Seend Pump Station

PUMP AUDIT SUMMARY REPORT

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March 2020

Seend Pump Station

PUMP AUDIT SUMMARY REPORT

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Report No: 10031024-00517

Work Package: Improving existing systems and processes T1

Date: March 2020

Version Control

Version Number	Date issued	Author	Checker	Approver	Changes
P1	10/12/19	N. Taylor	J. Bernard	N. John	Issue for Comments

Content

1 Introduction

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

- data provided by the Canal and River Trust (CRT)
- a preliminary site visit undertaken on 4th June 2019
- a site investigation by Arcadis and Samatrix on 30th October 2019.

The report aims to cover the following areas:

- Derivation and analysis of the existing system curves and pump curves;
- Measurement and analysis of Net Positive Suction Head (NPSH) and compliance with currently installed equipment;
- Report on current available pumped volumes under both single and dual pump operation at variable frequencies;
- Report on current condition and defects including indicators of significant wear or performance issues;
- Highlight non-conformance and potential risk areas for equipment or infrastructure damage;
- Review and comment on current civils arrangements;
- Identify and present potential areas for improvement.

Figure 1 – Seend PS wet well showing Pump 2

2 System Description

2.1 Pumping Station

Seend PS is situated near Devizes, Wiltshire, UK. Its purpose is to supply water up from Lock 17 to Lock 21 on the Kennet and Avon Canal. Constructed in 1986, it consists a wet well housing 2 no. Xylem submersible pumps that normally operate in a duty/assist operation. The valve chamber forms part of the wet well structure and is primarily designed as a dry well for access. This arrangement differs from the given record drawings, where no valve chamber was shown to be present. The valve chamber is suspected to have been constructed at a later date.

The valve chamber was designed to be a dry well but due to rainfall run off from the access road and lack of drainage within the valve chamber, it is normally flooded. For the purposes of the pump audit this chamber was drained and cleaned to allow access.

The pumps at Seend have had some previous issues. In 2015, Pump 2 suffered various issues including: -

- Impeller damage (chipping)
- Seal leakage
- Top bearing failure resulting in seizing of shaft
- Burnt out motor stator

It is unconfirmed whether repairs were completed, or a new Xylem unit was installed.

Table 1 – Pump Details

Parameter	**Description**
Pumps	Xylem (Flygt) NP3301.180
No. of Pumps	2
Duty Configuration	Duty / Assist
Rated Motor Output	55 kW
Impeller Diameter	444 mm
Drives	Variable Speed (Mitsubishi)
VSD Operation	30 s ramp & 47.5 Hz Operating Frequency
Pipework	300 mm diameter (250 mm outlet on pumps)
Non-Return Valves	Lever assisted swing check valves
Wet Well Level Sensor	Float switch
Wet Well Level	42.85-43.13 mAOD*
Pump Centre Line	42.35 mAOD*

**Based on historical drawings*

2.2 Rising Main

From the provided drawings, the rising main is approximately 1129 m in length and was manufactured from uPVC. It is noted that the record drawings do not show the valve chamber or the flow meter chamber that are present on site.

Anecdotal reports from CRT indicate that the main has since been replaced and is assumed to be of PE material. Historical records indicate that the original main was 450 mm OD PVCu but this report casts doubt on whether the new main installed was of similar diameter and this is discussed further within Section 3 System Curves. Reported below are Arcadis' assumptions based upon results from this report but are subject to confirmation (e.g. by an additional inspection).

Table 2 – Rising Main Details

Parameter	**Description**
Length	1129 m
Elevation Rise	13 m
Pipe Diameter	630 mm OD
Discharge Level	127.6 mAOD
Pipe Material	PE80 SDR11 (10 bar rating)

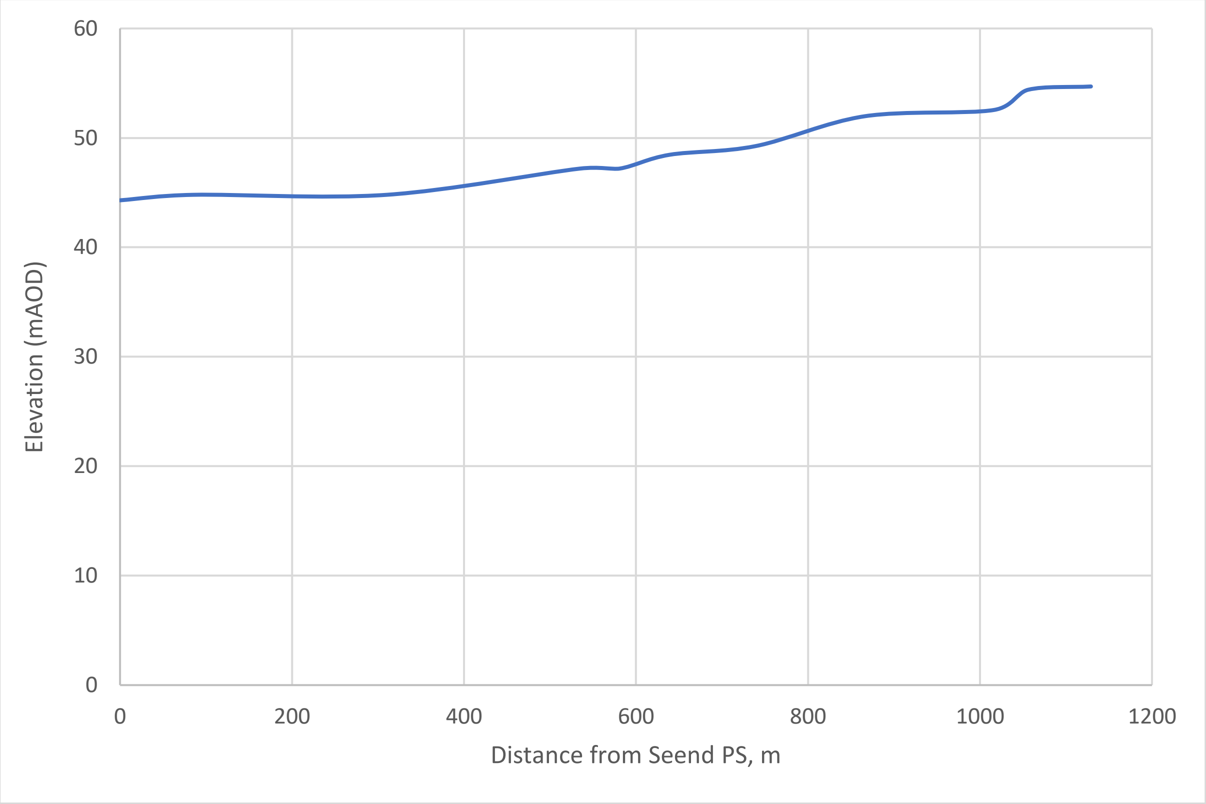


Figure 2 – Seend PS Elevation Profile

3 System Curves

System curves have been derived for the following three operating scenarios:

- Pumps P1 and P2 operating in parallel.
- Pump P1 operating only.
- Pump P2 operating only.

The suction and delivery elevations, flow rates, power usage, static head and operating pressures have been based on recorded site measurements.

It is noted that the system curve as obtained from the site audit data could not be calculated utilising a 450mm PVCu main as per the record drawings. This supports the assumption that the main has been replaced with a larger diameter pipe.

In addition to the derived system curves for single and dual pump operation outlined in Figure 3, Figure 4 and Figure 5. Figure 7 and Figure 8 shows the operating pump curves for both Pump 1 and Pump 2. This was achieved by artificially raising the head within the system by closing the outlet valves on each pump.

