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WATER SUPPLY OPERATIONS MANAGEMENT SERIES

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The Reduction and Control of Unaccounted-for Water

Working Guidelines

Philip Jeffcoate and Arumukham Saravanapavan

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The Reduction and Control of Unaccounted-for Water

Working Guidelines

WATER SUPPLY OPERATIONS MANAGEMENT SERIES

(Distribution Systems Management)

The management of water supply infrastructure is a complex activity, involving both the operation and maintenance of existing facilities and the construction of new facilities. Water supply managers in developing countries, however, sometimes give a lower priority to operation and maintenance of old facilities than to the construction of new ones. Moreover, the management of water supply distribution systems often has a relatively low status in many water companies compared to the attention given to production facilities. As a consequence, there are large water losses caused by the premature deterioration of water mains, frequent metering failures and decreased revenues. This, in turn, can lead to economic inefficiencies caused by doubtful investment decisions.

This series of technical papers is intended for waterworks managers, distribution system maintenance engineers, and those concerned with making investment decisions for the rehabilitation or replacement of water supply facilities and the construction of new works. A subseries on Distribution Systems Management, of which this is one volume, aims to provide guidance on some of the most pressing institutional, technical and social problems faced by the managers and engineers of water supply distribution system in developing countries. Two other volumes in this subseries will be published shortly:

- Corrosion Protection of Pipelines for Water and Waste Water: Guidelines
- The Selection, Testing and Maintenance of Large Water Meters in Developing Countries: Guidelines

Proposed future volumes in the Distribution Systems Management subseries will cover topics such as selecting, procuring, and maintaining small domestic water meters; the political, social, institutional, and organizational implications of programs to reduce water losses; detecting and regularizing illegal service connections; and the scope for privatization in operation and maintenance.

Topics likely to be addressed in the main operations management series include reducing losses at source, raw water transmission and water treatment; meter reading, billing, and collection; and the characteristics of users who connect to available supply sources. All of these concerns influence the timing and scale of additional facilities.

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ABSTRACT

These guidelines are in eight sections and are designed for use by Bank project officers and, through them, for the managers of water authorities in developing countries. They are suitable for authorities serving populations of 200,000 or more and may need to be abridged or simplified for use in smaller cities.

Section 2, "Summary of the Guidelines," is meant for the general manager of a utility. Since it summarizes most of the text, the interested technical reader may want to proceed directly to the following sections.

THESE GUIDELINES ARE NOT INTENDED TO BE ADOPTED AS RULES.

Control of UFW entails the continual repetition of a series of simple, logical processes and tasks to obtain increasingly accurate, detailed data that facilitates ever-more-efficient detection of deficiencies. If there is political resolution, domestic metering procedure may be improved relatively simply. But effective reduction of leakage is likely to demand long, persistent efforts by dedicated staff over five to ten years, followed by a permanent, organized, and disciplined maintenance thereafter. **Above all, it must be stressed that modern leak detection equipment only rarely offers significant shortcuts to the achievement of satisfactory conditions.**

CONTENTS

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PREFACE

Efforts to reduce excessive unaccounted-for water (UFW) in developing countries may be hampered by several factors: lack of awareness of the practical possibilities and the potential financial and operating benefits by top management; lack of motivation at the operational level; and, particularly, lack of resources. These guidelines are intended to clarify issues, correct wrong impressions, and stimulate the interest of administrators and operators in making the resources available to improve reduction and control.

Recent national and international publications have identified the problem of unaccounted-for water, but little has been done to relate it to the conditions in developing countries. Nor have efforts been made to show how action can best be taken by management, in logical steps, to achieve effective control even when operational problems seem insurmountable.

The waterworks manager has many problems -- perhaps more political and institutional than technical -- but, first and foremost, the aim will be to provide enough water, at adequate pressure over the whole area served, to meet increasing demands. For this the manager must have the human, technical, and financial resources to meet both investment and operating costs.

Typically, the project officer faces a situation in which the authority seeks to continue its traditional policy of improving the supply of water either by developing new resources or by expanding works. Data relating to the existing supply is likely to be inadequate for a realistic assessment of the supply situation; available figures on the quantity of water produced and consumed may be so inaccurate as to call for a good deal of interpretation by a seasoned professional. The different divisions within the authority frequently lack confidence in the figures produced by the others, which perpetuates ignorance of true data and obviates opportunities for improved control. Excessive UFW is usually a clear indication of poor workmanship and lack of maintenance. Excuses may be offered for delayed action, but it is necessary to begin to accurately measure and assess the data to determine immediate and long-term strategy, which will necessarily include improved maintenance practices.

The aim of these guidelines is to demonstrate one way of proceeding, step-by-step, in producing more accurate data. A clear picture of the existing situation will facilitate the development of a strategy for whatever improvements are warranted. They may be in the area of physical supply conditions or in the equitable collection of revenue necessary for the financing of improvements.

If the production of accurate data demonstrates the existence of either an excessive loss of revenue from water consumed or an excessive loss of water from leakage -- or indeed both types of loss -- the guidelines go on to show how, by cost-benefit analysis, a strategy should be developed and implemented by stages to effect those improvements found to be economically justified.

The Bank has prepared a narrative slide presentation on reducing UFW, which can be obtained from the Economic Development Institute (EDI). An instructor's guide and participants manual with reading exercises and case studies are also available. Interested utility managers could order these for their staff.

These guidelines have been published as a single, bound volume for ease and economy of manufacture and distribution. A looseleaf format would be more useful, however, so that revised or new sections could be added as more information is developed and so that users could add their own notes as well. Each section is self-contained, and a looseleaf format would allow relevant sections to be removed and taken on mission. We recommend that users remove the spine of this volume and punch the pages to fit a looseleaf binder.

Suggestions are invited for future areas of research pertaining to UFW and related topics.

SECTION 1

ISSUES

1.1 Definitions and Significance of Terms

The term "unaccounted-for water" (UFW) is self-explanatory. It represents the difference between "net production" (the volume of water delivered into a network) and "consumption" (the volume of water that can be accounted for by legitimate consumption, whether metered or not). The definition is simple, but determining the true figure can be difficult.

1.1.1 Net Production

The volume of water delivered into the distribution network should be accurately metered, but frequently meters are nonexistent, out of operation, or seriously inaccurate. Similar or greater inaccuracies are found with treated water flows estimated from rated pump outlets into the distribution system. (See Section 3.1.3).

1.1.2 Consumption

Where all domestic, industrial, and commercial consumption is metered, the quantity of accounted-for water must include an estimate of legitimate unmetered public supplies, such as those used for firefighting, mains flushing, public standpipes, and toilets. To put it as an equation, total consumption = metered consumption + estimated consumption for all private and public purposes. Sample test metering will probably be necessary to obtain reliable estimates. Metering is essential for large government offices or military establishments, even when no charges are levied. Where domestic consumption is not metered, it has to be estimated by a sample household study, which will require a special effort. (See Section 3.1).

1.1.3 Categories of UFW

UFW calculated from the difference between production and consumption falls into two categories:

(a) Water consumed but not recorded by consumer's meters or otherwise accounted for by government or other public use. This is referred to as a "nonphysical" loss and is reflected in lost revenue. It includes water consumed through illegal connections.

(b) Water lost through leakage, also referred to as "physical" loss. This is a resource loss and is reflected in the cost of production.

The significance of each category varies enormously in different countries and even in different water systems in the same country.

1.1.4 Wasted Water

Other losses arise from wastage by the consumer. They may arise either from wasteful use or from defective fittings. In a fully metered system it is often assumed that such losses have no impact on revenue and are excluded from estimates of UFW. This assumption is not justified because the loss is frequently not recorded on the consumer's meter. In some situations a severely progressive charge for increased consumption will discourage excessive water use for wasting water, and prompt early attention to defective fittings. The tariff for wasting water, however, must be higher than the cost of repairing fittings. (See Section 3.1).

Wasted water is a conservation loss and affects the cost of production. Waste, other than underground leakage, may be best controlled by the strict application of plumbing codes and bylaws. Public education and cooperation are essential to minimize losses from defective fittings and willful misuse of public standpipes or other unmetered supplies. ("Wasted water" should not be confused with "waste water," which is a term identified with sewage.)

1.1.5 Raw Water Supply is the total volume of untreated water taken from a source of supply such as a river or a borehole.[1/] When raw water is taken from a source, losses occur during storage, transmission, treatment, and treated water storage (apart from normal, acceptable use in the production process). Such losses can occur from leakage, overflow, or inefficient treatment plant operation.

These losses are excluded from UFW but can be of equal importance and require investigation by management at the same time. (Section 3.1.3.)

1.2 Nonrevenue Water (NRW)

In a fully metered system, revenue is derived from charges for the total quantity of water recorded by consumer's meters. All other water produced and not sold in this way is referred to as "nonrevenue water." It includes:

(a) unmetered water supplied to government, or for other public purposes;

(b) water supplied through illegal connections;

(c) water lost by leakage from the authority's network;

(d) water supplied to the consumer but not recorded by the meter or included in the meter reader's record. This may include relatively low rate flows from underground leaks or dripping taps in consumer's plumbing system that will not register on the

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[1/] This volume of water is sometimes called "Gross Production."

meter when there is no other draw-off, even if the meter is in mint condition;

(e) Water supplied to the consumer but not recorded because of defective metering.

In a system that is not fully metered, where revenue is derived partly from a property or a per capita levy, the concept of nonrevenue water is not relevant. For this reason the term nonrevenue water is not used in these guidelines.

1.3 Calculating UFW

UFW is usually calculated as a percentage of net production. When expressed thus, comparison of figures for different systems can be misleading, and quoted figures must be treated with caution.2/ However, since percentage figures are the standard form of expression, they are used in these guidelines. (See Section 3.1.2).

1.4 Continuity of Supply

When a continuous supply of water under pressure is not available, only limited tangible improvements in domestic metering or reduced leakage can be achieved in the short term. Nonetheless, much can be done in the areas of checking basic data, updating maps and records, and improving overall maintenance, which will be invaluable when the availability of water improves. A start can also be made on reduction of UFW in any areas where supplies are continuous.

When a continuous supply of water is available during a limited period of the year, much more can be done through a logical, phased program to identify the extent and the nature of the problem and to achieve positive results in UFW control.

1.5 Recognition of the Problem

Where records show that a UFW problem exists, it has probably existed for so long that its presence is tacitly accepted by management. Control is seen as a matter for attention sometime, but not yet. (See Section 3.2).

Some authorities cite UFW levels as high as 50 percent or more of all water produced; if UFW levels are above 25 percent, there is a probelem that can no longer be disregarded. Much lower figures (15 percent and less) have been recorded in particularly well-managed authorities but,in the general

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2/ In Europe it is becoming increasingly common to express UFW in litres per property per hour (l/prop/h) which enables comparisons to be more meaningful. The concept of losses per property may be considered additionally or at a future time. An interesting approach would be to use cubic meters per property per month since customer accounts are often presented on a monthly basis.

conditions that pertain in developing countries, are unlikely to be achieved in the foreseeable future. Whether action should be taken to try and reduce UFW levels is a matter for case-by-case judgment, bearing in mind that the decision must rest ultimately on economic considerations.

1.6 Strategy for Control

Control of UFW entails the continual repetition of a series of simple, logical processes and tasks to obtain increasingly accurate detailed data that facilitate ever-more-efficient detection of deficiencies. The next section summarizes the strategy proposed in these guidelines.

SECTION 2

SUMMARY OF THE GUIDELINES

NOTE: This section summarizes the guidelines and is meant for the top management personnel of the utility. Technical specialists may therefore want to proceed directly to Sections 3 to 8. These guidelines are intended to be comprehensive and may not be applicable in all cases. The order of procedure may vary in some countries.

2.1 First Six-to-Twelve Months: Initial Investigation and Immediate Action Program

2.1.1 General Manager's Checklist of Basic Data (see Section 3.4)

Where a problem appears to exist, the first step to be taken by the general manager should be to measure total water production and consumption.

Where there are separate districts or zones, the next step is to check the measurement of flows to each district or zone in order to locate probable problem areas.

Spot checks followed as necessary by extensive tests of all large consumers' meters (including reference to historic data on the consumer's industrial output) should be undertaken concurrently. A revised estimate should then be made of total water consumption.

Next, tests should be made to discover any major hidden leaks on trunk mains, which are rare, and for leaks from service reservoirs and tanks, which are much more common. These may be located only by isolation, which could entail tests and repairs of large valves. Losses by overflow from service reservoirs caused by uncontrolled pumping may also be important.

2.1.2 Strategy

If the basic data checks described above reveal that the level of UFW is truly excessive, an overall strategy must be devised, covering: maintenance, improvement in water supply, the basis of charges, and the justification for any change in the "status quo." This must inevitably entail a rapid appraisal of potential savings in terms of revenue and water. Set against this will be the potential cost of making such reductions. A preliminary financial analysis is required to justify an immediate policy decision. (See Section 3.5.)

2.1.3 Instructions

If the basic data checks indicate that the level of UFW exceeds 25 percent of net production, a preliminary investigation is justified.[1] An instruction is required from the general manager to prepare cost estimates and budget and loan applications (if appropriate) for proceeding with a preliminary study and possibly to begin selective remapping of the system. (See Section 3.6).

2.1.4 Economic Analysis

The initial calculations should then be reviewed and an economic analysis undertaken; budget allocation and financial approval for a further detailed study is required at this point. The board of directors or concerned ministry should be apprised of the problem and a commitment to further action obtained. (See Annex 3D).

2.1.5 Immediate Action Program: UFW Task Force

In anticipation of ongoing need for UFW control, an Immediate Action Program should be developed. One way of ensuring that effective action is taken is for the general manager to appoint a well-qualified personal assistant responsible for UFW.[2] This position should be seen as prestigious and challenging and should include additional compensation through special financing arrangements. It should be a stepping stone to promotion and might later on be rotated to provide selected senior engineers in the utility training in UFW control. The appointee must immediately be freed from all other responsibilities. She has to be responsible directly to the general manager for the initial studies, but must have the requisite stature to work in collaboration with the assistant managers responsible for finance, operations, maintenance, water production, and distribution. She should have the authority to agree upon and implement action plans with the assistant managers. She must be allocated sufficiently experienced staff to develop a separate UFW Task Force and should be given suitable assistance to undertake special studies. Alternatively, or additionally, she may be assisted by a consultant or by Bank (or other) technical assistance. The Task Force should also be provided with special financial incentives and motivation. (See Section 3.7 and 7.)

2.1.6 Production Meters

The first action of the UFW Task Force must be to check the production meters (see Sections 3.9, 1.3 and 2.3.7). If installed and apparently operating correctly, they must be checked for accuracy over the full working range because errors of up to 30 percent are not unknown, even in developed countries. If not installed or not operating, the same checks can be applied. Possible methods of checking are as follows:

1/ It is generally accepted that UFW over 15% may be considered to be excessive in some water-short countries.

2/ A one-year temporary assignment may be a good way to begin.

(a) Night test isolation and timed volume change in clear water tank or delivery tank/service reservoir compared with recorded output for each delivery pump in turn.

(b) Diversion to waste through weir or other test meter.

(c) Checking or installing weir or other meter in treatment plant and adjusting estimated production by volume changes in plant and clear water tank.

(d) Installing on each transmission main a temporary check meter, such as pitot, with transducer for accuracy at low flows, or an insertion turbine. Both of these can be installed under pressure. If no meters exist, the installation should be made permanent and readings taken at regular intervals thereafter.

(e) Checking each estimated pump output by standard pump test using closed delivery valve data to modify characteristic curves and applying the operating total manometric head.

2.1.7 Revised Estimate

Calculate the revised figure for UFW based on the more accurate data for water produced. If still more than 20 percent, proceed further with investigation.

2.1.8 Budget Approval

Redefine budget needs and obtain financing authority for the next steps.

2.1.9 Unmetered Consumption

Calculate the total figure for accounted-for water, which must include not only the water sold by meter but also water used for public purposes (government departments, military, and so forth). (See Section 3.10.)

2.1.10 Large Meters

Carry out an initial sample check for accuracy by connecting test meter or by replacement of meter or, where possible, by positive measurements on delivery to tanks. Results of initial tests will determine the extent of further checking justified to reassess losses due to underregistration at low flows. (Some of this work can be undertaken earlier). (See Section 2.1.1.)

2.1.11 Revised Estimate

Recalculate UFW after checks on large meters and assess the potential reduction in UFW.

2.1.12 Sample Survey

Concurrently with the actions outlined in Sections 2.1.4 to 2.1.9, undertake a study of actual domestic consumption by sampling procedure in different social areas (see Annex 3A). Compare the results with the metered consumption to assess the proportion of UFW attributable to underregistration of meters, nonmetering, and other losses such as illegal connections.

2.1.13 Allocation of UFW

Make a sample study of the accuracy of domestic meters and, with this data, reestimate total legal consumption. Deduct the total that is accounted for in order to determine the extent of nonphysical losses. Deduct this figure from the total UFW to determine total physical losses. If either figure exceeds 15 percent, further investigation is probably cost effective.

NOTE: At this stage, the losses from illegal connections have to be regarded as a form of leakage or "physical" loss. This will be corrected later (see 3.10). If the problem of illegal connections appears acute, it should be the subject of a special survey much earlier in the Immediate Action Program. (See Section 3.12.)

2.1.14 Existing Organization

Review the existing arrangements for leak detection, repairs and remapping. Examine the possibilities of making a survey of illegal connections. Undertake a preliminary cost analysis to determine the extent of additional investigation to be undertaken. This could include a preliminary review of design standards and construction and material specifications. (See Sections 3.11 and 3.12.)

2.1.15 Program and Budget Review

The budget should cover all actions described below, including preliminary estimates for long-term actions. (See Section 3.13.)

2.1.16 Future Action

On the basis of cost/benefit analysis (see Annex 3D), the general manager has to reconsider overall strategy and obtain the necessary authority and financial approval for proceeding with such additional works as are economically justified. (See Section 3.14.)

2.1.17 Policy Decision

Policy decision and implementation is now required, including confirmation of organizational changes. Decisions may include establishing the position of UFW Manager (or equivalent) and assigning him a team, remuneration and incentive payments, and the appointment of consultants required for special studies.[3/]

3/ UFW Manager could, after the first year or following achievement of results as head of the UFW Task Force, report to the head of the Department responsible for Operation and Maintenance.

