# Dover and Folkestone wastewater treatment scheme: design considerations and optimisation of the pressure surge control for Pumping Station PS2

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## ABSTRACT

The paper presents a brief overview of the design considerations for the Dover and Folkestone Wastewater Treatment Scheme, which is being implemented by Southern Water to meet the requirements of the EU Bathing Water and Urban Wastewater Treatment Directives.

The design considerations for the pumping station PS2 and the delivery pipeline to the treatment works at Broomfield Bank are discussed, together with the pressure surge investigation.


**Key words** | design, optimisation, pressure surge, pumping station, water treatment

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## INTRODUCTION

The scheme forms part of Southern Water's Operation Seaclean and combines the collection, treatment and disposal of sewage and the storage and disposal of stormwater from the two catchments in a single scheme with a capital value of £120 million.

Twelve separate contracts make up the scheme, including four major pumping stations, 18 km of tunnels and sewers, two long sea outfalls and one remote underground treatment works. Mott MacDonald has assisted Southern Water with the design of the scheme and construction supervision, which included a 50-strong team of site engineers, planners and designers. Commissioning of the scheme started in October 1999 when sewage flows from Dover were pumped to the treatment works for primary treatment. The Scheme was fully commissioned for primary treatment in March 2000. A further contract for the addition of secondary treatment will be completed in 2001.

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## SCHEME OVERVIEW

### Dover drainage area

The Dover drainage area comprises the town of Dover together with the outlying areas of Hougham, Alkham, Lydden, Shepherds Well, Whitfield and Guston. The collector system is combined in Dover. The catchment currently serves a resident population of 45,500 estimated to increase to 55,800 by 2015. The main sewer runs gravitate along the Dour valley towards the port area where flow is diverted into Elizabeth Street Pumping Station in the Western Docks. Historically Elizabeth Street Pumping Station pumped comminuted flows to a short sea outfall west of Admiralty Pier.

### Folkestone drainage area

The Folkestone drainage area comprises the town of Folkestone, together with the outlying areas of Sandgate, Hawkinge, Densole and Capel-le-Ferne. The collector

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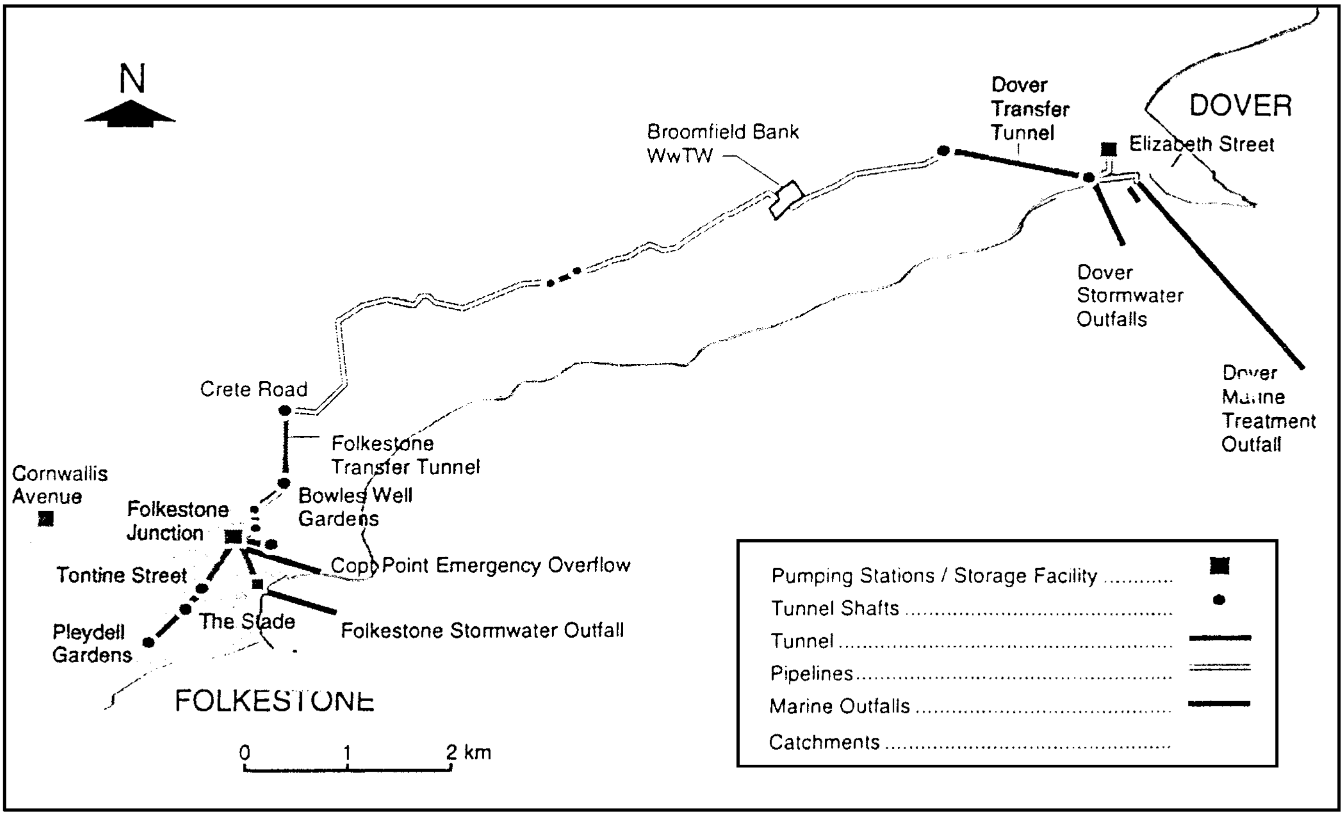


