Calcutt Pumping Station

PUMP AUDIT SUMMARY REPORT

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Content

1 Introduction

This report summarises the key findings of the desktop and site system audit for Calcutt Pumping Station (PS). The review is based upon:

- data provided by Canal and River Trust (CRT);
- a preliminary site visit undertaken on 3rd June 2019;
- a site audit by Arcadis and Samatrix on 28th October 2019.

Pump testing was undertaken at the site visit and the following parameters measured:

- Power (using Fluke power meter);
- Flow rate (using the existing electromagnetic flow meter);
- Levels and dimensions (laser/tape measure).

2 System Description

2.1 Pumping Station

Calcutt PS is situated near Southam, Warwickshire, UK and comprises a single, fixed-speed submersible pump within a 2.4 m diameter wet well and is automatically controlled on level. Level probes are located within the in wet well and pressure transducers are provided for measurement of downstream and upstream canal water levels in the lower and upper pound.

The pump station intake is direct from the lower pound downstream of Calcutt Bottom Lock No.3 and the pump discharges to the upper pound, upstream of Calcutt Top Lock No.1. The inlet is submerged and has a bar screen, and there is no method of isolation provided.

The wet well and valve chamber are of concrete construction and are provided with steel open mesh covering. There are various lifting points are located around the pump station, leading to the canal edge, as all equipment transportation is done via the waterway.

Figure 1 – Pumping station

Valve chamber is 1.5 m diameter and houses the check valve and isolation gate valve for the rising main. The pump discharge pipework is DN250 cast iron/ductile iron and connects to a plastic rising main (assumed HPPE/HDPE). An electromagnetic flow meter is installed within a chamber located downstream of the valve chamber.

The power supply is 400 V, 3-phase with the 100 A mains incomer, metering and pump MCC located in a small, brick-built hut with a metallic, domed roof. It is reported that there is a history of phase imbalance at site and burnout, and that there is also an issue with discrimination and earthing (TT system).

Table 1 – Pump Details

Parameter	Description
Pumps	KSB KRTK 200-330/414 UG (Noted post installation impeller revision)
No. of Pumps	1
Duty Configuration	Duty Only
Rated Motor Output	41 kW
Impeller Diameter	unconfirmed
Drives	Fixed Speed (Star-Delta)
Pipework	DN250
Non-Return Valve	Swing Check
Wet Well Level Sensor	Probes
Wet Well Level	95 mAOD (estimated TWL)
Pump Level	93.4 mAOD (estimated pump centre line)

2.2 Rising Main

The pipework between the valve chamber and flow meter is assumed to be 250 mm OD HPPE (PE100) pipework based on site observations and approximate measurements; however, the actual pressure rating/SDR is currently unconfirmed.

It should be noted that at this results in a very high velocities, in excess of 7 m/s, in this section of pipework and consequently, combined with the DN200/DN250 pump station discharge pipework, high head losses. Velocities in excess of 3.5 m/s can cause increase the risk of damage due to hydraulic shock and erosion from the abrasive action of particles in the water.

The rising main itself is approximately 390 m in length and is reported to be 450 mm in diameter and is assumed as 450 mm OD HPPE (PE100) pipe based on site observations and approximate measurements; however, the actual pressure rating/SDR is currently unconfirmed. There are no reports of bursts arising since construction.

The rising main is reported to run behind the adjacent hedgerows/tree line as opposed to be routed along the towpath. The outfall is reported to be a submerged “hatchbox”, possibly inclusive of a weir outlet, but this is unconfirmed. There are no isolation valves present on the rising main.

Table 2 – Rising Main Details

Parameter	Description
Approx. Length	390 m
Pipe Diameter	450 mm OD
Discharge Level	100.13 mAOD (estimated design water level)
Pipe Material	HPPE/PE100 Black (assumed SDR17)
Pipe Roughness (k_s)	0.0125 mm (estimated)

2.3 Particular Issues

2.3.1 Pump Capacity

Calcutt PS is the last in the chain of a series of eleven pumping stations along the Grand Union Canal and the pump is reported to be over-capacity. The required peak flow rate is approximately 200 l/s; however, flow rates in excess of 250 l/s have been observed – this is verified by the SCADA readings (Figure 2).

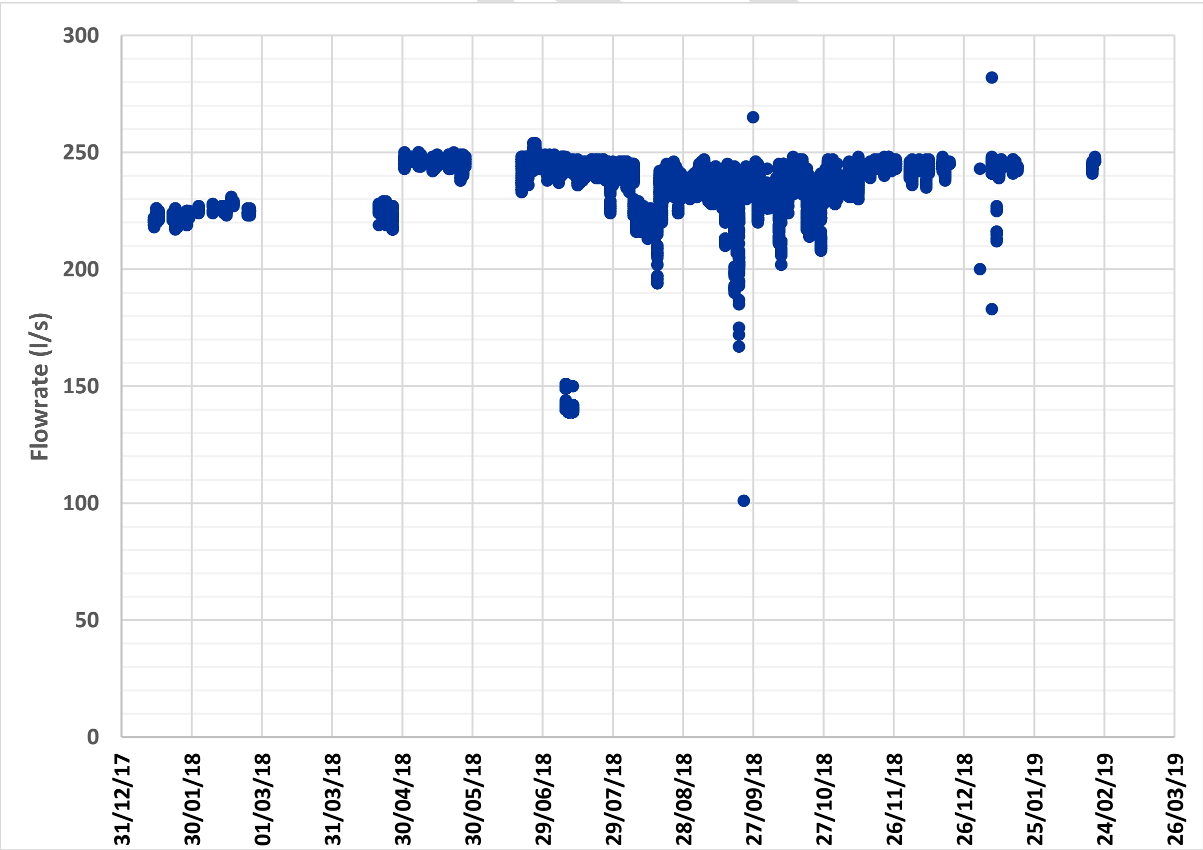


Figure 2 – Calcutt PS SCADA Flow Rate Data 2018/2019

The existing KSB Amarex pump was modified following its original installation in 2012. Originally it was thought that the bottom end had changed although KSB have confirmed the modification scope comprised a change of impeller only. It therefore does not operate as per the original pump curve.

