Environment Agency

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Resource use in the Environment Agency: the energy efficiency of pumping stations and their associated infrastructure

Science Report – SC070017

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Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

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Author(s):
Oliver Edberg, Charles Gaisford and John Veness

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Research Contractor:
AEA Energy & Environment,
The Gemini Building, Fermi Avenue, Harwell, Didcot, Oxfordshire OX11 0QR
Tel +44 (0)870 190 2945 Fax +44 (0)870 190 6318
www.aea-energy-and-environment.co.uk

Environment Agency's Project Manager:
Naomi Savory, Science Department

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Steve Killeen

Head of Science

Executive summary

The Environment Agency has a two-stage target to reduce its own carbon dioxide (CO_2) emissions by 15% in 2010 and 30% in 2012, against a 2006/07 baseline. In the year 2006-2007, the Environment Agency emitted 62,207 tonnes of CO_2, of which 56.7% was attributable to electricity use.

Pumping stations and their associated infrastructure are the largest consumers of electricity within the Environment Agency, accounting for two thirds of electricity use and 35% of total CO_2 emissions. This project looks at how cost-effective improvements in energy efficiency at the Environment Agency's pumping stations can contribute to meeting our carbon reduction targets.

The project analyses the energy performance of a sample of eight pumping stations, including the pumps and pumping operations, and the associated infrastructure. The sample is representative of all the Environment Agency's pumping stations, including examples of different energy sources (electricity/diesel), ages, geographical locations and functions. Our approach provides a template that could be applied to seek carbon reduction opportunities across all Environment Agency pumping stations.

The results of this study will be used by the Environment Agency's internal environmental management teams to co-ordinate and prioritise activities and actions to meet the carbon reduction targets.

The study provides benchmarks of energy performance, so that best practice or acceptable practice can be quantitatively assessed in the future. For each pumping station, we set out recommendations for improving energy management and reducing energy use.

The study also estimates the economic costs and savings associated with recommended actions at each station. This will allow us to prioritise our actions on a financial basis, and to judge whether the recommended actions are more favourable than carbon offsetting, as we move towards our target of being carbon neutral.

Findings and recommendations

Eight sites were examined, one from each region in England and Wales. Their combined electrical consumption in 2007 was 3,134,281 kWh, and their total CO_2 emissions (including diesel fuel) amounted to 1,725 tonnes.

Through implementing energy saving measures at these stations, a potential 255 tonnes CO_2 per year could be saved, representing 14.8% of their total emissions. The costs to implement these measures range from little or no cost to adjust pumping set point levels, to significant capital investments to replace heating systems. The average cost across all the measures identified is £283 per tonne CO_2 saved. Payback periods vary accordingly, ranging from immediate to more than 10 years.

The eight sites ranged from large stations, manned at least 35 hours per week, with several buildings and services, to small unmanned stations with no facilities at all. The energy saving measures identified included improving the performance of the pumping systems and improving facilities such as heating and lighting.

Key improvement measures include the following:

- Reduce the pumping head (lifting height) that the pumps work to. This is achieved through either raising the set point levels of the water supply channels that the pumps lift from, or lowering the level to which the water is delivered. For example, drainage channels might be allowed to rise further, or pumps on the coast set to pump out to sea only at low tides.
- Improve scheduling of pumps. Some sites include a mix of pumps with different efficiencies. It is preferable to run the most efficient pumps first.
- Improve building heating systems. This includes moving from electric heating to heat pump technology (air, ground or water sourced heat pumps), and using radiant heaters for comfort heating in large occupied spaces.
- Improve lighting controls and upgrade to more efficient lighting technologies.
- Improve general housekeeping practices. Turn down heating set points, switch off lights when not in use and close external doors.
- Use wind power for electrical generation. One site (Gronant, Wales) demonstrated potential for a wind turbine to supplement the electrical demand, and even to supply surplus electricity back to the grid
- Increase the collection of half hourly electrical date and the use of sub-metering. Information from these data can be used to identify potential energy savings and to verify actual performance and savings realised.

Further research:

This project provides a snapshot of the types of energy saving that may be available at pumping stations across the Environment Agency regions. If similar measures to those identified here, providing a 14.8% reduction in carbon emissions, were available across all of the Environment Agency’s pumping stations (some 2000), they would represent substantial progress towards meeting our carbon reduction targets.

However, the sample of eight pumping stations is not sufficiently large to provide confidence that this amount of carbon reduction is available across all pumping stations. For example the Anglian region operates over 20 land drainage stations, but the Kennet station surveyed here is used for water transfer and its energy consumption is an order of magnitude larger. We recommend that similar energy analyses are carried out on a larger sample of pumping stations.

The study identifies metrics to benchmark the performance of pumping stations, such as the calculation of tonnes of carbon per ‘liquid kilowatt’. Further research on these metrics, and analysis across a larger sample of pumping stations is recommended, to establish how robust and suitable they are for applying as standard across all the Environment Agency’s pumping systems.

At a number of the pumping stations, the original pumping system design data were either limited or not available (probably due to their age and history) and collation of performance data was difficult. For instance, it was frequently not possible to measure flow rates or volumes of water pumped, and electrical consumption data were limited. We recommend that the Environment Agency investigates building a library of these data and where possible collects half hourly electrical consumption data for its pumping stations from the utility suppliers. This will make it easier to identify sites where energy consumption is greatest and sites with the best carbon reduction potential.

The following table represents the savings potential identified at each site:

Site		Electrical consumption	Diesel consumption	Combined CO2 emissions (t)	Savings opportunities				Implementation costs		
Region	Site name	Annual consumption (kWh) 2007 – billing data	Annual consumption (litres) (2007)		Pumping (kW)	Other site (kW)	Total (CO2)	Savings as % of total site CO2 emissions	Cost to implement (£)	Payback (years)	Cost per tonne CO2 saved
North West	Crossens	1, 166, 655	27,300	682.0	91, 106.0	209, 000.0	92.2	13.5	9, 840.0	0.7	106.7
Anglian	Kennet	870, 602	-	455.3	50, 918.0	121, 343.0	90.0	19.8	36, 480.0	3.4	405.3
North East	Foss	513, 764	1, 056	271.5	29, 240.0	57, 009.0	45.2	16.6	14, 550.0	2.4	321.9
South West	West Sedgemoor	203, 640	-	106.5	32, 560.0	-	17.0	16.0	-	-	-
Southern	Union	186, 384	-	97.5	-	-	-	-			
Thames	Thamesmead	134, 018	4, 350	81.5	-	-	8.4	-	350.0	2.9	41.7
Wales	Gronant	24, 546	-	12.8	-	4,380.0	2.3	-	11, 000.0	38.6	4,782.6
Midlands	Highbridge	34,672	-	18.1	-	-	-	-	-	-	-
TOTALS		**3, 134, 281**		**1,725.2**	**203, 824.0**	**391,732.0**	**255.1**	**14.8**	**72,220.0**		**283.1**

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1 Resource use in the Environment Agency: energy efficiency of pumping stations and their associated infrastructure

1.1 Introduction

Climate change is one of the top priorities for the Government. It is introducing a national statutory target to cut carbon dioxide (CO_2) emissions by 60% by 2050. The Environment Agency has already set a two-stage target for reducing its own CO_2 emissions, as follows:

- Reduce CO_2 emissions by 15% on 2005/6 levels, by March 2010
- Reduce CO_2 emissions by 30% on 2005/6 levels, by March 2012

The Government set out its policy to deliver a secure, low carbon energy mix for the UK on 23 May 2007 in its Energy White Paper *Meeting the Energy Challenge.* Looking ahead to 2020, the White Paper announces specific measures that will ensure individuals, businesses and Government reduce their carbon emissions and save energy. A key announcement was for a mandatory national scheme – the 'Carbon Reduction Commitment' (CRC) – to require large commercial organisations to reduce their emissions. This will include the Environment Agency. The Government believes the CRC could come into force in January 2010.

The Carbon Reduction Commitment requires real reductions in CO_2 emissions. Carbon offsets or green electricity cannot be purchased as a substitute for absolute energy savings. Therefore the Environment Agency has to understand clearly where real energy savings, and consequent reductions in CO_2 emissions, can be delivered across the organisation.

The Environment Agency currently emits 62,207 tonnes of CO_2 a year (2006/07), of which 56.7 per cent is attributable to electricity use. The largest consumers of electricity within the Environment Agency are pumping stations, which account for two-thirds of electricity use and 35 per cent of the total Environment Agency CO_2 emissions.

This project represents the first stage in taking action to reduce CO_2 emissions from Environment Agency pumping stations. It is an analysis of their current energy use and how their CO_2 emissions could be reduced most cost-effectively.

This first chapter of the report describes our approach to the analysis, and provides a summary of the findings and recommendations. The following eight chapters provide detailed analyses for each of the sample pumping stations.

1.2 Scope of the project

This project analyses the energy consumption and efficiency (in kWh/volume water pumped) of pumping stations and their associated infrastructure and provides a benchmark for pumping station performance and emissions. It also provides a cost-benefit analysis of the options for reducing energy use and CO_2 emissions at eight pumping stations, with recommendations for improving energy management.

Objectives

- To collate and review data on energy consumption and efficiency, and current CO_2 emissions, for a sample of eight pumping stations operated by the Environment Agency (including both electric and diesel powered).
- To benchmark the energy efficiency of pumping stations and identify best or acceptable practice.
- To undertake a cost-benefit analysis of options for improving energy efficiency at pumping stations.
- To produce recommendations for organisational and site-level action plans for delivering energy savings and CO_2 emission reductions at pumping stations.

1.3 Approach

We visited eight sites between December 2007 and February 2008. These are listed in Table 1.1. The sites were chosen in collaboration with the Regional MEICA (Mechanical, Electrical, Instrumentation, Control and Automation) Engineers and were selected with the aim to include a representative sample of all the Environment Agency's pumping stations, taking into account type of energy used (electricity/diesel), age, geographical location and duties.

The primary uses of the pumping stations are to provide flood protection, land drainage and medium distance water transfer. The main function of each sample pumping station is given in Table 1.1. Land drainage pump stations are small, unmanned stations designed to automatically maintain water levels in their respective drainage canals. They have few or no services on site and maintenance visits are carried out on a weekly or longer schedule.

Flood protection stations are not continuously manned but do have facilities for 24 hour manning in the event of flooding. These stations may operate automatically, but operators can and do override the controls as they feel necessary.

The only water transfer station visited was the Kennet pumping station, which is unique in its size and function. Again, it has facilities for 24 hour manning when the largest pumps are running.

Prior to the site visits, questionnaires were sent to the responsible engineers who collated and supplied data accordingly. This was followed up with a telephone conference call where the pump station and its operation were discussed. This process served to prepare both the study team and the engineers for the site visits, and to inform the engineers about the project and its expectations.

Table 1.1 Pumping stations visited

Region	Name of pumping station	MEICA engineer	Primary function	Telephone interview date	Site survey date
Wales	**Gronant**	Ian Chambers	Land drainage	04 Jan 08	09 Jan 08
North West	**Crossens**	Andy Fitton	Land drainage	07 Dec 07	10 Jan 08
North East	**Foss**	Nigel Bulmer	Flood protection	06 Dec 07	12 Dec 07
Midlands	**Highbridge**	Martin Hayes	Land drainage		14 Feb08
Anglian	**Kennet**	Martin Lee	Water transfer	01 Feb 08	13 Feb 08
Thames	**Lake 4 (Thamesmead)**	Ian Sparks, Bill Reeves	Flood protection	21 Jan 08	24 Jan 08
Southern	**Union**	Neil Terry	Land drainage	19 Dec 07	29 Jan 08
South West	**West Sedgemoor**	Tim McCracken	Land drainage		11 Feb 09

The types of data collated included the following:

Pumping systems

- Pump and pumping system design data, including design duty information and pump performance curves
- Actual pump operating data: duty information including flow rates, operating pressures, power absorbed, operating speeds, electricity and diesel consumption
- Pipework and associated equipment sizes, types and layouts
- Operating profiles: number of pumps run and hours run
- Types of control system, control philosophy and set points
- Site electricity consumption, including monthly billing information and half hourly electrical readings.

These data were used to determine each pumping system's actual efficiency, which was compared with the original design specifications.

Where available, pump performance curves were used to estimate the efficiency of the pumps, in the ranges of head and flow rate in which they operate at each station. These performance curves were often supplied by engineers with the original pump. They are usually hand drawn and their presentation can differ. Nonetheless, we present them as found in this report, to demonstrate how we reached our conclusions about each pump's efficiency.

We developed short term and long term operating profiles for each system and identified possible energy saving opportunities.

Supporting services

- Generators: ratings, fuel consumption, annual running hours, other support services
- Air compressors: type, ratings, controls, operating set points, operating profiles, annual running hours
- Weed screen cleaners: type, ratings, operating profiles, annual running hours.

We established performance and operating profiles for these services, then identified opportunities to reduce energy consumption.

Buildings and associated site services

- Heating systems: types, ratings, controls and set points, operating patterns and annual running hours, fuel type, actual energy / fuel consumption
- Lighting: types, ratings, controls and operating patterns, annual operating hours, purpose
- Buildings: construction, size, insulation, natural lighting
- Occupation levels and activities on site
- Half hourly electrical consumption data.

Using these data, we calculated the actual energy consumed by these services, assessed their performance and developed an understanding of the need for them. Again, we identified opportunities to reduce energy consumption. Some of our calculations used energy saving assumptions provided by the Energy Saving Trust[1]. The half hourly data were particularly useful in establishing base load electricity consumption. (Base load refers to the minimum level of demand on an electrical supply system over a 24 hour period, i.e. the load that exists 24 hours a day)

In this study, we have used Defra's standard CO_2 conversion factors for calculating emissions. For electrical energy 1 kWh = 0.523 kg CO_2 and for diesel oil, 1 litre = 2.63 kg CO_2.

The electricity used in these pumping stations is purchased by the Environment Agency on a renewable energy tariff, so the conversion from kWh of electricity to CO_2 emissions may overestimate the emissions. We could not calculate the emissions due to this electricity more precisely, because we did not know what proportion of the electrical energy is derived from renewable sources.

1.4 Energy consumption overview

The quality and quantity of energy consumption data available for each site varied. Larger sites tended to have more data available than smaller sites and in one instance very sparse data were available except what could be collated during the site visit.

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[1] See www.energysavingtrust.org.uk/energy_saving_assumptions

The larger pumping stations are manned and the associated services contribute significantly to their overall energy consumption.

Table 1.2 summarises the 2007 energy consumption and CO_2 emissions for each site. Table 1.3 shows the energy savings potentials we identified for each site. Our study shows that there is potential to save 14.8% of the annual CO_2 emissions from this selection of pumping stations. If similar measures were available across all of the Environment Agency's pumping stations (some 2000), this saving could represent substantial progress towards meeting the carbon reduction targets.

However, the sample of eight pumping stations is not sufficiently large to provide confidence that this amount of carbon reduction is available across all pumping stations. For example the Anglian region operates over 20 land drainage stations, but the Kennet station surveyed here is used for water transfer and its energy consumption is an order of magnitude larger. We recommend that similar energy analyses are carried out on a larger sample of pumping stations, to ensure that the estimate of potential savings is representative.

The costs to implement these energy saving measures range from little or no cost to adjust pumping set point levels, to significant capital investments to replace heating systems. The average cost across all the measures is £283 per tonne CO_2 saved.

Table 1.2 Summary of 2007 energy consumption and CO_2 emissions at pumping stations

Site	Electricity						Diesel				Combined CO_2 emissions
	Annual use (kWh) Billing data	Annual use (kWh) Half hourly data	Base load rate (kWh)	Annual base load (kWh)	Base load as % of electricity use	Total CO_2 emissions (tonnes)	Annual use (litres)	Base load (litres)	Base load as % of diesel use	Total CO_2 emissions (tonnes)	(tonnes/year)
Crossens	1,166,655	1,144,310	7	61,320	5.25	610.2	27,300	20,000	73	71.8	682.0
Kennet	870,602	940,564	22.5-48.6	300,315	34.5	455.3					455.3
Foss	513,764	216,677	17.28-35.3	214,170	42	268.7	1,056			2.8	271.5
West Sedgemoor	203,640		*0.8 (estimated*)	*7,008 (estimated*)	3.4	106.5					106.5
Union	186,384	251,120	0.58-0.67	5,400	2.9	97.5					97.5
Thamesmead	134,018	152,194	11.4-16.7	119,000	78	70.1	4,350			11.4	81.5
Gronant	24,546					12.8					12.78
Highbridge	34,672		0.5	4,380	12.6	18.1					18.1
TOTAL	3,134,281					1,639.2				86.02	1,752.2

Table 1.3 Summary of energy saving opportunities at pumping stations for 2007

Site	Potential pumping energy saving (kWh)	Other site energy savings (kWh)	Total potential energy saving (kWh)	Potential saved CO_2 emissions	Savings as percentage of total CO_2 emissions/year
Crossens	91,106	209,000	300,106	92.2	13.5
Kennet	50,918	121,343	172,261	90.0	19.8
Foss	29,240	57,009	86,249	45.2	16.6
West Sedgemoor	32,560		32,560	17.0	16.0
Union					
Thamesmead				8.4	
Gronant		4,380	4,380	2.3	
Highbridge					
TOTAL	203,824	391,732	595,556	255.1	14.8

1.5 Summary of pump performance

Pumping schedules for all pumping stations are variable and weather dependent, and regular duty patterns could not be identified. Land drainage stations tend to run frequently whereas flood protection stations may only run for tens or hundreds of hours a year.

Table 1.4 shows the pumps surveyed and summarises their performance. The table also gives a sample of the measures that could be used to benchmark the performance of the pumps. Initially two are presented - kW per cubic metre of water pumped (kW/m^3), which does not take account of the height through which the water is lifted (head), and kW per cubic metre of water pumped per metre lifted ($kW/m^3/m$). These measures only apply to the pumps and the water delivery.

Table 1.5 summarises the carbon emissions associated with both the pump and the whole pumping station at each site, and presents other potential benchmarking measures. Here a measure called the ‘liquid kW’ (LkW) is used, which refers to the pump power output. This is the (amount of useful work done, or the amount of energy required for a given volume of water to be lifted and discharged through a known height and distance. The LkW is useful in relating the operations of the whole pumping station to the amount of pumping that has been done.

Given the small sample of pumping stations and the limited amount of actual performance data collated here, we recommend that further research is carried out on these benchmarking measures. A larger sample of pumping stations should be assessed, to establish whether the measures are robust and suitable to be used as standard metrics across the Environment Agency’s portfolio of pumping systems.

Table 1.4 Summary of pumps surveyed, operating ranges and benchmark performance figures

Pumping Station	Pump type	No of pumps	Pump performance				Site operating range		Benchmark performance	
			Rated kW	Speed (rpm)	Head (m)	Flow (l/s)	Head range (m)	Flow range (l/s)	(KW/m^3)	(KW/m^3/m)
Gronant	Allen Gwynne	3	37	743	3.35	700				
Crossens	Bedford DB8010	3	110	495	4.94	1500	3.1-4.8	1560-1760	0.0140-0.0178	0.0037-0.0045
	Bedford 42” Sluice	3	225	480	3.81	2985	2.5-4.2	3020-3440	0.0107-0.0173	0.0041-0.0043
	Bedford 42” Three Pools	3	225	480	3.81	2985	2.5-4.2	3020-3440	0.0107-0.0173	0.0041-0.0043
	Sulzer BSnl 500	2	75	735	6.98	850	5.2-7.2	880-970	0.0162-0.0225	0.0031
	Bedford DB 60 09 8	3	90	741	7.25	850	5.2-7.2	880-1060	0.0193-0.025	0.0035-0.0037
	W H Allen 24”	2	107	465	8.63	848				
Foss	Flygt 53-490-93	8	253	495	3.95	3500	3.4-4.5	3400-3700	0.0123-0.0159	0.0035
Highbridge	Flygt LL 3201-612	4	22		5.9	169.7	2.94-3.83	230-255	0.0196-0.0226	0.0059-0.0067
	Flygt NP3102.181	1	3.1	1450	7.6	25	3.56-3.83	42-47	0.02-0.0203	0.0053-0.0056
Kennet	Weir SBV42 x 2+3	2	2610	740	142.6	1315	113	1567-1664	0.39	0.0035
	Weir SBVM 1070 x 5	1	2480	740	123.3	1600	114	1741	0.37	0.0032
	Weir SBWM 600 x 3	2	385	1450	110.4	272	113.5	255	0.43	0.0038
	Pleuger QT20EKH/3	2	400	1445	110.4	272	113.5	264	0.405	0.0036
	Caprari E10S64/4B +MAC10150-BV	2	110	2920	106	81	113	77.5	0.39	0.0035
	Weir Uniglide SDB2/3	2	3.7		15.25	10.1				
	Grundfos	5	4							
	Grundfos	2	5.5							
Thamesmead	Spaans 2.9m Archimedes	4	300	25	8.36	2000	8.36	2000	0.031	0.0037
Union	Allen Gwynne 40”	1	165	365	unknown	2832				
	Allen Gwynne 27”	2	86	585	unknown	1416				
West Sedgemoor	40” Gwynne Mixed Flow	2	132	238	4.1	1846	2.3-2.7	2420-2596	0.006-0.0117	0.0026-0.0043
	WH Allen 600 submersible (VSD)	1	75	400-800	unknown	1200	0.15 – 3.1	600-1200	0.0029-0.0161	0.0052-0.0193
	KSB Ama-Drainer 303	2	0.8		8	2.5				

Table 1.5 Benchmarking measures for the performance of pumping stations. Where data were sufficient to calculate benchmark values, stations are presented with the worst performing (highest benchmark emissions) first. LkW refers to 'liquid kW'. See text for further explanation of this unit.

Pumping station	Total CO_2 emissions (t)	Pumping CO_2 emissions (t)	Pumps tCO_2/LKW	Pumps tCO_2/m^3	Station tCO_2/LKW	Station tCO_2/m^3
Kennet	455.32	309.6	0.004242	0.001312	0.006238	0.001929
Thamesmead	81.53	26.8	0.002179	0.000050	0.006628	0.000151
Foss	271.48	185.55	0.001065	0.000012	0.001558	0.000017
Crossens	681.96	650	0.000972	0.000011	0.001019	0.000012
Highbridge	18.13	15.8	0.000717	0.000007	0.000822	0.000008
Gronant	12.84	Insufficient data			Insufficient data	Insufficient data
West Sedgemoor	106.50	102.9			Insufficient data	Insufficient data
Union	97.48	94.7			Insufficient data	Insufficient data

Site data

During the survey it was found that some of the pumping stations, especially the older ones, did not have design or performance data available. Some of the pumps date back 40 to 60 years, and it was not possible to establish their performance on paper. For these installations we recommend that performance curves are developed from first principles, by measuring the installed performance as the duty is varied.

We recommend that the Environment Agency sets out a program to verify the availability of performance data for its pumping stations. These data could include:

(I). Original design data, including design duty points.

(II). Pump performance curves.

(III). Commissioning and actual performance operating data. These may be used as a reference in the future, to determine whether the pump's performance has changed.

(IV). Pump log book, detailing the maintenance history of the pump and any changes to its performance.

Due to the design of many of the pumping systems, it was not always possible to monitor the actual installed performance of the pumps. Flows and operating pressures often could not be measured as most systems were either open discharge or discharged through very short lengths of pipework. We recommend that in future pumping station designs, facilities are included to measure these parameters. Such facilities could include a gauging point in the discharge channel to measure flow, or a sump of known volume that fills up over time. The latter should be positioned so that it does not affect the pumping head.

Billing data and half-hourly electrical consumption data were provided for five of the sites surveyed. This enabled analysis of base load consumption and overall consumption for these sites. We recommend that half-hourly data are collated for all sites.

Pumping systems

We present a variety of energy saving options for the pumping systems analysed in this study. These include:

(I). *Reducing the pumping head* (lifting height).
This is achieved by raising the set point levels of the water supply channels that the pumps lift from, or by lowering the set point levels on the delivery side. If a pump is pumping into a channel influenced by the tide, then only pumping at low tide reduces energy use. If the set point levels of water supply channels are to be raised, the impact of a raised water level in the surrounding area must be considered.

(II). *Better scheduling of pumps.* Some sites include a mix of pumps with differing efficiencies. In such cases, it is preferable to run the most efficient pumps initially. At some sites, pumps may be scheduled to achieve the same effect as reducing the pumping head.

(III). *Replacing pumps with more efficient versions.* At one site the main duty pump was found to be relatively inefficient. Here an upgrade to a more efficient pump would be beneficial.

Sites and services

We identified a number of options to reduce carbon emissions associated with the sites. These include:

(I). Move from electric heating to heat pump technology. There are a number of variants to this technology including ground source, water source and air source heat pumps. Air source heat pumps are widely available and are capable of reducing carbon emissions by over 60% when compared with electric heating. Water source and ground source versions may achieve even better performance. A number of the best performing heat pumps are listed on the Enhanced Capital Allowances list (www.eca.gov.uk/etl).

(II). Use radiant heaters to heat large spaces. This applies mainly to the Crossens site where the large pumping hall is currently heated by a diesel-fired boiler. Radiant heaters working on timers or motion sensors would significantly reduce carbon emissions.

(III). Fit controls to lighting. This mainly applies to security lighting where it may be switched by timers, external light level sensors or motion sensors. In stations with high manning hours, controls in the internal areas may also be appropriate.

(IV). Improve insulation. A number of buildings that are regularly manned would benefit from additional thermal insulation and draught proofing measures.

(V). Diesel generator pre-heating. At Foss, it may be possible to switch off the diesel generator pre-heaters for long periods. At other sites such as Crossens, sump heaters could be fitted to the diesel engines as an alternative to heating the engines with hot air.

(VI). Improve housekeeping practices. At most sites there are smaller savings to be realised through basic measures such as turning down heating set points, either for space heating or frost protection, switching off lighting and other equipment when not in use, and closing external doors.

(VII). Wind power. There is an opportunity at Gronant to install a wind turbine to offset the electrical consumption of the site services and pumping. Other Environment Agency sites may offer similar opportunities (see section 1.7.2).

(VIII). Increased use of half hourly electrical data and sub-metering. Information from these data can be used to target where energy savings may lie and to verify actual performance and savings realised.

Automatic weed cleaners are installed at a number of sites, but these operate infrequently and their overall energy consumption is low. No recommendations are made regarding these.

1.6 Summary of findings for individual pumping stations

Foss (North East)

The site base-load electrical consumption varies from 35.3kW in winter to 17.28kW in summer and is due to the control systems, heating, lighting and other services provided at the pump station; it totals 214170kWh p.a. and is approximately 42% of the sites overall electrical consumption for 2007.

The annual diesel consumption due to testing the generators is estimated at 1,056 litres emitting 2.8 tonnes CO_2.

The sites combined CO_2 emissions for 2007 were 271.5 tonnes, and of this 112 tonnes (42%) were attributable to the electrical base load.

There are opportunities to reduce the CO_2 emissions associated with the building heating ranging from replacing the existing electrical heating services with heat pump technology, improving insulation in the control room, to better housekeeping. It is also worth investigating the possibility of switching off the preheating on the standby generators.

There are two types of opportunities associated with the pumps, one being to reduce the discharge head the pumps deliver to and the other being reducing the differential pumping levels of the waters in the river Foss.

In order to further reduce CO_2 emissions the fuel powering the diesel pumps could in the longer term be switched from fossil based diesel fuel to bio diesel. Consideration will however have to given to managing the degradation of bio diesel when stored for long periods.

The energy saving recommendations are summarised as follows:

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
Reduce pumped head by reducing span of level control	768	10965	5.7	0	0
or Reduce discharge head retaining existing impellers	**2046**	**29240**	**15.3**	**0**	**0**
or Reduce discharge head, and change pump impeller	3162	45183	23.6	100000	31.62
Convert from electric heating to heat pump technology	**3434**	**49059**	**25.7**	**14 000**	**4**
or Convert from electric heating to wet heating and gas boiler	1824	0*	22.6	5000**	2.7
Separate heating & lighting circuits in switchgear room	**201**	**2870**	**1.5**	**250**	**1.24**
Improved housekeeping (switch off lights, close external doors)	**250**	**3567**	**1.87**	**-**	
Seal draughts in control room	**65**	**923**	**0.48**	**100**	**1.55**
Increase insulation above the ceiling above the control room, repair hole.	**30**	**478**	**0.25**	**200**	**7**
Introduce T5 upgrade policy for florescent lighting	**14**	**112**	**0.06**	**na**	**na**
Revise diesel generators pre-heating policy	unknown	unknown	unknown		

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
OVERALL TOTALS (of best options)* **	**6040**	**86249**	**45.2**	**14550**	**2.4**

**There are no overall savings in kWh used rather a reduction in CO2 emissions.*

***This price excludes site gas connection costs*

****The overall total is additive, some of the options relating to heating will when combined produce less of an overall saving.*

Crossens (North West)

The site base-load electrical consumption is approximately 7kW and is principally due to the control systems and some limited heating in control panels; it totals 61320kWh p.a. and is approximately 5.25% of the sites overall electrical consumption for 2007.

The annual diesel oil consumption is estimated at 27,300 litres (73.7tCO_2). Approximately 7,300 litres (27%) were attributable to pumping and 20,000 litres (73%) were attributable to heating.

The sites combined CO_2 emissions for 2007 were 569 tonnes, and of this 54 tonnes (9.5%) were attributable to heating and 26 tonnes (4.6%) were attributable to the electrical base load.

There is a significant opportunity to improve the heating system, a number of methods exist however the preferred solution is to replace the existing hot water / hot air system with radiant heaters in the main pumping hall fuelled either by gas or electricity. The energy saving calculations assume electric radiant heaters have been selected as they will be not only more cost effective but are likely to be more easily installed. The installation of radiant heaters is considered in conjunction with an air source heat pump for heating the office areas. Preheating of the diesel engines could be achieved with the use of electric sump heaters on an as needed basis.

There are a number of opportunities associated with the pumps, the main ones being to either change scheduling in favour of the most efficient pumps or to reduce the pumping head required by raising the set points in the supply drains.

In order to further reduce CO_2 emissions the fuel powering the diesel pumps could be switched from fossil based diesel fuel to bio diesel.

The energy saving recommendations are summarised as follows:

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
Sluice Pumps **Run internal Sluice Pumps in preference to Supplementary Pumps**	**2520**	**36,000**	**18.8**	**0**	**0**

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
Back Drain Pumps **Run Sulzer Back drain pumps in preference to Bedford Pumps**	**2886**	**41,232**	**21.5**	**0**	**0**
Lift all supply channel set point levels by 10cm	**971**	**13,874**	**7.3**	**0**	**0**
Install insulated roller shutter doors	N/A	11%*	N/A	3250	
Install 8 fixed or portable infra-red radiant electric heaters with timers and a 5 kW air source heat pump	**7773**	***209,000***	**44.6**	**9840**	**1.3**
Install fixed or portable infra-red radiant gas powered heaters with timers and a 5 kW air source heat pump this excludes gas connection costs.	7826	N/A	46.4	9120	1.2
OVERALL TOTALS (of best options)	**14150**	**300106**	**92.2**	**9840**	**0.7**

**It is not possible to quantify the heat loss through the existing roller steel door and therefore to quantify savings is not possible.*

Gronant (Wales)

The energy billing and electrical consumption data supplied does not reconcile with estimates of the sites energy consumption due to pumping, consequently it was assumed this data was not reliable and associated analyses were not performed. Locating the correct energy data is advised in order to carry out future analyses.

Readings taken on site suggest the site base load electrical consumption to be in the region of 2.7kW and will be associated with the frost protection heating and controls for the pumps. The station is unmanned and there are no services.

It was not possible to establish long term energy consumption due to pumping or to describe duty patterns. In addition no pump performance data is available; this includes design data (pump design duty points), pumps curves and actual performance data. The design of the pump station is such that it does not easily lend itself to monitoring of flow rates or volumes of water pumped. In the absence of performance curves as a means of monitoring flow will have to be established before a performance curve could be generated from first principles (monitoring and recording actual performance parameters as the duty is varied).

As the Gronant pumping station is located on an exposed and windy site there is a good opportunity to utilise wind power to offset the sites energy consumption, and with a sufficiently large wind turbine to offset the energy consumption of other pumping stations. The energy savings calculation assumes a 2.5kW unit, however it may be possible to install a significantly larger one.

The energy saving recommendations are summarised as follows:

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
At high tide minimise operating head by allowing suction levels to rise.	*Insufficient data provided to perform analysis*				
Replace space heaters with panel heaters in control gear and anti condensation heaters in motors.	*Insufficient data provided to perform analysis*				
Install a micro-wind turbine to supplement the site's base load demand (2.5kW)	460*	4400	2.2	11,000	23.9
OVERALL TOTALS	285	4380	2.3	11,000	38.6

**The annual savings includes the 4p/kWh that can be obtained through ROCs.*

Thamesmead (Thames)

The site base load electrical consumption in 2007 varied between 11.4kW in summer to 16.7kW in winter totalling 11900kWh p.a. and was approximately 78% of the sites overall electrical consumption (from half hourly data). Whilst there are some limited services on site the site is unmanned and these are little used, some lighting is left on continuously for security reasons. The base load does appear to be high and may not be attributable to the electronic controls and security lighting only. Further investigations are recommended to establish how it is used.

There is an opportunity to upgrade the security lighting and fit better controls.

The pumps are rarely used and no recommendations are made apart from avoiding the use of P4 which is damaged and runs less efficiently.

From an economic perspective the electrical availability charge for this site is high relative to actual electricity use and consideration could be given to finding ways to mitigate the long term costs of this, one option could be to disconnect the electrically powered pumps from the grid supply and power them from diesel engines or diesel generators running on bio-diesel, no analysis of this is presented.

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
Avoid running pump 4 until repaired	na	na	na		
Turn down heating set points to 5^{o}C	975	15480	8.1	0	0
Fit dedicated internal security lighting with motion sensors	38	606	0.3	350	10
OVERALL TOTALS	1013	16086	8.4	350	2.9

Union (Southern)

The site base load electrical consumption for 2007 was approximately 5400kWh equivalent to approximately 2.9% of the sites overall electrical consumption. The site is unmanned with little services and the base load consumption is likely to be attributable to the electronic controls only.

A detailed analysis of the energy use by the pumps was not possible due to the lack of electrical consumption data and pump performance information. This includes design data, pump performance curves and actual performance data (flow, operating head and power absorbed). Generating pump performance curves from first principles and collation of long term performance data is beyond the scope of this study, consequently it is recommended that an exercise be conducted to collate this information and then a review of this site is conducted once again.

The energy saving recommendations are summarised as follows:

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
Run larger pump (100cusec) in preference to smaller pump (50cusec)	Insufficient data to perform analysis				
Raise suction level 'Start' set-point	Insufficient data to perform analysis				
Reduce pumping during high tide	Insufficient data to perform analysis				
OVERALL TOTALS					

West Sedgemoor (South West)

There was insufficient data to conduct an analysis of the site base load electrical consumption, this however is estimated to be low as the site is unmanned with little services; the base load consumption is likely to be attributable to the electronic controls only which are not significant.

There was no data relating to the fuel oil consumption due to the heater providing frost protection in the main pump house, again this is not likely to be significant.

There are opportunities to improve the performance of the main pumps P1 and P2 through raising the water levels in the supply channel thereby reducing the pumping head.

A detailed analysis of the energy use by the external variable speed controlled pump, P3 was not possible due to the lack of pump performance information (design duty information, performance curves). Performance data collected on site suggested that P3 is not very efficient and could be replaced with a more efficient pump. Generating pump performance curves from first principles is beyond the scope of this study and consequently it is recommended that an exercise be conducted to develop a performance curve for the pump and that further analysis is carried.

The energy saving recommendations are summarised as follows:

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
Set channel set point levels 10cm higher	2540	32,560	17	0	0
Evaluate replacement of external variable speed pump (P3) with a more efficient pump	*Insufficient data to perform analysis*				
OVERALL TOTALS	2540	32560	17	0	0

Kennet (Anglian)

The Kennet pumping station is a significant user of electrical energy both for pumping and maintaining operations on site which is typically manned five days per week.

In 2007 the site base load electrical consumption varied between 48.6kW in winter and 22.5kW in summer and represented approximately 32% of the sites overall consumption. There are two houses on site no longer occupied by Environment Agency staff whose electrical use is included in the site base load analysis. It is recommended that electricity meters on the supplies to these houses are installed to enable the Environment Agency to quantify electricity consumption due to the pumping station. In addition there are a number of other electricity users contributing to the base load consumption including the control systems and these need to be better quantified and addressed through a sub metering exercise.

There are opportunities to improve insulation, such as cavity wall insulation in the main office and control room building.

All heating on site is provided by electric heaters of various types, carbon emissions associated with this heating may be reduced by switching to an alternative heating technology such as heat pump technology. Water in the pump shaft could be used to service a water sourced heat pump or alternatively ground sourced or air sourced heat pump technology could be employed.

Florescent lighting should be replaced on failure with equivalent higher efficiency T5 units.

With regard to improving the efficiency of pumping the most effective means will be to reschedule the pump duties in order to favour the larger more efficient pumps, consideration will however have to be made as to how the delivered water can be most efficiently managed and retrieved for storage.

The energy saving recommendations are summarised as follows:

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
**Schedule pump 4 in preference to pumps 2 and 3	2732	44064	23.0	0	0

Recommendations	Estimated Annual Savings			Estimated Cost	Payback Period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
OR** Schedule pumps 13 and 14 in preference to pumps 11 and 12.	**3157**	**50918**	**26.6**	**0**	**0**
OR** Run pumps 13 &14 for short periods instead of 21 & 22	67	1079	0.56	0	0
OR** Run pumps 2, 3, or 4 for short periods instead of pumps 11, 12, 13, 14	3157	50918	26.6	0	0
Switch from electric heating in the main building & surge tank building to water source or air source heat pump technology	**4873**	**78594**	**41.1**	**30,000**	**6.2**
Use electrical sub-metering to investigate base load consumers such as the control systems and condition monitoring equipment	**930**	**15016**	**7.85**	**2000**	**2.15**
Fit electric meters to the electrical supplies for the adjacent houses on site	**520**	**8400**	**4.4**	**0**	**0**
Improve insulation in the main building – cavity wall insulation and roof insulation	**856**	**13807**	**7.2**	**4280**	**5**
Improve house keeping practices (switch off policy)	**325**	**5239**	**2.7**		
Fit draught sealing around the door between the pump hall and the switch room.	**20**	**287**	**0.15**	**200**	**10**
OVERALL TOTALS (of the best options)*	**10681**	**172261**	**90**	**36480**	**3.4**

** The totals are additive, some of the heating measures will in combination result in less reductions, i.e improved insulation will reduce the load on a heat pump meaning it does not need to operate at full capacity.*

*** Scheduling of pumps depends on the demand for pumping; only one option is selected to represent the savings potential.*

Highbridge (Midlands)

Highbridge pumping station is a small user of electricity and there are limited opportunities to improve the efficiency of pumping in the station. The performance of the pumps are similar, both operating at about the same kW/m^3.