**Figure 1** | Preferred scheme layout.

system is predominantly combined except for the network serving Hawkinge. The catchment currently serves a population of 58,000 estimated to increase to 72,000 by 2015. The main sewer runs gravitate west to east across the catchment. The combined wastewater was discharged untreated from a short sea outfall at Copt Point.

## Feasibility study

A comprehensive feasibility study was started in 1992 by Southern Water and Mott MacDonald. The study evaluated the options for improving the existing wastewater treatment facilities of the two catchments in line with legislative requirements. The study examined 38 potential sites for the provision of new wastewater treatment and disposal facilities either by the provision of separate treatment works for the individual catchments or by combined treatment facilities. The study also evaluated the technical options available to achieve the discharge requirements established by the National Rivers Authority (EA).

The Study concluded that, on the basis of both planning and environmental considerations and from technical and economic evaluation, the preferred scheme would be to provide a combined wastewater treatment facility on one of two sites in the Farthingloe Valley approximately 4 km west of Dover. The preferred scheme layout is shown in Figure 1.

The provision of treatment facilities remote from the two catchments necessitated the implementation of a scheme with the following principal components.

- Wastewater and stormwater interception from the existing sewerage systems of the two catchments.

- Stormwater storage facilities within each catchment to limit to an acceptable level the frequency of spills to the coastal waters.
- Stormwater discharge outfalls for each catchment for the acceptable discharge of storm runoff.
- Wastewater transfer systems to convey sewage flows up to the maximum flow to treatment to the site of the treatment works.
- Wastewater treatment works.
- Marine treatment outfall for the disposal of treated effluent.

## Design parameters

Southern Water have provided a level of service that will accommodate a peak flow equivalent to the one-in-five-year storm event.

The following additional parameters for stormwater and effluent discharges were adopted after discussions with the National Rivers Authority (EA).

### Dover and Folkestone catchment stormwater

Stormwater storage has been provided to limit discharges to 3.0 spills per bathing season for each individual catchment. Spills to receive 10 mm screening at Dover and 6 mm screening at Folkestone and to be discharged via an outfall with a minimum 2 m cover at mean low water spring (MLWS). A minimum of three dry weather flow (DWF) to be passed to treatment.

At Folkestone spills relating to storms exceeding the one-in-five-year event are overflowed direct to the receiving water.

### Wastewater treatment

This was originally based on 'an area of higher natural dispersion' classification for the receiving water requiring a treatment level of 6 mm screening and primary settlement to achieve an effluent quality standard to comply with the primary treatment standard in the Urban Wastewater Treatment Directive (UWWTD).

**Table 1** | Design flow data

| Town | Population | 3 DWF to treatment (l/s) | Peak storm flow ($m^3/s$) |
|---|---|---|---|
| Dover | 71,500 | 592 | 2.75 |
| Folkestone | 75,400 | 475 | 18.5 |

Subsequently this classification has been withdrawn and secondary treatment will be incorporated to comply with the secondary standard of the UWWTD.

### Flow data

The design flow data used for the investigation is specified in Table 1.