Arcadis enquired with KSB Pumps and they confirmed that the pump was originally rated for 200 l/s @ 8.9m head. The impeller was changed in January 2012 with a larger diameter impeller although the trim diameter has not been recorded by KSB. Based on the KSB Pump Curves provided (see Appendix A) Arcadis provisionally assumed that a 300 mm diameter trim impeller.

The pump has a fixed speed operation, so it is not possible to reduce the flow rate without throttling its delivery valve. This would not be a recommended permanent solution as it would waste energy and potentially lead to wear/blockage issues at the valve.

One alternative, to pump replacement would be retrofit of a variable speed drive (VSD) This would allow operation at a lower flow rate (Figure 3); however, it cannot be confirmed as to it whether this would bring significant efficiency benefits, particularly since the actual pump performance curve/impeller size is unverified.

2.3.2 Resilience

It is reported that there is a history of phase imbalance at site and burnout, and that there is also an issue with earthing (TT system). The number of starts is limited to 5 per hour. This suggests that the earthing system design and electrical supply require further detailed assessment by an electrical contractor.

The provision of a second pump is preferred by CRT, to improve pumping resilience and potential flexibility of operation.

The existing pump wet well has a 2.4 m internal diameter, and it is unlikely that this size well could accommodate two submersible pumps since space is limited. Realistically, a new wet well and valve chamber would be needed for a two-pump arrangement and, provided there is sufficient space, the preference would be for a new pumping station to be constructed offline and connected into the existing rising main pipework downstream of the existing flow meter.

3 System Curves

A system curve has been derived for the single pump operation. The suction and delivery elevations, pipe roughness values and diameters have been based on estimations made following the site visits and from GIS software. Ratings of SDR11 and SDR17 were assumed for the 250 mm OD and the 450 mm OD PE100 pipework respectively in order to match the duty point for the pump test site data with a suitable approximation for the internal diameters.

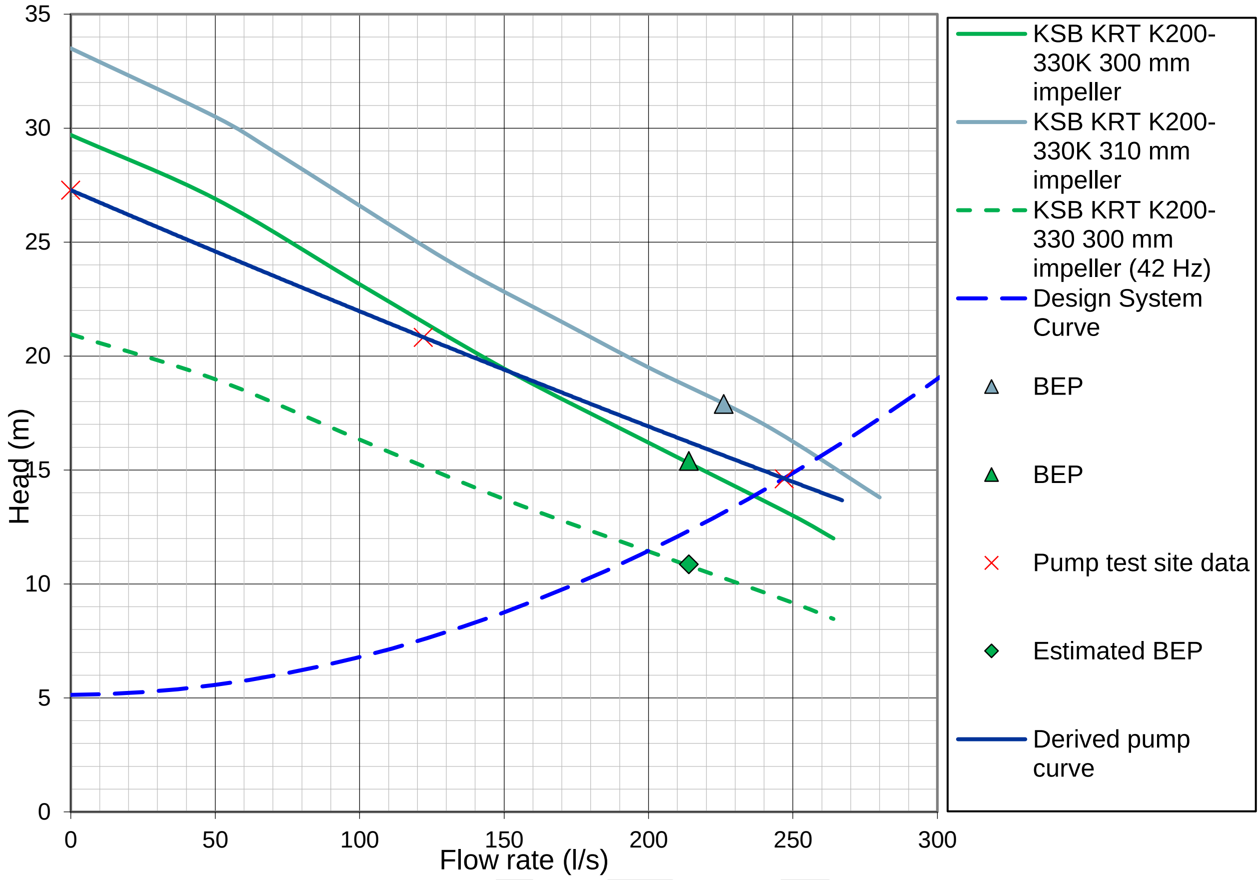


Figure 3 – Derived System Curve for Calcutt PS

The derived system curve and test data suggest an operating duty point of around 247 l/s at 14.8 m head which sits between the anticipated performance of a 300 mm and a 310mm diameter impeller.

As it can be seen from Figure 3, the data obtained during the site audit also indicates a variance in the closed valve head compared with the assumed 300 mm impeller KSB pump performance curve.

Possible reasons for the above observations include:

- Transient/fluctuating operating conditions (see Appendix D for site audit pump trend data)
- Data inaccuracies,
- Incorrect assumptions,
- Wet well hydraulic conditions,
- Pump/impeller wear or damage,
- Incorrect assumptions/data (e.g. pump model)
- Transient/fluctuating operating conditions (see Appendix D for site audit pump trend data).