2.2 First Two-to-Three-Year Plan: Metering and Associated "Nonphysical" Losses (see Section 4)

2.2.1 Large Meters

Concentrate on large meters and institute a program of (a) more frequent reading according to size; (b) regular (at least annual) testing on-site or replacement; and (c) critical examination of records and follow-up. Consider monthly reading and quarterly testing of meters 3 inches in diameter and over.(See Sections 4.1 and 4.3.)

2.2.2 Meter Reading Procedure

Study general meter reading procedure and results. Undertake spot tests by management for sample study of reliability of meters and meter readings. Undertake sample survey of illegal connections in selected areas. Take steps to eliminate irregularities and anomalies. (See Sections 4.2 and 4.4.)

2.2.3 Meter Repairs and Testing

Establish a program for regular (four-to-five year) meter changing and testing. Commence color coding or similar identification method. For this purpose a sample study of the meter condition is required; as is an analysis of installation problems. (See Section 4.5.)

2.2.4 Meter Standardization

Examine records of meter failures and failure to register low flows. Consider standardization appropriate to the operating conditions, of type and normal domestic diameter to minimize low-flow errors. Examine a mains flushing policy and water treatment procedures to improve water quality and reduce meter failures. Alternatively, consider the use of flow limiters instead of meters. A pilot study should be made because some flow limiters are useless under conditions of low pressure. Determine policy and purchase additional or replacement meters necessary to meet future needs. A local university might be approached to undertake these tasks as a research project.

NOTE: The reading, billing, and collection procedures, including costs, should at this time be reviewed by management, with technical assistance as necessary, and designed to improve data retrieval, as well as to highlight leakages on consumers' premises and reduce irregularities, underregistration, and illegalities.

2.2.5 Meter Repair Facilities

Study meter repair and testing shop procedure and capacity. Amend procedure as necessary to ensure testing at very low flows. Consider incentives for improved output of testing and repair. Study output per man and future manpower requirements. Study records of meter failures and establish necessary data retrieval procedure for reducing failures. Design any necessary expansion of meter testing, repair workshop, prepare estimates, obtain budget allocation, prepare tender documents and select contractor.

2.2.6 Boundaries of Districts

Examine all possible means of correlating meter consumption statistics with distribution district boundaries, including any necessary boundary changes. (See Section 4.6.)

2.2.7 Review and Further Action Program

Monitor and evaluate results and budget for further actions. (See Section 4.7.)

2.2.8 Expansion of Meter Repair

Expand meter testing and repair shop, recruit and train any additional employees required.

2.2.9 Incentives

Examine all possible incentive schemes to encourage employee's enthusiasm for improved metering. Consider improved status bonus payments and possible rewards to meter readers for reporting defective meters, leakage, irregularities, illegal connections, and so on. This activity should be under continual review and could well begin much earlier (see 2.2.3). Remember that, because the meter reader is normally the only employee known to the public, improved public relations must begin there. (See Section 4.8.)

2.2.10 Women Meter Readers

Examine the possible employment of women meter readers who are interested (a) as the major users of water, to ensure its availability at all times and at low production costs by reduction of waste, and (b) as keepers of the domestic purse, to ensure equitable payments by all consumers. There will of course be social problems and, in some countries, cultural problems which could vitiate any such proposal. (See Section 4.9.)

2.2.11 Pilot Metering Areas

Select one or more possible pilot metering areas for correlation with pilot waste meter district (see Section 2.4.5). **Pilot area networks must receive intensive cleaning, regular flushing, and generally improved maintenance to determine the effect on meter failures.**

2.2.12 Privatization of Meter Reading

Undertake, in-house or by consultant, a cost/benefit study of privatizing all meter reading (and possibly billing) through use of an incentive type of contract. The contract may or may not include meter testing and repair, as well as the survey and remapping of consumers' services, including illegal connections. (See Section 4.10.)

2.2.13 Contract for Privatization

Subject to results of study, implement policy of contract metering, starting in only one district.

2.2.14 Policy for Further Action

Monitoring and evaluation of achievements. Policy decision on all further consideration of improvements to metering and any associated billing procedures.

2.3 First Five-Year Plan: Leakage Detection and Repairs and Physical Losses

NOTE: This plan is designed for completion over a five-year period. For some large utilities, or when there is a resource constraint, it may take longer. The plan should be reviewed and updated annually.

Where metering and leakage problems are both evident, assume that the steps to be taken to correct both will proceed concurrently. The proposed "UFW Division" should be organized accordingly. (See Section 5.)

2.3.1 Existing Conditions for Leakage Detection and Repairs

Review existing arrangements for leak detection, and procedures for reporting and repairs. Consider all possible improvements using existing employees, including more intensive visual inspection -- particularly in conditions and in periods when pressures are high (see also Annex 3.2). Determine the extent of delays in repairing reported leaks and take action to reduce any backlog including, if necessary, temporary additional contract or other labor. Review existing equipment and assess needs. Intensify repair organization as necessary to deal with extra leaks detected. This may be required only temporarily, until the backlog of leaks found disappears. (See Section 5.1.)

2.3.2 Mapping, Records, and Network Analysis

Review progress on whatever remapping of the distribution network is necessary, beginning in the areas where the greatest leakage and metering problems are expected. Remapping should include finding, exposing, marking, and numbering all valves. This work may best be done in conjunction with remapping of consumers' service connections (see 2.1.3 and 2.2.12). **Consider having all the remapping completed by private contractor (covering also possibility of computer mapping in the future.)** This work shall be done at the same time as that suggested in Sections 2.3.6 to 2.3.11. (See also Section 5.2.)

2.3.3 Training and Equipment

Arrange for additional training in leak detection of employees selected from existing leak inspectors as well as one engineer/technician suitable for providing future extended training. The objective is to form a cadre of district inspectors by selecting honest, hard working staff for training; they too must have the opportunity for career improvement and promotion. This training may be on the job but preferably will initially include training with a foreign water authority (see also Annex 5A). Purchase of additional equipment is considered essential. Establish a stores inventory for all tools and equipment. (See Section 5.3.)

2.3.4 Technical Assistance

If considered desirable, apply for and obtain a very brief preliminary study and advice from external sources such as (a) foreign water authority, (b) individual expert, or (c) Bank or other technical assistance. This study is to assess short-term needs and to advise on action program from time to time. (See Section 5.4.)

2.3.5 Pressure Reduction

Make every effort to reduce all high pressures in the distribution network at all times of day and night. First reductions should be by selecting and isolating a pilot area and monitoring the effect by meter. Pressures and resulting leakage frequently increase at night and reductions in night pressures may be achieved by simply installing in-line pressure reducing valves (PRVs), without significantly reducing the daytime pressure necessary to ensure continuous supplies. A careful survey of fringe areas to zones and reconnecting of service connections often can be rewarding. Interzonal leakage must be strictly controlled. (See Section 5.5.)

2.3.6 Monitoring Net Production and District Flows

Check the 24-hour variation in production for the whole system and, as it becomes increasingly possible, for separate districts (see also Annex 5B). This normally has to be done during a period when demand is low and when it may be expected that all private tanks will have been completely filled during the earlier part of the night. (See Section 5.6.)

2.3.7 Net Production

Retest production meters (or estimates). Repair or install additional meters as necessary at all treated water and source pump stations, service reservoirs (inlets and outlets), and boosters. Test for leakage in (a) service reservoirs and (b) transmission mains. Begin regular monitoring of production and district flows. (See Section 5.7.)

2.3.8 Large Meter Night Consumption

Take sample readings on all large consumers' meters to assess industrial and commercial night consumption for the whole system. Adjust the total night production flows to determine the net (domestic) night demand and express as a percentage of production. This figure should not exceed 25 percent (or alternatively 10 litres/property/hour). Repeat for each district.

2.3.9 District Inspectors for Valve and Hydrant Operation

Select top-grade district inspectors to have the sole responsibility for all maintenance and operation of valves, including initial location and subsequent guarding of surface boxes (see 2.4.5). During the same period, install district (or zone) meters. Ensure that districts can be isolated permanently or, if this is not operationally possible, at least temporarily for test purposes. **Concentrate leak detection and repair in districts that appear to have the most leakage.** Always measure and record the quantity of leakage detected and stopped. (See Sections 5.8 and 7.3.)

2.3.10 Pilot Waste Meter Districts

Select one or more pilot areas (see 2.2.11) and install a waste meter making sure that all valves can be effectively closed. Undertake regular tests of 24-hour and night flows and, if possible, regular step tests (see Annex 5C). Initially test monthly for training purposes, later every six months. (See Sections 5.9 and 5.10.) [1/]

2.3.11 Production and Consumption

Study the 24-hour total production of water in relation to average total metered consumption in each district. For this purpose, boundary adjustments may have to be made to meter consumption records.

2.3.12 Physical and Nonphysical UFW

Reestimate the proportions of UFW due to metering deficiencies and waste.

2.3.13 Wasted Water

Review problems of wasted water, both public and private, and determine action to be taken by improved education and public relations as well as by strict application of bylaws. Review existing bylaws and make changes as needed. Where bylaws do not exist, prepare legislation for approval by the government (see Annex 5D). (Also see Section 5.11.)

2.3.14 Concentration of Effort

Experience shows that most leakage problems are due to innumerable small leaks on service connections. Even when domestic consumption is metered, these small leaks can often be found on the consumer's pipework. Correcting this problem is usually the responsibility of the householder, upon whom notice should be served to take action within a certain number of days. If no action is taken, faults should be rectified at the householder's expense. Repairs are a time-consuming and tedious task. Concentrate the leak detection and repairs in districts where night line tests suggest the greatest leakage losses occur. Do not expect that correlators or other modern equipment will normally solve the problem, though they may be invaluable for locating certain leaks. Monitor and evaluate for a trial one-to-two year period. Pinpoint possible areas where complete renewal of network may be the most economical solution.

2.3.15 Economic Appraisal

Make an economic study of the reduction in leakage achieved thus far. **If this part of the UFW (that is, excluding an estimated amount for underregistration of consumers' meters) is still greater than 12 percent,**

[1/] Since this paper was written, more advanced accoustic correlators (para. 3.11) have been shown to be much more effective in the rapid and accurate location of leaks. As a result, step-tests, with their attendant problems of extended night work, are becoming superseded.

review the procedure to determine (a) possible improvements in control without changing the basic control method; (b) additional potential savings by introducing waste meter districts or by complete replacement of all mains and services in selected streets (see also Annex 3D).

2.3.16 Policy and Budget

Reexamine policy and budget.

2.4 Second Five-Year Plan: Review and Update First Five-Year Plan

NOTE: Over the first five years, reliable teams for waste detection and repair will have become established. Procedures for valve maintenance and mains flushing should also have been developed. Guidelines for further action can only be suggested in general terms.

2.4.1 Organizational Aspects

Review the organization that has been set up for UFW control in the light of achievements. Either confirm or make needed organizational changes, as long as changes will not restrict further efforts toward controlling UFW. (See Section 6.1.)

2.4.2 Rechecking Data

Where the marginal cost of water indicates that further reduction is justified, proceed by steps, first repeating the original program of checking accuracy of production metering and accuracy of estimates of public unmetered water consumption. Examine potential savings offered by alternative methods of procedure. (See Sections 6.2 and 6.4.)

2.4.3 Pressure Reduction

Examine possible further reductions in pressure including the use of telemetry-controlled PRVs. (See Section 6.3.)

2.4.4 Service Reservoirs

Recheck leakage from service reservoirs and transmission mains. (See Section 6.5.)

2.4.5 Updating Waste Detection

Reexamine possible improvements using additional training, equipment, labor, and incentives. If not already instigated consider the introduction of a bonus scheme based on savings in annual operating costs resulting from reductions in UFW.

Introduce competitive spirit and appropriate rewards by monitoring, evaluating, and showing in chart form the achievements of each inspection group.

Extend the pilot scheme for waste meter districts by stages, beginning in those Sections where excessive leakage is expected. Step test to measure night demand and locate demand on each street. Repeat tests every six months and compare results (see Annex 5C).

Alternatively, or additionally, extend district metering by subdividing the original large districts and increase the frequency of monitoring districts (see Annex 5B). (Also see Section 6.6.)

2.4.6 Public Relations

Establish respect for bylaws by appointing plumbing inspectors to improve standards of consumers' internal plumbing or by such other means as appear practicable. This could include adult education, publicity, legal action, and community involvement. The private sector could be given incentives for providing low-cost and efficient plumbing services. (See Section 6.7.)

2.4.7 New Works and Repairs

Pay particular attention to improving the standard of construction of new works and repairs to ensure that all work is properly inspected and may be expected to remain leak-free for years to come.

2.5 Operation and Maintenance in Relation to UFW Control

The password is cleanliness. Operator training is a prerequisite for successful operation and maintenance.

If problems of grit in the meters, valves not shutting off, etc. are to be minimized, it is essential that proper attention be paid to all maintenance works, particularly on main and service repairs, to ensure thorough flushing out after completion of repairs. Additional hydrants and washouts must be installed if required for this purpose.

The guidelines refer to tests on production meters and alternative production estimates based on pump output. Testing of all meters and pumps is essential, annually or more frequently, as indicated by results. Protection from dust during building alterations is often overlooked and is a common cause of failure.

Pressure gauges and recorders subject to shock and vibration should be installed in duplicate. They rapidly become inaccurate and replacement becomes necessary, whether for permanent installations or for portable use. Regular testing and calibration is required at least annually. All gauges permanently installed and operating should be throttled to minimize vibration.

Although failures in transmission and leading mains are normally self-evident, regular inspection is desirable throughout their whole length to minimize failures. Total leakage tests of other mains is rarely possible, except for special investigations. Maintenance includes inspection, full operation, testing of effective closure and repairs to leaking glands, etc., on all valves. All air valves, PRVs, and hydrants should be inspected, tested, and repaired.

Examine possible cleaning and relining of distribution mains to obtain a clean system. In many circumstances internal cleaning and relining of mains may be desirable and economically justified, but this normally calls for the employment of specialized contractors and should be done initially on a pilot scale.

Re-examine potential improvements in operation and maintenance. One way of ensuring proper maintenance is to have "district inspectors" who have the sole responsibility for all valve operations for the repair teams. They may also undertake waste inspection while repairs are in progress in the same locality. They are also responsible for seeing that all valve boxes remain exposed during highway maintenance and after road repairs. They are responsible for all internal cleaning of mains, disinfecting and flushing after repairs and, finally, for seeing that all isolating valves remain closed and that all valves closed for repairs are reopened. (See Section 2.3.9).

All valves must have marker posts fixed, and must be numbered and recorded on distribution plans. All failures and repairs must be recorded and collated in a form which readily reveals operating conditions for each street.

When special pilot areas are established, preliminary flushing out of all pipelines and testing and replacement of all valves in the pilot area are required.

The cost of repairs to individual small underground leaks being relatively high, every effort must be made to ensure high quality workmanship, flushing out and testing before excavations are refilled.

Every effort must also be made to prevent the perpetuation of any corrosion problems, particularly in the replacement and repair of services. (See Section 7.) (See also Corrosion Protection of Pipelines for Water and Wastewater: Guidelines, World Bank Technical Paper No. 69.)

2.6 New Works in Relation to UFW Control

If the problems of leakage and underregistration are not to be perpetuated, it is essential that proper attention be paid to the design and construction of all new projects, whether for initial piped supplies or for extensions of the existing system. Concurrently with the guidelines for control of UFW, every effort is required to ensure the highest quality design and construction appropriate to local conditions. Special attention should be given to the following:

2.6.1 Design

Outline design must include, or make provision for:

(a) simple tests on all pumps and production meters by isolation and volume measurements on clear water tanks or reservoirs and/or by discharge to waste through test meters. Installation of adequate indicators of pressures (suction and discharge), flows, amps, volts, r.p.m. and hour counters;

(b) production meters at headworks to be supplemented by meters for delivery to, and discharge from, service reservoirs;

(c) ample district meters or, at least, the chambers and bypasses for later installation to be provided. For distribution extensions, smaller metered districts to be considered and allowances made in the layout. Adequate valves and hydrants to be provided for control, isolation, and flushing as well as tappings for insertion of pitometers or turbine meters;

(d) where waste meter districts are justified, include chambers and bypasses, planning one meter to serve two or three districts; and

(e) avoidance of high working pressures as may be appropriate.

Materials

Select materials that meet local conditions (such as aggressive soils or corrosive water) and comply with international or other appropriate standards (see Section 3.7).

Equipment

Select equipment appropriate to local conditions, with particular regard to allow for interchanging with existing equipment, minimizing stocks of spare parts, and simplifying operation, maintenance, and repairs. Suitability for purpose should take precedence over investment cost. Simple operation is preferable to the most modern sophisticated plant, especially where labor is plentiful.

Responsibility for selection of equipment ultimately rests with the Authority, whether design and construction are in-house or by consultant/contractor. For this reason close collaboration with such external agencies is essential.

Training of labor in construction standards is a key factor in obtaining satisfactory new works.

All construction must be required to comply with approved specifications. The same rigid specifications used for major contracts are required for small local contracts; the supervision and inspection of local contracts should be made the responsibility of a qualified consultant. For pipelaying contracts, particular attention should be paid to the provision of temporary stopends in order to prevent stones and grit from entering pipes during construction. Proper standards of construction, including depth, trench pumping, alignment, bedding, jointing, refilling, testing, swabbing, disinfecting, flushing, and retesting of all pipelines are essential. Retesting at working pressure should follow the provision of services.

Service connections should be bent to give flexibility and prevent excessive strain on tappings. Ferrules (corporation cocks) and, where appropriate, saddles should be provided. Main stop-taps with surface boxes should be fitted outside and adjacent to consumer's boundaries to give adequate night-time access for leakage sounding. Alternatively, surface boxes must be provided over the ferrules.

Complete records should be kept of all as-built work. (See Section 8.)