# PUMPING STATION DESIGN CONSIDERATIONS

## Folkestone catchment

Most flow from the catchment drains via the 1.8 m diameter tunnelled brick relief sewer at depths of up to 33 m which discharges at Copt Point. The remainder of the flow, including pumped transfer from Sandgate sub-catchment, drains to a chamber at the Stade.

The works consisted of intercepting sewers, principally tunnels to relieve local flooding and convey flows to the principal interception point at Folkestone Junction. Here flows for treatment are diverted to a high lift transfer station, and stormwater flows are initially pumped to storage and subsequently gravitate via a new tunnel to the Stade for screening and discharge via a new outfall.

The Tontine Street Interceptor is a 2.1 m diameter low-level tunnel which conveys flows from Playdell Gardens to Folkestone Junction where they are pumped to the Stade Outfall tunnel by low lift pumps.

The remaining stormwater flows from the Folkestone Relief Sewer discharge under gravity. Under severe storm conditions an overflow from Folkestone Junction will

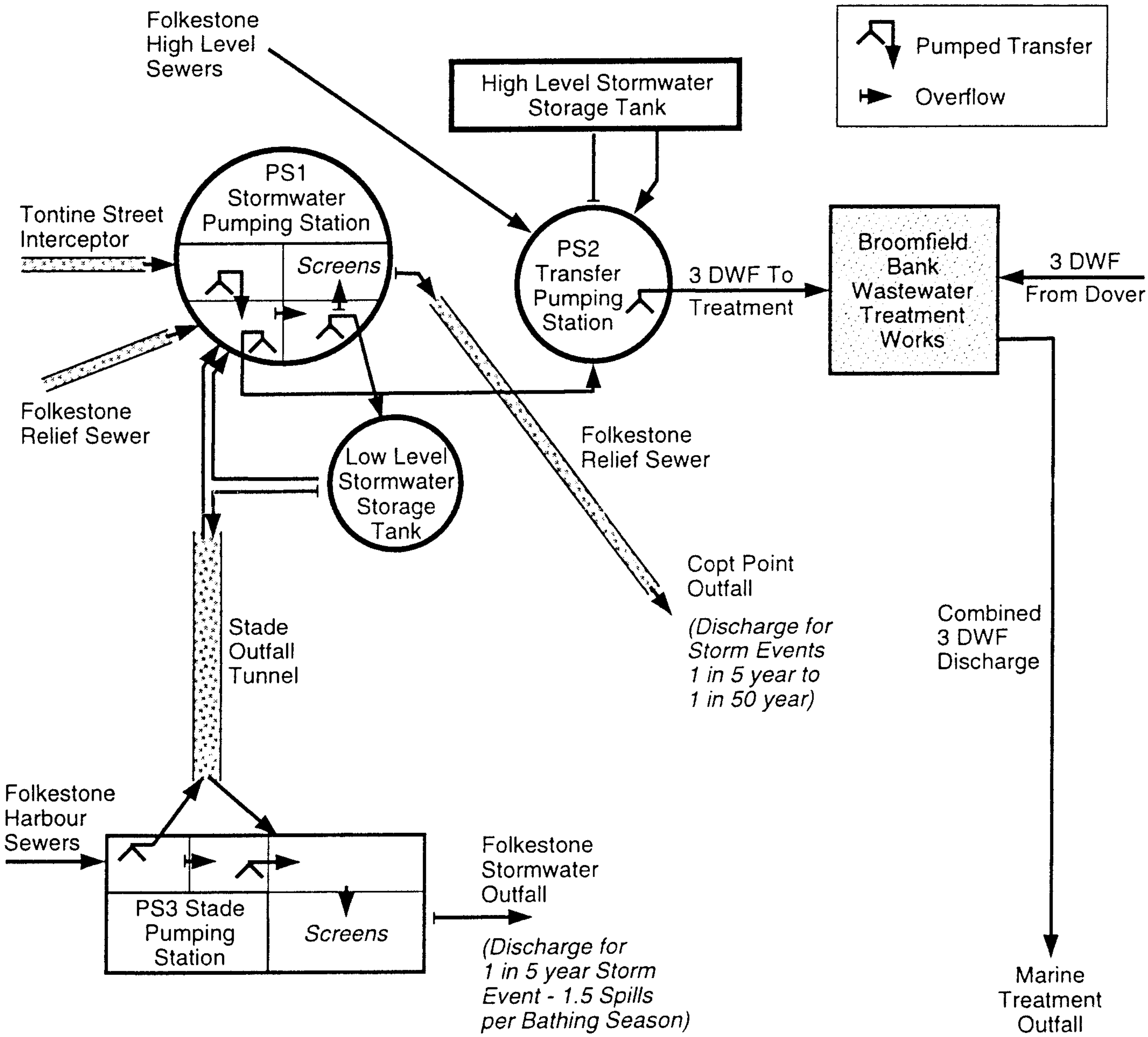


**Figure 2** | Folkestone Junction flow schematic.

operate discharging screened stormwater to Copt Point via the abandoned section of the Relief Sewer.

Storm storage is accommodated in the catchment together with offline storage at Cornwallis Avenue and high level tanks and shaft storage at Folkestone Junction. A Flow Schematic is shown in Figure 2.

## Folkestone Junction Transfer Pumping Station (PS2)

Flows are intercepted at high level by diverting the sewer that discharges to the Folkestone Relief Sewer at the Folly Road drop shaft and by the Warren Road tunnel, which transfers flows from the Warren Road drop shaft. These flows together with the three DWF pass forward flow from Pumping Station 1 (PS1) are fed to a wet well via disc screens with a 6 mm aperture.

The station is designed to transfer flows to the treatment works at a maximum flow of 475 l/s. The rising main discharges to a gravity sewer at 165.8 m above ordnance datum (AOD) before entering the treatment works at 85.0 m AOD.

The required pumping head of approximately 150 m is generated by a tandem pumping arrangement using pairs of pumps with similar capacity connected in series. Each pump operates at 1480 r.p.m. Each set consists of a type SV 25.61.4 submersible pump in the wet well and a second type SV 25.92.4 dry-mounted vertical shaft pump with a remote mounted motor. There are three pump sets: two duty and one standby. Double mechanical seals with a pressure lubrication system are provided for the drywell pumps. Alarms for seal failure and excess vibration are incorporated. The pumping plant, pipework and valves were supplied by The Bedford Pump Company Ltd. A sectional arrangement of the pumping station is shown in Figure 3.

