



KARACHI WATER & SEWERAGE BOARD

OFFICE OF THE PROJECT DIRECTOR (K-IV PROJECT)

Block "C", 9th Mile Karsaz Sharea Faisal Karachi
Tel. No. 99245160, Fax No: 99245121

No. KW&SB/PD/K-IV/2019/17/7
Dated: **October 10, 2019**

**Executive Director,
M/s Osmani & Company (Pvt.) Ltd.,
Karachi.**

**Brig (R) Rizwanullah Saeed
Chief Project Manager,
M/s. Osmani & Company Ltd,
Karachi.**

**Project: Greater Karachi Bulk Water Supply Scheme, Phase-I, K-IV
Project, (260 MGD)**

**Subject: SUBMISSION OF DRAFT DESIGN REVIEW REPORT ALONG WITH
ANNEXURES BY M/S. NESPAK FOR THIRD PARTY DESIGN
REVIEW OF K-IV PROJECT.**

Please refer to the captioned subject. It is stated that Draft Design Review Report along with Annexures of 3rd party design review of K-IV Project by M/s. NESPAK are enclosed for your information and necessary input please.

Thanks & Regards,

**Assad Zamin
Project Director
K-IV Project, KW&SB**

Copy to:

1. Secretary Local Government Department, GoS.
2. Secretary Planning & Development, GoS.
3. Managing Director, KW&SB.
4. CEO, M/s. Osmani & Company.
5. Office Copy.



KARACHI WATER & SEWERAGE BOARD
OFFICE OF THE PROJECT MANAGER (K-IV PROJECT)

Block "C", 9th Mile Karsaz Sharea Faisal Karachi
Tel. No. 99245160, Fax No: 99245121

No. KW&SB/PD/K-IV/2019

Dated **October 11, 2019**

✓ **Executive Director,
M/s Osmani & Company (Pvt.) Ltd.,
Karachi.**

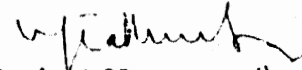
**Chief Project Manager,
K IV Project Construction Supervision,
M/s. Osmani & Company Ltd,
Karachi.**

**Project: Greater Karachi Bulk Water Supply Scheme, Phase-I, K-IV
Project, (260 MGD)**

**Subject: SUBMISSION OF ADDITIONAL ANNEXURES OF DRAFT
DESIGN REVIEW REPORT NESPAK FOR THIRD PARTY
DESIGN REVIEW OF K-IV PROJECT.**

In continuation of letter no. KW&SB/PD/K-IV/2019/1717 dated
October 10, 2019 (Copy enclosed), **Additional Annexures** of Draft Design
Review Report of 3rd party design review of K-IV Project by M/s. NESPAK
received dated October 11, 2019, are enclosed for your information and
necessary input please.

Thanks & Regards,


**Project Manager 11-10-19
K-IV Project, KW&SB**

Copy to:

1. Secretary Local Government Department, GoS.
2. Managing Director, KW&SB.
3. Project Director, K IV Project, KW&SB.
4. CEO, M/s. Osmani & Company.
5. Office Copy.

Karachi WTS third party review

Hydraulic analysis & simulations



Title
Karachi WTS third party review

Project	Attribute	Pages
11204220-002	11204220-002-HYE-0010	13

Keywords
Water transmission system, Wanda, water hammer

Summary

NESPAK is performing review works for Phase 1 of the Greater Karachi Bulk Water Transmission Scheme K-IV (K-IV) for Karachi Water & Sew Board (KWSB) and has contracted Deltares as a sub-contractor for third-party review.

Deltares has reviewed the pumping station design and NESPAK's hydraulic calculations of the canals and siphons. Deltares has performed multiple hydraulic calculations and simulations to check the pumping station design and verify the hydraulic calculations of NESPAK. This document is a brief description of the simulation models used by Deltares and the calculations performed by Deltares in order to perform the review of the design and hydraulic calculations of the Karachi WTS system.

The surge protection as specified in the original design report suffices to protect the pumping stations and rising mains during a full pump trip. However, the design allows for optimization of the surge protection because the current surge protection equipment (pneumatic vessels and pressure relief valves) are larger than what is necessary.

Although there are small (negligible) differences in the simulation results of NESPAK and Deltares for the hydraulic capacity of the canals and siphons, the conclusion is that the design flow rate of 260 MGD and 650 MGD can be transported by the canals and siphons.

References

Sub-Consultancy Services agreement between NESPAK and Deltares for Design Review/Vetting of the Greater Karachi Bulk Water Supply Scheme K-IV Project, Phase-I (260 / 650 MGD),

Version	Date	Author	Initials	Review	Initials	Approval	Initials
1.0	oct. 2019	M. Tukker	<i>MT</i>	A. Heinsbroek	<i>AH</i>	B. van Vossen	<i>BV</i>

Status
final

Deltares



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1 Introduction

NESPAK is carrying out review works for Phase 1 of the Greater Karachi Bulk Water Transmission Scheme K-IV (K-IV) for Karachi Water & Sew Board (KWSB). K-IV is a municipal infrastructure project being jointly developed by the provincial and federal governments in Karachi, Pakistan, to augment the city's daily water supply. The project is designed to provide 650 million gallons of water daily to Karachi in three phases. The new water supply will be extracted from Keenjhar Lake through three water canals. The total length of the Phase 1 of the project is approximately 120km, and consists of canal sections, intake structures, culverts, aqueducts and siphons.