Annex 2A. Proposed Action Program

Manager's Checklist

2.1 Initial Investigations/ Immediate Works (6-12 Months)		Indicative Target Time Scale			
		Weeks for Tasks		Weeks Cumulative	
		Min.	Max.	Min.	Max.
2.1.1	Check basic data	2	4	2	4
2.1.2	Devise strategy	1	2	3	6
2.1.3	Give instruction for cost estimates, budget, and loan applications	1	2	4	8
2.1.4	Budget allocation and financial approval	4	8	8	16
2.1.5	Establish a task force	2	4	10	20
2.1.6	Check on production meters	4	8	14	28
2.1.7	Revise estimate of UFW	2	4	16	32
2.1.8	Obtain further budget approval	2	4	18	36
2.1.9	Check total unmetered consumption				
2.1.10	Check large meters				
2.1.11	Revise estimate of UFW	2	4	20	40
2.1.12	Survey actual consumption	(10)	(20)	(20)	(40)
2.1.13	Allocate UFW to physical and nonphysical losses				
2.1.14	Preliminary estimates for further action	1	2	21	42
2.1.15	Review future programs	3	6	24	48
2.1.16	Approve budget for future action	2	4	26	52
2.1.17	Decide on policy				
	TOTALS	26	52	26	52

Manager's Checklist (Continued)

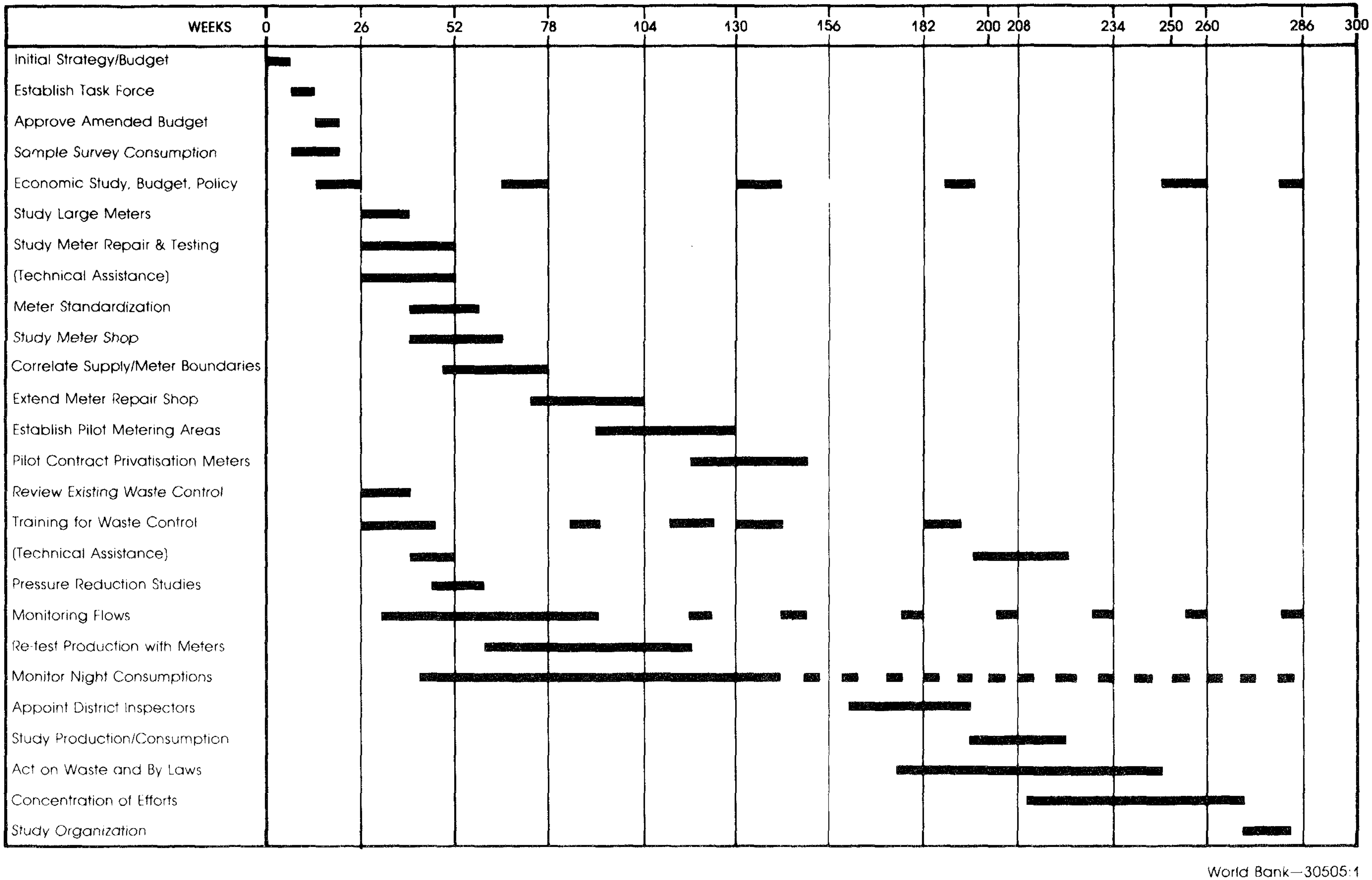
2.2 Extended Action for Reducing Nonphysical Losses (2-3 Years)		Indicative Target Time Scale			
		Weeks for Tasks		Weeks Cumulative	
		Min.	Max.	Min.	Max.
2.2.1	Read and test large meter	4	8	4	8
2.2.2	Study meter reading procedure	8	16	12	24
2.2.3	Establish meter repairs and testing program	13	26	25	50
2.2.4	Review meter standardization	4	8	29	58
2.2.5	Study meter repair shop facilities and required extensions	8	16	37	74
2.2.6	Correlate supply and metered consumption boundaries	13	26	50	100
2.2.7	Review and approve budget for further action	4	8	54	108
2.2.8	Expand meter repairs and recruit staff	20	40	74	148
2.2.9	Consider incentives				
2.2.10	Consider women meter readers				
2.2.11	Establish pilot metering areas	26	52	100	200
2.2.12	Review privatizing of meter reading	13	26	113	226
2.2.13	Let contract for pilot privatization	13	26	126	252
2.2.14	Decide policy on further action required	4	8	130	260
	TOTALS	130	260	130	260

Manager's Checklist (Continued)

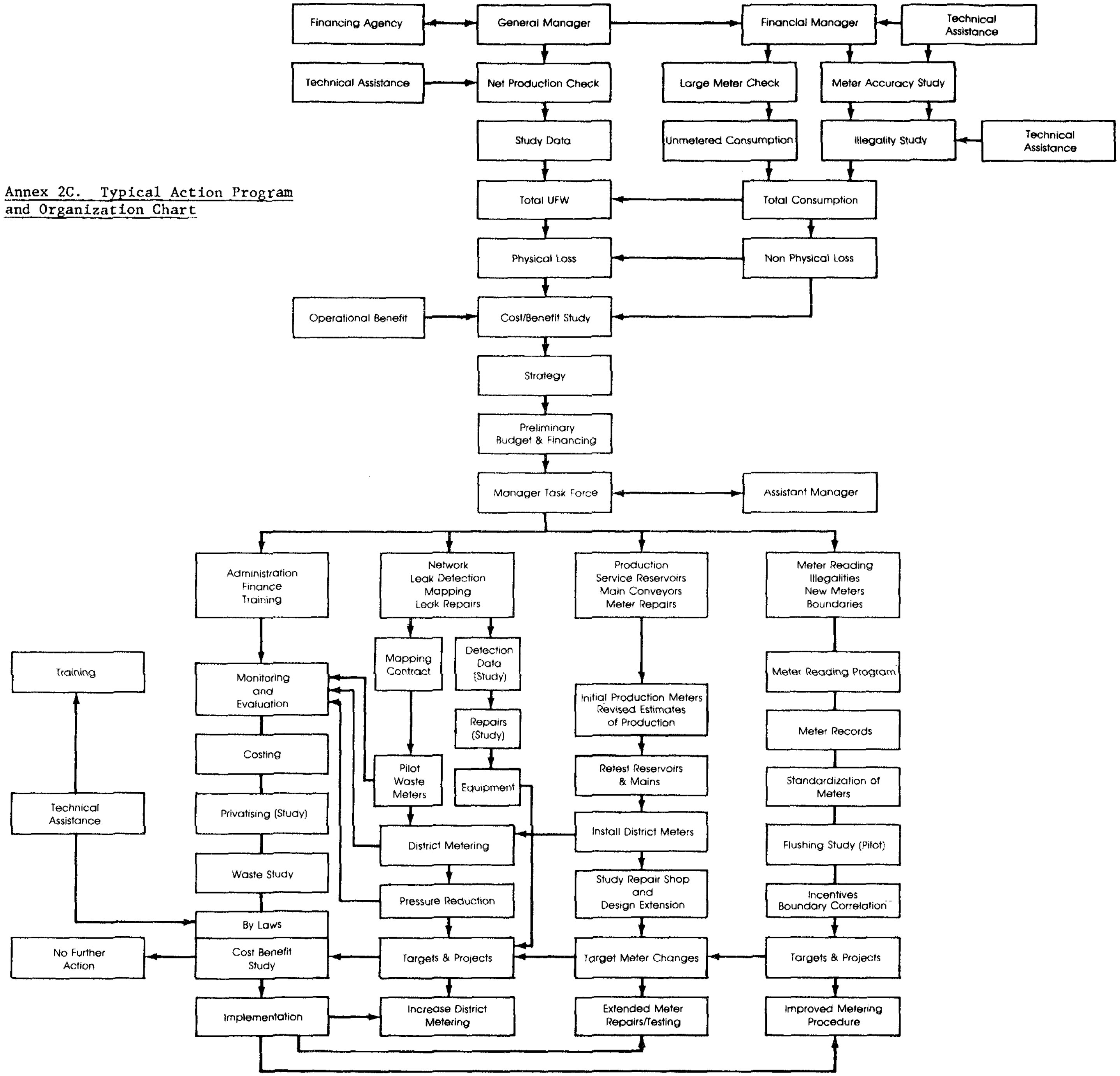
2.3 Extended Action for Reducing Physical Losses (5 Years)		Indicative Target Time Scale			
		Weeks for Tasks		Weeks Cumulative	
		Min.	Max.	Min.	Max.
2.3.1	Review existing leak detection and repairs	4	8	4	8
2.3.2	Review progress on remapping	2	4	6	12
2.3.3	Review training and equipment	8	16	14	28
2.3.4	Obtain technical assistance	8	16	22	44
2.3.5	Reduce high pressure	13	26	35	70
2.3.6	Monitor net production and district flows	26	52	61	122
2.3.7	Retest production with meters	26	52	87	174
2.3.8	Monitor large meter night consumption rates	26	52	113	226
2.3.9	Appoint district inspectors	26	52	139	278
2.3.10	Establish pilot waste water districts	26	52	165	330
2.3.11	Study production and consumption	26	52	191	382
2.3.12	Reestimate proportions physical and nonphysical	4	8	195	390
2.3.13	Study control of waste and take action	26	52	221	442
2.3.14	Concentrate effort	22	44	243	486
2.3.15	Make economic appraisals	13	26	256	512
2.3.16	Reexamine policy and budget	4	8	260	520
	TOTALS	260	520	260	520

NOTE: Many of the above tasks may take longer but can be undertaken concurrently to comply with the suggested program. This table and the related bar chart (Annex 2B) provide a format for the Manager or a Project Officer to propose an action program suited to the needs of a particular utility. Responsibility for the various tasks are allocated in the organization chart at Annex 2C.

Annex 2B. Target Program Bar Chart



Annex 2C. Typical Action Program and Organization Chart



SECTION 3

IMMEDIATE WORKS - TASK FORCE

3.1 Definition of Unaccounted-for Water

It is essential first to clarify what is meant by "unaccounted-for water (UFW)." It has been defined recently as:

> **"The difference between net production (the volume of water delivered into a network) and consumption (the volume of water that can be accounted for by legitimate consumption, whether metered or not). The definition is simple, but determining the true figure can be difficult.**

It includes leakage, or "physical" loss, but also underregistration or misreading of meters and supplies through illegal connections, or "nonphysical" loss.

There has been some confusion in the past as to whether, in systems where domestic supplies are metered, the volume of water accounted for should include water supplied without charge for central and local government establishments and for public purposes such as firefighting, parks, fountains, lavatories, flushing streets, and so on. All such water can be accounted for and has to be included in consumption figures. Confusion has also arisen in countries where domestic supplies are not metered. In these countries there has been a tendency to regard all UFW as water lost through waste, (that is, not through leakage only), and to disregard the nonphysical losses resulting from underregistration of bulk supply, industrial, and commercial meters, even though such losses may represent a significant percentage of the total supply.

For the purposes of these guidelines, unaccounted-for water comprises the following:

(a) **Water consumed but not recorded by consumers' meters or otherwise accounted for by government or public use. This referred to as a "nonphysical" loss and is reflected in lost revenue. It includes water consumed through illegal connections.**

(b) **Water lost through leakage, also referred to as physical loss. This is a resource loss and is reflected in the cost of production.**

Wasted water, sometimes simply called "waste," is water that is truly lost for reasons such as leakage. When domestic supplies are not metered much attention is paid to reducing waste other than leakage, whether it is wilful or not. When domestic supplies are metered, waste by the consumer is sometimes not regarded as a serious matter because it is assumed that the water is paid for. This assumption is probably not justified, because the rates of flow from waste whether from a dripping tap, an overflow, or an underground leak, may be too low to be recorded by a meter, even though the volumes are significant because of the continuity of flow.

Waste also occurs in government institutions, and should be discouraged by levying charges according to meter readings.

Waste that is actually recorded on consumers' meters and sold may be acceptable when surplus water exists, but not when there is a scarcity and reduction of waste could defer new capital expenditure. Control of waste, as indeed of UFW, normally has to be justified on economic grounds. In some situations a severely progressive charge for increased consumption will discourage excessive water use and prompt early attention to defective fittings. The tariff however, must be such that it costs more to use water needlessly than to have fittings repaired.

Wasted water is a conservation loss and affects the cost of production. Waste other than underground leakage may be best controlled by the strict application of plumbing codes and bylaws. Public education and cooperation are essential to minimize losses from defective fittings and willful misuse of public standpipes or other unmetered supplies.

Comparison of UFW figures between systems where domestic flows are metered and those where they are not is not meaningful. In unmetered systems, leakage or physical loss is usually the predominant factor, whereas in metered systems, underregistration and metering illegalities, or nonphysical loss, may be a significant, if not a dominant, factor. Such comparisons are also meaningless because of the doubtful reliability of data in unmetered systems.

The determination of the correct figure for UFW in any system may not be easy because frequently, even in so-called fully metered systems, much unmetered water is used and these quantities have to be estimated (in firefighting, for example). Where domestic water is not metered, much more of the volume of water actually consumed has to be estimated.

Terms other than UFW have been used in some studies, notably "nonrevenue water." Such terms are not sufficiently explicit and can be confusing when considering water put to legitimate public use but not metered, and even in regard to domestic use of water in systems where such water is not metered.

3.1.1 Nonrevenue Water (NRW)

In a fully metered system, revenue is derived from payment for the total quantity of water recorded on consumers' meters. All other water produced and not sold in this way is referred to as nonrevenue water. It includes:

(a) Water supplied on an unmetered basis for government, municipal, and public purposes;

(b) Water supplied through illegal connections;

(c) Water lost by leakage from the authority's network;

(d) Water supplied to the consumer but not recorded by the meter or included in the meter reader's record. It can include relatively low rate flows from underground leaks or dripping taps, etc., in consumer's plumbing system that will not register on the meter when there is no other draw-off, even when the meter is in mint condition;

(e) Water supplied to the consumer but not recorded because the meter is defective.

In a system that is not fully metered where revenue is derived partly from a property or capita levy, the concept of nonrevenue water is not relevant.

3.1.2 Calculating UFW

It has become customary to calculate UFW as a percentage of the volume of water put into the system. (It is therefore with a little reluctance that a departure from that custom should be contemplated.) But the aim must surely be to achieve a meaningful formula for measurement. One needs to be able to compare data for different systems and to have a basis for judging the range of acceptable figures under various circumstances. If, for instance, underregistration of meters is calculated as a percentage of total production, the figure will be dependent on the relative volumes consumed for industry/commerce and for domestic purposes. The same is true regarding leakage and the location of industry relative to the source of supply. Examination of the percentage figure shows that wide variations may have to be accepted and that comparisons can be misleading.

Experience shows that both physical and nonphysical losses are closely related to the number of properties served. Only in scattered rural areas, where UFW problems are unlikely to be significant in Bank projects, are the physical losses related more closely to the length of main than to the number of properties. It is for this reason that in the U.K., UFW is increasingly calculated in litres per property hour.[1/]

3.1.3 Source, Headworks, and Treatment Losses

Bank project officers have frequently become aware of physical losses of water not included in UFW. These are losses that occur before the water is put into the distribution system. They include leakages and overflows of untreated water from storage reservoirs and tanks, watershed leakage and bypasses inadequately controlled, leakage from untreated water transmission lines, and excessive use of water due to inefficient operation of the treatment process.

These losses are normally regarded in a separate light, their control being a matter for the maintenance staff working on problems of source of supply, raw water transmission, and water treatment plants.

1/ An interesting approach would be to calculate it in cubic meters/property/ month since many utilities bill monthly.

They may add up to a significant loss which merits close investigation and it is appropriate that attention be directed at this problem concurrently with the instigation of improved control of UFW.

These losses are excluded from UFW but can be of equal importance and require investigation by management at the same time.

3.2 Typical Situation Facing a Bank Project Officer

An historical review of investigations of UFW problems over the past century is given in the valuable report by J.B. Buky (see Annex). The study draws attention to the emphasis that has been placed in recently published literature on the physical losses experienced in the more developed countries.

It appears that nonphysical losses may not have been a serious problem, but they were not ignored entirely. In the U.K. 50 years ago it was considered good practice to change meters at regular intervals of five years or so, but this was not a major task because there were no domestic meters. No record has been found of any study of underregistration though it is known that a close watch was kept on consumption; enquiries would be made and explanations sought for any tailing off, or indeed of any exceptional increase, in individual metered supplies. In the U.S. there are references to metering problems in various papers in the American Water Works Association Journal over the past 40 years.

In developing countries, conditions have developed during recent decades -- stemming partly from a woeful neglect of maintenance and partly from a lack of public standards -- where underregistration or incorrect reading of meters and increasing numbers of illegal connections have become, in some systems, the predominant factor in UFW.

The major initial difficulty, mainly because of inadequate reliable data, is to determine the true level of UFW and assess whether or not it is excessive, bearing in mind that there are many reasonably operated systems in developed countries quoting UFW levels of up to 40 percent.

A project officer may face the following situations:

(a) For many years the authority has been unable to provide a continuous pressurized supply over the whole area. Conditions are relatively good if a continuous supply is available for some part of the year.

