Leinster Aqueduct

PUMP AUDIT SUMMARY REPORT

NICK TAYLOR

March 2020

Leinster Aqueduct

PUMP AUDIT SUMMARY REPORT

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Report No: 10031024-00524

Work Package: Improving existing systems and processes T1

Date: March 2020

Version Control

Version Number	Date issued	Author	Checker	Approver	Changes
P1	28/11/19	N. Taylor	J. Bernard	N. John	Issue for Comment

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Content

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1 Introduction

This report summarises the key findings of the pump station audit for Leinster Aqueduct Pumping Station (PS). This review is based upon the data provided by Waterways Ireland (WI) and a site visit undertaken on 9th September 2019.

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

- Power (using Fluke power meter)
- Flow rate (using Panametrics PT878 ultrasonic flow meter)
- Levels and dimensions (laser/tape measure)

2 System Description

2.1 Pump Station

Leinster Aqueduct PS is situated on the River Liffey, approx. 2 km north east of Donore, Co. Kildare. The pumping station lifts water from the River Liffey into the Grand Canal Lock system to replenish the system during the summer months.

Figure 1- Leinster Pump Station (viewed from Grand Canal)

Leinster Aqueduct pump station comprises of 3 no. KSB Amarex KRT K200-401/266 UG-S, fixed-speed, submersible pumps each located within individual pump bays. Each pump bay contains an Endress & Hauser level probe which operate for low level protection. The pumps are protected by a 50 mm bar screen.

The pumps are controlled in 'hand', with no other instrumentation present (flow meter, pressure transducer, etc). There was once a phone/radio operated control system in place, but this was reported to have only been in operation for a few months before failing and has never been utilised since.

The pump discharge pipework is DN200 Ductile Iron up to the pump house and connects into a DN200 Ductile Iron (DI) rising main. There are 3 no. individual DN200 DI mains in total, one for each pump. No isolation valves or check valves are present within the system, as these were all removed as part of refurbishment works in 2010.

Figure 2 -Leinster Pump Station Outfall

The 3 no. rising mains free discharge to a concrete outfall chamber on the Grand Canal approx. 20 m away, passing through the pump house en route.

In addition to the concrete outfall chamber, there is a sluice gate chamber complete with level sensor connected to a 600 mm PVC line to return water from the Grand Canal to the River Liffey over the winter months.

It is reported that the pump station operates between approximately March and September with the sluice gate drain in operation for the remainder, draining excess water from the canal network. The sluice is manually operated, and the level sensor found only serves for indication only not for any form of control on the sluice gate or pumps.

During the time of audit, the sluice gate appeared to be constantly leaking approximately 2-3 l/s even though closed. It is thought that the seal around the sluice gate has been compromised in some fashion.

Table 1 – Pump Details

Parameter	Description
Pump	KSB Amarex KRT K200-401/266
No. of Pumps	3
Duty Configuration	Duty/Duty/Standby (Submersible)
Rated Motor Output	24 kW
Impeller Diameter	346 mm
Drives	Fixed speed Star-Delta
Pipework	200 mm diameter
Non-Return Valves	N/A
Wet Well Level Sensor	E&H Ultrasonic for Low level protection
Wet Well Level	69.1 mAD
Pump Centre Line	Approx. 68.1 mAD

2.2 Rising Main

The 3 no. rising mains are approximately 20 m in length and manufactured from socket and spigot Ductile Iron past the pump station. It has been estimated based upon the original pump layout that

Pump 3 rising main is approximately 1.2m longer than Pump 2 which in turn is 1.2m longer than Pump 1.

There are no reports of bursts arising since construction.

The rising main runs from the pump house and free discharges to an outfall box on the Grand Canal. There are no isolation or check valves present on the rising main, nor was any additional instrumentation found.

Table 2 – Pump Discharge Main Details

Parameter	Description
Approx. Length	20 m
Elevation Rise	6.9 m
Pipe Diameter	200 mm
Discharge Level	75.33 mAD
Pipe Material	Ductile Iron
Pipe Roughness	ks = 0.6 mm assumed

3 System Description

System curves have been derived for the single pump operation as there is no common main within this system.

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

- Pump P1 operating only
- Pump P2 operating only
- Pump P3 operating only

The suction and delivery elevations, pipe roughness values have been based on the site recorded measurements as there is no SCADA data for Leinster Aqueduct pump station.

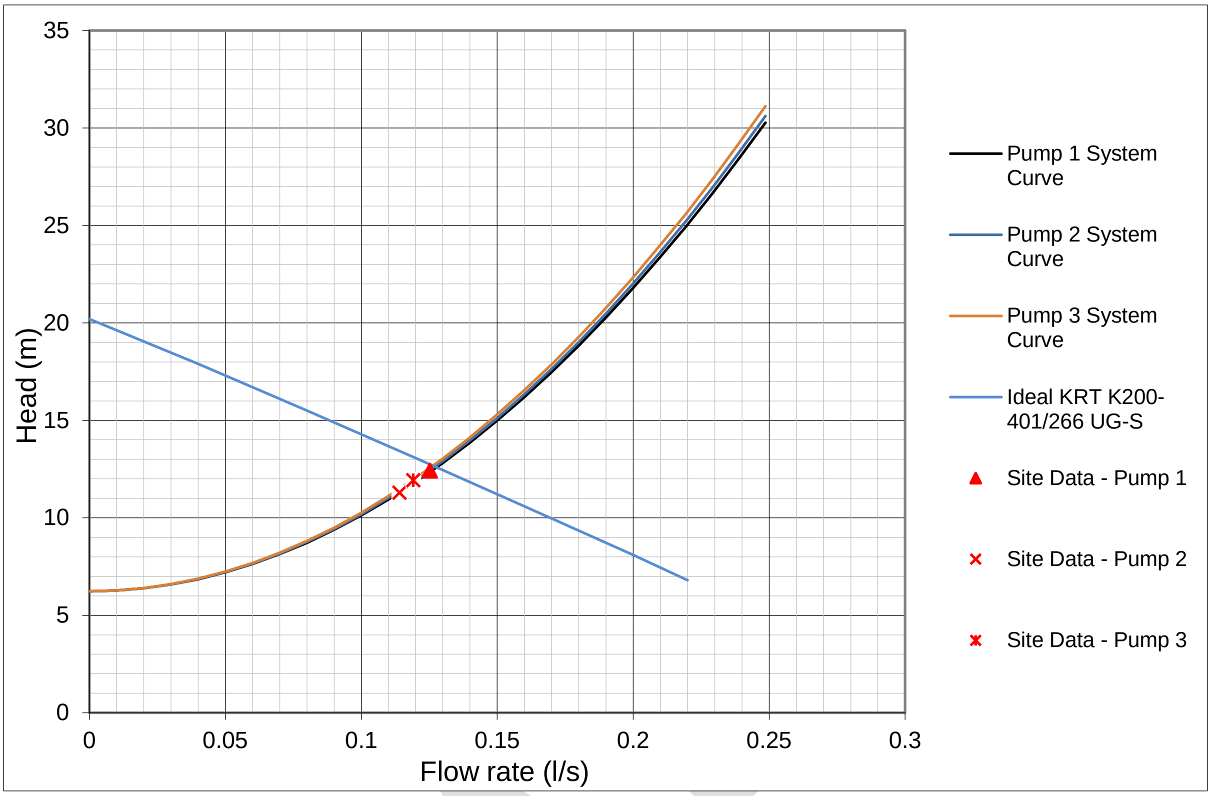

Figure 3 -Derived System Curve – All Pumps

It should be noted that the 3 no. separate rising mains have marginally different lengths (maximum difference approximated at 2.4 m between Pump 1 main and Pump 3 main) and marginally different flowrates, hence the variation in system curves that can be seen in Figure 3.

1 INPUT DATA

Gravity, g	9.81	m/s2
Atmos pressure	101.3	kPa
Fluid	Water	[select]
Temperature	10	°c
Kinem. viscosity	1.31E-06	m2/s
Density	999.7	kg/m³
Vap pressure	0.1245	m

Sump levels

TWL	69.1	mAOD
Design	69.1	mAOD
BWL	69.1	mAOD

Suction | Discharge

Pump level:	68.1	mAOD
Pump station located before reach:	1	[select]

Assumed Hydraulic Discharge levels

TWL	75.33	mAOD
Design	75.33	mAOD
BWL	75.33	mAOD

Static lift		
Minimum	6.23	m
Design	6.23	m
Maximum	6.23	m

Reach:		1	2	3	4	5	6	7	8	9	10	11	12	13
Description		DI pump discharge	DI pump discharge	DI rising main										
Length (m)		2	4.6	11.9										
Diameter (m)		0.2	0.2	0.2										
Flow area (m²)		0.03142	0.03142	0.03142										
Roughness (mm)	Low													
	Design	0.6	0.6	0.6										
	High													
Proportion of station flow		1.00	1.00	1.00										

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

Fittings Losses:	k-value	Number of fittings: 1	2	3	4
Inlet (slightly rounded)	0.25	1			
Short R 90° bend	0.75	2	1	1	
Taper up (4:5)	0.03				
Long R 90° bend	0.4		1		
Swing check valve	1				
Gate valve	0.12				
Gate valve	0.12				
Expansion 2:3	0.35				
Expansion 3:4	0.2				
Outlet	1			1	
Short R 45° bend	0.3				
Short R 22.5° bend	0.15		1		
Short R 22.5° bend	0.15			2	
		KNOWN	KNOWN	EST.	
Additional K (other devices)					
Total K		1.75	1.30	2.05	0.00

2 HYDRAULIC PROFILE

(All losses and heads in metres) Total pump station flow rate 125.21 l/s [select]

Figure 4 - Hydraulic Calculation Input Data for Pump 1

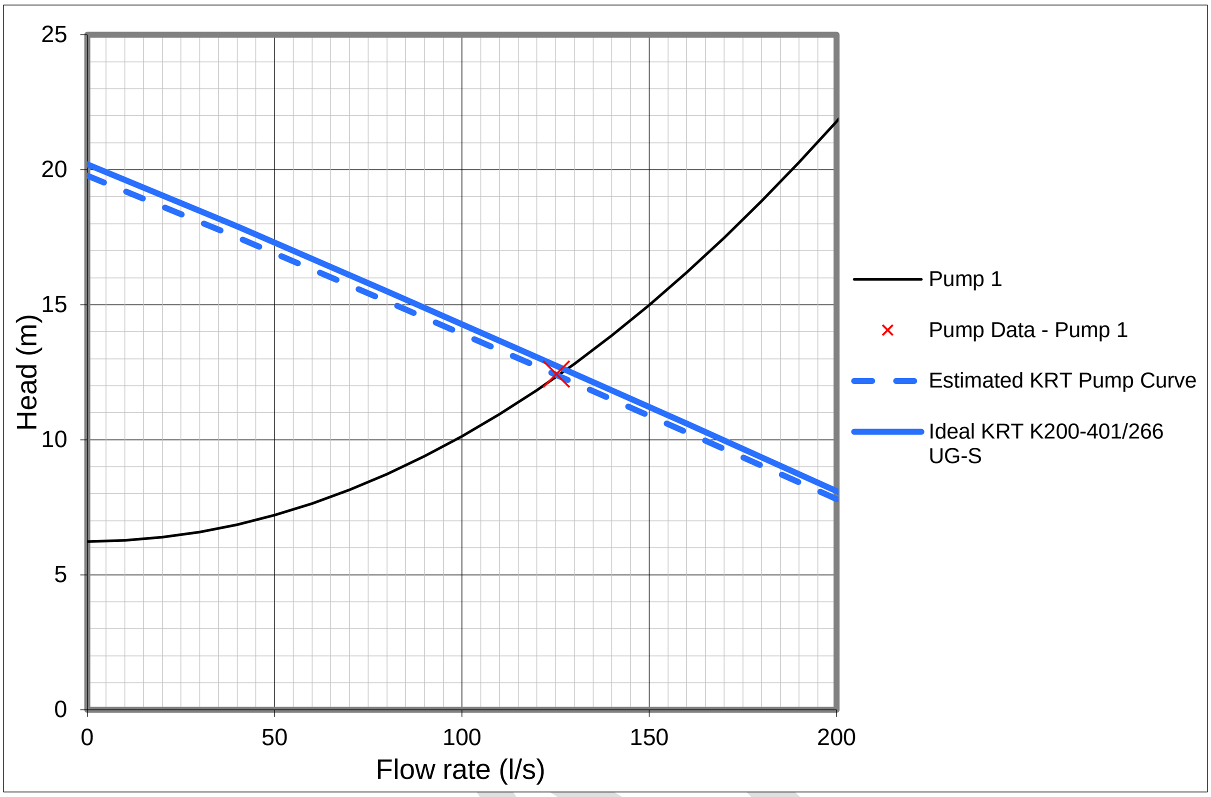

Figure 5 -Derived System Curve – Pump 1

1 INPUT DATA

Gravity, g	9.81	m/s2
Atmos pressure	101.3	kPa
Fluid	Water	[select]
Temperature	10	°c
Kinem. viscosity	1.31E-06	m2/s
Density	999.7	kg/m³
Vap pressure	0.1245	m

Sump levels		
TWL	69.1	mAOD
Design	69.1	mAOD
BWL	69.1	mAOD

Suction | Discharge

Pump level:	68.1	mAOD
Pump station located before reach:	1	[select]

Assumed Hydraulic Discharge levels		
TWL	75.33	mAOD
Design	75.33	mAOD
BWL	75.33	mAOD

Static lift		
Minimum	6.23	m
Design	6.23	m
Maximum	6.23	m

Reach:		1	2	3	4	5	6	7	8	9	10	11	12	13
Description		DI pump discharge	DI pump discharge	DI rising main										
Length (m)		2	4.6	13.1										
Diameter (m)		0.2	0.2	0.2										
Flow area (m²)		0.03142	0.03142	0.03142										
Roughness (mm)	Low													
	Design	0.6	0.6	0.6										
	High													
Proportion of station flow		1.00	1.00	1.00										

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

Fittings Losses:	k-value	Number of fittings: 1	2	3	4	5	6	7	8	9	10	11	12	13
Inlet (slightly rounded)	0.25	1												
Short R 90° bend	0.75	2	1	1										
Taper up (4:5)	0.03													
Long R 90° bend	0.4		1											
Swing check valve	1													
Gate valve	0.12													
Gate valve	0.12													
Expansion 2:3	0.35													
Expansion 3:4	0.2													
Outlet	1			1										
Long R 45° bend	0.2													
Long R 22.5° bend	0.1		1											
Short R 22.5° bend	0.15			2										
		KNOWN	KNOWN	EST.										
Additional K (other devices)														
Total K		1.75	1.25	2.05	0.00									

2 HYDRAULIC PROFILE

(All losses and heads in metres) Total pump station flow rate **114.07** l/s [select]

Figure 6 - Hydraulic Calculation Input Data for Pump 2

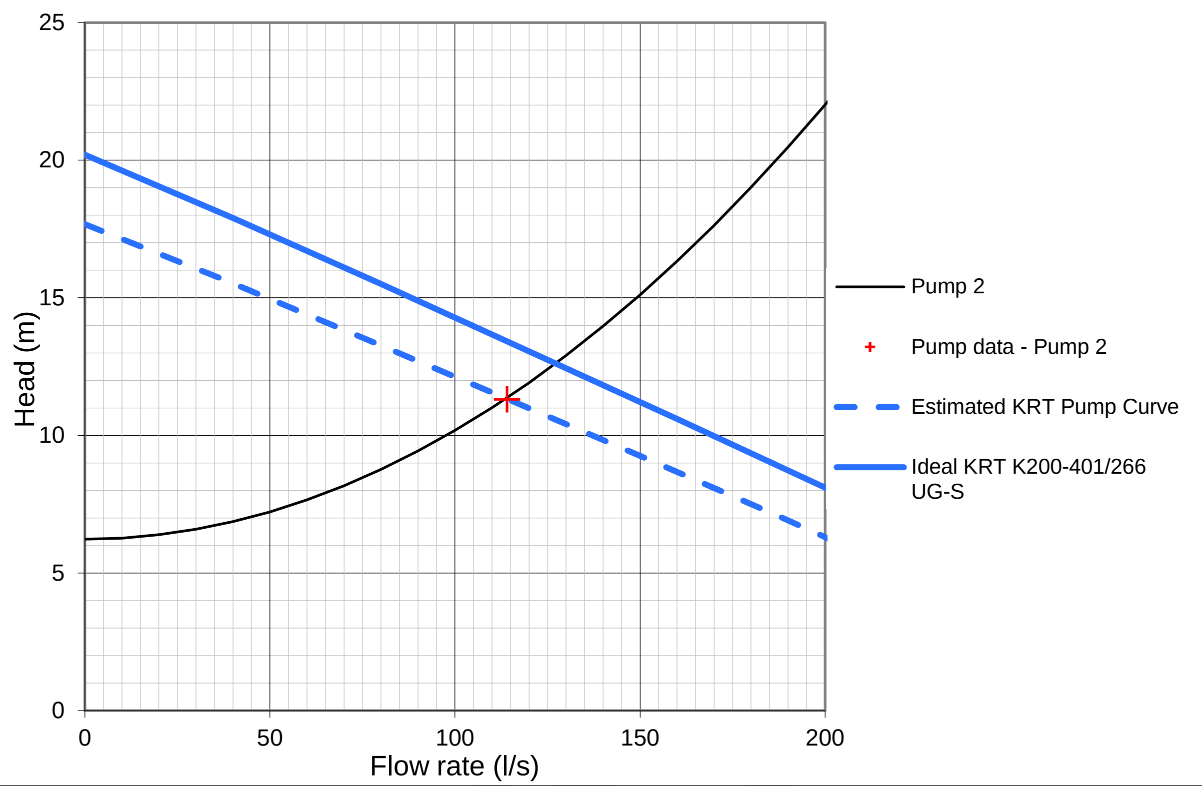

Figure 7 -Derived System Curve – Pump 2

1 INPUT DATA

Gravity, g	9.81	m/s2
Atmos pressure	101.3	kPa
Fluid	Water	[select]
Temperature	10	°c
Kinem. viscosity	1.31E-06	m2/s
Density	999.7	kg/m³
Vap pressure	0.1245	m

Sump levels

TWL	69.1	mAOD
Design	69.1	mAOD
BWL	69.1	mAOD

Suction | Discharge

Pump level:	68.1	mAOD
Pump station located before reach:	1	[select]

Assumed Hydraulic Discharge levels

TWL	75.33	mAOD
Design	75.33	mAOD
BWL	75.33	mAOD

Static lift		
Minimum	6.23	m
Design	6.23	m
Maximum	6.23	m

Reach:		1	2	3	4	5	6	7	8	9	10	11	12	13
Description		DI pump discharge	DI pump discharge	DI rising main										
Length (m)		2	4.6	14.3										
Diameter (m)		0.2	0.2	0.2										
Flow area (m²)		0.03142	0.03142	0.03142										
Roughness (mm)	Low													
	Design	0.6	0.6	0.6										
	High													
Proportion of station flow		1.00	1.00	1.00										

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

Fittings Losses:	k-value	Number of fittings: 1	2	3	4	5	6	7	8	9	10	11	12	13
Inlet (slightly rounded)	0.25	1												
Short R 90˚ bend	0.75	2	1	1										
Taper up (4:5)	0.03													
Long R 90˚ bend	0.4		1											
Swing check valve	1													
Gate valve	0.12													
Gate valve	0.12													
Expansion 2:3	0.35													
Expansion 3:4	0.2													
Outlet	1			1										
Long R 45˚ bend	0.2													
Long R 22.5˚ bend	0.1		1											
Short R 22.5˚ bend	0.15			2										
		KNOWN	KNOWN	EST.										
Additional K (other devices)	1													
Total K		1.75	1.25	2.05	0.00									

2 HYDRAULIC PROFILE

(All losses and heads in metres) Total pump station flow rate 119.01 l/s [select]

Figure 8 - Hydraulic Calculation Input Data for Pump 3

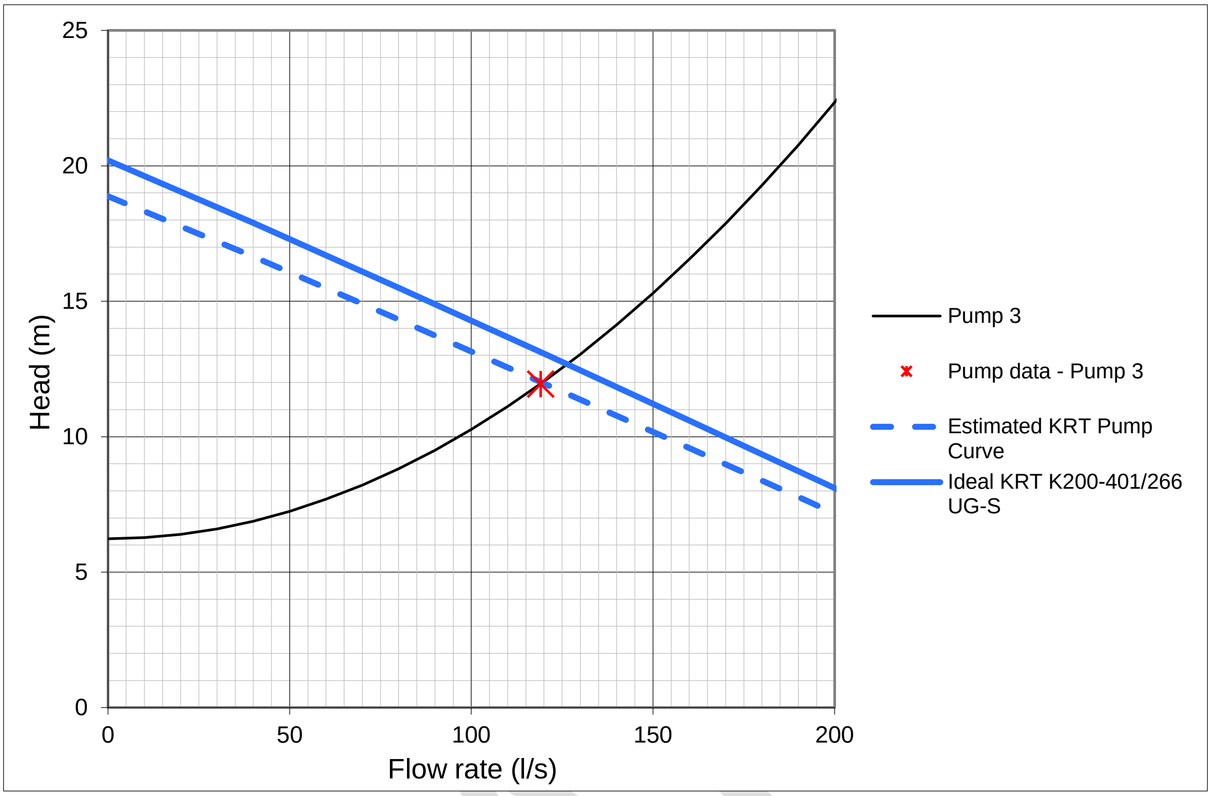

Figure 9 -Derived System Curve – Pump 3

3.1 Key Observations

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

a) Rising Main losses – an assumed roughness of 0.6 mm was taken as a reasonably conservative selection. The actual condition and roughness equivalent of the mains is unknown, and no pressure data was taken during the time of the pump audit.

b) In order to align the site results with the information obtained on the pump curve from KSB, the performance of the pump curves has been lowered from their ideal published performance curves. The dashed line on the individual pump system curve (Figure 5, Figure 7 & Figure 9) represents how an ideal pump is required to be reduced in output using the affinity laws , to indicate wear or smaller impeller trim dia.

c) It has been assumed in this instance that the motor efficiency has remained constant for each pump, which may not be case.

d) All three pumps are operating below the ideal system curves provided by KSB to some degree but it should be noted that Pump 1 does fall within the accepted criteria of the default 2B acceptance test, as outlined by Table 8 in BS EN ISO 9906:2012, of ±8% Flow and ±5% head. It is not known if a more stringent pump test was requested at time of purchase, so the default position of 2B has been taken.

There could be several reasons for this, with possibilities including:

- Increased rising main losses over that derived as pressure data could not be ascertained at the time of testing.
- Measurement or data inaccuracies taken from on-site data collection

4 Net Positive Suction Head (NPSH) & Submergence

NPSH calculations have been undertaken and the results suggest that there is approximately 8m margin between NPSH required and NPSH available, based on the 1 m submergence depth. This would be normally be considered sufficient. As such this has not been investigated any further as there have been no reports found of any cavitation issues at this pump station.

Initial ANSI-98 submergence calculations based on the levels indicated from the site audit have shown that there is sufficient water coverage above the pumps to find that submergence and the formation of vortices does not appear to be an issue at this station.

5 Energy Analysis

During the pump audit visit by Samatrix Ltd, a temporary "Fluke" power meter was connected at each individual pump starter compartment to record power into the star delta drives.

From the measured power, flow recorded, and estimated head based on system curve, 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.

Table 3 – Input power, Efficiency and Specific Energy

Pump Configuration	Measured Flowrate (l/S)	Calculated Head (m)	Measured Power Factor	Measured power (kW)	Pump Efficiency	Specific energy (kWh/1000 m^3)
Pump 1	125.21	12.4	0.81	22.4	78%	49.8
Pump 2	114.07	11.3	0.80	22.1	66%	53.7
Pump 3	119.09	11.9	0.77	22.3	72%	52.0
Ideal Unit	121	13	0.84	24	79.3	51.3

- Table 3 shows that all three pumps are operating less efficiently than an "as new" pump, only marginally in Pumps 1 and 3, but significantly in Pump 2.
- There is a difference between the anticipated "design" operating power of the pump of 24 kW and what was recorded on site of circa 22.5 kW.
- As no previous data has been acquired for this site in terms of power and operation, it will difficult to ascertain a precise energy saving potential can be gained without further long-term study. (Table 3)
- Pump 2 and Pump 3 both show a drop-in performance when compared to the ideal, it should be investigated to ascertain the reasons behind this. Possible explanations include:
    - Debris within the pump casing

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- o Damage or wear to impeller
- o Bearing/seal wear within pump unit

6 Potential Areas for Improvement

6.1 Pump Control and Instrumentation

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 scale, rather than a simple ON/OFF type operation to improve energy consumption. However, the practical feasibility would depend on the specific characteristics of the canal system and pumping capacity.

At present the pumps are effectively run manually in “hand” with the only control being an automatic stop from the low level ultrasonic contained within the wet well. This means that the pumps are likely pumping for periods of time where flow may not be required, and therefore wasting energy.

Operation upon level would necessitate an ultrasonic or radar type level sensor installed within a stilling well on the Grand Canal to measure the level and provide a signal back to the pump control panel and possibly SCADA. Predetermined level thresholds would be as set start and stop levels for the pumps.

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

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

Utilising the level sensor could limit the operational hours as 1no pump could be used to “top up” as required during quieter periods and 2no pumps would only be required when the level drops more significantly. The third pump could be used as a standby and all 3no pumps could operate on a rotational basis to increase the service life of the pumps.

In addition, there is currently no instrumentation measuring pump performance such as a flow meter or pressure indicating device. With no instrumentation there is little way of knowing how the pumps are operating day to day and gives no opportunity for any proactive maintenance or trends to be ascertained for the system.

It is recommended that a flow meter be installed on each rising main as a minimum as to ascertain flows over time. This could be included on the straight above ground sections immediately outside the pump house as to minimise excavation works.

It is recommended that a pressure transducer be installed on each line to ascertain pressure over time. This could be included on any accessible section of pipework within the station for ease of access and cabling. The pump pressure could then be calculated from known levels and losses between the transducer and the pump.

An ‘intelligent’ monitoring system could be adopted at this site to encompass parameters such as flow rate, pressure, power, efficiency, etc. This could be implemented based upon SCADA/telemetry data and programmed to allow automatic adaption and correction of operation, informative data

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analysis reporting, and preventative fault alarms to help save energy, reduce downtime and prevent pump blocking.

It should be noted that this option would require a capital investment to upgrade the EICA components within the pump station to achieve this.

6.2 Pump Selection

On initial findings, KSB Amarex K200 pumps, as installed, are suitably matched for the system. The closest Xylem alternative that could be found was a 22 kW NP3202 with a 376mm impeller and these pumps operate a slightly better as new efficiency than the KSB pumps, although not considered sufficient to warrant pump replacement.

Table 4 – Comparison of alternative pump selections

CONFIGURATION	SELECTION (XYLEM)	FLOW RATE (L/S)	PRESSURE (M)	INPUT POWER (KW)	PUMP AND MOTOR EFFICIENCY (%)	ESTIMATED SPECIFIC ENERGY* (KWH/1000 M^3)	SAVING ON SPECIFIC ENERGY (KWH/1000 M^3)	TOTAL KWH FOR PUMP STATION - PER YEAR*
Duty (1-pump) Fixed Speed	**NP3202 MT 640.376**	**127.8**	**13**	**22**	**70.8**	**50**	**1.3**	**126000**
Duty (1-pump) Fixed Speed	**KSB KRT K200-401-UG-S**	**121**	**13**	**24**	**69**	**51.3**	**-**	**129276**

**Based on estimated annual water requirement of 2520Ml*

6.3 Sluice Gate

During the pump audit it was noticed that the sluice gate draining the canal was leaking approximately 3 l/s. This flow rate accounts for 2.5% of a single pump flow and is simply wasted energy. If the sluice gate is repaired, then this could potentially save 46600 m^3 of required flow over a six-month period. This is the equivalent to 1no pump not operating for 107 hours.

Given the recommendation to link the pumps to level control there could be opportunity to actuate the sluice gate to automate high level control during the winter months. Care would need to be applied to the level control to stop the pumps from operating when the sluice gate was open to reduce the potential for unnecessary pumping but this could be looked into as a possibility.

7 Preliminary Recommendations

- A more efficient option of pumping is available by utilising the Xylem NP3202 MT640, which could save 1.3kWh per 1000m^3 pumped. A reduction of 2.5% in total kWh/year is possible when looked upon from a purely energy conservation point of view, which is not deemed enough to justify any pump replacement.
- Install a level control system on the pumps potentially via a radar/ultrasonic level sensor in a stilling tube.
- Investigate Pump 2 and Pump 3 for loss of efficiency, potential debris in pump/ motor deficiencies/ etc.

- Install instrumentation (e.g. flow/pressure) on each rising main to allow for trend data and proactive maintenance.
- Install power monitoring.
- Install a SCADA / HMI system which can be used to remotely monitor the pumping station and record data which can be used to optimise operation.
- Investigate the sluice gate for potential debris/seal issues.

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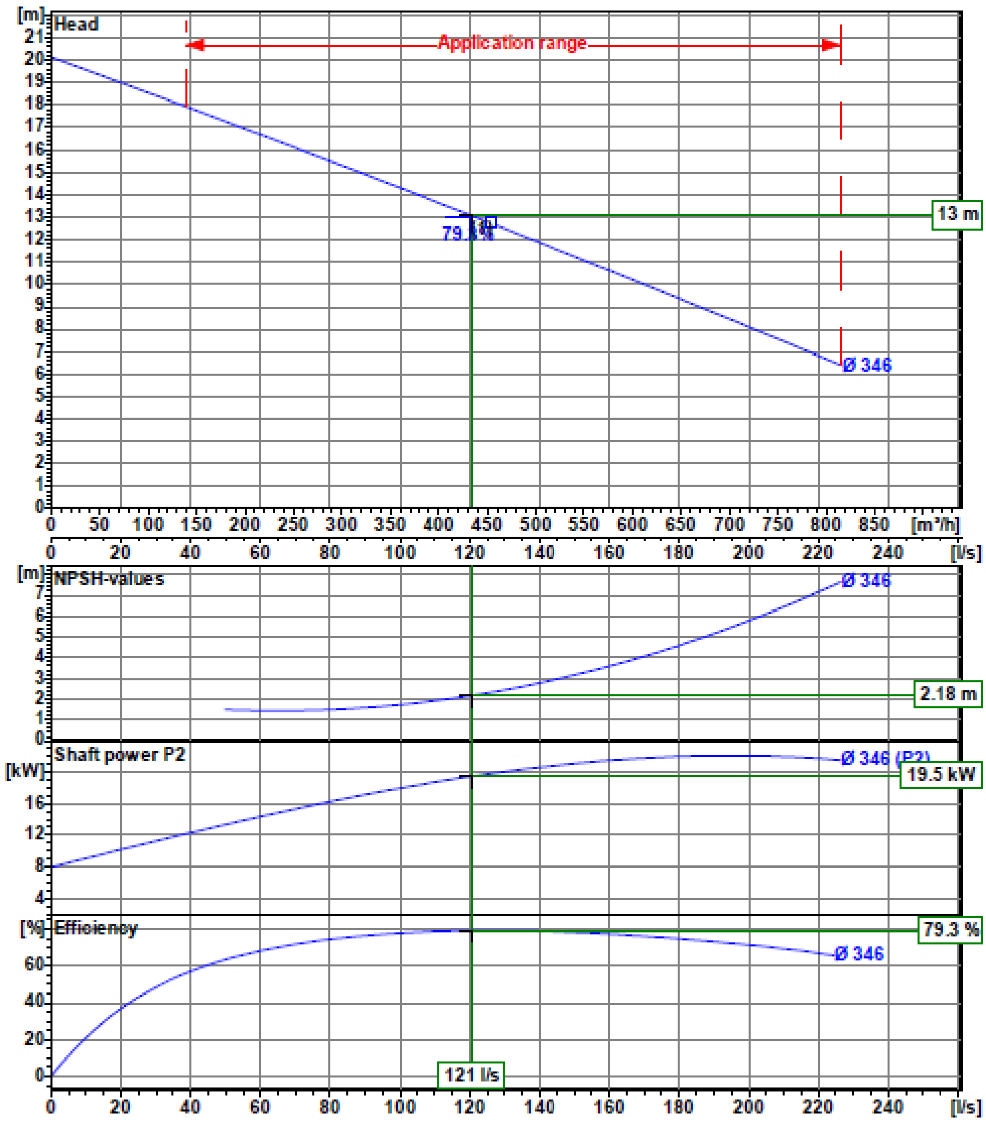
APPENDIX A

KSB AMAREX K200-401/266 PUMP

Project	Waterways Ireland	Page 3 / 5
Customer pos.no		2010-10-25
Project ID	Leinster Aquaduct water supply	
Pos.no	1	
Created by	Houston, Chris	

Performance curve

Pump type **Amarex KRT K 200-401/266UG-S**



Impeller type	Multi channel impeller Closed			Curve number	K43010/0
Free passage	80 mm	Density	0.9983 kg/dm³	Frequency	50 Hz
Impeller size	346 mm	Viscosity	1.005 mm²/s	Speed	960 1/min

KSB Aktiengesellschaft, Turmstrasse 92, 06110 Halle (Germany), Phone +49 (345) 48260, Fax +49 (345) 4826 4699, www.ksb.com

ALTERNATIVE PUMP SELECTION

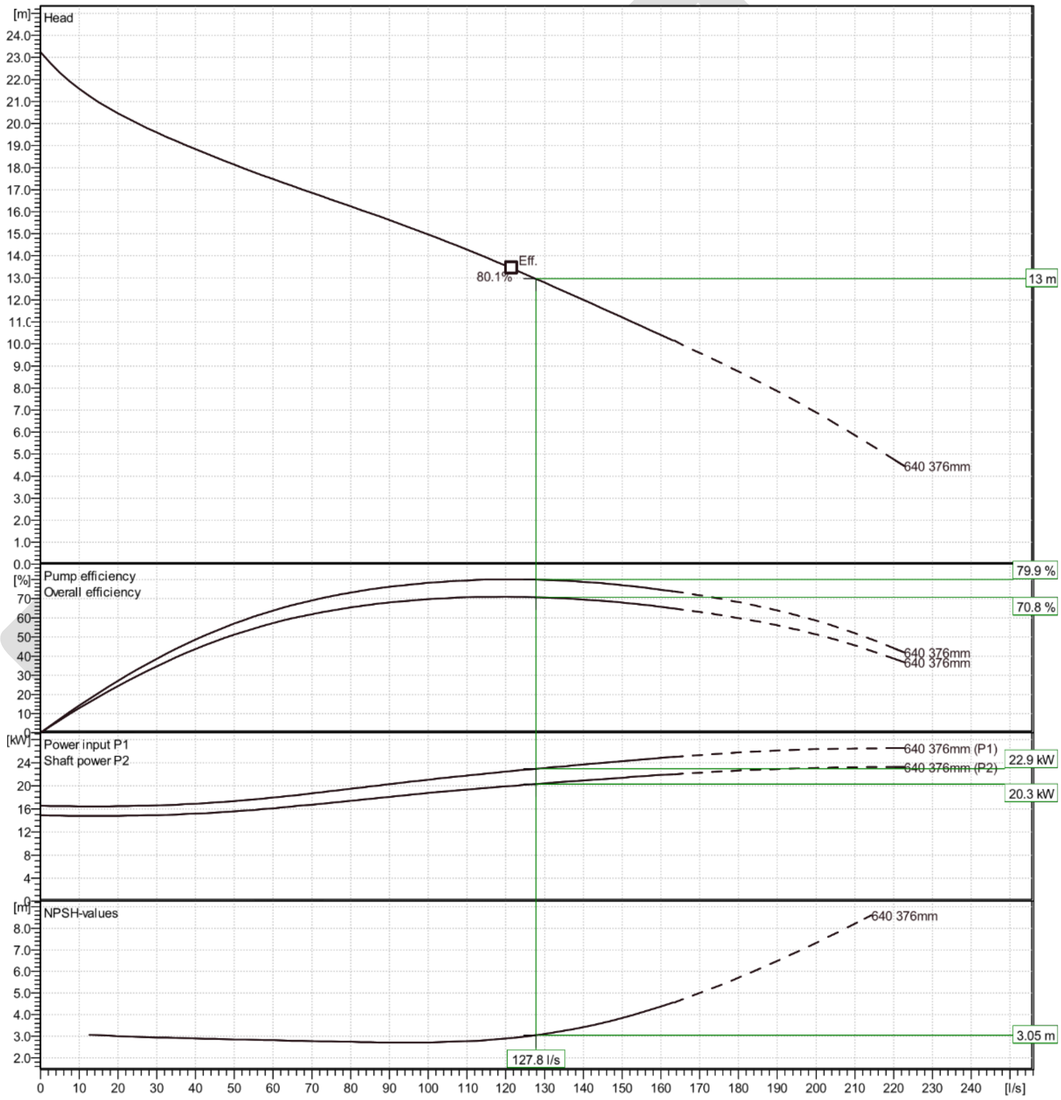
NP 3202 MT 3~ 640

Performance curve

Duty point

Flow	Head
128 l/s	13 m

Curves according to: Water, pure [100%],4 °C,999.9 kg/m³,1.569 mm²/s



Curve: ISO 9906

Project		**Created by**		**Last update**	
Block		**Created on**	11/4/2019		

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

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Voies navigables de France

VLAAMSE LAND MAATSCHAPPIJ