The small pump could be replaced with a marginally more efficient model, however this will only be economical if carried out when the existing pump needs replacing. The energy saving potential associated with this is not estimated.

The heating appliances are essentially set up for frost-protection at 5ºC and make up a very marginal component of the overall energy use. An indication of this is from the electrical data analysis, this showed that in 2007 the lowest site energy consumption occurred in November.

It is recommended that data be collected on half hourly intervals; this will help establish the profiles of electrical energy consumption.

1.7 Further recommendations

Environment Agency purchasing policies

The following recommendations should be considered for inclusion in Environment Agency purchasing policies:

(I). Pump system design

All pumping systems should be designed according to the lowest life cycle energy use and best practice design should be implemented wherever possible.

Facilities should be included to monitor the performance of pumps when installed. This will include methods to monitor flow rates and take pressure readings.

On systems with load discharge heads, the use of the siphonic effect should be implemented wherever possible.

(II). Pump controls

Pump control systems should be programmed to optimise the performance of pumps. This could include fixing level set points so that pumps operate as near to their best efficiency point as possible.

Control systems should keep a log of pump running hours and where facilities allow, power consumption (Amps or kW) and flow rates or operating pressures. This will help to further optimise the pump system performance.

(III). Motor replacement

All new electric motors purchased should comply with the performance standards described by the Energy Technology Criteria List on the Enhanced Capital Allowance Scheme (www.eca.gov.uk/etl).

Electric motors requiring repair should first be subject to a life cycle cost analysis. The repair and operating cost of a rewound motor should be evaluated against the purchase and operating cost of a new high efficiency motor.

For motors of 45 kW or smaller, it is usually more economical to purchase a new high efficiency version than to repair, when life cycle costs are taken into account. The Environment Agency will have to determine its own threshold for this policy.

(IV). Lighting systems and maintenance

Maintenance policies should recommend that T8 and T12 fluorescent lighting be replaced with more efficient T5 units on failure. Automatic controls such as timers or occupancy sensors should be utilised wherever possible.

(V). Sub-metering of electrical installations

Sub-metering should be included in all pumping facilities that have additional site services and capacities larger than 50kW. Sub-meters should be located so that the energy consumption due to site services and pumping systems may be distinguished.

Opportunities for wind generation

Environment Agency pumping stations are often in remote locations. Some are in coastal or highland areas that experience high mean wind conditions. At Gronant pumping station in North Wales, for example, it is so windy that the external lighting frequently suffers wind damage. Such sites have good potential to install a wind turbine, to meet the station's base load electrical demand (such as for heating) or more. This opportunity offers carbon savings and, in prime locations, financial benefits from sale of surplus electricity to the grid.

Table 1.6 gives an indication of the costs and carbon savings that are likely to be achieved through the installation of smaller wind turbines. If excess electricity is sold to the grid, the payback period on the initial investment improves with increasing turbine size. These calculations assume a value of £0.07/ kWh. The payback period may be further shortened if energy prices increase.

Table 1.6 Wind turbine costs and savings for Gronant pumping station

Manufacturer	kW	Annual generating capacity (kWh)	Price (£)	Saving per year (£)	Payback period (years)	Carbon savings (tonnes per year)
Proven	2.5	4380	11000	306.60	35.88	2.29
Proven	6	10512	22500	735.84	30.58	5.5
Proven	15	26280	50000	1839.60	27.18	13.74
Proven (25m mast)	15	35040	50000	2452.80	20.38	18.33

It is likely that a large number of pumping station sites have good potential for wind generation. For example, the mean wind speed measured at Crossens pumping station is higher than at Gronant. There is potential to:

1. Match the turbine size to each site, to offset the heating and base load electrical demand. For smaller unmanned pumping stations, the typical heating demand is below 5 kW. At these stations, micro-wind turbines are a good option to provide for the heating demand and electrical appliances excluding pumps.

2. Install a larger turbine that could offset the electrical demand of multiple sites.

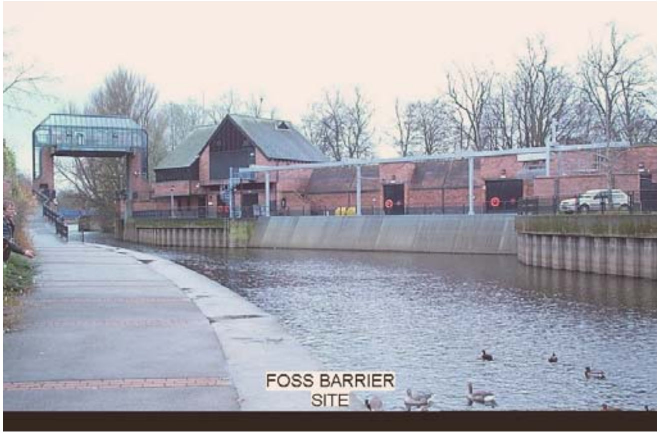
We recommend that the Environment Agency analyses all its pumping sites, to identify those with potential for wind turbine installation. This could help deliver significant carbon savings.

2 Foss (North East)

Site details: Foss Pumping Station, Georges Field, York, YO10 4AA

Contact person: Nigel Bulmer

Date of site visit: 12 December 2007



2.1 Site overview and function of pumping station

The station is located near the centre of the city of York on the banks of the river Foss at its confluence with the River Ouse. During periods of flooding, high water levels in the river Ouse can cause water levels in the Foss to back up and flood the surrounding area, including much of the centre of York. To avert this threat, a barrier is lowered across the Foss where it joins the Ouse, preventing the flow of water in either direction. The pumping station then transfers water from the Foss to the Ouse. It lifts the water and discharges it into a channel that gravity feeds into the Ouse. Over the past four years, the Foss barrier has been closed and the pumps operational for an average of 21 days per year.

The barrier and pumping station were built in 1980 to avert severe floods in York city centre.

The station is supplied from two separate 11 kV ring mains, each feeding a 1500 kVA, 11kV to 400V transformer. Each transformer is capable of supplying four pumps.

There are also two 1000 kVA Cummins Marine diesel generators (KTA50G1) for emergency backup purposes.

2.2 Site energy use

The primary energy consumption at the Foss pumping station is electrical. Diesel is only used by the backup generators.

From 1 January to 31 December 2007, the total site electrical energy consumption was 513,764 kWh, costing a total of £72,134. The average price per kWh is heavily affected by the monthly standing charge of £2,777.50, which is a necessary expense to maintain 4.8 kVA availability. Figure 2.1 demonstrates the monthly electrical consumption and relative costs.

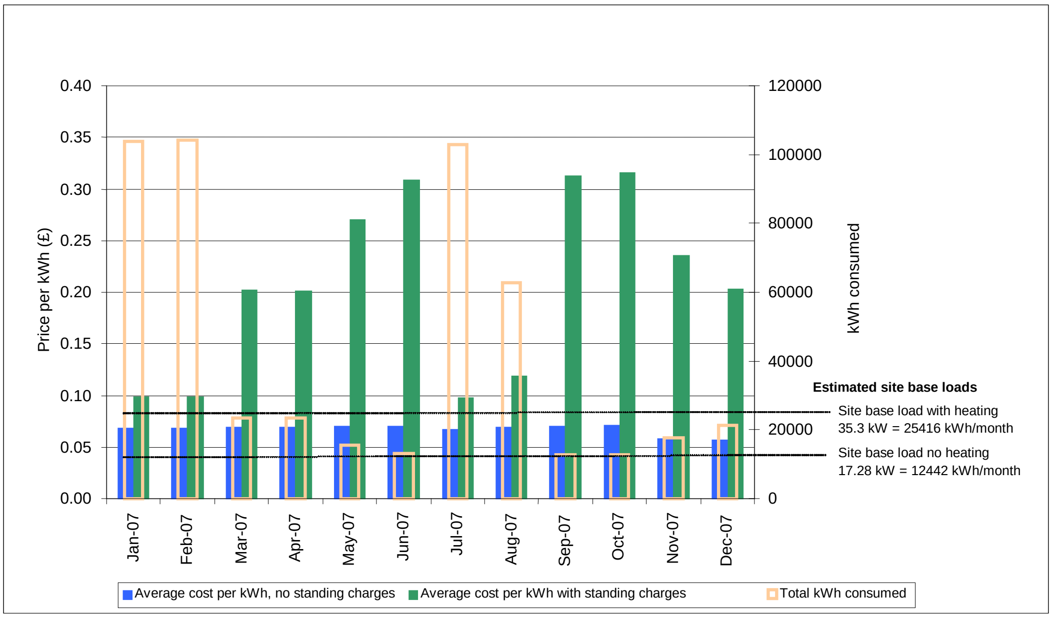


Figure 2.1 Electrical energy consumption and typical monthly costs (£/kWh) at Foss pumping station in 2007

Whilst the average electricity cost including standing charges was £0.14 per kWh, for the purpose of energy saving calculations we excluded the standing charges and assumed an electricity cost of £0.07/kWh.

The base load electrical consumption at Foss varies from 35.3 kW in winter to 17.28 kW in summer. It is due to the control systems, heating, lighting and other services provided at the pump station. The total annual base load is 214,170 kWh, approximately 42% of the site's overall electrical consumption for 2007.

The annual diesel consumption due to testing the generators is estimated at 1,056 litres, emitting 2.8 tonnes CO_2.

The total CO_2 emissions for 2007 was 271.5 tonnes. Of this, 112 tonnes (42%) were attributable to the electrical base load.

2.3 Pumping systems

Water is channelled under the pumping station to supply eight adjacent suction channels each fitted with an identical Flygt submersible pump, designed to lift water vertically and to overflow into a common outflow channel that discharges into the river Ouse. Each channel is hydraulically separate from the adjacent channel.

The pumps are Flygt model 53-490-93. They have 253 kW four pole motors with a rated duty of 3000 l/sec at 5.5m. The electrical rating is 400 V during operation and the starters are conventional Star-Delta units.

The operating head varies from 3.5 to 4.5 m, depending on the levels in the Foss. The average level is estimated at 4.1 m. Typical operation is from 6.8 m to 7.2 m Above Ordinance Datum (AOD), delivering to 11.3 m AOD when factoring in overflow levels over the channel wall. The operators can operate the pumps manually to lower the Foss basin (Browney Dyke) as low as 5.8 m, which they do either to: a) provide storage when they know a large amount of water is travelling down the Foss towards the barrier, or b) to keep Browney Dyke low enough to allow the surface drains to discharge effectively into the basin, preventing surface water backing up and flooding York.

In each pump delivery channel there is a penstock gate located 1 m below the discharge level, which may be opened and employed for testing purposes when the Foss water levels are low.

Due to the design of the Foss pumping station it is not possible to measure actual flow rates delivered by the pumps in operation. The pump performance had to be estimated using other sources of information, such as the pump performance curves and associated electrical consumption data.

Typical operation

The pump controls are designed to allow automatic operation of the pumps. The control system is an ABB Satline SCADA system (PC based), configured to automatically switch on the pumps sequentially, according to water levels in the Foss. Level sensing is by ultrasonic transducer.

The control system is programmed to start the pumping sequence when the Foss water levels reach 7.8 m AOD during periods of flooding. The pumps are automatically turned off between 7.2 m and 6.8 m AOD. In practice, during periods of flooding most of the pump controls are over-ridden by the operators, who manually supervise and switch the pumps. On occasions, operators will decide to pump the Foss levels down to 5.8 m in anticipation of flooding.

Detailed pump analysis

Records from the SCADA system suggest that in the previous 12 months (January – December 07), the pumps operated for approximately 156 hours, each equating to approximately 228,000 kWh consumption at average lift. The control system cycles the pumps to ensure that they all run for an equivalent number of hours, so 156 running hours per pump per year equates to 1248 pump hours. However electrical bills suggest that between December 2006 and November 2007 there are an estimated 1,462 pump run hours, consuming 301,222 kWh. It was not possible to extract data from the SCADA system going beyond 12 months, to examine this discrepancy further.

Annual running hours are dependent on weather conditions and duty patterns also vary according to the severity of any flooding event. Figure 2.2 shows the duty in a recent flood period (18 – 22 January 2008), and Figure 2.3 shows the typical operating range (on the pump curve) experienced by the submersible pumps.

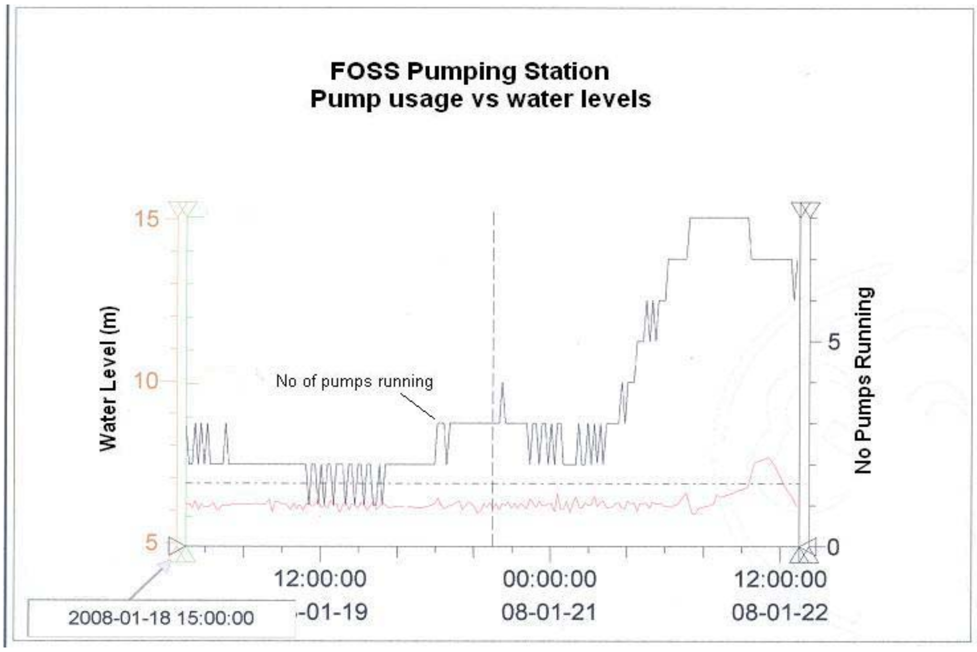


Figure 2.2 Typical duty pattern for submersible pumps at Foss pumping station

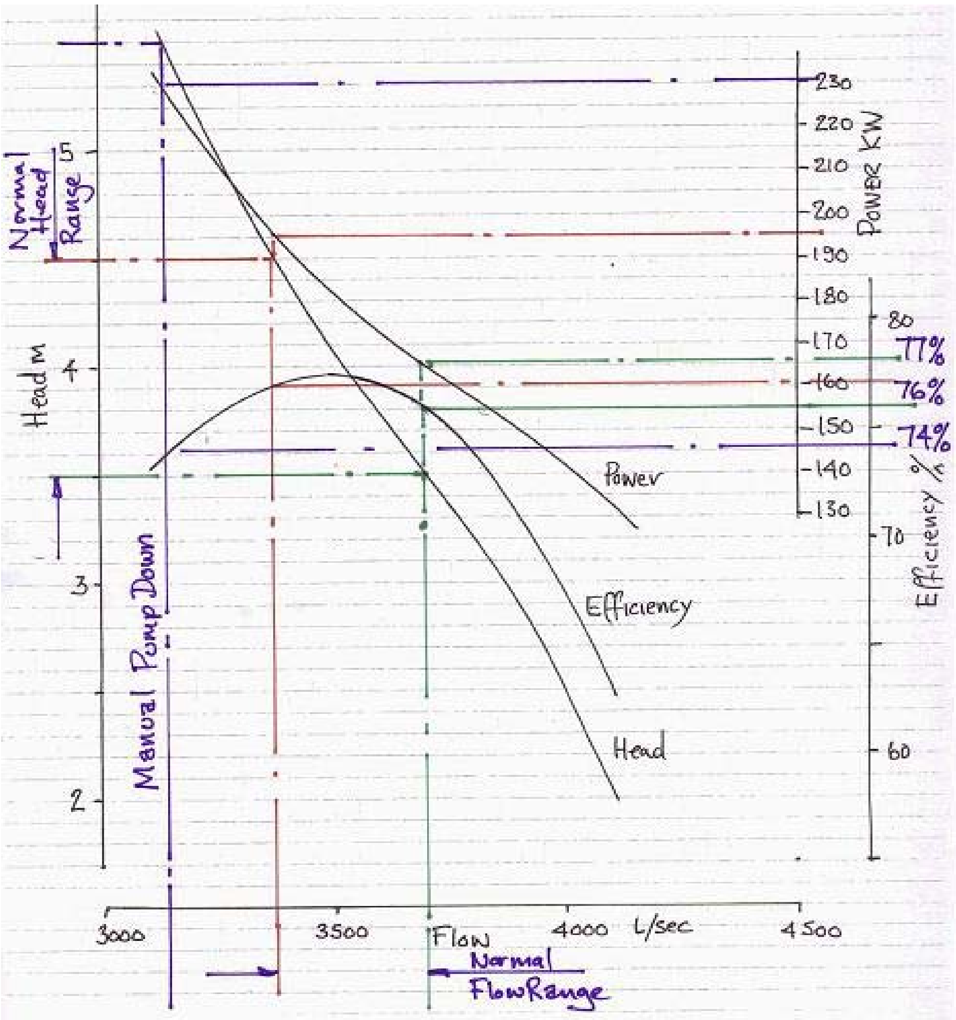


Figure 2.3 Typical operating range experienced by the submersible pumps

During the site visit, we took live readings of pump electrical consumption, when the Foss water levels were approximately 1 m below the typical operational level.

The average pump duty as 3220 l/sec at 5.1 m head, whilst motor absorbed power was 216 kW. The average efficiency of the pumps at this duty is 75%. Extrapolating this to a typical duty where the operating head would be 4.1m, the performance of the pumps becomes 3480 l/sec at 77.5% efficiency.

Considering the pumps as they stand, the main influence on pump efficiency is the variation in levels of the water in the Foss. This causes a corresponding variation in the pumping head. According to the pump curves, these pumps are operating at 76 to 77% efficiency over the normal operating range on this site. However, pump efficiency drops to 74% on manual pump down, as demonstrated in Figure 2.3 above.

The performance of these pumps, in kW per cubic metre of water pumped, therefore ranges from 0.0123 kW/m^3 to 0.0159 kW/m^3.

The number of kW per cubic meter of water pumped continues to reduce as the flow increases, right up to maximum capacity, even though the overall hydraulic efficiency peaks at 3500 l/sec. Therefore, reducing the operating head will reduce the power consumed per unit volume.

We have identified the following possible opportunities to improve the efficiency of the Foss pumping station:

(I). **Reduce the discharge head, and change the pump impeller to accommodate higher flows**

There is a lower penstock opening for each pump approximately 1 m below the current weir overflow level. This was installed to allow the pumps to be run and tested when water levels in the Foss are traditionally low in the summertime. When the Foss barrier is initially lowered, the differential head between the Foss and the discharge level will be low and pumping could start initially through the lower penstock. Due to the reduction in head, this would reduce the power absorbed by about 25 kW (approximately 15%), which would improve the performance to 0.010 kW/m^3 pumped. Between December 2006 and November 2007, an estimated 1,462 pump run hours consumed 301,222 kWh. This 15% saving would save approximately 45,183 kWh, worth £3,162, or 23.63 tCO_2.

In order to make this change, operators will need to ensure the following:
a) There is sufficient capacity in the discharge channel to run more than one pump consecutively without the water in the discharge channel flowing back into the discharge of any non-running pump. This could also be affected by high water levels in the Ouse.
b) As levels in the Foss increase, the differential head across the pump must not be allowed to reduce too far, causing the pump to ‘run out’. Running the pump against too little head would result in cavitation damage to the impeller. In this scenario the pumps could reach 4000 l/sec, which is beyond their best efficiency point.

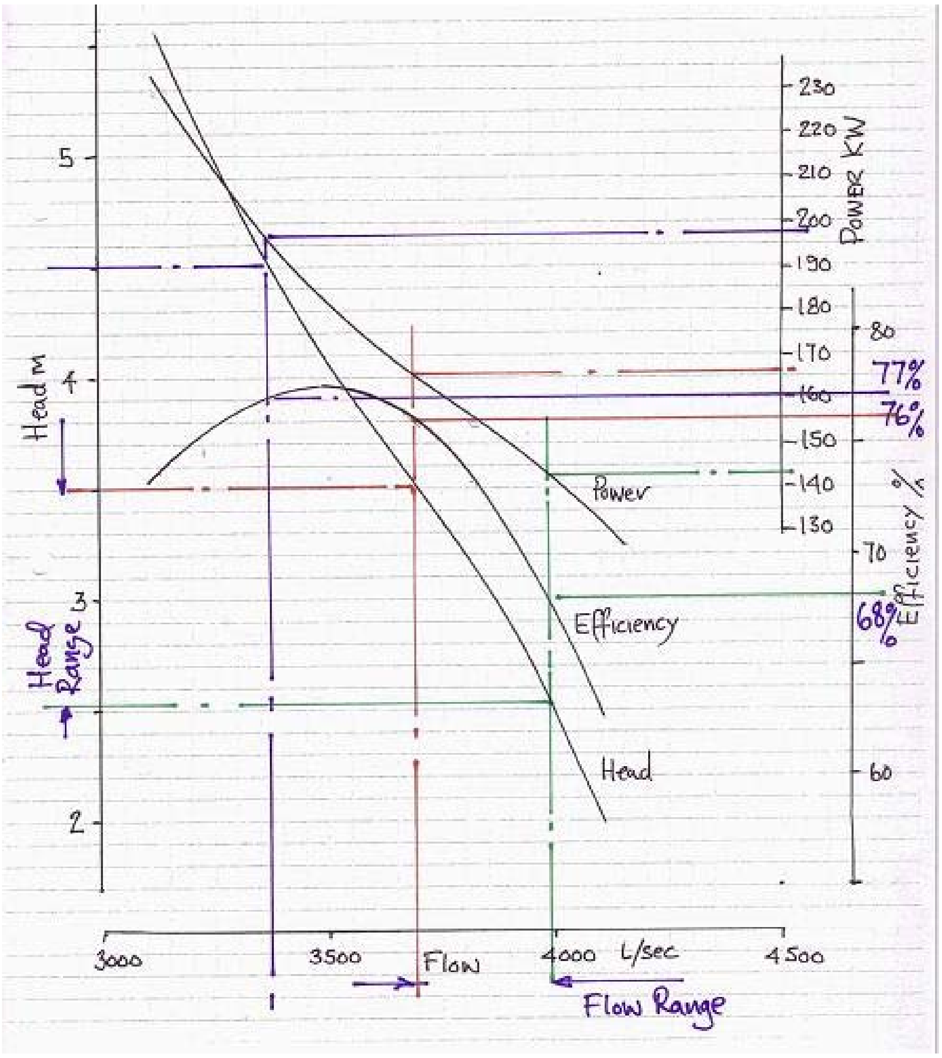


Figure 2.4 Variation in pump efficiency against operating head with lower penstock open

The pump supplier provided the following information:

- The PL 7115 remains a current pump in their range, with only minor hydraulic changes and a revised drive motor.
- There is an impeller suitable for higher flows with an 18 degree blade (this is the largest available). With this blade, at 4000 l/s, the head is a little higher at 2.5 m whilst the required suction head (NPSHr) is 8.9m.
- A reduction in the discharge head must be accompanied by an increase in submersion so there is adequate NPSHre. If the hours run at this condition are less than 250 hours per annum, the NPSH margin may be reduced.
- The cost for a new 18 degree impeller (as a spare part) is £7,871.00. The outer mechanical seal is fixed to the propeller and this would require overhaul and re-lapping or replacement. The seal cost is £3452.43 Seal overhaul and re-lapping costs are approximately £500 and there would be an additional labour cost for this conversion.
- There is an alternative pump, the PL 7121, which performs better at higher flows (see Figure 2.5). It is unlikely to offer any cost benefit, though, as it costs £67,000 compared with £47,000 for the existing model.

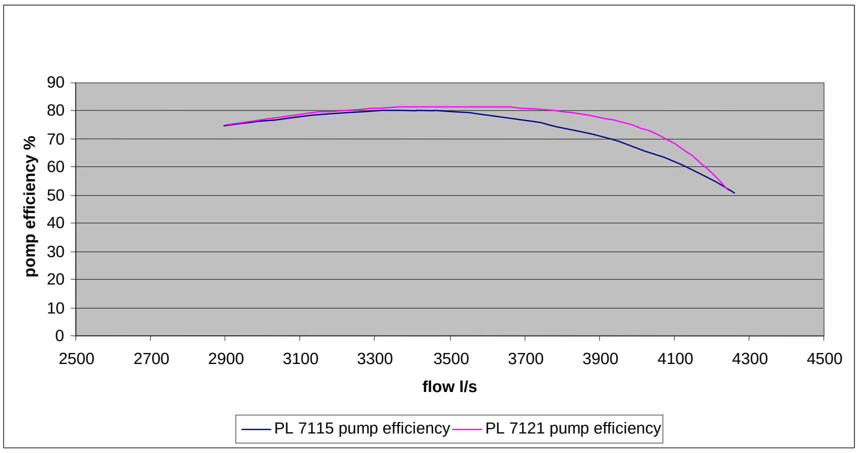


Figure 2.5 Comparison of the performance of two pumps, the PL 7115 currently installed and the alternative, PL7121.

We understand that when all pumps are running, the mains supply transformers are operating at or close to 100% load, so changing to higher kW pumps may also require an electrical upgrade. However, our review of daily electricity consumption for 2007, shown in Figure 2.6, shows that all pumps run together only for very limited periods. If it is possible to synchronise the backup diesel generators with the mains supply, it may be worth considering employing the diesel generators as a supplementary supply during such extreme circumstances.

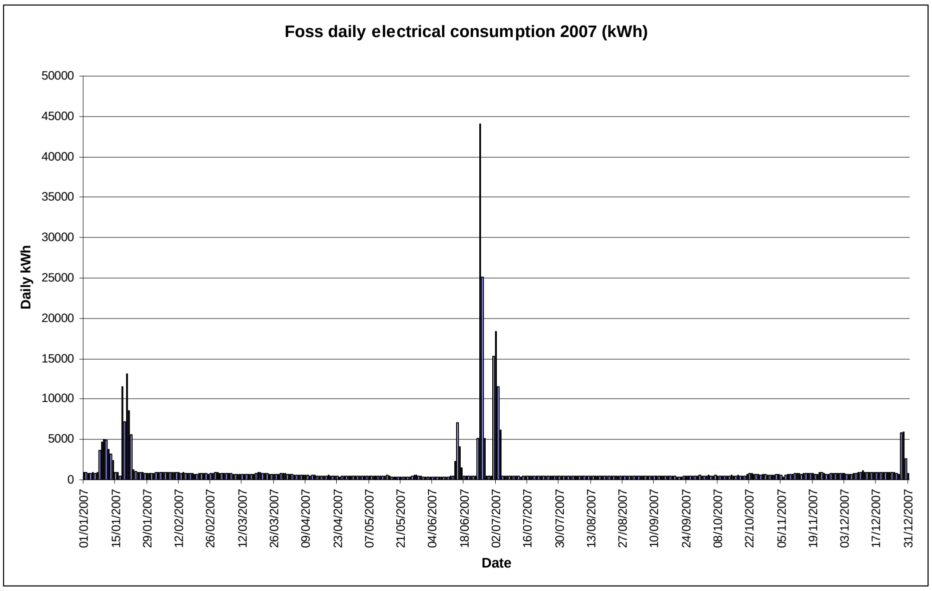


Figure 2.6 Foss daily electricity consumption in 2007 (kWh)

(II). **Reduce discharge head retaining existing impellers**

If the Foss level is controlled between 6.8m and 7.3m whilst pumping through the lower (opened) penstock, the pumps would operate between 3 and 3.5 m discharge head. This would control run out on the pump curve, allowing the existing impellers to be retained. As stated previously it may not be possible to run all eight pumps into the discharge channel when the lower penstock is open and a site test will be required to assess how many pumps can be run in this condition. When manual pump down is carried out to lower the level to 5.8 m, the penstocks should be open. At this low level, the head required from the pumps is 5.5 m and the power 230 kW. With the penstock open this would reduce to 198 kW.

Savings based on 1,462 pump run hours consuming 301,222 kWh between December 2006 and November 2007 equate to an estimated 29,240 kWh, worth £2,046 or 15.3 tCO_2.

(III). **Reduce pumped head by reducing the range of level control while pumping over the existing weir**
Currently in normal operation, the pumps operate at 7.8 AOD and pump down to 6.8m. If the minimum level were increased to 7.3m, then the operating range for the pumps would be from 3.5 to 4 m. This would reduce the maximum draw on the pumps by 15 kW (7.5%) at the lower level. Savings based on 1,462 pump run hours consuming 301,222 kWh between December 2006 and November 2007 equate to an estimated 10,965 kWh, worth £768 or 5.73 tCO_2.

2.4 Other equipment

Diesel generators

Two 1000 kVA (800 kW) Cummins Marine diesel generators (KTA50G1) are maintained for emergency backup purposes should the mains electricity supply fail. Each generator has sufficient capacity to power two pumps. Since their installation in approximately 1988, they have not had to be used, but the risk of mains power failure during flooding remains.

The generators are tested once a month and are run for approximately 30 minutes each. Lead acid batteries provide starting power for the generators and these are maintained on trickle charge. In addition, the generators' lubrication oil and cooling water are continuously preheated to approximately 40^{o}C, by circulating the liquids through external electric heater units regulated by thermostat.

The diesel consumption rate of the KTA50G1 diesel engine is approximately 226 litres per hour at full load. When the generators are tested, under no load conditions, the consumption is estimated at 88 litres per hour. Consequently, the annual diesel consumption due to testing the generators is estimated at 2 x 0.5hrs x 12months x 88lit/hr = 1,056 litres. The annual CO_2 emissions associated with this are 1056lit x 2.63kgCO_2/lit = 2.78 tCO_2.

Information about heat loss and energy consumption due to the oil and water preheating in the engines is not available, although it is likely the heaters will be rated around 1 kW each. In order to determine a realistic consumption value, we recommend a sub-metering exercise ,where the energy consumption of the heaters is logged and tracked against external air temperatures for several days. It would then be possible to extrapolate these results against temperature data and determine a realistic electricity consumption figure.

A conversation with Cummins technical support service revealed that it is feasible to either switch off the heaters when the site operators are confident the risk of flooding is reduced and only preheat prior to routine testing, or to reduce the thermostat set points to a lower temperature, say 20 ^{o}C. In the UK, Cummins do not supply preheating systems as standard on their engines. These options should be further investigated with Cummins or the site's local support agent.

Opportunities to reduce carbon emissions include:

(I). Reduce preheating set point temperature to 20^{o}C.

(II). Change preheating schedule from continuous heating to preheating only in winter or during periods when flooding is likely, such as 24 hours prior to heavy rain forecasts.

(III). Switch from electric heaters to a heat source provided by alternative technology such as heat pump technology.

2.5 Site services

Building and insulation

The ground floor of the building is constructed from a mixture of materials and this includes face brick clad solid concrete walls, concrete floors and roofs for the electrical switch room, transformer rooms and service areas, whilst the upper floor is of brick with a high pitched tiled roof. All windows are single glazed. The control room is separated from the ceiling space by a suspended ceiling insulated with approximately 80 mm of mineral wool laid on the upper side of the suspended ceiling tiles. The four external ground floor doors are of watertight design and manufactured from steel.

During the site visit, when external temperatures were approximately 5^{o}C, it was observed that some of the ceiling tiles in the control room had been broken and there was a large hole (400 x 400 mm) allowing warm air to pass straight up into the roof space. Consequently the heating unit (a 2.8 kW heat pump) was unable to maintain adequate temperatures in the room.

The downstairs access door adjacent to the kitchen was left ajar. Operators advised that this large watertight steel door was too heavy to continually open and close for regular access. Consequently cold draughts were observed in much of the downstairs area. There is an alternative access door to the rear of the building on the upper floor that is of standard design.

Some of the hinged windows in the control window were observed to be poorly fitting with gaps allowing the ingress of cold air.

Opportunities to reduce energy consumption:

(I). In cold weather, close the lower access door and use the upper access door only. In addition fit a draught screen (such as PVC strip curtains) across the door space for incidents when use of this door is necessary. Implement procedures to ensure external doors are kept closed whenever possible.

(II). Repair the damaged ceiling tiles in the control room.

(III). Fit additional insulation above the suspended ceiling in the control room, ensuring a minimum thickness of 300 mm. Increasing roof insulation from 50 mm to 270 mm will typically result in a carbon saving of 250 kg per year (*Energy Saving Trust*).

(IV). Seal the draughts around the windows in the control room.

(V). Consider upgrading the windows to double glazed units. Heat loss is reduced by half through double glazing in comparison to single glazing (*Energy Saving Trust*).

Lighting

External lighting at the pumping station comprises seven external wall mounted units fitted with 70 W sodium lamps and one 250 W sodium floodlight. These are used for security and safety purposes and are controlled by photocell. In addition, there are four 200 W halogen floodlights fitted to the weed cleaner and these are manually switched on only when the weed screen is operational. Given that sodium lamps have high efficiency (>150 lumen/watt) and that the units in question are switched by photocell, no further energy saving recommendations can be made.

Internal lighting is comprised of a mixture of fluorescent lighting units ranging from 1500 mm T12 units with reflectors to recessed luminaries fitted with 900 mm T12 lamps and diffusers in the control room.

Some light fittings such as those in the ground floor hallway have been replaced with 1449 mm T5 high frequency fluorescent lamps, which are the most efficient type of fluorescent lamp available.

Control of all the internal lights is manual and these tend to be turned off when the site is unoccupied. In the motor control room the lighting circuit is linked to the heating controls and consequently the lights remain on continuously when the heating is on.

The estimated electrical load due to the lighting (combined) is shown below:

Table 2.1 Electrical load due to lighting at Foss pumping station

Instantaneous lighting load (kW)			
External			**Internal**
Sodium 1 x 250 W	Sodium 7 x 70 W	Halogen Spotlights 4 x 200 W	Florescent (mixed)
276	581	800	2850

During our survey, we observed that many lights were left on even when rooms were unoccupied. When unoccupied all the internal lights are switched off except for those in the switch room, which are connected to the heating circuit. As occupation of the pump station is erratic, it was not possible to estimate an ‘average’ lighting load. However, analysis of half hourly data suggests the night time lighting load, including security lighting, is approximately 2.0 kW (see Appendix 1).

The ten 1800 mm T8 florescent lamps in the switch room absorb approximately 820 W (82 circuit Watts each). Given that the heating system will be switched on for approximately 4000 hours (6 months) per annum the total energy consumption due to these lights will be 3,280 kWh (equivalent to 1.7 t CO_2).

Opportunities to reduce energy consumption:

(I). Implement a switch-off policy for internal lighting.
See Appendix 1. Assuming 1,040 hours of internal lighting per annum (4 hrs per day for 5 days per week) the annual lighting consumption will be 1,125 kWh per annum. Therefore a 10% reduction in lighting use will realise a saving of 113 kWh (0.059 tCO_2), worth £8.

(II). Separate the heating and lighting circuits in the motor switch room.
Assuming actual demand for lighting in the heating months is 500 hours, the

saving by switching off these lights is 3,500 hrs x 0.82 kW = 2,870 kWh, equivalent to 1.50 tCO_2, worth £201.

(III). Introduce an upgrade policy in the lighting maintenance programme so that all fluorescent lighting units are replaced by their T5 equivalent units as they fail or as part of a regular upgrade programme. A 10% saving on the fluorescent lighting is assumed (some units are already T5). Assuming annual consumption of 1,125 kWh per year, then 112kWh (0.06 tCO_2), worth £14 could be saved. The cost of this measure would be covered by the annual maintenance budget.

Heating and ventilation

The majority of the building is heated by electric heater batteries installed in the ventilation ducts. In addition there are electric panel heaters in the transformer rooms and the generator room. In the control room the heating system was more recently upgraded to a 2.8 kW heat pump unit.

Air temperatures are regulated by thermostats fitted within the ventilation ducts. In the switchgear room, the air temperature is maintained at approximately 18^{o}C to reduce the risk of condensation. It was not possible to determine set point temperatures in other parts of the building. During the survey, the set point on the heat pump unit in the control unit was set at 30^{o}C. This is probably because heat loss through the hole in the ceiling meant the heat pump was struggling to maintain equilibrium in the room.

Table 2.2 Analysis of the previous year's electricity consumption at Foss

Foss average base loads (kWh)	
Winter	62,208
Summer	87,090
Winter heating	64,872
Annual site base load	**214,170**

Electricity consumption figures for December 06 to November 07 are shown in Table 2.2. The data also indicate an average winter heating demand of approximately 18 kW. This seems a little low, when compared against calculations of building heat loss. However, it may be explained by the heating being turned off in some parts of the building, such as the transformer rooms (frost protection panel heater only), passageways and battery room. Also, 2007 was noted as being one of the warmest years on record in the UK, which would have reduced heat loss from the building. We have assumed there is no heating in the summer months.

Opportunities to reduce energy consumption:

(I). Convert from electric heater units in the ventilation system to a heat pump system.
A heat pump is a device that uses refrigeration technology to transfer heat from a source to the space to be heated. It is the same technology as the air conditioning unit used to heat the control room. The Enhanced Capital Allowance Scheme (www.eca.gov.uk/etl) lists various types of heat pump, typically with coefficient of performance (COP) values above 3.2. This means that for every kW of electrical energy supplied, approximately 3.2 kW of heating are delivered. This technology is considerably less carbon intensive than electrical heating and it is widely available. However, there are other

environmental impacts associated with it, due to the refrigerant gases used. There are many variations to the technology, ranging from the popular air sourced versions to ground sourced and water sourced types, some of which achieve COP values well over 4. Given the proximity of the Foss river, a water sourced version should be considered.

When selecting a heat pump, especially air sourced versions, consideration should be given to the COP as external air temperatures drop. Icing of the external condenser unit can reduce the COP and render the unit little more carbon efficient than electric heating. Fortunately the UK does not experience prolonged periods of freezing temperatures and it is likely that over the course of a heating season the heat pump will prove more carbon efficient. The unit's output may however need to be supplemented during extremely cold periods. Ground source heat pumps do not experience this limitation as ground temperatures remain relatively constant throughout the year. The same is true for water sourced heat pumps, to a lesser extent.

Further investigations are recommended to determine which option is most suitable for this site. Assuming an average COP of 3.2 and using the benchmark winter heating demand (5.5 months at 12,974 kWh/month) the annual electrical consumption due to heating will drop from 71,359 kWh to 22,300 kWh, saving 49,059 kWh (equivalent to 25.66 tCO_2).

The indicative cost of a 25 kW multi-split air sourced heat pump comprising one condenser unit and four evaporator units is in the region of £12,000 plus installation costs of approximately £2000.