(b) The general manager and all senior engineers are more than fully engaged dealing with day-to-day problems related to providing a better supply. Usually there has been a major expansion of the system, possibly with squatter housing and numerous illegal connections.

(c) Production figures are usually based on estimates of doubtful validity. Of the consumers' meters, if 25 percent are not operating then probably at least another 25 percent are seriously underregistering and the remainder are under-registering to a lesser extent. Meters are probably too large for accurate measurement of low flows. All properties have huge storage tanks for use when the supply fails. Most of the flow to properties is very slow due to low pressure or slow filling of storage tanks through old ball valves. This alone is the cause of much underregistration. Where the flow is not naturally slow, it may be intentionally throttled by the consumer to encourage underregistration.

(d) Records may not have been updated for 20 years. Maps of the distribution system are also outdated and of little value. Valves are few; most have been covered by highway resurfacing and cannot be found since marker posts do not exist. Where valves can be found they cannot be operated effectually because of stones in the gate or bent spindles -- and the glands leak. Hydrants are sparse and are rarely used or tested; mains are never flushed, so the water contains grit or rust particles; maintenance is minimal. The new mains extensions have been badly designed and constructed with no regard for recognized standards.

(e) Night demand is almost as high as day demand, but that is said to be due to the nighttime filling of numerous private tanks. That may well be, but by late night all tanks should be full or the private storage would gradually be depleted. So the late night or early morning flow <u>should</u> be low if it were not for leakages.

In these circumstances it would be remarkable if the UFW figure were not excessive.

The general manager may accept that the UFW level is high but insist that, calculated as a percentage of production, it is no higher than it has been for years. The fact that it should have reduced as the proportion of new mains and new meter installations has increased is overlooked.

The first task is to try and clarify the situation. What in fact is the <u>true</u> extent of UFW? How much is due to metering deficiencies and illegal connections? How much is due to leakages? Often there is an inbuilt reluctance to face up to any problem. The estimated production figures are usually thought to be too high; they often are but the supply manager prefers to have it that way. Because the finance manager doesn't believe the figures, he accepts that the total of meter consumptions is probably reasonable. The distribution manager says there is no leakage because nothing shows at ground surface. Above all, the management staff are busy; their attitude is that the problem probably does exist, but in any event things have always been thus and have come to be accepted. Moreover there is a belief that curing one leak only increases the pressure elsewhere, causing another leak. A feeling of hopelessness is engendered by the lack of resources and know-how to tackle the problems.

The initial step is for the general manager and, through him, the chairman of the board to make a commitment to at least investigate the questions "How much water is accounted for? "How much of it is due to leakage?" and "What is the effect on revenue and costs?" The enthusiastic encouragement of the finance manager is often the best way to obtain this commitment (see also Section 3.4).

3.3 An Atypical Situation

In another situation, the utility could be well managed with good standards of operation and maintenance presently have a reasonable level of unaccounted-for water. However, pressures may be low and a new service of supply might be on the verge of being commissioned. This could result in a future and unexpected increase of UFW brought about by the increased pressure unless maintenance is strengthened.

3.4 Preliminary Checks of Basic Data

The problems arising from lack of accurate data may appear overwhelming but they may be solved by a careful study of existing data. An attempt should be made using the existing organization to obtain the required additional data described below.

Commonly occurring errors arise from inaccurate estimates of production. In the unlikely event that there is a production meter in operation, it is often found to be giving grossly inaccurate readings. Otherwise, discharges are estimated assuming that pumps are operating at duty point and in pristine condition, which is rarely the case.

Where a problem appears to exist, the first step to be taken by the general manager and the existing staff should be to measure total water production and consumption.

Sample tests on meters and pumps by checking volume changes in suction tanks of service reservoirs should be made and, if gross errors are discovered, these tests should be extended if possible.

Failing that, all pressure and suction gauges must be checked on dead weight equipment or equivalent. Following this, a closed valve test on all except displacement pumps should be made in order to discover the delivery and suction pressures. Taking the pump characteristic curve and drawing a parallel curve through the actual points for observed total manometric head at zero flow, one can estimate the pump discharge at the normal operating pressure (see also Section 3.9).

From the above tests the actual production figures may be re-assessed with adjustments for seasonal variations.

The next step is to reestimate the quantity of water consumed for private and public purposes and above all for any government service for which there is no charge and which may not be metered. The public purposes include lavatories, parks, street cleaning, and firefighting, as well as the authority's own use for hydrant flushing etc.

Where there are separate districts or zones, the next step is to check the measurement of flows to each district or zone in order to locate probable problem areas.

A study of the night flows may indicate whether there is excessive leakage. The minimum late night or early morning demand should not exceed 20 percent of the average 24-hour day demand.

Finally, spot checks should be made on bulk supply meters and other large meters. These may be checked by volume changes in private tanks or by the use of a test meter connected in series or on a hydrant discharge.

> **Spot checks followed as necessary by extensive tests on all large consumers' meters (including reference to historic data on the consumer's industrial output) should be undertaken concurrently. A revised estimate should then be made of total water consumption.**
>
> **Next, tests should be made to discover any major hidden leaks on trunk mains, which are rare, and for leaks from service reservoirs and tanks, which are much more common. These may be located only by test isolation which could entail tests and repairs of large valves. Losses by overflow from service reservoirs caused by uncontrolled pumping also may be important.**

After these basic checks have been made, it is possible to arrive at an estimated value of UFW and have some idea whether it is high due to leakage or due to metering problems such as underregistration, unreliable reading, or illegal connections.

3.5 Initial Analysis

Before embarking on a major investigation of UFW as described above, it is useful to assess the need by a thoughtful analysis of the water supply situation from known facts.

First, consider potential problems of underregistration and illegal connections. It may be that one section of the community is having to bear the whole cost of supply because of the failure to collect revenue from the remainder of the community. As a result, either revenue is insufficient for maintaining a proper supply, or a subsidy from central government or other source is required, or the tariff is inordinately high.

It may be that there is a high percentage of very poor people who are unable to pay for water and receive only sporadic supplies. In such cases, a subsidy may be justified on public health or equity grounds, since insuperable difficulties in collection of tariffs would be likely, even if metered supplies were provided.

Such examples may be rare and, in a normal system, either full domestic metering or no domestic metering must be the policy. If full domestic metering is decided upon, it must be operated accurately and fairly to be effective. In general, all problems of underregistration or other illegalities must be overcome.

Before embarking on any form of active waste detection one has to consider the extent to which it is economically justified.

Answers to the following questions are normally available and can help in the initial analysis:

(a) Is there a scarcity of water sources?
(b) What are annual operating costs?
(c) What would that cost be if demand were halved?
(d) What would that cost be if demand were doubled?

There may be circumstances in which the cost of production and distribution or expansion would be less than that of reducing leakage. In such instances, nonetheless, the consequential costs of leakage must not be overlooked. Leaks can cause damage to other structures and to expensive stored goods. When pressures are negative, polluted water can enter the system. The extra cost of treating an increased flow of sewage is also a possible factor.

If water is not continuously available under pressure in some areas but is continuous in others, consider what steps can be taken to reduce waste in the fortunate areas in order to extend them.

If water is scarce, the elimination of leakage may produce a continuous supply for all. If future growth will require the development of additional water supply sources, improved leak control may defer huge capital expenditure as well as reduce operating costs.

Experience shows that even in relatively well operated "old" systems, leakage may not be less than 20 percent and can be as high as 40 percent. Where no active leak detection is practiced half the water put into supply is probably wasted. Experience also shows that the costs of active leak detection and repair are so high that it may not be economical in some conditions to maintain a figure less than 20 percent.

If active control of leakage can reduce physical losses to 25 percent and if those operating costs that are directly related to the amount of water produced are about half the total operating costs, one can quickly deduce that a potential saving of 1/8 of the total operating costs is possible without making any spectacular claim which might be difficult to achieve. (If these savings were large enough to defer capital expenditure on additional source development, the potential saving is greater.)

Thus the question to be answered is "what sum is represented by 1/8 of the total operating cost?" If such a sum will more than meet the cost of improved leak detection and repair, then the improvement is financially viable and will facilitate better management.

Where water is scarce, or in a situation of exceedingly high operating cost for additional water, the option of NOT introducing active leak detection may not be available.

CONCLUSIONS FOLLOWING BASIC CHECKS

If the basic data checks described above reveal that the level of UFW is truly excessive, an overall strategy must be devised covering maintenance, improvement in the water supply, the basis of charges,

and the justification for any change in the "status quo." This must inevitably entail a rapid appraisal of potential savings in terms of revenue and water. Set against this will be the potential cost of making such reductions. A preliminary economic analysis is required to justify an immediate policy decision.

3.6 Preliminary Estimate, Budget, and Financing for the Initial Study

Having examined overall strategy and decided that a reduction of UFW is desirable, it will be necessary to obtain formal approval to proceed and, for that purpose, **a preliminary cost estimate must be prepared covering the initial investigation to be undertaken in the first six to twelve months.** For this it must be assumed that an individual will be nominated to take responsibility for the preliminary study and that sufficient suitably experienced staff will be detailed to assist. Allowance must be made in the estimate for renewing consumption meters for larger consumers, installing additional production meters, pressure gauges and recorders, pressure reducing valves, sluice valves, and simple sounding devices. It must be accepted that the work will entail a great deal of overtime, particularly during the night. An additional allowance must be included for any outside technical assistance required to advise on the details of the study. **If it can be expected that additional revenue will be quickly derived from improved registration of the larger meters,** the initial investigation **may prove to be self-financing.**

The preliminary estimate of cost for setting up the organization and making the initial study will depend on the organizational changes required and the additional installations proposed. The provision, installing, and testing of new meters will be based on tenders, but the testing and replacement or refitting of any large valves required will need particularly careful study. Training of selected employees will be costed according to tenders received. A high estimate for the initial work is normally sound practice.

If the basic data checks indicate that the level of UFW exceeds 25 percent of net production, a preliminary investigation is justified. An instruction is required from the general manager to prepare cost estimates and budget and loan applications (if appropriate) for proceeding with a preliminary study and possibly to being selective in remapping of the system.

The initial calculations should then be reviewed and an economic analysis undertaken; budget allocation and financial support for a further detailed study is required at this point. The Board of Directors or concerned ministry should be appraised of the problem and a commitment to further action obtained.

3.7 Organization - UFW Task Force Approach

In anticipation of ongoing need for UFW control, an immediate action program should be developed. One way of ensuring that effective action is taken is for the general manager to appoint a well-

qualified personal assistant responsible for UFW.[2] This position of the task force manager should be seen as prestigious and challenging and should include additional compensation through special financing arrangements. It should be a stepping stone to promotion and might later on be rotated to provide selected senior engineers in the utility training in UFW control. The appointee must immediately be freed from all other responsibilities. He or she has to be responsible directly to the general manager for the initial studies, but must have the requisite stature to work in collaboration with the assistant managers responsible for finance, operations, maintenance, water production, and distribution. The task force manager should have the authority to agree upon and implement action plans with the assistant managers. The taks force manager must be allocated sufficiently experienced staff to develop a seperate UFW task force and should be given suitable assistance to undertake special studies. Alternatively, or additionally, the task force manager may be assisted by a consultant or by Bank (or other) technical assistance. The task force should also be provided with special financial incentives and motivation.

The next step is to determine how the investigation should proceed. The initial work may be undertaken in-house in order that the knowledge and experience thereby gained is of permanent value. Some degree of outside technical assistance to support an in-house study may be necessary. The difficulty with carrying out an in-house study is that senior employees are generally too busy with other work. This difficulty has to be overcome if progress is to be made. Alternatively the utility could obtain technical assistance from a bilateral agency, or call in a firm of UFW consultants. The latter option may entail a lengthy procedure, and the terms of reference should be carefully drafted to ensure that local staff receive adequate training.[3]

With the general manager's full support, the UFW task force manager should be given the facilities and authority to: (a) obtain whatever data is necessary for the preliminary study; (b) make a best estimate of each type of UFW that exists and its extent; and (c) develop a preliminary program for control.

For this purpose the task force manager should be given authority to put together a UFW task force capable of undertaking all the necessary work. This will include: tests on all available meters, pressure gauges, and pumps at works; checks on the operation and output of pumps; positive leakage tests on leading mains and service reservoirs; random accuracy tests on consumers' meters, both large and small; a review of existing leak detection and repair with estimated costs. Typical tests and studies are described in other sections of these guidelines.

2/ A one-year temporary assignment is a good way to begin.

3/ These guidelines could be given to the Technical Assistance Team to review for comments and with their agreement made part of their TOR.

This program may not be acceptable in certain conditions, and some alternative may have to be adopted to avoid problems with the existing personnel and establishment. It may be that the existing organization for leak detection is considered sound but that its past activities and achievements have been restricted only by lack of policy, direction, or finance.

But whatever the circumstances peculiar to an authority, experience shows that effective action can be expected only if the financial manager is fully involved and if UFW control is vested in someone not only dedicated to achievement of results but also with the necessary patience and persistence to pursue a steady methodical course over an extended period. It must be recognized that results, certainly for leak detection and repair, will not be achieved quickly and that much unrewarded effort may be necessary. The employee will have to take charge of a task force and to imbue his team with the same dedication and enthusiasm, because they may all need to work unsocial hours and face many disappointments. Above all they must not be diverted from their normal duties in UFW control, except in the event of a dire emergency. Each time a waste water inspector is called upon to undertake other duties, the impetus is lost.

3.8 Task Force Operations

The task force should begin by examining all relevant data collected during the Basic Data Check and carry out the following additional tests:

3.8.1 Production

i. tests on production meters, pressure gauges, pumps, and operational wasted water;

ii. tests on delivery mains and service reservoirs;

iii. tests on zone meters, if any, and leakage between zones;

iv. tests on night flows of entire districts and zones and calculation of net (domestic only) night flows by reference to 3.7; and

v. tests of effect on production of reducing pressures for entire area, if practicable, and for selected areas.

3.8.2 Consumption

i. tests on bulk supply meters and all large industrial or commercial meters;

ii. examination of records of large meter readings and investigation of reasons for past changes;

iii. tests on all large meter night consumptions;

iv. sample study of accuracy of small meters, which may require technical assistance;

v. sample study of actual domestic consumption (metered, unmetered, illegal) over 24 hours;

vi. calculation of nonphysical losses; and

vii. a review of organization, output of meter readers, and other cost data as well as the meter testing/repair arrangements and costs.

3.8.3 Leak Detection and Repairs

i. study existing organization, personnel, overtime, costs etc., records of leaks found, soundings per week, leaks repaired, and time delays;

ii. study possibilities for improved leakage control;

iii. study training requirements and assistance available; and

iv. estimate costs for the reconditioning or replacement of old mains and services;

v. study pipe materials, soil aggressivity, and corrosion; and

vi. study construction standards and workmanship.

3.8.4 Mapping

i. study existing maps, records of connections, and updating arrangements. Obtain quotations for any necessary remapping by contract and compare with alternative in-house operation;

ii. survey illegal connections; and

iii. study location, condition, and operation and maintenance of valves, hydrants etc. Consider appointment of district inspectors or other measures for improved operation and maintenance.

3.8.5 Advice on Policy

i. prepare a cost estimate of various additional investigations required, including recruitment and training;

ii. prepare a cost/benefit analysis of potential reductions in UFW;

iii. develop a plan for future organization, personnel, equipment and training; and

iv. consider the use of consultants/technical assistants/ specialized contractors.

3.9 Production

Tests on production meters are essential because even newly installed meters have been found to have errors of up to 30 percent. Usually the production meters are found to be out of operation but, if operating, the readings should be compared with estimated pump outputs and, after checking for zero, by direct volume measurements on isolated suction tanks or service reservoirs. Where meters are not in operation, pump outputs should be checked similarly by volume changes. Where this is not possible, and cannot be achieved by simple pipework changes, characteristic curves may be used with discretion. First, all delivery and suction pressure gauges must be tested because they are frequently incorrect. Loss of output and efficiency since the installation of the pump can be determined by reading the pressure gauges and the total manometric head with closed delivery valve (see Figure 3-1). Plotting a parallel characteristic curve through the closed valve total pressure ordinate as recorded will give the output at normal operating pressure.

Operational practice must be investigated to ensure that losses do not occur because of uncontrolled pumping and resulting overflow from service reservoirs at night.

Tests for leakages from trunk mains and service reservoirs must be made, again by observation of volume changes under isolation conditions. (Isolation may be difficult to ensure; closed valves must be sounded to verify that they shut off tight.)