NESPAK requires expert advice on hydraulic aspects of the K-IV project and has selected Deltares as a subcontractor to NESPAK for this third-party design review work. Deltares has reviewed the pumping station design and NESPAK's hydraulic calculations of the canals and siphons. Deltares has performed multiple hydraulic calculations and simulations to check the pumping station design and verify the hydraulic calculations of NESPAK. Deltares' conclusions were reported to NESPAK in separate memo's^{1,2} and have been discussed with NESPAK during a visit to Lahore in August 2019.

This document is a brief description of the simulation models used by Deltares and the calculations performed by Deltares. The waterhammer analysis of pumping stations 1 and 2 is described in chapter 2, the hydraulic analysis of the canal bed profiles and hydraulic capacity is analyzed in chapter 3.

¹ Deltares memo 11204220-002-HYE-0003, "Review Design report Pumping station - K-IV phase 1 260 MGD".

² Deltares memo 11204220-002-HYE-0008, "Review L-profiles and hydraulic calculations Reach 2 & 3 canals and siphons".



2 Pumping stations

The pumping stations PS1 and PS2 each consist of 6 pumps, of which 4 pumps will be in operation simultaneously. The pumping stations both are discharging into high reservoirs (forebays) by means of four parallel rising mains. The surge protection for the four rising mains is provided by eight pneumatic vessels (surge vessels), two surge vessels are connected to each pipeline.

Additionally, a pressure relief valve is connected to the pump header that discharges back into the pump sump. The pressure relief valve at PS-1 has a set pressure of 70 psi (4.83 barg) and a rated discharge of 7 m³/s. The pressure relief valve at PS-2 has a set pressure of 130 psi (8.96 barg) and a rated discharge of 7 m³/s.

The design report states that the air vessels have been designed using a general design rule. No justification for the pressure relief valve specifications is given in the report. This chapter discusses the simulations and analysis performed by Deltares to verify that the surge protection suffices to protect the pumping stations and rising mains in case of a full pump trip.

2.1 Input data

The design of the pumping stations is detailed in the report "Pumping station design report, K-IV phase 1 – 260 MGD", submitted by Osmani Consultancy. Deltares has used an assumed value for data that was not specified in the report, these assumptions will be discussed in the following paragraphs.

2.1.1 Pipeline properties

The report does not state the exact wall thickness of the pipelines used in the pumping stations and rising mains. However, the wall thickness has been calculated from the inner- and outer diameters of the pipes specified in the report. The pipeline properties used in the model are shown in Table 2.1. The report also doesn't state the maximum allowable pressure in the rising mains or pumping station piping. Based on the stated diameter and wall thickness, a maximum allowable pressure of 10 barg is assumed for all pipes.

Table 2.1 Pipeline properties

Property	DN1800	DN2500
Outer diameter (mm)	1829	2590
Inner diameter (mm)	1800	2546
Wall thickness (mm)	14.5	22
Young's modulus (N/m ²)	2.1×10^{11}	2.1×10^{11}
Wave speed (m/s)	962	987
Maximum allowable pressure (barg)	10	10

2.1.2 Pump characteristics

The characteristics for the pumps are not clearly specified in the report, but the rated discharge and head is stated. Based on the rated discharge and pump head, an ideal pump is selected using standard design rules. The polar moment of inertia of the pumps is also estimated via standard design rules.

• Due to the static head of the system, the check valves will close almost immediately after a pump trip. Therefore, the influence of these pump properties on the pressures in the pipeline

during a full pump trip is negligible. The pump characteristics used in the model are shown in Figure 2.1 and Figure 2.2.

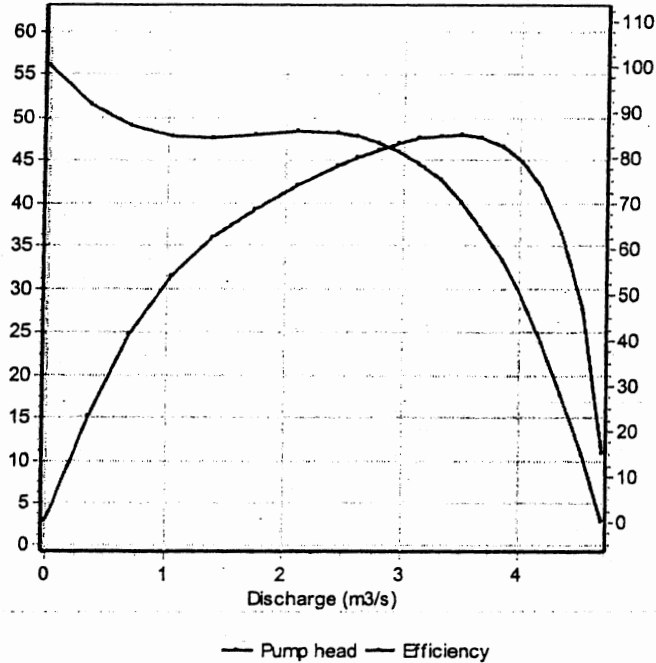


Figure 2.1 Pump characteristic (QHE) of the pumps in PS-1. The polar moment of inertia of the pump is 616 kgm²