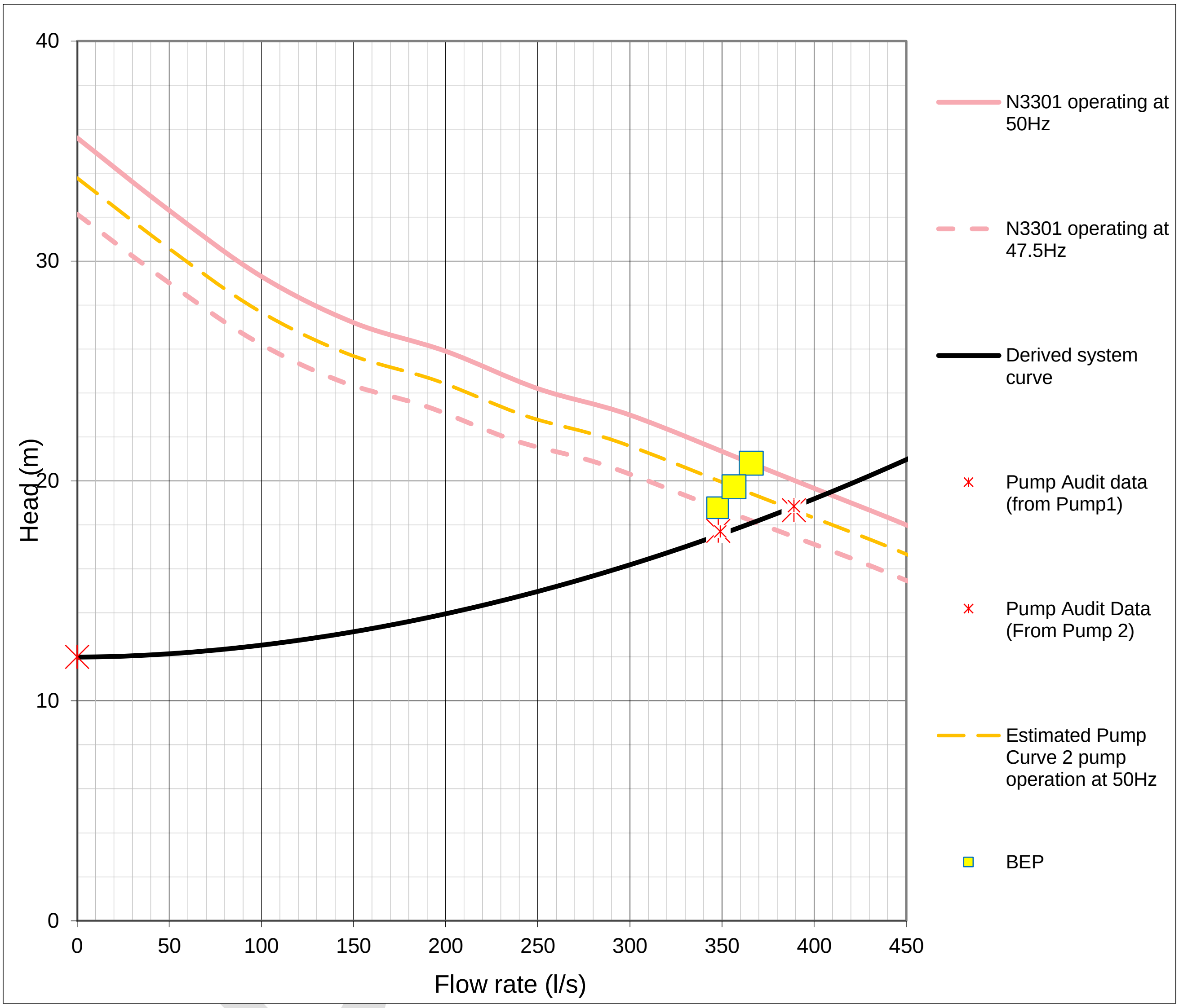


Figure 3 – Derived System Curves for 2-Pump Operation

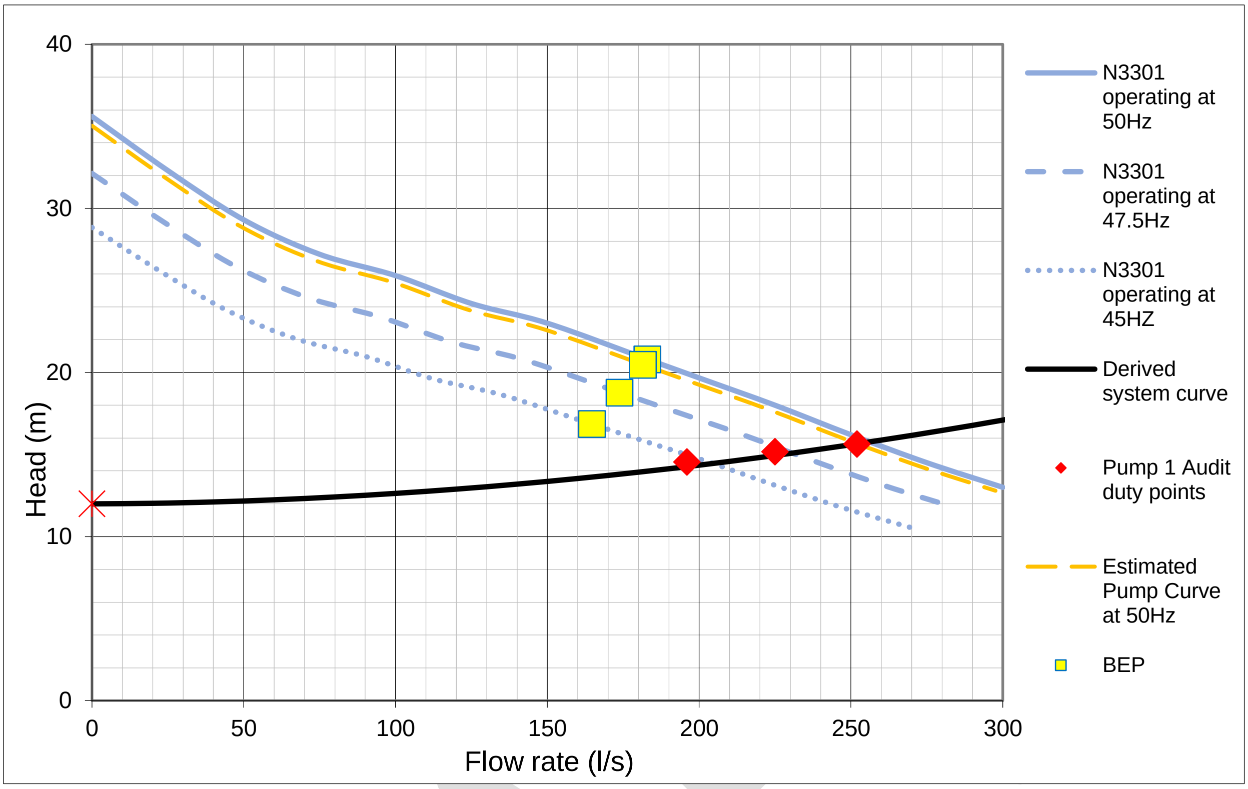


Figure 4 – Derived System for Pump 1 Only Operation

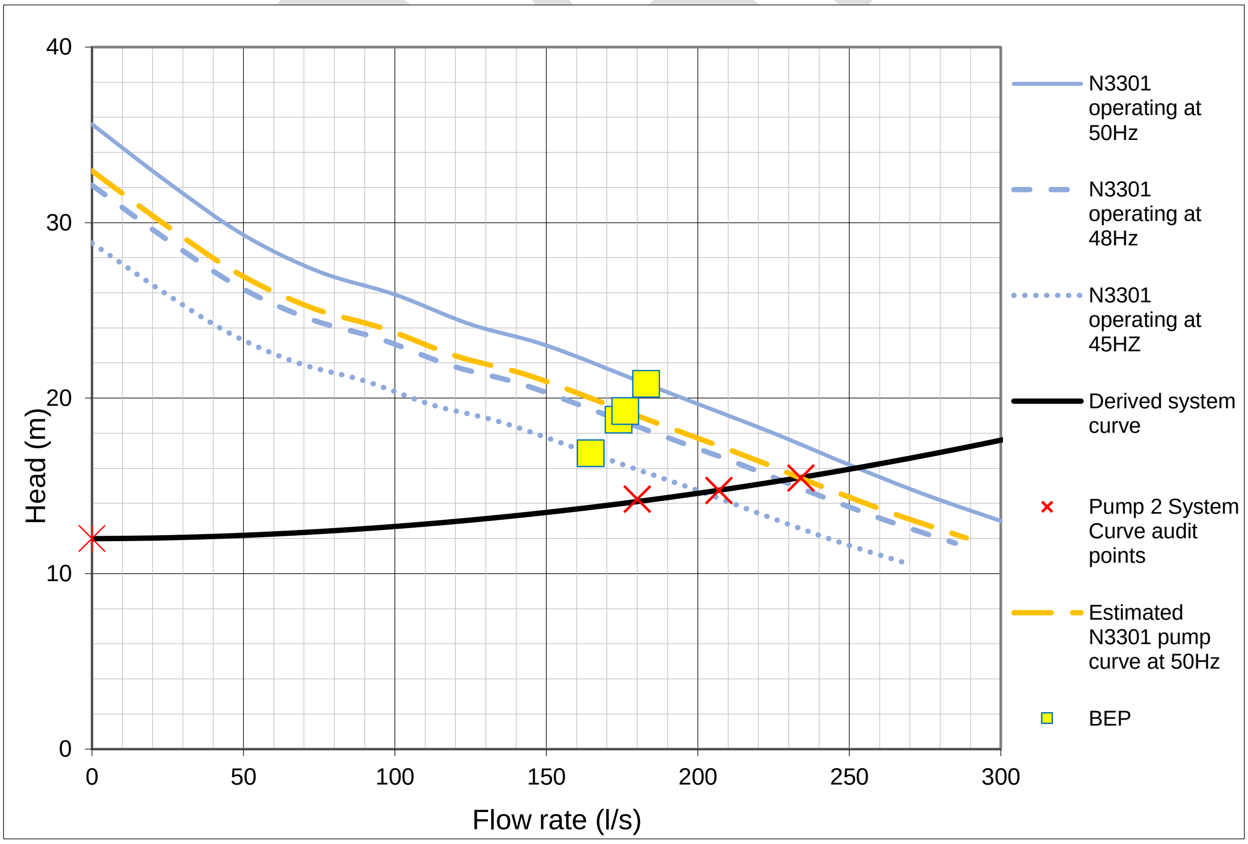
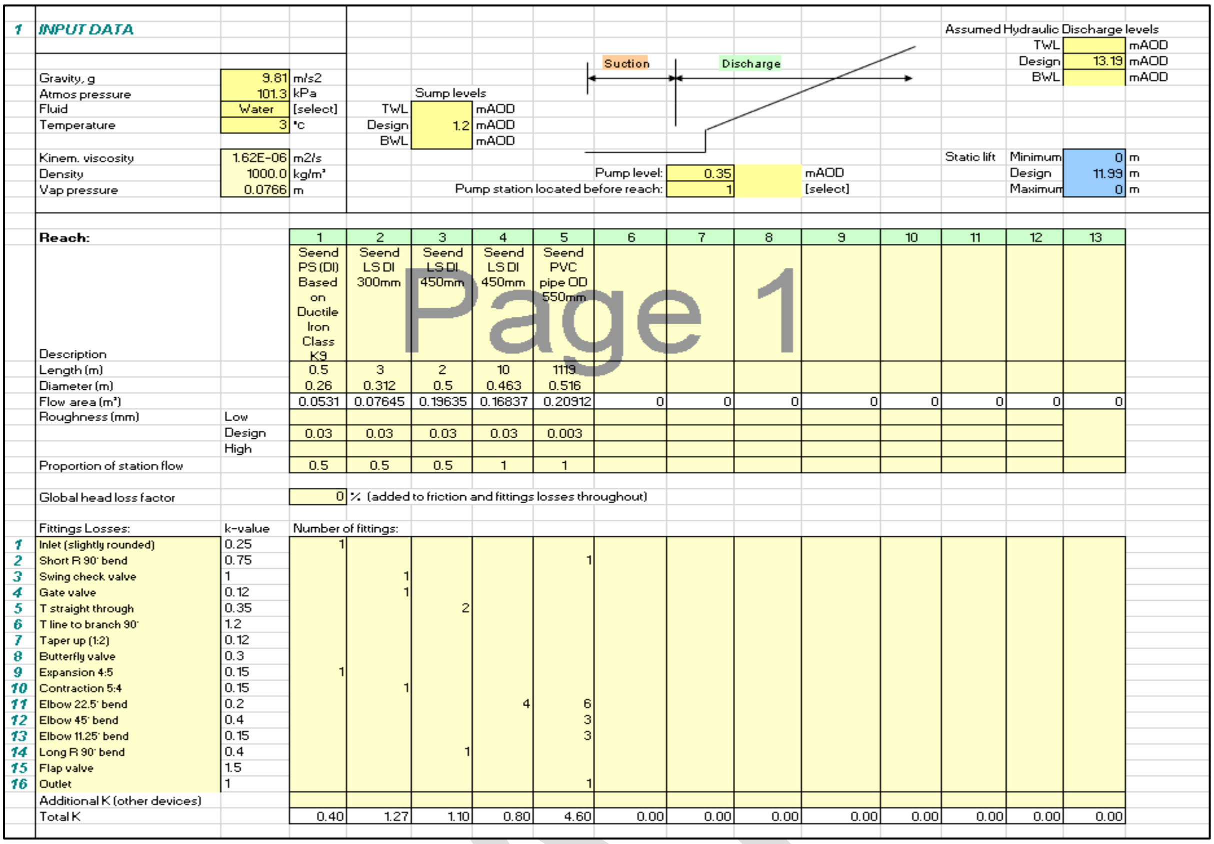


Figure 5 – Derived System Curves for Pump 2 Only Operation



1 *INPUT DATA*

Gravity, g	9.81	m/s2
Atmos pressure	101.3	kPa
Fluid	Water	[select]
Temperature	3	°c
Kinem. viscosity	1.62E-06	m2/s
Density	1000.0	kg/m³
Vap pressure	0.0766	m

Sump levels

TWL		mAOD
Design	1.2	mAOD
BWL		mAOD

Pump level:	0.35		mAOD
Pump station located before reach:	1		[select]

Assumed Hydraulic Discharge levels

TWL		mAOD
Design	13.19	mAOD
BWL		mAOD

Static lift	Minimum	0	m
	Design	11.99	m
	Maximum	0	m

Reach:		1	2	3	4	5	6	7	8	9	10	11	12	13
Description		Seend PS (DI) Based on Ductile Iron Class K9	Seend LS DI 300mm	Seend LS DI 450mm	Seend LS DI 450mm	Seend PVC pipe OD 550mm								
Length (m)		0.5	3	2	10	1119								
Diameter (m)		0.26	0.312	0.5	0.463	0.516								
Flow area (m²)		0.0531	0.07645	0.19635	0.16837	0.20912	0	0	0	0	0	0	0	0
Roughness (mm)	Low													
	Design	0.03	0.03	0.03	0.03	0.003								
	High													
Proportion of station flow		0.5	0.5	0.5	1	1								

Global head loss factor 0 % (added to friction and fittings losses throughout)

	Fittings Losses:	k-value	Number of fittings:												
1	Inlet (slightly rounded)	0.25	1												
2	Short R 90° bend	0.75					1								
3	Swing check valve	1		1											
4	Gate valve	0.12		1											
5	T straight through	0.35			2										
6	T line to branch 90°	1.2													
7	Taper up (1:2)	0.12													
8	Butterfly valve	0.3													
9	Expansion 4:5	0.15	1												
10	Contraction 5:4	0.15		1											
11	Elbow 22.5° bend	0.2				4	6								
12	Elbow 45° bend	0.4					3								
13	Elbow 11.25° bend	0.15					3								
14	Long R 90° bend	0.4			1										
15	Flap valve	1.5													
16	Outlet	1					1								
	Additional K (other devices)														
	Total K		0.40	1.27	1.10	0.80	4.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 6 – Hydraulic Calculation Input Data