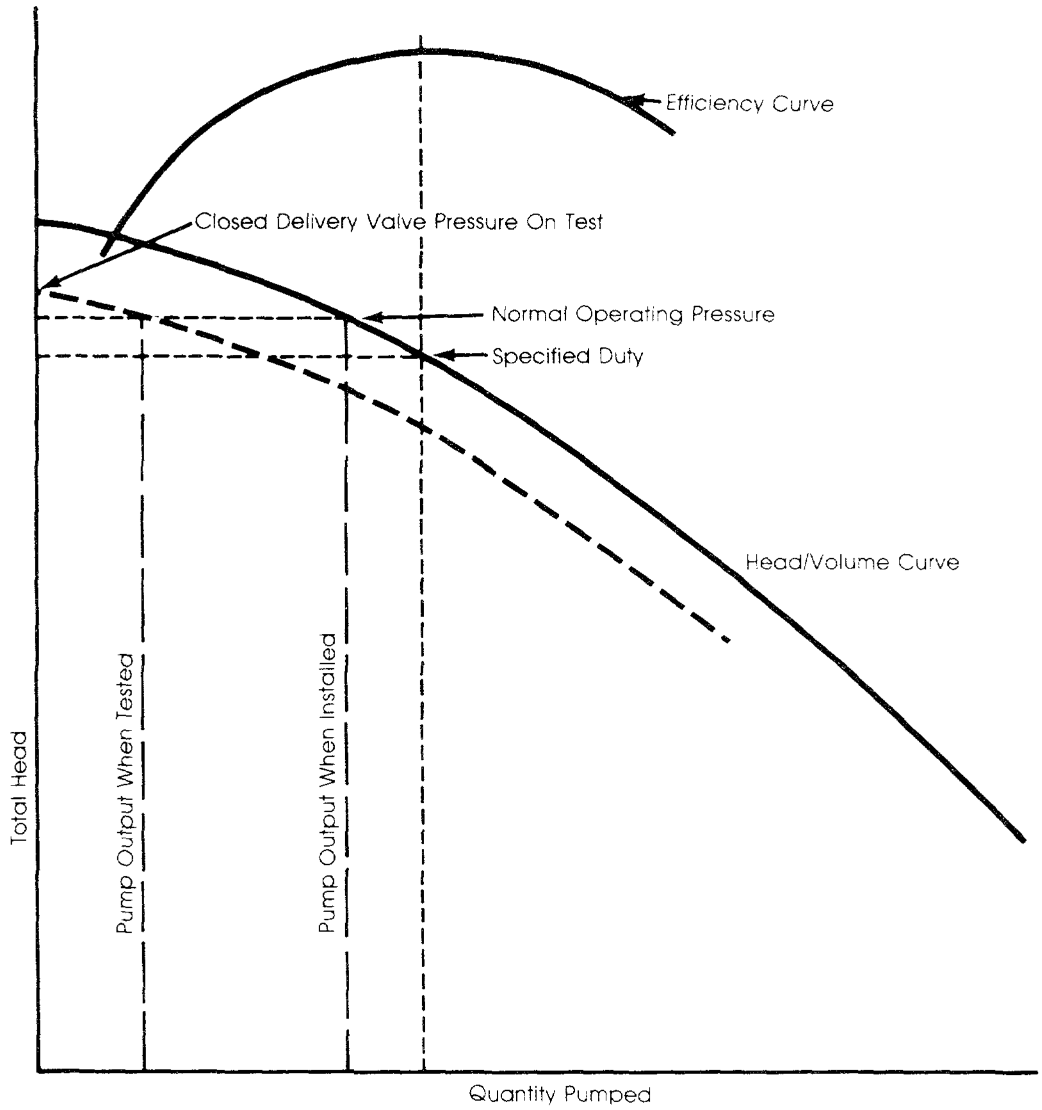
Tests on production meters, or on pumps, may be separated to indicate total production to separate zones or districts. If any district meters exist they must also be checked for accuracy. Leakage between zones must be investigated and, if found, should be stopped permanently. If this is impracticable for supply reasons, it may possibly be stopped temporarily for test purposes and actual interzone leakage may then be assessed.

Where no production meters exist and tests by volume changes are impracticable, an effort must be made to measure flows by independent meters. It may be possible to measure flows in treatment plants by inserting temporary flumes or weirs. Insertion of venturi meters in large trunk mains is an expensive exercise that cannot be contemplated. Modern alternatives are electromagnetic and supersonic meters but the installation of either of these could entail shut-down of the delivery main, which might be extremely difficult while maintaining the supply. The simple versions of the supersonic meter are prone to errors arising from variations in the upstream velocity profile.

The alternative is to insert a meter under pressure without stopping normal flows. In the past the insertion meter used in this way was a pitot, but this type of meter does not record low flows accurately. If the modern transducer is used in place of the old manometer to measure the pressure difference, accuracy is improved. Otherwise, it is now possible to insert under pressure a small turbine meter that measures pipe velocities in the same way as the pitot and is accurate over a wide range.

FIGURE 3-1

TYPICAL PUMP CHARACTERISTIC CURVE
Estimated Pump Discharge Based on Test with Closed Delivery Valve



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Having tested production meters and pumps, the next important information to be obtained is a measure of the rate of demand for a continuous period of many days, if possible, or 24 hours at a minimum. The actual consumption figures may not be easy to determine because they are masked by the filling of private storage tanks. But for supply from tanks to be continuous they must fill, like service reservoirs, before daytime draw-off recommences. That is, by the early hours of the morning, all tanks should be filled and the demand at that time will reflect only the true consumption plus loss from leaks. It is accepted that when seasonal demands are at their highest, this may not occur; tanks do not completely fill; gradually they become less and less full as the days go by and eventually supplies become discontinuous. It may be that conditions are so serious that supplies are always discontinuous, but this is rare and in such conditions it is not possible to measure the true night demand. **Otherwise, true night demand figures can be obtained during periods when demands are low.** To obtain the domestic or net night demand it is necessary to deduct the demand for bulk supplies, industry, commerce, hospitals, public lavatories, and other nondomestic purposes (see Section 3.8.2.iii).

The clearest indication of physical losses is reflected, without doubt, by the figure for **minimum net night flow from sources**, adjusted by gain or loss from service reservoirs. This figure should not be more than 20 percent of the average domestic demand. Figure 3-2 shows what can be done by active waste control. Careful investigations by some authorities have shown that the true night demand is no more than 15 percent of the average 24-hour demand.[4/] This figure may be higher in other cities depending on social conditions, hours of work, shift working etc. In recent years night domestic demand in some cities has increased due to the operation of domestic washing machines at night, in order to use off-peak electricity. Excessive figures for night demand are a clear indication that large leakages are one cause of high levels of UFW.

Having determined the night demand figure for the whole area, it may then be possible to calculate similarly for each zone or district in the system. Otherwise this will have to be deferred to the second five-year plan.

Losses from leakage are highest at night, when pressures are high. The results of trials in a recent experimental research program has shown that the relationship between high pressure and the rate of leakage does not follow the square root and is not even a straight line. Doubling the pressure increases the leakage by about two-and-a-half to three times (see Figure 3-3). In practice, some variation to this curve may be experienced. Studies should be made on selected parts of the system to determine whether operating pressures can be reduced without producing discontinuous supplies during peak demand periods. It may be found possible to introduce pressure reducing valves (PRV's) into certain leading mains, which will prevent a rise in

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4/ Where domestic supplies are not metered and the whole of UFW is related to leakage, the current aim in a well organized authority is to maintain the net night demand below 5 to 10 l/prop/hour. (Where no active leak control is practiced the figure may be 30 l/prop/h or higher.)

FIGURE 3-2

Example of Net District Flow Before and After Active Leak Control

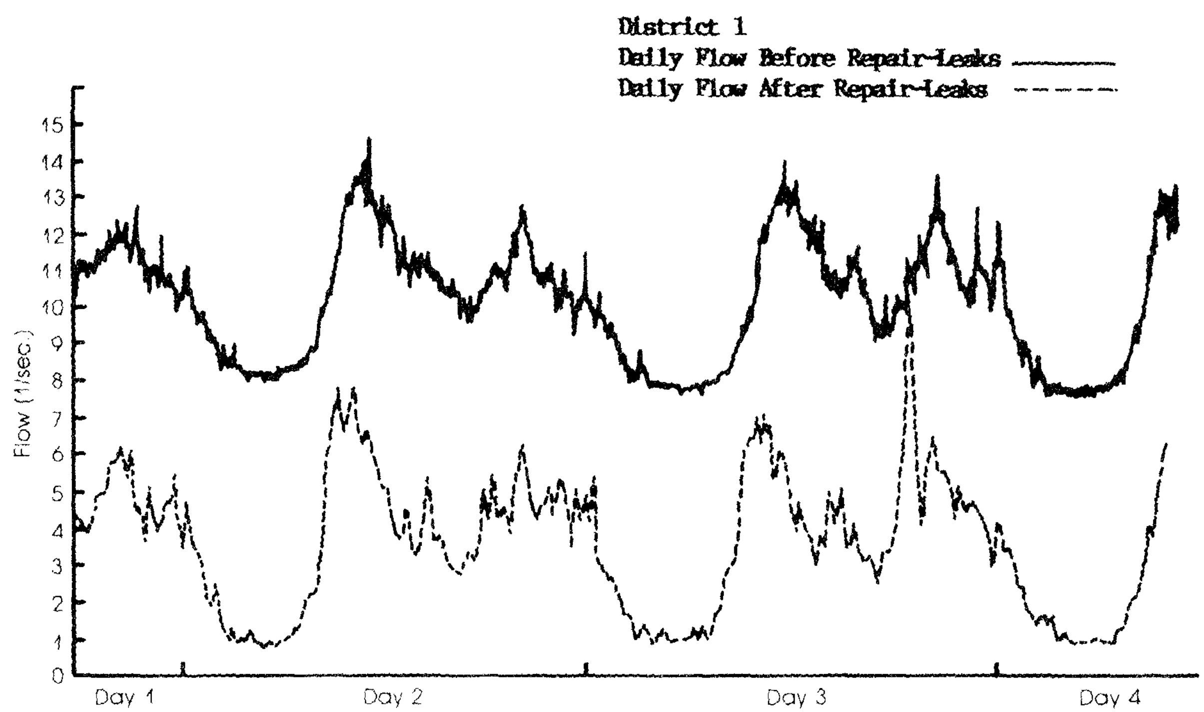

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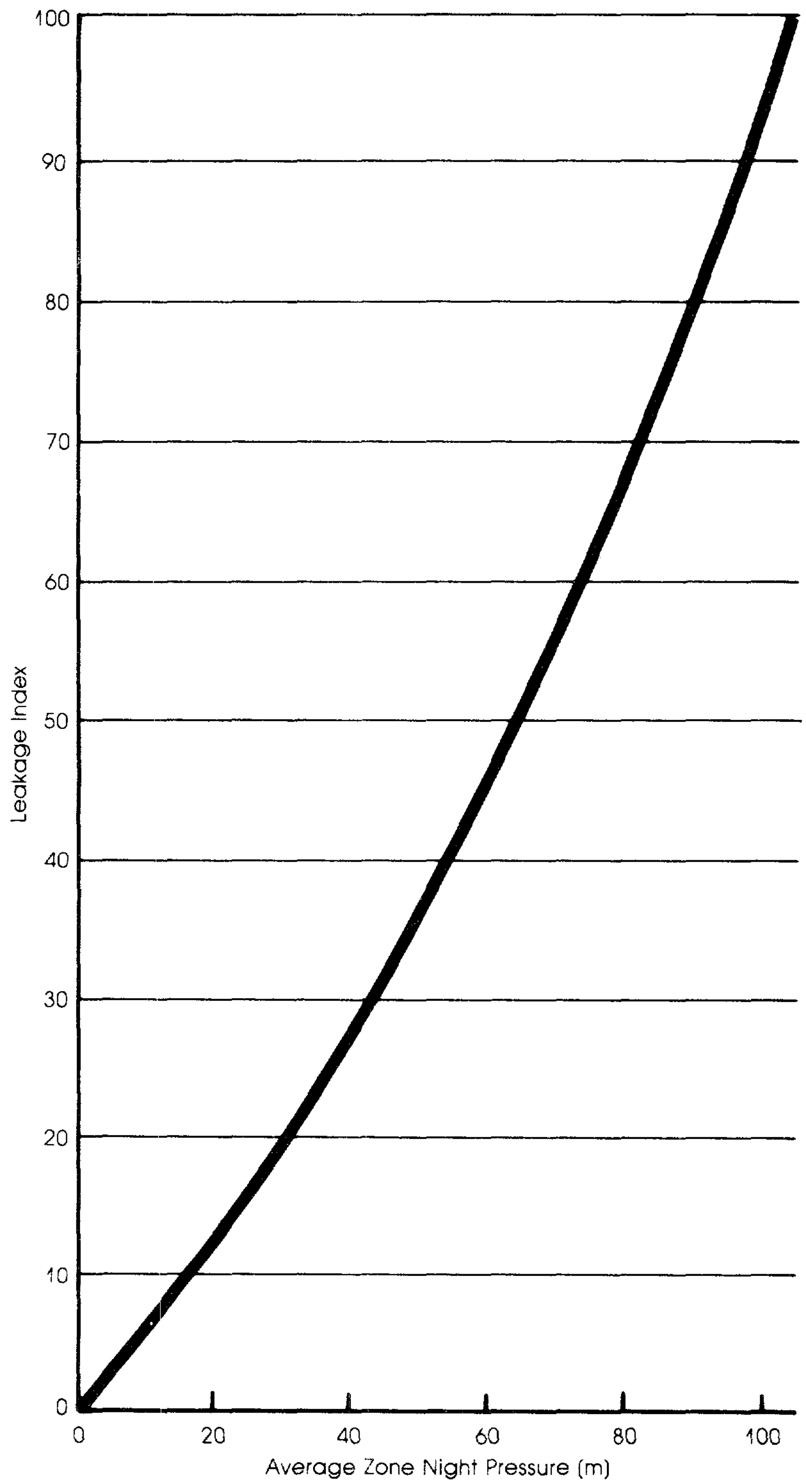
FIGURE 3-3

Typical Relationship Between Leakage (Net Night Flow) and Pressure



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operating pressures on the district at night without restricting supplies or significantly reducing daytime pressures. The effects of reduced pressures on night demand should be determined.

By now there should be some early impressions on the standards for operation and maintenance, and preliminary organizational changes in the water production area could be proposed.

The first action of the task force must be to recheck the production meters. If installed and apparently operating correctly they must be checked for accuracy over the full working range. If not installed or not operating, the same checks can be made. Possible methods of checking are as follows:

(a) Night test isolation and timed volume change in clear water tank or delivery tank/service reservoir compared with recorded output for each delivery pump in turn.

(b) Diversion to waste through weir or other test meter.

(c) Checking or installing weir or other meter in treatment plant and adjusting estimated net production by volume changes in plant and clear water tank.

(d) Installing on each transmission main a temporary check meter, such as pitot with transducer for accuracy at low flows, or an insertion turbine. Both of these can be installed under pressure. If no meters exist, the installation should be made permanent and readings taken at regular intervals thereafter.

(e) Checking each estimated pump output by standard pump test using closed delivery valve data to modify characteristic curves and applying the operating total manometric head.

Calculate the revised figure for UFW based on the more accurate data for water produced. If still more than 20 percent proceed further with investigation.

Redefine budget needs and obtain financing authority for the next steps.

3.10 Consumption

At this stage a concurrent study is needed of the operation, testing, and reading of all consumers' meters beginning with the large meters used for bulk supplies and for industry, hospitals etc. Sample checks on the accuracy of these meters using test meters, or possibly by volume changes on private tanks, is normally a simple procedure. The total "large meter" demand may then be adjusted to allow for the estimated inaccuracies based on the sample study. **Concentrated attention to ensuring the accuracy of the large meters can pay handsome dividends in increasing the revenue from water sales.** This may be rewarding work that yields a rapid return for the increased effort.

Instead of (or in addition to) checking the accuracy of all large meters, it may be helpful to examine historical data relating to the volumes recorded and charged for in the accounts of heavy users. Unexplainable variations in monthly or quarterly consumption unrelated to production figures for the particular industry warrant investigation. Such investigations may be helpful to the industries concerned in pinpointing waste or leakage on their premises.

Having checked and, by repairing and replacing meters, eliminated serious inaccuracies in the large meters, arrangements should be made to determine the rates of demand through these meters during the night. These figures can then be deducted from the gross night production figures to determine net domestic night demand.

Calculate the total figure for <u>accounted-for water</u>, which must include not only the water sold by meter but also water used for public purposes (government departments, military and so forth).

<u>Check all large meters</u>. Carry out an initial sample check for accuracy by connecting test meters or by replacement of meter or, where possible, by positive measurements on delivery to tanks. Results of initial tests will determine the extent of further checking justified to reassess losses due to underregistration at low flows. (Some of this work can be undertaken earlier.)

Recalculate UFW after checks on large meters and assess the potential reduction in UFW.

A further sample study should then be made on the accuracy of the domestic meters, but this must be undertaken with care to give meaningful results and may require technical assistance from an outside source. Of particular importance is the accuracy at low flows (see Annex 3B).

Examination of the total supply provided through domestic meters is helpful. If this figure, for example, is less than 100 liters per capita per day there may be serious anomalies in the meter sales and much of the UFW may be attributable to nonphysical loss. Interpretation of this figure will vary according to social conditions. It is also helpful to compare this figure with the total domestic supply as calculated by the total production less the total bulk, industrial, and commercial supply. This survey should reveal any irregularities in the reading of meters that may exist in some cities.

As a corollary to this study of domestic meters, a sample survey can be made concurrently of the actual domestic consumption as revealed by test meters (or by normal meters after testing). This has to be done for different areas where social conditions differ. True domestic consumption may then be assessed for this particular water authority, which may be more helpful than adopting a standard such as 100 liters per capita per day. Reference has been made to the importance of accuracy at low flows of domestic meters. **Particular problems arise when all the supply passes through a ballvalve to a large private storage tank. When the ballvalve is new, the period of shutting (when low flows occur) is short, but when the ballvalve is old, extended closing periods occur and much of the water is taken so slowly that the meter does not register.** This is serious enough, but the problem is compounded if the storage tank is large and the inflow is throttled by the consumer to ensure that it is always very slow; underregistration then becomes continuous.

Very recent research shows that in almost half the properties with tank supplies, significant underregistration may be expected. Adjustment of the tariff could recover lost revenue but is inequitable because of the large variations in underregistration. Turbine-type meters are the most susceptible to error and should be replaced by the semi-positive displacement type when possible. (If the water supply contains large amounts of grit or rust particles, this may not be practicable.) Nominal domestic flow rates of domestic meters are usually 1.5 cubic metres per hour, but recent developments suggest that meters with a nominal flow rate of only 0.75 cubic meters per hour can be used where the supply is to a storage tank. A wholesale change may well be justified by the potential increase in revenue. It is appropriate at this stage to study this possibility and to undertake a cost/benefit analysis (see also Section 4.2).

Concurrently with the actions outlined in Sections 2.1.4 to 2.1.9, undertake a study of actual domestic consumption by sampling procedure in different social areas (see Annex 3A). Compare the results with the metered consumption to assess the proportion of UFW attributable to underregistration of meters, nonmetering, and other losses such as illegal connections.

After the sample analysis of domestic meter accuracy has been undertaken, it will be possible to estimate the nonphysical part of the estimated UFW. The total level of UFW has been reassessed following accurate measurement of production and unmetered supplies. It is thus possible at this stage to determine how much of the total UFW is due to physical losses and how much to nonphysical losses. It also provides the information necessary for the evaluation of possible reduction of nonphysical UFW losses and the estimation of costs of further investigations and actions necessary.

Make a sample study of the accuracy of domestic meters and, with this data, reestimate total legal consumption. Deduct the total that is accounted for in order to determine the extent of nonphysical losses. Deduct this figure from the total UFW to determine total physical losses. If either figure exceeds 15 percent, further investigation is probably cost effective.

At this stage, the losses from illegal connections have to be regarded as a form of leakage or "physical" loss. This will be corrected later (see 3.9). If the problem of illegal connections appears acute, it should be the subject of a special survey much earlier in the immediate action program (see 3.11).