(II). Convert from electric heater units in the ventilation system to a conventional gas-powered boiler and wet heating system.
This option would offer reduced carbon emissions over electrical heating but will not be as effective as heat pump technology. The indicative cost of a gas boiler of 25-30 kW range is approximately £900. The typical efficiency is in excess of 90%. Installation costs and associated pipework mean the total cost of an appropriate system is in the region of £5000. A gas fired boiler would require connection to the local low pressure gas network and connection costs are in the region of £8,000-£10,000. A specialist gas connection company would be needed to finalise this cost, as it largely depends on the distance and ease of access to the nearest connection. Alternatively an oil-fired boiler could be considered.

(III). Improve insulation through sealing draughts in the control room.

(IV). Better housekeeping practices to prevent heat loss. Only keep doors open when this is essential. We assume that 5% of the energy demand could be saved through keeping the doors closed when not in use.

2.6 Summary and recommendations

The site base load electrical consumption varies from 35.3 kW in winter to 17.28 kW in summer and is due to the control systems, heating, lighting and other services provided at the pump station. The total annual base load is 21,4170 kWh, approximately 42% of the site's overall electrical consumption for 2007.

The annual diesel consumption due to testing the generators is estimated at 1,056 l, emitting 2.8 tonnes CO_2.

A total of 271.5 tonnes of CO_2 was emitted from the Foss pumping station in 2007. Of this, 112 tonnes (42%) were attributable to the electrical base load.

The CO_2 emissions associated with heating the building could be reduced by replacing the existing electrical heating services with heat pump technology, improving insulation in the control room, and better housekeeping practices. It is also worth investigating the possibility of switching off the pre-heating on the standby generators.

There are two types of opportunity associated with the pumps. One is to reduce the discharge head the pumps deliver to, the other is to reduce the differential pumping levels of the water in the river Foss.

To further reduce CO_2 emissions, the fuel powering the diesel pumps could be switched to biodiesel. However, the Environment Agency would have to consider how to manage the degradation of biodiesel when it is stored for long periods.

The energy saving recommendations are summarised in Table 2.3.

Table 2.3 Summary of energy saving recommendations at Foss pumping station. Recommendations in bold type are considered the best options, and only these are included in the total costs and energy/carbon savings in the final row. Using different options relating to heating and pumps may produce a different overall saving.

Recommendations	Estimated annual savings			Estimated cost	Payback period
	(£)	(kWh)	CO_2 (tonnes)	(£)	(years)
Reduce pumped head by reducing span of level control	768	10965	5.7	0	0
or Reduce discharge head retaining existing impellers	**2046**	**29240**	**15.3**	**0**	**0**
or Reduce discharge head, and change pump impeller	3162	45183	23.6	100000	31.62
Convert from electric heating to heat pump technology	**3434**	**49059**	**25.7**	**14000**	**4**
or Convert from electric heating to wet heating and gas boiler	1824	0*	22.6	5000**	2.7
Separate heating and lighting circuits in switchgear room	**201**	**2870**	**1.5**	**250**	**1.24**
Improved housekeeping (switch off lights, close external doors)	**250**	**3567**	**1.87**	**-**	
Seal draughts in control room	**65**	**923**	**0.48**	**100**	**1.55**
Increase insulation above the ceiling above the control room, repair hole.	**30**	**478**	**0.25**	**200**	**7**
Introduce T5 upgrade policy for fluorescent lighting	**14**	**112**	**0.06**	**0**	**0**
Revise diesel generator pre-heating policy	unknown	unknown	unknown		

Recommendations	Estimated annual savings			Estimated cost	Payback period
	(£)	(kWh)	CO_2 (tonnes)	(£)	(years)
TOTALS (best options only)	**6040**	**86249**	**45.2**	**14550**	**2.4**

Notes: *There are no overall savings in kWh used, but still a reduction in CO_2 emissions.

**This price excludes gas connection costs.

3 Crossens (North West)

Site details: Crossens Pumping Station, Banks Road, Southport, PR9 8JG

Contact person: Andy Fitton

Date of site visit: 10 January 2008

3.1 Site overview and function of pumping station

The Crossens pumping station is located to the north of Southport and functions as part of a large land drainage scheme serving an area of 44,000 acres. Three land drainage canals meet at the pumping station. The water from these is lifted, pumped approximately 30 metres under an adjacent road and discharged into the base of a canal which leads out to sea some three miles away. The drainage canals are pumped during the wet season (winter). During the dry season (summer) there are long periods when little pumping occurs and the water from one canal may be re-directed through a series of gates into another to meet demand for agricultural irrigation. The pumps are deployed to maintain constant water levels in the individual drainage canals and this is monitored by ultrasonic level transducers. There are two nominal level settings, one for the wet season and one for the dry season. Water levels in the discharge canal are affected by tidal movements.

The station was originally built in 1961 and the pumps were diesel driven. In the 1990s most of the diesel units were replaced with electric motors and an automatic PLC based control system was installed. Only four pumps remain diesel driven, as a contingency measure against power cuts.

The station is supplied from two 500 kVA 11kV to 400 volt transformers, located in an adjacent building. Power factor correction units maintain a power factor of approximately 0.96.

3.2 Site energy use

The primary energy consumption on site is electrical. Diesel oil is used by four reserve pumps, a diesel generator and the site heating boiler.

During the period from January to December 2007 the total site electrical energy consumption was 1,166,655 kWh, costing a total of £89,754. The average price per kWh is affected by the monthly standing charges of approximately £800, which are necessary to maintain 1000 kVA availability. Figure 3.1 demonstrates the monthly electrical consumption and relative costs.

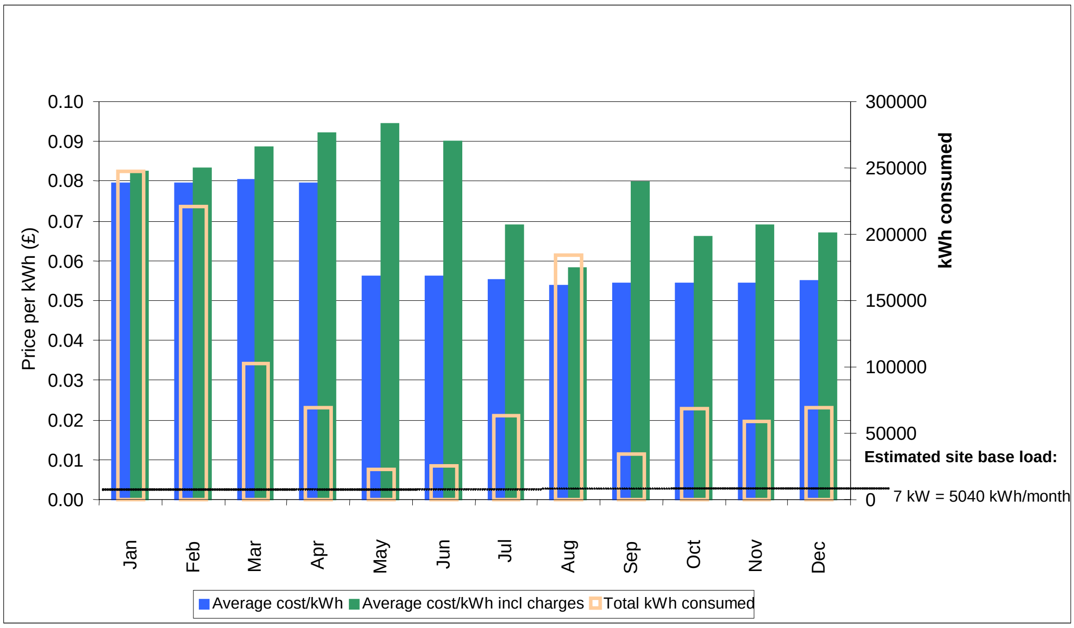


Figure 3.1 Electrical energy consumption and typical monthly costs (£/kWh) at Crossens pumping station in 2007.

The site base load electrical consumption is approximately 7 kW, principally due to the control systems and some limited heating in control panels. The total annual base load is 61,320 kWh, approximately 5.25% of the site's overall electrical consumption for 2007.

Whilst the average electricity cost including standing charges was £0.08 per kWh, for the purpose of energy saving calculations we excluded standing charges and assumed an electricity cost of £0.07/kWh.

The annual diesel oil consumption is estimated at 27,300 litres, worth £12,560 at current prices (£0.46/l) and emitting 71.8 tCO_2.
Approximately 7,300 litres (27%) were attributable to pumping and 20,000 litres (73%) to heating.

The site's combined CO_2 emissions for 2007 were 682 tonnes. Of this 52.7 tonnes (7.7%) were attributable to heating and 32 tonnes (4.7%) to the electrical base load.

3.3 Pumping systems

The pumping systems can be considered as three separate systems according to their water source. The three water sources are:

a) Sluice

b) Back Drain

c) Three Pools.

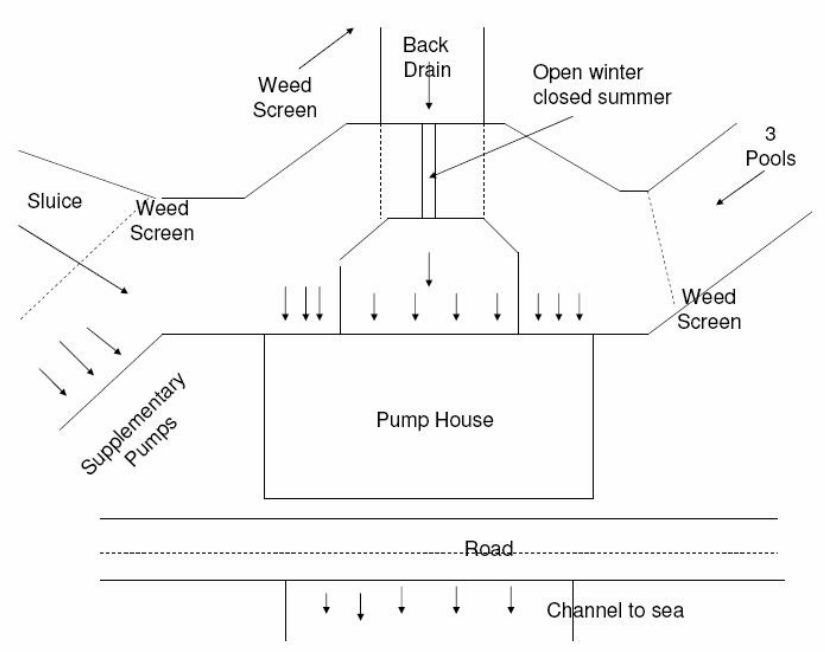


Figure 3.2 Layout of drainage canals at Crossens

The Back Drain is below sea level and below the levels of the Sluice and Three Pools supplies.

The Back Drain supply enters the station through an underground channel that runs beneath a channel connecting the Sluice and Three Pools supplies

During the winter months, the Three Pools source and the Sluice source are connected, as the dividing gate between the two, above the Back Drain, is opened. In summer, the gate is closed as the maintenance levels of the two sources differ.

There is a valved connecting pipe between the Three Pools source and the inner Back Drain basin which can be used to divert water to the Back Drain.

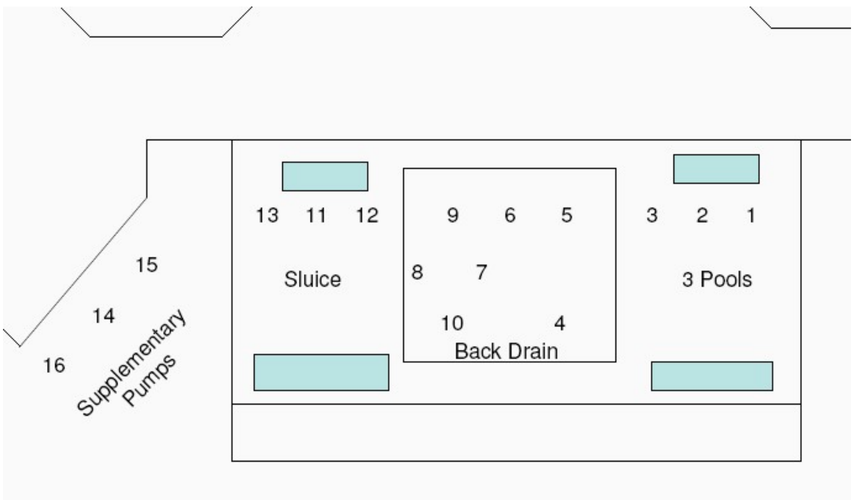


Figure 3.3 Pump arrangement at Crossens

The 16 pumps serving the three water sources are located in separate areas within the station. Most pumps draw water by submerged suction, pumping initially vertically. Then the pipework turns back on itself to drop below the level of the road before entering the channel to the sea. At the highest point in each pumping leg there is a siphon breaker valve to prevent backflow when taking advantage of siphonic assistance. All pumps also have an isolation valve on the discharge side, and most have a discharge pressure gauge immediately after the pump.

Typical operation

The pump controls are designed to allow automatic operation of the electric pumps. The control system is a Bradley PLC, configured to automatically switch the pumps sequentially according to water levels. Level sensing is by ultrasonic transducer.

During periods of high water level (and flooding), an automatic sequence of pump starting (electric pumps only) occurs when water levels in the drain reach pre-determined thresholds. These thresholds change between summer and winter seasons. The diesel pumps are manually started and only run when the electric pumps are at capacity.

Annual running hours and set points are shown in Appendix 2 (Tables A2.3 and A2.4).

Detailed pump analysis

Prior to the site visit there had been considerable rainfall, and 13 of the 16 pumps were running. The remaining three were out of service for maintenance. The volume of rainfall combined with high tide meant that for most of the time when the testing was carried out the pumps were operating against abnormally high heads with a significant amount of water backing up in the channel leading to the sea. With lower suction levels in the summer, the pumps would normally operate at lower heads, reducing energy consumption. Higher heads can be experienced in summer as well, however.

During the site visit, live readings of pump electricity consumption were recorded to establish a benchmark reference (see Appendix 2). Due to the design of the pumping system it was not possible to take actual flow measurements, so the analysis of pump performance is derived from the pump performance curves where available. All pumps were fitted with pressure gauges on the discharge but a review of these throughout the site showed that several were either faulty or their isolation valves seized. We therefore decided not to use this means of assessing pump performance.

3.3.1.1 Sluice pumps

Six pumps service the Sluice canal, three inside the pump station and three outside. These comprise:

Internal pumps. Pump references 11, 12 and 13 are 43 inch vertical spindle Bedford Pumps. Pumps 11 and 12 are electrically driven by 225 kW electric motors and gearboxes at 1489/480 rpm. Pump 13 is diesel driven. All pumps are rated at 2985.3 l/s at 3.81 m, and the gearbox supplier estimates the efficiency of the gearboxes at 98%. These pumps are located in the pump hall and are designated as the sluice pumps.

External pumps. Pump references 14, 15 and 16 are Bedford Pumps type DB 80 10, driven by 110 kW electric motors at 495 rpm. All these pumps are rated at 1500 l/s at

4.94 m. These pumps were added in 1991 and are outside and adjacent to the station. They are designated as the supplementary pumps.

Performance of the internal Sluice pumps

The benchmark measurement showed the Sluice pump duty as 3180 l/s at 3.4 m head, whilst motor absorbed power was 166 kW. The average efficiency of the pumps at this duty is 70%. Extrapolating this to a typical duty where the operating head would be between 2.5 and 4.2m, the performance of the pumps ranges from 3020 to 3440 l/s at between 62 and 74% efficiency, as demonstrated in Figure 3.4.

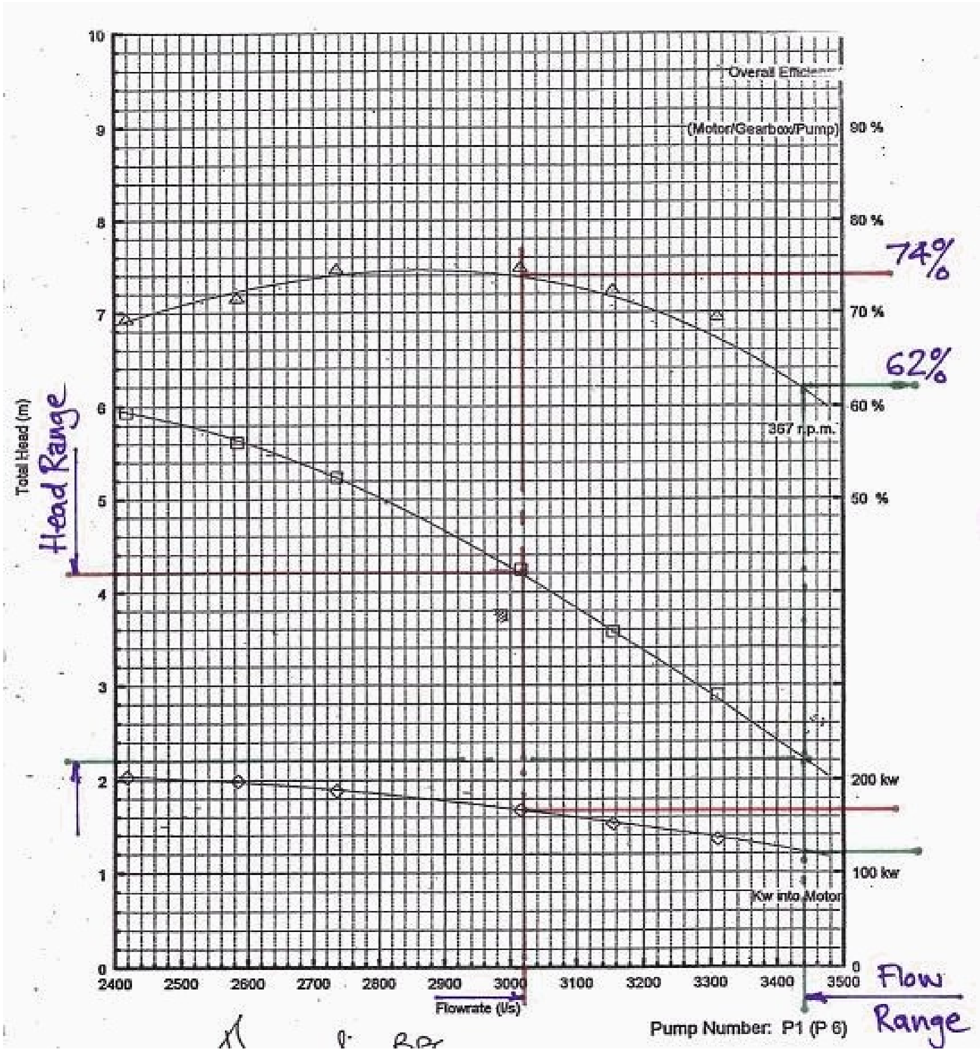


Figure 3.4 Sluice pumps: pump performance curves

Benchmark performance of these pumps ranges from 0.0107 kW/m^3 to 0.0173 kW/m^3.

Performance of the external Sluice (supplementary) pumps

The benchmark measurement showed the supplementary pump duty as 1500 l/s at 5.4 m head, whilst motor absorbed power was 101 kW. Extrapolating this to a typical duty where the operating head would be between 3.1 and 4.8 m, the performance of the pumps ranges from 1560 to 1760 l/s at between 68 and 79% efficiency, as demonstrated in Figure 3.5.

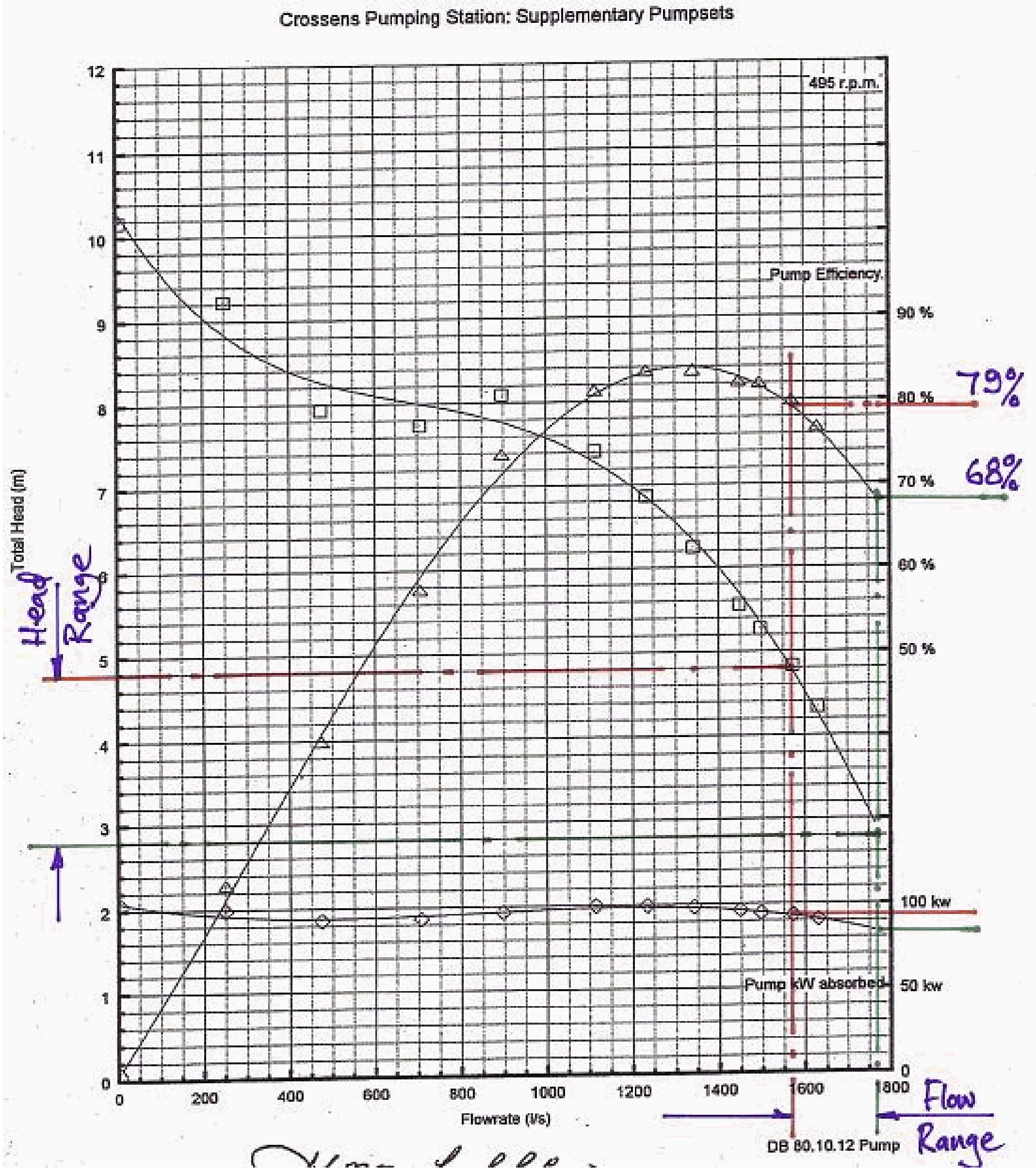


Figure 3.5 Supplementary pumps: pump performance curves

Benchmark performance of these pumps ranges from 0.0140 kW/m^3 to 0.0178kW/m^3 pumped.

Opportunities to improve the efficiency of the Sluice pumps include the following:

(I). Both the supplementary and Sluice pumps feed from the same source and are required to maintain the same levels. The supplementary pumps have a higher hydraulic efficiency over the design lift for the station. Perhaps because they are newer pumps, they run for more hours than the internal Sluice pumps. However the larger internal Sluice pumps deliver more flow per kW and should be selected as the preferred option for routine pumping. In winter, when the Three Pools and Sluice channels are connected, the Three Pools pumps may also be used to advantage before operating the supplementary pumps.

During 2007 the external supplementary pumps ran for a total of 5,288 hours and the internal Sluice pumps a total of 731 hours. The supplementary pumps consumed approximately 475,920 kWh at mean head during this period. If the Sluice pumps had run they would have pumped the same volume in half the time and would have consumed 439,946 kWh at mean head. If the Sluice pumps had been run instead of the supplementary pumps there would have been a saving of approximately 36,000 kWh costing £2,520 and equivalent to 18.8 tCO_2.

3.3.1.2 Back Drain pumps

There are seven pumps servicing the Back Drain canal. They are all located on the lower level of the pump hall and comprise:

Pump references 5, 6 and 9. Bedford Pump model DB 60 09 8 driven by 90 kW electric motors at 741 rpm. Rated for 850 l/s at 7.25 m.

Pump references 7 and 8. Sulzer Pump model BSn 500nl – 24 inch, driven by 75 kW electric motors at 738 rpm. Rated at 850 l/s at 6.98 m when running at 735 rpm.

Pump references 4 and 10 – 24 inch W H Allen Double entry split case, driven by diesel engines. Rated for 848 l/s at 8.63 m. These pumps require assisted priming as they are located above water suction level.

Performance of pumps 5, 6 and 9, the Back Drain Bedford pumps

The benchmark measurement showed the average pump duty as 940 l/s at 6.8 m head, whilst motor absorbed power was 77.4 kW. The average efficiency of the pumps at this duty is 83.5%. Extrapolating this to a typical duty where the operating head would be between 5.2 and 7.4 m, the performance of the pumps ranges from 880 to 1060 l/s at between 82 and 84% efficiency. This is demonstrated in Figure 3.6.

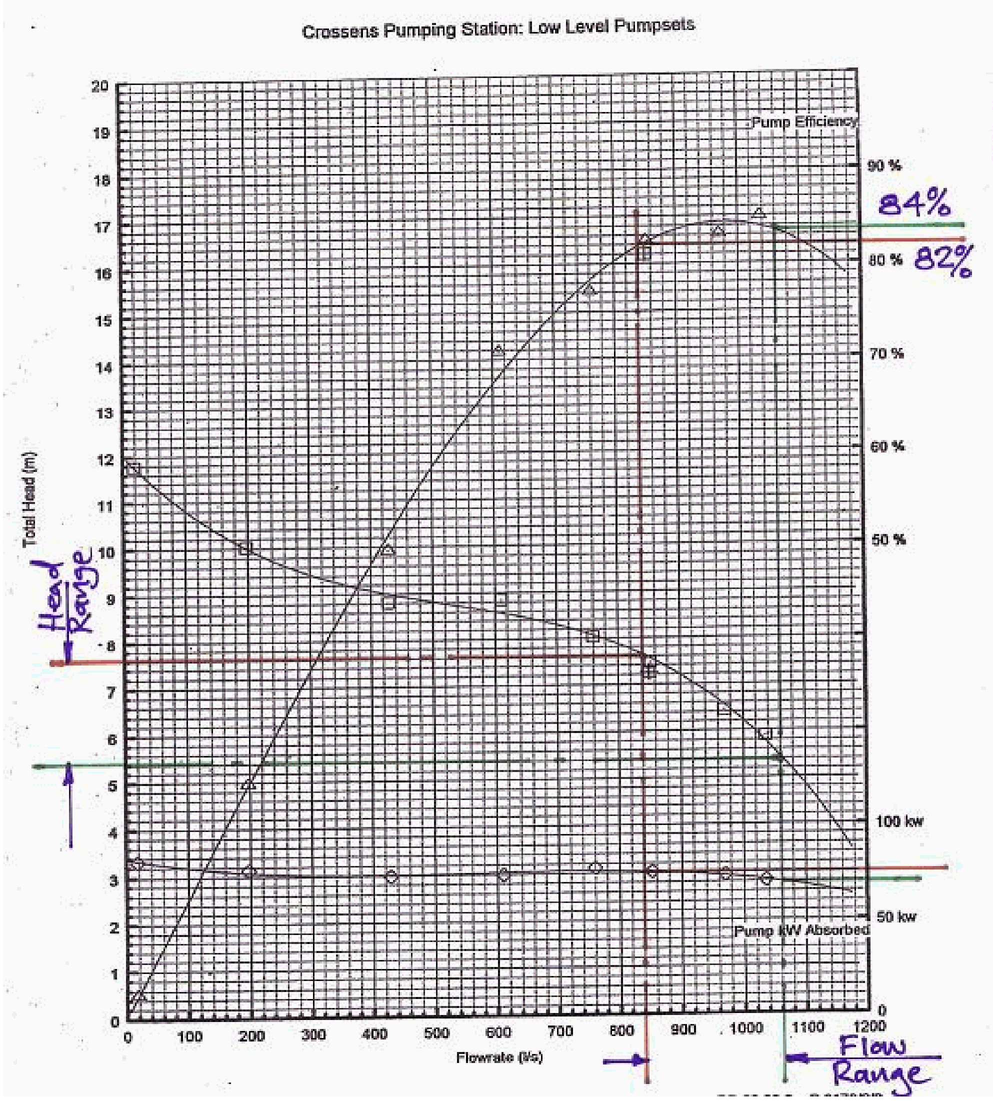


Figure 3.6 Back Drain Bedford pumps: pump performance curves

Benchmark performance of these pumps therefore ranges from 0.0193 kW/m^3 to 0.025 kW/m^3.

Performance of pumps 7 and 8, the Back Drain Sulzer pumps

The benchmark measurement showed the average pump duty as 600 l/s at 8.2 m head whilst motor absorbed power was 77.4 kW. The average efficiency of the pumps at this duty is 76%.

Extrapolating this to a typical duty where the operating head would be between 5.2 m and 7.6 m, the performance of the pumps ranges from 820 to 970 l/s at between 92 and 94% efficiency, and this is demonstrated in Figure 3.7.

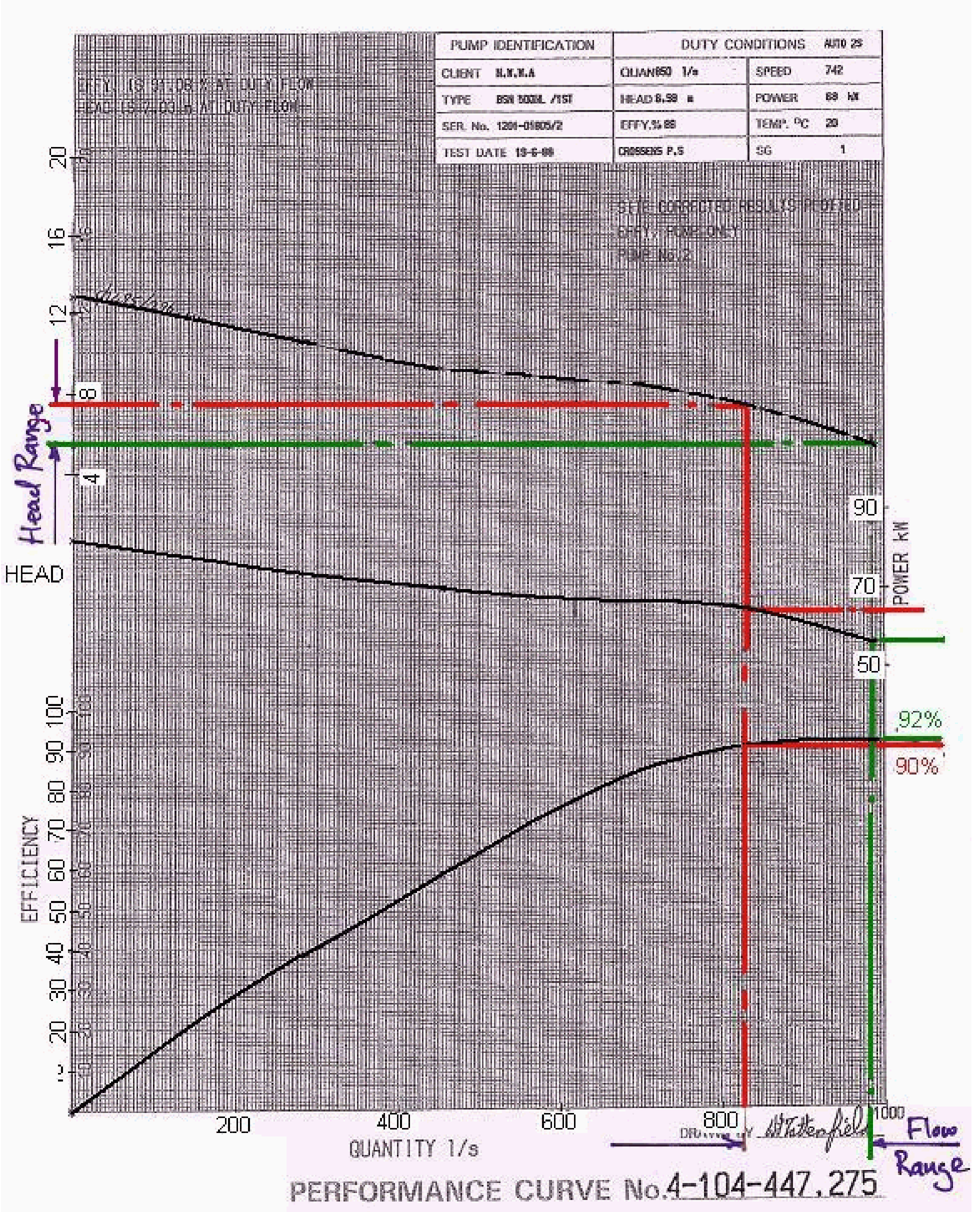


Figure 3.7 Back drain Sulzer pumps: pump performance curves

Benchmark performance of these pumps therefore ranges from 0.0162 kW/m^3 to 0.0225 kW/m^3.

There is an energy saving if the Sulzer pumps are run in favour of the Bedford pumps. During 2007, the Bedford pumps ran for a total of 2,577 hours and consumed approximately 188,121 kWh at mean head during this period. If the Sulzer pumps had run they would have consumed 146,889 kWh at mean head and there would have been a saving of approximately 41,232 kWh, costing £2,886 and equivalent to 21.56 tCO_2.

Performance of pumps 4 and 10, the Back Drain W H Allen pumps

Performance curves are not available for these pumps.

They are double suction split casing pumps. Their specific speed is close to the optimum for efficiency. It is likely that they would be more efficient than the Bedford pumps and as efficient as the Sulzer pumps.

Opportunities to improve the efficiency of the Back Drain pumps include the following:

(I). Run Sulzer pumps in preference to Bedford Pumps.
The Sulzer pumps consume 22% less energy than the Bedford pumps for every cubic metre pumped. Based on 2007 hours if these pumps were favoured against the Bedford pumps there would be a saving of 41232kWh (21.56tCO_2) worth £2886.

(II). Level management:
The lift required by the pumps influences the power they draw. A 10 cm increase in the supply level of the Back Drain would save 112 kWh, based on 3,366 hours of running time in 2007. This saving is small due to the relatively flat power curve of the Sulzer pumps.

3.3.1.3 Three Pools pumps

Three pumps inside the pumping station service the Three Pools canal. They comprise:

Pump references 1, 2 and 3. 43 inch vertical spindle Bedford Pumps. Pumps 1 and 2 are electrically driven through a gearbox by a 225 kW electric motor at 1489/480 rpm. Pump 3 is diesel driven. All pumps are rated at 2985.3 l/s at 3.81 m. These pumps are located in the pump hall.

During the site visit, live readings of pump electrical consumption were recorded to establish a benchmark reference (see Appendix 2). Due to the design of the pumping system it was not possible to take actual flow measurements and so the analysis of pump performance is derived from the pump performance curves.

The benchmark measurement showed the average pump duty as 3000 l/s at 4.2 m head, whilst motor absorbed power was 179 kW. The average efficiency of the pumps at this duty is 74%.

Extrapolating this to a typical duty where the operating head would be between 2.2 and 4.2 m, the performance of the pumps ranges from 3020 to 3440 l/s at between 62 and 74% efficiency. This is derived from Figure 3.4, as these pumps are the same as the Sluice pumps.

Benchmark performance of these pumps therefore ranges from 0.0107 kW/m^3 to 0.0173 kW/m^3.

Opportunities to improve the efficiency of the Three Pools pumps include the following:

(I). Level management:
An increase of the Three Pools suction level by 10cm would save 195 kWh, based on hours run in 2007.

3.3.1.4 Overview of pumping system at Crossens

When all the pumps installed in this station are considered, a further influence on pump efficiency is the variation in levels of the water, and the corresponding variation in pumping head. A 0.1 m increase in supply channel height across all pumps would reduce the pumping energy use by 13,874 kWh per year, based on 2007 pumping activity. This equates to 7.26 tCO_2, and is worth £971.

The pumps discharge into a channel which is unmonitored, but on the basis of readings taken at low and high tide appears to vary by about 1.3 m. Monitoring of the discharge channel and cessation of pumping across the period of high water would make an additional energy saving.

3.4 Other equipment

Diesel generators

There is one 65 kVA diesel generator installed for emergency standby purposes. In the event of an electrical power cut, this generator will be used to power the air compressors which generate compressed air for starting the diesel pump motors. To date this emergency scenario has not occurred. The generator is test run once a month for approximately 15 minutes.

Air compressors

Compressed air is used to for two purposes at Crossens. The first is to operate the water transfer valve between the Three Pools and Back Drain canal, and the second is to start the four diesel generators. These demands are serviced by different compressors.

The water transfer valve is served by a reciprocating Atlas Copco LT5-S compressor unit with 1.8 kW motor and 500 litre receiver. Operating pressure is 230 psi (15.9 bar) and regulation is by pressure switch. The water transfer valve operates in a Fail Closed position, which means compressed air is required to maintain it open. The system was recently tested for air leaks and none of significance were found. In the winter season and periods when the valve is unlikely to be used, the compressor is switched off.

Electrically operated valves tend to consume far less energy than their pneumatically operated counterparts. In this application it is likely that an electric version would consume less than 10% of the energy the pneumatic compressor does. Unfortunately an analysis of this potential saving was not possible, as insufficient data were available to indicate how often or for how long the water transfer valve operates. If these hours are significant, it may be worth investigating replacement of the compressor.

The starting systems for the diesel motors are served by two reciprocating compressors, both Boge SRH-460 units with 4 kW motors. The operating pressure is 250 – 300psi (17 - 20 bar) and regulation is by pressure switch. These compressors are only operated prior to starting the diesel motors.

3.5 Site services

Building and insulation

The pump station comprises a large machine hall measuring approximately 70 m x 14 m with an internal roof height of approximately 9 m. In the centre of the hall is an open basement approximately 22 m x 7 m and approximately 3.5 m deep. The hall is of concrete and brick construction with double glazed windows covering approximately 40% of the wall area down both lengths of the hall. There was no evidence of insulation in the roof. At both ends of the hall are large metal rolling shutter doors measuring approximately 3.5 m x 4 m and 3.5 m x 6 m. There is no insulation associated with these doors and they are not airtight. There may be opportunities to reduce heat loss associated with these doors. Each is fitted with a personnel access door and use of the roller mechanism is rare, especially in the winter months. These doors could be replaced with more modern insulated versions (these contain foam insulation and are airtight). Draught excluders in the form of flexible PVC strip curtains could also be considered.

Assuming that the roller door is stainless steel with a thickness of 5 mm, the direct heat loss over the door's surface area is 2,900 W. Highly insulated roller doors are commercially available with a thermal conductivity (U) value of 0.69, this results in 348 W of heat loss (over a 3.5 m x 6 m door area). The insulated door allows only 11% of the heat loss associated with the traditional roller steel door. The cost of installing a 6 m x 4 m energy saving roller door with a U value of 0.69 would be in the region of £3,250. The overall energy and carbon savings would depend upon temperature levels set inside the pumping hall.