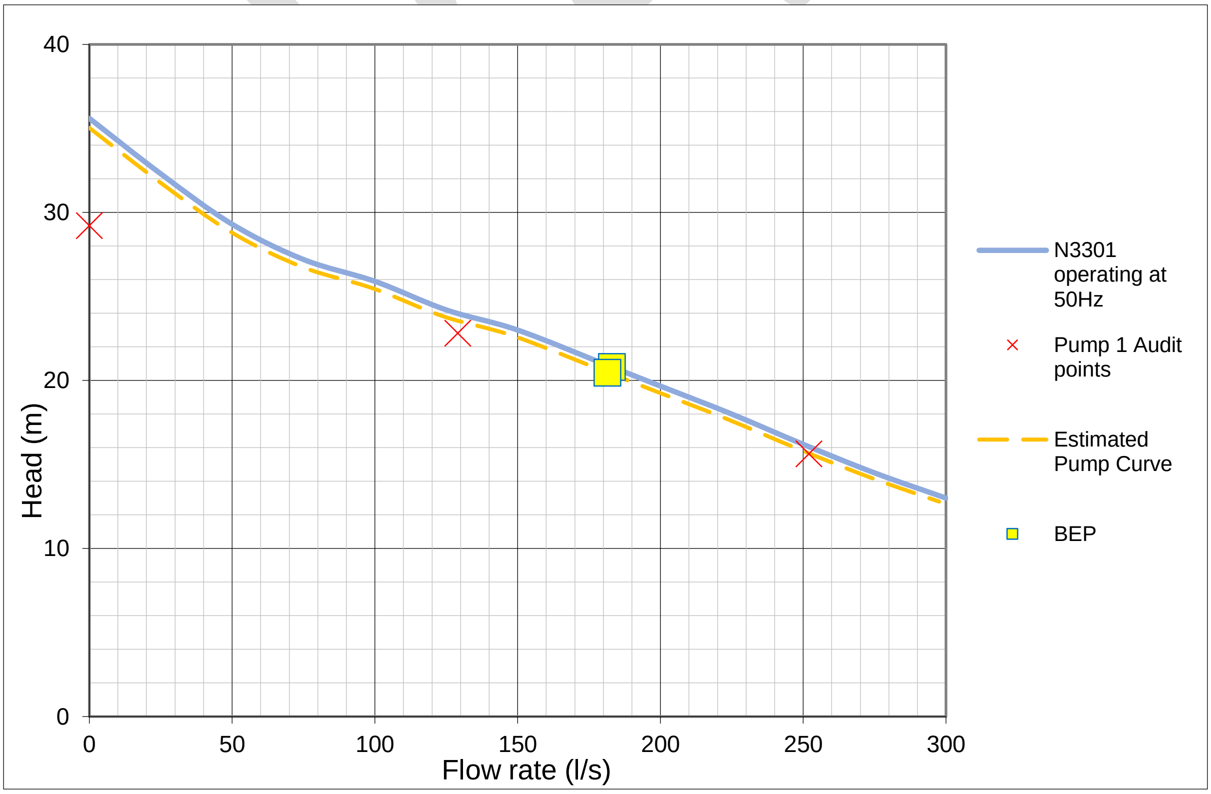


Figure 7 – Pump 1 Audit data

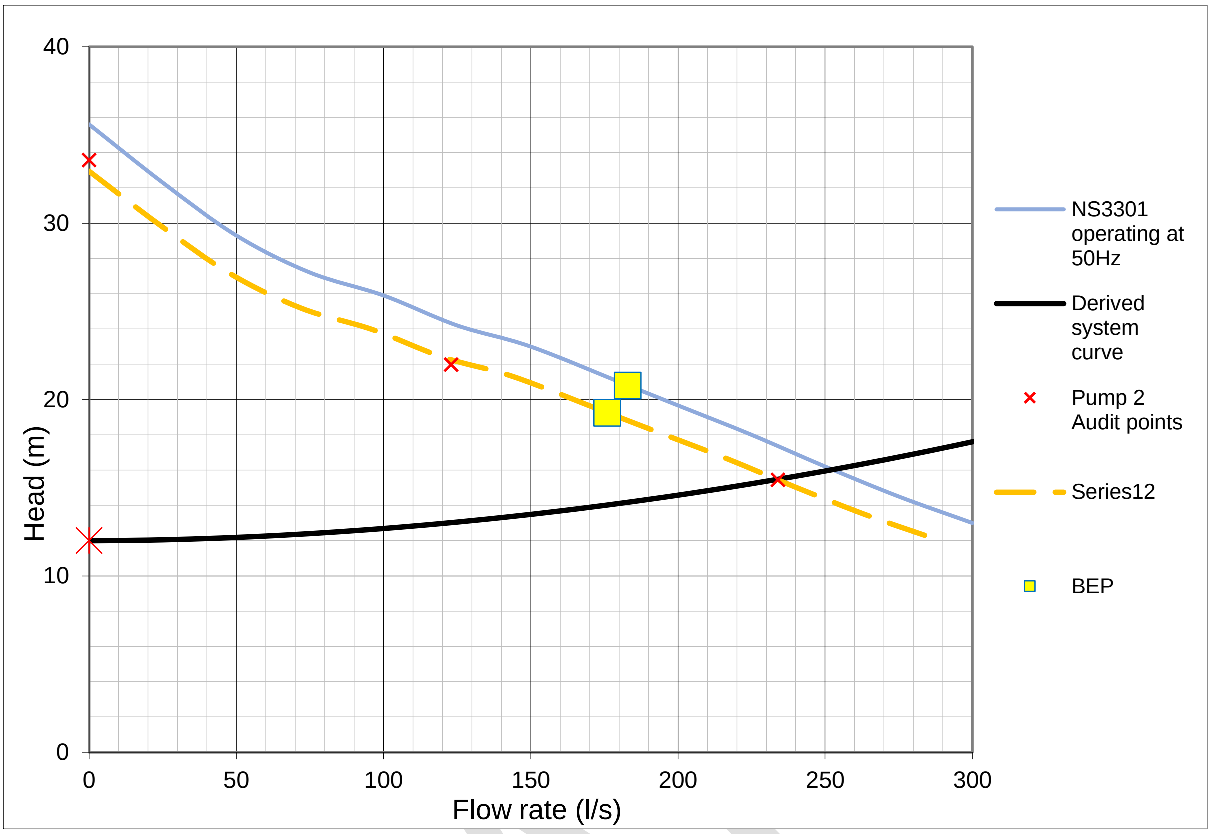


Figure 8 – Pump 2 Audit data

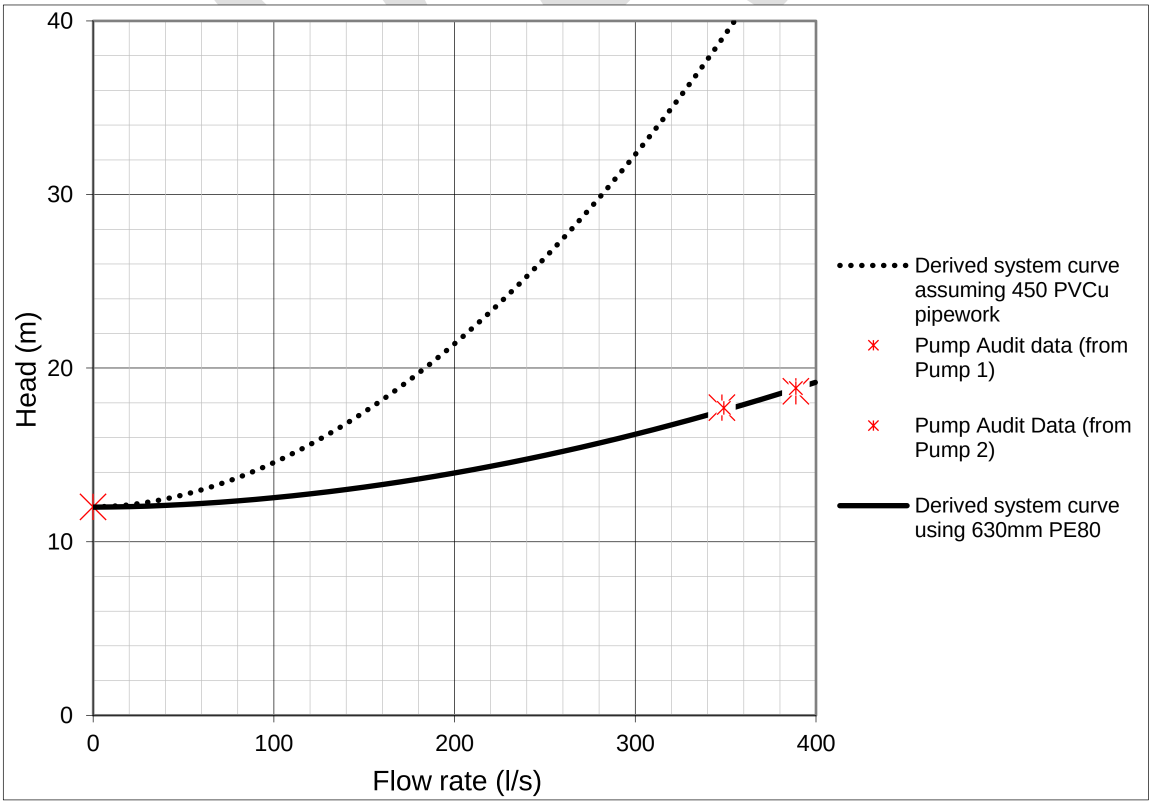


Figure 9 – System curves for 450mm PVCu pipe work versus 630 mm PE80 pipework

The key observations from the derived system curves are as follows:

a) The pump audit data for the rising main pipework downstream of the flow meter correlates with a design curve for 630 mm PE80 not 450 mm PVCu as stated in the record drawings.
b) The performance of the 50 Hz pump curves was adjusted down slightly from their ideal published performance curves in order to align with site results.
c) From the derived system curve and P1 50Hz test results the relative operating points at Seend PS for single and dual pump operations have been estimated. The operating points for combined and single operation for P1 were found at 194.5 l/s and 252 l/s respectively. These figures equate to 104% and 135% of the flow rate at BEP and confirm that the pump is operating within its preferred operating region (80%-120% x BEP Flow Rate) during dual pump operations. Under normal circumstances, the pumps operate at 47.5 Hz and under single pump operation this is 117% of flow rate at BEP, and therefore within the preferred operating region.

It is noted that impeller chipping was present on Pump 2 during the 2015 service report which may have had an impact on results, as it is unclear whether this issue was resolved at the time of refurbishment.

It is also noted that the reduction in performance of Pump 1 is within the tolerance of standard pump test criteria (using BS EN 9906: 2012 and assuming a 2B Test acceptance grade). Therefore, it is unclear as to whether this reduction is due to the variations in manufacture, or local factors from flow inlet conditions/impact/wear.

4 Net Positive Suction Head (NPSH)

NSPH calculations have been undertaken and the results indicate there is a margin (difference) of approximately 6 m, between NPSH required and NPSH available. This level of margin is satisfactory. As such this has not been investigated any further as there have been no reports found of any cavitation issues at this pump station.

5 Submergence and Flow Presentation

Observations on site noted the presence of surface vortices (Figure 6) and vortex shedding, especially during the 50 Hz operation. Surface vortices are highly dependent on the approach flow patterns and the stability of these patterns, as well as on the inlet Froude number.

Submergence calculations based on ANSI/HI 9.8-1998 suggest that during one pump operation there is insufficient water coverage over the water level range to limit the formation of surface and potentially sub-surface vortices. During two pump operation, as the individual pump flows are lower during two pump operations, the effect is reduced.

The well depth (water surface to floor) at the time of the initial visit was 1.2 m (43 mAOD). The level of the pump intake bell mouth has been approximated at 42.055 mAOD based on historical and technical drawings.

An initial review has indicated based on ANSI/HI 9.8 gives the minimum submergence criteria of 1.139 m (43.194 mAOD) which could explain the surface vortices shown above as this criterion is not being met even at the highest water level within the wet well.

From the record drawings the maximum weir level in the canal is 43.13 mAOD, but this level is taken outside the trash screen. The trash screen could potentially see some further blinding effect from debris in the canal, particularly from seasonal vegetation presence, which could lower the water level in the well further and exacerbate this scenario.

It was observed at the initial site visit that surface turbulence was present which is assumed to be exacerbated by the inlet arrangement and the relative positions of the pump within the wet well. Calculated velocities (assuming clean) over the submerged sump sill are generally low (under 0.5 m/s) which is normally deemed acceptable when compared to ANSI/HI 9.8-1998. Although not deemed ideal, this does not appear to be causing any adverse effect in this pump station.

The positioning of pumps within the wet well is off centre which creates a rotating flow pattern near the pump which could be accentuating the swirl pattern and vortices shown in Figure 12. Baffles around the pump could increase sump velocities and should reduce pockets of still flow where siltation occurs.

The presence of siltation in the well can impact on flow presentation to the pump and adversely affect performance. Heavy siltation exists behind the baffle walls (circa 1 m in depth) which is to be expected. However, no siltation could be detected around the pumps during the staff measurements that were made of the wet well during the pump audit.

