers:

Dixon Bros.
Straw Pellet Producers
Porters House Farm

West Hall Road
Rickinghall
Diss
IP22 1LY

R. A. Foster-Clarke
Wood Pellets / Wood & Straw Pellets / Straw Pellets
Cherry Tree Farm
The Common
Metfield
Harleston
IP20 0LP
Tel : 01986 785 278

8. CONCLUSIONS

8.1 Summary of Possible Uses of Fen Products

The aim of this report was to identify how fen harvesting could be made sustainable by finding a productive and hopefully commercial end-use for the arisings.

The principle focus has been on making biofuel pellets from reed, as the technology for harvesting, processing and burning pellets is now well established. However, there are a number of constraints, most of which have solutions, as summarised in Table 4.

Table 4 : Constraints and Solutions For Reed Pelleting

Constraint	Solution
The moisture content must be below 16%.	Harvest between January and April.
Near-pure reed is required. Mixed fen does not pelletise easily.	Harvest only reedbeds. Adopt other end-uses for mixed fens.
Supply of feed stocks is limited. A medium-sized fixed mill requires around 3,000T/yr. Reedbeds in this region produce around 50T/ha, providing a requirement of 600ha/yr if cut annually or 1200ha if cut every other year. An analysis of reedbed availability indicates there is a total resource of 200ha, excluding commercial reedbeds.	The most critical constraint. Several solutions: • Develop a partnership with other reedbed managers in Norfolk, Suffolk and Cambridgeshire to supply reed to the Mill. • Develop new, extensive reedbeds in the Broads to increase supply (this also meets other policy objectives). • Consider ways of managing the Mill with lower volumes of production.
Many supply sites are small, dispersed throughout the Broads and are located in difficult to manage sites.	Capital investment to upgrade the access and management infrastructure. A range of harvesting machinery, including small-scale hand cutting and removal, may be required. One or two large and cost-effective reedbeds could cross-subsidise management of small sites.
There is currently no end-user infrastructure in the region.	Partnerships with public bodies should be developed to promote this sustainable fuel supply. Meanwhile, pellets could be sold to power stations licensed to burn straw.
Implementing reed pelleting technology	Grants such as the EU Life fund together with Government biodiversity and

requires high capital investment.	sustainability grants could form the core set-up fund. Section 106 and Growth Area funding could also be sourced especially if biofuels are integral to developments. Contributions from beneficiary organisations could provide the matched funds. Long term service contracts could underpin sustainability.

While reed pelleting has many constraints, there are potential solutions for them all. They will require considerable development. In the medium term, substantial capital investment and commitment from a partnership will be needed. Even then, pelleting will not provide a comprehensive solution for fen harvesting.

Composting can accommodate all green materials from fen management, ideally with a moisture content above 35%. Summer-cut material is ideal. In addition, composting can accept other materials into the mix such as peat, litter and even silt dredgings.

At the current scale of operation, composting could provide a low-tech option for dealing with fen arisings. The prevailing practise, incorporation into nearby arable land, is essentially a disposal option. It can be scaled-up to a certain degree, allowing for a limited expansion of the fen harvesting operation. However, the practise is constrained by the availability of cooperative landowners, by the ability of such land to repeatedly accept additional treatments, and by the requirement to meet certain conditions which allow exemption from waste disposal regulations. In addition, such disposal is a resource burden, being time-intensive and producing no income. Its long-term sustainability is therefore questionable.

Many more benefits, and genuine sustainability, come with a commercial scale composting operation. Benefits include incorporation of a wide range of non-harvest materials, production of a useful and saleable product which is not simply disposed of, and the integration of fen management with wider farming practises. Developing a large scale and commercially-based composting scheme requires significant investment and the development of a broadly based partnership. Many of the infrastructure and funding issues described for reed pelleting (Table 4) also apply here. The current composting practise should be continued while the commercial operation is developed.

A third process that should be investigated further is pyrolysis of organic material. This can produce biodiesel and other fuels, and also a near-pure carbon product (Biochar) which is analogous to charcoal but made from fen cuttings. The technology for pyrolytic materials is less advanced than the other two processes, and there appears to be no commercially available proprietary equipment on the scale currently required. However, this is a fast moving area of technology. Continued investigations would be fruitful as these processes could bridge the moisture content gap of 16-35% which lies between pellets and compost.

Disposal of products arising from scrub clearance also has a biofuel option. Wood chip burners are an established outlet. Baling of larger material for burning in power stations is also an important potential end-use.

Commercial cutting and sale of fen hay is likely to make a small contribution to the overall fen management requirement. However, because this would deliver high quality management to some very important fen sites, and because of the improved links into the local community it would develop, it is recommended that this option be pursued. It would have a low cost with modest equipment requirements and little or no technical development.

All of the above options for use of fen produce are complementary to traditional commercial management practises such as thatching sedge and reed. Existing commercial reedbeds are excluded from all calculations and there are no proposals for utilising *Cladium* sedge beds. Maintaining a viable reed and sedge industry remains core to a sustainable fen management strategy.

8.2 Recommendations

The foregoing review provides the following recommendations:

1. Composting, with disposal to nearby land, provides the most cost-effective option for accommodating fen arisings at the current scale of operation.
2. Any expansion in fen harvesting, or any move to true sustainability, requires development of a broad range of outlets for fen produce. No single solution can meet all of the needs.
3. An enhanced, commercial composting operation could accommodate a wide range of products including woodchip, peat and dredging silt. It can deal with moisture contents above 35%. It is recommended that this option be pursued vigorously, starting with developing the required partnerships.
4. Reed pelleting for biofuel provides the best use for near-pure stands of reed, cut in winter and with a moisture content of 16% and below, although there are considerable constraints. It is recommended that this option also be pursued.
5. Products of pyrolysis, particularly bio-diesel and biochar, provide the outlet for materials with moisture contents of 16-35%. The technology is at an early stage and therefore it is recommended investigations continue before development is proposed.
6. Smaller scale outlets such as marsh hay and products of scrub clearance would provide a modest but important "niche" outlet for some fen products. They should also be pursued vigorously.
7. The only existing sustainable management technique, traditional commercial sedge and reed cutting, should continue to be supported. Ways in which the above practises can complement and enhance traditional management need to be explored.
8. Because of the potential connections between various options for utilisation, and the synergies that would arise from large-scale development of all of the options, it is recommended that a partnership be formed which can take forward an integrated package of measures for sustainable use of fen products.

9. REFERENCES

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