Along the west side of the hall are a reception area, office, canteen, storeroom and toilet facilities. These measure approximately 46 m x 4 m and the windows are double glazed.

Lighting

The main hall is lit by two rows of twelve 250 W sodium floodlights fitted in ceiling mounted luminaries approximately 9 m above floor level. These lamps are manually switched on when the station is occupied. Additional fluorescent lighting services all other internal areas, including the office and kitchen, again manually switched when the station is manned. The fluorescent lights are predominantly T8 with standard 50 Hz ballasts. Some units have been replaced with their more efficient T5 equivalents.

Externally, there are eight 200 W halogen floodlights servicing the weed screen areas and seven 250 W sodium floodlights. Again these lights are only switched on during the hours of darkness when the pump station is occupied.

We recommend implementing a policy to replace fluorescent lighting units with their T5 equivalents when they fail.

Heating and ventilation

The building is heated by a wet heating system comprising a diesel fired boiler, five radiators servicing the office, kitchen, toilet and associated areas and four fan assisted overhead convective heaters in the machine hall.

The boiler is a Riello RL28 rated at 180 – 230 kW with the water output set at 90^{o}C. The rated fuel consumption is 23.43 l diesel oil per hour. Control of the boiler is by water temperature thermostat only. The radiators are fitted with thermostatic radiator valves and during the survey we observed that there was no consistent setting on them. There is no control of the convective heaters and there is no overall control of the heating system. It is manually switched on in late September and runs continuously until the end of March. During the survey, temperatures in the machine hall were approximately 20^{o}C (with most pumps running) and at times the external personnel access doors were left open. On average the boiler consumes approximately 200 gallons per week, at a fuel cost of £0.46 per litre. This costs the Environment Agency £418 per week, and emits 53 tCO_2 in 22 heating weeks every year (see Appendix 2, Table A2.1). With no controls, this heating system is extremely inefficient. More efficient condensing boilers are now available.

The pump station is manned during normal working hours by one or two personnel only. Given the size of the machine hall and the occupancy level, we recommend that alternative methods of providing frost and condensation protection and comfort heating are considered. There are a number of ways to achieve this.

Alternative heating solutions:

(I). (*Best Practice Recommendation*) Install gas fired radiant heaters in strategic locations about the machine hall, ideally above locations where personnel are likely to spend any extended periods of time, such as the motor control panels. The heaters could be switched either by manual switch or by motion detectors. Gas or electric versions are available. The existing boiler could then be replaced by a smaller domestic boiler for servicing the offices, canteen and toilet facilities only.
Infrared radiant heater technology is good practice for heating in large buildings such as the main pumping hall. Kennet pumping station has five electric radiant heaters installed in the workshop building. We recommend installing eight such heaters in the main pumping hall at Crossens. Each electric infrared radiant heater costs approximately £400 for a 4 kW heater that can be ceiling or wall mounted. Timers or sensors would ensure they are only in operation when personnel are undertaking work in the pumping hall. A gas powered radiant heater is more expensive but offers greater carbon savings. A 15 kW gas powered heater retails for approximately £700, and at least four such heaters would be required. Gas connection costs will need to be considered, to determine whether this is a viable option. This is likely to cost in the region of £8,000 to £10,000 and will vary depending upon ease of access to the local gas network.

(II). Investigate opportunities to install heat pump technology in the office, kitchen and associated service areas (and use electric heaters for supplementary heating during periods of extreme cold). For a suitable 5 kW air source heat pump system, the indicative cost would be in the region of £6,000 to £8,000 installed. In the energy saving calculations a 2 kW continuous base load is assumed for this option.

(III). AND fit sump heaters to the diesel engines.
The operators expressed concerns over removal of the fan assisted convective heaters. They currently blow warm air on the diesel engines, which keeps the oil warm and eases starting when the engines are required. Sump heaters will perform the same task and could be controlled such that they are only turned on a few hours prior to starting the engines.

There are insufficient data to perform an accurate calculation of the energy savings due to these measures, as occupancy levels will need to be determined. The energy saving calculations are based on radiant heaters operating for 330 hours per year and a smaller central heating boiler running 3696 hours per year.

If the existing wet heating system is retained, the following improvements could be made:

(IV). Switch boiler fuel from diesel oil to natural gas or biodiesel.
In the case of natural gas this will include replacing the boiler with a higher efficiency condensing boiler. However, the site does not have a gas supply so there would be a connection cost.

(V). Fit an electronic timer and weather compensating controls to the boiler and heating system.

(VI). Fit electronic room thermostats in the machine hall and reduce temperature set points to say 14°C to ensure adequate condensation protection. These controls will be linked to the convection heaters.

(VII). AND install portable or local radiant heaters in strategic positions (see comments under option (I)).

(VIII). Reset thermostatic radiator valves on the radiators.

(IX). We have investigated the option of a biomass boiler as an alternative to the existing boiler. We concluded that efforts should first be made to reduce the building heat loss, before considering a small biomass boiler.

3.6 Summary and recommendations

The site base load electrical consumption is approximately 7 kW and is principally due to the control systems and some limited heating in control panels. The annual base load totals 61,320 kWh, approximately 5.25% of the site's overall electricity consumption for 2007.

The annual diesel oil consumption is estimated at 27,300 litres (73.7 tCO_2). Approximately 7,300 litres (27%) were used for pumping and 20,000 litres (73%) were used for heating.

The site's combined CO_2 emissions for 2007 were 569 tonnes. Of this 54 tonnes (9.5%) were attributable to heating and 26 tonnes (4.6%) were attributable to the electrical base load.

There is a significant opportunity to improve the heating system. Our preferred solution is to replace the existing system with radiant heaters in the main pumping hall fuelled either by gas or electricity, and an air source heat pump for heating the office areas. We selected electric radiant heaters as they are more cost effective and likely to be easier to install. Preheating of the diesel engines could be achieved using electric sump heaters when necessary.

The main energy saving opportunities associated with the pumps are to change scheduling in favour of the most efficient pumps and to reduce the pumping head by raising the set points in the supply drains.

To further reduce CO_2 emissions, the fuel powering the diesel pumps could be switched from fossil based diesel fuel to biodiesel.

Table 3.1 Summary of energy saving recommendations at Crossens pumping station. Recommendations in bold type are considered the best options, and only these are included in the total costs and energy/carbon savings in the final row.

Recommendations	Estimated annual savings			Estimated cost	Payback period
	(£)	(kWh)	CO_2 (tonnes)	(£)	(years)
Sluice Pumps. Run internal Sluice pumps in preference to supplementary pumps	**2520**	**36000**	**18.8**	**0**	**0**

Recommendations	Estimated annual savings			Estimated cost	Payback period
	(£)	(kWh)	CO_2 (tonnes)	(£)	(years)
Back Drain pumps **Run Sulzer Back Drain pumps in preference to Bedford pumps**	**2886**	**41232**	**21.5**	**0**	**0**
Lift all supply channel set point levels by 10cm	**971**	**13874**	**7.3**	**0**	**0**
Install insulated roller shutter doors		11%*		3250	
Install eight fixed or portable infra-red radiant electric heaters with timers and a 5 kW air source heat pump	**7773**	**209000**	**44.6**	**9840**	**1.3**
Install four fixed or portable infra-red radiant gas heaters with timers and a 5 kW air source heat pump	7826	N/A	46.4	9120**	1.2
Overall totals (of best options)	**14150**	**300106**	**92.2**	**9840**	**0.7**

*It is not possible to quantify the heat loss through the existing roller steel door, so energy savings cannot be calculated.

**This excludes gas connection costs.

4 Gronant (Wales)

Site details: Gronant Land Drainage Pumping Station,

Shore Road, Gronant, Prestatyn LL19 9SS

Contact person: Steve Illage

Date of site visit: 9 January 2008

4.1 Site overview and function of pumping station

Gronant pumping station was built in 1961. It is located by the coast outside of the village of Gronant, providing land drainage and flood protection to the village. The pumps installed in the station lift from an open channel which drains the surrounding area stretching along the coast to Prestatyn, and discharge into a small reservoir which flows over a weir into a channel leading to the sea. The reservoir is normally above sea level. At high tide the sea level can rise above the height of the reservoir. Flap gates are located beyond the overspill weir, which close (by water back pressure) for about three hours at high water to prevent backflow from the tide. There is no natural gravity so pumps must operate continuously (although intermittently) to ensure drainage from this low lying area.

The station is unmanned and there are no services.

4.2 Site energy use

All energy used on site is electrical.

The energy billing and electrical consumption data supplied (shown in Figure 4.1) did not reconcile with our estimates of the site's energy consumption due to pumping. Consequently, we assumed these data were not reliable and did not perform associated analyses. We advise locating the correct energy data in order to carry out future analyses.

Analysis of the electrical data supplied for the period from January 2007 through December 2007 showed the total site electrical energy consumption was 24,546 kWh, costing a total of £1,672. Figure 4.1 demonstrates the monthly electrical consumption and relative costs.

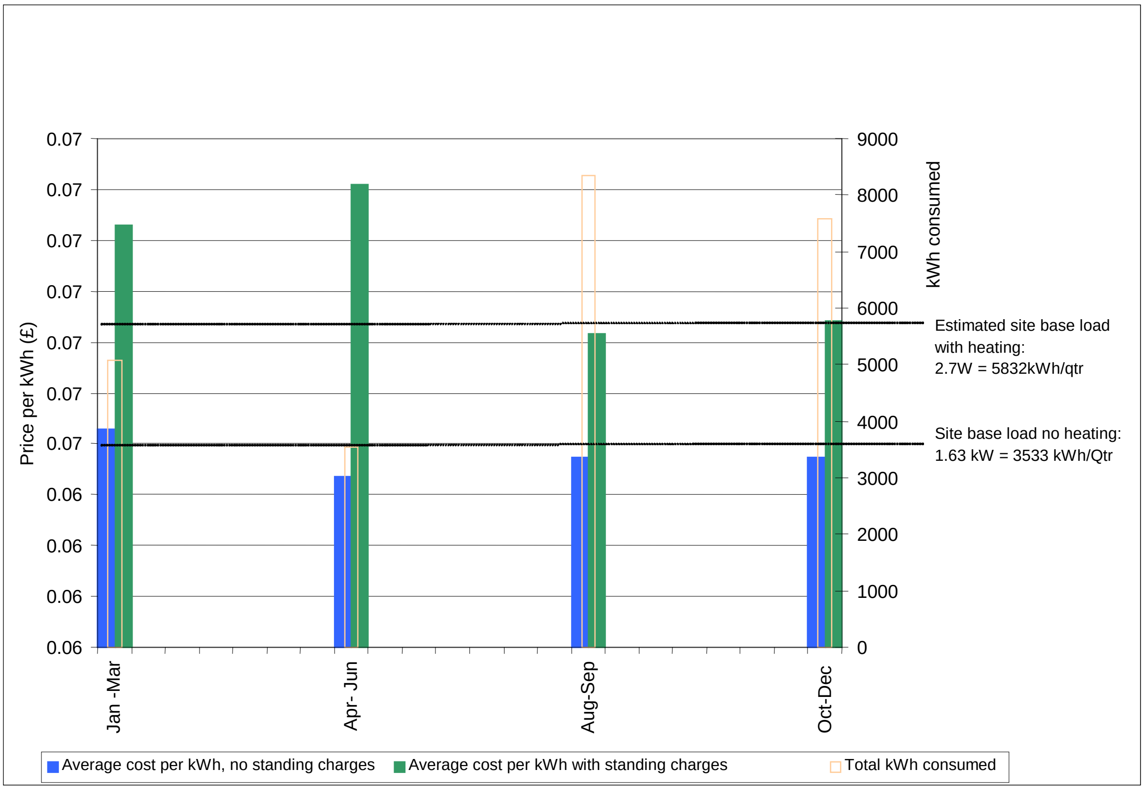


Figure 4.1 Electrical energy consumption and typical monthly costs (£/kWh) supplied for Gronants pumping station in 2007. Our estimates of energy use suggest that these data are inaccurate and not representative of the Gronant pumping station

Readings taken on site suggest the site base load electrical consumption to be in the region of 2.7 kW, which is associated with the frost protection heating and pump controls.

For the purpose of energy saving calculations the standing charges are excluded and an electrical cost of £0.065/kWh is assumed.

During 2007 the overall carbon emissions from the site were 12.84 tCO_2.

4.3 Pumping systems

The channel leading to the station feeds through a weed screen, where it divides into three suction channels providing a discrete monitored suction level for each of the three long shaft, axial flow, 37 kW Allen Gwynne Pumps. We believe these pumps to be rated at 700 l/s at 3.35 m head.

The pumps are driven by 37 kW Brook Crompton electric motors at 743 rpm. The motors were replaced three years ago and at that time high efficiency models were not available. The motors are installed in the main room of the station and are connected to the pump shaft by direct coupling (pin and rubber bush). Each pump extends vertically below the floor level where the pump head is immersed in the flow channel.

Each pump is fitted with a grease pump for its bottom bearing which runs automatically for six minutes before the main pump starts. The grease pump stops when the pump stops. The grease pump is approximately 100 W rated and uses environmentally friendly biodegradable grease which escapes into the pumpage.

The pumps lift the water between 0 and 1 m depending on levels, to a small holding reservoir which overspills a weir into a gravity fed tidal channel.

The holding reservoir can be below high tide level and flap gates hold back the weight of tidal water for about three hours at high tide. The reservoir is reported to have capacity to contain continuous pumping if necessary during this period.

Problems have been reported with the pumps when the gates at the end of the discharge reservoir jam shut due to build up of rubbish. The discharge level then rises and the pumps struggle to prime and overcome the additional head. There can be a large build up of weed in the summer and installation of automatic weed screens is planned.

Typical operation

The pumps are controlled primarily by ultrasonic level control PLC/Relay. Suction and delivery channels are monitored and the level in each of the three split suction channels is measured independently. Channel to pump suction monitoring can detect weed blockage. Prior to installation of the system 18 months ago, weed blockage was a significant problem resulting in pumps running ‘dry’. The pumps operate at 1.215 m suction level and shut off when the level drops to 0.9 m. There is a Lavel Probe Backup system.

Normally to reduce this level will take from 1 to 1.5 hours and pumping will usually start again six to eight hours later, depending on rainfall. In the morning prior to the site visit, the level was timed to drop 0.5 m in 83 minutes with the pump running.

Typically only one pump operates at a time. The control system schedules the pumps to run sequentially.

The reservoir on the discharge side is large enough to accommodate the capacity from the pump if the pump continues to operate during the three hour high water period.

The ultrasonic control system has an internal data logger that can record hours run by each pump

A Secomet power monitor is fitted to the control panel and indicates kW-Amps-Volts-PF for the complete site. The accuracy of the instrument has been called into question and has been considered for upgrade to include internal memory and data download facility. For example, the operator reported a base load of 13 A (8.6 kW), which is much greater than the 2.7 kW reading taken during our site visit.

Detailed pump analysis

Little performance information about the pumps is available, and pump curves were not found. The pumps are Allen Gwynne units with 37 kW motors., they are believed to be rated at 700l/sec at 3.354m. Their serial numbers are 8168Z, 8169Z and 8170Z.

The pumps raise water vertically from the suction channel and the delivery pipework travels over a bend and discharges vertically into the discharge reservoir. The discharge pipe is immersed and therefore has an energy recovery benefit when full from the siphon effect. There is a siphon breaker at the top of the discharge bend to break the siphon once the pump is stopped to prevent backflow.

One pump was run during the visit and readings were taken from the ammeter on the panel and from the Secomet power meter.

These readings were 427 V, 44 A, Power Factor 0.88 and 11.99 kW. At the time, the level in the supply channel was 1.11 m, the level in the pump chamber 1.04 m and the level in the reservoir 2.13 m. It was close to high tide so the outlet gates were shut and the pump was operating close to its maximum lift.

In the morning prior to the visit the pumps were tested with a power meter and the following readings recorded (see Figure A3.1):

Site base load with no pumps running – 2.7 kW (lighting off)
Pump 1 - 28.18 kW excluding base load – 26.3 kW pump only
Pump 2 - 30.2 kW excluding base load – 28.2 kW pump only
Pump 3 - 30.5 kW excluding base load – 28.5 kW pump only

This would indicate that the pumps may be running close to their rated flow, but a performance curve for the pump is needed to make a better evaluation.

Levels were logged during the morning but long term data were not available.

We discussed how it might be possible to assess the flow through these pumps. One method would be to pump into the reservoir at high water with the tidal outlet shut, and measure the rise in level against time. Unfortunately, considering the reservoir profile and vegetation this would only give a very coarse estimate of flow rate. If the outlet reservoir were made from concrete then it might be possible to use a mobile pump to lower the level to a more uniform point before measuring level rise against time. Another option might be to accurately measure the weir and ascertain if it can be calibrated for flow.

Due to the lack of information such as pump performance curves, flow readings and even electrical consumption data (for determining run hours and duty cycles), we were not able to perform detailed analyses of energy use by the pumps at Gronant. We can suggest the following energy saving opportunity, although it is not quantified:

(I). If the pump is operating when the tidal gates are shut at high tide then it will be forced back up its curve by the higher head and will pump inefficiently. It may be possible to include an override that allows the suction level to rise above its normal start level during this period. This should be further investigated and analyses of risk and carbon savings carried out.

4.4 Other equipment

There are no backup diesel generators or air compressors on site.

4.5 Site services

Building and insulation

The pump station comprises a small rectangular concrete base and a brick building measuring approximately 3.5 m x 7 m with an internal roof height of approximately 5 m. There was no evidence of insulation in the concrete flat roof. There are four single-glazed metal frame windows providing light and at one end of the station there is a large uninsulated wooden double door for access.

Below the main hall there is a basement which is accessed through a metal covered hatch to the pump channels, where operators may remove any debris that passes the screens.

The pump shaft stool passes through the floor of the main hall and is protected by a wire grill guard. This and the associated access space allow cold air ingress, rising into the building from the water channels below. There may be an opportunity to replace these guards with a solid plate to reduce the ingress of cold air. A further evaluation of any cooling provided by the grill will be needed.

There are no staff facilities as the building is unmanned and may only be attended for one or two hours a week for inspection, or longer for weed removal in the summer.

Opportunities to improve the efficiency of the pump station include the following:

(I). Replace the pump shaft protection grills with solid covers, to reduce ingress of cold air and reduce the frost protection heating load, in winter time.

Lighting

The station is lit by ten 70 W fluorescent T8 lamps at ceiling level about 4.5 m above the floor. These lights are manually switched on when the station is occupied which is not more than two hours a week.

In the basement there are three 24 V, 60 W (metal filament) bulkhead lights that are turned on if necessary during maintenance and rubbish clearance.

Externally there is one 500 W halogen floodlight above the access door and two 200 W halogen floodlights above the weed screen areas. Again these lights are only switched on during hours of darkness when the pump station is occupied.

Heating and ventilation

The building is heated continuously to protect against frost and condensation, by wall mounted electrical tubular heaters. There are two 5 ft units located at one end of the building and and two 4 ft units located at the opposite end of the building. Their heating capacity is rated at 60 W/ft giving a total capacity of 1080 W. The thermostat is set at 12^{o}C, which was the approximate temperature at the time of the visit.

Cold air ingress through the pump shaft grill guards is likely to result in stratification of heat in the building, with warmer air collecting near the roof.

Due to the lack of electrical consumption data it has not been possible to determine the base load consumption at this site due to heating. We suggest the following opportunity to save energy, but it has not been quantified:

(I). Switch off the space heaters. Fit panel heaters to the motor control switchgear and anti-condensation heaters to the motors as a measure against condensation.

Other opportunities – wind turbine

We recommend installing a micro-wind turbine to supplement the site's base load demand (power to the panel heaters, motor anti-condensation heaters, pump controls and lighting). The site is exposed and known to be windy, as supported by evidence in the Department for Business Enterprise and Regulatory Reform (BERR)'s wind speed database.

A 2.5 kW wind turbine should be suitable to deliver a heat load to the building. Such a device, manufactured by Proven, could be mounted on a mast adjacent to the pump building. The annual energy production would be approximately 4,400 kWh based upon a mean wind speed of 5.1 m/s. The turbine could be grid-connected or use battery storage. As the site is likely to require little heating demand during the summer, the grid-connected option is more appropriate. A range of larger turbine options are listed in Appendix 3 (Table A3.1). The payback periods are not short, but they are reduced with a taller mast.

4.6 Summary and recommendations

The energy billing and electrical consumption data supplied for this site were not satisfactory, so detailed analyses could not be performed. We recommend locating the correct energy data.

Readings taken on site suggested the site base load electrical consumption to be in the region of 2.7 kW, associated with frost protection heating and controls for the pumps.

It was not possible to establish long-term energy consumption due to pumping or to describe duty patterns. In addition no pump performance data are available, including design data (pump design duty points), pump curves and actual performance data. The design of the pump station does not allow easy monitoring of flow rates or volumes of water pumped, which would be necessary to generate pump performance curves from first principles.

As the Gronant pumping station is located on an exposed and windy site there is a good opportunity to utilise wind power to offset the site's energy consumption. A sufficiently large wind turbine could even offset the energy consumption of other pumping stations. The energy savings calculation in Table 4.1 assumes a 2.5 kW unit, but it may be possible to install a significantly larger one.

Table 4.1 Energy saving recommendations for Gronants pumping station

Recommendations	Estimated annual savings			Estimated cost	Payback period
	(£)	(kWh)	CO_2 (tonnes)	(£)	(years)
At high tide minimise operating head by allowing suction levels to rise	Insufficient data to perform analysis				
Replace space heaters with panel heaters in control gear and anti-condensation heaters in motors	Insufficient data to perform analysis				
Install a micro-wind turbine to supplement the site's base load demand (2.5 kW)	460*	4400	2.2	11000	23.9
Overall totals	**285**	**4380**	**2.3**	**11000**	**38.6**

*This annual savings includes the 4p/kWh that can be obtained through selling Renewable Obligation Certificates (ROCs).

5 Thamesmead (Thames)

Site details: Lake Four Pumping Station, Linton Mead, Thamesmead SE28 8DT

Contact person: Bill Reeves

Date of site visit: 25 January 2008

5.1 Site overview and function of pumping station

Part of the Thames anti-flood defences, Lake Four pumping station is unmanned and is one of four stations on interconnecting lakes that pump ground water and run off into the Thames river from the Thamesmead area, much of which is reclaimed land.

The site was built in 1978 and has a 200-year event capacity. A current study suggests that the embankment may have to be raised to cope with water level rises due to global warming.

The station is supplied by two 11 kV to 400V, 1250 kVA transformers.

In addition there is a 37 kVA diesel generator for emergency backup, which would be used to start the diesel driven pumps in the event of a power failure. The current installation does not connect the generator to some of the building utilities, although this will be resolved shortly by a planned upgrade to the electrical control system.

The station is manned for one day a week (currently Fridays) for contractors to carry out routine maintenance.

5.2 Site energy use

The energy types used on site are electricity and diesel.

From January 2007 to December 2007, the total site electricity consumption was 134,018 kWh, costing a total of £14,918. The average price per kWh is affected by the monthly standing charge of approximately £404, which is necessary to maintain 4.8 kVA availability. Figure 5.1 demonstrates the monthly electrical consumption and relative costs.

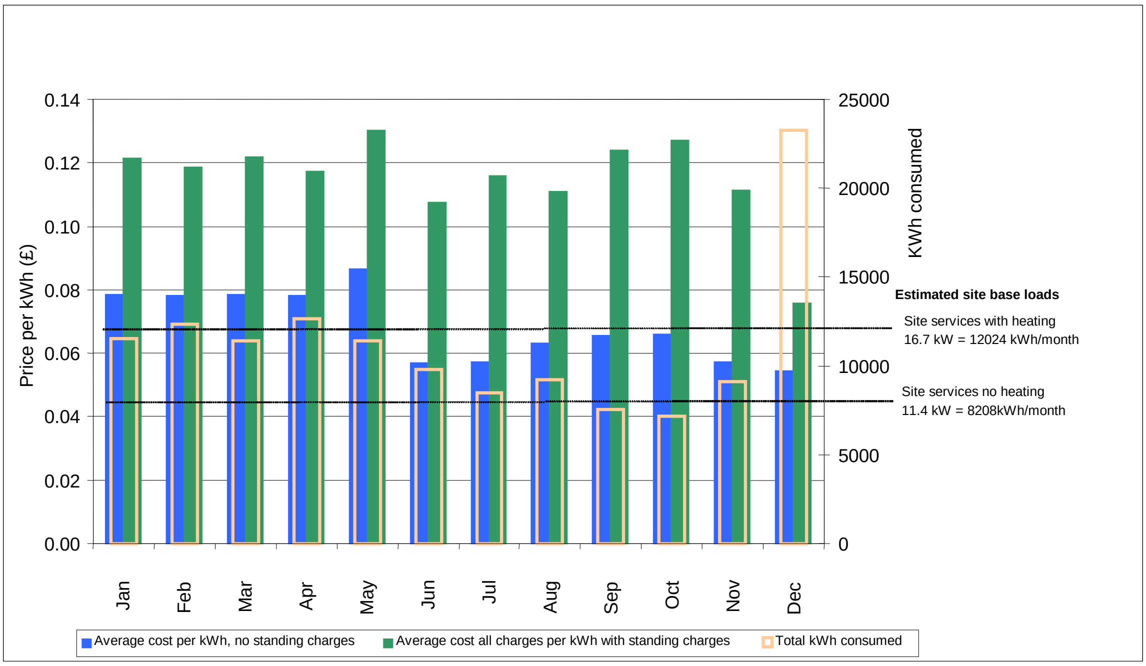


Figure 5.1 Electrical energy consumption and typical monthly costs (£/kWh) in 2007 at Thamesmead Lake Four pumping station

The site base load electrical consumption in 2007 varied between 11.4 kW in summer and 16.7 kW in winter. The total annual base load was 11,900 kWh, approximately 78% of the site's overall electrical consumption (derived from half hourly data).

Whilst the average electricity cost was £0.11 per kWh, for the purpose of energy saving calculations we excluded the standing charges and assumed an electricity cost of £0.063/kWh.

Diesel is used to power two pumps and one standby generator. Consumption during the period from April 2006 through March 2007 was 4350 l, emitting 11.4 tCO_2.

The site's combined annual CO_2 emissions for 2007 were 81.5tCO_2, of which the base load contributed 6.2 tonnes (7.6%).

5.3 Pumping systems

The station has four 2.9 m diameter Archimedes Screw lift pumps supplied by Spaans Babcock, a Dutch manufacturer. They are rated for a nominal 2000 l/s at 8.36 m and run at 25 rpm. The angle of lift is 38 degrees. Each pump draws from the lake through a common weed/debris screen and each has its own individual suction pen.

Two of the pumps (1 and 2) are electric, driven by Mather and Platt 300 kW motors at 1500 rpm. The other two pumps (3 and 4) are driven by Dorman 8QTCW 480 hp diesel engines at 1500 rpm.

The electric motors are fitted with 240 V, 360 W heaters. The temperature measured on the motor end was 23.8^{o}C before running.

The diesel engines are each fitted with 1.5 kW and 2 kW tubular heaters, which maintain the water in the block at 40^{o}C. The temperature output from one heater during the site visit was measured at 30^{o}C.

The diesel engines have remote air blast water cooling with the water pumped to heat exchangers at the end of the building. The pumps and an alternator to drive the fans are contained within the engine, so the diesel consumption accounts for all energy losses.

Output to the screws is delivered via V belt drive (eight belts on the electric powered pumps and ten belts on the diesel powered pumps) to a Spaan gearbox, which is coupled to the screw.

The pumps raise water and discharge into a common channel, which spills over a weir into a short tidal gravity channel. This flows under an adjacent service road and public pathway into the Thames.

One of the diesel pumps suffered a catastrophic bottom bearing failure in March 2001, which went undetected for some time. This resulted in heavy wear to the screw and the concrete channel it runs within. Clearance of approximately 50 mm could be observed compared with the snug fit of the remaining screws.

The pumps are progressively having their plain metal bottom bearings replaced by sealed for life rolling element bearings, to remove the need for grease lubrication and contamination of the water pumped.

The pump running hours are low, and were primarily made up by routine testing. For the period from February to December 2007 Pump 1 ran for 8.6 hrs, Pump 2 ran for 5.2 hrs, Pump 3 ran for 28.3 hrs and Pump 4 for 26.5 hrs.

Typical operation

The pumps run for only a few hours per month and operate on automatic ultrasonic level control (Milltronics Multiranger). In general, Pumps 3 and 4 (diesel) are run in winter, and Pumps 1 and 2 (electric) in summer. Levels are monitored for each suction pen and each pen start trip is progressively higher so that additional pumps are started as levels rise. Normally only one pump runs or two at most. The first pump to run in the summer or winter pairs is set manually on an ad hoc basis, based on the hours each pump has already run. Switchgear and control gear will be replaced shortly with a new and more sophisticated control system that will take away this manual intervention.

The difference between the high and low levels is only about 0.1 m, and each pump would normally run for about half an hour. The maximum accumulated time run by any individual pump in any quarter of 2006-7 was 21.5 hrs.

The pumps discharge over a weir about 8.36 m high into a common channel which discharges over a lower weir into a short tidal channel into the Thames. The common discharge channel has a bypass that can be opened to test the pumps with recirculation back to the lake.

Detailed pump analysis

Data for the screw pumps (2.9m) are not shown in the current Spaans literature,, however a typed page available on site indicated the rated duty of the pumps as 2130 l/sec at 8.36 m with an efficiency of 77%.

Interpolating between published data for 2800 and 3000 mm screws, the rated flow should be 1980 l/s at up to 10.3 m maximum lift.

Spaans publishes a pump maximum efficiency of 75% over a submergence range from filling point to centre of screw, which would cover the current installation. It is not clear whether this efficiency is for the pump alone or includes belts and gearbox.

Bill Reeves (site MEICA engineer) carried out a top channel fill test on the pumps in 2007 and recorded estimated flows of 1800l/s at 8.36 m for pumps 1, 2 and 3 and 720 l/s at 8.36 m for pump 4, with the damaged screw.

A site test of one of the electric pumps showed the pump train absorbing 220 kW.

Allowing for motor efficiency of 96%, gearbox efficiency of 97% and belt drive efficiency of 97%, the drive train efficiency is 90% (=0.96 x 0.97 x 0.97). If the flow is assumed as 1980 l/s, the hydraulic efficiency of the pump alone is 84%. If the flow is assumed as 1800 l/s, as measured in the fill test, the pump hydraulic efficiency is 74%.

The outlet from the station is discharged over a weir and it may be possible to calibrate the weir and use this to monitor any future deterioration in performance. This may not be necessary, however, as the pumps are relatively efficient and their operation cannot easily be modified.

Table 5.1 Pump run hours for 2006-2007 at Thamesmead Lake Four

	Pump 1 Electric (hrs)	Pump 2 Electric (hrs)	Pump 3 Diesel (hrs)	Pump 4 Diesel (hrs)
January-March	0.8	0.5	12	21.5
April-June	2.1	2.4	5	6.5
July-September	0	0	0	0
October-December	0.9	2.6	10.5	6.5
Total	3.8	5.5	28.5	34.5

It is clear that running Pump 4 with the damaged screw should be avoided where possible. Yet in the period 2006-7, this pump had the highest running hours (see Table 5.1). During the site visit, Pump 4 was scheduled to run due to a problem with Pump 3’s diesel engine. We understand that it was considered uneconomic to repair this pump, given the installation and the damage to the concrete housing. The high hours on Pump 4 may also reflect the fact that this pump is slow and takes longer to reduce the lake level.

A decision must be made regarding the future use of this pump. However, the pumps at Thamesmead Lake Four are not the major site energy users. The initial priority should be management of site services.

Benchmark performance of these pumps is 0.031 kW/m^3 pumped.

5.4 Other equipment

Diesel generators

There is one 37 kVA diesel generator installed for emergency standby purposes. In the event of a mains electrical power failure, this generator will be used to power the air compressors, which will generate compressed air to start the diesel pump motors. The generator is run once a month for approximately 30 minutes for test purposes.

Air compressors

Compressed air is used to start the two diesel engines on Pumps 3 and 4.

There are two Worthington Simpson reciprocating compressors with 15 kW motors set to deliver compressed air at 10 bar. The compressed air is stored in three receivers. The compressor controls are continuously powered and regulated by pressure switch. The site engineer estimates that air leaks are low and the compressors only run for approximately one hour per week to maintain the set point pressure.

There is a small energy saving opportunity in powering down the compressors and only enabling them prior to starting the pumps.

5.5 Site services

Building and insulation

The pump station comprises a large machine hall measuring approximately 25 m x 12 m with an internal roof height of approximately 12 m.

The building is primarily of brick construction, with a concrete floor and external aluminium cladding. The roof is flat concrete with an asphalted, watertight finish.

Entry is through a personnel door in a larger metal roller shutter door, which is kept shut. Entry is at the level of the generator and compressor room. Stairs lead up to an access point to a small room used as a store and to monitor the fuel tanks, then carry on up to the main equipment and control hall.

There is a large bank of windows on the south of the building overlooking the lake, and a glazed access door and small length of glass observation panelling on the north side, overlooking the discharge channel. All the glass is single glazed. Two lengths of angled glass panels run the full length of the roof on either side.

Along the east side of the equipment hall there is an office, canteen and toilet facilities, and on the west side of the hall is a small meeting room, which is also used to store site records.

Lighting

The main hall is lit by 12 MBX 70 W, 80 mm pressurised mercury floodlights, fitted in ceiling mounted luminaries approximately 9 m above floor level.

Two of these are left on continuously for security purposes and the remainder are manually switched on when the station is occupied in the hours of darkness. The glass roof panelling allows natural light in and during the site visit it was not necessary to turn on additional lights. Power consumption due to the security lighting is estimated as 160W, or 1400 kWh per year.

There are also six 40 W fluorescent lights servicing all other internal areas including the office and kitchen. Again, these lights are manually switched when the station is manned. These fluorescent lights are predominantly T8 type, with standard 50 Hz ballasts. However some units have been replaced with their T5 equivalents.

Externally there are four 250 W halogen floodlights servicing the entrance door and the path to the pump suction pen area. There are also a number of small lights on the railings alongside the fuel tank observation area. The external lights are only switched on during the hours of darkness when the pump station is occupied.

Heating and ventilation

The building is heated by four 6 kW wall-mounted fan heaters in each corner of the building. Each of these has its own thermostat. At the time of the visit these were set at 22^{o}C and the machine hall measured a comfortable 17^{o}C. An initial check of the temperature in the roof space showed that it was 1.5^{o}C above that at floor level.

There are small convection heaters in the meeting room and in the office, an electric wall tube heater in the toilet area and a wall mounted fan heater in the canteen. All of these draw approximately 1 kW each.

On arrival, the heater in the office area was turned up high, probably since the last contractor occupation.

There is a small electric 1 kW boiler under the sink in the canteen, which was switched off.

Half hourly data shows that the site heating base load is 5.3 kW, of a total winter base load of 16.7 kW and total summer base load of 11.4kW.

There are eight louvers in the ceiling, which are used for ventilation in the summer. We believe that four are opened to let air in and four are used for extraction. Fitted to these are 3 kW fans, which when operated created significant air movement.

Opportunities to improve the efficiency of the pump station through management of the site services include:

(I). Turn the heating thermostats down to maintain anti-condensation levels (between 5^{o}C and 12^{o}C) (and isolate from interference). Since the control panels, motors and diesel engines are all fitted with individual heaters, these can all be turned down. We calculate that the heating base load could be reduced from 5.3 kW to approximately 1 kW.

Table 5.2 Savings from reducing the heating base load at Thamesmead

	Heating load kW	Annual hours	Annual consumption (kWh)	Electricity cost (£/kWh)	Operating cost (£)	CO_2 emissions (tonnes)
Current	5.3	3600	19080	0.063	1202.04	9.98
Proposed	1	3600	3600	0.063	226.8	1.88
Saving			15480		975.24	8.10

(II). Review security lighting arrangements. Leaving lights on continuously is not recommended. There are a number of alternative options to consider:
a) The mercury lights in the hall could be replaced by higher efficiency T5 fluorescent units. Two of these may then be designated for security lighting (this will decrease the load from 160 W to 108 W) and switched on either by timer or external light sensors.
b) Fluorescent lamps (T5) controlled by external light sensors and motion detectors (PIR) could be deployed to switch on in the event of an intrusion.

Table 5.3 Potential savings from altered lighting arrangements at Thamesmead

Lamp type	Qty	Circuit load (watts)	Annual hours	Annual power consumption (kWh)	Electricity price (£)	Operating cost (£)	CO_2 emissions (tonnes)
70 W mercury	2	80	8760	700.8	0.063	44.15	0.37
49 W T5 fluorescent	2	54	1752	94.6	0.063	5.96	0.05
Savings				606.2		38.2	0.32

(III). Consider isolating the roof fans and assess whether the use of louvers alone will provide adequate cooling in summer. There were insufficient data available to perform an analysis of the savings potential of this action.

5.6 Summary and recommendations

The site base load electrical consumption in 2007 varied from 11.4 kW in summer to 16.7 kW in winter, with an annual total of 11,900 kWh. Base load was approximately 78% of the site's overall electrical consumption (from half hourly data). Whilst there are some limited services on site, this site is unmanned so these are little used. However, some lighting is left on continuously for security reasons.

There is an opportunity to upgrade the security lighting and fit better controls.

The pumps are rarely used and no recommendations are made apart from avoiding the use of Pump 4, which is damaged and runs less efficiently.

From an economic perspective, the electrical availability charge for this site is high relative to actual electricity use. There may be ways to mitigate the long term costs of this, such as disconnecting the electrically powered pumps from the grid supply and powering them from diesel engines or diesel generators running on biodiesel. We have not presented an analysis of this option.

Table 5.4 Energy saving recommendations for Thamesmead Lake Four pumping station

Recommendations	Estimated annual savings			Estimated cost	Payback period
	(£)	(kWh)	CO_2 (tonnes)	(£)	(years)
Avoid running Pump 4 until repaired	No analysis performed				
Turn down heating set points to 5^{o}C	975	15480	8.1	0	0
Fit dedicated internal security lighting with motion sensors	38	606	0.3	350	10
Overall totals	**1013**	**16086**	**8.4**	**350**	**2.9**

6 Union (Southern)

Site details: Union Pumping Station, East Guildford, Rye, East Sussex, TN31 7PH

Contact person: Neil Terry

Date of site visit: 29 January 2008

6.1 Site overview and function of pumping station

The Union pumping station was built in 1969 and is located just outside Rye. It forms part of a drainage system serving 16,480 acres of land in the Rother Area. The pumps lift water from a drainage canal and discharge it into a channel that flows into the sea about two miles away. The channel has gates further downstream, which can be closed if the tide is excessively high.

To assist local farming and irrigation the supply ditches are kept as high as possible in summer and as low as possible in winter.

The station and is served by an 11kV to 400V, 500 KVA transformer.

6.2 Site energy use

All energy consumed on site is electrical.

During the period from January 2007 to December 2007, the total site electrical energy consumption was 186,384 kWh, costing a total of £24,054. The average price per kWh is affected by monthly standing charges of approximately £950, which are necessary to maintain 500 kVA availability. Figure 6.1 demonstrates the monthly electrical consumption and relative costs.