4 Net Positive Suction Head (NPSH) and Submergence

NSPH calculations have been undertaken (Figure 4) and the results suggest that there is approximately between 3 m and 4 m margin, based on an assumed 300 mm impeller diameter KSB pump, between NPSH required (NPSHr) and NPSH available (NPSHa) at a 1.6 m submergence depth.

The NPSHa is considered to adequate and there is no reported evidence that cavitation currently exists.

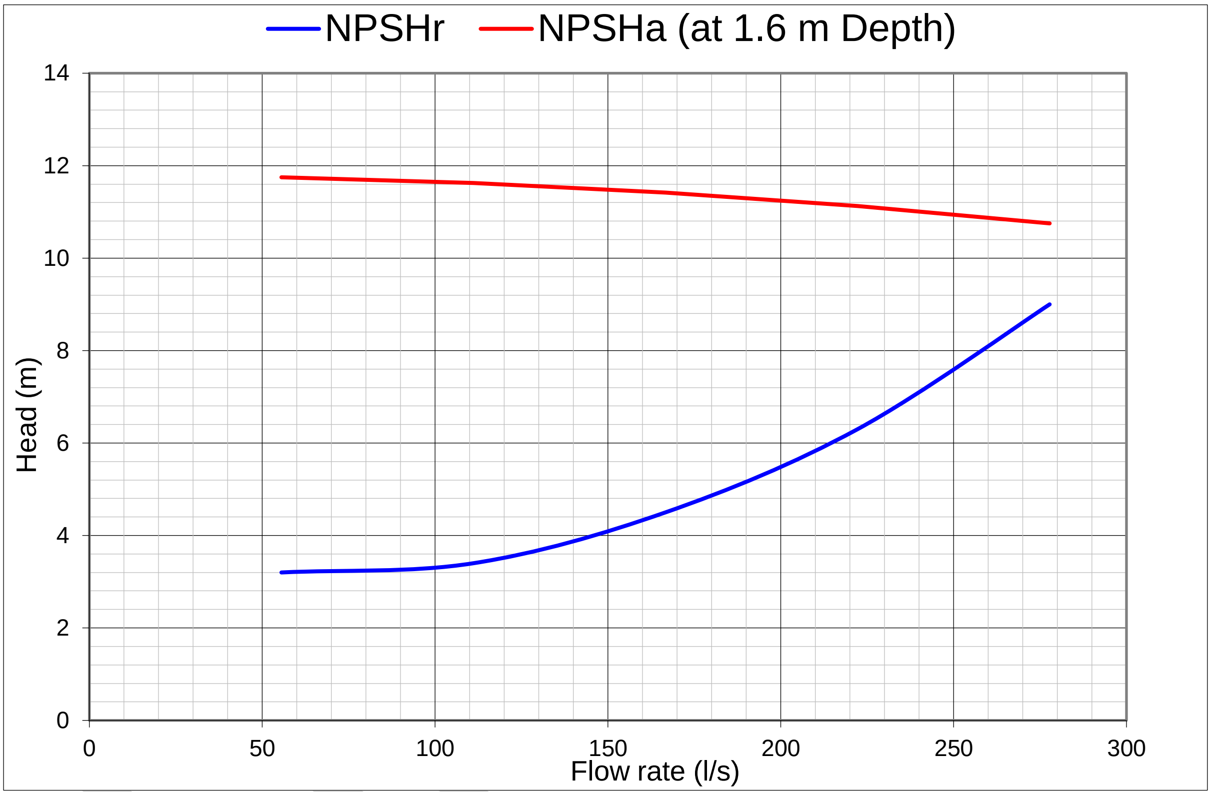


Figure 4 – NPSH Curves for KSB KRTK 200-330/414 UG pump

5 Energy Analysis

During the pump audit visit by Samatrix, a temporary "Fluke" power meter was connected at each individual pump starter compartment to record power into the fixed speed (star-delta) drives. From the measured power, flow and pressure data recorded, an analysis of pumping efficiency and the amount of energy needed to pump flows has been undertaken.

Table 3 summarises the measured input power, and derived efficiency and specific energy findings.

Installation of a suitably selected pump with high efficiency motor will provide improved efficiency and CO_2 reduction benefits, particularly as it would be operating at a lower flow rate of 200 l/s.

Table 3 – Input power, Efficiency and Specific Energy

Measured Flow rate (l/S)	Measured Power Factor	Measured power (kW)	Pump Efficiency	Specific energy (kWh/1000 m^3)	ENERGY CONSUMPTION (kWh per annum)
247	0.94	47	77%	52.3	203,693**
122*	0.94	43	59%	97	-

**partial closed valve*

***Baseline of 50% utilisation assumed, which equates to 3,894,696 m^3 per annum*

6 Potential Areas for Improvement

6.1 Pump Selection

The test data and derived system curve suggest a required design duty point of 200 l/s at 10.4 m head.

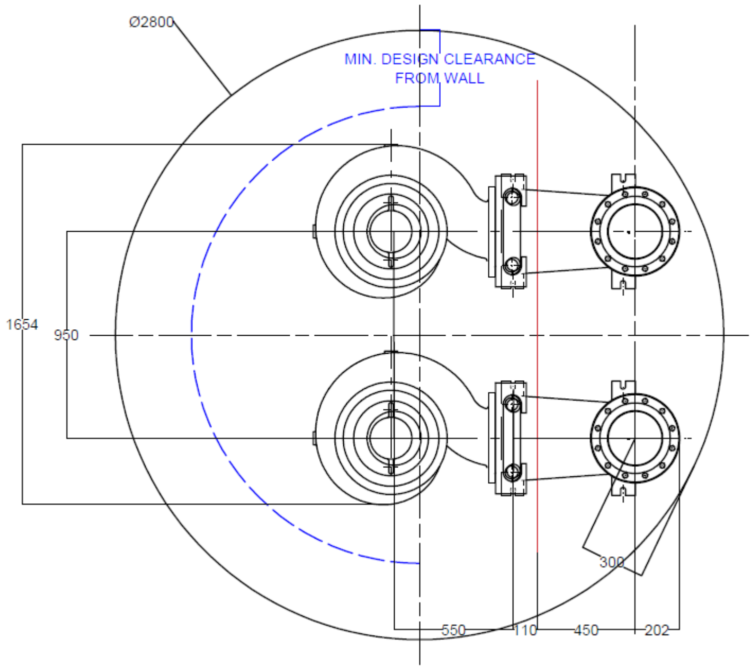
Arcadis has reviewed preliminary pump selections to assess the specific energy performance of the existing pumps and to investigate more energy efficient alternatives to the existing pumps.

If a duty only pump arrangement is adequate for canal operations, then the existing 2.4 m diameter wet well should be able to accommodate a single pump unit. However, should a duty/standby configuration be required for resilience, then a new wet well will need to be constructed.