Figure 10 – Surface Vortices on Pump 2

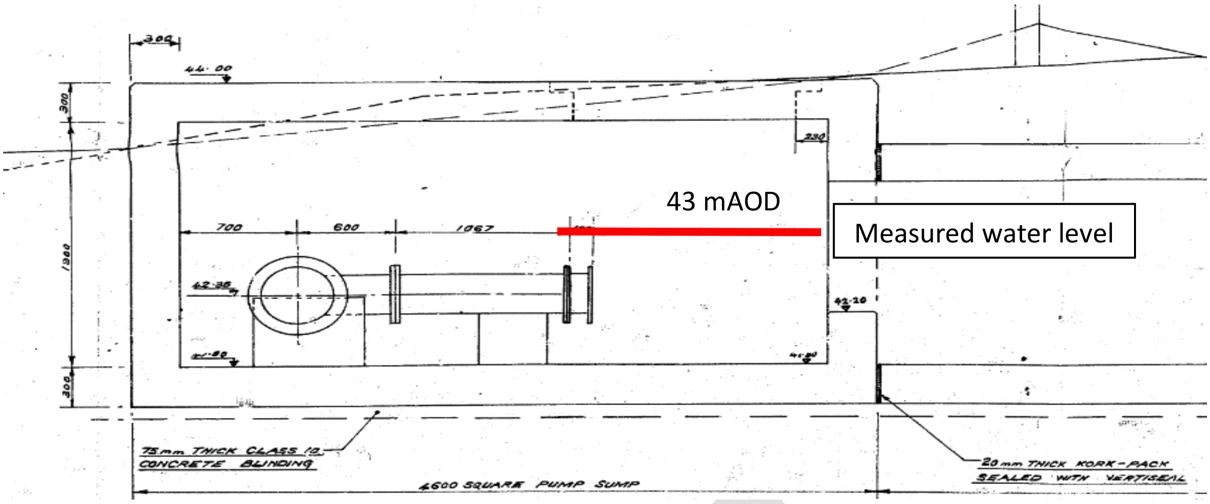


Figure 11 – Sectional View of Seend PS

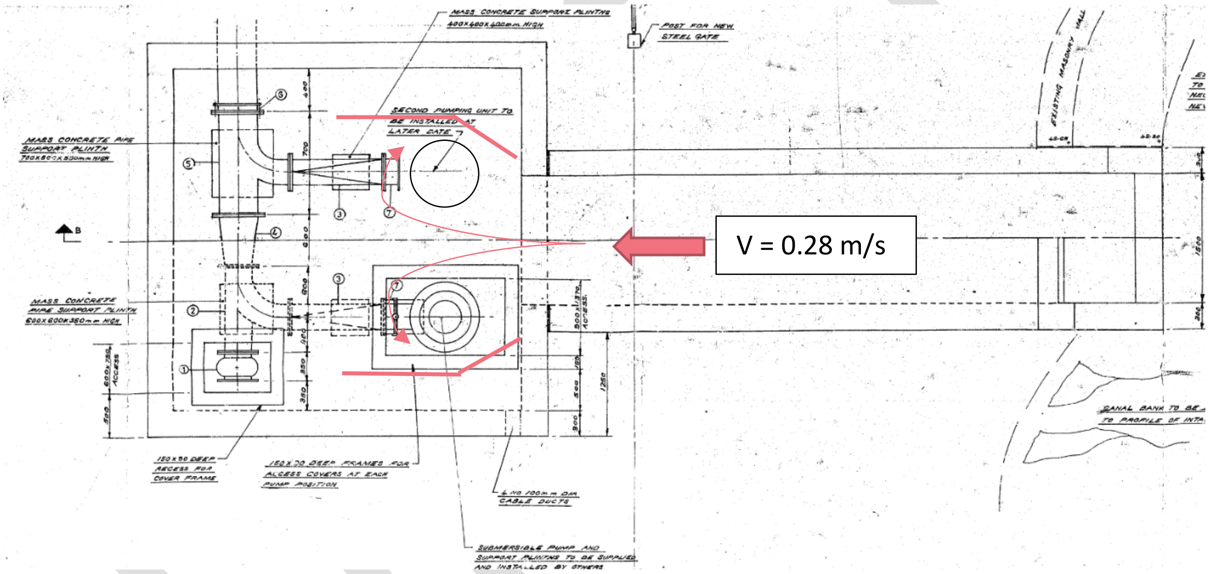


Figure 12 – Plan View of Seend PS

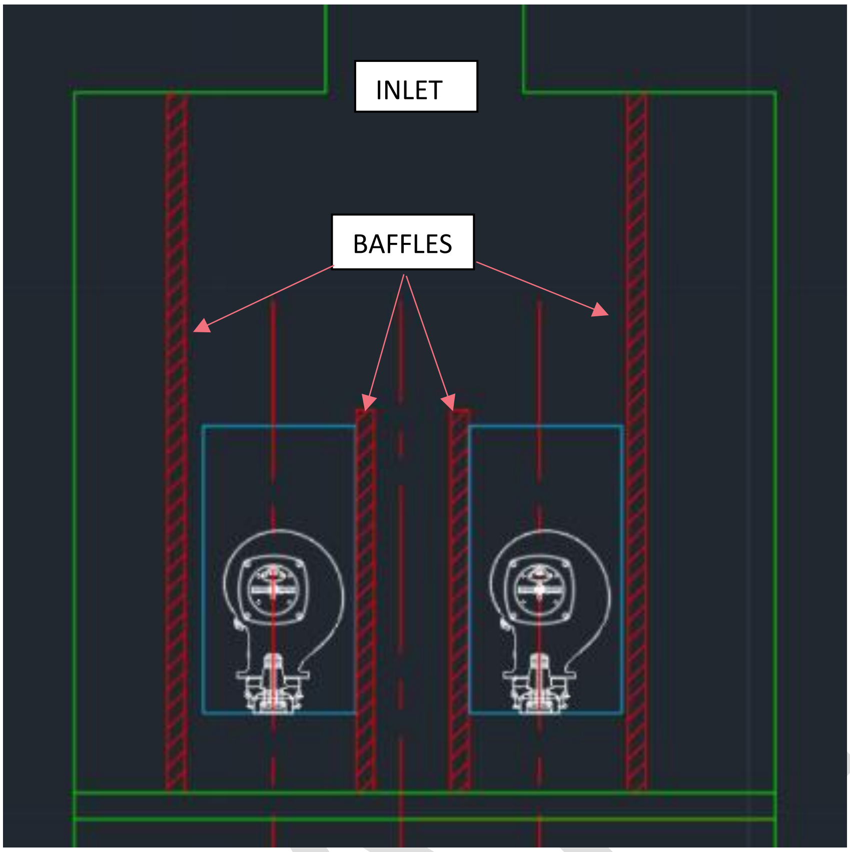


Figure 13 – Seend PS with optional pump bays

A case could be made for potentially altering the design of the wet well by creating individual pump bays by means of either concrete or steel baffles as outlined in Figure 13. This would straighten the inlet flows and limit the rotational flow around the pumps

To incorporate such a change the pumps would need to be moved further away from the inlet for the bays to be formed. This change would require the access hatchways for the pumps and the davits being moved atop of the wet well, as well as significant internal baffling. Any additional baffling would most likely need to stay clear of the rising main drain pipework located approximately centrally within the wet well.

It should be noted that pump inlet design is not an exact science and changes of this nature should be made in tandem with physical modelling to negate any unforeseen issues arising.

Ideally, a lower wet well floor would be beneficial to increase the submergence of the pumps, but this would require major works such as a complete rebuild or new wet well to achieve.

6 Energy Analysis

At the pump audit visit by Samatrix, a temporary “Fluke” power meter was connected at the individual pump start compartment to record power into the pump VSD.   From the measured power, flow and pressure undertaken during the Samatrix audit visit, an analysis of pumping efficiency and the amount of energy needed to pump flows has been undertaken.

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

Table 3 – VSD Input power, Efficiency and Specific Energy

Pump Configuration	**Measured Flow rate (l/s)**	**VSD Frequency (Hz)**	**Measured Power Factor**	**Measured power (kW)**	**String Efficiency ***	**Specific energy (kWh/1000 m^3)**
Pump 1 Only	252	50	0.86	59	66%	64.8
	225	**47.5**	**0.84**	**50**	**68%**	**61.2**
	196	45	0.82	42	67%	58.8
Pump 2 Only	234	50	0.86	57	63%	67.1
	207	**47.5**	**0.84**	**48**	**63%**	**63.9**
	180	45	0.81	39	64%	60.6
Both Pumps (Power Measured at Pump 1)	389	50	0.89	56	64%	76.25**
	348	**47.5**	**0.88**	**47**	**65%**	**71.5****
Both Pumps (Power Measured at Pump 2)	389	50	0.88	51	70%	76.25**
	349	**47.5**	**0.87**	**43**	**71%**	**71.5****

* String Efficiency is overall "wire to water" efficiency including the VSD (96%)

** Combined from both Pump 1 and Pump 2 individual measured power readings

The normal running frequency at Seend PS is 47.5 Hz. From Table 5, running at 45 Hz results in a lower specific energy, and therefore energy cost, than running at 50 Hz or 47.5 Hz. It can also be seen that 2-pump operation results in a higher specific energy and a lower overall operating efficiency.

7 Pump Control

Under normal operation, the pumps operate automatically via level control. The lock flight level at the discharge location (Lock Flight 21) is monitored and transmitted to Seend PS via telemetry. Upon this level falling to a pre-set low level, the pumps are started. Each pump ramps up to a manually set VSD speed of 47.5 Hz and both pumps operate in parallel (duty/duty) at fixed speed. When the discharge lock flight 21 level rises to a pre-set high level, the pumps both ramp down and stop.

Flow rate is measured via an on-site electromagnetic flowmeter, but it is not utilised for control. Additionally, both pumps have relay protection and low level (suction) protection.

Key pumping station data is available on CRT's central SCADA facility.

8 Pump Reliability

The pumps have some known reliability and overheating issues. Pump No.2 recently (2015) was removed following a failure after only 3 years operation. The Pump Service centre inspection report stated the following findings:

- Impeller was chipped but serviceable but no mention of pitting
- Glycol in the inspection void indicating seal leakage
- Top bearing was broken up and seized to the shaft
- Stator has burnt out

The pumps are not jacket cooled and motors are exposed above the liquid surface at lower water levels, and there are historic issues with the pumps overheating. This is due to the expectation that non-jacket cooled submersible pumps will either be fully submerged or be partly submerged only for short periods of time, as would typically be the case in sewage wet wells upon draw down at the end of a pump cycle. The overheating is likely being exacerbated when operating at 50 Hz due to higher electrical loads.

It would be recommended that any new pumps installed at Seend PS are fitted with cooling jackets in order to resolve the overheating issues. Based on anecdotal issues advised by CRT regarding pressurisation of glycol filled cooling jackets on Xylem pumps, it would be recommended to use pumped-media cooling for the jackets.

During the pump audit, Pump 2 was seen to be noticeably vibrating when operating in single duty mode. Although it is operating within its preferred region at 47.5Hz, it is possible that the pump stool/guide rail mountings have loosened over time. It is recommended that the existing mountings are inspected to establish whether this is the case.

9 Potential Areas for Improvement

9.1 Alternative Pump Selection

The data suggests that the original main (as shown on the provided drawings dated) has been replaced with a larger diameter as the flow rate data is higher than expected from the drawings provided. Based on the system curve analysis, the installed pumps provide a reasonably efficient hydraulic performance.

The existing pump efficiencies appear to be lower than those expected for “as new” pumps, which may be being exacerbated by the overheating issues, and possibly hydraulic presentation from the offsetting of the pumps to the incoming channel.

On a duty/assist 2-pump operation the current Xylem pump selection is considered a good selection. The duty conditions cannot be achieved by Hidrostal, ABS or KSB from their standard ranges.

A preliminary search for alternative selection from Xylem, based on the duties calculated, has suggested the following selections (Table 4), as based on the existing pipeline losses.

Table 4 – Alternative pump selections from Xylem

Configuration	Selection (Xylem)	Flow Rate (l/s)	Input Power (kW)*	Pump Motor and Efficiency (%)	Assumed VSD Efficiency (%)	Estimated Specific Energy* (kWh/1000 m^3)
Duty/Assist (2-pumps) VSD + IE3 Motor at 50 Hz	**NP3301/630 (55 kW) 444 mm Impeller*** **	**406.9**	**99.8**	**77.7**	**96**	**71.2**
Duty/Assist (1-pump) VSD+ IE3 Motor at 50 Hz	**NP3301/630 (55 kW) 444 mm Impeller*** **	**247**	**54.6**	**72.2**	**96**	**59.6**
Duty/Assist (2-pumps) VSD + IE3 Motor	NP3301 / 632 (55 kW) 424 mm Impeller	363	82.2	78	96	65.4
Duty/Assist (1-pump) VSD+ IE3 Motor	NP3301 / 632 (55 kW) 424 mm Impeller	232	44.7	73.7	96	54.5
Duty/Assist (2-pumps) Fixed speed + IE3 Motor	NP3301 / 632 (45 kW) 424 mm Impeller	363	82.2	78	-	62.8
Duty/Assist (1-pump) Fixed speed + IE3 Motor	NP3301 / 632 (45kW) 424 mm Impeller	232	44.7	73.7	-	53.3
Duty/Assist (2-pumps) Fixed speed+ Standard Motor	NP3315 /636 (75 kW) 421 mm Impeller	402	99.4	75.9	-	68.7
Duty/Assist (1-pump) Fixed speed+ Standard Motor	NP3315 /636 (75 kW) 421 mm Impeller	255	53.2	70.0	-	57.5
Duty/Standby VSD (50 Hz) + IE3 motor	NP3306/706 631 (100 kW) 475 mm Impeller	386	90.5	79.7	96	67.9
Duty/Standby VSD (40 Hz) + IE3 motor	NP3306/706 631 (100 kW) 475 mm Impeller	243	46.4	79.3	96	53.1

* To Pump and Motor (excluding VSD) at 50 Hz (unless otherwise stated)

** Taken as an average over Pump 1 and 2 at 50 Hz

*** As existing model (but with IE3 motors)

From

Table 4, in terms of reducing energy consumption, the optimum configuration from Xylem is the selection of the same model pump with a smaller impeller operating in duty/assist configuration. This option gives the best overall performance for both single and twin flow rates but does come at the cost of reducing the flow rate from 389 l/s to 363 l/s for twin operation and 252 l/s to 232 l/s for single operation. Therefore the feasibility of this option is dependent on whether CRT could accept this flow reduction.

The duty/standby option of the NP3306 with a 475 mm impeller does give comparable energy performance for twin pump operations. However, it is physically a larger pump which consequently would require a new larger MCC to accommodate 100 kW+ drives and a new wet well, due to the existing shallow depth, to accommodate the pumps. This means that the duty/standby option is unlikely to be of great benefit without a complete reconstruction of the pumping station.

9.2 Pump Controls

The existing control does not automatically vary duty configuration or flow rate based on lock flight level. It is suggested that pumping configuration could be tailored according to a level banding, rather than a simple ON/OFF type operation in order to improve energy consumption. However, the practical feasibility would depend on the characteristics of the canal system and pumping capacity.

Adopting a smart, predictive monitoring system that encompasses flow rate, bearing temperature, power, efficiency, vibration, specific energy, etc. is a viable proposition at Seend PS and other sites. This could be implemented centrally on SCADA based upon telemetry data and coded to allow automatic adaption/correction of operation, informative data analysis reporting, and preventative fault alarms. It might also be of benefit in preventing pump operation during peak tariff and triad periods, reducing both cost and potentially CO_2 (indirectly) output even further.

Predetermined level thresholds would be as set start and stop levels for the pumps in either duty or duty/duty operation.

Regarding the type of sensors, ultrasonic or radar type sensors are recommended. Using either ultrasonic or radar type level sensors would allow the following benefits:

- Low maintenance measurement
- Unaffected by medium properties and fouling
- Freely adjustable measuring range
- Measured level outputs can be used for both information and control

Utilising this level banding could limit the operational hours on one of the pumps if the single pump operation is predominantly the other pump with one pump being used to “top up” as required during quieter periods and two pumps only being required when the level drops more significantly. This would have the benefit of staggering wear / operational maintenance that relates to operational hours for the two machines, which introduces a degree of risk management from a resilience perspective.

Flow rate is measured via an on-site electromagnetic flowmeter, but it is not utilised for control. The SCADA data indicates a 7 l/s flow rate when neither pump is in operation. Testing and recalibrating both the flow meter and SCADA readings would assure this issue does not deteriorate further.

Installing a pressure transducer on each line would allow measurement and recording of pressure over time. This could be included on any accessible section of pipework within the station for ease of access and cabling. The only accessible pipework is within the valve chamber or the flow meter chamber, and it would be preferable to install a transducer on each individual pump discharge within the valve chamber (the common line is not accessible within the valve chamber) than introducing a tapping near to the flow meter within the flow meter chamber, as such installations can affect flow metering accuracy. The pump pressure could then be automatically calculated from known levels and losses between the transducer and the pump.