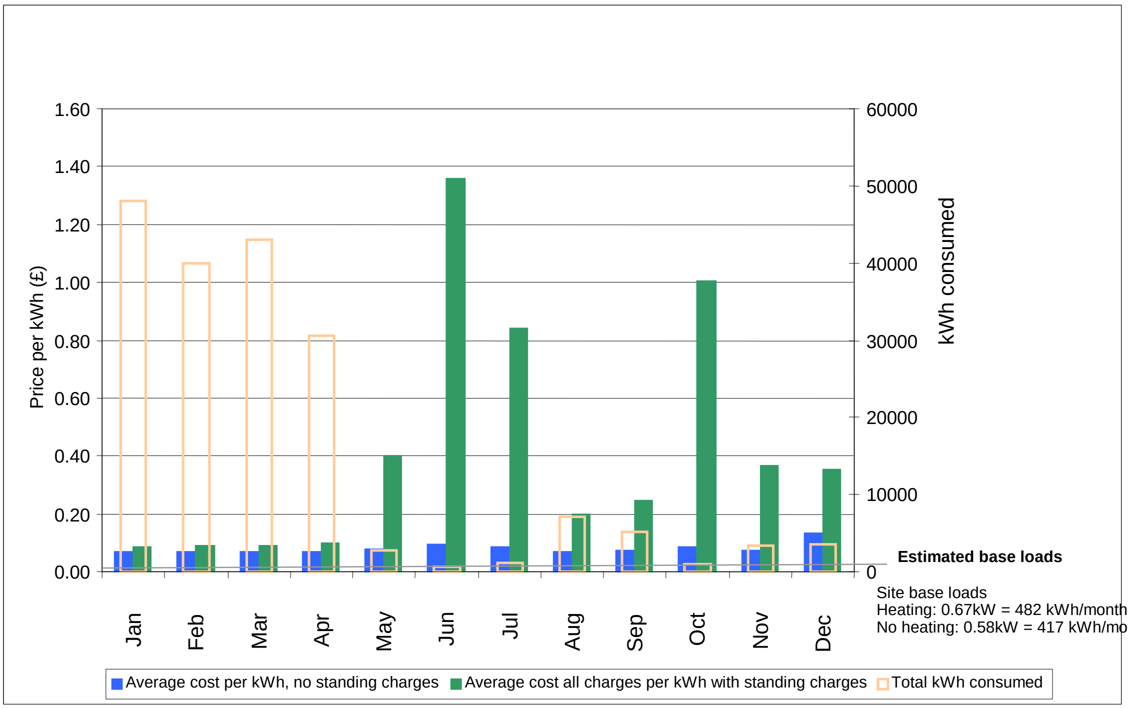


Figure 6.1 Site electrical energy consumption and typical monthly costs at Union pumping station in 2007 (£/kWh)

The site base load electrical consumption varied between 0.58 kW in summer and 0.67 kW in winter. The total annual base load was 5,400 kWh, approximately 2.9% of the site's overall electrical consumption.

Whilst the average electricity cost was £0.13 per kWh, for the purpose of energy saving calculations the standing charges were excluded and we assumed an electricity cost of £0.068/kWh.

The site's overall CO_2 emissions for 2007 totalled 97.5 tonnes, of which the base load contributed 2.8 tonnes (7.63%).

6.3 Pumping systems

The channel leading to the station feeds through a weed screen where it is divided into three penstocks that feed the pumps. The differential level across the weed screen is monitored to provide automatic activation of an electric weed screen cleaner if the screen becomes blocked during pumping.

There are three Long Shaft, Axial Flow Pumps.

Two of the pumps are 220 hp Allen Gwynne Pumps, model 42/40/VS (Drg 67/2895), rated at 100 cusecs[2] (2.83 m^3/sec), with the impeller at a 14.5° Tip Angle (Drg No 67/3002).

The remaining, smaller, pump is a 115 hp Allen Gwynne Pump (model 27/24.5/VS, Drg No 67/3014, impeller 24° angle, Drg No 68/1501), rated at 50 cusecs (1.416 m^3/sec).

The pumps are driven by Laurence Scott electric motors. Two are 165 kW rated, running at 365 rpm. The other is rated 86.25 kW, running at 585rpm. The motors are

[2] 1 cusec = 28.317 litres/sec

connected to the pump shaft by rubber cush drive couplings. The motors are outside and sit on the roof of the pump house. The pumps pass through the station below, supported at floor level. The pumps and motors are due for refurbishment and have not been looked at for the past six years at least.

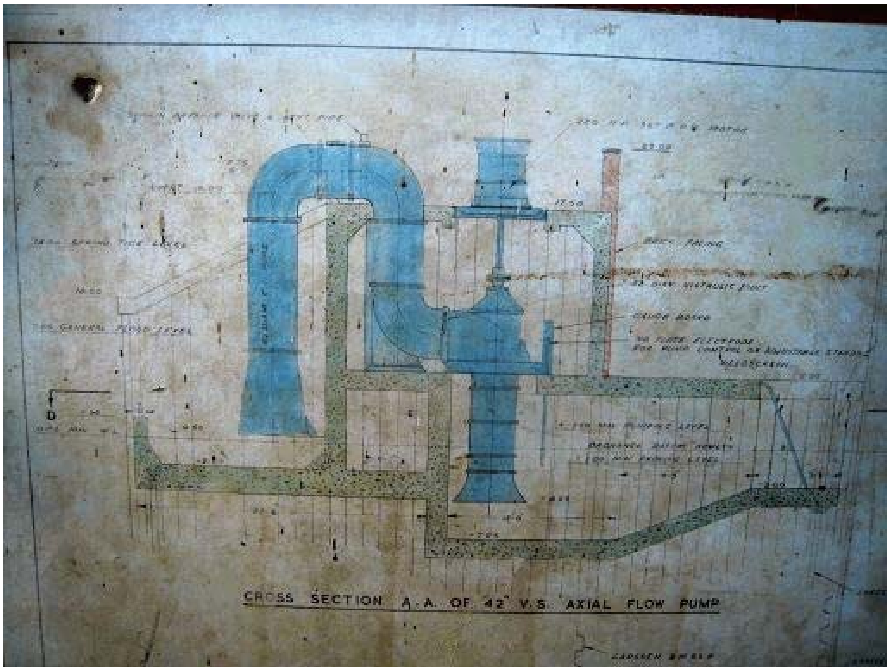


Figure 6.2 Diagram showing layout of the pump and pipework detail

Each pump is fitted with a grease pump for its bottom bearing, which runs and stops at the same time as the pump. The grease pump is rated 0.5 A (approximately 100 W).

The pumps are normally required to lift across a level differential of between 0 and 2.9 m (at flood level). The maximum spring tide could push the head required to 4.25 m. The pumps lift the water through pipework, which raises it (to a maximum height of) 5.5m before dropping into the discharge channel. The discharge outlet is submerged to benefit from siphonic gain and the top of the pipework is fitted with a siphon breaker to prevent backflow.

Typical operation

The pumps are controlled by a Hydroranger Miltronics control system, with ultrasonic sensors that use low and high level warning limits and inhibits to maintain summer and winter levels.

Normal high and low set points are 0.5 m and 0 m AOD. On arrival at the site, one pump was operating and subsequently shut off at 0 m AOD. This is 0.3 m above the minimum designed suction level for these pumps.

If only one pump is required to run, the smaller pump is operated. In the event of flooding, the two larger pumps are run. All three rarely run together.

Operating hours for each pump are recorded weekly in a log on site, but this is not consolidated. Old site records showed that for 12 months in 2004-5, the small pump ran for 521 hours in total and the larger pumps for just five hours each.

Detailed pump analysis

During the site visit, live readings of pump electrical consumption were recorded, to establish a benchmark reference for each pump. Prior to the visit, the three pumps had been run together and a total power reading was also recorded. Due to the design of the pumping system, it was not possible to take actual flow measurements so analysis of pump performance would have to be derived from pump performance curves. Unfortunately, performance curves are not available for these pumps, either in the site files or within the pump industry. The original site plans showed gauge boards fitted but these are no longer installed.

Our visit to this site occurred just after low tide, so the head required by the pumps was at its lowest. The suction level was at 0 m AOD and the discharge level at 0.5 m AOD.

A review of electrical data for the site (Figure 6.3) shows that during 2007, the daily maximum was 5,163 kWh, which is when one large and one small pump were running virtually continuously. These data also indicate that the large units are called on to pump for less than 30 days a year.

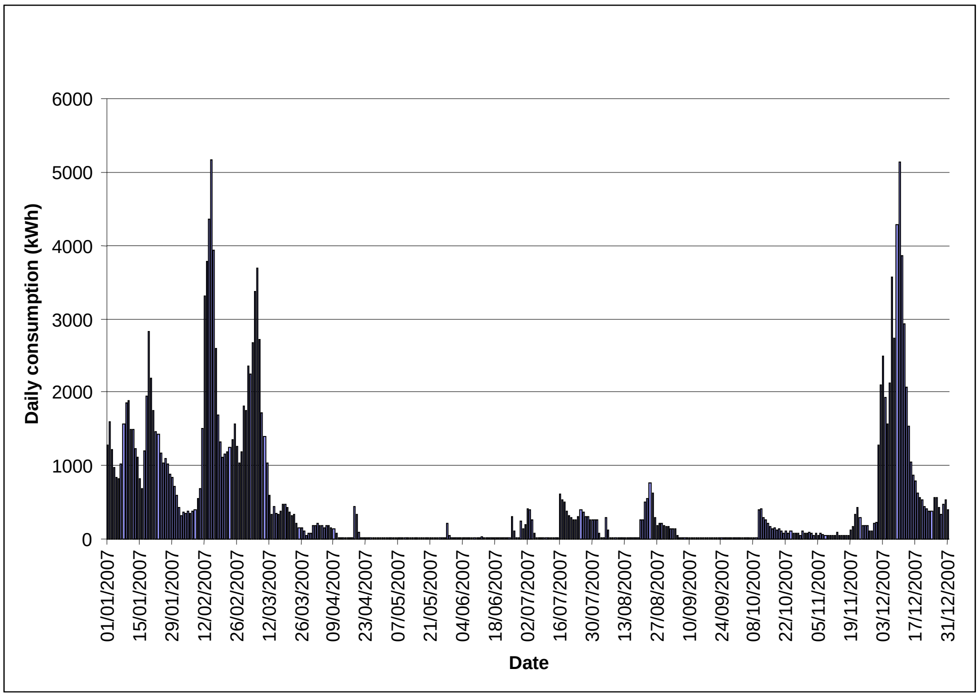


Figure 6.3 Daily electrical energy consumption at Union pumping station, 2007

The average minimum daily demand was 14 kWh, which is the power required on site for controls and instrumentation (0.58 kW).

The mean daily demand is 138 kWh, which equates to the small pump running for short periods of time.

A review of the half hourly electrical readings throughout the year shows a small propensity for increased power consumption in late morning and late evening. This may relate to influences on water levels upstream of the station.

Due to the lack of pump performance data, we were unable to quantify opportunities to improve the efficiency of the pumps at Union pumping station. However, we suggest the following as likely options:

(I). Consider running a larger pump more often, as they are likely to be more efficient than the smaller pump.

(II). Raise the suction level at which the pumps start working.

(III). Cease pumping at high tide, subject to capacity to accommodate additional volume in the supply source for three to four hours. This would require level monitoring to be added in the discharge channel, to allow effective control.

6.4 Other equipment

There are no diesel generators or air compressors on this site.

6.5 Site services

Building and insulation

The Union pumping station comprises a rectangular concrete base with a brick constructed building measuring approximately 10 m x 5 m, with an internal roof height of approximately 3.2 m. Two wooden single entrance doors provide access. The station is not heated, the motors are fitted outside on the roof of the building whilst the pumps are suspended below the building. Consequently there is a passage of air from the channel below into the building and to the motor stool. At one end of the building there is a raised control panel room (motor control centre). The building itself forms part of the dam that holds back the tidal stream on the discharge side of the pumps.

There are no windows.

There are no staff facilities, as the building is unmanned and may only be attended for one or two hours a week for inspection or maintenance.

Lighting

The station is lit by ten 70 W fluorescent T8 ceiling mounted lighting units. These are manually switched on when the station is occupied, which is not more than two hours a week.

Outside there are two 70 W bulkhead lights that are turned on if necessary during maintenance or rubbish clearance. There are also two 500 W halogen floodlights. The external lights are only switched on during the hours of darkness when the pump station is occupied.

Heating and ventilation

There is no heating within the building. The pump control panel is fitted with four 10 W panel heaters with thermostats set at 10^{o}C. These panel heaters are probably partly responsible for the base load increasing by 0.09 kW in winter.

6.6 Summary and recommendations

The total base load electrical consumption for 2007 was approximately 5,400 kWh, just 2.9% of the site's overall electrical consumption. The site is unmanned with few services and the base load consumption is likely to be attributable to the electronic controls only.

A detailed analysis of the energy use by the pumps was not possible due to the lack of electrical consumption data and pump performance information. There were no design data, pump performance curves or actual pump performance data (such as measurements of flow, operating head and power absorbed). Generating pump performance curves from first principles, and collating long term performance data are beyond the scope of this study. We recommend an exercise to collate this information, followed by a further review of the site's energy use.

Table 6.1 Energy saving recommendations for Union pumping station

Recommendations	Estimated annual savings			Estimated cost	Payback period
	(£)	(kWh)	CO_2 (tonnes)	(£)	(years)
Run one larger pump in preference to the smaller pump	Insufficient data to perform analysis				
Raise suction level start set point	Insufficient data to perform analysis				
Reduce pumping during high tide	Insufficient data to perform analysis				
Overall totals					

7 West Sedgemoor (South West)

Site details: West Sedgemoor Pumping Station, grid reference ST 376286

Contact person: John Wilkins

Date of site visit: 11 February 2008

7.1 Site overview and function of pumping station

The West Sedgemoor pumping station was built in 1944 and was designed to drain 11,000 acres of the Somerset Levels and Moors. The pumps lift water from the West Sedgemoor main drain and discharge it into the River Parrett. The station lies just downstream of the river's tidal limit.

The station was originally designed with diesel engine driven pumps that have now been converted to electrical. A further pump has also been added.

In the main pump house are two large pumps, used for transfer and disposal of water into the River Parrett. There is a smaller external submerged pump, which is used for moving water around to maintain the correct summer penning levels on the moor.

There are three buildings on site: the main pump house, a small building that was the original fuel oil store and a control house for the external pump, which was added later.

The station is served by an 11 kV to 400 V, 370 kVA transformer. There is an external, double skinned fuel oil tank supplying the heating system within the main pump house.

7.2 Site energy use

The primary energy consumption on site is electrical. There is also a small consumption of fuel oil, for frost protection heating.

During the period from January 2007 through December 2007, the total site electrical energy consumption was 20,3640 kWh, costing a total of £17,901. Figure 7.1 demonstrates the monthly electrical consumption and relative costs.

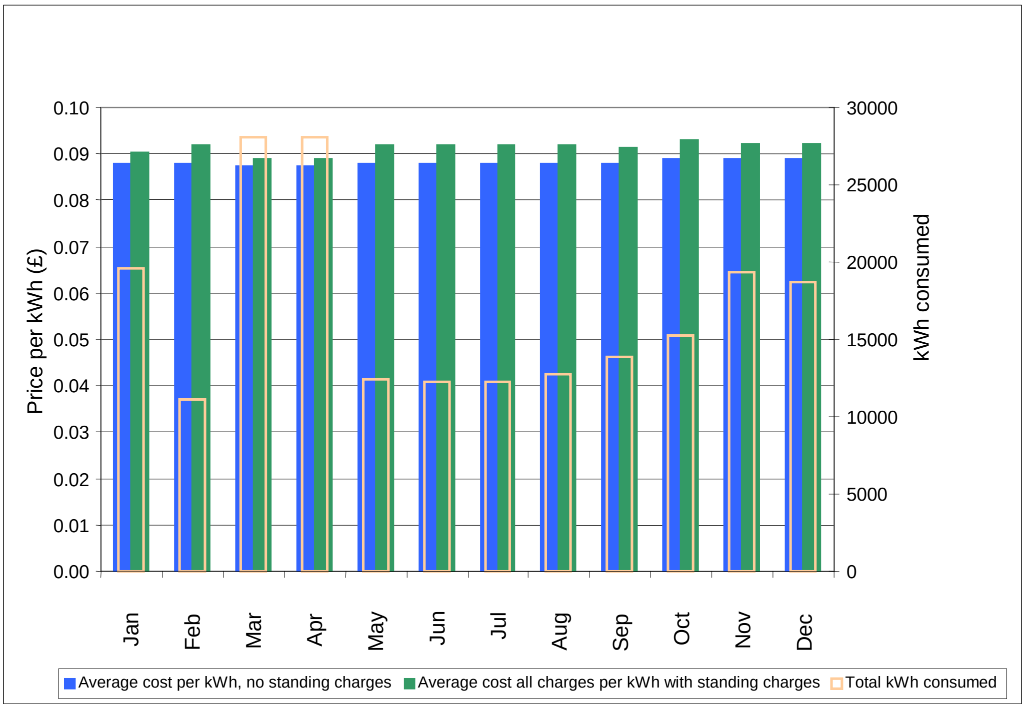


Figure 7.1 Site electrical energy consumption and typical monthly costs, 2007 (£/kWh)

There were insufficient data to estimate the site base load electrical consumption. There were no data relating to the fuel oil consumption by the heater providing frost protection in the main pump house.

Whilst the average electricity cost was £0.0911 per kWh, for the purpose of energy saving calculations we excluded the standing charges and assumed an electricity cost of £0.078/kWh.

The site's overall CO_2 emissions for 2007 totalled 106.5 tonnes (excluding fuel oil), of this the base load is estimated to have contributed 3.7 tonnes (3.4%).

7.3 Pumping systems

The drainage channel leading to the station feeds through a weed screen and passes under the adjoining road, where it is divided into penstocks that feed the pumps.

In the pump house are two long shaft, Allen Gwynne vertical spindle pumps, installed in interconnecting penstocks (here designated P1 and P2). The pumps were originally diesel engine driven but were modified to electric motor driven with vertical David Brown gearboxes. The motors are four pole (1488 rpm), 132 kW-rated, and the speed reduction gearboxes reduce their output to 265 rpm, resulting in a rated pump duty of 1846 l/sec.

The pumps (P1 and P2) are fitted in a dry well (Figure 7.2) and discharge to the river. Water flows from the pumps through an actuated penstock gate. There is also a penstock that bypasses the pumps for gravity drainage. Beyond the penstock are gravity gates, which prevent backflow from the river when its level is higher than the supply drain.

There are two small submersible pumps (KSB Ama – Drainer 303) in the dry well to pump out any water that leaks into this area. The well was flooded during the site visit and the pump was operated manually to pump out the water.

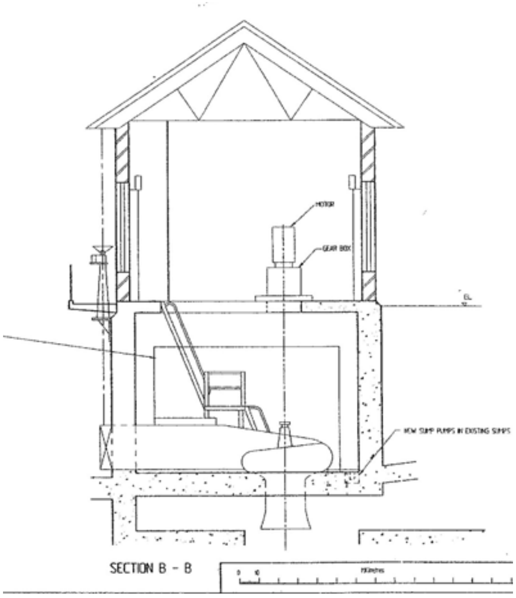


Figure 7.2 Layout of the main pump hall and pipework detail at West Sedgemoor

The main pumps (P1 and P2) are fitted with an Interlube electric greasing system that operates when the pumps are run.

The external pump (here designated P3) is a vertical submerged WH Allen 600 mm submersible pump, rated for 1200 l/sec at a maximum speed of 800 rpm. It is installed in a wet pit and discharges through pipework into the river (See Figure 7.3). The discharge pipework is fitted with a siphon breaker to prevent backflow. This pump has variable speed control and the associated 75 kW Altivar inverter is located in the separate dedicated control house.

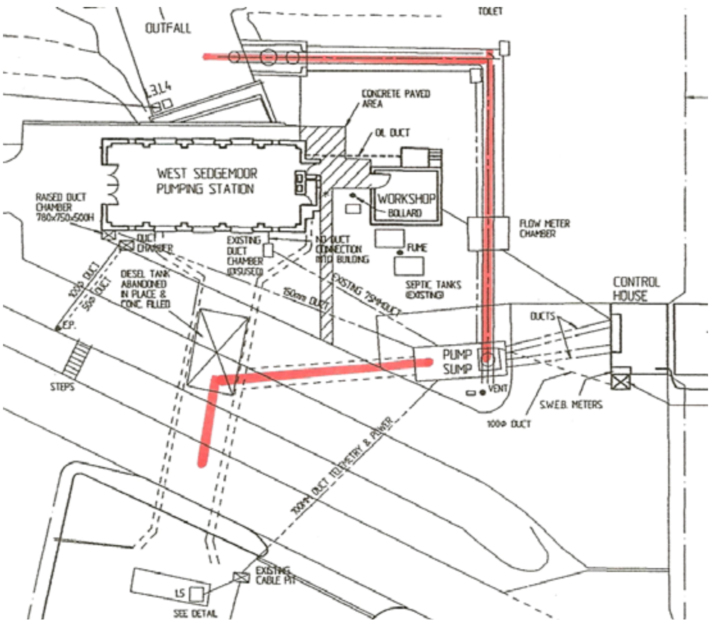


Figure 7.3 Layout of West Sedgemoor pumping station, showing external pump and pipework detail

The external pump (P3) is normally required to lift water up to a 3.1 m differential head. The pumps lifts and discharges through 700 mm pipework, in which a magnetic flow meter is fitted. The pipework rises to a maximum of 5 m before dropping into the discharge channel. The discharge outlet is submerged to benefit from siphonic gain, whilst the top of the pipework is fitted with a siphon breaker to prevent backflow.

If the level in the river rises excessively, the pump station is isolated and pumping is stopped.

Sometimes, levels in the main drain rise higher than the river level. When this occurs, the bypass penstock is opened to allow gravity flow and all pumps are isolated.

Typical operation

The pumps are controlled by an electronic controller (PLC) linked to pressure transducers. This maintains summer and winter levels, based on low and high level warning limits and inhibits.

The normal lift required is approximately 3.1 m, with extremes of 4.4 m when the river level is high. There are times when the river level can drop below the channel level, during these periods a penstock is opened to allow gravity drainage and the pumps are stopped.

If only one pump is required to run, the smaller variable speed pump (P3) is operated. Its variable speed controller interfaces with the magnetic flow meter to control P3 at a constant draw down rate, maintaining the flow above 600 l/s. At full speed and minimum head, P3 can achieve double this flow. If it fails to bring the channel level down, one of the larger pumps is run. All three pumps are rarely run together.

A weekly log of pump operating hours is maintained on site and occasionally power readings (in kWh) from the meter on site are also recorded. No power readings had been taken recently. We collected sample copies of these logs for analysis.

Detailed pump analysis

During the site visit, live readings of pump electrical consumption were recorded, to establish a benchmark reference for each pump.

Due to the design of the pumping system, it was not possible to take actual flow measurements for the large pumps (P1 and P2). Consequently our analysis of pump performance is derived from the available pump performance curves.

The benchmark measurements took place when the lifting head was 2.1 m.

According to the pump curves (example shown in Figure 7.4), the power recorded during measurements indicated a flow rate of 2010 l/sec. Based on historic levels, this result translates to an operating range from 2420 l/sec to 2596 l/sec. At median lift, the flow would be 2492 l/s. The best efficiency point BEP for these pumps is at 2080 l/sec.

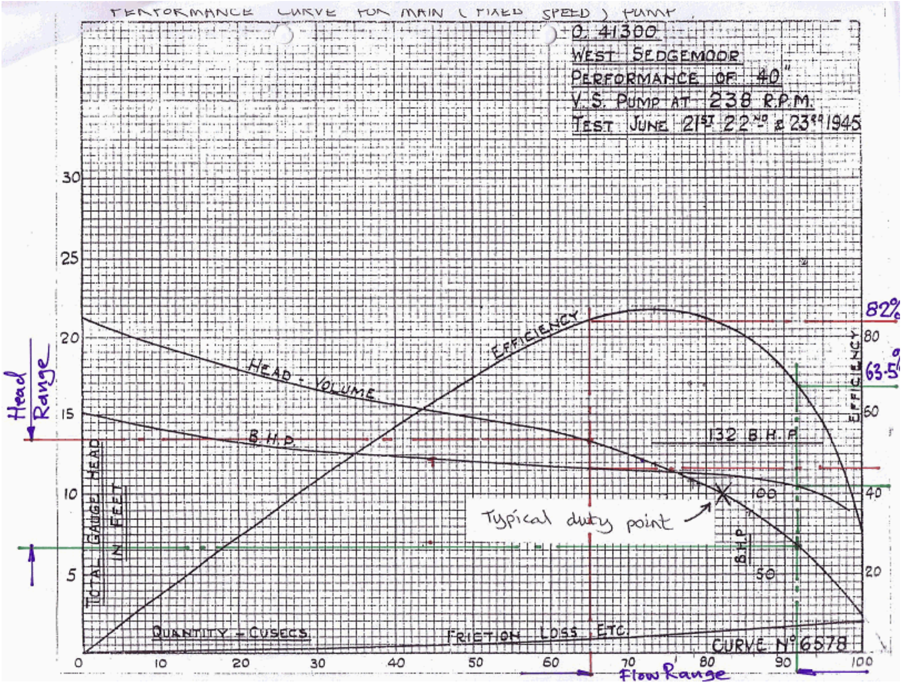


Figure 7.4 Pump performance curve for West Sedgemoor Pump 1. During testing, this pump was drawing 132 kW at a lifting head of 2.1 m. Note that the head scale on this figure is in feet, not metres.

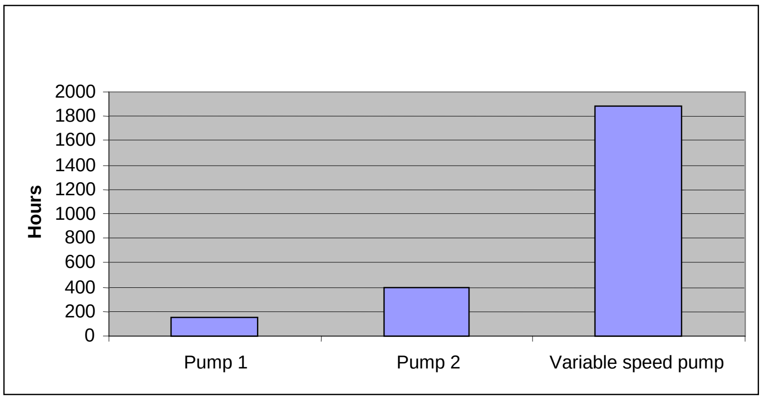


Figure 7.5 Pump running hours for 2006-7 at West Sedgemoor

Figure 7.5 shows the pump running hours recorded in the log during a 12-month period in 2006-2007. In those 12 months, P1 ran for only 149 hours and P2 for 396 hours. For many months they were not run, indicating that channel levels did not rise excessively during this period.

The smaller pump (P3) averages just over five hours a day throughout the year, with occasional continuous runs in times of flood.

We tested P3 at 100% and 80% maximum speed. With a 2.1 m lift, the flow was measured at 2810 m^3/hr, absorbing 52 kW at full speed. At 80% speed, the pump produced a flow of 1980 m^3/hr, absorbing 30.4 kW.

Commissioning data for this pump show similar measurements. It was commissioned at a lifting head of 1.13 m, where the flow rates are higher due to a lower head. However, there is no pump characteristic curve available for P3. We recommend an on-site exercise to measure the performance (head and flow) of P3 against power absorbed, in order to develop a full pump performance curve.

On the basis of the tests taken on site and some basic evaluation of P3's performance, we draw the following conclusions:

- If P3 runs at 75% speed or above, there would be a benefit in running the larger pumps (P1 or P2) instead, as they will consume less power per m^3 of water pumped.

- If P3 runs at less than 75% of full speed, then P3 consumes less power per m^3 of water delivered than the two main pumps.

An evaluation of normal operating hours and level history suggests that P3 usually runs at less than 75% of full speed. However, our readings suggest that P3 is relatively inefficient. Subject to further evaluation, a more economic replacement may be advisable in the future.

Due to the lack of information such as the pump performance curve for P3, flow readings for P1 and P2, and site electrical consumption data (for determining run hours and duty cycles), it has not been possible to perform a detailed analysis of energy savings available at West Sedgemoor. We present the following opportunities, although they cannot be quantified:

(I). Evaluate the opportunity to replace P3 with a more efficient model. This analysis requires a performance curve for P3. As there is a flow meter attached to the pump output, a curve can be developed by checking the power absorption and flow rate against varying site conditions during routine site maintenance visits. It may take several months to include high and low level extremes, but the resultant operating curve will allow a proper assessment of the pump's efficiency. Based on the measurements made during our site visit, the pump appears to be less than 40% efficient. However, an initial review of alternative units shows that this low efficiency could be inevitable, as a pump is required that can cover a comparatively large head range between the operating extremes.

(II). Raise the suction level set points. With the existing main pumps (P1 and P2) the opportunities to save energy lay mainly with increasing the channel level to reduce the head required from the pumps. There is a 4.3 kW saving per cm head rise for P1 and P2 and an estimated 0.5 kW saving per cm head rise for P3. Assuming P1 and P2 run for a combined 545 hours a year at a mean lifting head of 2.6 m, then 32,560 kWh would be saved by raising the channel level set points by 10cm. This provides a saving of £2,540 and 17 tCO_2.

7.4 Other equipment

There are no diesel generators or air compressors on site.

7.5 Site services

Building and insulation

There are three buildings on site. The main pump station comprises a rectangular concrete base, brick-constructed building, measuring approximately 10 m x 5 m, with an internal roof height of approximately 3.2 m. There is a small wooden single entrance door to provide access and large wooden double doors at one end of the station. There are three large double glazed windows on each side of the building.

The roof has internal cladding with inset lighting, which may have some insulating effect.

There is an internal, soundproof steel office.

A small, flow-activated electric heater provides hot water in the toilet facility.

The control house for the third pump comprises a rectangular concrete base and brick-constructed building measuring approximately 4 m x 2 m, with an internal roof height of approximately 3 m. There is a small wooden personnel access door and a pair of steel double doors for equipment access. There are no windows and the building is unheated.

The third building is used as a store. It is brick and is unheated. It measures approximately 3.6 m x 3.6 m, with a roof height of approximately 2.2 m.

Lighting

The main station is lit by six 200 W mercury lights at ceiling level (approximately 3.1 m). There are two internal emergency 500 W halogen floodlights and one fluorescent light in the dry well. The lights are manually switched on when the station is occupied, which is for about two hours a week.

The store building has two fluorescent 70 W lights.

In the small pump house are two fluorescent 70 W T8 lights. Outside it, there is one 70 W GLS PIR bulkhead light and one 500 W halogen floodlight. that is turned on if necessary during maintenance or attendance in hours of darkness.

On the outside of the main pump house there is one 70 W GLS bulkhead light and four 500 W halogen floodlights that are manually turned on if necessary during maintenance or attendance in hours of darkness.

All the external lights are only switched on during the hours of darkness when the pump station is occupied.

Heating and ventilation

There is an oil fuelled fan heater fitted in the main pump building, with the thermostat set at 5^{o}C to provide frost protection. The heating unit is rated at 35 kW or 100 BTU/hr. There are no records of oil use available, so it is not possible to determine the performance of this heating system. Given that it is used for frost protection, its energy consumption is unlikely to be significant.

Figure 7.6 The oil fuelled fan heater in the main pump building at West Sedgemoor

The pump control panel is fitted with panel heaters for frost protection.

The pump motors are fitted with 110 V 99 W (8A) anti-condensation heaters.

There is an extraction fan at each end of the station and an extraction fan in the dry well.

7.6 Summary and recommendations

There were insufficient data to conduct an analysis of the site base load electrical consumption at this site. However, as the site is unmanned with few services, the base load consumption is likely to be low.

There were no data relating to the fuel oil consumption by the heater providing frost protection in the main pump house. Again, this is not likely to be significant.

The performance of the main pumps P1 and P2 could be improved by raising the water levels in the supply channel, thereby reducing the pumping head.

A detailed analysis of the energy use by the external variable speed controlled pump, P3, was not possible due to the lack of pump performance information. Performance data collected on site suggested that P3 is not very efficient and could be replaced with a more efficient pumping solution or pump. Generating pump performance curves from first principles is beyond the scope of this study. We recommended that a performance curve is developed for P3, followed by further analysis of its efficiency in this setting.

Table 7.1 Energy saving recommendations for West Sedgemoor pumping station

Recommendations	Estimated annual savings			Estimated cost	Payback period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
Set channel set point levels 10cm higher	2540	32,560	17	0	0
Evaluate replacement of external variable speed pump (P3) with a more efficient pump	Insufficient data to perform analysis				
Totals	**2540**	**32,560**	**17**	**0**	**0**

8 Kennet (Anglian)

Site details: Kennet, Newmarket, Suffolk, CB8 7QL

Contact people: Martin Lee, Steve Reeves and Gerald Engwell

Date of site visit: 13 February 2008

8.1 Site overview and function of pumping station

The pumping station makes up part of the Ely Ouse-Essex water transfer scheme and was built between 1968 and 1972. The scheme uses a combination of channels, pumps, tunnels, pipelines and natural rivers to convey water principally to the Abberton and Hannington reservoirs which serve the south Essex area.

The Kennet pumping station is supplied with water taken from the River Ouse at the Black Dyke intake, via 12 miles of 2.5 m diameter underground tunnel. The tunnel terminates in five 4.6 m diameter and one 7.3 m diameter vertical shafts, to create a reservoir with a standing water level of about 63 m.

The Kennet station pumps are used to raise water through nine miles of 1.8 m diameter pipeline, over an elevation of 88 m, to a small reservoir at Kirtling Green outfall. There the water cascades by gravity into the river Stour and into a channel feeding the Wixoe pumping station.

The station is serviced by a 33 kV supply and is stepped down to 11 kV, 3.3 kV and 400 V by four transformers (two 11-3.3 kV and two 3.3-400 V transformers) with a combined supply capacity of 30 MVA. The site has no back-up generators, because it is for water transfer rather than flood alleviation.

The station is manned five days a week, from 07:30 to 16:30. When the large pumps are operating, it is manned 24 hours a day.

8.2 Site energy use

All energy used on site is electrical.

From January to December 2007, the total site electrical energy consumption was 870,602 kWh, costing a total of £144,462. The average price per kWh is affected by monthly standing charges of approximately £7,395, which are necessary to maintain the 30 MVA availability. Figure 8.1 shows the monthly electrical consumption and relative costs.

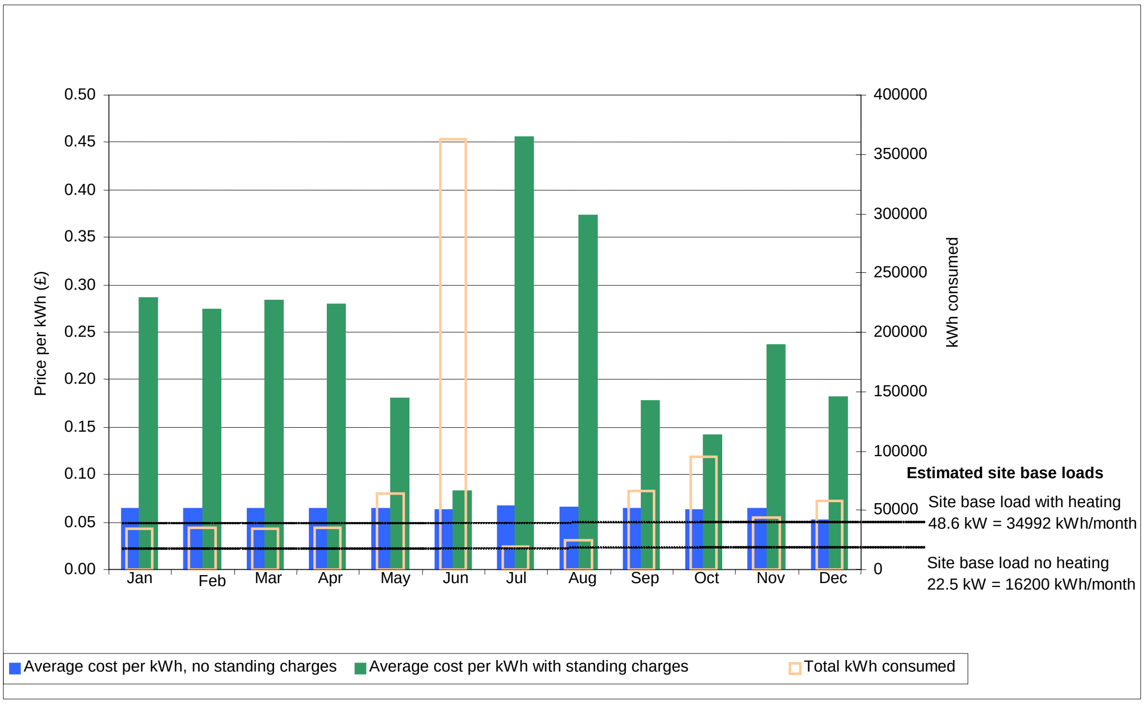


Figure 8.1 Electrical energy consumption and typical monthly costs (£/kWh) at Kennet pumping station in 2007

The site's base load electrical consumption varies between 48.6 kW in winter and 22.5 kW in summer, as shown in Figure 8.2 below.

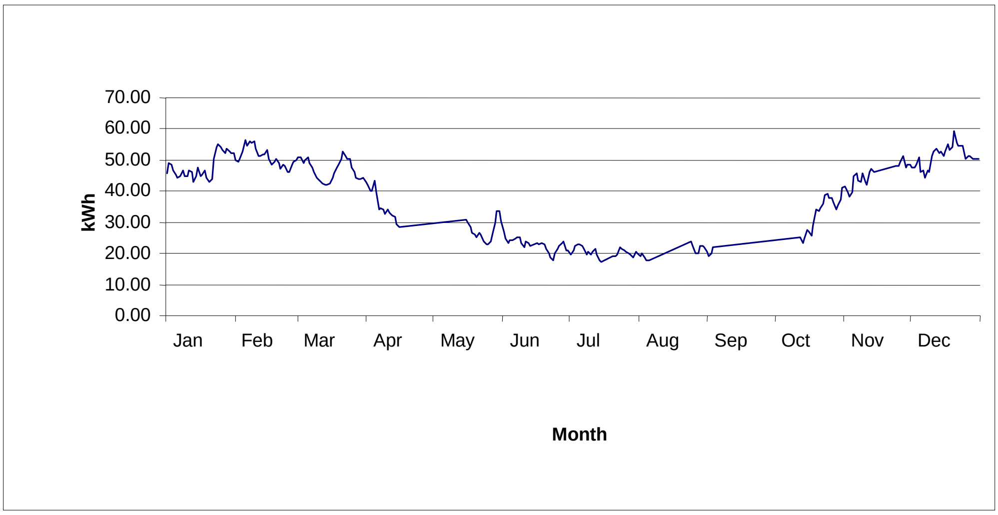


Figure 8.2 Base load electrical consumption at Kennet pumping station in 2007

Adjacent to the site are two houses whose electricity supply is from the site. These houses are electrically heated and there is no sub-meter to indicate their consumption. Consequently, the base load data presented include the electrical consumption due to these houses. In the absence of further sub-metering, it is difficult to determine how much electricity is used for heating and lighting in each of the buildings and how much is used for other services such as the control system, condition monitoring equipment and the telemetry system.