Indications are that the Hidrostal duty/assist configuration should be able to fit within a 2.4 m diameter wet well (Figure 5) and 2No. Hidrostal duty/standby pump units should fit within a 2.8 m diameter wet well (Figure 6).

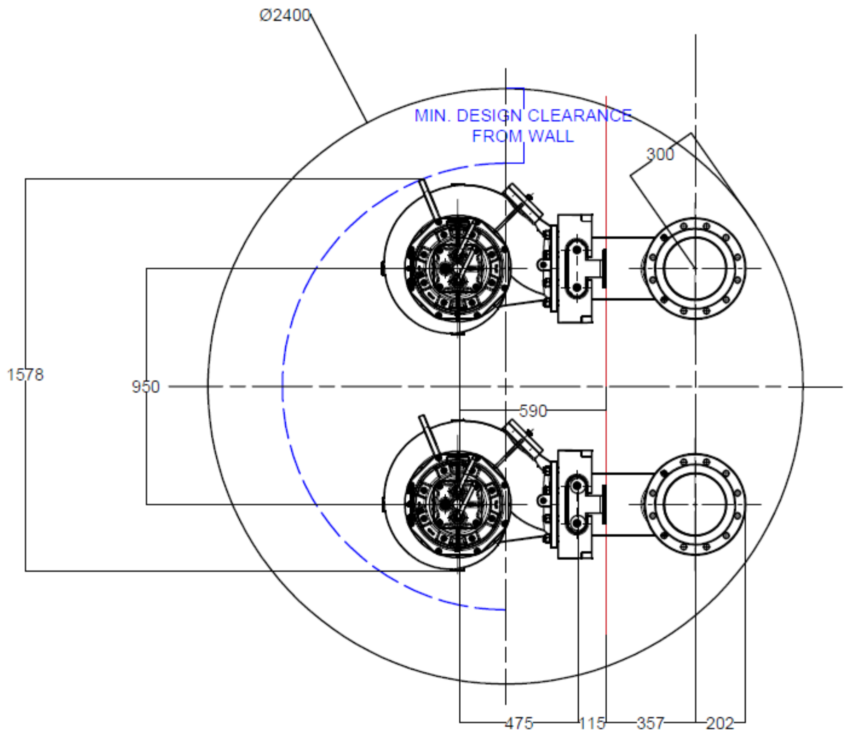
Xylem recommend a minimum wet well diameter 3.0 m for 2No. NP3202 MT pumps and 3.5 m for 2No. NP3202 LT pumps.

All cases, a larger valve chamber would be required to accommodate the two sets of pump discharge pipework and valves.



DUTY STAND BY
HIDROSTAL MODEL F10K HLT1 FE030X4 GSEK1AA

Figure 5 – Hidrostal F10K duty/standby configuration



DUTY ASSIST
HIDROSTAL MODEL E08U SLN1 EE020X4

Figure 6 – Hidrostal E08U duty/assist configuration

The preliminary Hidrostal pump selections would require DN200/DN250 discharge pipework and calculations have assumed that the pipework between the valve chamber and flow meter would be retained as existing (250 mm OD SDR11 HPPE), based on undertaking a minimal amount of additional work and modifications to the existing pipework installation.

The FE030X4 appears to be well matched to the system curve (Figure 5) and operating close and just to the right of its Best Efficiency Point (BEP) although the velocity would be still relatively high in this section of pipework, i.e. in the order of 6 m/s. Lower velocities of less than 3.0 m/s to 3.5 m/s are recommended in terms of long-term, economical operation of the pumping station and the pipeline.

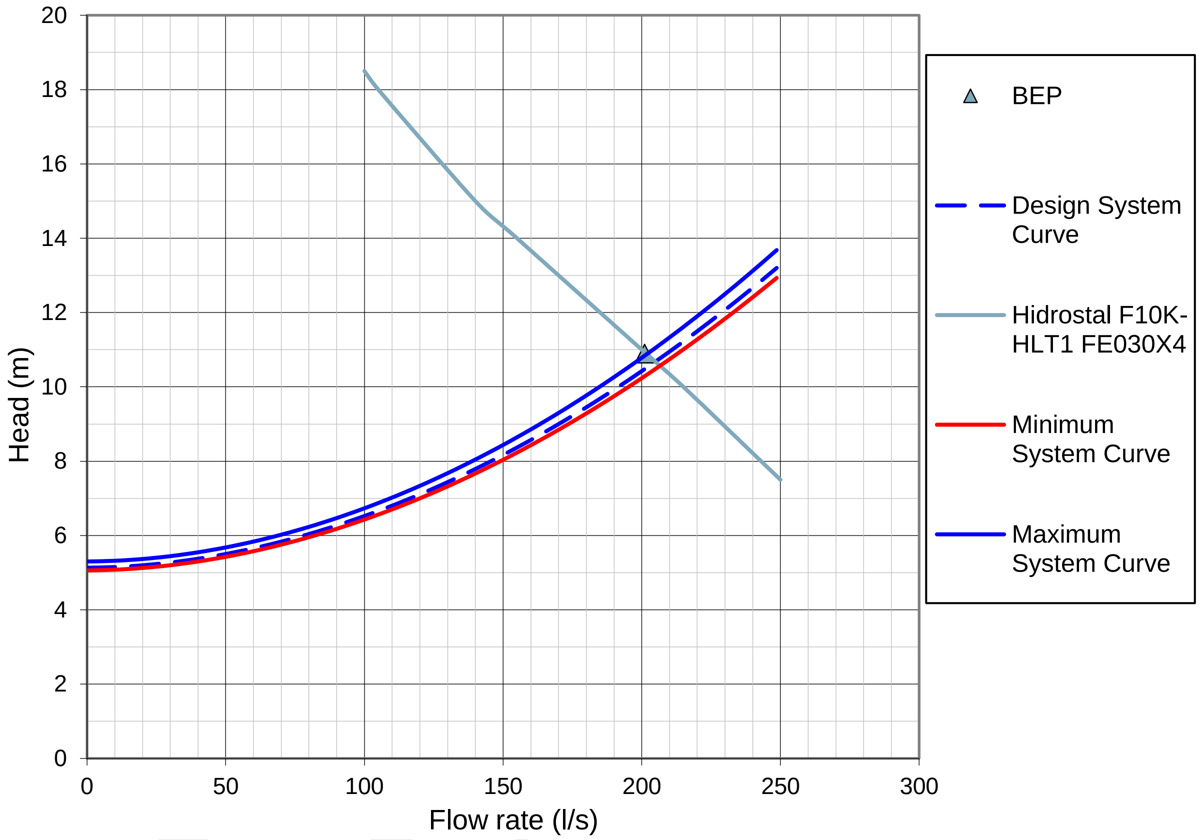


Figure 7 – Alternative pump selection, Hidrostal (single pump, duty operation)

Upsizing this section of pipework to match the rising main diameter (i.e. 450mm OD) would reduce the velocity to approximately 1.6 m/s and thus reduce the overall head loss. The pump selection is unlikely to change and a reduction in specific energy is anticipated, although the improvement to be small due to the relatively short length of pipework.