The daily output volumes taken from the 2018 SCADA data in Figure 7 suggest that opportunities exist for optimising control. Incorporating a two-level control system running off a newly installed level sensor would enable one pump to be run during periods of low flow requirements to maintain small changes in level with the two operating in high flow periods as triggered from a lower level setpoint.

Using the daily total flow as guideline and a 21 hour per day pumping regime, 2018 results indicate that Seend could operate on 1no pump on most days of the year. However, it is acknowledged that averaging out the daily flow is an oversimplification and may not be feasible at times to maintain a navigable canal level where 2-pumps will be necessary.

However, this development is subject on the required volume over time needed to safely maintain canal levels for navigation, and a closer assessment would be needed to conclude its feasibility.

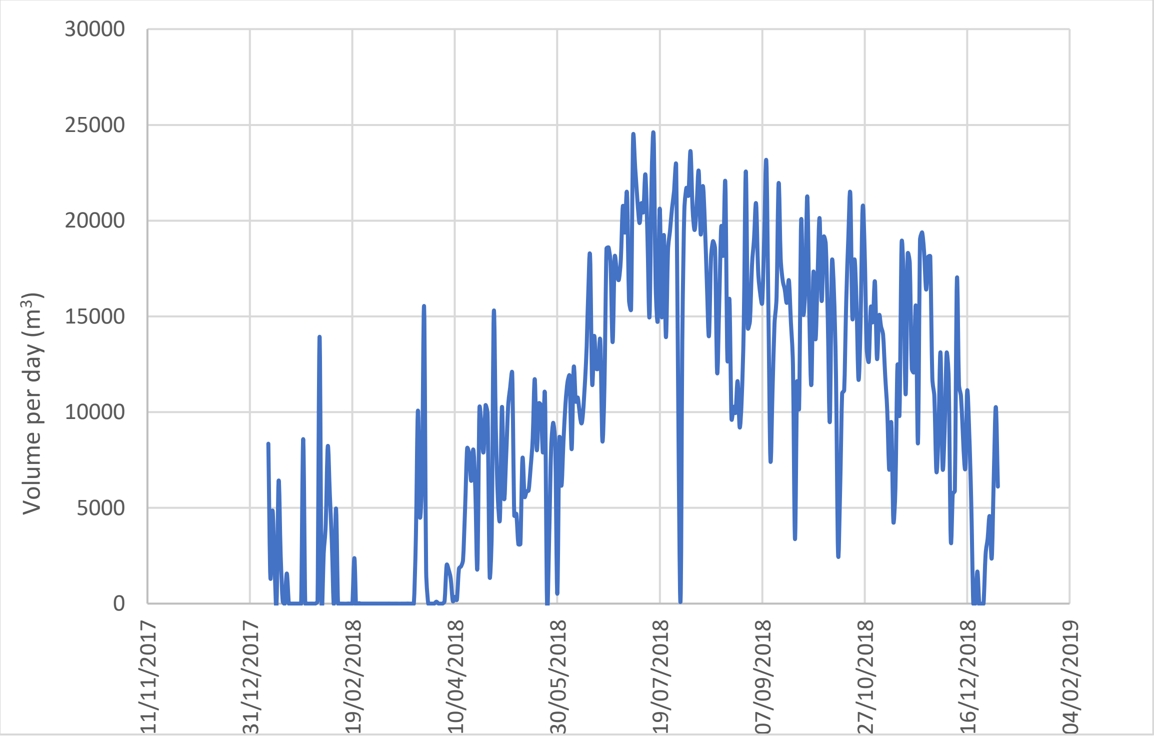


Figure 14 – Daily Volume Pumped during 2018 (Estimated from SCADA data)

10 Preliminary Conclusions

10.1 Existing Pump Hydraulics Performance and Selection

In terms of hydraulic sizing, the installed pumps have been selected appropriately by Xylem, although this has been based upon the assumption of 450 mm PVCu main which is suspected has been replaced. The shallow well depth is not suitable for the type of motor cooling installed.

There is a more efficient solution to the current pumps by operating with a smaller impeller, but this does come with a slight reduction in flow rate. It should be noted, as per the existing pumps, that the NP3301.632 pumps suggested do not operate within 70% to 120% of the pump BEP at single duty when operating at 50 Hz and will require cooling jackets to avoid overheating.

A selection for 1-pump duty/standby operation could provide a more energy efficient option but only when operating during high flows. During low flow operation, the benefits are significantly reduced and would likely attract a higher capital investment.

IE3 motors are available for either of the selections above and it would be recommended that this option is explored further to reduce energy consumption.

Replacing the VSD units with soft start/stop drives and revert to back to a fixed speed operation will reduce energy consumption. This would have the additional benefit of reducing electrical losses, simplifying the system and controls. However, operational preferences with using VSDs is accepted.

10.2 Pump Control

Based on the specific energy analysis and review of daily pumped volume, the pump control could potentially be optimised to provide energy savings. The review of control would be subject to the hydraulic modelling review being undertaken by University of Liege and agreement from CRT on potential and future requirements.

10.3 Rising Main

From the calculations, based on the provided SCADA and pump audit data, it is suspected that the rising main is not as stated within the As Built drawings and has been replaced with a larger diameter downstream of the flowmeter. It is recommended that this investigated by means of a small trial pit to confirm as required.

10.4 Energy Saving Potential

There is potential here to reduce overall energy usage at this site. There are several possibilities that could be explored such as using more refined level control, changing impeller diameter, using IE3 motors, and potential VSD removal. By combining options, it may be feasible to achieve between 10% and 18% in energy savings.

Table 8 – Potential energy savings by option/action (based on 2018 flows and 3.45M m³ total volume)

Option/Action	% Saving over Existing	kWh / Annum**
IE3 Motors	3.3	11,575
Fixed Speed Drives (+IE3)	4.5 to 12.1	14,720 to 40,020
Larger impeller/motor Duty/Standby Configuration (+ IE3) (New PS)	6	19,780
Changing to 2-Point level Control*	3	10,062

** based on existing pumps & 25% single pump operation*

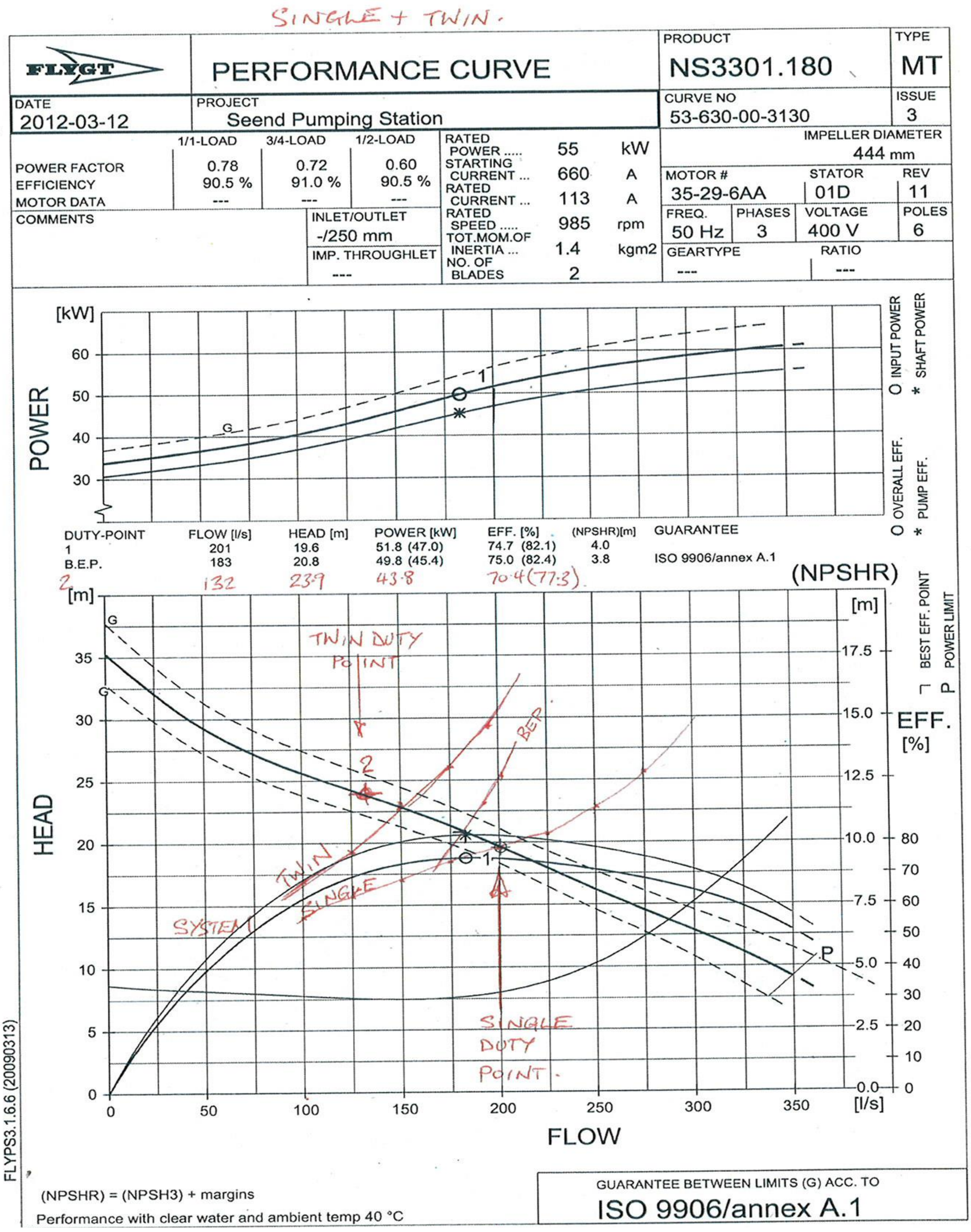
*** Based on existing 2-pump operation at 47.5 Hz*

11 Recommendations

- It is recommended that the vibration issues on Pump 2 are investigated, and that the pump stool is assessed during the next wet well inspection/clean down.
- Assess the cost-benefit opportunities for duty/standby and fixed speed options.
- Inspect and potentially recalibrate the existing flowmeter and SCADA values.
- The rising main diameter should also be further investigated to confirm the assumptions within this report.
- Investigate and potentially implement a 2-level pump control system which allows pump flow rate to vary with Lock 21 flight levels. For example, reducing flow rate when levels are approaching the existing “Stop pump” level.
- Consult with University of Liege and finalise the levels and flow rates required to maintain the system in operation before finalising the pump selection and duty configuration: -
    - Assuming the flow rates can be reduced, provide NP3301.632 with 424 mm impellers and new IE3 jacket cooled motors.
    - If flow rates are fixed or require to be marginally increased, then replacing the existing pumps like-for-like complete with jacket cooled IE3 motors would be the best option.

APPENDIX A

Existing Xylem pump performance curve



SINGLE + TWIN.

FLYGT

PERFORMANCE CURVE

PRODUCT	NS3301.180	TYPE	MT		
DATE	2012-03-12	PROJECT	Seend Pumping Station		
CURVE NO	53-630-00-3130	ISSUE	3		

	1/1-LOAD	3/4-LOAD	1/2-LOAD
POWER FACTOR	0.78	0.72	0.60
EFFICIENCY	90.5 %	91.0 %	90.5 %
MOTOR DATA	---	---	---

COMMENTS

INLET/OUTLET -/250 mm

IMP. THROUGHLET ---

RATED POWER	55	kW
STARTING CURRENT ...	660	A
RATED CURRENT ...	113	A
RATED SPEED	985	rpm
TOT.MOM.OF INERTIA ...	1.4	kgm2
NO. OF BLADES	2	

IMPELLER DIAMETER 444 mm

MOTOR #	STATOR	REV
35-29-6AA	01D	11

FREQ.	PHASES	VOLTAGE	POLES
50 Hz	3	400 V	6

GEARTYPE	RATIO
---	---

DUTY-POINT	FLOW [l/s]	HEAD [m]	POWER [kW]	EFF. [%]	(NPSHR)[m]	GUARANTEE
1	201	19.6	51.8 (47.0)	74.7 (82.1)	4.0	
B.E.P.	183	20.8	49.8 (45.4)	75.0 (82.4)	3.8	ISO 9906/annex A.1
2	132	23.9	43.8	70.4 (77.3).		