Additional information is required to review the organization necessary for undertaking any further work. This will include a review of the present arrangements for the reading, changing, repair, and testing of all meters. It is particularly important to ensure that the utmost emphasis is placed on the testing of all meters at very low flows and, where accuracy at such flows cannot be achieved, to replace the meters. It is also appropriate at this time to review all aspects of reading and billing procedures.

3.11 Leak Detection and Repairs

Before investigating any possible reduction in leakage, a study must be made of the existing organization and effectiveness of leak detection already being undertaken by the authority. Normally the only action taken is known as "passive." That is, there is no team of employees actively engaged in looking for leaks. Action results only from loss of pressure and supply or actual leaks observed at ground surface by employees, the police, or the general public. Reports are received and action is then taken by inspectors to trace the source of leakage before a repair team is called in. Leaks not showing at the surface probably discharge directly into sewers and drains and are not easily found.

A review is required of the leakages found and the delay in repair. Where there are inspectors already engaged in locating pipes and sounding for leaks, data is required showing the number of leaks mended, volume of water saved and, particularly, the personnel, equipment, and costs of this work in relation to the estimated benefit.

Active leak detection can take various forms. Given the time and organization, the ideal approach would be that described in Section 6.0 (i) to (iv) of Buky's report of June 1982. But time rarely allows, and as a rule, immediate results are sought that require minimal effort. The simplest approach would be to call in experienced inspection teams to undertake methodical observations and sounding throughout the day or at night, listening for leaks over the whole system. Methodical observation by experienced inspectors can be very effective. Possible leaks may also be located visually from damp ground, discoloration of walls, recent excavations, crossings by other services, uneven road or pavement surface, and so on. All valves and hydrants call for special attention.

Sounding is best carried out by listening on consumers' stop taps, main valves, and hydrants. In some systems the consumers' stop taps are covered over and not accessible, or else are on their premises and are not accessible at night. There are then only very few places where direct contact with the mains or service connections is possible at night. Sounding must then be carried out on the ground surface, but this is not normally very rewarding. Whether to undertake sounding at night or in the daytime depends on labor costs and operating conditions.

Sounding in the daytime is difficult not only because there are many extraneous noises, but also because pressures are low and the sound, as well as the actual volume of leakage, is reduced. Sounding has been found less effective for most leaks when the pressure is less than about 15 meters. One major problem is that large leaks can occur without much noise being produced, whereas small leaks may make a great deal of noise. Initial training followed by long experience are invaluable identifying real problems.

For most systems the precise location of the service connections and of most of the mains are not known. They are located normally by using specialized electromagnetic equipment which, with careful use, can reveal the depth as well as the line of the pipe.

More complete details of sounding problems and practices are given in Annex 3B.

A modern device for leak detection is the acoustic correlator. This was invented and first developed in the U.K., but then underwent improvements in Japan and France. Further developments have continued by a leap-frogging process in all three countries, and their equipment is now comparable. The function of this equipment is to measure the difference in time taken for a sound to travel to two pickup points. This equipment is valuable for the accurate location of a leak not traceable by other means. For normal leaks, the traditional means of sounding is effective and much quicker. The acoustic correlator is invaluable at certain times, but its use has to be restricted for detection to be effected economically.

The use of conventional rods by experienced personnel is often the most cost-effective method of leak detection. In developing countries where labor costs may be low, the employment of large numbers of detection teams rather than any sophisticated metering system may prove to be best in economic terms.

In developing countries, a team consisting of an inspector and at least one laborer/assistant be able to make no more than 100 soundings a day. Thus, for example, to sound 100,000 properties twice a year requires 2,000 team days, or eight teams. One may estimate needs and costs for simple active control in this way, keeping in mind local problems, including the actual performance of existing inspection teams. It may be possible for one means of transport to serve at least two teams, thereby adding only 15 percent to labor costs.

District Metering

More effective leak detection may be achieved more quickly and economically by concentrating efforts in those areas where leakages are prevalent due to the age, material, and condition of the pipes or to ground conditions or other factors. This concentration can be logically developed by district metering. The supply network is broken down, by isolating valves, into different districts each of which can be metered to determine demand either over 24 hours or at night. Such districts occur naturally where there are different pressure zones, but these may be divided further as appears practicable. It may not be possible for districts to be isolated permanently (that is, in a ring main system), but temporary isolation and monitoring is usually feasible. It is essential to be able to show that isolation is effective. Regular tests of demand for each district will show where leakage appears to be most extensive and will also show any changes occurring due to increased leakage. The normal district will contain about 5,000 to 10,000 properties. The net night demand in each district is a crucial figure to obtain.

District metering has the additional advantage of showing management how the system is working.

Gradually the areas can be broken down by progressively reducing the size of each district to, for example, 2,000 properties and, in developing countries, this may be the most effective method of active waste control (see Annex 5B).

Action may be concentrated still further (if found to be justified in economic terms) by breaking down each district into separate waste meter districts, each of which can be effectively isolated by valves that shut off tight. Each such waste district can be supplied through a single recording waste water meter and, by sequential valve operation on a night test, the night demand can be recorded for each street in the district. Regular "stepped" night tests of this type show up variations in night demand normally attributable to leakage, and this determines where detailed inspection can be concentrated to produce the most effective results. Stepped testing will be found impracticable unless there is adequate pressure, at least 15 metres, during the night (see Annex 5C).

The sensible first step in any improved leakage control program is to introduce district metering. In most developing countries this alone can be a mammoth task because valves are frequently inoperable and most if not all have to be changed to ensure that district isolation is achieved. Only after this has been done can waste meter districts be contemplated and then only on a pilot scale.

Above all, it is essential to have a cadre of inspectors trained in a logical approach to the problem, in coping with the various difficulties encountered in the detection of leaks, and in the use of modern equipment to make the tasks less difficult. Any new program of active leak detection must begin with at least one trained inspector for each 50,000 properties. This number will probably have to be doubled or quadrupled over a period. Preferably, a few selected employees should receive ten weeks of training by a water authority in a developed country. The first trainees should normally include semi-skilled employees as well as one engineer/technician who will subsequently be able to undertake the training of additional inspectors at home. Thought should also be given to obtaining additional outside assistance from the country selected for training. This assistance is likely to be required for specialized advice on the initial testing, and on district meter installation and operation during the early stages of development of active waste detection. The cost for initial training in the U.K. (including accommodations and travel) for an Engineer/Trainer and two junior engineers from a Middle-Eastern country was US$25,000 in 1985.

In some cities growth has been such that the existing water supply network is inadequate to provide a continuous supply. Where skyscrapers have replaced two-story buildings, the complete replacement of all mains and services may be necessary. Extensive reinforcement may be an alternative, but if the existing pipework is very old the cost of replacement may be met by the resulting reduction in UFW. A sample study is required for refurbishing a typical pilot section. For this purpose the metering of demand for that section throughout a 24-hour period is required. Where in situ cement lining has been emplaced by specialized contractors, experience has frequently shown improvements in flows and pressures as well as reductions in leakage. It all depends whether leakages are occurring mostly in the mains, in the services, or at the service connections.

3.12 Surveys, Maps, and Illegalities

There exists a body of feeling that in most developed countries standards are such that little can be done in the way of improved control of

UFW until existing maps and records have been carefully checked and updated. This may be true, but in developing countries conditions are likely to be such that, although accurate mapping will be necessary before control can be very effective, much can be done to reduce UFW while mapping and updating of records is in progress. The checklist includes much that should begin and show tangible results before accurate mapping and updating of records may be initiated. Initially it will be necessary to review existing records and decide which parts of the system require remapping.

A clear, detailed picture of the system must be made available both for careful upgrading of the metering of total consumption and for the final planning of separately metered zones and districts. However, in many developing countries the physical effort of locating all valves and hydrants, testing their ability to open and close, and replacing them when necessary is essential before a district or a pressure zone can be effectively isolated. The accurate location of long consumers' services near zonal boundaries is also essential before the boundaries can be delineated. Mapping must be started immediately by the task force; this will have permanent value for the operation of the system, even if extensive UFW control is not found to be economically justified.

The work of locating mains and services and accurately recording them is likely to be beyond the scope of the authority's staff, which is fully occupied on other matters. For this reason it may be desirable, or in fact necessary, for this work to be undertaken by specialized contractors. Many companies specialize in such work, which may entail no more than visual inspection and location of valves but is much more likely to require that all mains, including buried valves, be electronically traced and plotted on new maps. The cost of the latter might, for budget purposes, be estimated as $1,500/$2,000 per sheet, size A1, scale 1:1,250/2,500. The cost of this work could be as high as $50,000 a month and require many months work for a large city.

Illegal Connections

An intractable problem in many cities is the existence of numerous illegal connections. They are difficult to trace and, after removal, are frequently replaced. It is reported that in many cities they represent a major cause of nonphysical losses. In such cases a separate mapping exercise to locate, list and map all such connections will be required. This type of work has been undertaken by students, and this may be appropriate. If not, some other means (such as an aerial survey) must be adopted. Whatever method is used, it will be essential for management to sample check at regular intervals areas that have been surveyed and mapped to ensure that illegal connections that have been removed have not subsequently been replaced.

A major problem in many cities arises from lack of supervision and maintenance of the distribution system over an extended period of years. In fact, high figures for UFW are usually associated with inadequate maintenance of works. The lack of adequate maintenance is often revealed by the failures of valves to operate effectively or even by the loss of valves and hydrants. The location of all valves and hydrants is an essential part of the mapping process and this must be followed by repair, replacement, and the provision of new surface boxes and marker posts. They must also all be numbered for future reference and use in the leak detection work.

Serious consideration must be given to the appointment of senior inspectors to be solely responsible for the operation of all valves during repair work and for ensuring that valves are maintained in full working order and are not covered over in new road surfacing work. Some organization of this type must be adopted to ensure that improved standards being introduced will be perpetuated.

If this is not done, remapping will prove of little value (see Section 5.8).

Review the existing arrangements for leak detection, repairs and remapping. Examine the possibilities of making a survey of illegal connections. Undertake a preliminary cost analysis to determine the extent of additional investigations to be undertaken. This could include a preliminary review of design standards and construction and material specifications.

3.13 Advice on Policy for Further Works

The task force should at this stage have obtained sufficient data to assess the many problems to be confronted and to determine what additional work is justified economically. An estimate of cost is now required of all the additional investigations, including the recruitment and training of additional staff required and of retaining any outside advisors, specialized contractors, or other technical assistance considered necessary to ensure the success of proposed improvements in control.

Following this, a cautious assumption may be made of the potential savings in UFW both in nonphysical and physical losses, and a cost/benefit analysis is then possible based: first, on potential increases in revenue and savings in production costs; second, on reduced loan charges by deferrment of capital expenditure on new source, treatment, and transmission works and, finally, on the reinforcement of distribution networks to improve detailed supplies.

For the purpose of this analysis assumptions have to be made regarding the additional personnel and equipment that will be required and the future organization necessary to achieve UFW control. It may be that the existing task force can be continued and expanded as necessary to undertake the additional works. Clearly there are great advantages in retaining the operation directly under the general manager's control for at least a few years, until a degree of improved control has been achieved. But the works necessary impinge on the activities of the separate managers responsible for maintenance pumping, distribution, and finance. Close and continuous cooperation with these divisions will require the exercise of a considerable degree of tact for success. A better alternative might be to merge the UFW task force with the utility's regular maintenance activities and strengthen the entire maintenance effort. The permanent establishment of additional staff may entail government approval of a revised "establishment."

The final task is the preparation of a program and budget for such additional investigations, operations, and new works as are shown to be justified bv the anticipated improvements. One factor to bear in mind is that the control of UFW is not a "once-only" operation, but a continuing process.

It must not be thought that after a great effort for a few years no further effort will be required. If the process comes to an end, the conditions will revert completely within a year or so.

It could be that some variations in effort over the years may be economically justified. For instance, if new works have been completed, while there is surplus water available there may be less justification for high expenditure on leak detection and repair, depending on the marginal cost of water. But even if some easing off may be accepted, the basic aims and staff must be retained ready for reexpansion when conditions change.

Distribution System Maintenance and UFW

The UFW task force cannot achieve its objective without the cooperation of the distribution system engineer and his staff. The general manager of the utility should, at the same time he is supporting the UFW task force, upgrade distribution system maintenance standards over the same period of five years. At the end of the period, the comparative efficiency of the two units should be very carefully studied and their activities merged. UFW activities for the second five-year program would then be carried out by the distribution system engineer under the assistant manager for operations and maintenance.

3.14 Strategy

It is assumed that from this point onward, UFW would be the responsibility of the assistant manager (O&M). The manager now has adequate data and is in a position to reconsider the overall strategy and to decide on a future provisional program and the measures to be adopted to implement that program. It may well be that this cannot be a final decision, and that the result of operations in the early years could justify some cutting back or expansion of the program. This will be possible provided all operations are closely monitored and evaluated continuously.

Review program and budget to cover all actions described below, including preliminary estimates for long-term actions.

On the basis of cost/benefit analysis, the general manager has to reconsider overall strategy and obtain the necessary authority and financial approval for proceeding with such additional works as are economically justified.

Policy decision and implementation is now required, including confirmation of organizational changes. Decisions may include establishing the position of UFW manager (or equivalent) and asigning him a team, remuneration and incentive payments, and the appointment of consultants required for special studies.[5/]

5/ UFW Manager could, after the first year or following achievement of results as head of the UFW Task Force, report to the head of the Department responsible for Operation and Maintenance.

Annex 3A. Typical Investigation of Consumer's Meter Accuracy and Domestic Consumption

This investigation should be based on a 1 percent random sample of the total domestic meters in each zone or district. The account register is used for selection, taking 1 percent from each zone/district. At random, groups of about six meters are selected (rather than invididual meters) in order to reduce field work. From the account numbers, the meter reading books are used to provide the meter serial number, manufacturer, recorded consumption for the two previous quarters, and most recent date and reading.

The selected meters are then site tested by a test team made up of an engineer/technician, a meter reader, and a meter supervisor. The test equipment consists of a pressure gauge and a test meter with filter, two lengths of hose, and couplings. The meter is located, read, and removed after noting the extent to which any isolating valves are throttled. The pressure is recorded. The meter is coupled in series with the test meter and connected by hose to the supply pipe and, for discharge, into the drain. The pressure reading will serve to check the zone in which the consumer is connected.

The average flow rate over the past two periods is calculated and the meter tested at about that rate, and at one quarter of that rate. If the supply is indirect to tank through a ballvalve, the meter should also be tested at 20 liters per hour, which is the probable average flow rate for a closing ballvalve. The accuracy should be calculated as the mean of the percentage at average flow rate and one quarter of the average flow rate or, if there is a storage tank, at the mean accuracy at average flow rate and at 20 liters per hour. The supervisor should obtain details of the number of people served by the meter and any changes that have occurred.

The results are analyzed to show the mean accuracy for each meter and the average daily consumption, as calculated from the last two meter readings and corrected for the inaccuracy now determined. Per capita consumption can also be calculated.

The recorded and corrected consumption rates are totalled, and the average inaccuracy and average consumption in (liters per capita per day) is calculated for each zone or district. Where practicable, the results may be separated to determine per capita consumption in different social groups.

Annex 3B. Method of Locating Leaks by Sounding

The location of leaks by sounding demands considerable experience, which can be acquired by good training in which the various problems are carefully demonstrated. It is, of course, far easier to detect leaks by direct contact with a main valve or service connections than through the ground. Some basic points on sounding techniques are covered in the following paragraphs.

An ordinary metal rod or a valve key will transmit the sound of a leak, but extraneous noises make this simple sounding difficult. An improvement has been developed by fitting double earpieces containing diaphragms which amplify the sound. The sound can be detected by a microphone and amplified electronically. When this technique is used, leak sounds can be indicated visually and heard at greater distances. Traffic noises are deadened by rubber seals around the earpieces facilitating the detection of sound patterns that indicate types of leakage. Unfortunately, extraneous sounds other than traffic may also be amplified. All this equipment is valuable, but good training is essential for its proper use and above all for care in handling to avoid breakage. Batteries must be checked and well maintained, and all contacts must be cleaned to avoid corrosion.

Differences in the type of sound will indicate to an experienced operator whether he is listening to a leak or to water being drawn off for consumption. If the leak is near by, the sound is normally of a higher frequency. Listening on a valve is often useful, provided the pipe material is not asbestos cement or plastic. Leaks are easier to detect in metal pipes than in asbestos cement and most difficult of all in plastic and rubber pipes. Leaks are more easily detected in dry soils than when the pipes are below the water table. If there are air pockets in the pipe, sound is not transmitted beyond them. But the sound of a slight leak from a gland on a valve will drown out the sound of a larger leak at a distance. The sound heard from hydrants or service pipes is much more faint, unless the leak is associated with the particular branch.

It is extremely difficult to locate a leak by reference to the intensity of sound at different points. Usually final location is best achieved by indirect sounding on the ground or by listening on a pin driven down to contact with the pipe.

For indirect sounding on the ground, it is usually best to use geophones with dual hollow tubes connected to ground plates or to pointed probes containing diaphragms. This equipment is also available with microphones and amplifiers. The plates or probes need to be vertically above the pipe, thus it is usually best to begin by using magnetic pipe locators to determine the pipe location accurately. The sounds heard by indirect sounding are of a very low pitch and not easy to differentiate from traffic noises. Only by changing the position of the probe/plate in relation to the leak may differences be detected. Sounds emitted from metal pipes tend to be concentrated along the line of the pipe whereas those emitted from plastic pipes are spread uniformly in all directions. False indications can be obtained through transmission by foundation walls in contact with the pipe.

Depending on labor conditions, simple sounding -- without any means of concentrating effort by district metering or otherwise -- aimed at covering the whole area of supply twice a year could entail the employment of one three-man team for every 20,000 properties.

Annex 3C. Costs of Various Components of UFW Control

Task	Range of Costs* (U.S.$)		
Sound 1,000 properties (three-man team)	200	to	400
Read 100 consumer's meters	20	to	50
Read 100 district meters	160	to	350
Install pressure tapping and construct chamber	400	to	600
Install district meter and set up district	2,500	to	5,000
Isolate a district and record night flow	100	to	150
Install PRV and set up zone	2,500	to	5,000
Undertake service reservoir drop test	50	to	100
Locate one leak with correlator	30	to	60
Replace consumer's meter	20	to	40
Associated large-scale work on meter (testing, repair, etc.)	50	to	100
Remapping with electronic tracing survey (per square kilometer)	2,000	to	10,000
(Alternatively, per kilometer of network pipelines)	100	to	200

For equipment allow $500 for a valve box locator, $1,000 for a pipe locator, and $20,000 for a correlator

* These are based on 1987 prices.