The current duty/assist option comes with either a DN200 discharge pipework and this option would most likely require VSD operation for control of a single pump to maintain efficiency and to ensure that the pump does not operate too close to the end of its curve which potentially may cause issues due to runout.

The E08U-SLN1 pump units appear to be well matched to the system curve under duty/assist operation and could provide circa 120 l/s with 1no pump running at a reduced speed (Figure 8).

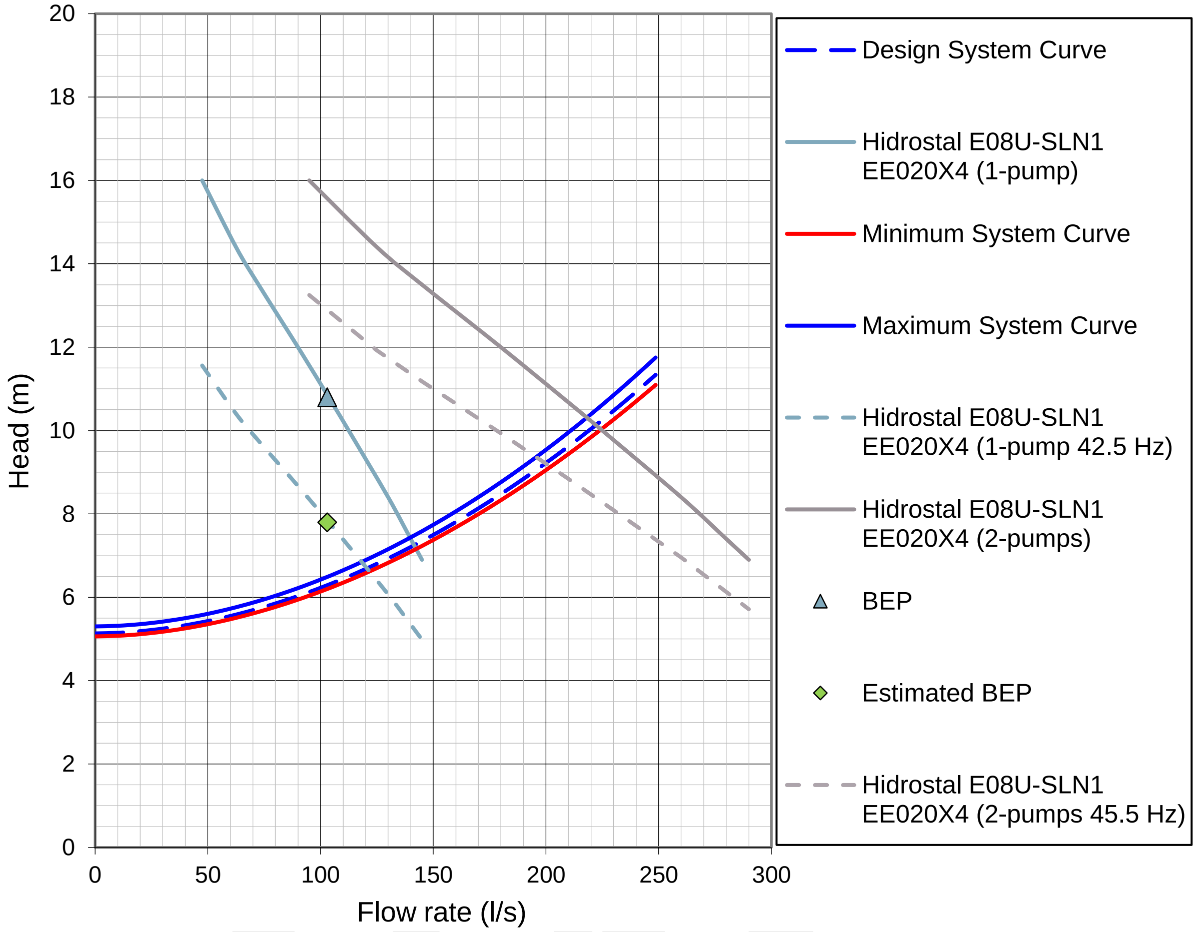


Figure 8 – Alternative pump selection, Hidrostal (two pump duty/assist operation)

It is not anticipated that significant energy savings would be achieved through the use of VSDs with two pumps running in parallel compared with fixed speed operation (see Table 4), as VSDs are not 100% efficient and would introduce their own energy loss of approximately 3% to 4% depending manufacturer, model and running frequency. These losses partly offset the reduced pump energy when running at a lower flow rate and head.   However, VSDs are recommended for this particular pump model in a duty/assist configuration to ensure operation within 120% of BEP when only one pump is running.

As an alternative two different sized pumps could provide operating efficiency benefits compared with duty/standby or duty/assist configurations. However, this would require confirmation of minimum flow rates and have impacts on operation and maintenance due to having two different pump models.

The preliminary Xylem duty or duty/standby pump selection would require a DN300 discharge pipework and calculations have assumed that the existing plastic pipework between the valve chamber and flow meter would be replaced and upsized with new 315 mm OD SDR11 HPPE pipework, based on providing a close match between the two pipework sections.

As shown in Figure 7, an NP3202 LT 615 pump would be operating close to and to the left of its BEP.

Upsizing the section of pipework between the valve chamber and flow meter chamber, e.g. to match the rising main diameter (i.e. 450mm OD), would reduce the overall head loss and provide a reduction in specific energy since the pump would operate slightly closer to its BEP, although the improvement would be small due to the relatively short length of pipework.