The site's overall CO_2 emissions for 2007 totalled 455 tonnes. Half hourly data suggest the site's total electrical base load contributed approximately 157 tonnes (34.5%) to this total.

Whilst the average electricity cost was £0.166 per kWh, for the purpose of energy saving calculations we excluded the standing charges and assumed an electricity cost of £0.062/kWh.

8.3 Pumping systems

There are nine pumps in the Kennet pumping station. There have been a number of upgrades since the original station was built and the pumps now comprise:

Two 2610 kW long shaft, suspended bowl multi-stage Weir SBV42 x 2 + 3 pumps, rated at 1315 l/s at 142.6 m.

One 2480 kW long shaft, suspended bowl multi stage Weir SBVM 1070 x 5 pumps rated at 1600 l/s at 123.3 m. This was fitted more recently than the other two large pumps.

Two 385 kW SBWM 600 x 3 electro submersible borehole pumps, rated at 272 l/sec at 110.4 m.

Two 400 kW Pleuger QT20EKH/3 electro submersible pumps, rated at 272 l/sec at 110.4 m, fitted in 2001.

Two 110 kW Caprari E10S64/4B+MAC10150-BV electro submersible pumps, rated at 81 l/sec at 106 m, also fitted in 2001.

The three large pumps are supplied with softened water to flush the seals and bearings. The associated water softening plant incorporates six 4 kW Grundfos and two 5 kW Weir Isoglide pumps, to circulate and pressurise the ring main.

The water pumps all discharge into a common manifold, which discharges into the main pipeline. A building at the far end of the pumping station houses two large pressurised surge vessels connected to the main pipeline. The pipes to each pump and the main line are fitted with non-return valves, to ensure that the discharge pipeline is maintained full of water.

Typical operation

The pumping station receives weekly requirements for transfer of water. The combination of pumps to be brought on line is decided according to how much water is required. Table 8.1 shows the pump combinations that will achieve a given pumping capacity per day.

Table 8.1 Kennet pump scheduling combinations. Numbers in each cell show the total daily pumping capacity in megalitres/day, using different combinations of pumps. * Ml = megalitres (1 Ml = 1000 litres).

Pump capacity (Ml*/day)		7	7	23	23	23	23	136	136	136
	Number of pumps running	1	2	1	2	3	4	1	2	3
7	1	7								
7	2		14							
23	1	30	37	23						
23	2	53	60		46					
23	3	76	83			69				
23	4	99	106				92			
136	1	143	150	159	182	205	228	136		
136	2	279	286	295	318	341	364		272	
136	3	415	422	431	454	477	500			408

There is a preference to run the smaller pump combinations when possible, because operating the large pumps (136 Ml/d) requires the pump station to be manned 24 hrs a day, which entails a substantial staffing cost.

Detailed pump analysis

Pump numbers are allocated to the pumps as shown in Table 8.2. Pump numbers 2, 3, 4, 11 and 12 were tested using the thermodynamic method in 2002. We have used this information to evaluate their performance for this study, as it was not possible to run the pumps during our site visit.

Pumps 13, 14, 21 and 22 were newly fitted just prior to the AEMS testing. We have obtained copies of their performance curves from the supplier. These data indicate that there is very little frictional resistance on the discharge side of the pumps when the pumps are running individually.

Table 8.2 Kennet pumps and their performance ratings

Pump numbers	Make/model	Number on site	Pump rated performance			Site operating range		Benchmark performance	
			kW	Head (m)	Flow (l/s)	Head (m)	Flow range (l/s)	kW/m^3	kW/m^3/m
2, 3	Weir SBV32 x 2+3	2	2610	142.6	1315	113	1567-1664	0.39	0.0035
4	Weir SBVM 1070 x 5	1	2480	123.3	1600	114	1741	0.37	0.0032
11, 12	Weir SBWM 600 x 3	2	385	110.4	272	113.5	255	0.43	0.0038
13, 14	Pleuger QT20EKH/3	2	400	110.4	272	113.5	264	0.37	0.0032
21, 22	Caprari E10S64/4B + MAC10150-BV	2	110	106	81	113	77.5	0.39	0.0035
	Weir Isoglide	2	5						
	Grundfos	4							
	Grundfos	2							

From our calculations of pump performance in kW absorbed per m^3 of water pumped (see Table 8.2), we conclude the following:

(I). There is a 5% energy saving if Pump 4 is run in preference to Pumps 2 and 3

(II). There is a 5% energy saving if Pumps 13 and 14 are run instead of 11 and 12.

(III). There is a 9% energy saving if Pumps 13 and 14 are run for short periods instead of 21 and 22

(IV). Running Pumps 2, 3 or 4 for short periods instead of 11, 12, 13, 14 could save up to 14% of energy used.

Due to the interaction of the Kennett station with Wixoe, a decision on running larger pumps instead of smaller pumps will depend on the short term capacity of Wixoe station and the general downstream capture and storage capacity to accommodate this.

There are no detailed records of run times for individual pumps, but pumping requirement call off data from 2006 indicate how the three broad categories of pump are run on an annual basis (Figure 8.3). These data show that the larger pumps, 2,3 and 4 are used the least, and the four medium sized pumps, 11, 12, 13 and 14, are used the most frequently.

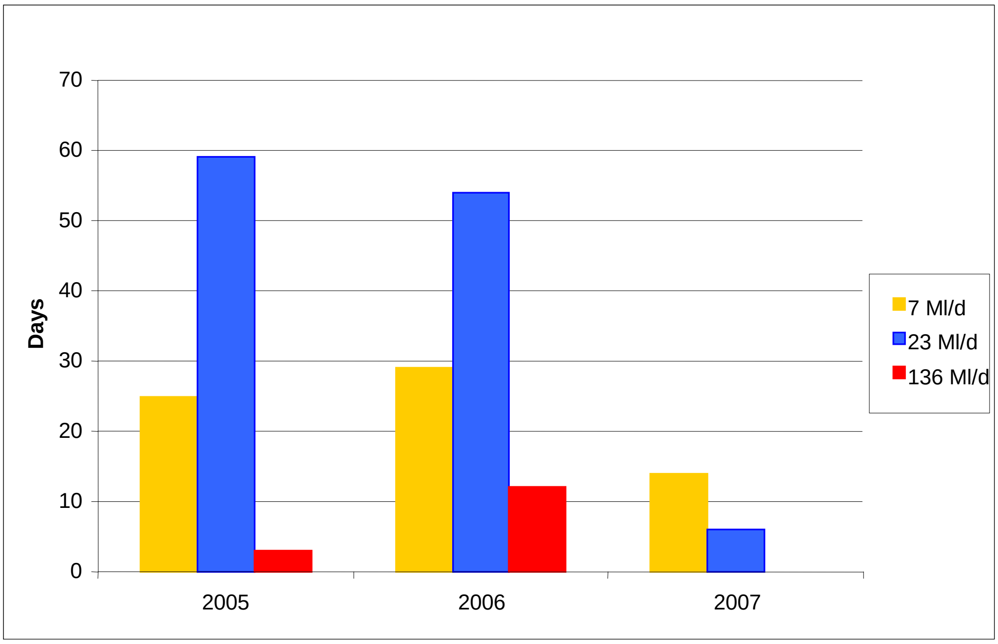


Figure 8.3 Kennet pump usage (total number of pumping days in 2006) according to pump capacity

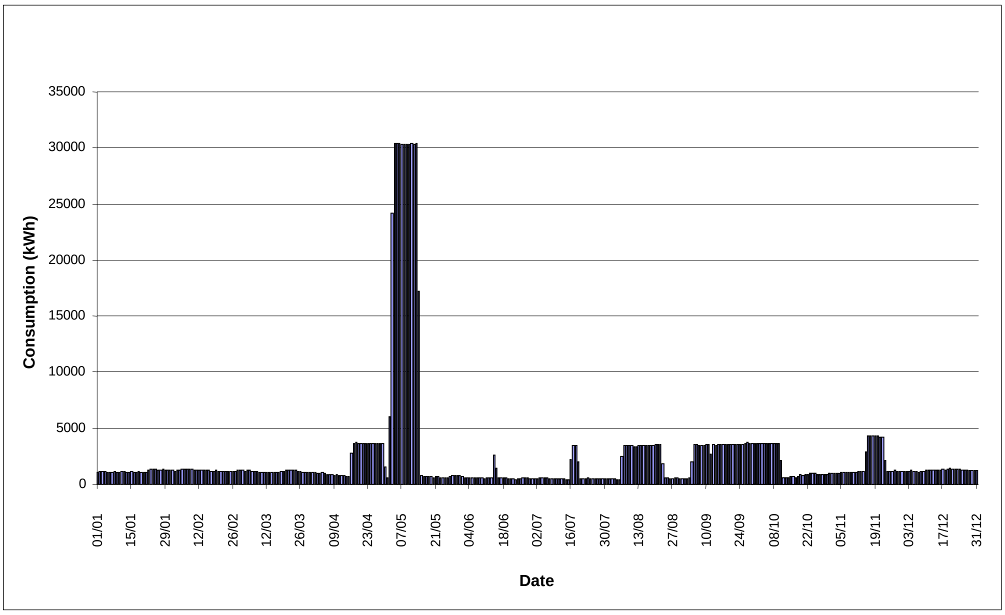


Figure 8.4 Kennet daily electrical consumption (2007)

Opportunities to improve the efficiency of the pumps include the following:

(I). Based on 2006 running patterns, the difference between selecting the best or the worst combination of pumps was 186,000 kWh, equating to 97 tonnes of CO_2, and worth £11,530.
However based on a more realistic initial pump selection the saving opportunity is in the region of 40 tCO_2 by favouring pump numbers 4, 13 and 14.

(II). Evaluating the efficiency of the pumps against the best available for the duties specified, the newer pumps (4, 13, 14, 21 and 22) are all within one per cent of the best achievable. Pump numbers 2, 3, 11 and 12, however, lag behind the best in their classes by between four and five per cent. If any of these pumps needs a major repair in the future, the economy of replacement should be reviewed.

8.4 Other equipment

Air compressors

Compressed air is used to charge the two surge tanks connected to the main discharge pipeline. Two 5.5 kW reciprocating compressors, switched by pressure switch, are used to charge the tanks to 12.5 Bar. There is no record of actual usage or run hours by the compressors. They are permanently enabled, but engineers believe that air leakage from the surge tanks is extremely low, so the compressors rarely run. We recommend periodic leak checks, to ensure minimal compressor use.

Other equipment

The main pumps are fitted with condition monitoring and vibration analysis equipment. During our site survey, this equipment was powered up and active, despite the pumps having been switched off for several weeks. It was not possible to quantify the energy consumption due to this equipment.

The main control system (PLC) for the pumps is also continuously powered, even when the pumps have been switched off for several weeks. One of the reasons for this is that it interfaces to the telemetry system. It was not possible to quantify the energy consumption due to these controls. However, given the age and the type of electronic technology employed, it is likely that the associated power consumption is significant.

The energy saving potential associated with this equipment and other parts of the site could be quantified following a short sub-metering exercise. In our energy saving calculation, we assume a saving of five per cent of base load, from managing this equipment differently.

8.5 Site services

Building and insulation

The site comprises four buildings: the main building, the pump house, the surge tank house and the store house. None of the buildings have high levels of insulation, although this is only a concern in the offices and control room, which are regularly manned (Monday – Friday).

The main building measures approximately 40 m x 10 m. This contains the switch room, control room, canteen, offices and a meeting room. Underneath this building is a 30 m long basement housing the pump starters, which is accessed via stairs from the control room. The building has a concrete base and roof with brick walls. There is no roof insulation and the air cavity in the brickwork is not filled. All windows are fitted with modern double glazing.

Adjoining the main building via the switch room is the pump house, which measures approximately 30 m x 15 m. The pumping hall is essentially outdoors, although it is shielded from the weather by a retractable roof. The retractable roof enables overhead crane access for pump removal or maintenance. During the site visit, we noticed that the roof was likely to need refurbishing over the coming years.

The wooden door between the pump room and the switch room is part glass and provides little insulation or draught proofing between the two. This is of concern, as the switch room is fitted with electric heating for anti-condensation protection. The pump hall and the switch room are rarely occupied.

The surge tank house measures approximately 30 m x 12 m and houses two large air receivers spanning almost the whole length of the building. The building fabric is concrete and there are no windows. It is rarely occupied.

The stores building contains a loading bay, stores room, a water softening plant and a small water tank upstairs. It measures approximately 10 m x 25 m. Access to the rear store room could be obtained via a roller steel door. The loading bay area serves as a workshop where small mechanical repairs can be carried out. This building is used intermittently and is not occupied for any significant length of time.

Lighting

The main building is lit by 42 T8 fluorescent lights of varying sizes, 13 of which are in frequent use when the building is occupied. The transformer room contains a further fifteen 70 W T8 florescent lights, which are lit only during maintenance or pumping hours. The pump hall is lit by seven low bay 250 W sodium lamps and luminaries, and

12 ceiling mounted T8 fluorescent units at approximately 9 m above floor level. The compressor building contains 22 four inch T12 fluorescent lights, which are rarely used. The stores building contains 25 fluorescent T8 lights. The loading bay area also contains four low bay metal halide 250 W lamps and luminaries.

External security lighting is provided by eleven 250 W high pressure sodium (SON-T) floodlights. These are controlled on timers and light sensors.

The lighting demand in the occupied offices and the control room is relatively high throughout the year, whilst on the remainder of the site it is low due to low occupancy.

We recommend implementing a policy to upgrade all the fluorescent lighting to T5 equivalent units on failure.

Heating and ventilation

The main building is heated by eight 1.5 kW wall-mounted electric panel heaters, located across the different rooms in the building. Three rooms are rarely occupied and consequently the heaters operate infrequently. During the visit, when external air temperatures were low (3-5ºC), the heaters in the office areas were set high. The control room is heated by an air source heat pump (Toshiba RAV-200AH) unit, which was set to 18ºC on the day of the visit. Domestic hot water is provided by a 3 kW immersion heated tank.

Anti-condensation protection in the switch room is provided four 1.5 kW wall-mounted electric panel heaters of the same style as in the main building. These were turned on high during the site visit and the estimated room temperature was between 12 and 14^{o}C. Due to the high heat loss from this room, the heaters were likely to remain on high throughout the winter.

The surge tank building was heated by six wall-mounted tubular electric heaters, which were switched on at the time of our visit. An instantaneous load reading in this building showed a demand of 6.9 kW. We assume at least 6 kW of this are due to the heating load.

The stores building contained five 3 kW quartz infra-red radiant heaters, controlled by motion sensors. The dosing room, which makes up part of this building, contained a wall-mounted electric panel heater of the same type as in the main building.

Opportunities to improve the efficiency of the buildings and services include the following:

(I). Install cavity wall insulation in the main building, and investigate opportunities to install insulation in the ceiling. Cavity wall insulation cost approximately £4.70 per m^2 of external wall. The surface area of the side walls of the main building add up to 400 m^2. Total cost would be roughly £2,400. Loft insulation costs approximately £6 per m^2, for 250 mm of thickness. The total cost would be £2,200. In our energy saving calculations, we make a conservative estimate that this insulation would save 20 per cent of the energy used.

(II). Fit draught sealing around the door between the pump hall and the switch room.

(III). Improve housekeeping practices by turning down heater set point temperatures and switching off lights and other equipment when it is not required.

(IV). Switch from electric heating in the main building and surge tank building to a central source of heating such as a heat pump. There appears to be a good opportunity to use the water in the main pump shaft to run a water sourced heat pump that would achieve high COP values (see section 2.5). No drilling costs would be required, improving the cost effectiveness of such a system. This system could heat the main building and potentially the surge tank house. Alternatively, ground sourced or air sourced heat pumps could be considered. However, the annual COP values of an air sourced version would be slightly lower at this site.

(V). Carry out an electrical sub-metering project to quantify the different users contributing to the base load electrical consumption. Then identify ways to reduce the base load. For example, the existing PLC-based control system could be upgraded to a more powerful and efficient version, or the condition monitoring equipment could be turned off when the pumps are not running.

(VI). Install electricity meters on the supplies to the adjacent houses on site. These are no longer occupied by Environment Agency staff. Data from the meters will enable the Environment Agency to quantify electricity consumption due to the pumping station. The calculations in Table 8.3 assume these houses each consume 4200 kWh per annum, the figure for a typical house.

8.6 Summary and recommendations

The Kennet pumping station is a significant user of electrical energy, both for pumping and for maintaining operations on site. It is typically manned five days per week.

In 2007, the site base load electrical consumption varied between 48.6 kW in winter and 22.5 kW in summer and represented approximately 34.5 per cent of the site's overall consumption. There are two houses on site, no longer occupied by Environment Agency staff, whose electrical use is included in the site base load analysis. We recommend that electricity meters are installed on the supplies to these houses, to enable the Environment Agency to quantify electricity consumption due to the pumping station. The various electricity users on site that contribute to the base load consumption, including the control systems, need to be better quantified through a sub-metering exercise.

There are opportunities to improve insulation, such as cavity wall insulation, in the main office and control room building.

All heating on site is provided by electric heaters. Carbon emissions associated with this heating may be reduced by switching to an alternative heating technology such as a heat pump. Water in the pump shaft could be used to service a water sourced heat pump, or ground sourced or air sourced heat pump technology could be employed.

Fluorescent lighting should be replaced on failure with equivalent higher efficiency T5 units.

The most effective means to improve the efficiency of pumping is to reschedule the pump duties to favour the larger, more efficient pumps. However, this change requires consideration of how the delivered water can be most efficiently managed and retrieved for storage.

Table 8.3 Energy saving recommendations at Kennet pumping station

Recommendations	Estimated annual savings			Estimated cost	Payback period
	(£)	kWh	CO_2 (tonnes)	(£)	(years)
Schedule Pump 4 in preference to Pumps 2 and 3**	2732	44064	23.0	0	0
OR **Schedule Pumps 13 and 14 in preference to Pumps 11 and 12** **	**3157**	**50918**	**26.6**	**0**	**0**
OR Run Pumps 13 and14 for short periods instead of 21 and 22**	67	1079	0.56	0	0
OR Run Pumps 2, 3, or 4 for short periods instead of Pumps 11, 12, 13, 14**	3157	50918	26.6	0	0
Switch from electric heating in the main and surge tank buildings to water sourced or air sourced heat pump technology	**4873**	**78594**	**41.1**	**30,000**	**6.2**
Use electrical sub-metering to investigate base load from control systems and condition monitoring equipment	**930**	**15016**	**7.85**	**2000**	**2.15**
Fit electric meters to the supplies for the two houses on site	**520**	**8400**	**4.4**	**0**	**0**
Improve insulation in the main building – cavity wall insulation and roof insulation	**856**	**13807**	**7.2**	**4280**	**5**
Improve housekeeping practices (switch-off policy)	**325**	**5239**	**2.7**		
Fit draught sealing around the door between the pump hall and the switch room	**20**	**287**	**0.15**	**200**	**10**
Overall totals*	**10681**	**172261**	**90**	**36480**	**3.4**

Notes:

* The totals are additive, but some of the heating measures will provide less saving in combination. For example, improved insulation will reduce the load on a heat pump, so it does not need to operate at full capacity.

** Scheduling of pumps depends on the demand for pumping. Only one option is selected, in bold, to represent the savings potential.

9 Highbridge (Midlands)

Site details: Highbridge Pumping Station (SK0897016693)

Contact person: Martin Hayes

Date of site visit: 14 February 2008

9.1 Site overview and function of pumping station

The Highbridge pumping station was built in 1986. It consists of two unmanned stations on either side of the River Trent, with submersible pumps that lift water from drainage canals and discharge it to the river. The station on the southern side drains land that has subsided and the station on the northern side drains farm land through drainage ditches.

9.2 Site energy use

All energy consumption on site is electrical.

From January to December 2007, the total site electrical energy consumption was 34,672 kWh, costing a total of £2,190.96. Figure 9.1 demonstrates the monthly electrical consumption and relative costs.

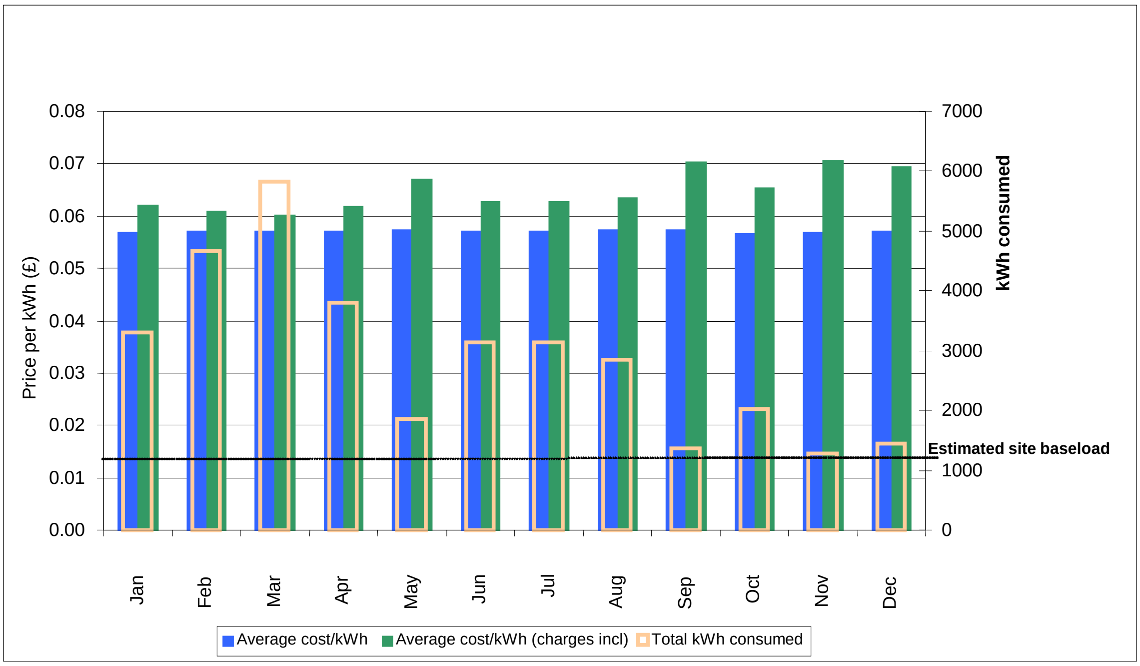


Figure 9.1 Electrical energy consumption and typical monthly costs (£/kWh) at Highbridge in 2007

The site base load electrical consumption is estimated at 0.5 kW, with an annual total of 4,380 kWh. It is approximately 12.6 per cent of the site's overall electrical consumption.

Whilst the average electricity cost was £0.063 per kWh, we excluded the standing charges in our energy saving calculations and assumed an electricity cost of £0.057/kWh.

The overall CO_2 emissions due to electrical consumption for the site in 2007 were 18.12 tonnes.

9.3 Pumping systems

The stations on the south and north sides of the river are similar. The south side is equipped with two 22 kW Flyght LL 3201-612 submersible pumps in individual wet wells.

On the north side there are four pumps. Originally there were four pumps identical to those on the south side, but one was replaced in 1996 with a 3.1 kW Flyght NP3102.181, to handle low flow rates more efficiently. When the 22 kW pumps are switched off, the water in the discharge column flows back to the suction drains, wasting the energy imparted in lifting. When the 3.1 kW pump was installed, the discharge was piped in with a non-return valve to retain water in the pump flow lines when the pump is shut off.

The channels leading to the north and south stations feed through a weed screen. On the south side, an 800 mm intake pipe opens into a penstock to feed both pumps. On the north side the arrangement is similar but with two 800 mm pipes feeding the four pumps.

The two pairs of pumps on the north side are not interconnected.

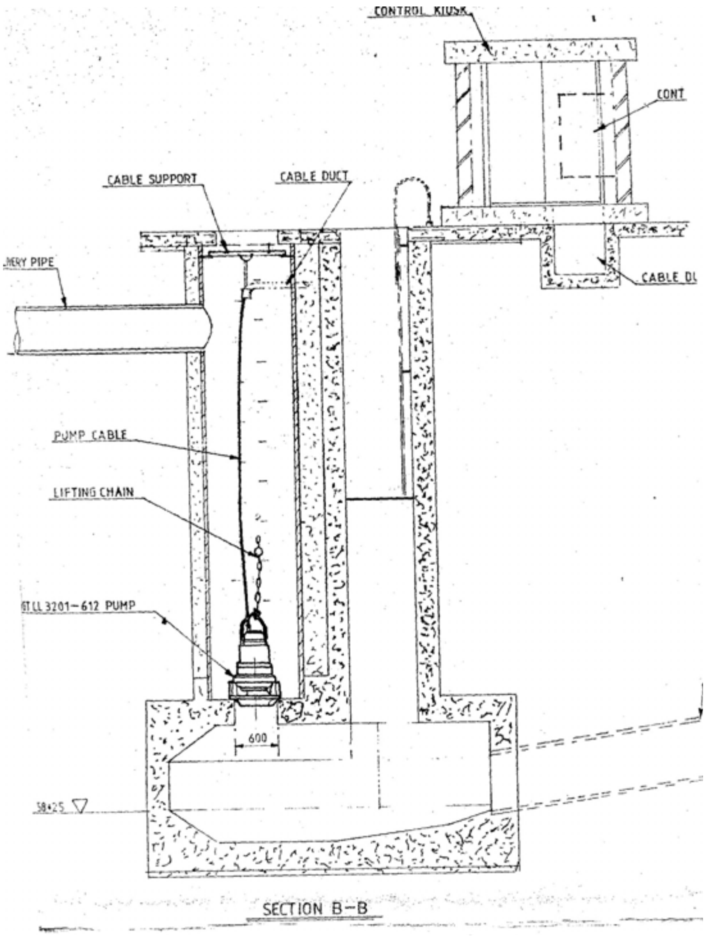


Figure 9.2 Layout of the pumps and pipework detail at Highbridge pumping station

The pumps are normally required to lift between 2.94 and 3.84 m differential. As they discharge over a fixed height and cascade into the river below they are unaffected by river levels, so there is no beneficial siphonic affect.

Typical operation

The pumps are controlled sequentially by a Hawker controller fitted with pressure transducers, which is programmed to maintain summer and winter levels in accordance with low and high level set points.

On the north side, if only one pump is required, the smaller pump is operated. In the event of flooding, two of the larger pumps are run, but rarely all three together.

There are run time meters on site. We advised engineers to record these figures during maintenance visits.

The supply channel and river levels are monitored and recorded by telemetry, and historical data were provided in a spreadsheet for both stations. Short term data indicated that the small pump on the north side is starting and stopping almost constantly.

During the visit, one of the large pumps on the south side was observed to start and run for approximately five minutes before stopping.

Detailed pump analysis

During the site visit, both small and large pumps were observed operating. Discharge from the 600 mm outlet pipes showed the water only partially filling the discharge pipe so there was no backup and friction loss in this line.

The ammeter on the small pump did not register a reading when running and the configuration of the control panel did not facilitate the connection of a portable power meter to taking power readings.

The large pump ammeter recorded 34 A (approximately 18.8 kW) with the pump running, which corresponds well with our calculation of the operating point from the lift required.

Running hours were available for 2007 (see Figure 9.3). At the north station, the small pump (Pump 1) ran 57% of the time, with the addition of one of the larger pumps (Pump 3) when pumping rates required it. At the south station the combined operation of 425 hours was evenly split between the two pumps.

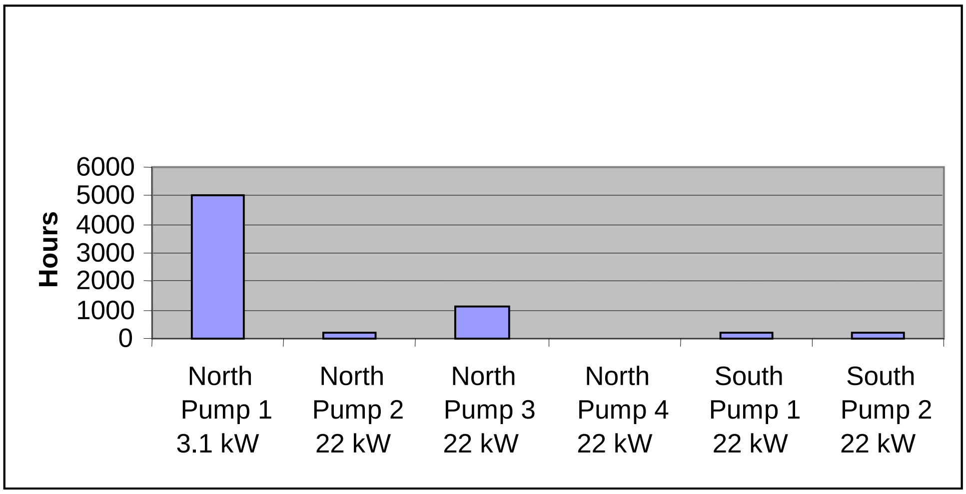


Figure 9.3 Highbridge pump run hours for 2007

The design of the lift station makes it simple to estimate the operating point from the original pump curves, shown in Figure 9.4.

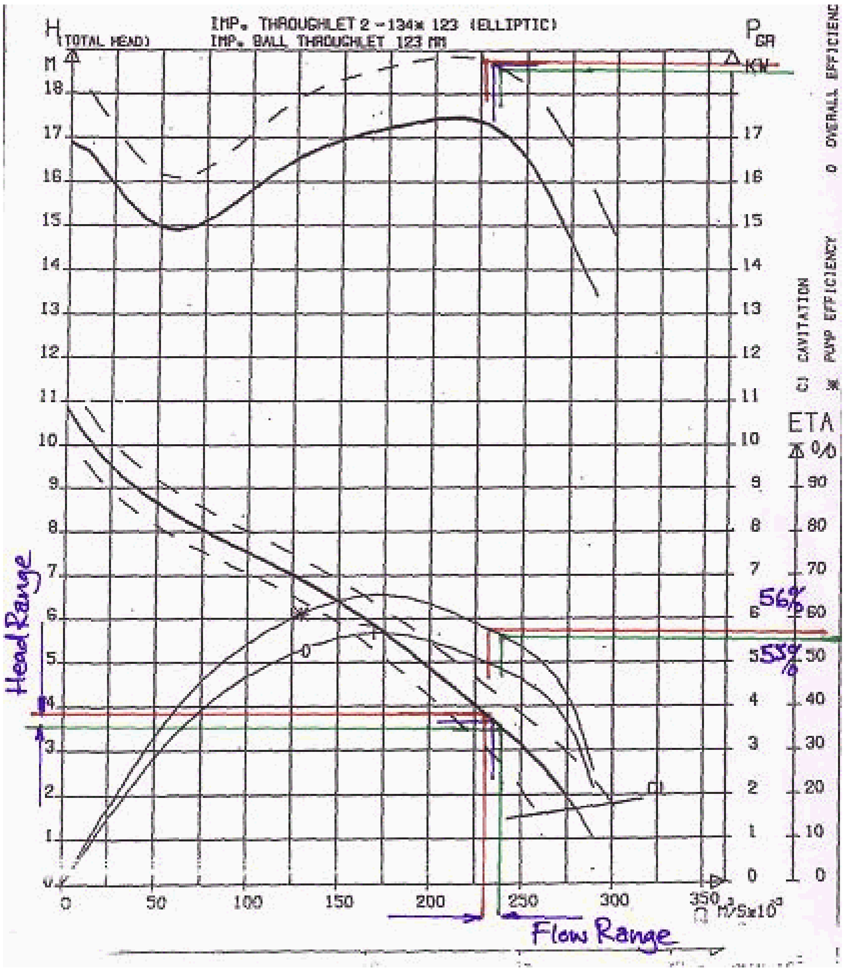


Figure 9.4 Operation of the 22 kW pumps at Highbridge

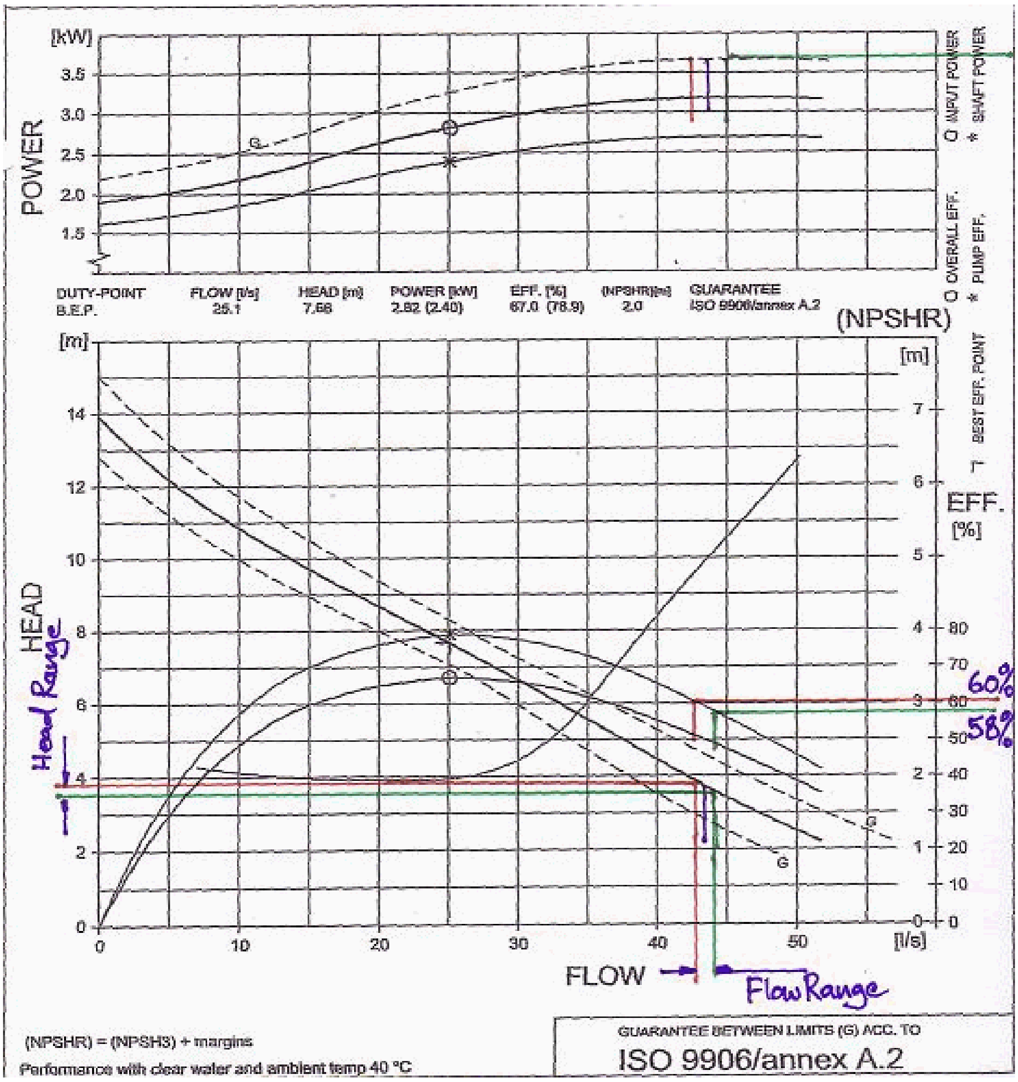


Figure 9.5 Operation of the 3.1 kW pump at Highbridge north

Both the large and small pumps are running well to the left of their best efficiency points, which may result in higher than expected impeller wear. We recommend periodic inspection of the impeller. But relative to kW absorbed per m^3 pumped they are running at a lower level than they would at best efficiency point (BEP). The small pump on the north station uses four to nine per cent less energy than the large pump, not allowing for the added benefit of not having to fill the discharge pipe each time it starts.

It is not advisable to raise the suction levels to reduce head at this site, as this would push the pumps further out on their efficiency curve and may result in excessive wear or cavitation.

In the case of the small pump, there is an alternative model available (MT 53 421 00 6502) that would reduce the operating power by ten per cent for normal operation. However, as the pump is only 3.1 kW rated, the payback period for installing this new pump would be excessive, over 10 years excluding installation costs.

In the case of the large pumps there are alternative models better suited to current flow rates, but their energy use does not present any savings.

The current large pumps are not fitted with the latest impeller available from the manufacturer. However, the new impeller would absorb about six per cent more power at normal flow rates, although it would operate closer to its BEP. A change to the new impeller should only be considered if the current impeller is found to be failing.

If one of the pumps on the south station has to be replaced at a later date due to wear, a replacement with a smaller pump similar to the one in the north station could be considered, although this will lower the flood capacity of the station.

A fundamental redesign of the pump station could take advantage of siphonic assistance if the pumps were hard piped on the discharge side and the discharge pipework submerged in the river at its lowest level. Siphon breakers would need to be fitted to prevent backflow.

9.4 Other equipment

There are no diesel generators or air compressors on site.

9.5 Site services

Building and insulation

The two pump stations are identical and comprise a rectangular concrete base and single skin brick constructed building measuring approximately 2.5 m x 3 m with an internal roof height of approximately 2.5 m. The roof is solid concrete and uninsulated. There are double non-insulated steel entrance doors to provide access, but no windows.

There are no other facilities as the buildings are unmanned and only attended for inspection or maintenance.

Lighting

Each station is lit by two 70 W fluorescent T8 ceiling mounting lighting units. These lights are manually switched on when the station is occupied, and this is infrequent.

There is no external lighting.

Heating and ventilation

Each station is heated by a 3 kW wall-mounted fan heater set to 5^{o}C for frost protection purposes. Within each station is a control panel for each pump, fitted with an anti-condensation heater.

9.6 Summary and recommendations

Highbridge pumping station is a small user of electricity and there are limited opportunities to improve the efficiency of pumping in the station. The performance of the pumps are similar, both operating at about the same level of kW/m^3.

The small pump could be replaced with a marginally more efficient model. However this will only be economical if carried out when the existing pump needs replacing. We have not estimated the energy saving potential of this action.

The heating appliances are set up for frost-protection at 5ºC and make up a very marginal component of the overall energy use. Electrical consumption data showed that in 2007, the lowest site energy consumption occurred in November, when it is likely that frost protection was frequently required.