Annex 3D. Economic Assessment Models*

General

Water distribution systems can be analyzed by examining main break and leak patterns, corrosion history, and environmental stresses. By monitoring the distribution system, managers can assess its stability over time. The availability of this information greatly eases the manager's decision to repair, replace or rehabilitate water mains. In addition to this information economic analysis can also assist in maintenance planning. This section presents several economic analysis approaches for the evaluation of the repair, replacement, and rehabilitation options.

There are a limited number of maintenance actions that can be used to preserve the structural integrity of a water distribution system. Several economic models have been developed to assist management decisions, based upon particular system conditions. The three maintenance alternatives for which economic models have been developed include:

(a) Main Break Repair or Replacement
(b) Cleaning and Lining
(c) Leak Detection and Repair

These alternatives and their associated economic evaluations are discussed in the following subsection.

Main Break Repair or Replacement

Water Main Break Costs

There are several direct and indirect costs which can result from water main breaks. These include:

(a) Direct water utility repair and emergency crew costs.

(b) Direct water utility treatment and pumping costs associated with water loss from breaks.

(c) Direct water utility expenses related to water damage claims.

(d) Indirect city costs for utility overhead and for emergency police and fire protection during major breaks.

(e) Commercial and residential water damage costs not reimbursed by the water utility.

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(g) Costs imposed on other utilities.

(h) Costs of traffic and public transport disruption.

These costs vary, from specific and quantifiable expenditures for repair materials and labor to more generalized and less quantifiable traffic and service disruptions.

The water utility should record labor and materials used in break repairs so that realistic estimates of direct break repair cost can be made. While police, fire and streets department personnel often respond to main breaks, these detailed labor cost records are not usually available. Water damage costs from main breaks are not easily determined. For this reason, damage claim costs are not included in repair cost estimates presented below.

Indirect overhead costs included in the estimates are for services provided to the water utility from other local government agencies, paid leave, fringe benefits, equipment and vehicle depreciation, in-house support (paperwork), maintenance, power, gasoline, and supervisory functions. There is no specific information on the extent and severity of indirect costs associated with traffic or service disruptions and nonreimbursed business and residential water damage losses. It is likely that the latter indirect costs greatly exceed the direct repair, emergency response, and claim settlement costs.

Break Repairs

The actual costs for water main repairs depend upon the pipe diameter and the type of break. Circumferential breaks are simpler to repair than longitudinal breaks. While a circumferential break can be repaired using a clamp around the broken pipe, a longitudinal break necessitates replacement of a main section.

Break-Even Analysis

An economic model was developed to determine when main replacement becomes more cost effective than the continuation of its repair. The economic analysis for repair or replacement consists of determining the number of repairs per mile per year that can be performed before this break-even point is reached. This analysis is based upon direct labor and material costs for both repair and replacement as well as indirect over head costs.

The economic trade-off between repair and replacement of a water main compares the initial cost of main replacement with the projected savings of future repair costs. Theoretically, the break-even rate may be defined as the point at which the cost of main replacement equals the future cost savings of break repair. If the occurrence of breaks on a particular pipe section exceeds the break-even rate, it is economically advantageous to replace the main.

Conversely, segments with less than the break-even rate are not candidates for current replacement.

The break-even situation is presented in Equation 10:

$$R = C \qquad (10)$$

where:

R = present worth of expected break repair savings.

C = present cost of replacement.

Equation 11 defines the present worth of main repair costs.

$$R = B \times U \times P(j,i,n) \qquad (11)$$

where:

B = initial main break rate; breaks/mile/year.

U = cost of main repair for a single break.

j = growth rate (break rate increase per year).

i = net discount rate after accounting for inflation.

n = period of study (years).

P(j,i,n) = present worth equivalency factor (16)

The present worth equivalency factor indicates the present worth at i percent interest of $1 of incurred cost at the end of the first year, and of amounts increasing by j percent from year to year until n years are completed. It is calculated by Equation 12.

$$P(j,i,n) = \frac{1}{\frac{[1 - (1+K)^{n}]}{k}} \qquad (12)$$

where: $K = \left(\frac{1+i}{1+j} \right) - 1$

The break-even situation occurs when the present worth of repair cost savings (R) equals the replacement costs (C) as presented in Equation 10. The break-even rate (B') can be determined by combining Equations 10, 11, and 12 and rearranging terms.

$$B' = \frac{C}{U \times P(j,i,n)} \qquad (13)$$

where:

B' = Current break-even main break rate such that the present worth of future break repair cost equals current replacement costs.

Equation 13 can be rearranged to introduce a factor, F, which is the ratio of replacement costs/mile to the cost of a single break repair.

$$B' = \frac{F}{P(j,i,n)} \qquad (14)$$

where:

F = C/U

Figure 3D-1 presents a plot of Equation 14 for five main break growth rates: 1%, 3%, 5%, 8%, and 10%. It can be seen that the initial break-even rate depends upon the replacement costs, repair costs, and the projected growth rate. This break-even analysis can be used on individual pipe sections to assess the cost of repair or replacement. As an example, consider a 3,000-foot section of 6-inch main which has had five breaks over the past two years. A 7% discount rate and a twenty-five year study period is assumed. This situation can be evaluated as follows:

1. Calculate initial main break rate:

$$B = \frac{5B/2yr}{3000ft/5,280ft/mi}$$

$$B = 4.3\ B/mi/yr$$

2. Calculate replacement-repair cost ratio:

$$F = \frac{\text{Replacement Cost}}{\text{Repair Cost}} = \frac{\$400,000/mi}{\$4,000/B} = 100\ B/mi$$

3. Determine break growth rate for utility:

$$i = 1\%/\text{year break rate increase.}$$

4. Determine break-even break rate from the ordinate of Figure 25:

$$B' = 9\ B/mi/yr$$

5. Compare break rate from Step 1 to break even rate from Step 4:

$$4.3 < 9$$

Action: Continue to repair main, do not replace.

In this example, replacement of the main can not be justified since the break-even rate (B') was not achieved. The cost of replacement is greater than the present value of the future repair costs for a 1% growth rate in breaks per year and a replacement-repair cost ratio of 100. A break frequency growth rate of 8% or greater (see Figure 3D-1) is required to justify replacement. It should be stressed that these results will change if one assumes a different discount rate and/or study period.

Sensitivity Analysis

The sensitivity analyses confirm that the break-even break rate depends upon the ratio of replacement-to-repair costs, the break growth rate, the net discount rate and the planning period. The cost ratio was found to have the greatest impact.

The break-even break rate was found to:

1. Vary directly and to be highly sensitive to the ratio of replacement and repair costs. Doubling the costs ratio results in a doubling of the break-even number of breaks/mile.

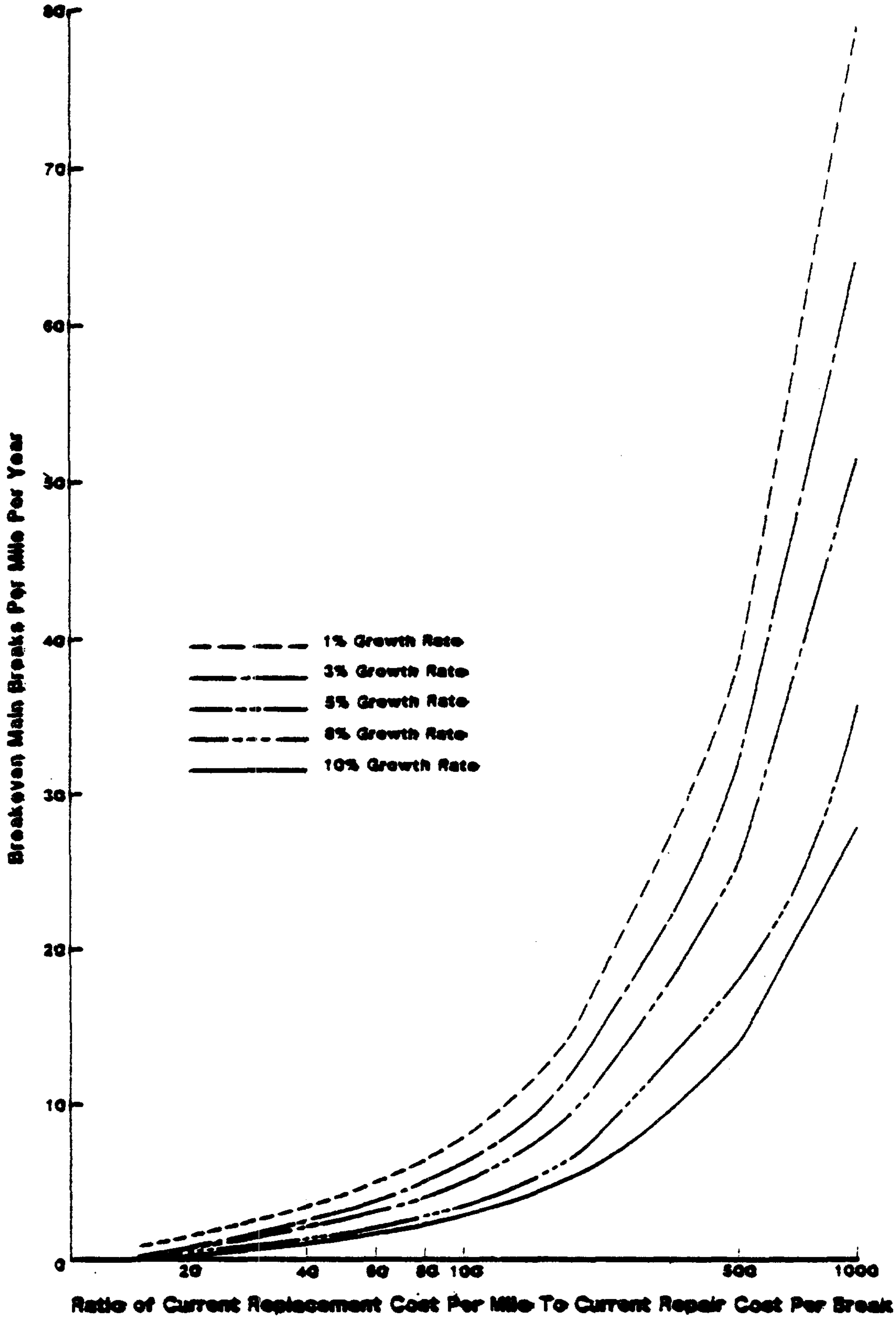

Figure 3D-1. Break-even Main Break Rate for Five Annual Growth Rates

2. Vary inversely with the break growth rate such that higher growth rates require fewer initial breaks/mile before replacement can be justified.

3. Vary directly with the net discount rate in the 4-9 percent range such that increased financing costs permit more breaks/mile before replacement is justified.

4. Vary inversely with the planning period such that longer study periods allow fewer breaks/mile to justify replacement. The longer period favors early investment.

Role of Indirect Costs

The repair verses replacement cost comparisons described above indicate that the direct and overhead costs for main repairs are relatively minor when compared to replacement costs. These low break repair costs result in surprisingly high break-even break rates, which may be unacceptable from a public convenience standpoint.

The direct and overhead cost comparisons yield these results because they consider only the easily measurable utility costs. They do not include the indirect costs of water and transportation service interruptions nor the unmeasured damages to other utilities and the road base. The true costs of water main breaks include these detrimental impacts. Unfortunately these costs are difficult to measure with data currently available.

One strategy to account for these intangible costs is to develop a risk assessment mode. Water mains in select areas are prioritized for replacement according to a risk assessment scoring system. Scores are first assigned to each main based upon the potential for such hazards as traffic disruptions and damage from potential flooding. Weights are then assigned to each hazard based upon an assessment of the relative magnitude of indirect costs each contributes. A hazard assessment score is then prepared by multiplying the scores and weights for each hazard and adding up all these products. Mains may then be ranked based upon this score along with other considerations.

Another strategy which may be used is to quantify these indirect costs on a cost basis using available data. These two methods have been used by several utilities to handle these indirect costs.

Cleaning and Lining

One available option to reduce costs for repair and replacement of water mains is to implement a rehabilitation program. In an attempt to increase the service life of unlined mains, address water quality problems, and improve hydraulic capacity, unlined cast iron mains can be cleaned and cement lined. Mains meeting certain pipe characteristics and maintenance criteria may be candidates for a cleaning and lining program (see Section 8). An economic model has been developed to evaluate the costs and benefits of cleaning and lining as a technique for prolonging the useful life of older mains. This evaluation is based on estimated material and labor construction costs for both options. The benefits of improved water quality, improved hydraulic capacity and increased fire flow capability from a health, safety and public relations standpoint have not been quantified. These benefits may override the cost/benefit analysis thereby making rehabilitation of certain mains beneficial.

Economic Model

Cleaning and lining is attractive because it is considerably less costly than main replacements. The lower unit cost enables the utility to rehabilitate more miles of main with its limited capital funds. The economic model presented here has been developed to provide a method of evaluating costs of deferring replacement by cleaning and lining against the incremental costs of allowing the mains to continue deteriorating until replacement becomes necessary.

It is recognized that cleaning and lining a main does not eliminate the need to replace it eventually. Rather, cleaning and lining is a method of prolonging the main's useful life and deferring replacement. The cleaning and lining cost trade-off presented conceptually in Figure 3D-2, shows the cash flows for both the rehabilitation and replacement options. The clean and lining option involves the initial rehabilitation cost and the replacement cost at a future year equal to the sum of the initial remaining main life and the additional service interval secured by rehabilitation. Replacement, on the other hand, involves the cost of replacement at the end of the main's remaining life. Cleaning and lining does not enhance the structural condition of mains, but it can prolong the useful life if the main has not deteriorated beyond an acceptable level.

Ignoring break repair costs, the relative economics of replacement and rehabilitation can be defined by comparing the present worth costs for the two options. The present worth of costs for cleaning and lining may be estimated by Equation 15, below:

$$\text{PW-Reh} = R1 + R2\,\frac{(1+j)^t}{(1+i)^t} \tag{15}$$

where:

PW-Reh = present worth of cleaning and lining costs.
i = discount rate.
j = replacement cost inflation rate.
R1 = current cleaning and lining cost, dollars.
R2 = replacement cost in initial year dollars.
t = year in which deferred replacement occurs; the sum of remaining life (r) and additional service period (p).

The present worth of costs for the unaltered replacement option is presented in Equation 16, below:

$$\text{PW-Rep} = R2\,\frac{(1+j)^r}{(1+i)^r} \tag{16}$$

where:

PW-Rep = present worth of undeferred future replacement.
R2 = replacement cost in initial year dollars.
r = estimated remaining years in original main.

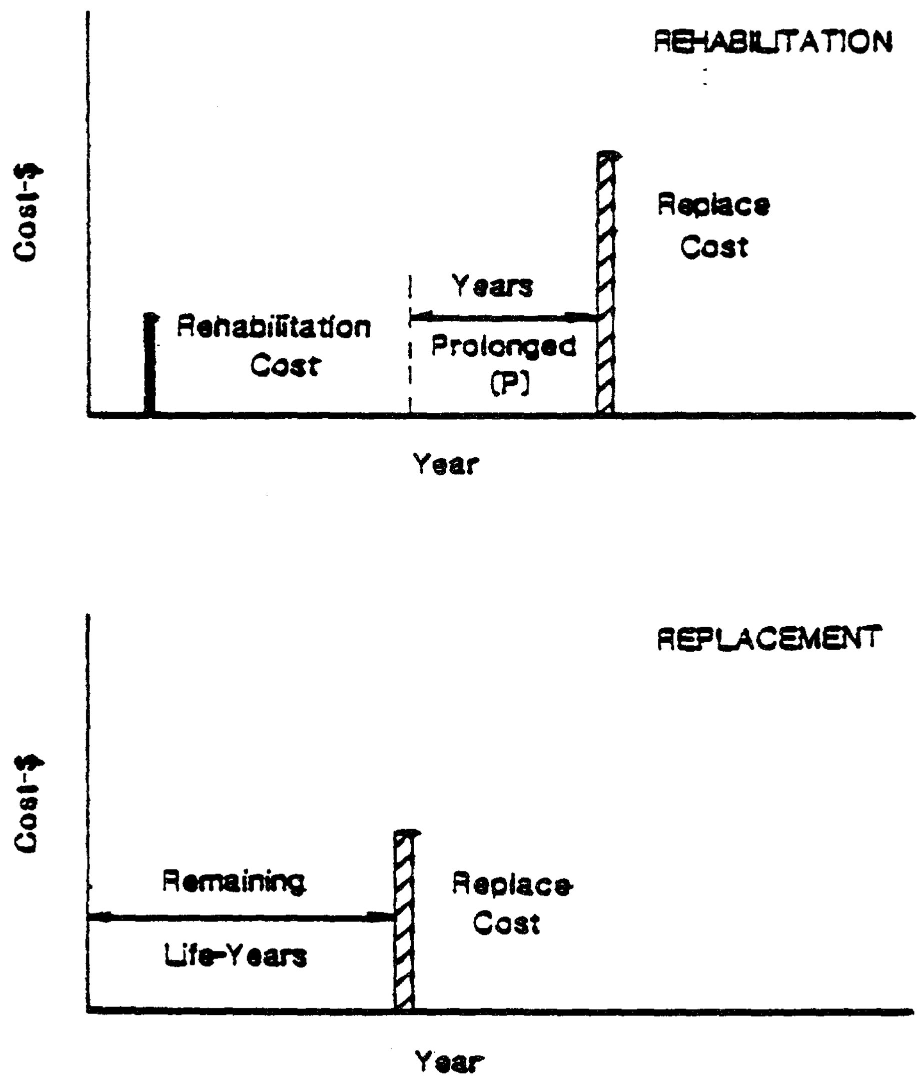

Figure 3D-2. Rehabilitation and Replacement Option Cost Trade-off

The ration of Equation 16 to 15 can be used to compare the options, as shown in Equation 17.

$$K = \frac{\text{PW-Rep}}{\text{PW-Reh}} \qquad (17)$$

where:

K = Ratio of the present worth of costs associated with replacement (Equation 16) to the present worth of costs for current rehabilitation and later replacement (Equation 15).