(NPSHR) = (NPSH3) + margins

Performance with clear water and ambient temp 40 °C

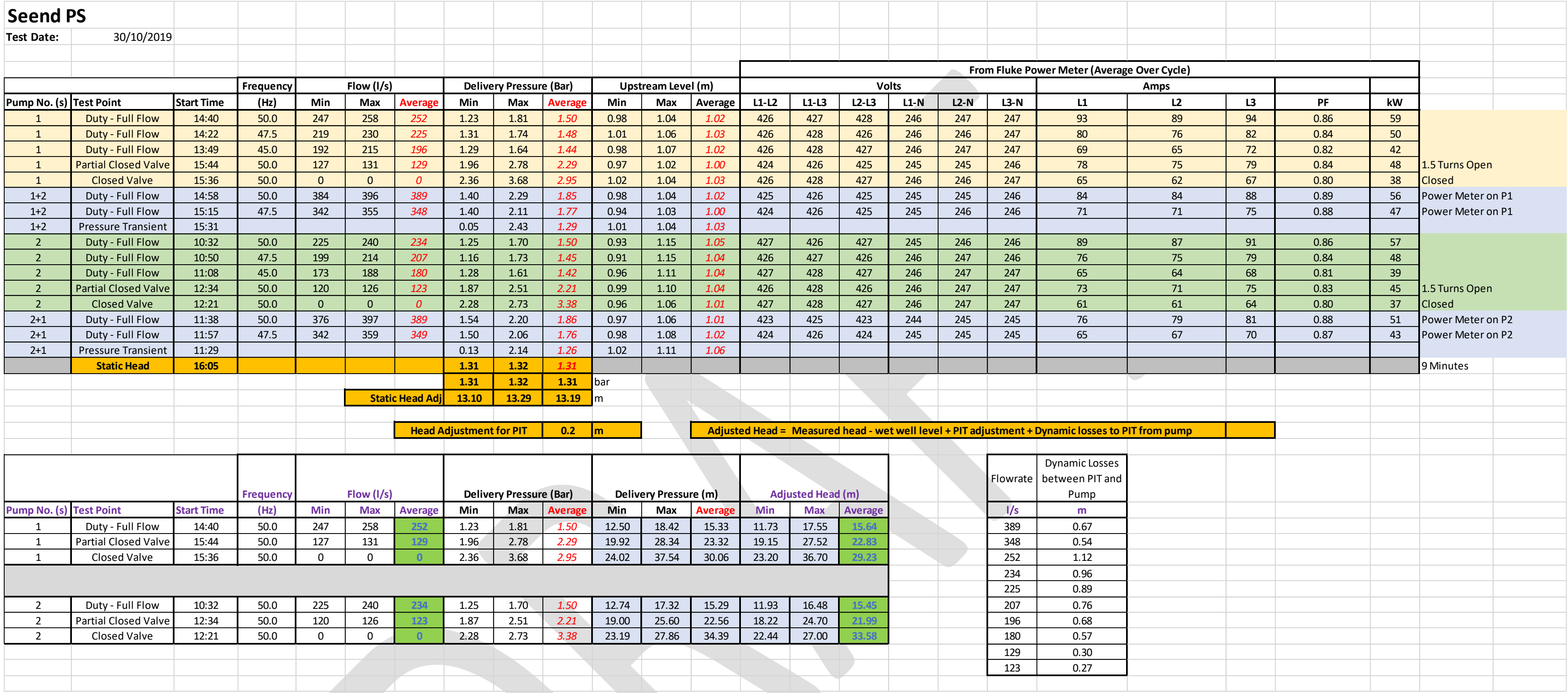
GUARANTEE BETWEEN LIMITS (G) ACC. TO

ISO 9906/annex A.1

Figure 15 – Xylem Issued Pump Curve and Design Operating Points

APPENDIX B

On Site Measurements – Pump Audit Test Data



Seend PS

Test Date: 30/10/2019

			Frequency	Flow (l/s)			Delivery Pressure (Bar)			Upstream Level (m)			From Fluke Power Meter (Average Over Cycle) 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	14:40	50.0	247	258	*252*	1.23	1.81	*1.50*	0.98	1.04	*1.02*	426	427	428	246	247	247	93	89	94	0.86	59	
1	Duty - Full Flow	14:22	47.5	219	230	*225*	1.31	1.74	*1.48*	1.01	1.06	*1.03*	426	428	426	246	246	247	80	76	82	0.84	50	
1	Duty - Full Flow	13:49	45.0	192	215	*196*	1.29	1.64	*1.44*	0.98	1.07	*1.02*	426	428	427	246	247	247	69	65	72	0.82	42	
1	Partial Closed Valve	15:44	50.0	127	131	*129*	1.96	2.78	*2.29*	0.97	1.02	*1.00*	424	426	425	245	245	246	78	75	79	0.84	48	1.5 Turns Open
1	Closed Valve	15:36	50.0	0	0	*0*	2.36	3.68	*2.95*	1.02	1.04	*1.03*	426	428	427	246	246	247	65	62	67	0.80	38	Closed
1+2	Duty - Full Flow	14:58	50.0	384	396	*389*	1.40	2.29	*1.85*	0.98	1.04	*1.02*	425	426	425	245	245	246	84	84	88	0.89	56	Power Meter on P1
1+2	Duty - Full Flow	15:15	47.5	342	355	*348*	1.40	2.11	*1.77*	0.94	1.03	*1.00*	424	426	425	245	246	246	71	71	75	0.88	47	Power Meter on P1
1+2	Pressure Transient	15:31					0.05	2.43	*1.29*	1.01	1.04	*1.03*												
2	Duty - Full Flow	10:32	50.0	225	240	*234*	1.25	1.70	*1.50*	0.93	1.15	*1.05*	427	426	427	245	246	246	89	87	91	0.86	57	
2	Duty - Full Flow	10:50	47.5	199	214	*207*	1.16	1.73	*1.45*	0.91	1.15	*1.04*	426	427	426	246	247	246	76	75	79	0.84	48	
2	Duty - Full Flow	11:08	45.0	173	188	*180*	1.28	1.61	*1.42*	0.96	1.11	*1.04*	427	428	427	246	247	247	65	64	68	0.81	39	
2	Partial Closed Valve	12:34	50.0	120	126	*123*	1.87	2.51	*2.21*	0.99	1.10	*1.04*	426	428	426	246	247	247	73	71	75	0.83	45	1.5 Turns Open
2	Closed Valve	12:21	50.0	0	0	*0*	2.28	2.73	*3.38*	0.96	1.06	*1.01*	427	428	427	246	247	247	61	61	64	0.80	37	Closed
2+1	Duty - Full Flow	11:38	50.0	376	397	*389*	1.54	2.20	*1.86*	0.97	1.06	*1.01*	423	425	423	244	245	245	76	79	81	0.88	51	Power Meter on P2
2+1	Duty - Full Flow	11:57	47.5	342	359	*349*	1.50	2.06	*1.76*	0.98	1.08	*1.02*	424	426	424	245	245	245	65	67	70	0.87	43	Power Meter on P2
2+1	Pressure Transient	11:29					0.13	2.14	*1.26*	1.02	1.11	*1.06*												
	Static Head	**16:05**					**1.31**	**1.32**	***1.31***															9 Minutes
							1.31	**1.32**	**1.31**	bar														
						Static Head Adj	**13.10**	**13.29**	**13.19**	m														

Head Adjustment for PIT **0.2** **m**

Adjusted Head = Measured head - wet well level + PIT adjustment + Dynamic losses to PIT from pump

			Frequency	Flow (l/s)			Delivery Pressure (Bar)			Delivery Pressure (m)			Adjusted Head (m)		
Pump No. (s)	Test Point	Start Time	(Hz)	Min	Max	Average	**Min**	**Max**	Average	**Min**	**Max**	Average	Min	Max	Average
1	Duty - Full Flow	14:40	50.0	247	258	252	1.23	1.81	*1.50*	12.50	18.42	15.33	11.73	17.55	15.64
1	Partial Closed Valve	15:44	50.0	127	131	129	1.96	2.78	*2.29*	19.92	28.34	23.32	19.15	27.52	22.83
1	Closed Valve	15:36	50.0	0	0	0	2.36	3.68	*2.95*	24.02	37.54	30.06	23.20	36.70	29.23
2	Duty - Full Flow	10:32	50.0	225	240	234	1.25	1.70	*1.50*	12.74	17.32	15.29	11.93	16.48	15.45
2	Partial Closed Valve	12:34	50.0	120	126	123	1.87	2.51	*2.21*	19.00	25.60	22.56	18.22	24.70	21.99
2	Closed Valve	12:21	50.0	0	0	0	2.28	2.73	*3.38*	23.19	27.86	34.39	22.44	27.00	33.58

Flowrate	Dynamic Losses between PIT and Pump
l/s	m
389	0.67
348	0.54
252	1.12
234	0.96
225	0.89
207	0.76
196	0.68
180	0.57
129	0.30
123	0.27

Figure 16 – Tabulated Data Summary from Site Audit 30/10/2019

Trend P1

Figure 17 – Site Audit Measurement Trends for P1 only running at various frequencies (45Hz/47.5Hz/50Hz)

Pressure in bar

Flow rate in l/s

Sump Level in mm

Trend P2

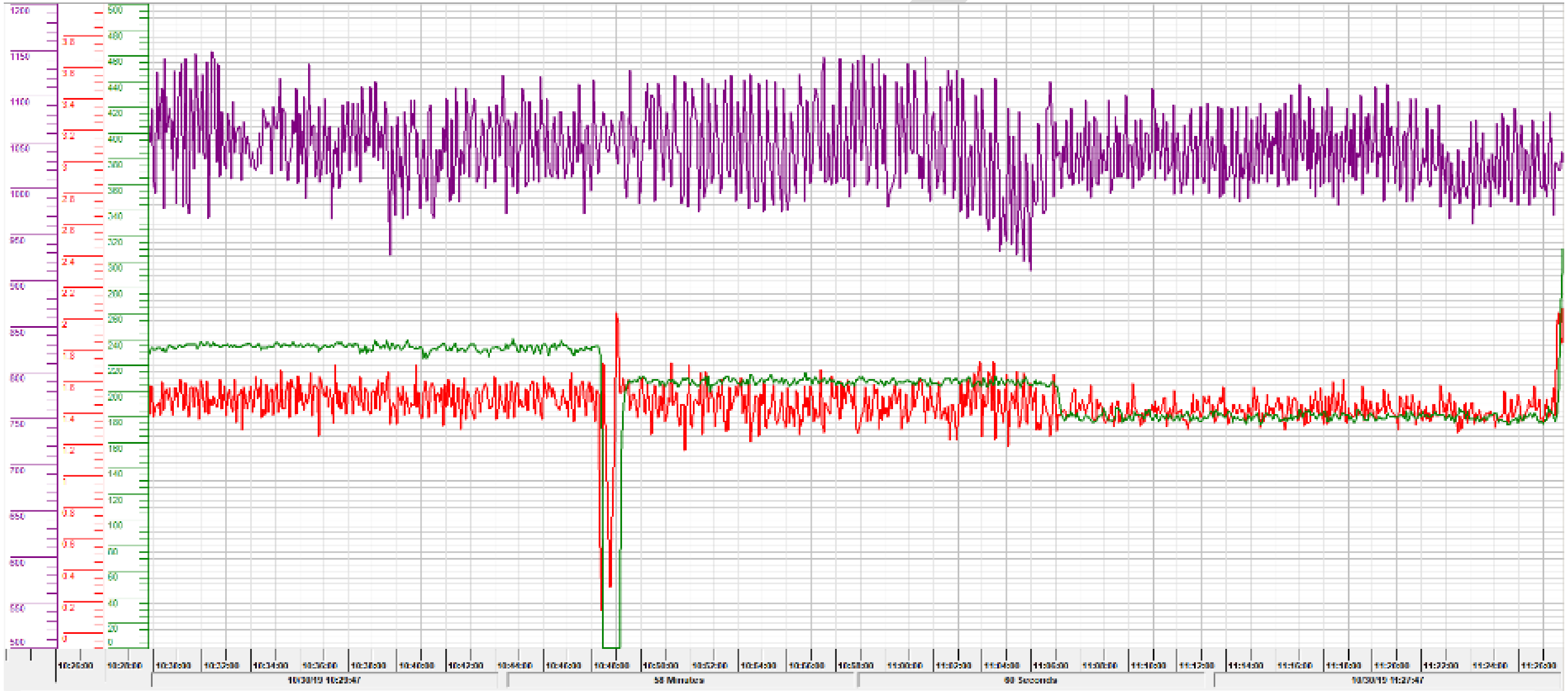


Figure 18 - Site Audit Measurement Trends for P2 only running at various frequencies (50Hz/47.5Hz/45Hz)