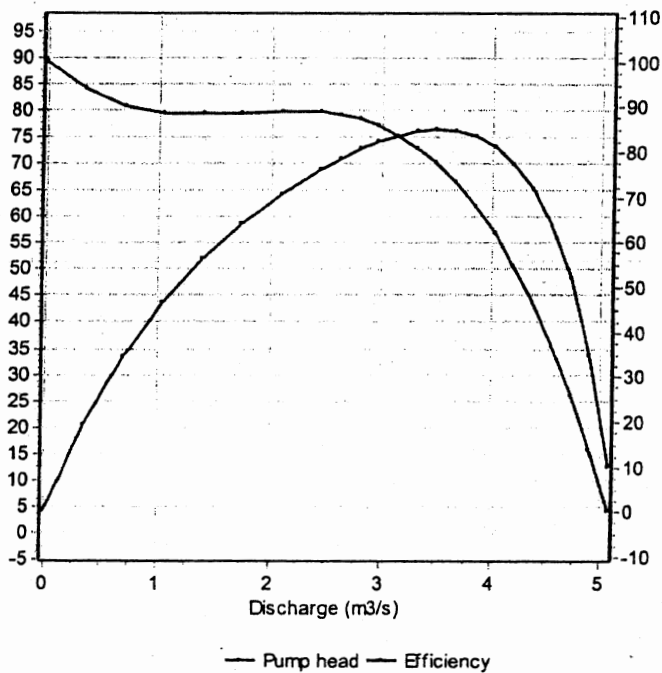


Figure 2.2 Pump characteristic (QHE) of the pumps in PS-2. The polar moment of inertia of the pump is 1200 kgm²



2.2 Analysis and simulation results

The Hydraulic behavior of the pumping stations is identical due to the similarities in their layout and design, therefore, only the behavior of PS-1 is discussed in detail. The figures for the surge analysis of PS-1 and Rising main 1 are shown in Figure 2.3 through Figure 2.5. The results for PS-2 and rising main 2 are shown in Figure 2.6 through Figure 2.8.

After the pumps trip, a negative pressure surge propagates from the pumps into the rising main and pneumatic vessels. The pneumatic vessels react to this by discharging into the manifold, which causes the check valves to close. When the check valves are closed, the discharge from the pneumatic vessels propagates into the rising main, preventing negative pressures. When the pressure surge reaches the forebay it is reflected and travels back to the pneumatic vessels. The water level in the pneumatic vessels decreases due to the discharge into the rising mains, causing the pressure in the pneumatic vessel to decrease. The low pressure in the pneumatic vessels causes the liquid column in the rising main to decelerate and reverse flow direction. The reverse flow causes the water level in the pneumatic vessels to rise (refilling), increasing the pressure. When the pressure reaches the set point of the pressure relief valve, it briefly opens and discharges into the pump sump. The pressures in the rising main and pump manifold remain well within acceptable limits.

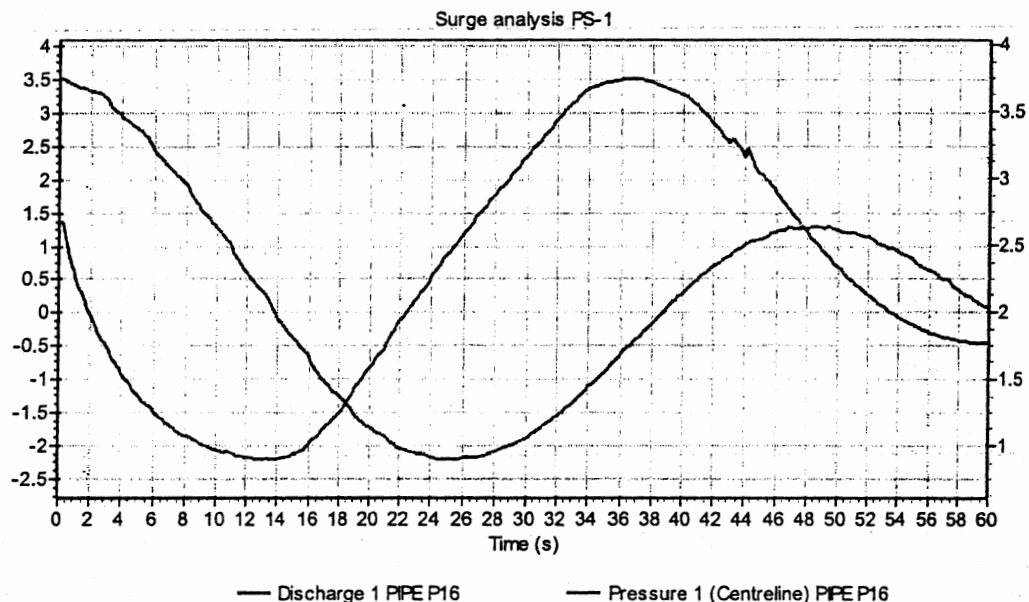


Figure 2.3 Discharge and pressure at the start of the rising main for PS-1.

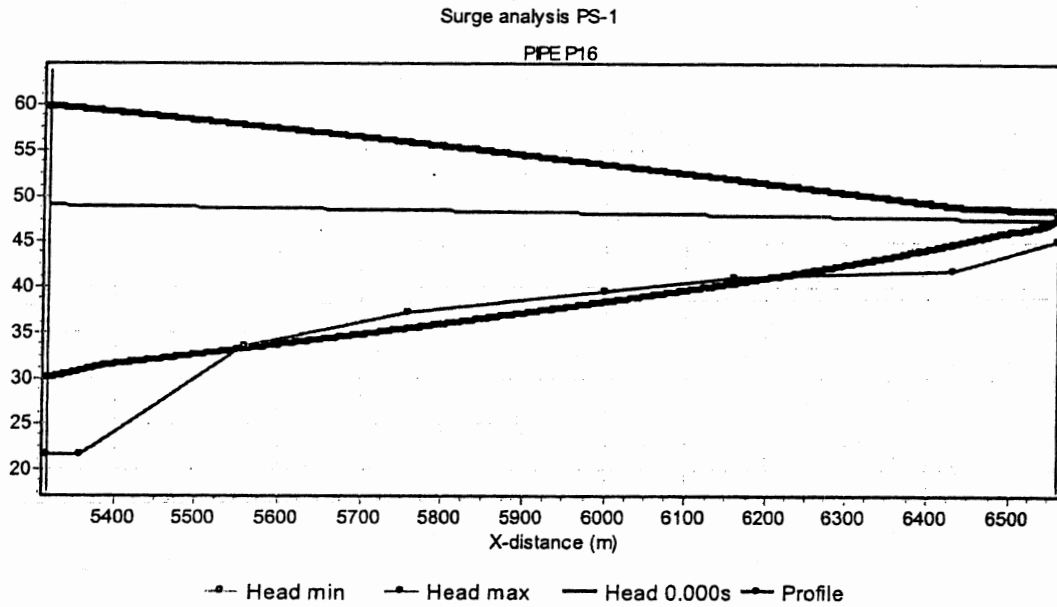


Figure 2.4 Steady-state (maximum design discharge) and minimum/maximum head envelope for the rising main 1 during a full pump trip.

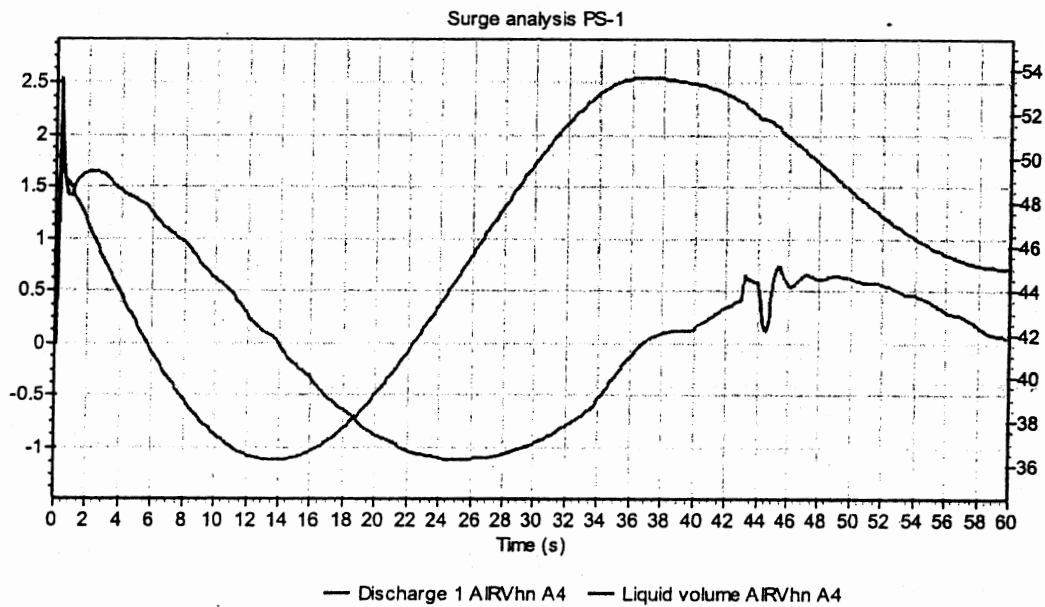


Figure 2.5 Discharge and liquid volume from one of the pneumatic vessels for PS-1.



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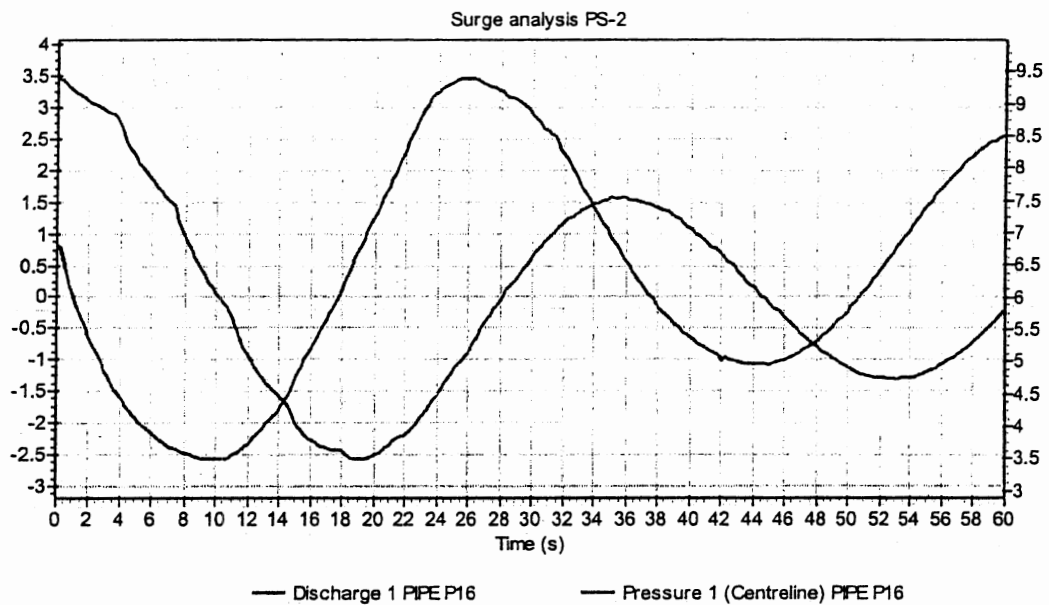


Figure 2.6 Discharge and pressure at the start of the rising main for PS-2.

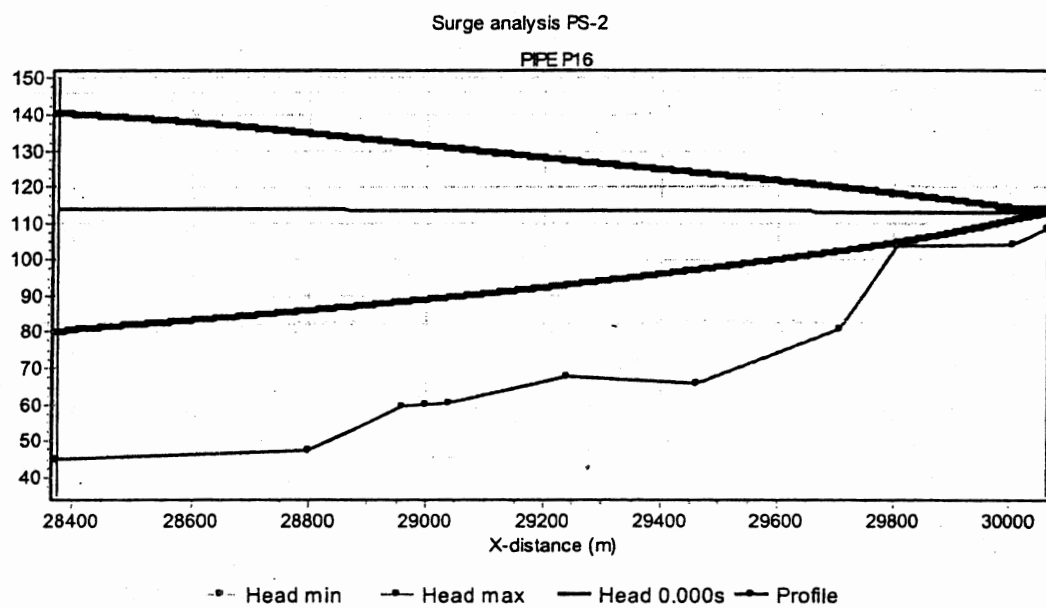


Figure 2.7 Steady-state (maximum design discharge) and minimum/maximum head envelope for the rising main 2 during a full pump trip.

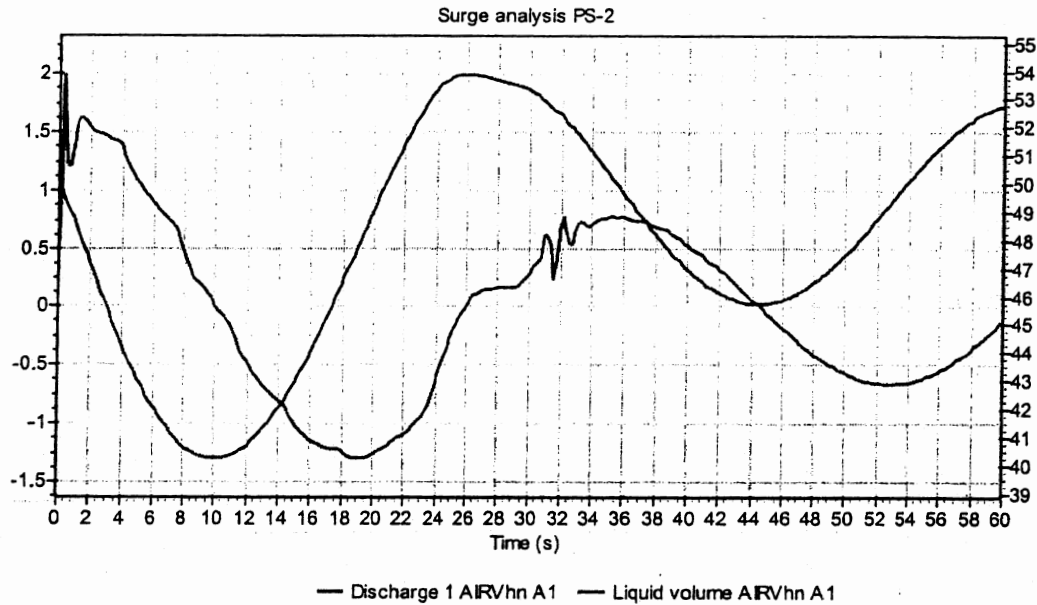


Figure 2.8 Discharge and liquid volume from one of the pneumatic vessels for PS-2.

2.3 Conclusions

From the simulation results discussed in the previous chapter, it is concluded that the surge protection as specified in the pumping station design report suffices to protect the pumping stations and rising mains during a full pump trip.

However, the design allows for optimization of the surge protection because the current surge protection equipment (pneumatic vessels and pressure relief valves) are larger than what is necessary.



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3 Canals

There are two long canals in the system, Reach 2 and Reach 3. Reach 2 connects Forebay-1 to the Pumping station 2 and Reach 3 connects Forebay-2 to the end-basin near Karachi. Multiple siphons are located in both canals to provide crossings for rivers and roads. Deltares has performed hydraulic calculations of the canals and siphons using the software Wanda to verify the calculations performed by NESPAK and to verify the hydraulic capacity of the canals.

3.1 Input data

All input data for these calculations is provided by NESPAK, via the hydraulic calculation sheets that were provided to Deltares.

The energy losses in the Wanda simulations performed by Deltares are calculated from the wall roughness using the Colebrook-White and Darcy-Weisbach equations. For both the 260 MGD and the 650 MGD scenario the Darcy-Weisbach friction factor is specified directly, a value of 0.02 is used for the friction factor in the 650 MGD scenarios. The MS siphons have an assumed wall roughness of 1 mm and the RCC siphons have a wall roughness of 2 mm. Note that the wall roughness in this model also includes all hydraulic losses, such as bends and section-transitions.

3.2 Simulation results

The Free-surface-flow (FSF-)conduit (which solves the Saint-Venant equations) is used to simulate open channel flow in the canals. The siphons are modelled using the pipe component in Wanda. Both rectangular and circular pipes are modelled in these calculations. Please note that in the Wanda software, the elevation profile of the FSF-conduits is specified as the bed-level (bottom), but for the pipes the profile is specified as centre-line. This has no effect on the hydraulic calculations, but it results in a difference in displayed elevation at the transitions from canal to siphon and vice versa when plotting the elevation profile for both the canal and siphons in a single figure.

