Guidelines for the design and control of intermittent water distribution systems

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Water supply in many towns and cities is intermittent, with low and uneven pressures around the system. The guidelines described here help engineers design systems with a more equitable distribution of available water within the constraints of intermittent water supply.

Water scarcity in urban areas of developing countries is of particular concern. The water quantity available for general supply is not sufficient to meet the demands of the population and water conservation measures are often employed. One of the most common methods of controlling water demand is by making the supply intermittent, though this is usually a matter of necessity rather than design. In South-east Asia, 91 per cent of systems are intermittent[1] and nearly all Indian cities are reported to operate intermittent systems.[2] This results in insufficient pressure (many areas have zero pressure); inequitable distribution of the available water; and a short duration of supply (between one and three hours per day).

The first question is: why do distribution networks perform poorly when operating under intermittent supply conditions? Intermittent systems are designed based on low per capita allocation, with the assumption that demand will be spread over 24 hours (using peak factors of 2.5 times average). In reality most water is used in a short period. The networks are therefore undersized for the requirements and the water flow in pipes is much greater at these times than anticipated. This results in severe pressure losses creating a generally low pressure in the network.

Consumers in high pressure areas collect more water, denying those in low pressure areas

Why is the supply inequitable? Intermittent systems are generally water starved and consumers try to collect as much water as possible during supply hours. The quantity they collect is therefore directly related to pressure at the outlet and since pressures vary greatly in the network the quantity they collect is inequitable (consumers in high pressure areas collect more water, denying those in low pressure areas).

Discussions with the design engineers of water authorities worldwide confirm that this is a common problem, but these engineers know of no satisfactory alternative since there are no proper guidelines and design tools developed specifically for intermittent systems.

The next question is therefore: is it possible for design distribution networks to perform well under intermittent supply conditions? Conventional methods developed for continuous systems, being demand driven, are not suited for the analysis of intermittent systems because of the strong influence of pressure on outflow. The design objectives also differ from the conventional approach because the aim of improving the equity of supply is more relevant than satisfying the conventional minimum pressure targets.

Design guidelines

In response to the findings of discussions with engineers in India, a major research project began to develop new guidelines for the design and control of intermittent water distribution systems. The Water Development Research Unit (WDRU) at South Bank University led the project in collaboration with Indian Institute of Technology, Madras and Kerala Water Authority, funded by the Department for International Development (DFID, UK). The guidelines (and PC based software), are now completed and will be disseminated through a series of regional workshops in both Asia and East Africa. For further details please contact the authors or see WDRU's website (www.sbu.ac.uk/wdru).

The guidelines do not *promote* intermittent water supply, as there are many serious shortcomings with these systems. However, where 24 hours' supply provision is not a realistic option, an attempt must be made to be proactive in the design of an intermittent system to ensure adequate service standards and in particular a more equitable distribution of the limited quantity of water.

The design guidelines are driven by a modified set of design objectives to be met at least cost. These objectives are:

Equity in supply. Equitable distribution of the limited quantity of water is the keystone of the entire design process outlined in the guidelines

Intermittent water supply system – not enough water to satisfy consumers

Pressures are often so low that outlets often have to be below ground-level

and is a non-negotiable design objective.

People-driven levels of service (PDLS). This is central to the design philosophy of the guideline and can be regarded as the 'golden thread' of the design with all components of the process feeding into this thread. The PDLS are defined in terms of four parameters: duration of the supply; timings of the supply; pressure at the outlet (or flow-rate at outlet); and others, such as the type of connection required and the locations of connections (for standpipes in particular).

It should be noted that all the above objectives are taken for granted when designing continuous systems, but are variables in the design of intermittent water distribution systems.

Structure of the guidelines

The guidelines are in four parts. Part 1 gives a 'General overview' of the entire guidelines. Part 2 and Part 3 concern 'Preliminary design' procedure and 'Surveying people's needs'. Part 4 deals with the 'Detailed design' process and the use of the design software.

A major component of this new approach is modified mathematical modelling tools specifically developed for intermittent water distribution systems. These tools combine with optimal design algorithms with the objective of providing an equitable distribution of water at the least cost.

All parts of the guidelines make reference to the accompanying supplementary documents: 'Field data collection and handling'; and 'NETIS: users guide (software manual)'. In addition to these documents there is an 'Example design' document that contains examples of applications of the entire process.