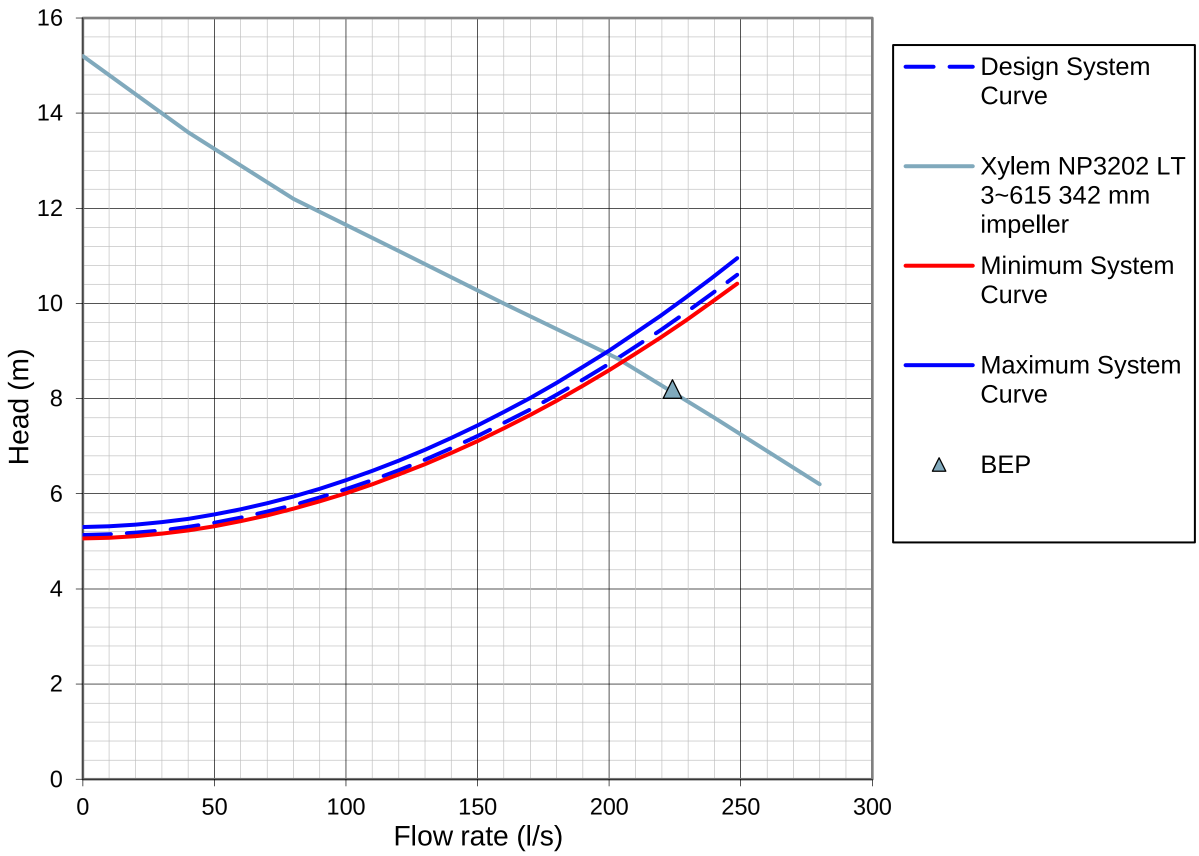


Figure 9 – Alternative pump selection, Xylem (single pump, duty operation)

The Xylem duty/assist pump selection would require DN200/250 discharge pipework and calculations have assumed that the pipework between the valve chamber and flow meter would be retained as existing (250 mm OD SDR11 HPPE), based on undertaking a minimal amount of additional works and modifications to the existing pipework installation.

Similarly, upsizing the section of pipework between the valve chamber and flow meter chamber, e.g. to match the rising main diameter (i.e. 450mm OD), would reduce the overall head loss and provide a reduction in specific energy since the pump would operate slightly closer to its BEP.

The NP3202 MT 642 appears to be well matched to the system curve under duty/assist operation and would provide circa 160 l/s with 1no pump running (Figure 8). As such, use of a VSD would not be recommended with this particular model of pump.

As indicated in Table 4, would appear that 2-pump operation under peak conditions would result in a lower operating efficiency (higher specific energy) than the current pumps; however, as the specific energy is lower, energy savings can be achieved by running with a single pump for most of the time, i.e. greater than one third.

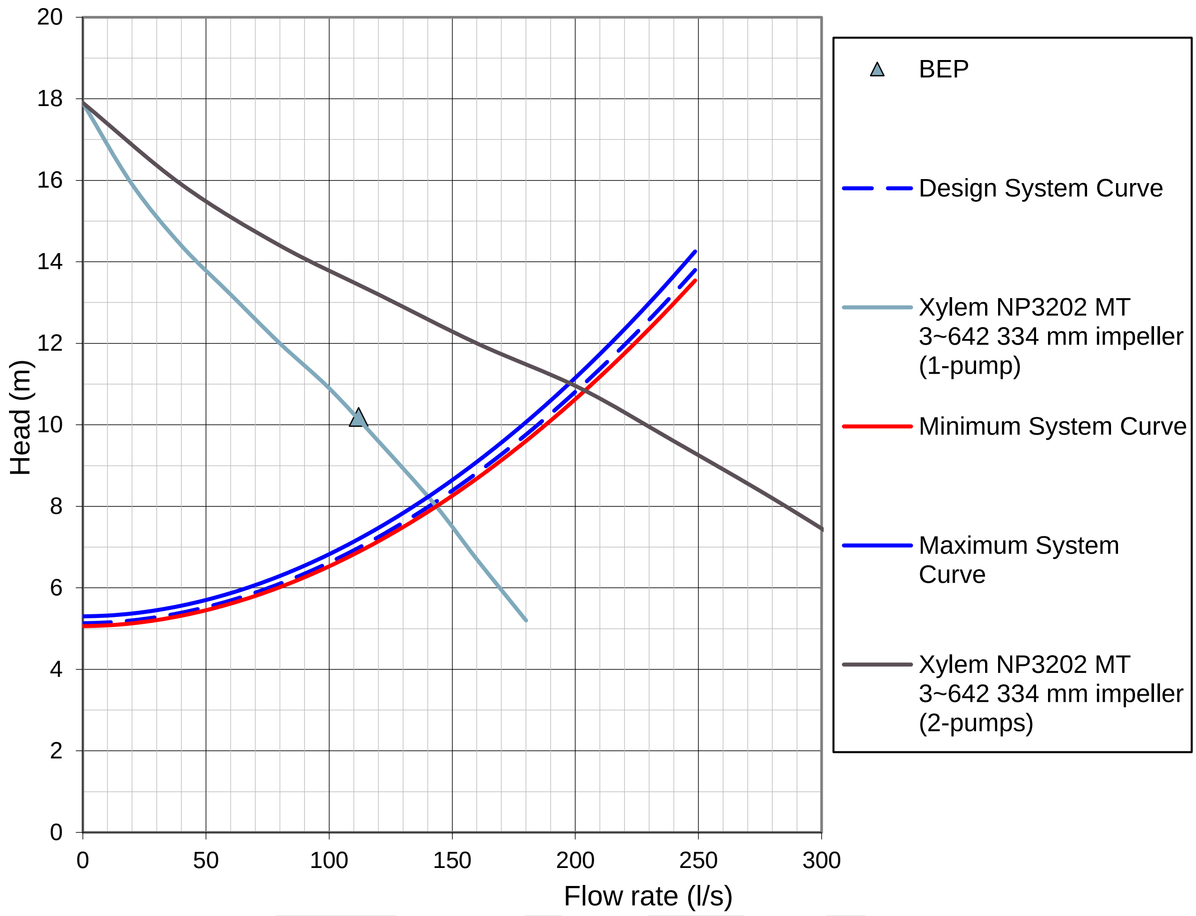


Figure 10 – Alternative pump selection, Xylem (two pump, duty/assist operation)

As indicated in Table 4, duty/assist configuration with 2No. pumps operating simultaneously in parallel would be less efficient than appropriately selected duty pumps (e.g. designed to operate between 80% to 105% of BEP). The Hidrostal preliminary selections indicate that they provide the greatest potential for energy efficiency savings and CO_2 reduction; however, implementation of the final configuration (Single, duty only fixed speed pump; Duty/standby fixed speed pumps; or , Duty/assist variable speed pumps) may depend on site constraints and overall cost.