### Folkestone transfer pipeline

The Folkestone transfer pipeline carries effluent from Folkestone Junction Transfer Pumping Station No. 2 (PS2) to Broomfield Bank WWTW. The main consists of a 600 mm diameter ductile iron pipe up to Manhole 47 and a 600/750 mm diameter concrete main from Manhole 47 to the treatment works at Broomfield Bank. The main rises continuously from PS2 to Manhole 47, and gravitates from Manhole 47 to the treatment works. The ductile iron main has a 25 bar rating.

The transfer main crosses a railway approximately 250 m from PS2 and runs in a 6–9 m deep open cut trench alongside the railway for a distance of approximately 90 m before the crossing. The main crosses the railway installed in a 1350 mm diameter concrete pipe and is held in position within the pipe with stainless steel spiders; the annular void between the pipes is in-filled with a foam concrete grout. From the railway, the main rises to Bowles Well Gardens along the edge of a housing development. The pipe is buried approximately 2 m deep in this section but is protected by a 6 m wide exclusion zone through the future development area.

The transfer pipeline passes through two chambers on its way to Manhole 47: one is at Bowles Well Gardens and the other is at Crete Road (CR). The chamber at Bowles Well Gardens houses a non-return valve, which is fitted in the 600 mm diameter rising main to stop approximately 550 m$^3$ of screened sewage from flooding properties or the railway line should the transfer main be fractured upstream of the non-return valve. The non-return valve is fitted with a 350 mm diameter bypass and isolating valve. The bypass is required for draining the transfer main.

Two surge vessels are installed on the transfer main, the first at the discharge of the pumping station (PS2) and the second in a chamber at the Crete Road pipe junction. The vessels are vertical welded steel with a working volume of 6 and 7.725 m$^3$, respectively. In the event of a malfunction of the pressure surge protection or an abnormal sequence of events the rising main pipework is protected from overpressure by a bursting disc. The disc is located in a pipework leg, which in the event of rupture drains to the wet well while an upstream valve is closed in 60.0 seconds to shut the system down to a safe condition.

## PRESSURE SURGE INVESTIGATIONS

The Bedford Pump Company Limited commissioned HYDROSIM Consultants Limited to undertake pressure surge investigations for the pumping stations PS5 and PS2 and associated discharge mains, located at Dover and Folkestone, respectively. Both investigations involved an extensive series of computer simulations so as to optimise the pressure surge measures and the recording/analysis of the pressure surges generated by several pump trip scenarios undertaken as part of the site commissioning tests. The investigation for pumping station PS2 is summarised in this paper.

### PS2: computer simulations

The computer simulations used the program PTRAN developed by Dr Adrian P. Boldy. The program is based on

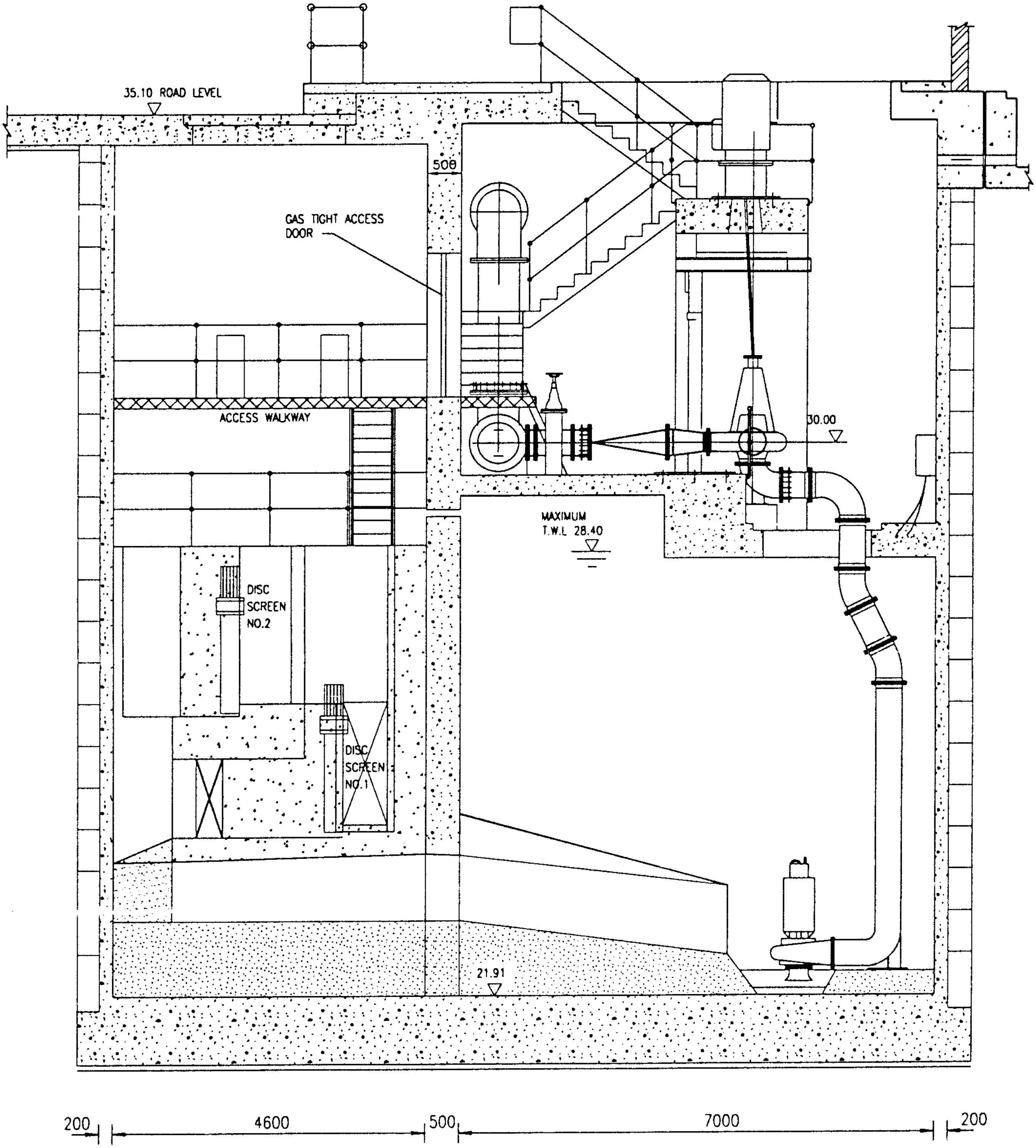


**Figure 3** | Sectional elevation.

the *method of characteristics* which converts the quasi-linear, hyperbolic, partial differential equations of motion and continuity describing the unsteady flow of a fluid in any internal flow system, into a set of ordinary differential equations, which are then expressed in a finite difference form in order to produce a solution algorithm. The variant of the method used is called the *method of specified time intervals*, which computes the values of the piezometric pressure head and velocity at a constant time interval for each node in the system (see Swaffield & Boldy 1993). Any of the following boundary conditions may be incorporated in a simulation using PTRAN.

- Pump (with flywheel; with bypass);
- Hydraulic turbine (Francis, Kaplan, Reversible pump-turbine);
- Air vessel;
- Surge chamber (throttled; variable area);
- Feed tank;
- Reservoir;
- Check valve;
- Control valves (normal operation or pressure reducing/sustaining);
- Pressure relief valve;
- Air inlet/outlet valve.

The results of the computer simulations were used to define the following operational settings for the air volume inside the 6 and 7.725 $m^3$ capacity air vessels to be located at the pump station and Crete Road junction, respectively:

| Setting | Air volume ($m^3$) in air vessel at: Pump Station | Crete Road |
|---|---|---|
| Trip pump set running | 1.00 | 0.60 |
| Trip one pump set: continue pumping with other pump set | 2.35 | 1.00 |
| Compressor Start | 2.60 | 1.25 |
| Compressor Stop | 2.80 | 1.45 |
| Trip one pump set: contrinue pumping with other pump set | 3.05 | 1.70 |
| Trip pump set running | 4.00 | 3.75 |

All the simulations incorporate an inflow by-pass arrangement in the pipe connection to the air vessels with a head loss coefficient of 175 and 125, respectively for the vessel at the pump station and at Crete Road.

The simulations demonstrate that the installation of the air vessels will limit the maximum and minimum static pressure head in the rising main to approximately 151.6 and −4.4 m, respectively, during the transient flow generated by the simultaneous trip of one or two pump sets.

Table 2 summarises the results of a series of simulations based on the steady-state conditions defined by the operation of two pump sets, delivering a flow of 510 l/s, with clean pipe conditions. With the steady-state air volume inside each air vessel maintained within the compressors start and stop settings, the maximum and minimum transient static pressure heads generated in the rising main by the simultaneous trip of two pump sets are 147.9 and −4.4 m, respectively, while the air volume reaches a maximum of 450 and 5.67 $m^3$ in the air vessel at the pump station and Crete Road, respectively. It is acceptable to continue pumping with two sets of pumps with the air volume in the air vessel at the pump station within the range of 2.35 and 3.05 $m^3$, and/or, the air volume in the air vessel at Crete Road within the range of 1.00 and 1.70 $m^3$. If the air volume in either air vessel reaches either of the above minimum or maximum

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**Table 2** | Series of simulations based on the steady state conditons defined by the operation of two pump sets with clean pipe conditions. $Q_0$=510 l/s

| Normal operation | Transient operation | Run number | Air volume (m³) in air vessel at pump station | | | Air volume (m³) in Aar vessel at Crete Road | | | Static pressure head (m) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Pump delivery | | Upstream NRV | | Downstream NRV | | Minimum at Node |
| | | | $V_o$ | $V_m$ | $V_t/V_m$ | $V_o$ | $V_m$ | $V_t/V_m$ | Max | Min | Max | Min | Max | Min | |
| Trip one pump set | Normal operation | P2-1282F | 2.35 | 2.83 | 2.12 | 1.00 | 2.43 | 3.18 | 151.6 | 113.6 | 124.2 | 96.7 | 123.8 | 96.0 | – 1.6@54 |
| Continue pumping | Simul't trip of | P2-1082F | 2.35 | 3.93 | 1.53 | 1.00 | 4.89 | 1.58 | 146.9 | 69.3 | 121.7 | 26.9 | 127.7 | 67.5 | – 4.4@34 |
| Second pump set | Two pump sets | P2-1085F | 2.35 | 3.91 | 1.53 | 1.70 | 6.18 | 1.25 | 146.9 | 69.7 | 121.7 | 27.9 | 132.2 | 68.5 | – 3.5@34 |
| Compressor | Simul't trip of | P2-1073F | 2.60 | 4.24 | 1.42 | 1.25 | 5.30 | 1.46 | 147.2 | 72.0 | 121.7 | 28.4 | 124.8 | 71.9 | – 4.4@34 |
| Start | Two pump sets | P2-1074F | 2.60 | 4.24 | 1.42 | 1.45 | 5.67 | 1.36 | 147.2 | 72.1 | 121.7 | 28.6 | 125.8 | 70.8 | – 4.2@34 |
| Compressor | Simul't trip of | P2-1064F | 2.80 | 4.49 | 1.34 | 1.45 | 5.65 | 1.37 | 147.9 | 73.3 | 121.7 | 30.7 | 124.5 | 72.2 | – 4.1@34 |
| Stop | Two pump sets | P2-1063F | 2.80 | 4.50 | 1.33 | 1.25 | 5.28 | 1.46 | 147.9 | 73.2 | 121.7 | 31.0 | 124.8 | 71.9 | – 4.3@34 |
| Trip one pump set | Normal operation | P2-1252F | 3.05 | 3.61 | 1.66 | 1.00 | 2.43 | 3.18 | 148.1 | 116.9 | 123.8 | 99.0 | 123.4 | 98.1 | – 1.6@54 |
| Continue pumping | Simul't trip of | P2-1052F | 3.05 | 4.82 | 1.24 | 1.00 | 4.85 | 1.59 | 146.9 | 76.7 | 121.7 | 36.1 | 127.8 | 73.5 | – 4.3@34 |
| Second pump set | Two pump sets | P2-1055F | 3.05 | 4.80 | 1.25 | 1.70 | 6.14 | 1.26 | 146.8 | 77.0 | 121.7 | 35.6 | 127.0 | 74.5 | – 3.5@34 |

**Table 3** | Series of simulations based on the steady state conditons defined by the operation of one pump set with clean pipe conditions. $Q_0$=270 l/s

| Normal operation | Transient operation | Run number | Air volume (m³) in air vessel at pump station | | | Air volume (m³) in Aar vessel at Crete Road | | | Static pressure head (m) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Pump delivery | | Upstream NRV | | Downstream NRV | | Minimum at Node |
| | | | $V_o$ | $V_m$ | $V_t/V_m$ | $V_o$ | $V_m$ | $V_t/V_m$ | Max | Min | Max | Min | Max | Min | |
| Trip pump set | Normal operation | P2-2100F | 1.00 | 1.51 | 3.97 | 0.60 | 2.11 | 3.66 | 139.9 | 77.4 | 115.8 | 40.4 | 139.0 | 76.5 | – 2.8@54 |
| Compressor start | Trip pump set | P2-2073F | 2.60 | 3.40 | 1.76 | 1.25 | 3.08 | 2.51 | 141.2 | 93.8 | 115.8 | 62.6 | 125.3 | 83.4 | – 2.5@54 |
| Compressor stop | Trip pump set | P2-2064F | 2.80 | 3.63 | 1.65 | 1.45 | 3.37 | 2.29 | 141.4 | 95.0 | 115.8 | 62.7 | 124.5 | 85.0 | – 2.4@54 |
| Trip one pump set | Normal operation | P2-2036F | 4.00 | 4.97 | 1.21 | 3.75 | 6.35 | 1.22 | 142.7 | 100.6 | 115.8 | 67.8 | 124.5 | 90.5 | – 1.8@54 |

volumes, one pump set should be tripped and pumping continued with the other pump set.

Table 3 summarises the results of a series of simulations based on the steady-state conditions defined by the operation of one pump, delivering a flow of 270 l/s, set with clean pipe conditions. With the steady-state air volume inside each air vessel maintained within the compressors start and stop settings, the maximum and minimum transient static pressure heads generated in the rising main by the trip of one pump set are 141.4 and −2.4 m, respectively, while the air volume reaches a maximum of 3.63 and 3.37 $m^3$ in the air vessel at the pump station and Crete Road, respectively. It is acceptable to continue pumping with one set of pumps with the air volume in the air vessel at the pump station within the range of 1.00 and 4.00 $m^3$, and/or the air volume in the air vessel at Crete Road within the range of 0.60 and 3.75 $m^3$. If the air volume in either air vessel reaches either of the above minimum or maximum volumes, the pump set should be tripped.

The graph plots of the computer simulation P2-1073F are included as a typical set of results.