We recommend that electrical consumption data are collected at half hourly intervals to establish more detailed profiles of electrical energy consumption for this pumping station.

Appendix 1 - Foss

Foss pump installation

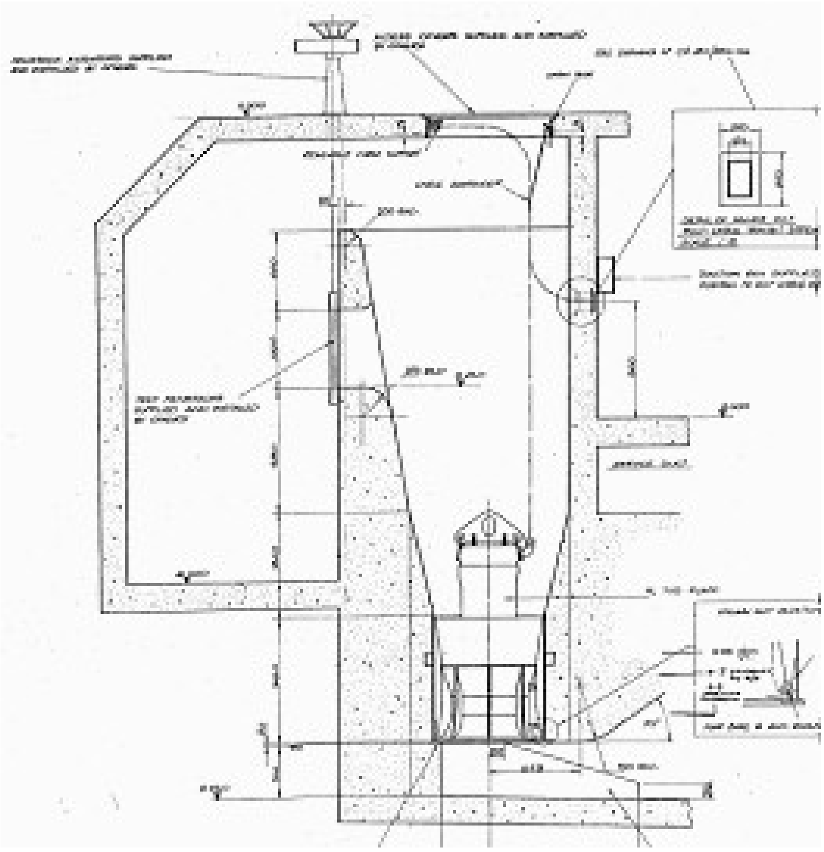


Figure A1.1 Cross section of pump chamber and discharge channel at Foss

Foss electrical consumption

The following graphs demonstrate the pattern of electrical consumption measured half hourly, across a sample of periods in 2007 and 2008.

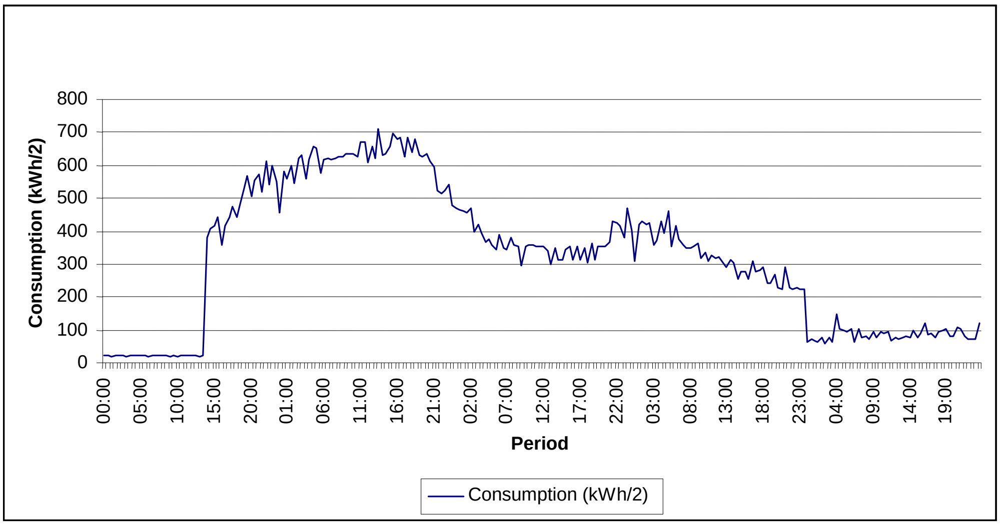


Figure A1.2 Electricity consumption at Foss 15 – 19 January 2008. This demonstrates energy consumption due to pumping as pumps are switched on and off.

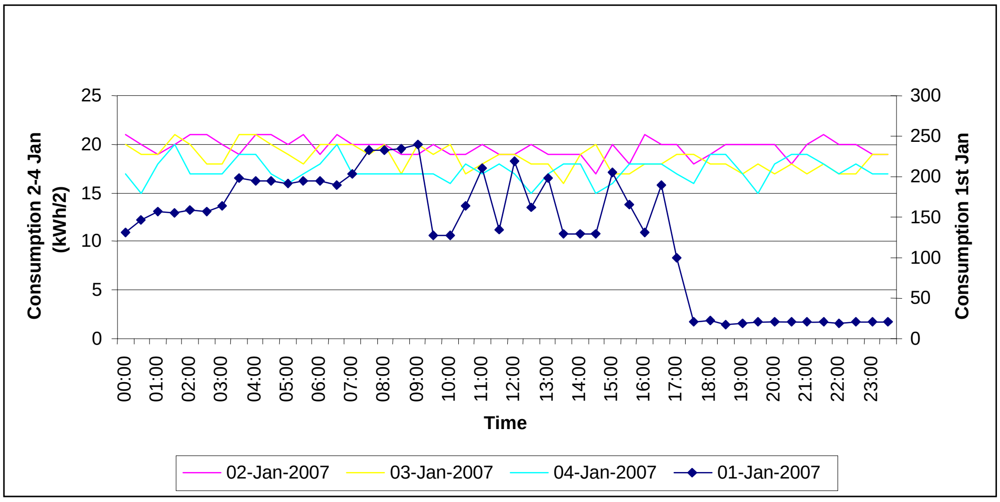


Figure A1.3 Electricity consumption at Foss, 1 – 4 January 2007. This demonstrates energy consumption due to pumping on 1 January 2007 (right hand y-axis), and the site base load on 2, 3 and 4 January 2007 (left hand y-axis). The average winter base load was 35.3 kW.

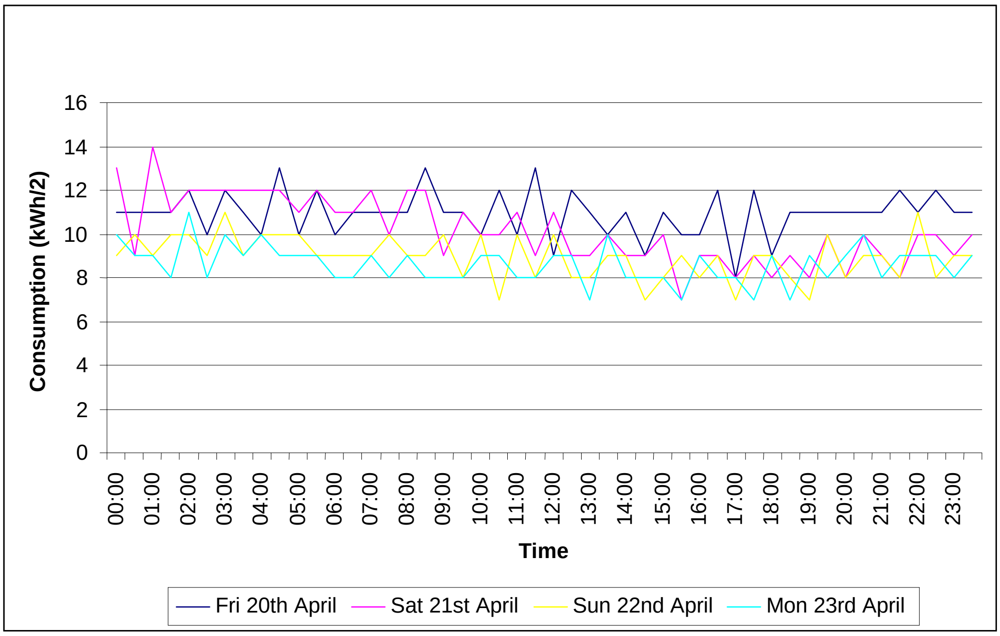


Figure A1.4 Electricity consumption at Foss, 20–23 April 2007. The average spring energy consumption due to the site base load was 18.0 kW.

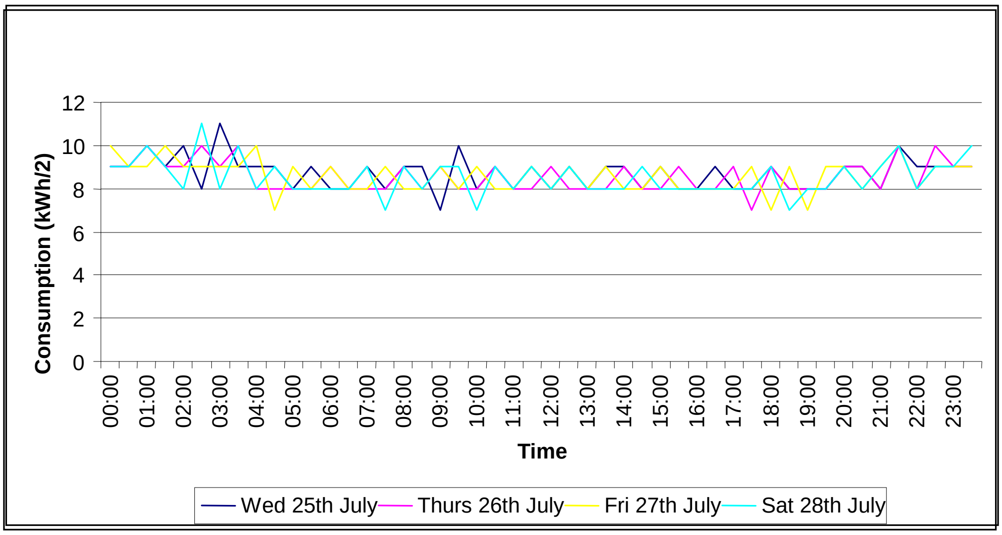


Figure A1.5 Electricity consumption at Foss, 25–28 July 2007. The average summer energy consumption due to the site base load was 17.28 kW. Note that during daylight hours the load is 17 kW and at night it is 19 kW, indicating that the security lighting load is 2 kW.

Given the winter base load of 35.3 kW and the summer daytime base load of 17.28 kW, the average continuous heating demand in winter is 18 kW. This includes pre-heating the diesel generators.

Foss lighting

Table A1.1 Foss internal lighting schedule

Room	Lamp type	Length	Quantity	Watts	Circuit Watts	Total circuit (W)
Battery/workshop	T12	1500	3	65	75	225
Passage (downstairs)	T8	1500	4	58	70	280
Passage (downstairs)	T5	1449	2	49	54	108
Passage (downstairs)	T8	1500	1	58	70	70
Switch room	T8	1800	10	70	82	820
Control room	T12	600	12	20	24	288
Generator	T8	1500	4	58	70	280
Txfr1	T8	1500	2	58	70	140
Txfr2	T8	1500	2	58	70	140
Kitchen	T8	900	3	30	37	111
Conference	T12	1200	8	40	49	392
TOTAL						2854

Table A1.2 Estimated Foss lighting load, excluding switch room

	Lighting load
Hours per day	4
Days per week	5
Week per year	52
Total number of hours	1040
Typical circuit load (W)	1082
Annual consumption (kWh)	1125.28
Monthly consumption (kWh)	93.77
Daily consumption (kWh)	4.33

Table A1.3 Foss electrical base load and heating demand

	Daily (kW)	Monthly (kW)	Months	Annual (kW)
Winter baseload	35.3	25416	5.5	139788
Summer baseload	17.28	12441.6	6.5	80870.4
Winter heating	18.02	12974.4	5.5	71359.2
Winter baseload (no heating)	17.28	12441.5	5.5	68428.8
				220658.4

Table A1.4 Analysis of energy savings from using a heat pump at Foss

Annual heating load (kW)	Annual energy demand by heat pump, COP = 3.2 (kW)	Annual energy saving (kW)	CO_2 emission factor for electricity (kg/kW)	Annual emissions saving (tCO_2)	Annual cost saving, assuming £0.07 per kW (£)
71359	22300	49059	0.523	25.658	3,434

Note: The existing heat pump servicing the control room is assumed to have a low COP and is ignored in this calculation.

Table A1.5 Analysis of energy savings from using a gas boiler at Foss

Annual heating load (kW)	Annual emissions from electric heating (tCO_2)	Annual energy demand by gas boiler, 90% efficient (kW)	CO_2 emission factor for 1 kW gas (kg/kW)	Annual emissions saving from changing to gas boiler (tCO_2)	Annual cost saving, assuming gas cost £0.04 per kW (£)
71359	37.321	79288	0.19	22.256	1824

Appendix 2 - Crossens

Crossens fuel oil consumption

Table A2.1 Estimated boiler consumption and emissions at Crossens

Weekly boiler consumption (gallons)	200
Weekly consumption (litres)	910
Fuel cost (£/l)	0.46
Weekly operating cost	418.60
CO_2 conversion factor for diesel fuel (kg/l)	2.63
Emissions per week (tCO_2)	2.393
Annual running weeks	22
Annual consumption (l)	20020
Annual running cost (£)	9209
Annual CO_2 emissions (tCO_2)	52.65

Table A2.2 Estimated diesel pump consumption and emissions at Crossens, for January – December 2007. Calculations here use a fuel cost of £0.46 per litre and a CO_2 conversion factor of 2.63 kg/l, as in Table A2.1. The diesel pumps are test-run for 15 minutes each month.

Pump →	M13 Pools	M3	M4 Back Drain	M10 Back Drain	M13 Sluice	Total
Hours run / year	63		54	49	60	
Consumption rate (gallons/hr)	7-9	7-9	5-7	5-7	7-9	
Average consumption (gallons/hr)	8	8	6	6	8	
Annual consumption (gallons)	504	0	324	294	480	
Annual consumption (l)	2291	0	1473	1337	2182	7283
Annual running cost (£)	1054	0	678	615	1004	2296
Annual CO_2 emissions (t)	6.026	0.000	3.874	3.515	5.739	13.128

Crossens Electrical Consumption

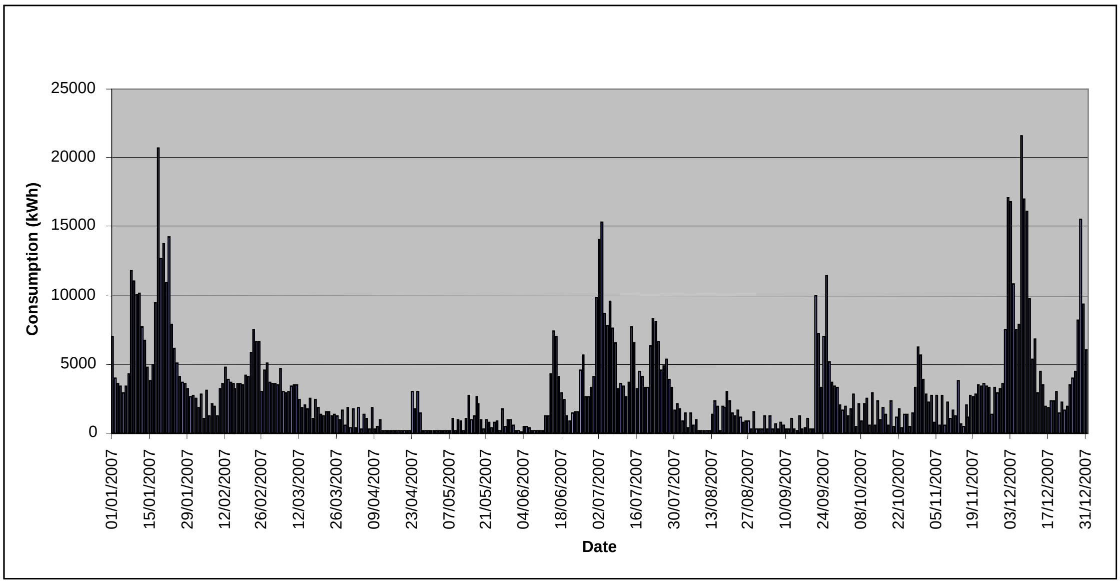


Figure A2.1 Daily electrical consumption at Crossens, 1 Jan – 31 Dec 2007

The following graphs demonstrate the pattern of electrical consumption across a sample of periods in 2007. Consumption varies considerably and there is no clear pattern. Site base load due to control systems is approximately 7 kW.

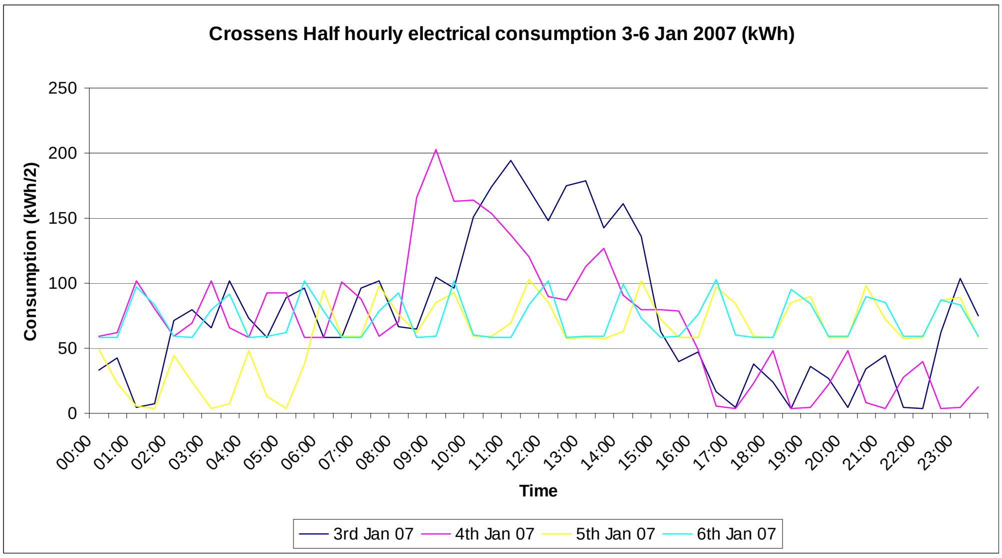


Figure A2.2 Half hourly electrical consumption at Crossens 3 – 6 January 2007, demonstrating pumping activity

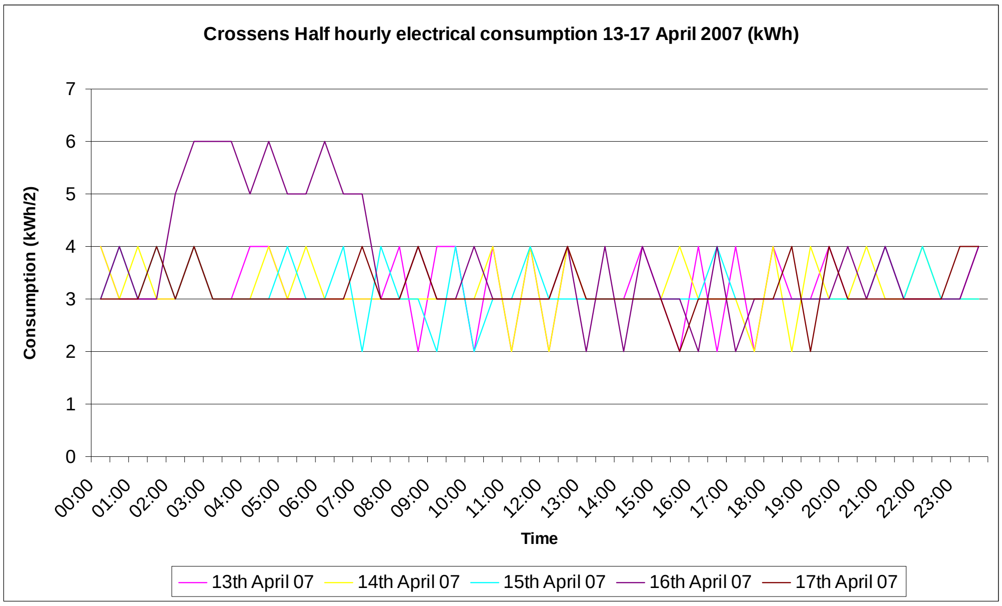


Figure A2.3 Half hourly electrical consumption at Crossens, 13 – 17 April 2007, demonstrating base load consumption

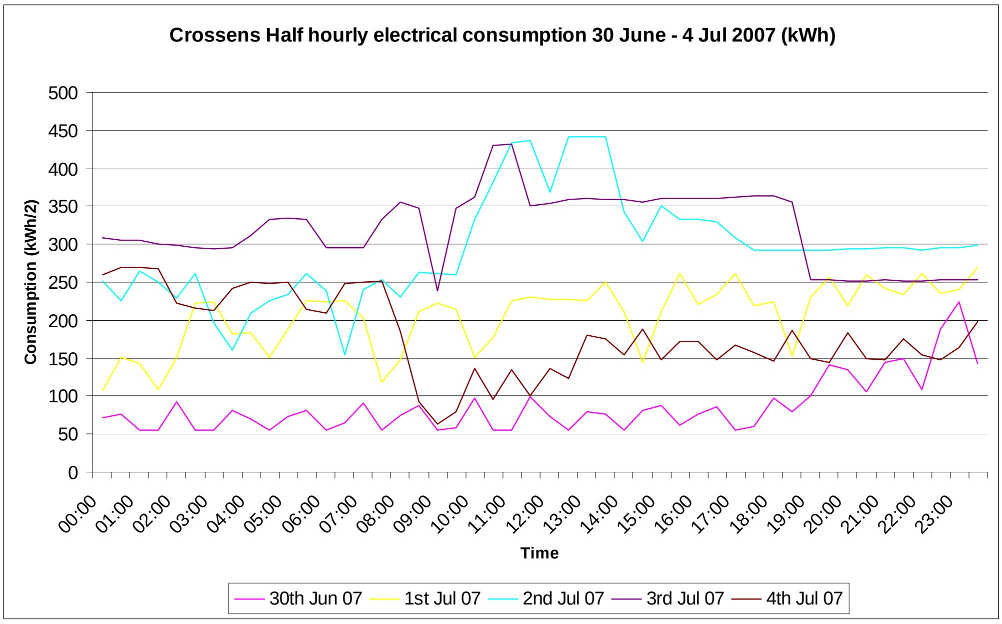


Figure A2.4 Half hourly electrical consumption at Crossens, 30 June – 4 July 2007, demonstrating pumping activity

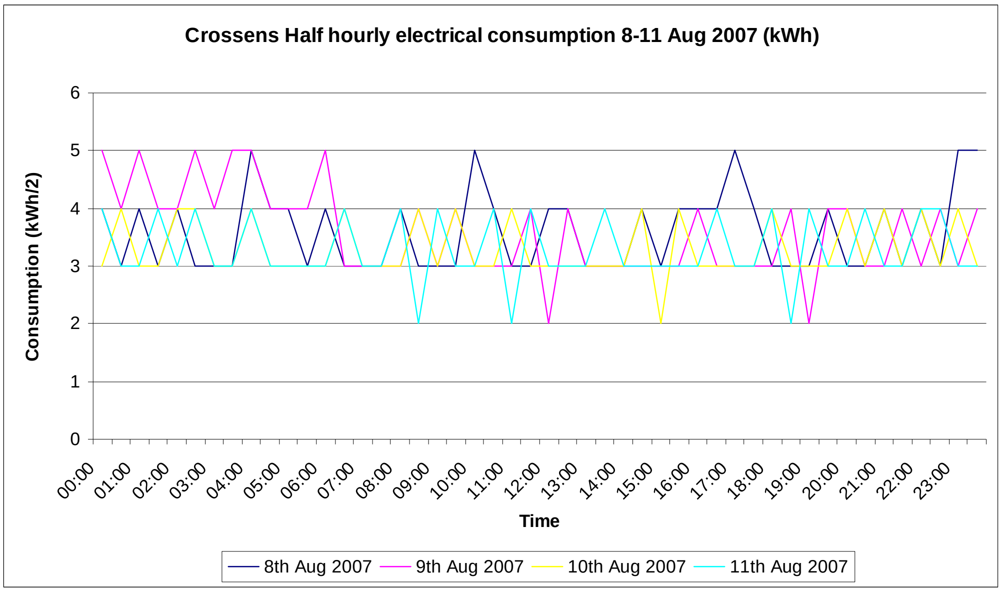


Figure A2.5 Half hourly electrical consumption at Crossens, 8 – 11 August 2007, demonstrating base load consumption

Table A2.3 Crossens pumps running hours (2007)

Pump (*where D = diesel powered*)	Hours run in 2007
M10 Back Drain	49
M4 Back Drain	50
M5 Back Drain	63
M9 Back Drain	135
M8 Back Drain	164
M7 Back Drain	526
M6 Back Drain	2379
M1 Three Pools (D)	63
M3 Three Pools	168
M2 Three Pools	379
M13 Sluice (D)	60
M11 Sluice	279
M12 Sluice	392
M15 supplementary	729
M14 supplementary	2131
M16 supplementary	2428

Figure A2.6 Crossens external Sluice pumps

Table A2.4 Set points for Crossens pump controls

Date 24-Jan-08

Sluice Setpoints			
	Metres		Metres
Winter upper level	1.829	Summer upper level	1.830
Winter lower level	1.100	Summer lower level	1.530
Winter duty start	1.370	Summer duty start	1.770
Winter Asst 1 start	1.470	Summer Asst 1 start	1.790
Winter Asst 2 start	1.570	Summer Asst 2 start	1.800
Winter Asst 3 start	1.700	Summer Asst 3 start	1.830
Winter Asst 4 start	1.830	Summer Asst 4 start	1.890
Winter high level	1.900	Summer high level	1.900
Winter Asst 4 stop	1.570	Summer Asst 4 stop	1.730
Winter Asst 3 stop	1.470	Summer Asst 3 stop	1.680
Winter Asst 2 stop	1.370	Summer Asst 2 stop	1.710
Winter Asst 1 stop	1.100	Summer Asst 1 stop	1.630
Winter duty stop	1.100	Summer duty stop	1.630
Winter low level	0.762	Summer low level	0.762
Winter low low level	0.700	Summer low low level	0.700

Back Drain Setpoints			
	Metres		Metres
Winter upper level	-0.500	Summer upper level	0.000
Winter lower level	-1.510	Summer lower level	-0.650
Winter duty start	-1.250	Summer duty start	-0.680
Winter Asst 1 start	-1.100	Summer Asst 1 start	-0.660
Winter Asst 2 start	-0.950	Summer Asst 2 start	-0.640
Winter Asst 3 start	-0.800	Summer Asst 3 start	-0.630
Winter Asst 4 start	-0.650	Summer Asst 4 start	-0.620
Winter high level	-0.400	Summer high level	0.000
Winter Asst 4 stop	-0.900	Summer Asst 4 stop	-0.850
Winter Asst 3 stop	-1.050	Summer Asst 3 stop	-0.830
Winter Asst 2 stop	-1.220	Summer Asst 2 stop	-0.800
Winter Asst 1 stop	-1.270	Summer Asst 1 stop	-0.780
Winter duty stop	-1.370	Summer duty stop	-0.750
Winter low level	-1.500	Summer low level	-1.500
Winter low low level	-1.570	Summer low low level	-1.570

Three Pools Setpoints			
	Metres		Metres
Winter upper level	1.831	Summer upper level	1.850
Winter lower level	1.100	Summer lower level	1.530
Wint clsd duty start	1.470	Summ clsd duty start	1.670
Wint clsd asst start	1.700	Summ clsd asst start	1.730
Wint clsd high level	1.900	Summ clsd high level	1.900
Wint clsd asst stop	1.370	Summ clsd asst stop	1.600
Wint clsd duty stop	1.100	Summ clsd duty stop	1.530
Wint clsd low level	0.762	Summ clsd low level	0.762
Wint clsd low low	0.700	Summ clsd low low	0.700
Wint open duty start	1.620	Summ open duty start	1.810
Wint open asst start	1.770	Summ open asst start	1.870
Wint open high level	1.900	Summ open high leve	1.900
Wint open asst stop	1.220	Summ open asst stop	1.680
Wint open duty stop	1.100	Summ open duty stop	1.750
Wint open low level	0.762	Summ open low level	0.762
Wint open low low	0.700	Summ open low low	0.700
3P link t'hold clsd	1.670	BD link t'hold	0.000
3P link t'hold open	1.770		

Appendix 3 - Gronant

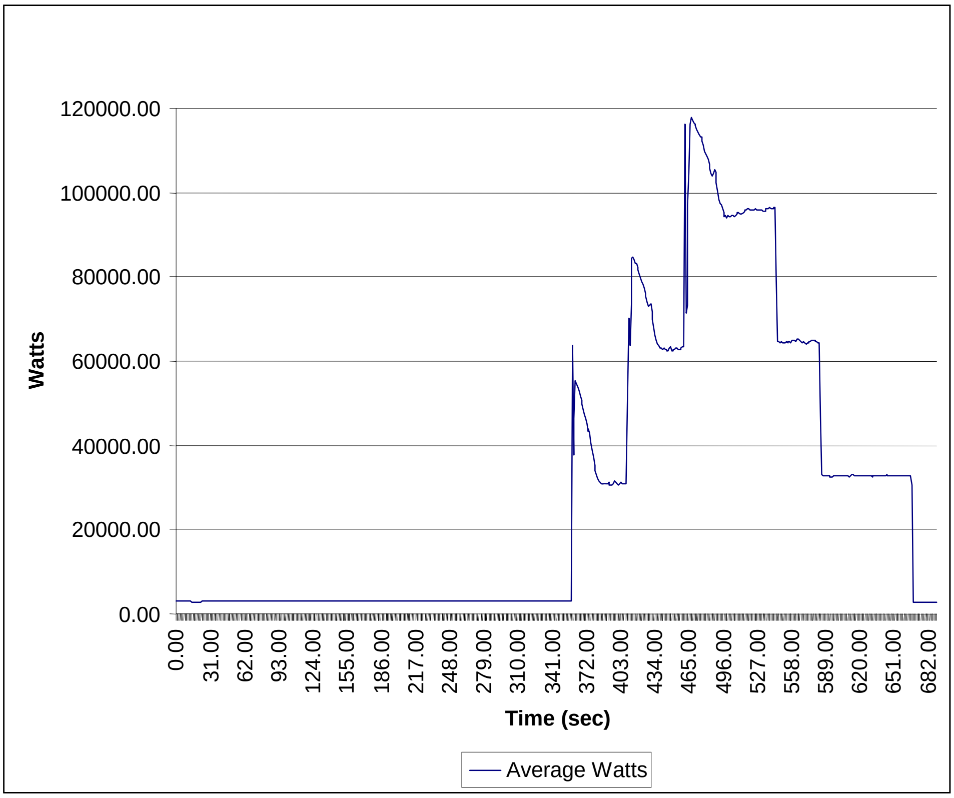


Figure A3.1 Sample reading of electrical power absorbed at Gronant, due to pumps P1 – P3 being sequentially switched on

Table A3.1 Wind turbine costs and carbon savings for Gronants pumping station

Turbine manufacturer	Swift	Proven	Proven	Proven	Proven (25m mast)
kW rating	1.5	2.5	6.15	15	15
kWh Gronants (10m)	1500	4380	10,512	26,280	35,040
Price (£)	10,000	11,000	22,500	50,000	50,000
Annual saving (£)	98	285	683	1708	2278
ROC value per year (£)	60	175	420	1051	1402
Total value per year (£)	158	460	1104	2759	3679
Payback period	63	24	20	18	14

(years)					
Annual carbon saving (tCO_2)	1	2	5	14	18

Department for Business Enterprise and Regulatory Reform (BERR) wind speed database:
http://www.berr.gov.uk/energy/sources/renewables/explained/wind/windspeed-database/page27326.html

Appendix 4 - Thamesmead

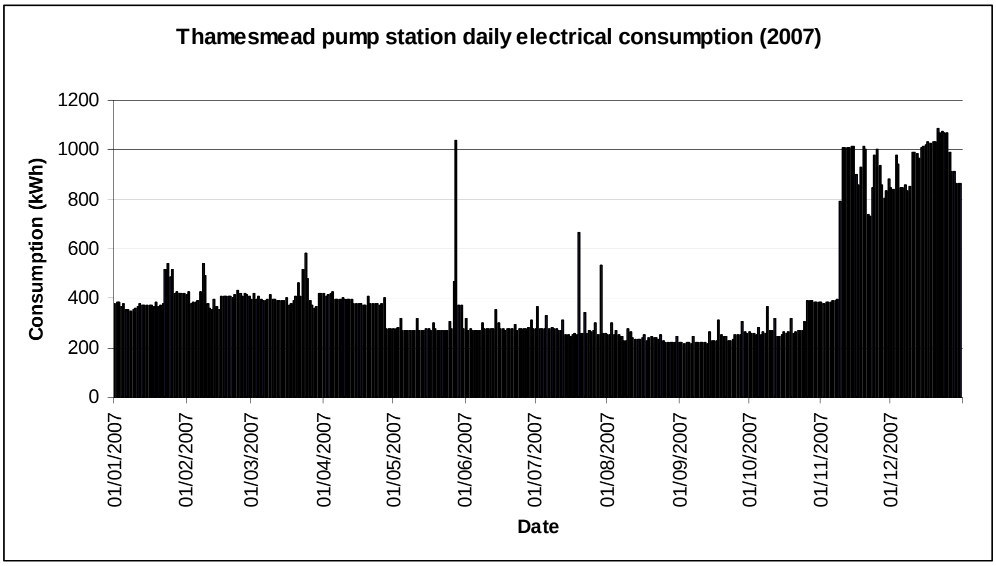


Figure A4.1 Daily electrical consumption at Thamesmead Lake 4, January – December 2007

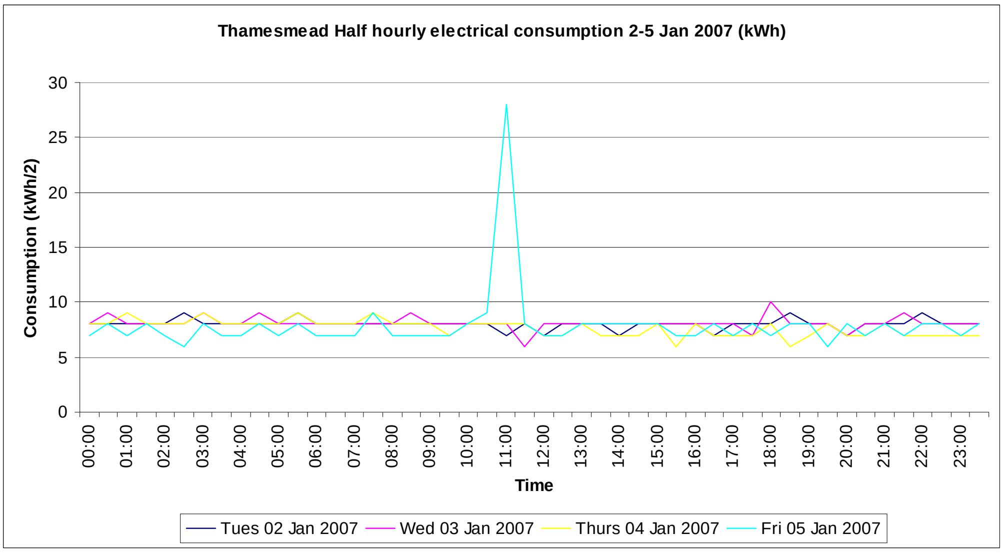


Figure A4.2 Half hourly consumption at Thamesmead Lake 4, 2 – 5 January 2007. Winter base load is estimated at 16.7 kW.

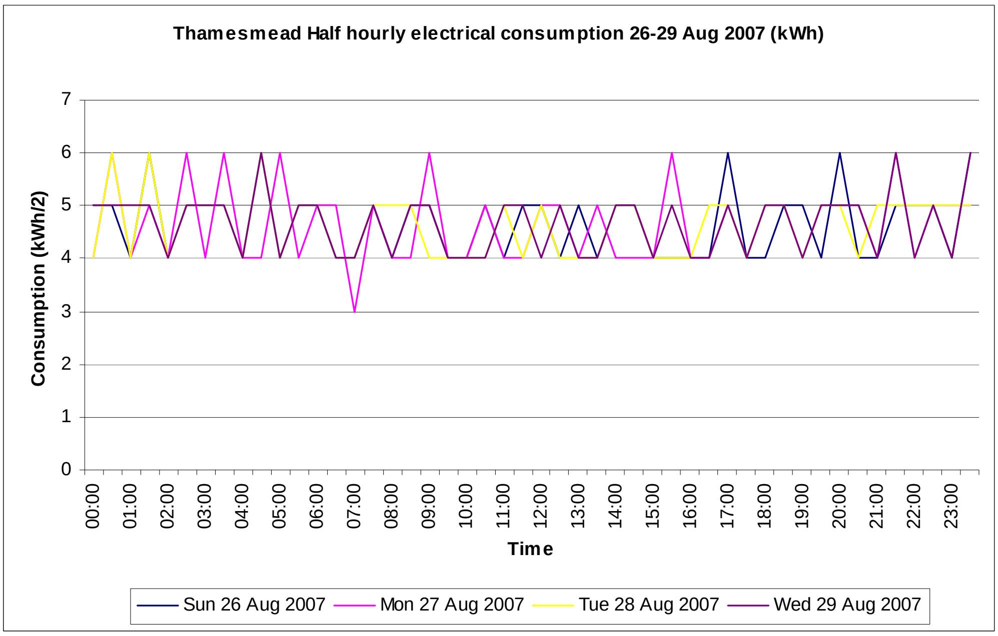


Figure A4.3 Half hourly consumption at Thamesmead Lake 4, 26 – 29 August 2007. Summer base load is estimated at 11.4 kW.

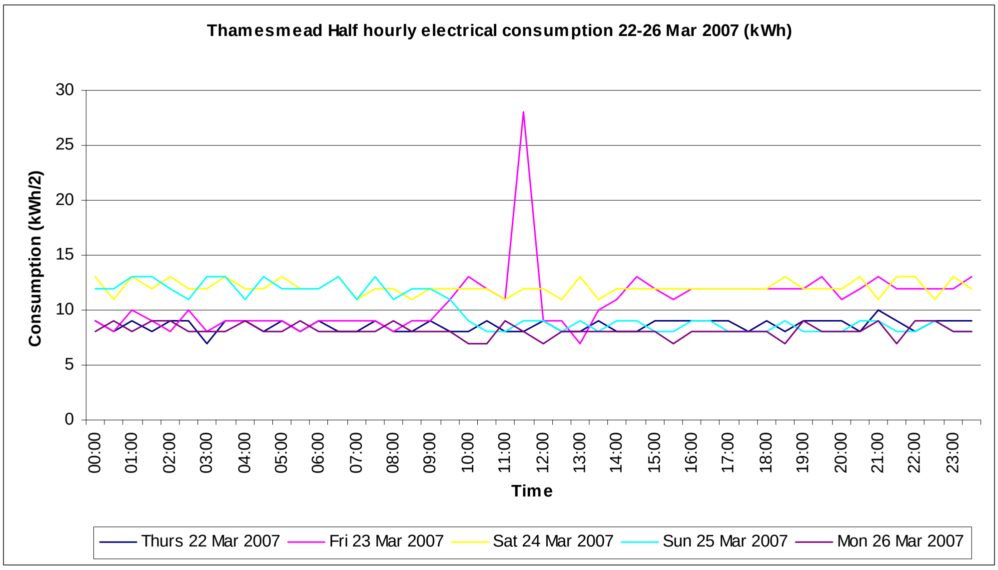


Figure A4.4 Half hourly consumption at Thamesmead Lake 4, 22 - 26 March 2007. Did the contractors turn the heating up on Friday and then forget to turn it back down again?