Table 4 – Comparison of alternative fixed speed pump selections

Pump UNIT	**DUTY POINT**		**OPERATING FreqUENCY**	**SHAFT POWER**	**Pump Efficiency**	**OVERALL Pump & Motor EfficiencY**	**Specific energy**	**energy SAVINGs**
	(L/S)	**(m)**	**(Hz)**	**(kW)**	**(%)**	**(%)**	**(kWh/1000 m³)**	**(kWh per annum)**
Hidtostal FE030X4	206	10.6	50	29.1	81.4	73.3	31.1	82,608

Pump UNIT	**DUTY POINT**		**OPERATING FreqUENCY**	**SHAFT POWER**	**Pump Efficiency**	**OVERALL Pump & Motor EfficiencY**	**Specific energy**	**energy SAVINGs**
	(L/S)	**(m)**	**(Hz)**	**(kW)**	**(%)**	**(%)**	**(kWh/1000 m^3)**	**(kWh per annum)**
Duty (single pump)								
Xylem NP3202 LT 615 Duty (single pump)	203	8.9	50	21.5	81.8	76*	31.7	80,231
Hidrostal EE020X4 Duty/ assist (1 pump running) – Variable speed	120	7.0	46.0	12.2	77.0	67.7	29.4***	82,608
Hidrostal EE020X4 Duty/ assist (2 pumps running) – Variable speed	200 [100]	10.2	48.6	28.0 [14.0]	81.2	71.6	40.5***	46,051
Hidrostal EE020X4 Duty/ assist (2 pumps running) – Fixed speed	210 [105]	10.7	50	30.6 [15.3]	81.2	71.6	40.5	46,050
Xylem NP3202 MT 642 Duty/assist (1 pump running)	160	11.5	50	22.7	79.2	73.4*	42.6	37,779

Pump UNIT	**DUTY POINT**		**OPERATING FreqUENCY**	**SHAFT POWER**	**Pump Efficiency**	**OVERALL Pump & Motor EfficiencY**	**Specific energy**	**energy SAVINGs**
	(L/S)	**(m)**	**(Hz)**	**(kW)**	**(%)**	**(%)**	**(kWh/1000 m³)**	**(kWh per annum)**
Xylem NP3202 MT 642 Duty/ assist 2 pumps running	203 [102]	15.4	50	38.9 [19.5]	78.9	73.5*	57.1	-18,695

** 6-pole IE3 motor*
*** IE2*
**** Includes VSD losses @ 4%*
[#] per pump

6.2 Intake

Construction of a new intake would be an additional cost and potentially cause disruptions to the waterway. In order to avoid construction of a new intake, either:

a) the existing inlet pipe could be intercepted between the intake and the existing wet well, and a new (standard 1.2m diameter) manhole constructed to divert the flow to the new pumping station, or

b) a new pipe connection between the existing wet well and the new pumping station could be made, so that the existing wet well itself would be used to divert the flow.

Both options would mean that the exiting pumping station wold be unavailable while the works are being undertaken and require isolation of the intake to stop flows from the canal.

6.3 Preliminary Recommendations

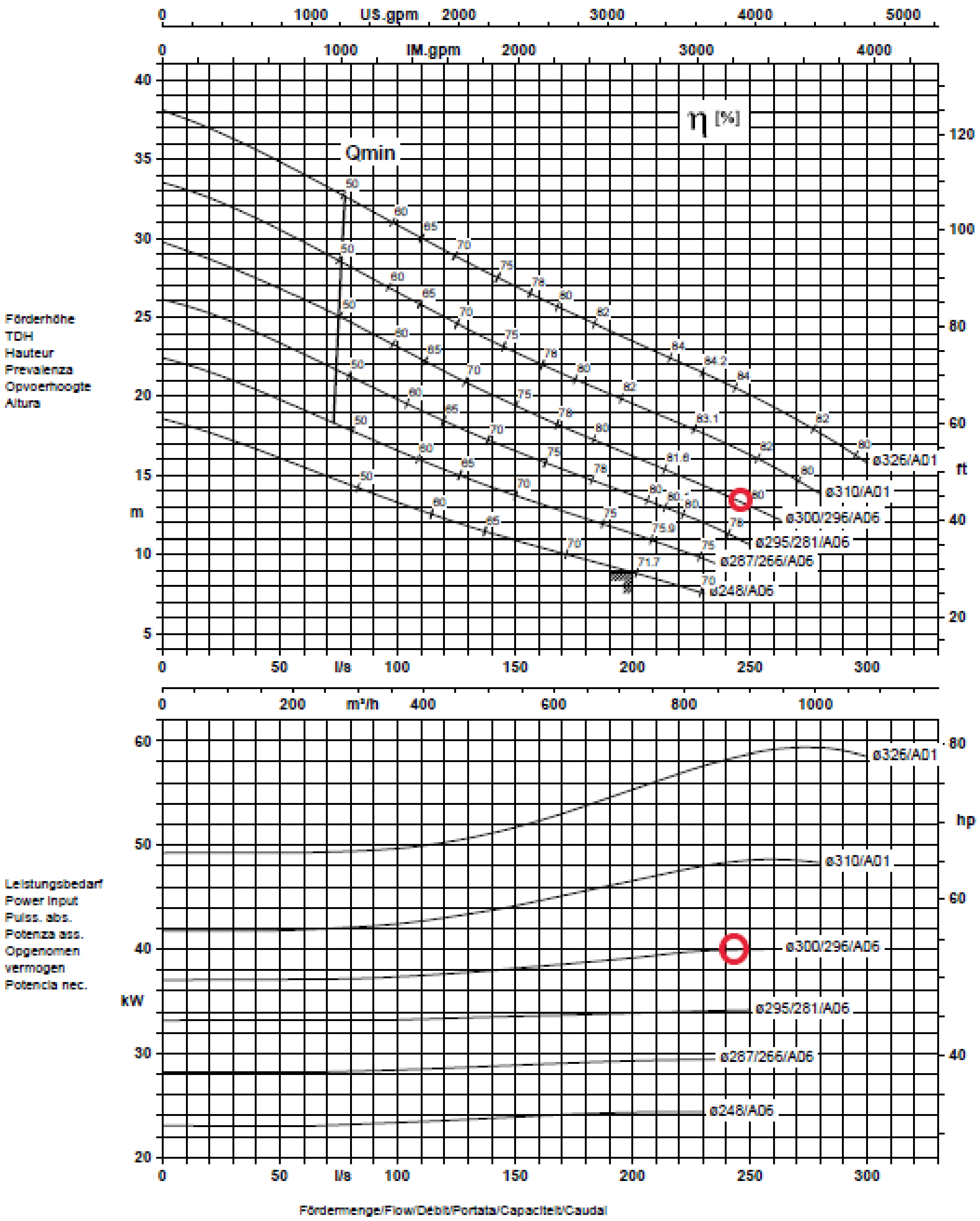
- Undertake topographical and utilities survey of pumping station area to confirm available space and viability of offline construction of a new pump station (wet well and valve chamber);
- Investigation to confirm specification details/diameter of existing plastic pipework and consider upsizing existing HPPE pipework upstream of flowmeter;
- Provide new duty only or duty/standby submersible pumping installation complete with IE3 high efficiency motor, pipework, valves and level instrumentation;
- Consider desktop review to determine if two different sized pumps could provide operating efficiency benefits compared with duty/standby or duty/assist configurations.;
- Detailed investigation into earthing system and associated electrical installation/power supply issues at the site;