## PS2: site tests

### Data logging systems

A separate data capture and logging system was installed at the pump station Bowles Well Gardens and Crete Road. Each system consists of:

i. An electronic interface which conditions the signal of the output from the transducers. Normally in industrial situations the transducers are 4–20 mA, which reflects the zero to full-scale deflection of the transducers.
ii. An exclusive 16-channel hardware conversion unit utilising the most advanced and accurate integrated circuitry providing an accuracy of ±0.02%.
iii. The conditioned signals are fed into a PC computer with a LABDAS 12 bit interface card with an accuracy of 0.015% ± 1 bit. The computer software records the signals as a 0–5 V value corresponding to the 4–20 mA zero to full-scale deflection of a transducer.

At the pump station an additional system allows up to four channels to be viewed in real time on a computer screen so that steady-state conditions can be monitored prior to a test.

### Recorded parameters

All the pressure transducers were provided and installed by The Bedford Pump Company Limited, together with their calibration and appropriate elevation.

The following parameters were recorded at the pump station:

i. Dry well pump number 1—on/off.
ii. Dry well pump number 2—on/off.
iii. Dry well pump number 3—on/off.
iv. Static pressure head on the discharge header pipe of the dry well pumps.
v. Air volume in the air vessel.

The following parameters were recorded at Bowles Well Gardens:

i. Static pressure in the main, 350 m downstream of the NRV.
ii. Static pressure upstream and downstream of the NRV.

The following parameters were recorded at Crete Road:

i. Static pressure in the main.
ii. Air volume in the air vessel.

### Comparison of site tests and computer simulations

The following three pressure surge site tests were undertaken during the period 10–12 November 1999:

i. Test No. PS2-1: one pump set in operation. Steady-state air volume in the air vessels: PS2 = 2.84 $m^3$; CR = 1.71 $m^3$.
ii. Test No. PS2-3: two pump sets in operation. Steady-state air volume in the air vessels: PS2 = 2.84 $m^3$; CR = 1.38 $m^3$.

**Table 4** | Comparison of site test and simulation results

| | | Static pressure head (m) | | | | | | | | Max. air volume ($m^3$) In air vessel | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Minimum at discharge of DW Pump | | Maximum downstream of NRV | | Minimum upstream of NRV | | Minimum at Crete Road | | Pump Station | | Crete Road | |
| Site test no. | Simulation number | Sim | Test | Sim | Test | Sim | Test | Sim | Test | Sim | Test | Sim | Test |
| PS2-1 | P2-2065F | 96.7 | 99.9 | 128.9 | 128.7 | 69.3 | 68.6 | – 0.2 | 5.0 | 3.66 | 3.58 | 3.69 | 2.53 |
| PS2-3 | P2-1065F | 78.9 | 75.4 | 131.5 | 134.3 | 37.3 | 41.6 | – 4.2 | 0.9 | 4.53 | 4.30 | 5.52 | 3.15 |
| PS2-4 | P2-1083F | 73.0 | 74.4 | 134.2 | 138.0 | 36.9 | 36.4 | – 4.4 | 0.5 | 3.88 | 3.66 | 4.92 | 2.58 |

iii. Test No. PS2-4: two pump sets in operation. Steady-state air volume in the air vessels: PS2 = 2.34 $m^3$; CR = 1.00 $m^3$.

Table 4 shows the comparison between the site test results and the subsequent computer simulations based on the recorded steady-state conditions.

The graph plots showing the comparison of the site test PS2-3 and the computer simulation P2-1065F are presented. Owing to the data logging procedure the time scale for the site test graph plots does not relate to the initiation of the pump trip scenario. The same time scale is used for the graph plots on a given page to enable the comparison of the site test and the simulation results.

The comparison of the site test and simulation results indicate that:

i. There is very good agreement for the minimum static pressure head at the discharge of the dry well pumps, the maximum static pressure head downstream of the NRV, the minimum static pressure head upstream of the NRV and the maximum air volume in the air vessel at the discharge of the pump station.
ii. The simulations generate a lower value for the minimum transient static pressure head at Crete Road compared with that recorded during the site tests.
iii. The simulations generate a higher value for the maximum air volume in the air vessel at Crete road compared with that recorded during the site tests.
iv. The site test results indicate more damping of the amplitude of the transient static pressure oscillations compared to that generated in the simulations. This is explained by the fact that the simulation is a one-dimensional model and does not take into consideration the real, three-dimensional transient flow damping. Although there are several theoretical expressions for this effect they have not been sufficiently validated to incorporate into the simulations and therefore, it is prudent to slightly oversize the pressure surge protection system.

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