Part 2: Preliminary design. This part of the guidelines describes methods to establish feasible and practical sets of levels of service objectives for the proposed design. After this collection (5–6 sets) of levels of service objectives, the local community being served by the scheme are consulted (by performing surveys, detailed in Part 3), to establish people-driven levels of service objectives – PDLS.

Novel techniques are presented to calculate durations of supply (for a given per capita allocation), for different minimum pressure requirements (minimum pressure requirements are stated in terms of outflow rates at a connection). The calculated duration of supply is then used to generate different timings of supply and this is used to estimate the capacity of water towers (assuming inflow patterns are known).

Part 3: Surveying people's needs. Part 3 of the guidelines describes methods to establish *specific* PDLS. The PDLS developed on completion of the activities described in this document, are crucial for the detailed design process presented in Part 4, as they are used to establish the specific design objectives.

Techniques are presented on how to design and perform surveys of the people in the supply area. From the results of this preliminary survey, methods are presented that show how to select representative samples for a more detailed survey, and how to design questionnaires tailored specifically for the local conditions that exist in the proposed supply area.

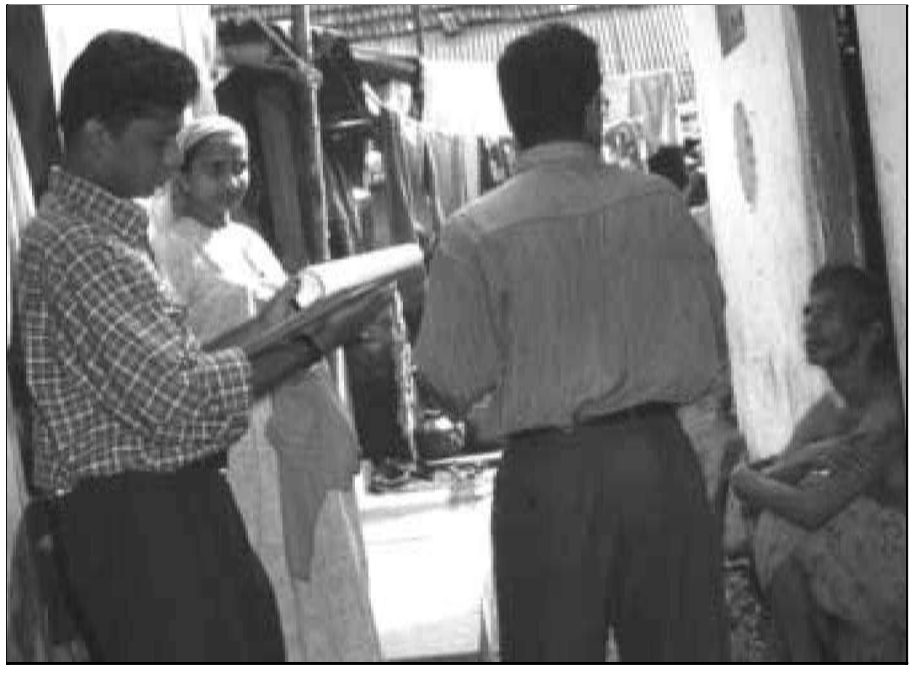
Equity of supply is controlled by minimizing the variation in pressure around the system

Part 4: Detailed design. Part 4 is the central document in the guidelines, and enables engineers to produce a detailed network design that provides an equitable distribution of water and meets the PDLS at least cost.

Equity is controlled directly by minimizing the variation in pressure around the system. This objective is addressed at three stages of the design: the zoning process; the physical sizing of the network; and establishing the operational control (this involves strategically locating valves to even out the pressure).

PDLS are addressed by establishing minimum pressure constraints (that will affect durations of supply); and by providing adequate storage in the network (that will affect the timings of supply).

Both the above objectives relating to equity and PDLS are incorporated into



Part 3 of the guidelines involves surveying to establish 'people-driven levels of service' (PDLS)

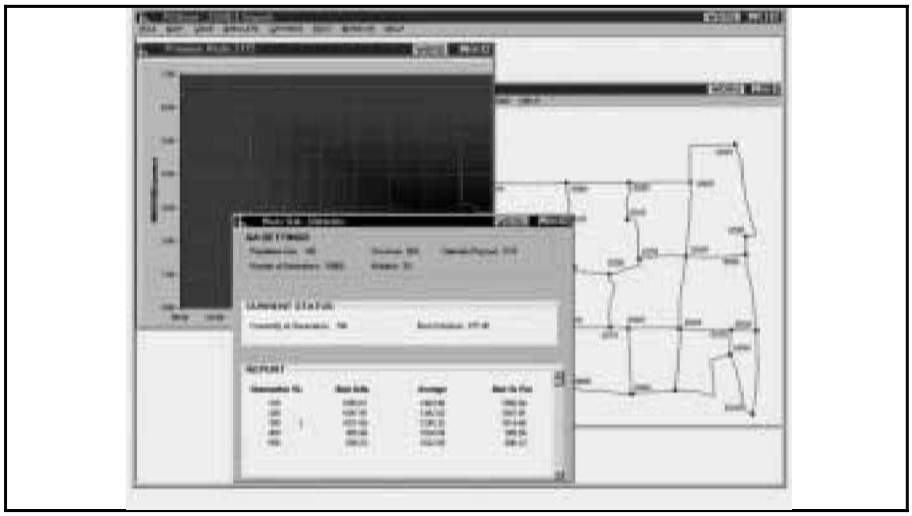


Figure 1 Screenshot: 'NETIS', the accompanying software, is used to produce an optimal design

the detailed design optimization model that is formulated and solved using the software that accompanies these guidelines. This document is divided into four main sections detailing how to generate a design objective data file; a network link data file; network primary nodal data file; and finally how to combine these files to generate the optimal design data file (for the optimal design programme).

On completion of this component of the guidelines a detailed design report can be prepared including: the network design specifications (i.e. dimensions of pipes, water towers etc. and their costs); operational details for the proposed network (control of water towers and valves etc.); performance details of the proposed network (pressures and flows etc.).

Supplementary documents (SD)

In addition to the four main parts of the guidelines there are three supplementary documents.

SD 1: Field data collection and handling manual: provides details of the data required and how to collect it.
SD 2: NETIS – Users' guide: provides a description of the accompanying optimal design software.
SD 3: Example designs: provides two example network designs (the first design is for a new system and the second for the reinforcement of an existing system).

Conclusions

These guidelines outline how to design urban water distribution systems in order to maintain adequate and equitable supplies under conditions of water shortage. It is anticipated that these new guidelines will ultimately find extensive application in developing countries where intermittent supplies are unavoidable for the foreseeable future.

In many developing countries intermittent supplies are unavoidable for the foreseeable future

What is novel about the guidelines is that they recognize the reality of intermittent supply and provide new methods of analysis and design appropriate for such systems. In addition, new design objectives specifically tailored to intermittent systems are developed that drive the design process. These objectives are expressed in terms of equity in supply, adequate pressure at water connections and supply times that are convenient to the consumers. All the objectives recognize the relationship between outflow at a water connection and the pressure at that connection.

Acknowledgements

Thanks go to DFID who generously supported this work both in the UK and in India, and to the Kerala Water Authority, whose help, support and vision made this project possible.

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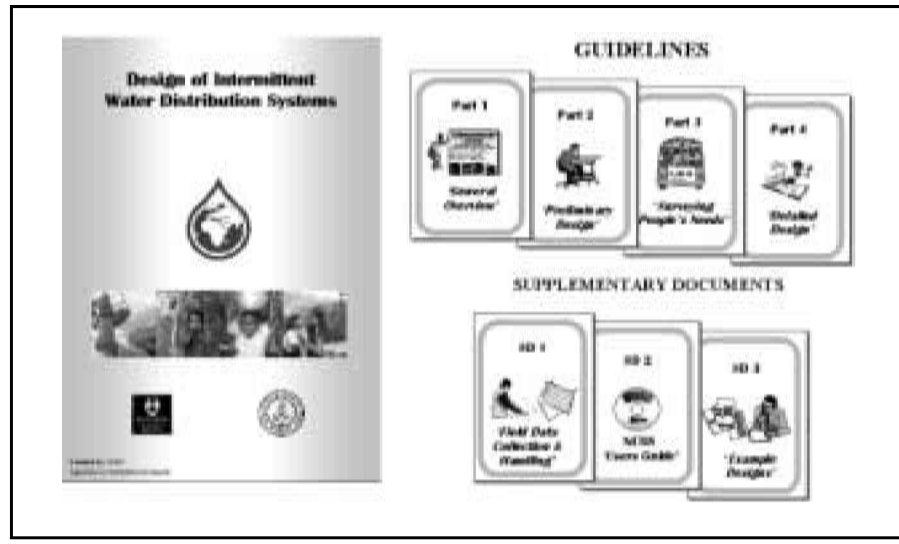

Figure 2 The *Guidelines for the design of intermittent water distribution systems*