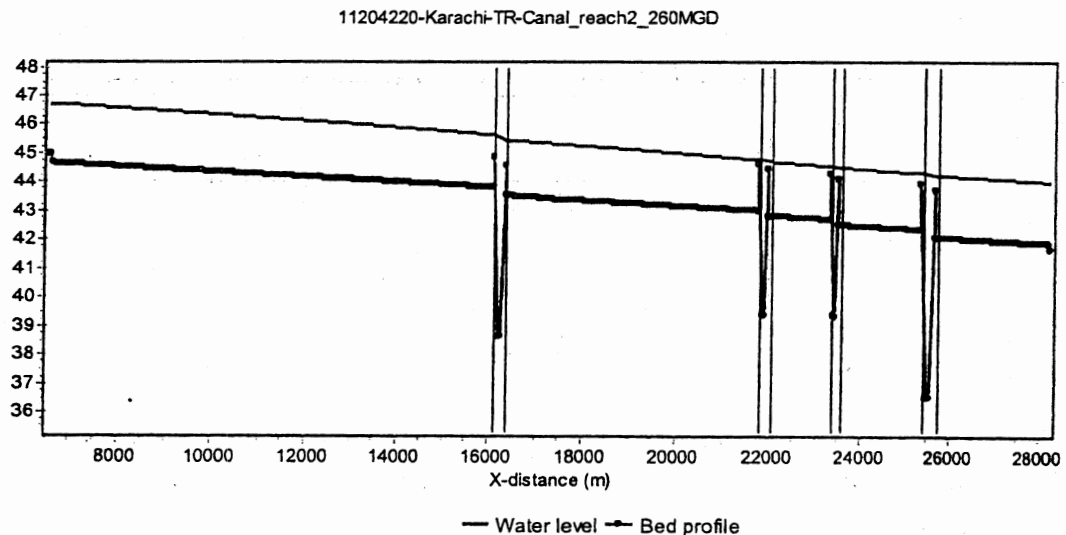


Figure 3.1 Head envelope of Canal Reach 2 and siphons for a discharge of 260 MGD ($13.4 \text{ m}^3/\text{s}$)

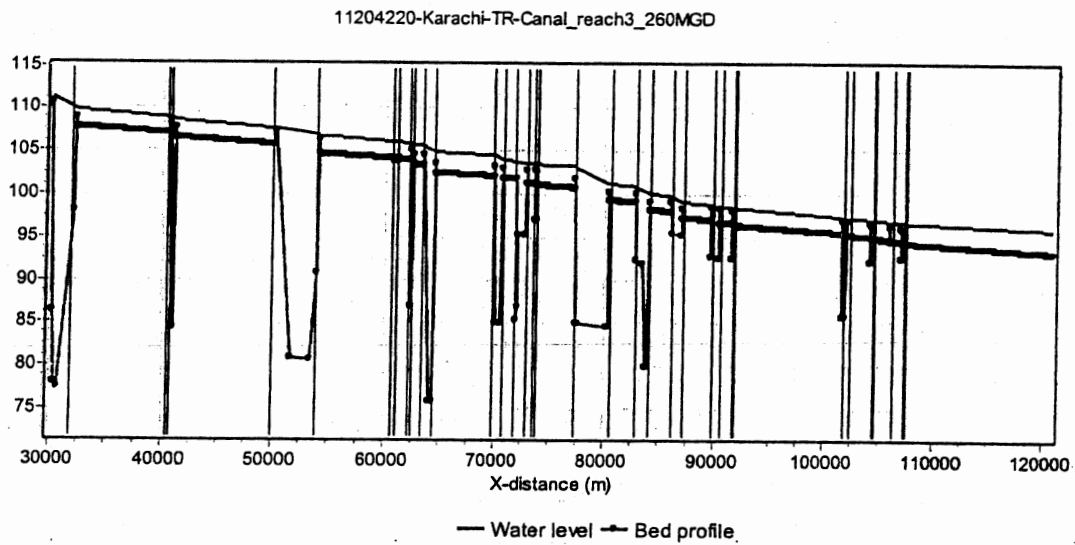


Figure 3.2 Head envelope of Canal Reach 3 and siphons for a discharge of 260 MGD ($13.4 \text{ m}^3/\text{s}$)

