AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Public Works

Reliability of Water Networks

A Thesis submitted in partial fulfilment of the requirements of the degree of

Doctor of Philosophy in Civil Engineering

(Public Works)

by

Alaa ElDin Hisham Mohamed Naguib Ali

Master of Science in Civil Engineering

(Public Works)

Faculty of Engineering, Ain Shams University, 2015

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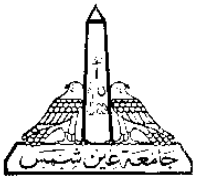

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Statement

This thesis is submitted as a partial fulfilment of Doctor of Philosophy in Civil Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Thesis Summary

Water supply systems reliability is the ability of the system to supply the required demand with sufficient pressure at normal and abnormal conditions. Reliability of water systems is generally overlooked in design.

A methodology is developed for the assessment and enhancement of water distribution networks reliability. Upgrade scenarios are introduced to increase the network reliability, then optimization analysis is carried out for the selection of the optimum upgrade scenario according to a predefined objective function.

A case study of Monshaat Al Qanater is conducted to illustrate the application of proposed methodology. It can be concluded that single supply pipeline should be avoided. Network Loops should be balanced as possible in terms of hydraulic capacity. Increasing number of working pumps and percentage of standby pumping capacity improve network reliability. Network reliability can also be improved by reducing the break rate, by preventive maintenance of the system components, or using high quality of pipe materials and pumps.

Design guidelines to improve system reliability are introduced which indicated that: in order to achieve a system target reliability of 99%, transmission pipelines with break rate exceeding 0.05 break/km/year and 1-day repair time should be duplicated if longer than 73 km. Pumps with break rate exceeding 3 break/year and 5-day repair time should have standby capacity of at least 150%, 67% or 25% in case of 2, 3 or 4 working pumps respectively. If the target reliability cannot be achieved, then water storage at destination should be provided. A design formula is proposed to calculate the required minimum storage.

Key words:
Water Network, Reliability, Availability, Mechanical Reliability, Hydraulic Reliability, Break Rate.

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INTRODUCTION

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Water supply systems represent a major management challenge from both operational and public health point of view. Furthermore, they constitute the majority of physical infrastructure for water supplies, such that their rehabilitation and replacement represent a vast financial liability [1].

A minimum level of service should be realized to maintain a reliable water supply system and user satisfaction. Failure of any component of water supply system would impact negatively on system reliability. For this reason, water companies usually allow for emergency storage, standby pump units, and network looping in order to maintain continuous water supply without interruption throughout the whole year.

Water utilities stakeholder throughout the world have high concerns of the deteriorating water systems. Water companies give high concerns for the condition of water mains and the services they provide. Water supply systems should satisfy the following requirements:

1. Supply the required water demand with the adequate pressure for operation.
2. Preserve the water quality.
3. Satisfy fire-fighting requirements in terms flow and pressure.
4. Minimize the effect of service interruption.
5. Minimize water losses.
6. Minimize the use of energy.

Water supply systems consist of the following components as shown in Figure 1-1: water treatment plants, pumping facilities, transmission systems, distribution systems, and storage tanks.

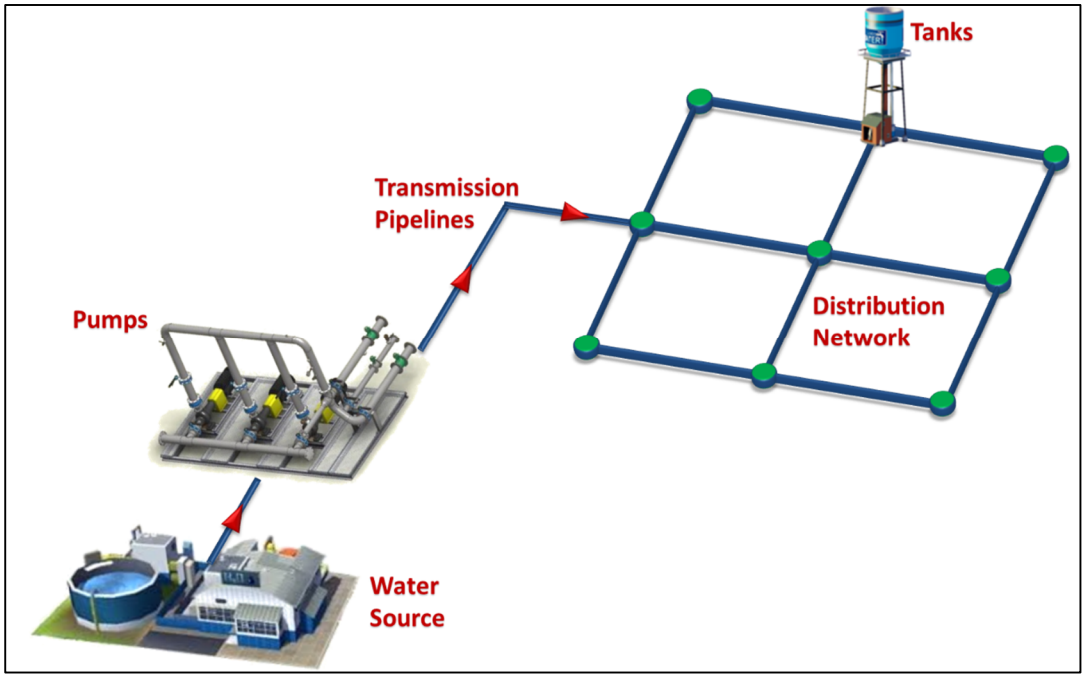

Figure 1-1 Water Supply Systems Components

Water treatment plants are the facilities used for purification of raw water making it safe for drinking (potable water). The primary aim of water treatment is the elimination of any pathogenic micro-organisms present and pollutants by sedimentation, filtration and disinfection processes. Ground storage at the end of treatment is commonly provided to compensate reduced production due to failure of any treatment unit.

Transmission systems deliver water from source to destination. Doubling of transmission pipelines is sometimes adopted to maintain continuous supply in case of pipe failure.

Pumping facilities are used to overcome static and friction losses and provide suitable residual pressures in the system. Mechanical equipment is more subjected to failure than pipes. Therefore, sufficient standby capacity is normally provided at pump station.

Distribution systems deliver water to consumers with appropriate quantity, pressure and quality. Network looping and elevated storage are used to overcome interruption of supply due to any pipe failure.