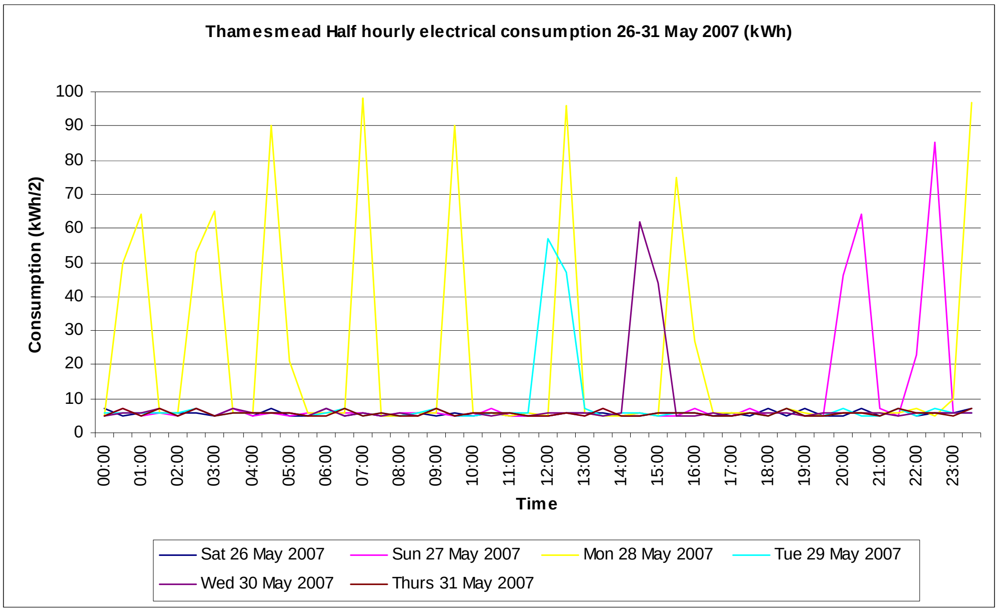


Figure A4.5 Half hourly consumption at Thamesmead Lake 4, 26 – 31 May, showing pumping activity

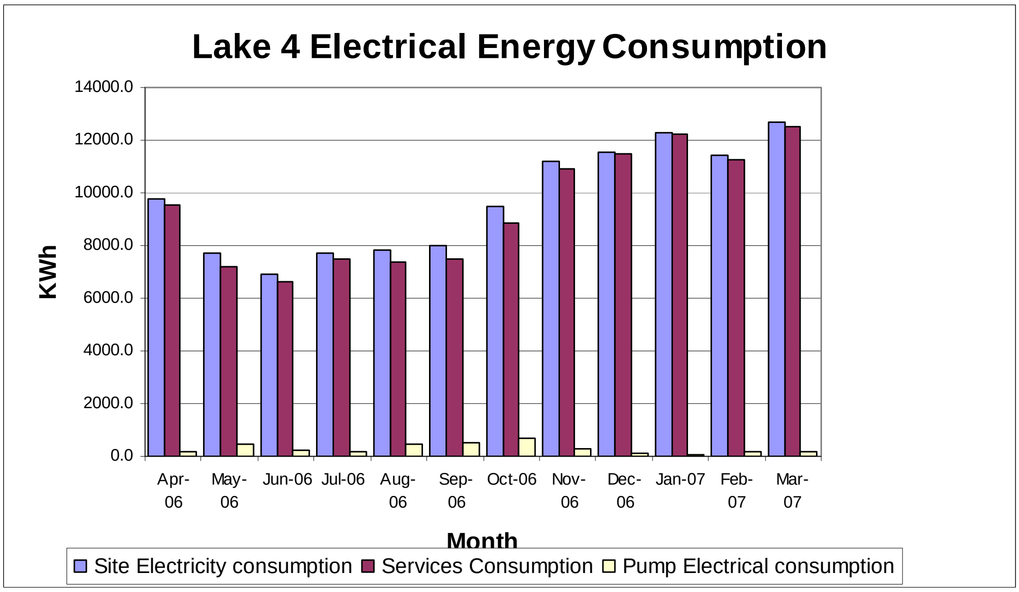


Figure A4.6 Electricity consumption at Thamesmead Lake 4, April 2006 – March 2007

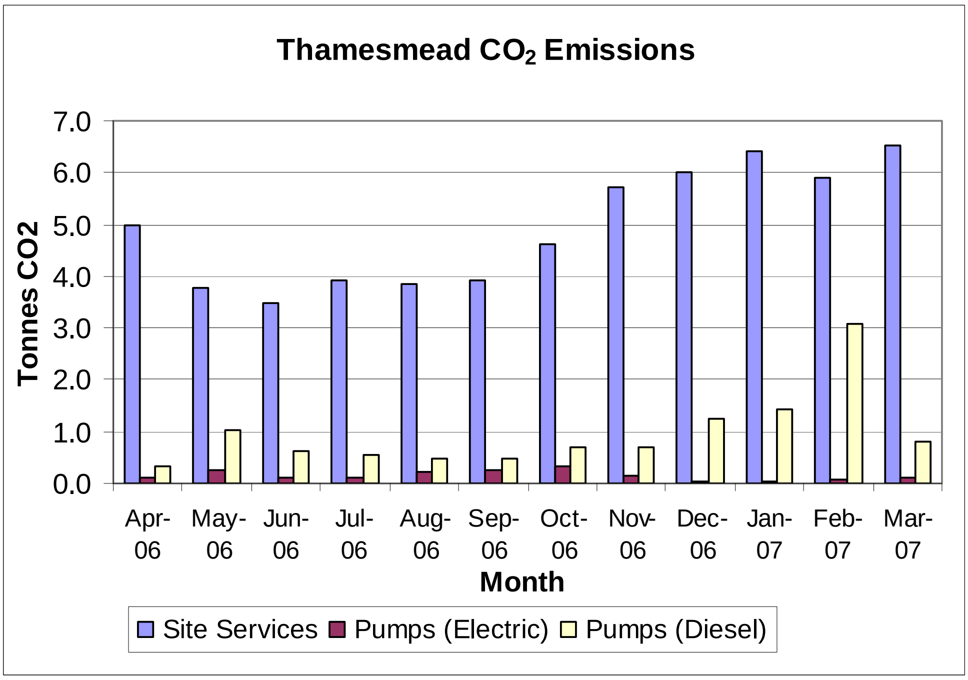


Figure A4.7 CO_2 emissions from Thamesmead Lake 4, April 2006 – March 2007

Appendix 5 – Union (Rye)

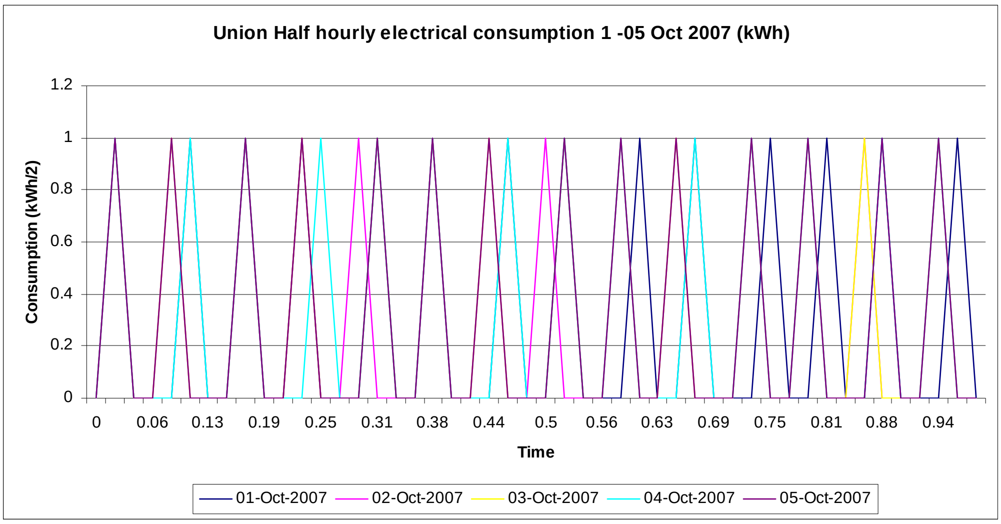


Figure A5.1 Half hourly consumption at Union, 1 – 5 October 2007. Winter base load is estimated at 0.67 kW whilst summer base load is estimated at 0.58 kW.

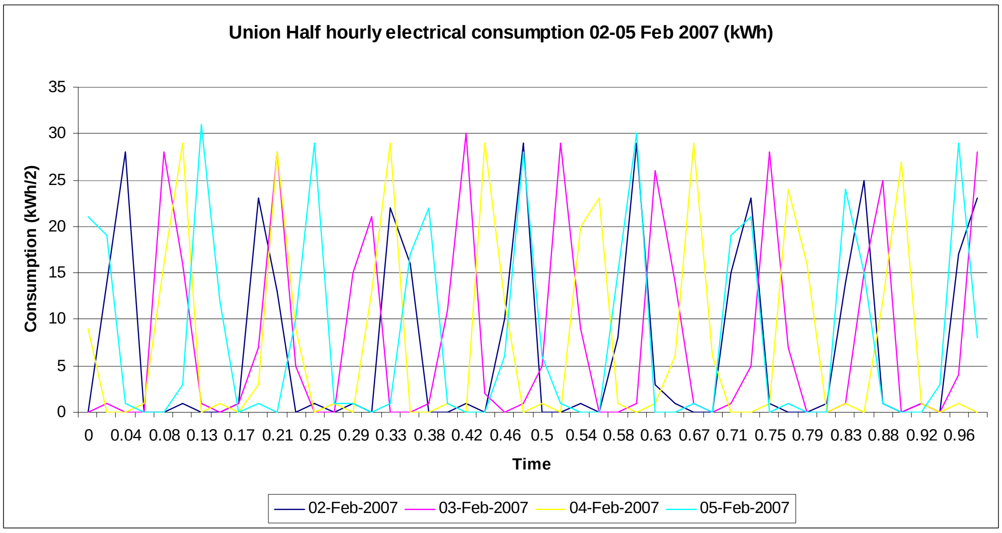


Figure A5.2 Half hourly consumption at Union, 2 – 5 February 2007 demonstrating pumping activity

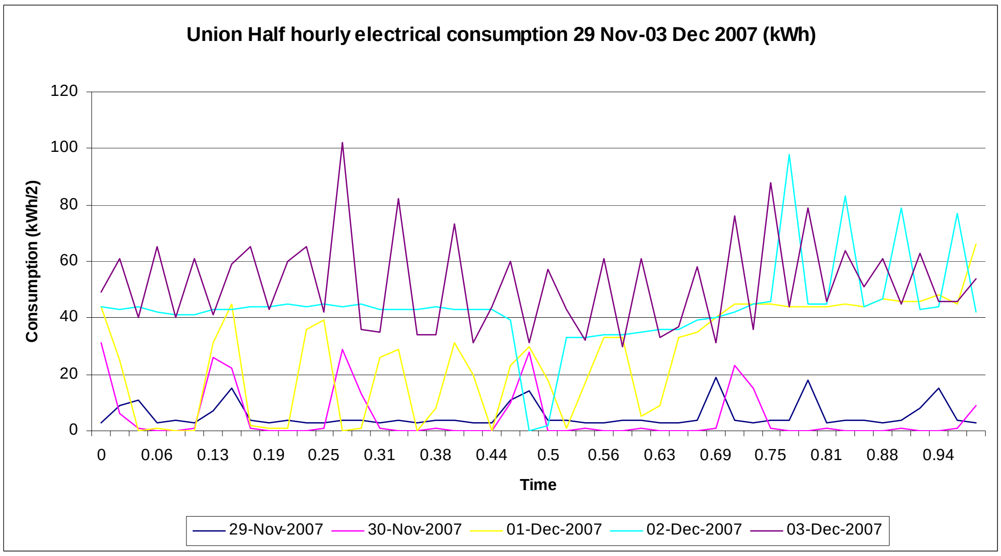


Figure A5.3 Half hourly consumption at Union, 29 November – 03 December 2007 demonstrating pumping activity

Appendix 6 – West Sedgemoor

No information available.

Appendix 7 - Kennet

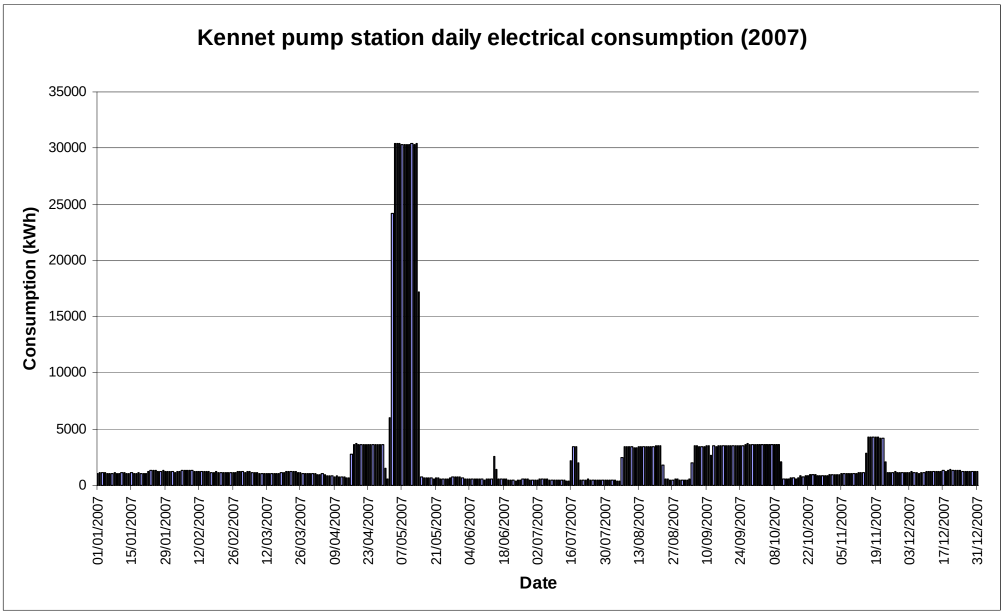


Figure A7.1 Daily electricity consumption at Kennet, January – December 2007. The average winter base load is estimated at 48.6 kW, whilst the average summer base load is estimated at 22.5 kW.

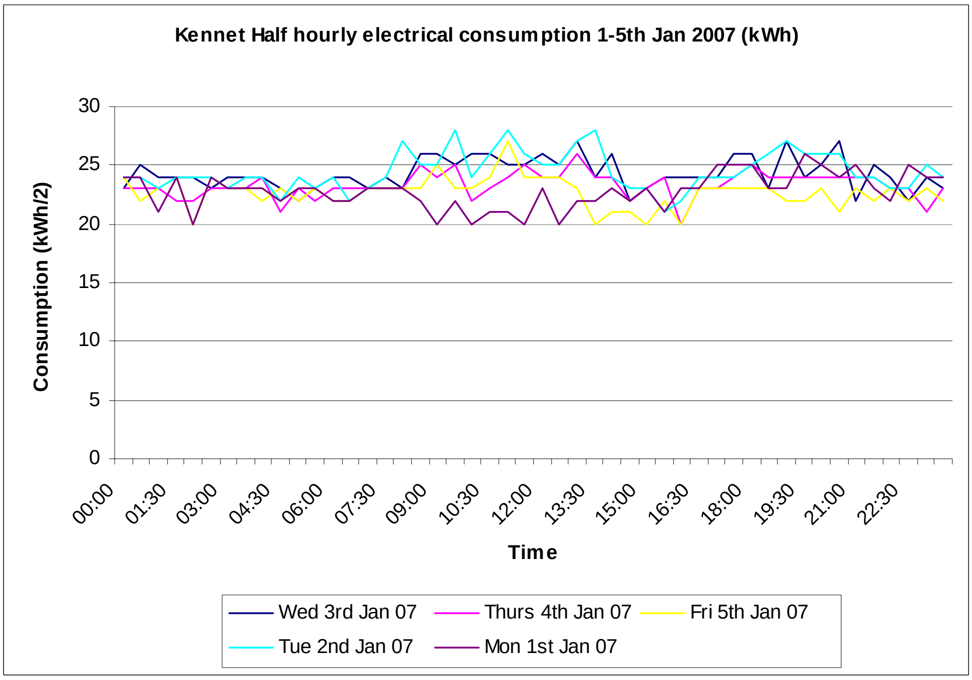


Figure A7.2 Half hourly consumption at Kennet, 1 – 5 January 2007

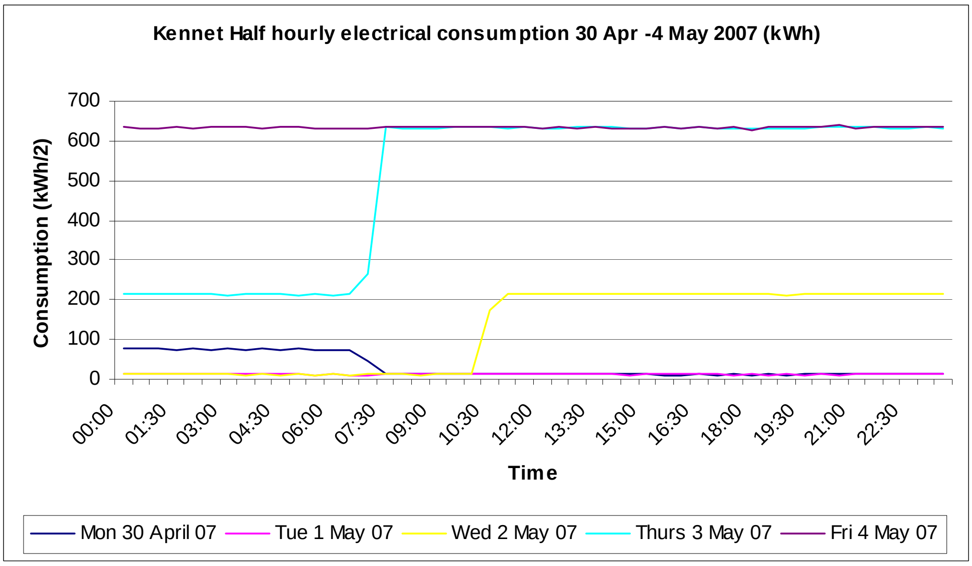


Figure A7.3 Half hourly consumption at Kennet, 30 April – 4 May 2007, showing pumping activity

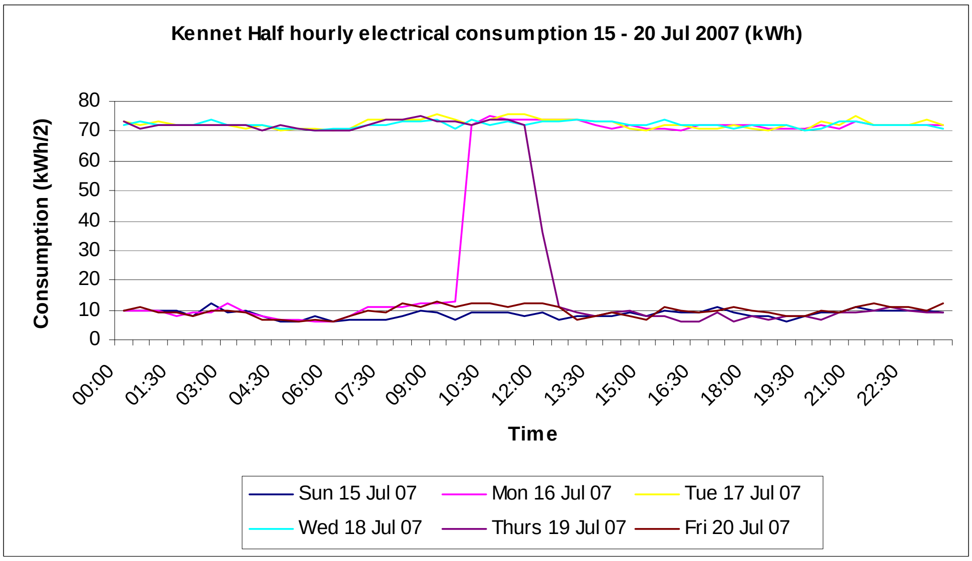


Figure A7.4 Half hourly consumption at Kennet, 15 – 20 July 2007, showing pumping activity

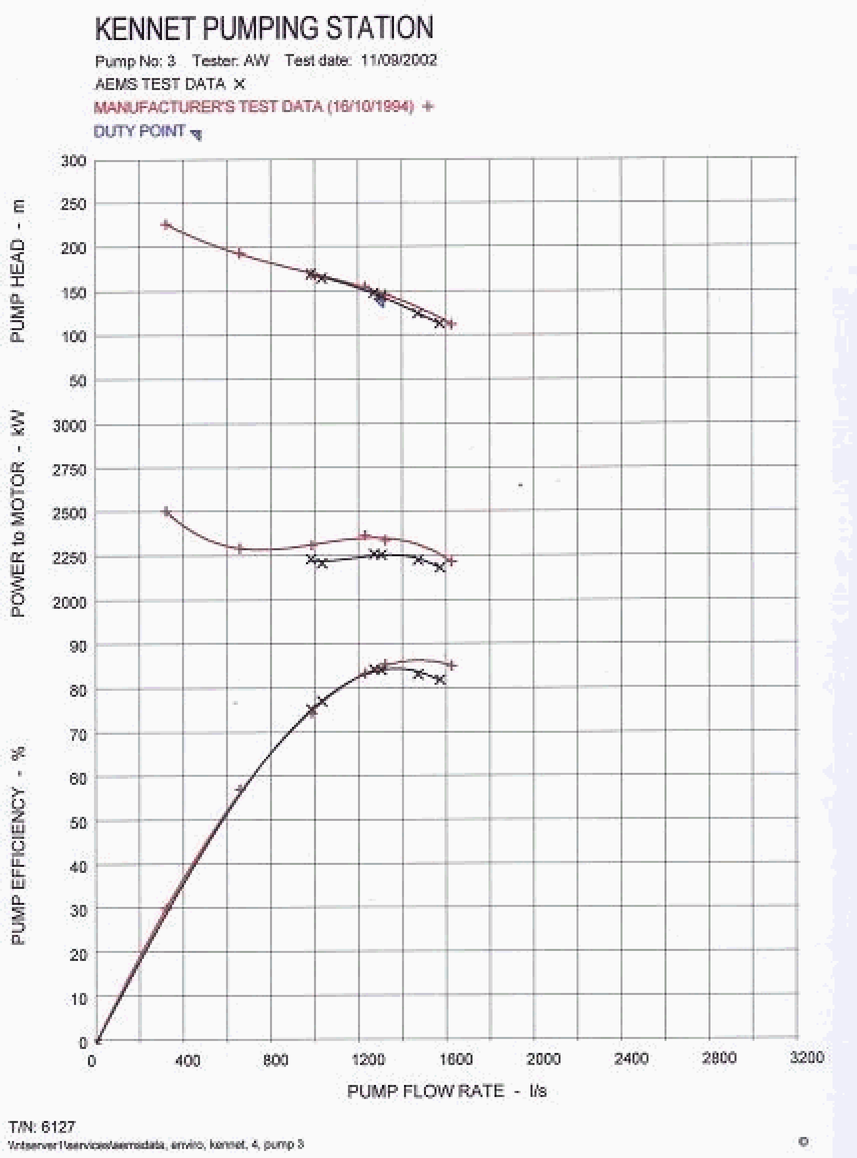


Figure A7.5 Kennet Pump 3 performance curve

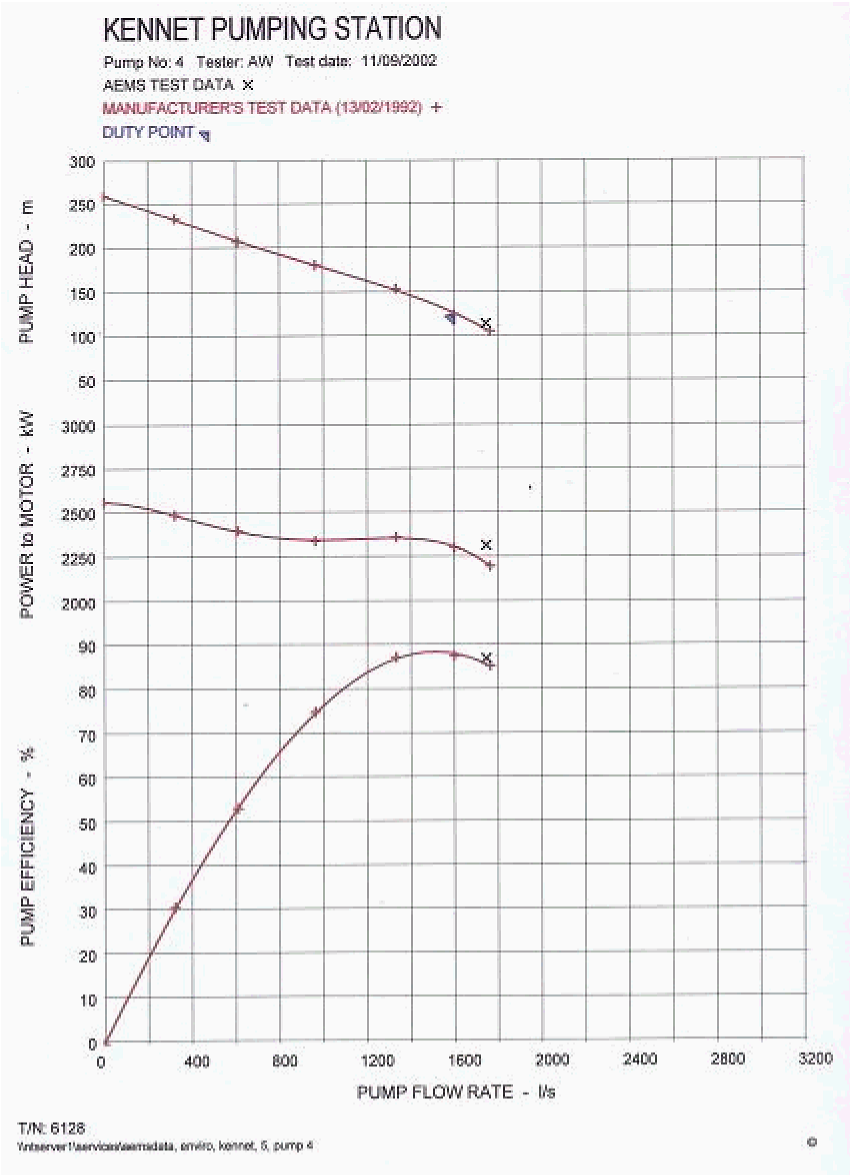


Figure A7.6 Kennet Pump 4 performance curve

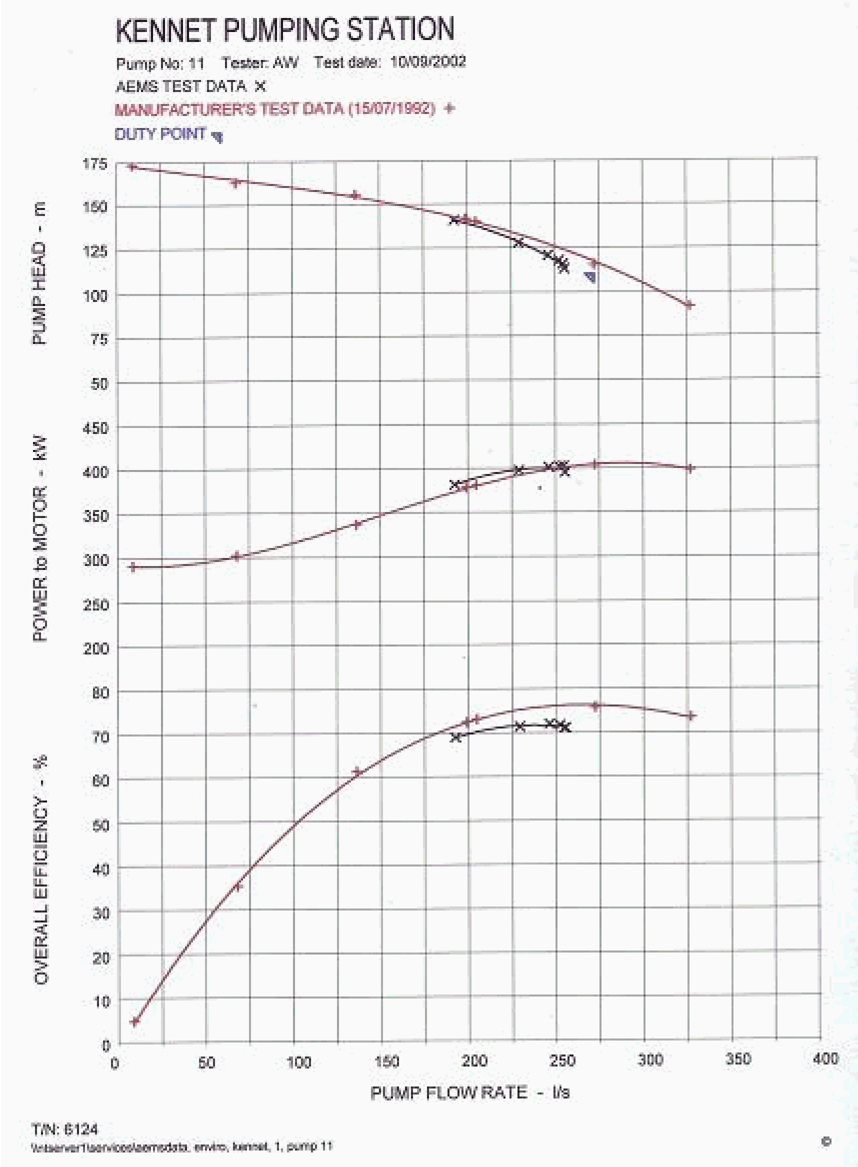


Figure A7.7 Kennet Pump 11 performance curve

FLOWSERVE PUMP DIVISION Newark Operations		PERFORMANCE TEST CURVE	
Customer	THE ENVIRONMENT AGENCY	Order No.	G432881/0010
Customer Order No.	011006996	Serial No.	432881-0010-01
Customer Item No.	1	Pump Size	QT20EKH/2

DUTY CONDITIONS					
Flowrate	979 m³/h	Total Head	110.4 m	Speed	1445 rpm
Specific Gravity	1.00	Efficiency	84.06 %	Impeller Diameter	414 mm

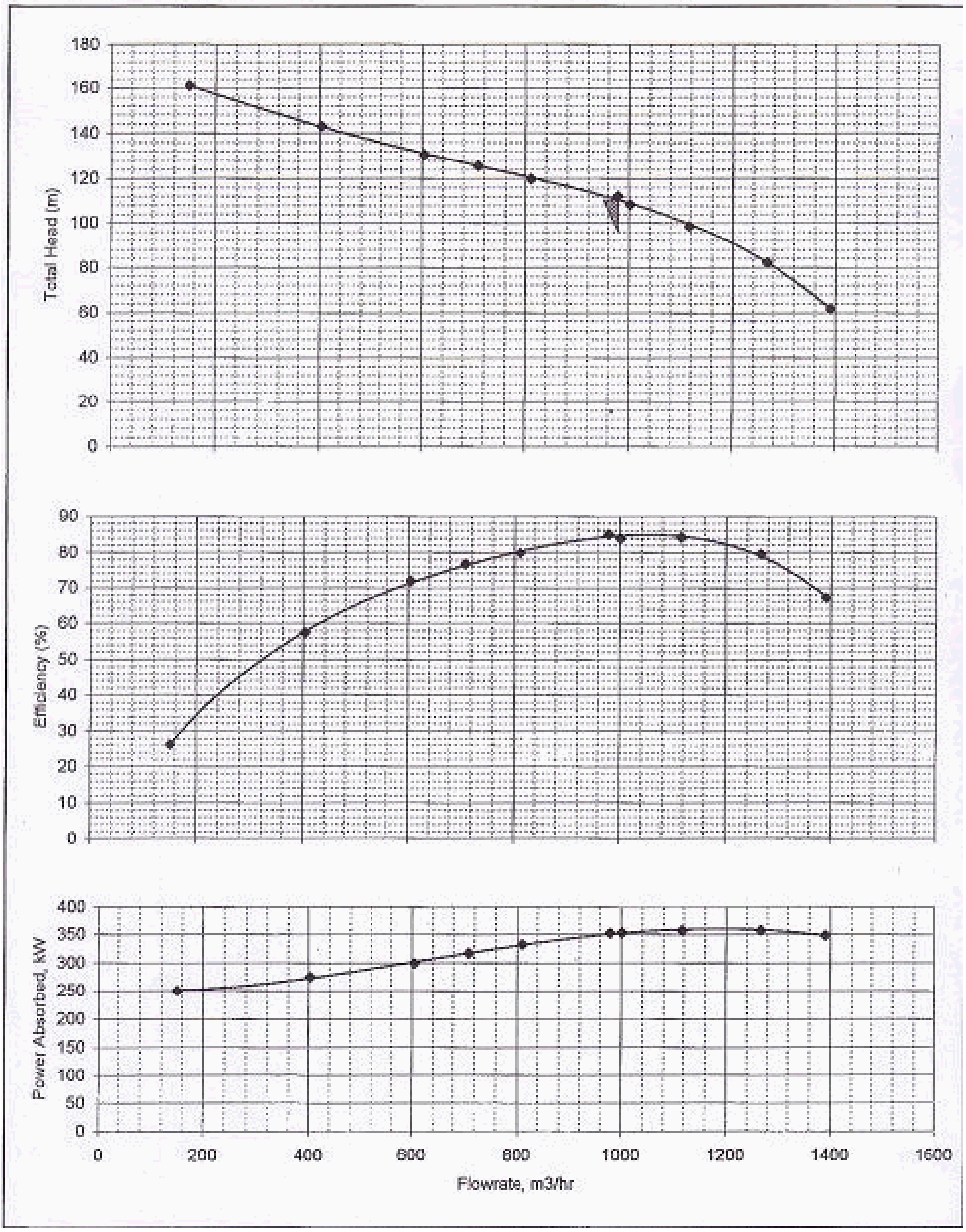


Figure A7.8 Kennet Pump 13 performance curve

caprari pumping power

Technical data

COMPANY WITH QUALITY SYSTEM CERTIFIED BY DNV =ISO 9001/2000=

E10S64/4B + MAC10150-8V

Requested data

Flow	0 l/min
Head	0 m
Fluid	Clean Water
Pumpe type	Single head pump
No. of pumps	1

Operating pump data

Flow	
Head	
Shaft power	
Efficiency	%
Head H(Q=0)	172 m
Head loss in check valve	1.4 m
Discharge connection	DN150

Motor data

Frequency	50 Hz
Rated voltage	400 V
Nominal speed	2920 1/min
Number of poles	2
Rated power P2	110 kW
Rated current	207 A
Motor type	3~
Insulation class	Y
Degree of protection	IP 68

Operating limits

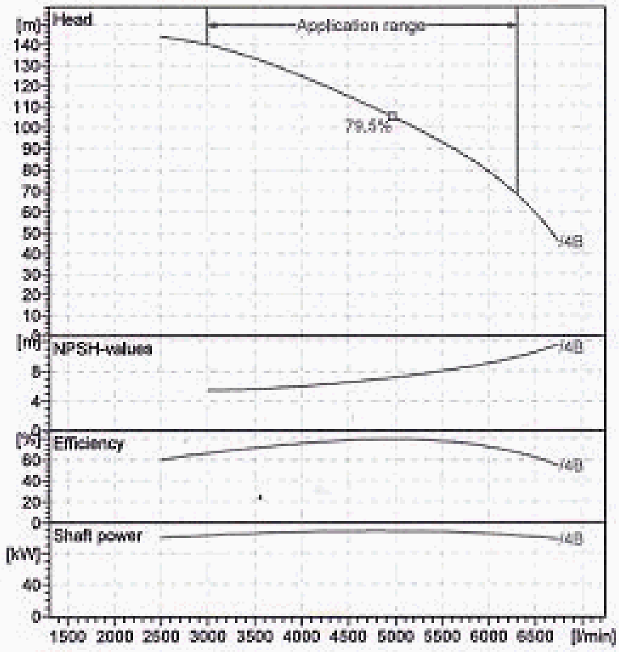
Starts per hour max.	6
Maximum temperature of pumped fluid	25 °C
Maximum content of solid	40 g/m³
Max. Density	998 kg/m³
Max. viscosity	1 mm²/s

General data

Weight	394 kg

Materials

PUMP CONSTRUCTION	-
Valve casing	Cast iron
Conical valve	Cast iron/Stainless steel
Suction casing	Cast iron
Stage casing	Cast iron
Shaft	Stainless steel
Impeller	Cast iron
Wear ring	Rubber
Strainer	Stainless steel
Cable guard	Stainless steel
Shaft coupling	Stainless steel
MOTOR CONSTRUCTION	-
Upper bracket	Cast iron
Lower bracket	Cast iron
Stator shell	Stainless steel
Shaft	Stainless steel
Seal ring	Steel/rubber
Sand guard	Rubber
Winding	Insulated copper
Thrust bearing	Michell type

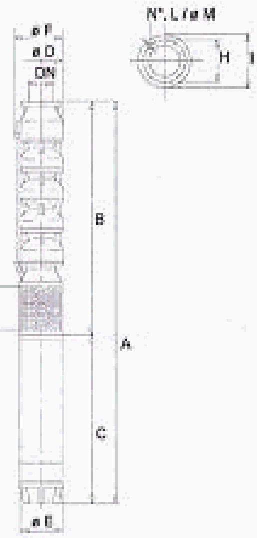


Operating data ISO 9906 GRADE 2

Q [l/min]	H [m]	P [kW]	Eff. [%]	NPSH [m]

Dimensions mm

A = 2740
B = 1145
C = 1595
D = 240
DN = 150
E = 242
F = 249
G = 198
H = 206
I = 234
L = 8
M = 16



Remarks:

Date	Page	Offer no.	Pos.no
2008-02-29	1		

Figure A7.9 Kennet Pumps 21 and 22 performance curves

Appendix 8 - Highbridge

Figure A8.1 Highbridge pumping station

We are The Environment Agency. It's our job to look after your environment and make it **a better place** – for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.

Published by:

Environment Agency
Rio House
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 0870 8506506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk