STAT 804
Case Study 2019

19 August 2019

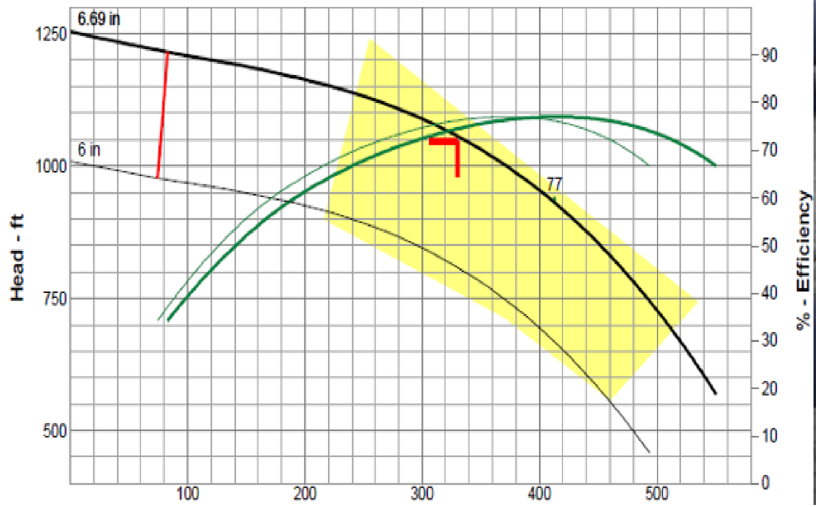
Introduction

Suez

Water Industry Brief

Key Elements
Pumps

- Pumps lift water by transferring energy from the pump's motor to the water.
- Pump performance/efficiency depends on pump design and conditions it is operated in.



Key Element
Valves

- Valves control the flow of water.
- Valve Types – Flow Control, Pressure Reducing, Pressure Sustaining, Isolation, Check etc.
- Flow Control Valve – Restrict how much water can go through a pipe.

Key Element
Tanks

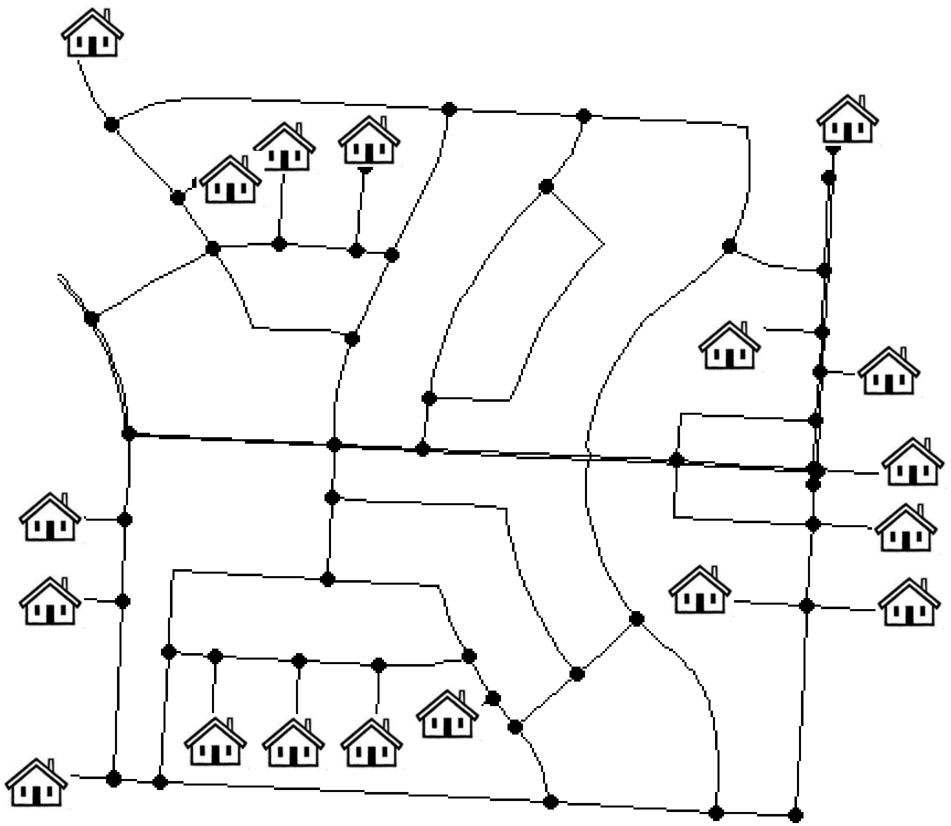
- Tanks are water containers which can be filled and emptied as desired. They provide pressure break and supply safety.
- Reservoirs Types: Elevated Tanks, Lakes, Underground Storage, Towers
- Tanks can be bottom or top filled.
- Bottom Filled tanks have more dynamic static head
- Top Filled tanks have fixed static head

Key Element
Pipes

- Pipes conduct water in a pressurised manner – if you push water in one end it has to come out of the other.
- For this case study we assume that pipes are frictionless to help with mass balance calculations.

Key Element
Consumption

- Demand or Consumption is the water used in the zone to supply demand/customers
- Typically, in residential areas the demand for water is higher in the morning and evening
- We can predict demand based on previous consumption, however this is only a forecast
- For this case study we will assume that we know what the demand is for each reticulation zone



Energy

kWh

$$\boldsymbol{Energy} = \frac{\mathbf{Q} * \boldsymbol{\rho} * \boldsymbol{g} * \mathbf{H} * \boldsymbol{time}\ (\mathbf{seconds})}{\boldsymbol{efficiency} * \boldsymbol{conversion\ factor}}$$

$\boldsymbol{\rho}$ = water density, 1000 kg/m3

$\boldsymbol{g}$ = gravity [m/s2]

$\mathbf{H}$ = pump lift [m]

$\mathbf{Q}$ = pump flow [m3/s]

$\boldsymbol{efficiency}$= pump efficiency %

$\boldsymbol{time}$ = time the pump is running [s]

$\boldsymbol{conversion\ factor}$ = 3.6 $*10^6$J to kWh

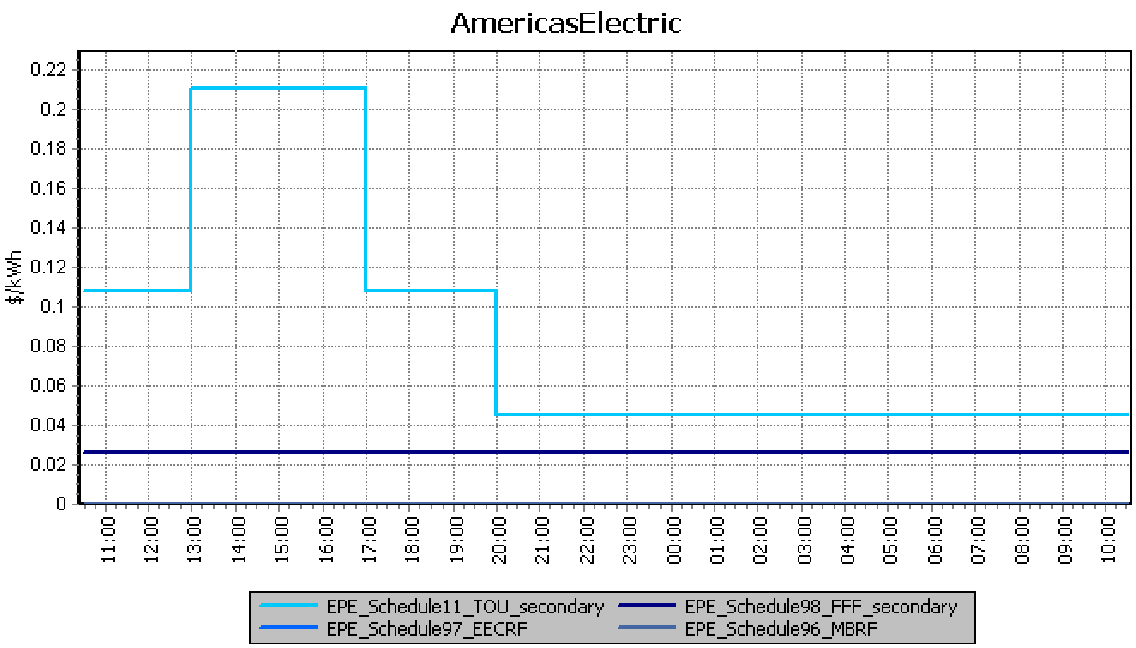
*Assumptions:

All tanks are top filled – this means that the static lift of the pumps is always the same. We will ignore the change in suction as the tanks volume changes throughout the day. Instead we will assume that the suction pressure is equal to the top of the suction tank.

All pumps operate at 65% efficiency – in reality pump efficiency is based on individual pump characteristic and the hydraulics of the network

Tariff
$/kWh

- Time of Use tariff, TOU – prices vary based on time of day
- Flat tariff – prices are always the same, day and night
- Real time market – prices are locked in 2hrs before energy is used
- Day Ahead tariff – prices are locked in a day before the energy is used



Cost
$

$$\mathbf{Cost = Energy \ * Tariff}$$

Energy = energy used while the pump is running

Tariff = identify during which part of the day the pump was running and what price band does it fall under

Cost
Example

$$\boldsymbol{Running\ Cornwall\ P1\ between\ 8\ and\ 9am\ will\ cost}:$$

$$Energy = \frac{\mathrm{Q} * \rho * g * \mathrm{H} * time\ (\text{seconds})}{efficiency * 3.6 * 106}$$

$$Energy = \frac{\frac{600}{3600} * 1000 * 9.8 * (250 - 160) * 3600}{0.65 * 3.6 * 106} = 226kWh$$

$$Cost = Energy\ * Tariff = 226 * 0.1 = \$\, 22.6$$

Assumptions:

Suction and discharge pressure are always the same – the top of the relevant tank

8 to 9 am is defined as off peak - tariff is 0.1 $/kWh

Case Study Introduction

Case Study Aim

Part 1: Build the most cost effective 24 hour schedule for Suez Town water distribution network, while making sure each tank ends up with the same or similar volume of water as in the beginning of the day.

You can assume that the day starts at 8:00am

Case Study Aim

Part 2: Cost Benefit Analysis

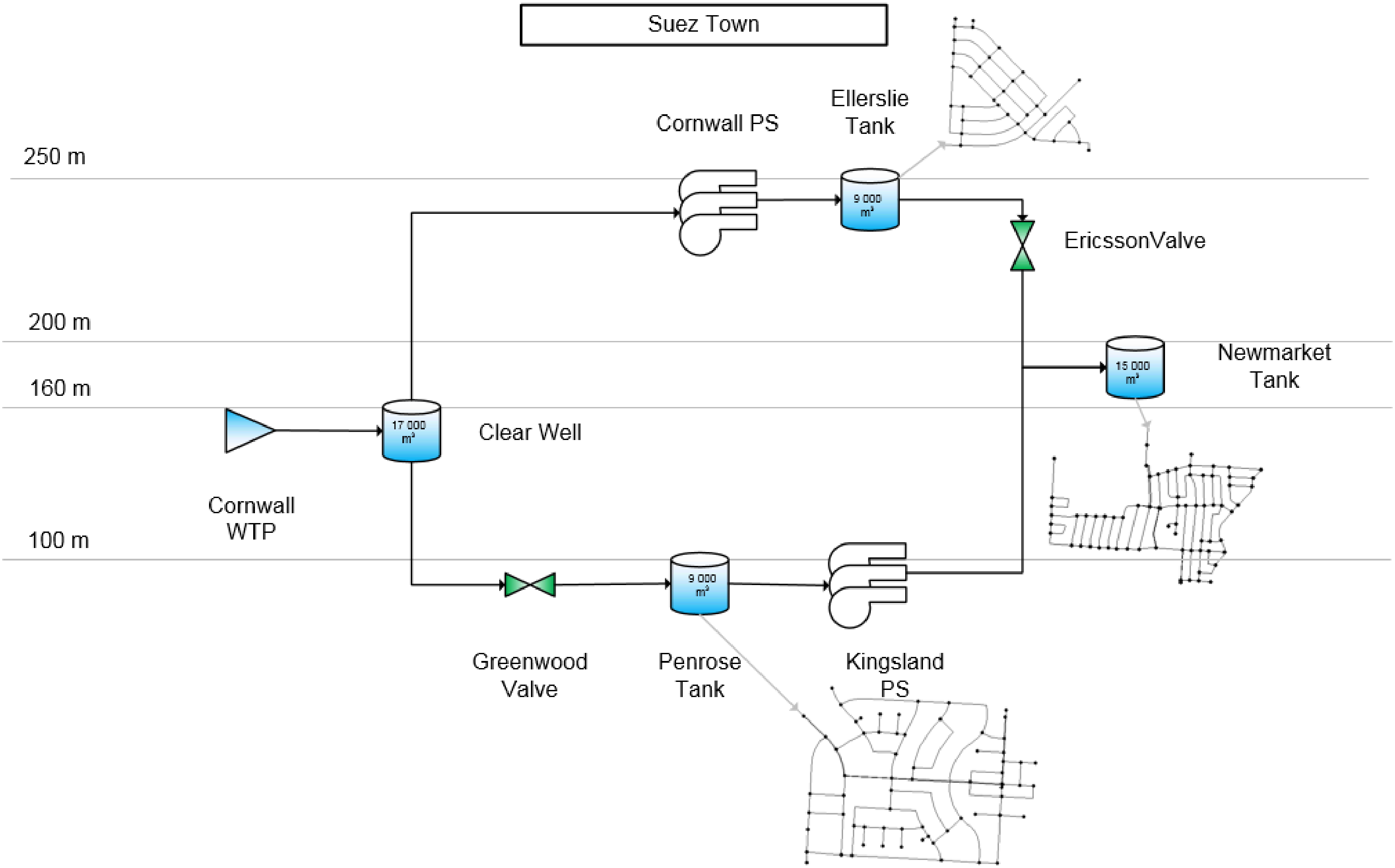
What benefit is there in upgrading pumps to more efficient ones

- We assumed that the each of the pumps at Kingsland PS and Cornwall PS operate at 65% efficiency
- Brand new modern pumps operation at ~ 85% efficiency
- What benefit could be achieved by upgrading some or all of these pumps to more efficient modern pumps?

The town is growing

- City planners are forecasting 10% population growth year upon year.
- At what point would new infrastructure be required to keep up with this growing demand for water ?
- Which assets should be upgraded first in order to meet this growing demand ?

Network Diagram



Network
Source Constraints

- Water Source: Cornwall Water Treatment Plant
- Minimum production rate 800 m3/h
- Maximum production rate 3500 m3
- Source **cannot** stop production

Extension:

- Extension: source can only change flow rate every 4 hours

Network

Tank Constraints

Clear Wells

- Min volume 15,000 m3
- Max volume 32,000 m3
- Cross sectional area 15,000 m2
- Top elevation 160 m
- Initial volume 29,000 m3

Ellerslie

- Min volume 5,000 m3
- Max volume 14,000 m3
- Cross sectional area 750 m2
- Top elevation 250 m
- Initial volume 11,000 m3

Penrose

- Min volume 5,000 m3
- Max volume 14,000 m3
- Cross sectional area 750 m2
- Top elevation 100 m
- Initial volume 11,000 m3

Newmarket

- Min volume 12,000 m3
- Max volume 18,000m3
- Cross sectional area 750 m2
- Top elevation 200 m
- Initial volume 17,000 m3

Network

Pumps Constraints

Cornwall PS

- Pump 1: lifts @ 600 m3/h at 65% efficiency
- Pump 2: lifts @ 600 m3/h at 65% efficiency
- Pump 3: lifts @ 800 m3/h at 65% efficiency

Extension:

- A pump has to run for at least 2 hours

Kingsland PS

- Pump 1: lifts @ 800 m3/h at 65% efficiency
- Pump 2: lifts @ 800 m3/h at 65% efficiency
- Pump 3: lifts @ 400 m3/h at 65% efficiency

Extension:

- A pump has to run for at least 2 hours

Network
Valve Constraints

Greenwood FCV – flow control valve

- Min flow: 500 m3/h
- Max flow: 1500 m3/h
- Valve **can** be closed.

Extension:

- If a valve is open, it has to stay open at the same flow rate for at least 4 hours

Ericsson FCV – flow control valve

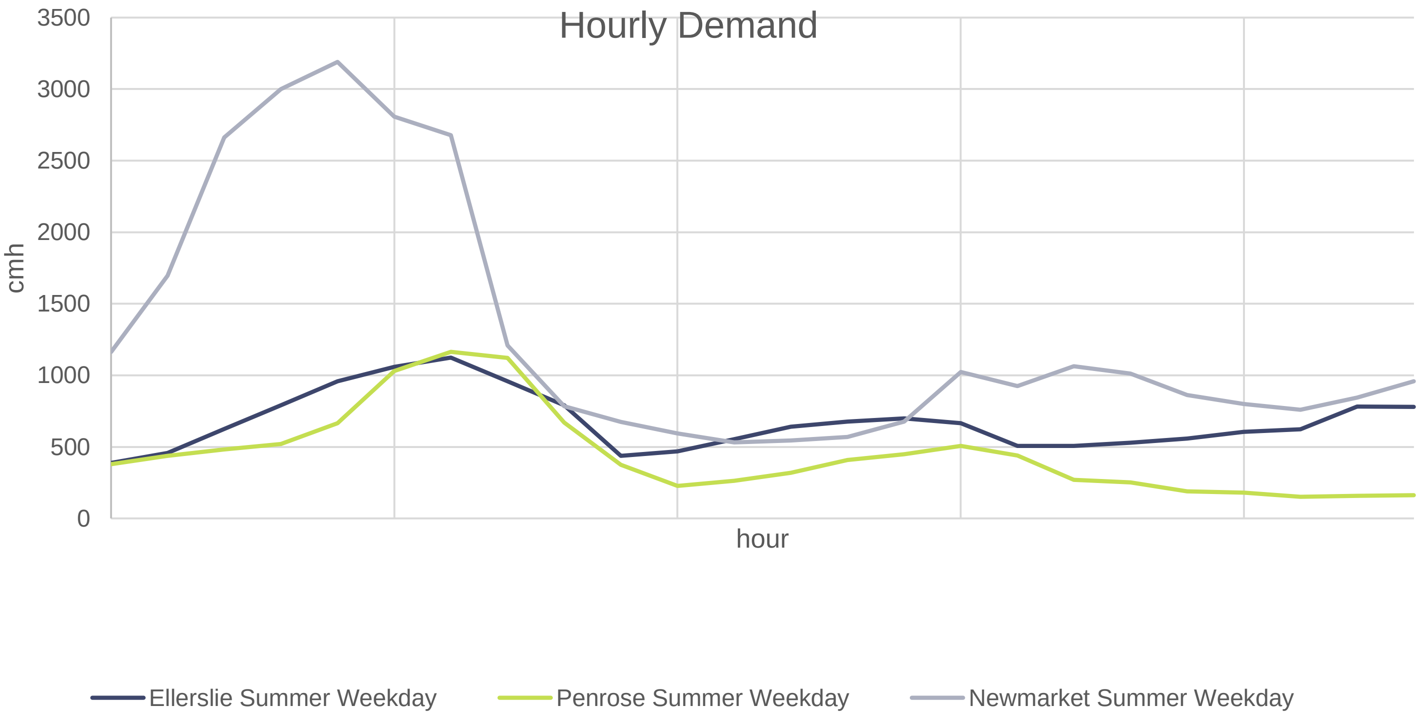
- Min flow: 200 m3/h
- Max flow: 1000 m3/h
- Valve **can** be closed

Extension:

- If a valve is open, it has to stay open at the same flow rate for at least 4 hours

Network

Demand (Consumption) Profiles



Network
Demand (Consumption) Data Table

Ellerslie Summer Weekday		Penrose Summer Weekday		Newmarket Summer Weekday	
time	m3/h	time	m3/h	time	m3/h
8:00	388	8:00	379	8:00	1165
9:00	458	9:00	438	9:00	1696
10:00	625	10:00	483	10:00	2663
11:00	792	11:00	521	11:00	3000
12:00	958	12:00	665	12:00	3190
13:00	1058	13:00	1030	13:00	2809
14:00	1125	14:00	1164	14:00	2679
15:00	958	15:00	1121	15:00	1209
16:00	792	16:00	669	16:00	783
17:00	438	17:00	375	17:00	675
18:00	469	18:00	228	18:00	594
19:00	554	19:00	263	19:00	533
20:00	642	20:00	320	20:00	546
21:00	677	21:00	408	21:00	569
22:00	700	22:00	448	22:00	677
23:00	665	23:00	506	23:00	1023
0:00	506	0:00	439	0:00	924
1:00	506	1:00	270	1:00	1063
2:00	529	2:00	252	2:00	1013
3:00	559	3:00	189	3:00	863
4:00	606	4:00	180	4:00	801
5:00	623	5:00	152	5:00	759
6:00	781	6:00	158	6:00	844
7:00	779	7:00	163	7:00	958

Network
Tariffs

Cornwall PS				Kingsland PS		
hour	tariff type	$/kWh		hour	tariff type	$/kWh
8:00	off peak	0.1		8:00	off peak	0.06
9:00	part peak	0.17		9:00	off peak	0.06
10:00	part peak	0.17		10:00	part peak	0.12
11:00	part peak	0.17		11:00	part peak	0.12
12:00	peak	0.24		12:00	peak	0.18
13:00	peak	0.24		13:00	peak	0.18
14:00	peak	0.24		14:00	peak	0.18
15:00	peak	0.24		15:00	peak	0.18
16:00	peak	0.24		16:00	part peak	0.12
17:00	peak	0.24		17:00	part peak	0.12
18:00	part peak	0.17		18:00	part peak	0.12
19:00	part peak	0.17		19:00	part peak	0.12
20:00	part peak	0.17		20:00	part peak	0.12
21:00	part peak	0.17		21:00	off peak	0.06
22:00	part peak	0.17		22:00	off peak	0.06
23:00	part peak	0.17		23:00	off peak	0.06
0:00	off peak	0.1		0:00	off peak	0.06
1:00	off peak	0.1		1:00	off peak	0.06
2:00	off peak	0.1		2:00	off peak	0.06
3:00	off peak	0.1		3:00	off peak	0.06
4:00	off peak	0.1		4:00	off peak	0.06
5:00	off peak	0.1		5:00	off peak	0.06
6:00	off peak	0.1		6:00	off peak	0.06
7:00	off peak	0.1		7:00	off peak	0.06

Thank You