Pressure in bar

Flow rate in l/s

Sump Level in mm

Trend P1 + P2

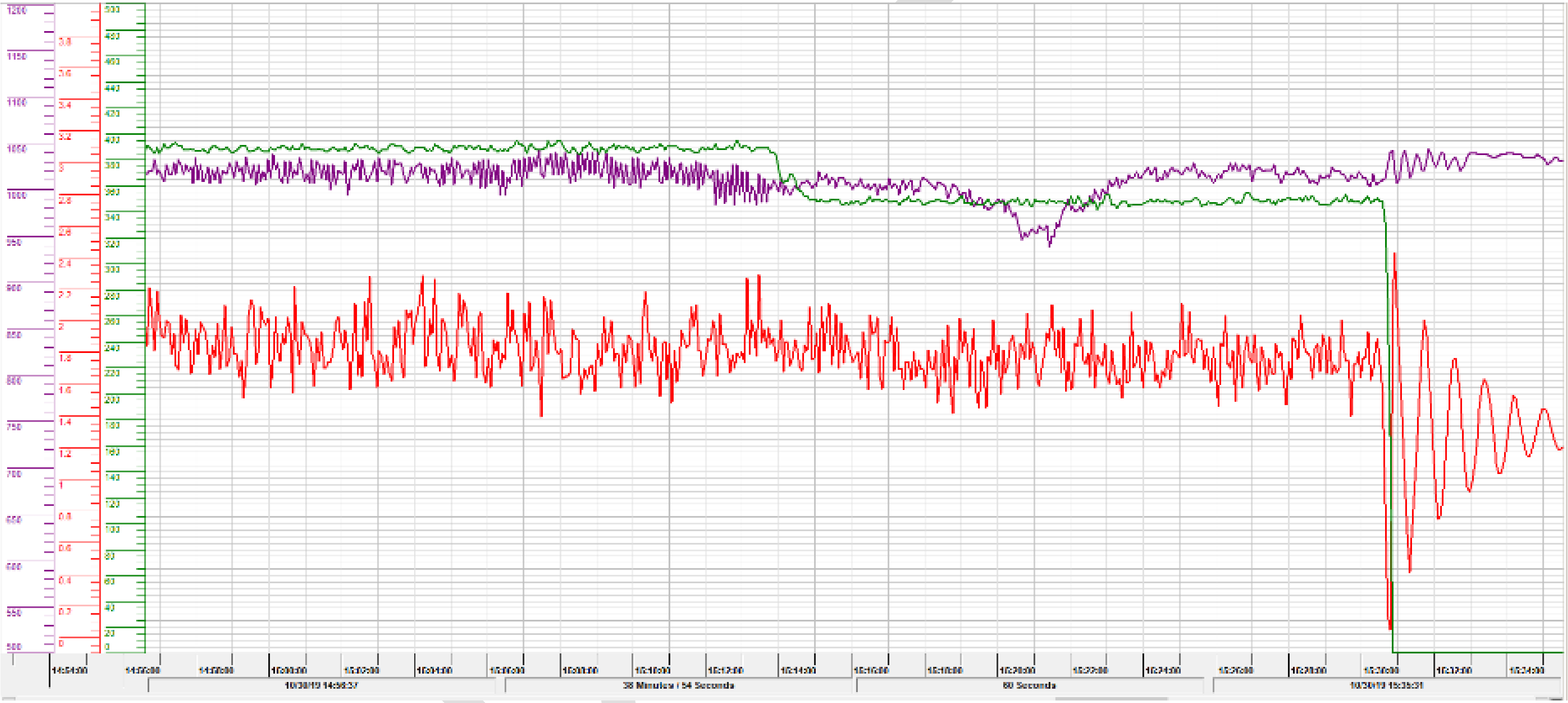


Figure 19 - Site Audit Measurement Trends for P1 (+ P2) when running in parallel at various frequencies (50Hz/47.5Hz)

Pressure in bar

Flow rate in l/s

Sump Level in mm

Trend P2 + P1

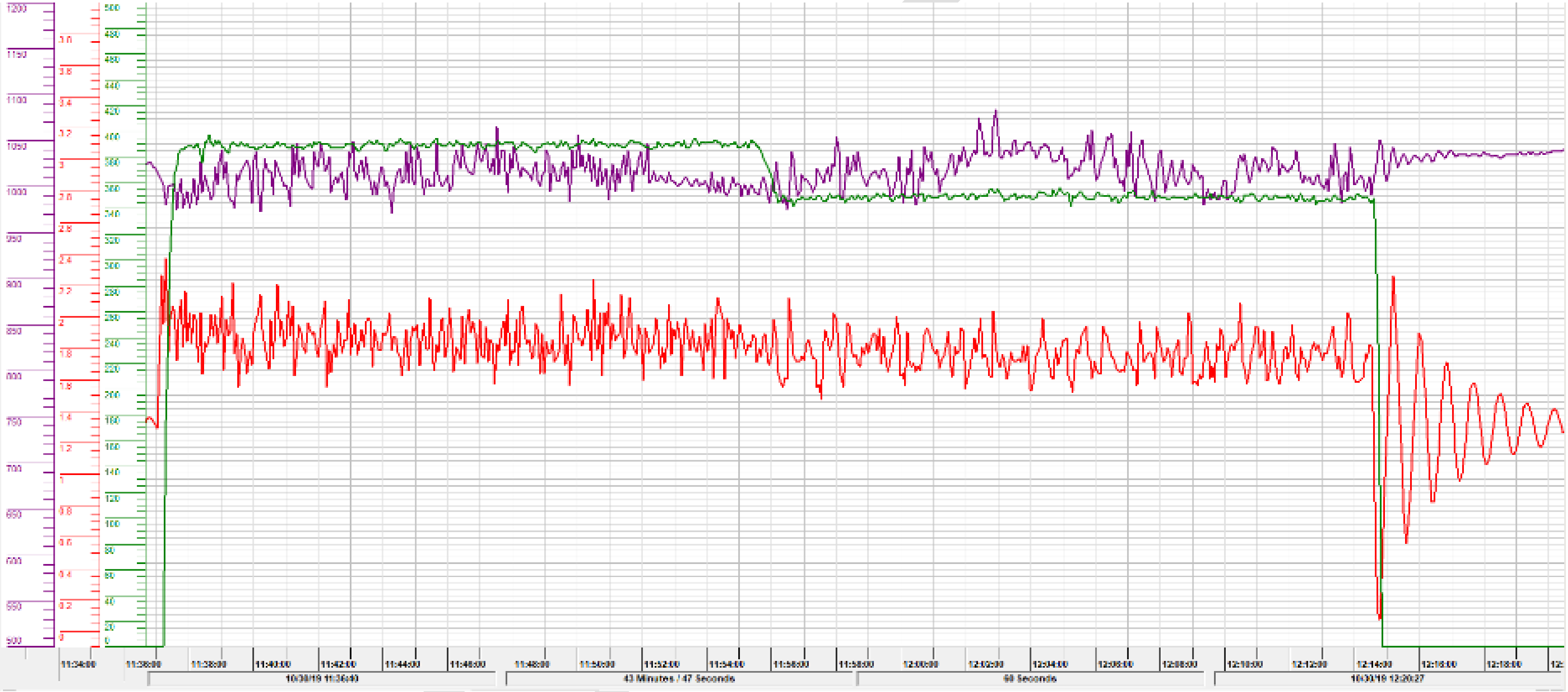


Figure 20 - Site Audit Measurement Trends for P2 (+ P1) when running in parallel at various frequencies (50Hz/47.5Hz)

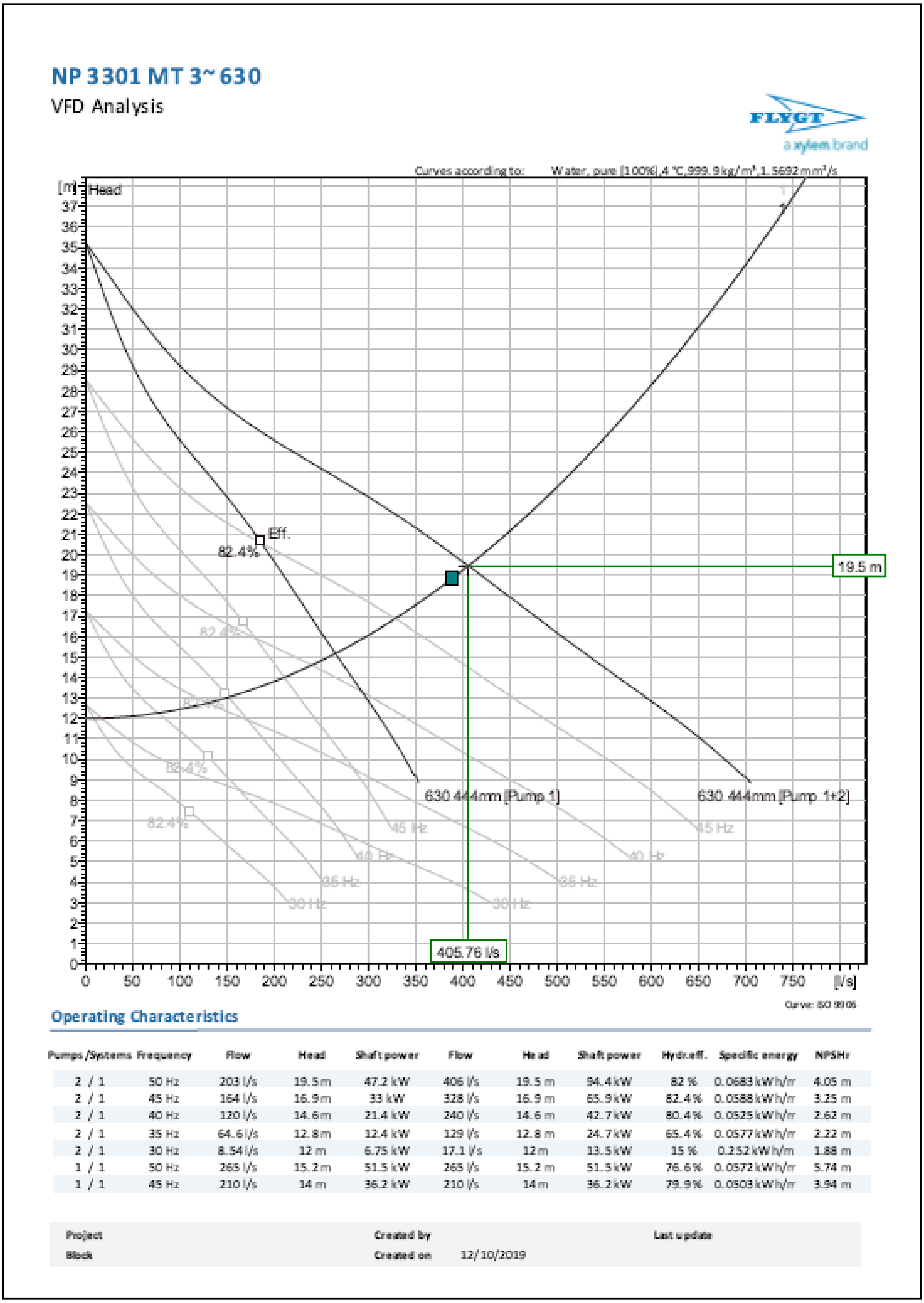
Pressure in bar

Flow rate in l/s

Sump Level in mm

APPENDIX C

Alternative Pump Selection Data Sheets



NP 3301 MT 3~630

VFD Analysis

Operating Characteristics

Pumps /Systems	Frequency	Flow	Head	Shaft power	Flow	Head	Shaft power	Hydr.eff.	Specific energy	NPSHr
2 / 1	50 Hz	203 l/s	19.5 m	47.2 kW	406 l/s	19.5 m	94.4 kW	82 %	0.0683 kWh/m³	4.05 m
2 / 1	45 Hz	164 l/s	16.9 m	33 kW	328 l/s	16.9 m	65.9 kW	82.4 %	0.0588 kWh/m³	3.25 m
2 / 1	40 Hz	120 l/s	14.6 m	21.4 kW	240 l/s	14.6 m	42.7 kW	80.4 %	0.0525 kWh/m³	2.62 m
2 / 1	35 Hz	64.6 l/s	12.8 m	12.4 kW	129 l/s	12.8 m	24.7 kW	65.4 %	0.0577 kWh/m³	2.22 m
2 / 1	30 Hz	8.54 l/s	12 m	6.75 kW	17.1 l/s	12 m	13.5 kW	15 %	0.252 kWh/m	1.88 m
1 / 1	50 Hz	265 l/s	15.2 m	51.5 kW	265 l/s	15.2 m	51.5 kW	76.6 %	0.0572 kWh/m³	5.74 m
1 / 1	45 Hz	210 l/s	14 m	36.2 kW	210 l/s	14 m	36.2 kW	79.9 %	0.0503 kWh/m³	3.94 m

Project		Created by		Last update	
Block		Created on	12/10/2019		

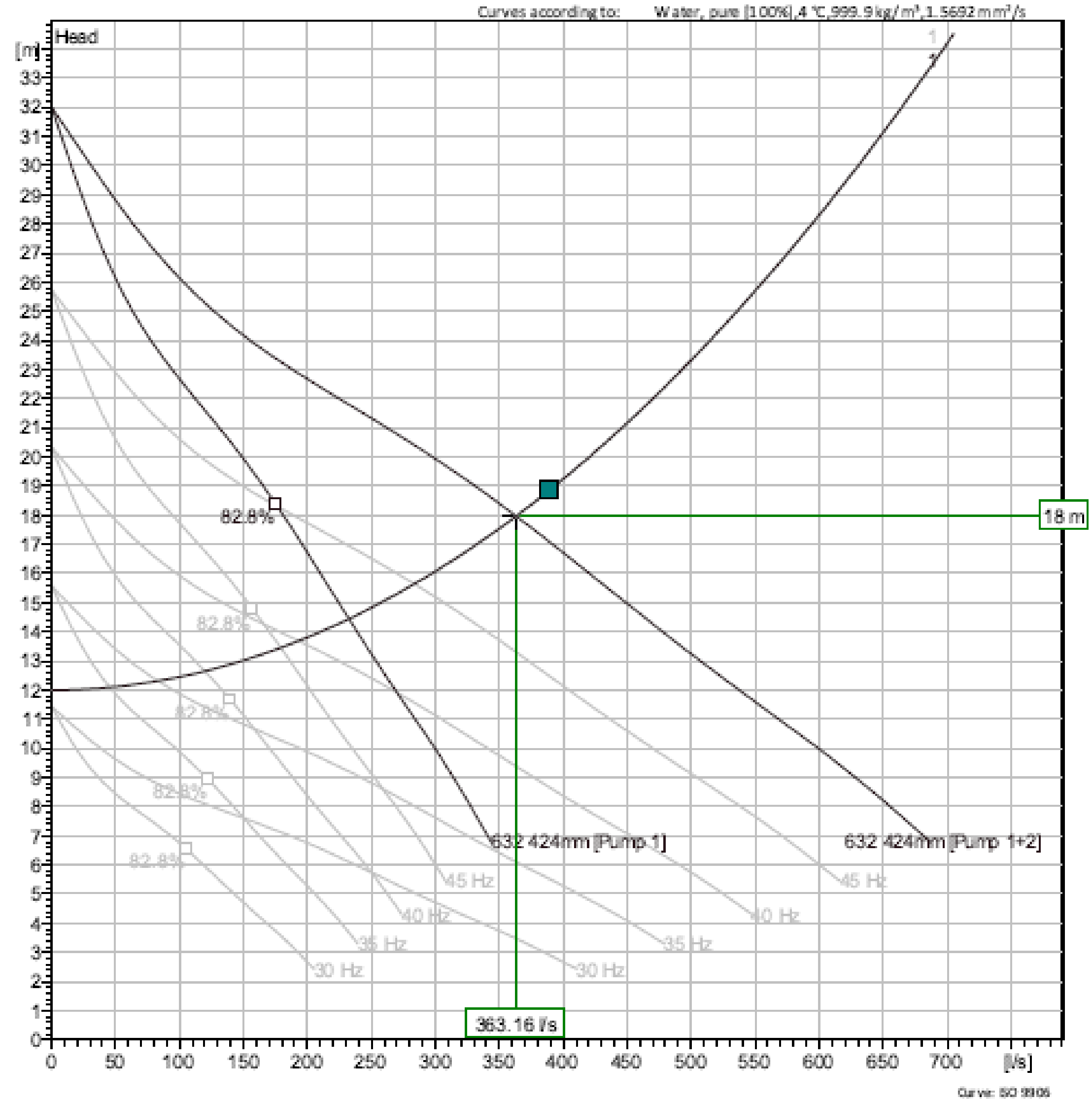
Figure 21- Xylem NP3301 444mm Selection (Existing) Operating Curves & Data