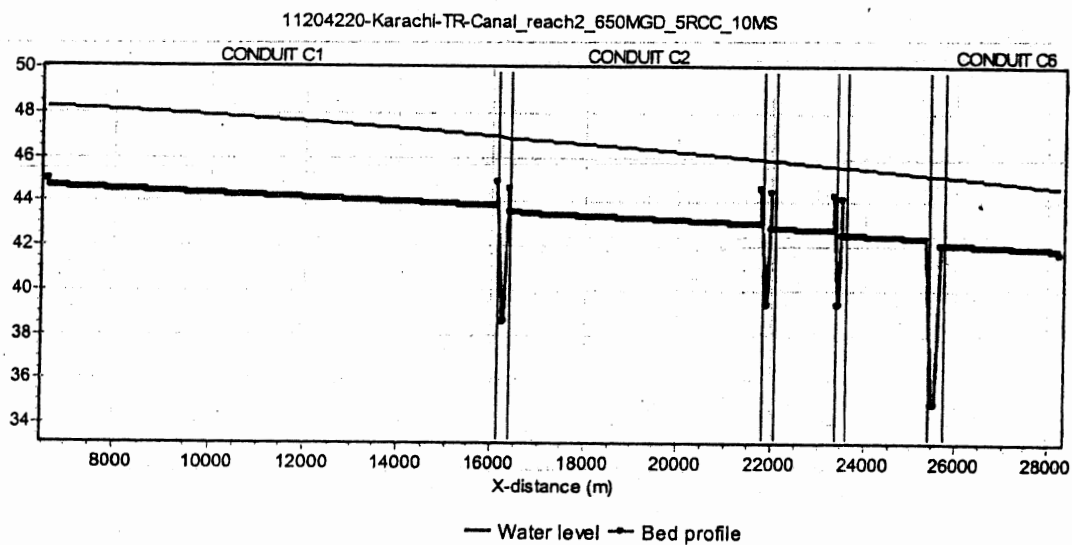


Figure 3.3 Head envelope of Canal Reach 2 and siphons for a discharge of 650 MGD ($34.2 \text{ m}^3/\text{s}$)



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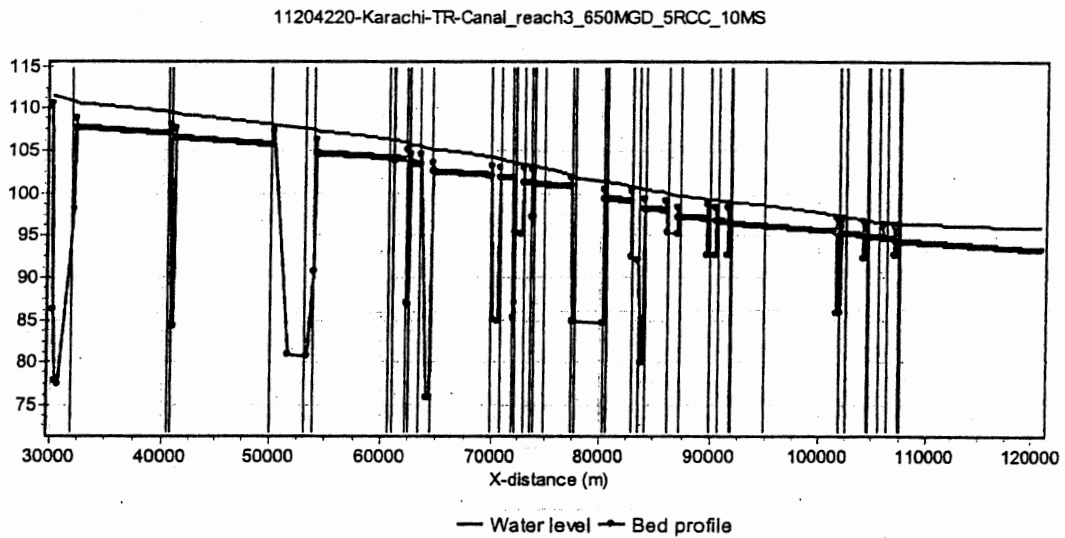


Figure 3.4 Head envelope of Canal Reach 3 and siphons for a discharge of 650 MGD (34.2 m³/s)