- Consider implementation of a 'intelligent' drive/predictive monitoring system could be adopted at this site to encompass parameters such as flow rate, bearing temperature, power, efficiency, etc. This could be provided based upon SCADA/telemetry data and programmed to allow automatic adaption and correction of operation, informative data analysis reporting, and preventative fault alarms to help save energy, reduce downtime, etc.

APPENDIX A

Existing KSB pump performance curve

Baureihe-Größe / Type-Size / Modèle — Tipo / Serie / Tipo	Nenndrehzahl / Nom. speed / Vitesse nom. — Velocità di rotazione nom. / Nominaal toerental / Revoluciones nom.	Laufrad-ø / Impeller dia. / Diamètre de roue — ø girante / Waaier ø / ø rodete	
Amarex KRT 200-330K	1450 1/min		
Projekt / Project / Projet — Progetto / Projekt / Proyecto	Angebots-Nr. / Quotation No. / N° de l'offre — N° offerta / Offertenr. / N° oferta	Pos.-Nr. / Item No. / N° de pos. — N° pos / Pos. nr. / N° de art	KSB LIMITED 2 Cotton Way LOUGHBOROUGH Leicestershire LE11 5TF



Laufradaustrittsbreite/Impeller outlet width/Largeur à la sortie de la roue 92 mm
Luce della girante/Waaier uittredebreedte/Anchura de salida rodete 92 mm

Aus Kurve K41792/4 gerechnet
T251-Loughborough, Bailey David, 2011-02-09

APPENDIX B

On Site Measurements – Pump Audit Test Data

TABULATED RAW DATA

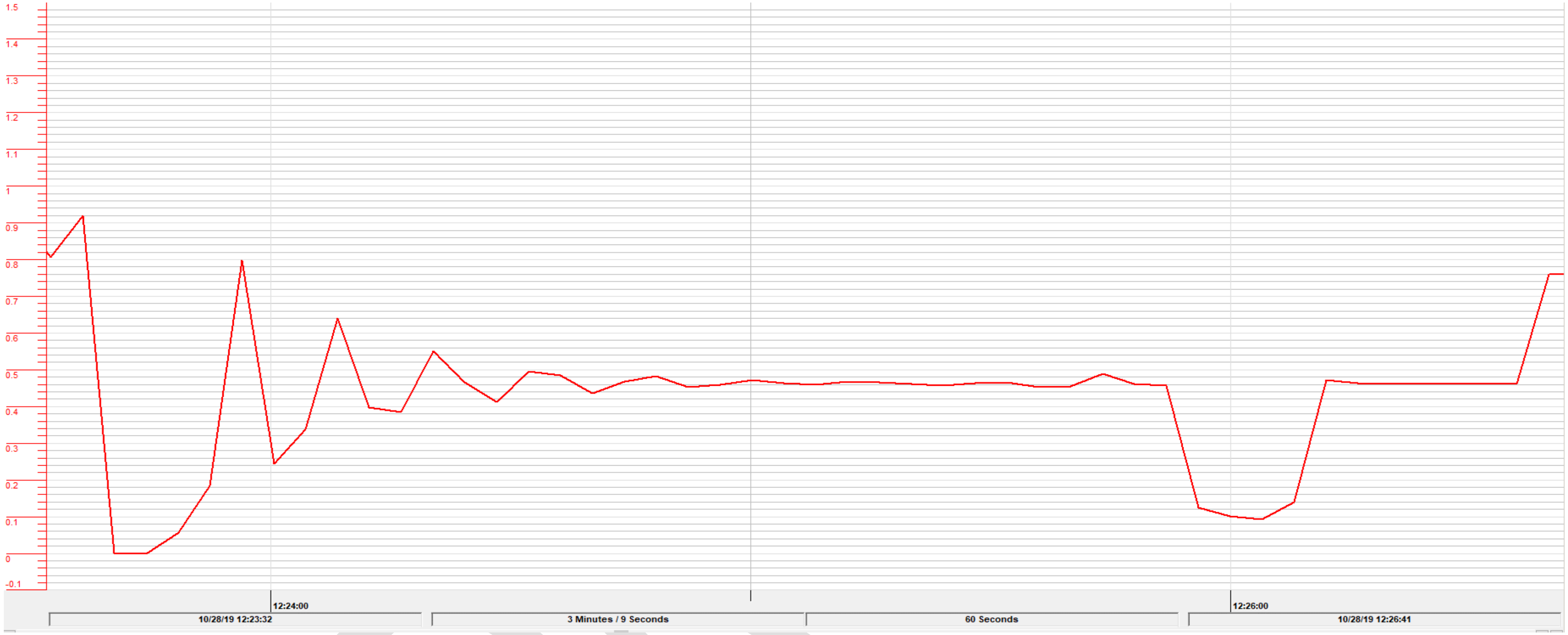
													From Fluke Power Meter (Average Over Cycle)										
			Frequency	Flow (l/s)			Delivery Pressure (Bar)			Upstream Level (m)			Volts						Amps				
Pump No. (s)	Test Point	Start Time	(Hz)	Min	Max	Average	Min	Max	Average	Min	Max	Average	L1-L2	L1-L3	L2-L3	L1-N	L2-N	L3-N	L1	L2	L3	PF	kW
1	Duty - Full Flow	11:23	50.0	240	253	*247*	0.67	1.14	*0.93*				421	422	420	242	244	243	67	69	68	0.94	47
1	Partial Closed Valve	12:28	50.0	121	124	*122*	1.48	2.55	*1.90*				421	423	420	242	244	244	60	64	62	0.94	43
1	Closed Valve	12:57	50.0	0	0	*0*	2.06	3.78	*2.66*				422	424	421	243	244	244	54	58	56	0.94	38
1	Pressure Transient	12:24					0.00	0.92	*0.40*														
	Static Head	12:25					0.46	0.48	*0.46*														

PUMP TREND RAW DATA

Pressure in bar

Flow rate in l/s

TRANSIENT & STATIC TREND DATA



Pressure in bar

APPENDIX C

Recommended Pump Selection Data Sheet