NP 3301 MT 3~ 632

VFD Analysis

FLYGT
a xylem brand

Curves according to: Water, pure [100%],4 °C,999.9 kg/m³,1.5692 mm²/s

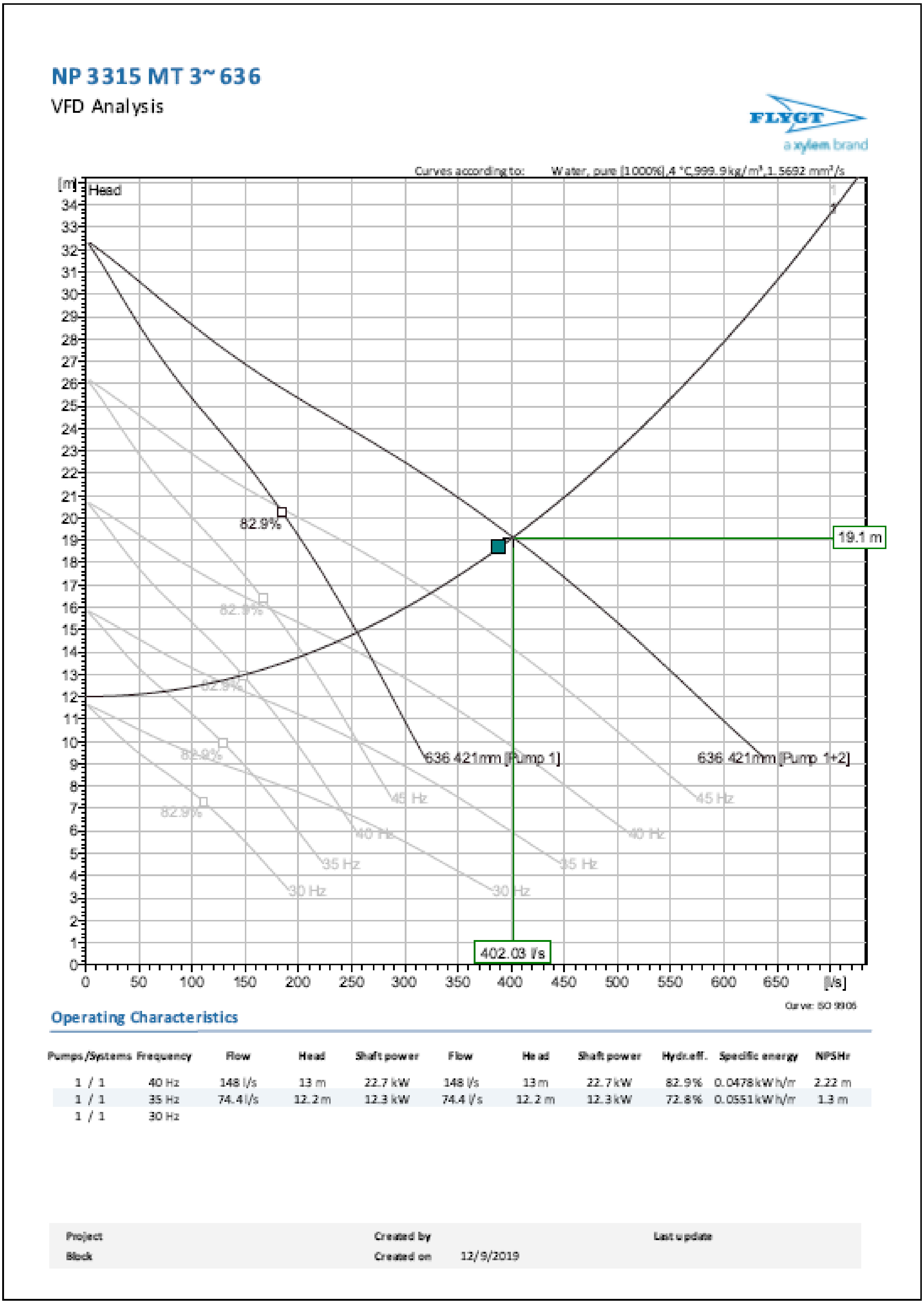


Operating Characteristics

Pumps /Systems	Frequency	Flow	Head	Shaft power	Flow	Head	Shaft power	Hydr.eff.	Specific energy	NPSHr
2 / 1	50 Hz	182 l/s	18 m	38.7 kW	363 l/s	18 m	77.4 kW	82.7 %	0.0628 kWh/m³	3.83 m
2 / 1	45 Hz	144 l/s	15.7 m	26.9 kW	287 l/s	15.7 m	53.9 kW	82.3 %	0.055 kWh/m	3.17 m
2 / 1	40 Hz	98.4 l/s	13.8 m	17.2 kW	197 l/s	13.8 m	34.4 kW	77 %	0.0515 kWh/m³	2.66 m
2 / 1	35 Hz	43.2 l/s	12.3 m	9.97 kW	86.4 l/s	12.3 m	19.9 kW	52.5 %	0.0691 kWh/m³	2.29 m
2 / 1	30 Hz									
1 / 1	50 Hz	232 l/s	14.4 m	41.9 kW	232 l/s	14.4 m	41.9 kW	78.6 %	0.0533 kWh/m³	4.62 m
1 / 1	45 Hz	182 l/s	13.5 m	29.4 kW	182 l/s	13.5 m	29.4 kW	81.8 %	0.0474 kWh/m³	3.41 m

Project		**Created by**		**Last update**	
Block		**Created on**	12/10/2019		

Figure 22 – Xylem NP3301 424mm Selection (Best Specific Energy) Operating Curves & Data



NP 3315 MT 3~636

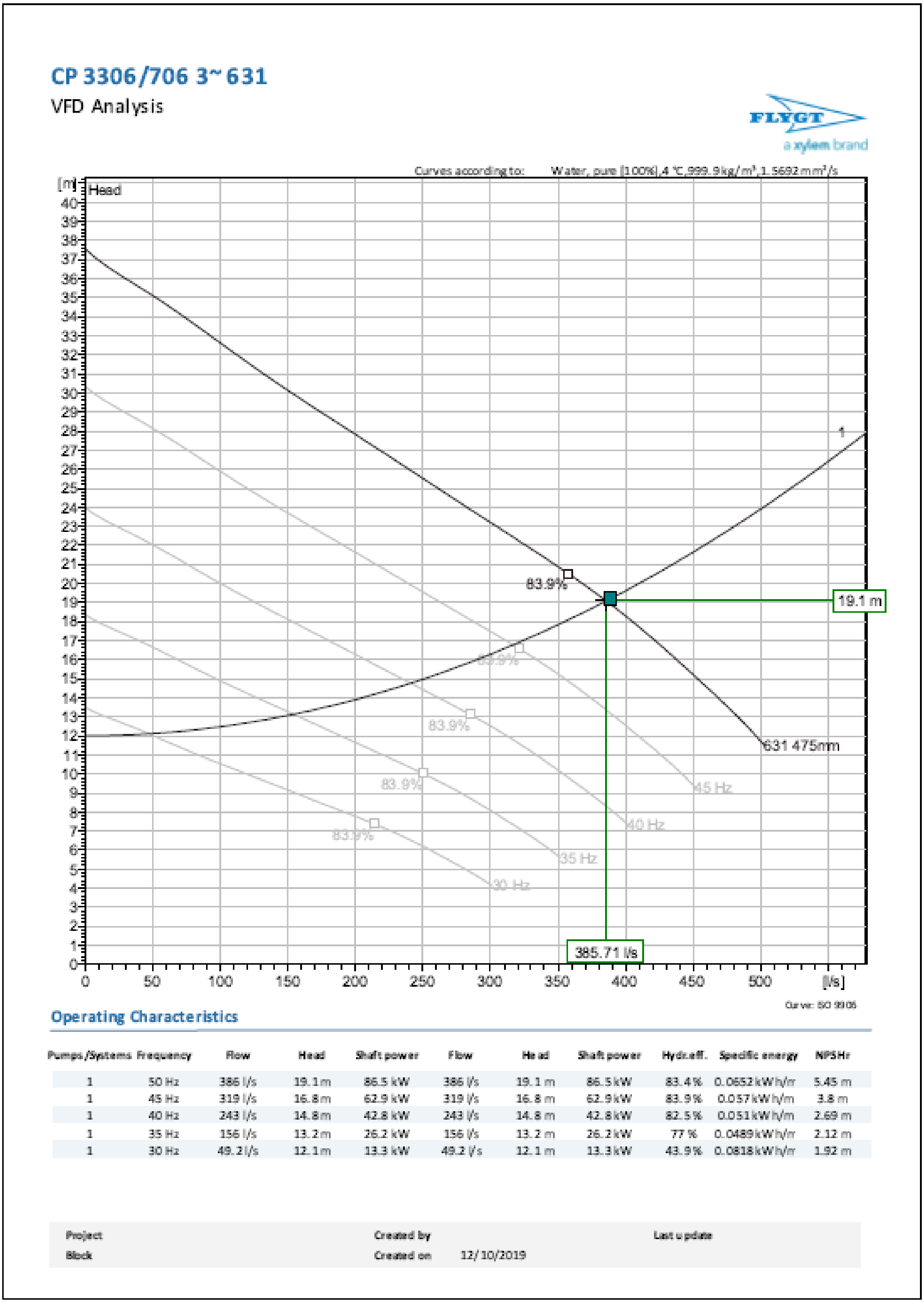
VFD Analysis

Operating Characteristics

Pumps /Systems	Frequency	Flow	Head	Shaft power	Flow	Head	Shaft power	Hydr.eff.	Specific energy	NPSHr
1 / 1	40 Hz	148 l/s	13 m	22.7 kW	148 l/s	13 m	22.7 kW	82.9%	0.0478 kWh/m³	2.22 m
1 / 1	35 Hz	74.4 l/s	12.2 m	12.3 kW	74.4 l/s	12.2 m	12.3 kW	72.8%	0.0551 kWh/m³	1.3 m
1 / 1	30 Hz									

Project	Created by		Last update	
Block	Created on	12/9/2019		

Figure 23 – Xylem NP3315 421mm Selection Operating Curves & Data



CP 3306/706 3~ 631

VFD Analysis

Curves according to: Water, pure [100%],4 °C,999.9kg/m³,1.5692mm²/s

Operating Characteristics

Pumps/Systems	Frequency	Flow	Head	Shaft power	Flow	Head	Shaft power	Hydr.eff.	Specific energy	NPSHr
1	50 Hz	386 l/s	19.1 m	86.5 kW	386 l/s	19.1 m	86.5 kW	83.4 %	0.0652 kWh/m³	5.45 m
1	45 Hz	319 l/s	16.8 m	62.9 kW	319 l/s	16.8 m	62.9 kW	83.9 %	0.057 kWh/m³	3.8 m
1	40 Hz	243 l/s	14.8 m	42.8 kW	243 l/s	14.8 m	42.8 kW	82.5 %	0.051 kWh/m³	2.69 m
1	35 Hz	156 l/s	13.2 m	26.2 kW	156 l/s	13.2 m	26.2 kW	77 %	0.0489 kWh/m³	2.12 m
1	30 Hz	49.2 l/s	12.1 m	13.3 kW	49.2 l/s	12.1 m	13.3 kW	43.9 %	0.0818 kWh/m³	1.92 m

Project		Created by		Last update	
Block		Created on	12/10/2019		

Figure 24 - Xylem NP3306 475mm Selection (Duty/Standby Option) Operating Curves & Data

Interreg
North-West Europe
Green WIN
European Regional Development Fund

Canal & River Trust
Making life better by water

LIÈGE université

Ministerie van Infrastructuur
en Waterstaat

Waterways Ireland
Uiscebhealaí Éireann Watterweys Airlann

vnf
Voies navigables de France

VLAAMSE
LAND
MAATSCHAPPIJ