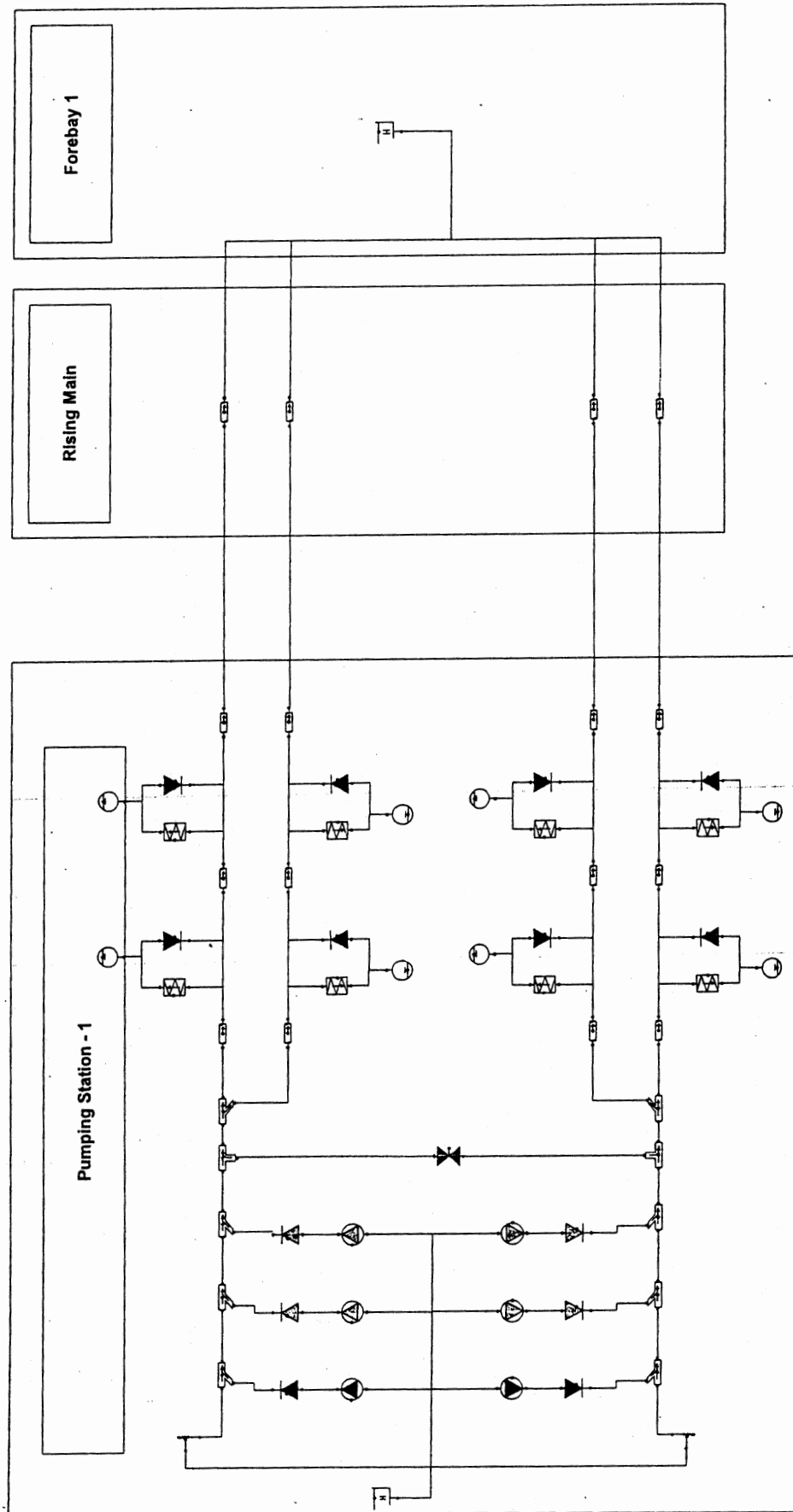
3.3 Conclusions

The results from these simulations have been used to verify and confirm the hydraulic calculations performed by NESPAK. There are small differences in the calculation results from Deltares and NESPAK. These differences have been analysed and discussed with NESPAK engineers and our mutual conclusion is that these differences are negligible and are caused by the differences in the numerical modelling methods that were used.

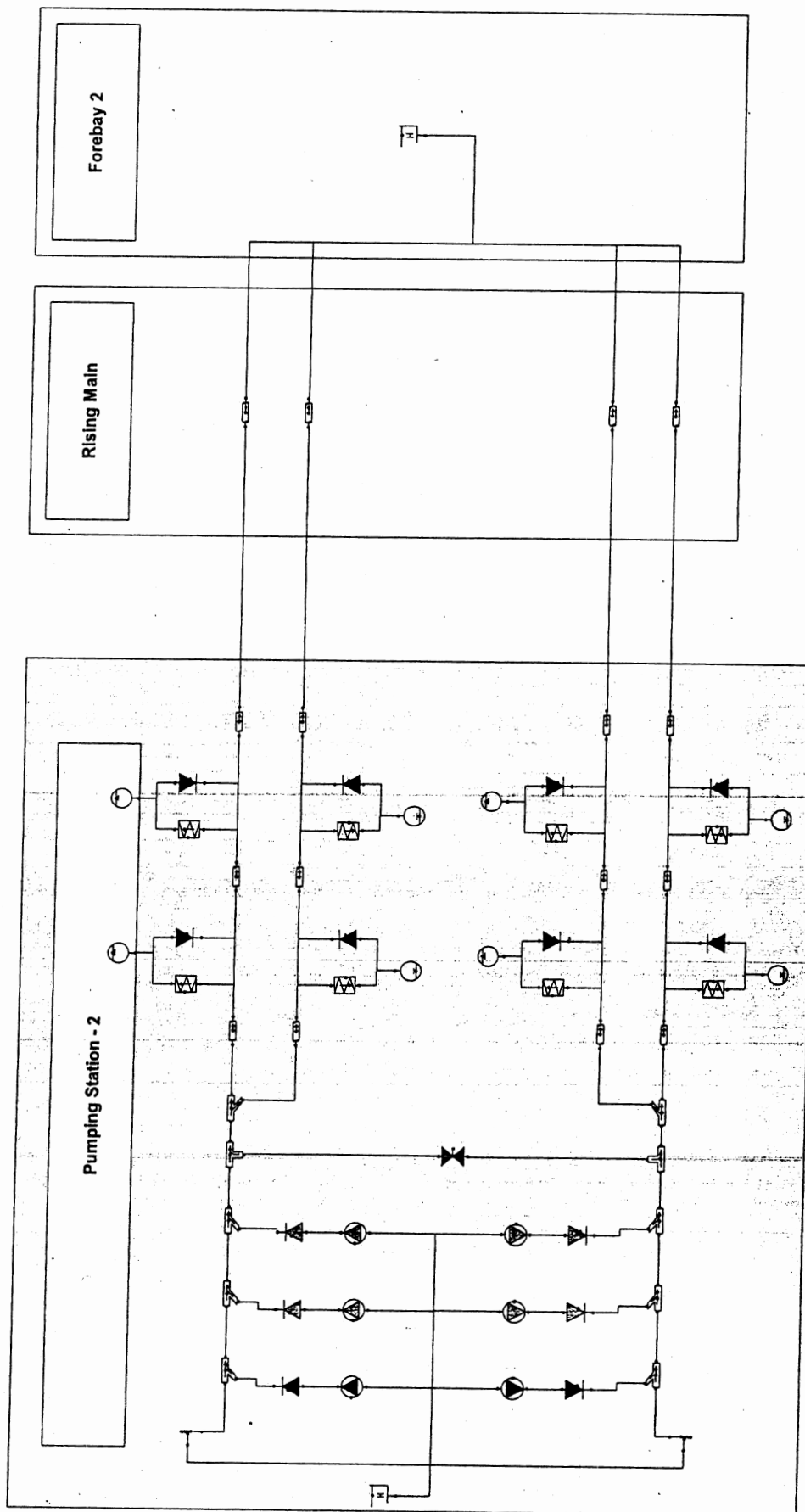
The conclusion is that the design flow rate of 260 MGD and 650 MGD can be transported by the canals and siphons. The water levels in the canal are within acceptable limits.

A Simulation models





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