Cases where the cost ratio is less than 1.0 indicate that future replacement is more cost-effective than rehabilitation. Figure 3D-3 presents estimates of the ratio K for various combinations of remaining life (r) and of prolonged years (p) due to rehabilitation. This figure is based on a net discount rate of 7% per year, rehabilitation costs of $35/LF, replacement costs of $125/LF and small diameter mains (6" and 8"). For this specific example, rehabilitation of mains with an estimated 20-30 years remaining life will never become economically favorable. These mains should be replaced rather than cleaned and lined. However, while replacement of these mains is economically favorable, the utility may not want to wait 20-30 years to replace them if severe hydraulic and/or water quality conditions exist. In this situation, the utility may decide to rehabilitate these mains immediately, despite the lower economic benefits, due to health, safety and public relations considerations. For mains with 10 years of remaining life, the return on the rehabilitation investment is achieved in the twelfth year.

Sensitivity Analysis

Ignoring break repair costs, the replacement/rehabilitation cost ratio K depends upon several factors, namely:

(a) Remaining life in main
(b) Life extension from rehabilitation
(c) Discount rate
(d) Replacement unit cost
(e) Rehabilitation unit cost.

The sensitivity of the replacement rehabilitation cost ratio to the above factors are summarized in the following paragraph.

The K ratio was found to:

1. Be highly sensitive to both the estimated remaining life of the mains and the extension of life secured by cleaning and lining. (See Figure 3D-2.)

2. Vary inversely with the discount rate such that rehabilitation becomes less economically attractive with higher discount rates. This is illustrated in Table 3D-1 for the case of a pipe with twenty years remaining life and the same rehabilitation and replacement costs. As the discount rate is reduced from 7% to 3%, rehabilitation becomes more attractive, especially as the years prolonged by rehabilitation increases. At the current 3% net discount rate, the curves shown in Figure 3D-3 would shift upward to favor a greater use of rehabilitation .

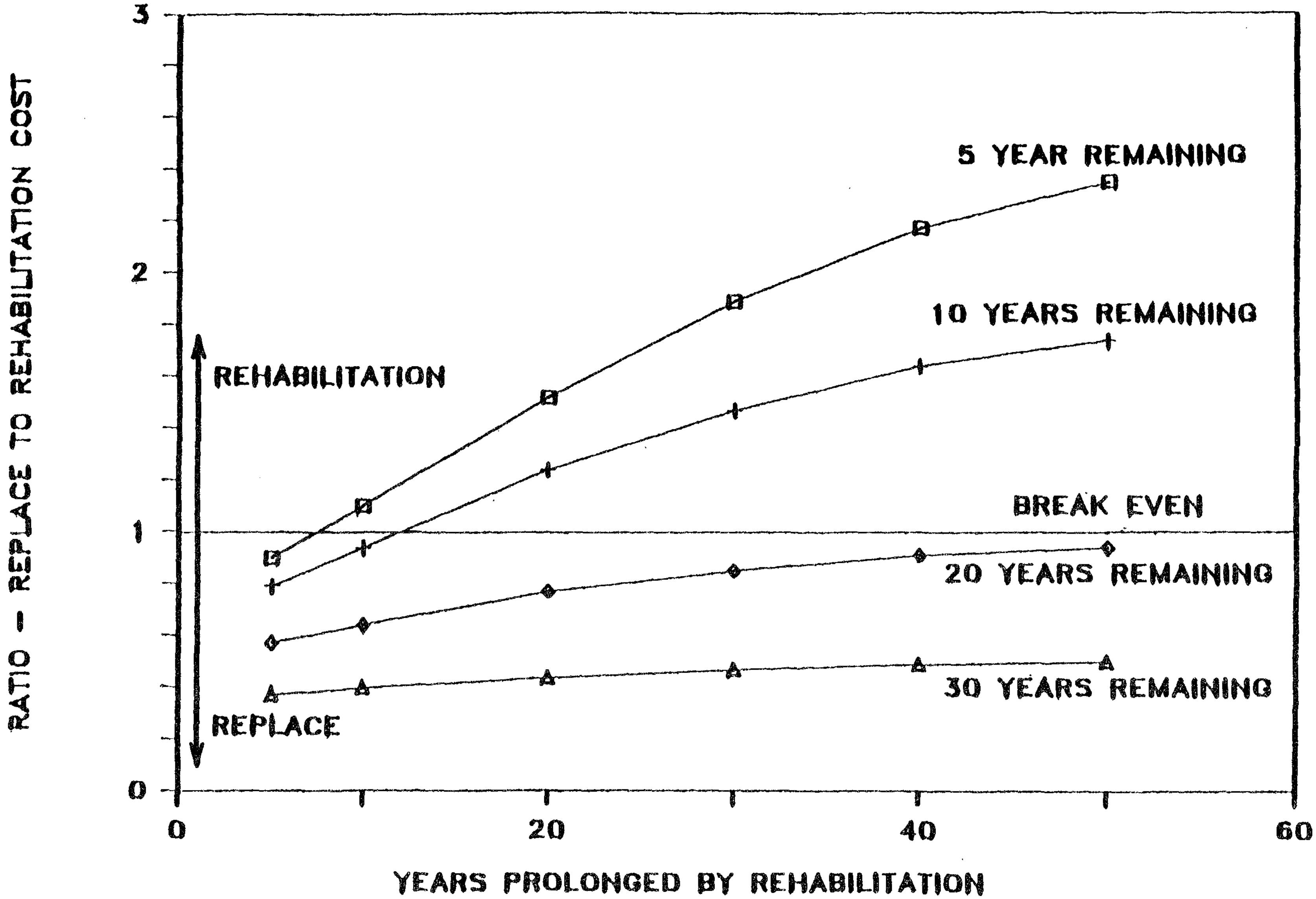

Figure 3D-3. Sensitivity to Replacement to Rehabilitation Cost Ratio to Prolonged Life

Note: Based on net discount rate of 7% rehabilitation at $35 per linear feet and replacement at $125 per linear feet. Ratio is very sensitive to all three factors.

Table 3D-1. Replacement/Rehabilitation Cost Ratio Discount Rate Sensitivity for 20 Years of Remaining Life

Years Prolonged By Rehabilitation	Discount Rate % 3	7
5	0.73	0.57
10	0.80	0.64
20	0.94	0.77
30	1.09	0.85
40	1.23	0.91
50	1.36	0.94

3. Vary inversely to the unit costs of rehabilitation and replacement. This analysis indicates that cleaning and lining is generally more cost effective and the cost difference between the two alternatives increases. It should be noted that the replacement option does not assume any cost for continued break repair.

It should be noted that these findings do not apply to larger diameter transmission mains. The relative costs of rehabilitation of these mains are much lower. In addition, the energy savings from improved hydraulic conditions may make cleaning and lining cost-effective.

Further, rehabilitation may be a worthwhile strategy due to the benefits of improved hydraulic capacity, improved water quality, improved fire flow capability, and improved public relations. These economically intangible benefits have not been included in this mode. They are, however, an important part of the decision process. For this reason, a water main rehabilitation decision system may include these factors as criteria in the selection process.

In addition, it should be mentioned that cement lining will neither renew consumer service connections, nor reduce external corrosion. The utility must still decide whether either of these factors should affect the decision to clean and line any particular segment of main.

Leak Detection and Repair

Along with addressing the costs of water main breakage, each utility should examine the cost effectiveness of leakage detection. The relationship between water main leakage and water main breaks has not been extensively explored. It is hypothesized that areas with high rates of leakage will also be areas with many main breaks. It is further hypothesized that these leaks are one possible cause of main breaks. If this is correct, an aggressive leakage detection program should significantly increase utilities' abilities to reduce the rate of increase in main breaks. By taking action before leaking mains break, the life of existing mains will be prolonged.

The flow chart presented in Figure 3D-4 traces the procedure for comparing the costs and benefits of implementing a leak detection and repair

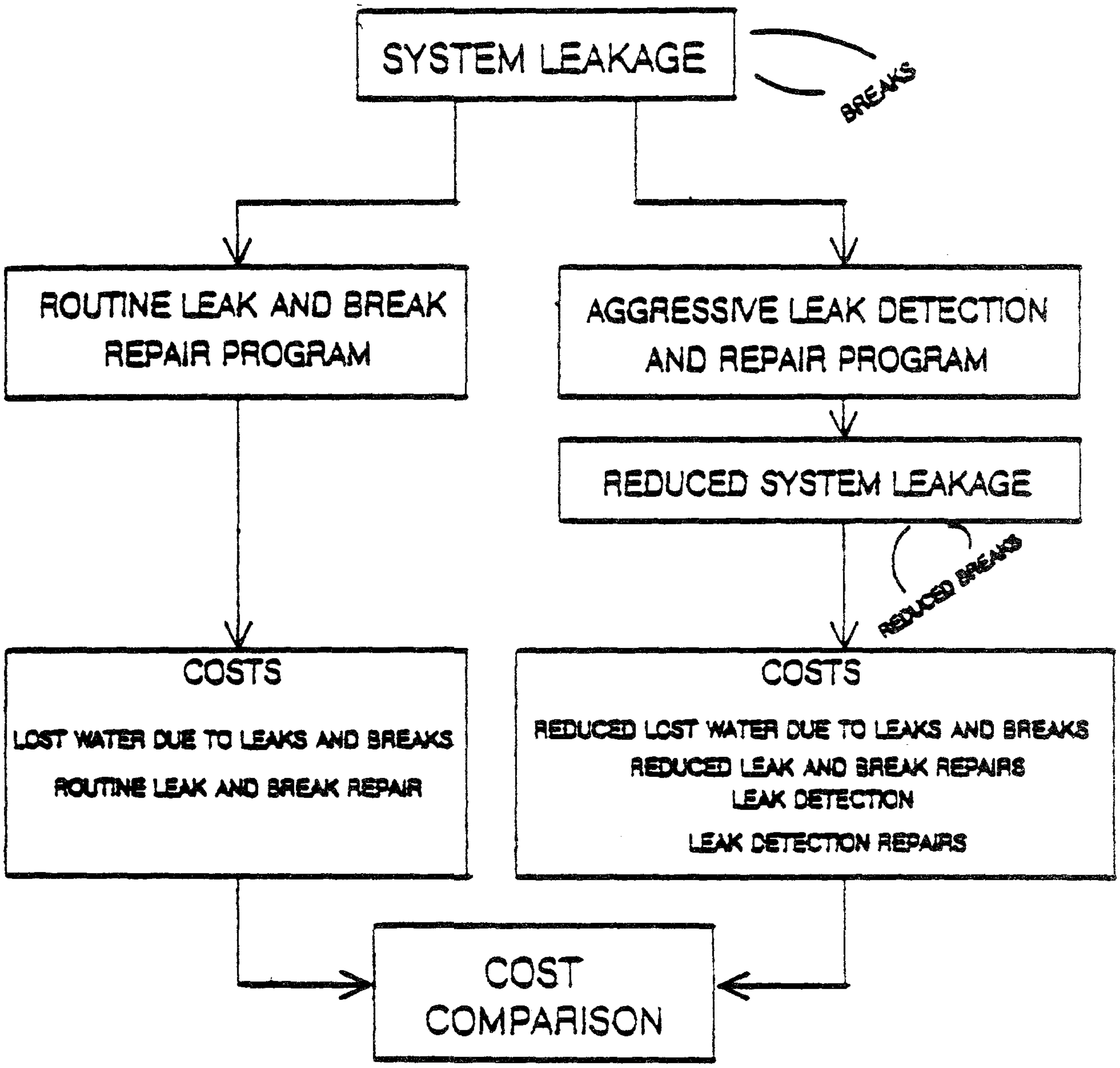

Figure 3D-4. Conceptual Illustration of the Leak Detection and Repair Model program. If a utility chooses not to implement a program, its costs will include the cost of the lost water and the leak and break repair costs. When a utility implements a detection program and repairs the leaks discovered, the amount of lost water in the system decreases. The reduction in leakage may result in a reduction in break occurrences.

The cost of the leak detection and repair activity must be compared to the benefits of a reduction in lost water and the possible reduction in additional break and leak repairs to determine the value of such a program.

Leakage Control Model

A leakage control model was developed to compare the projected future costs of a leak detection and repair program with the cost of lost water. The model has five elements, as follows:

(a) Leakage in Base Year
(b) Leakage Growth, percent/year
(c) Leakage Located and Corrected Routinely
(d) Leak Detection and Repair Program
(e) Cost in Base Year

Each element is discussed below.

Leakage - this is the rate of water loss in a given year from all different sources.

Growth Rate - new leaks form continuously. The rate of formation varies by leak type and area.

Routine Leakage Located - water utility crews repair many leaks throughout the year as part of their routine work. These leak repairs may result from customer complaints or from leaks found by crews in the course of other maintenance activities.

Leak Detection and Repair (LD&R) Program - A LD&R program includes both the leak detection and repair components.

Costs - leakage and its control includes three sets of costs: (1) cost of lost water, (2) cost of leak detection, and (3) cost of leak repairs. Main break costs are omitted from the analysis presented here since a precise relationship between break frequencies and leakage levels is difficult to determine.

The leakage control model simulates the projected leakage condition over a user specified number of years under both control-program and no-program conditions.

The economic trade-off between having a leak detection program or not must compare the cost of inspection and repair of detected leaks with the projected cost of lost water from the same leaks left unrepaired. If the cost of leaking water saved exceeds the cost of detection and repair, it is economically advantageous to proceed with a leak detection program. The situation is presented in Equation 18.

$$PWB = F2 - F1 \qquad (18)$$

where:

PWB = present worth benefit of detection program.

F1 = present worth of costs with a detection program.
F2 = present worth of costs with no detection program.

Equation 19 defines the costs of the leak detection program for any one year, ignoring break rate and cost effects.

$$F1 = L_1 \times C_R + L_2 \times S \times C_W + M \times C_D + L_3 \times C_R \qquad (19)$$

where:

L_1 = leaks located by detection.

L_2 = leaks remaining after inspection.

L_3 = leaks routinely located.

C_R = cost of repair/leak.

C_W = cost of water.

C_D = cost of inspection/mile.

M = miles inspected.

S = size of leak (gpd).

Equation 20 defines the costs for no program.

$$F2 = L_3 \times C_R + L_2 \times S \times C_W + L_1 \times S_1 \times C_W \qquad (20)$$

The benefit in any year associated with a detection and repair program can therefore be stated as shown in Equation 21.

$$B = L_1 \times S \times C_W - M \times C_D - L_1 \times C_R \qquad (21)$$

Sensitivity Analysis

The present worth costs of the leak detection program and no-program alternatives are dependent upon several factors, namely:

(a) Cost of water
(b) Cost of repair
(c) Leakage growth rate
(d) Routine leak location rate
(e) Net discount rate
(f) Survey cycle

The conclusions of the analyses are as follows:

1. As the cost of water increases, the cost of both the leak detection program and no program alternatives increases. As the water costs increase, the net savings for leak detection also increase.

2. The leak detection program is economically justified in nearly all cases of leak growth and leak location rates. See Table 3D-2.

3. The two alternatives vary inversely with the net discount rate. Although the leak detection program is the more favorable alternative, the net savings of leak detection decreases with the net discount rate.

4. The survey cycle only has an impact on the leak detection program alternative. It was found in the case examined that as the cycle changes, so does the net present worth of the program. A review of the net present worth costs under a variety of survey cycles can be used to determine the cycle where the program cost is the lowest and the net savings the greatest. A two-year inspection cycle for this situation was found to give the greatest savings.

Future Detection and Repair Programs

Using the economic model, future leak detection programs can be developed. The model in combination with a given utility's maintenance and cost experience, can be applied to develop a cost-effective survey cycle for each utility's survey district.

To illustrate how the model can be used, a copy of printed results is presented in Table 3D-3. This illustrative application of the model addresses a twenty-year planning period, using data drawn from the accelerated program of leak detection in North Philadelphia (43). Discounted costs are shown, with and without a continuing detection program, for the assumption stated.

Table 3D-2. Sensitivity of Present Worth Benefits of Leak Detection to Leak Growth Rates and Routine Leak Location Rate

Percentage Leak Growth Rate/Year	Percentage Routine Leak Location Rate	Alternative with Lower Present Worth	
		Program	No Program
1.0	1.0	x	
1.0	3.0	x	
1.0	5.0	x	
1.0	9.0	x	
1.0	13.0		x
2.5	2.5	x	
2.5	7.5	x	
2.5	12.5	x	
2.5	17.5	x	
5.0	1.0	x	
5.0	3.0	x	
5.0	5.0	x	
5.0	9.0	x	
5.0	13.0	x	
7.5	2.5	x	
7.5	7.5	x	
7.5	12.5	x	
7.5	17.5		x
13.0	1.0	x	
13.0	3.0	x	
13.0	5.0	x	
13.0	9.0	x	
13.0	13.0	x	

Table 3D-3. Sample Worksheet of the Leak Detection and Repair Model for Leak Detection Program and No-Program Options

LEAK DETECTION AND REPAIR MODEL

FY 82-83 - ESTIMATED DATA
ACCELERATED NO. PHILADELPHIA PROGRAM

Distribution System Data:

Number Miles:	200 Miles	Leak Growth Rate:	8%
Leakage Rate/Mile:	61000 GPD/MI	Avg Location Rate:	5%
Avg Leak Size:	20502 GPD		
Number of Leaks:	596 #	Total Leakage:	12.2 MGD

Economic Data:

Water Cost:	90 $/MG	Leak Detection	
Repair Cost:	265 $/Leak	Efficiency:	95%
Leak Detection:	1019 $/MI	Net Discount	
Survey Cycle:	3 Years	Rate:	7%

Leak Detection and Repair Program Evaluation

Year	Number Leaks	Leakage (MGD)	Routine Leaks Located	New Leaks	Miles Inspected	Leaks Located	Leakage Located (MGD)	Remain Leaks	Remain Leakage (MGD)	Cost LD&R	Cost Water	Current Costs
1984	596	12.2	30	48	0	0	0.00	614	12.59	$7,898	$413,470	$421,367
1985	614	12.6	31	49	67	200	4.11	432	8.86	$265,243	$291,014	$556,257
1986	432	8.9	22	54	67	146	2.99	315	6.46	$112,358	$212,190	$324,549
1987	315	6.5	16	52	67	111	2.28	240	4.92	$101,598	$161,738	$263,329
1988	240	4.9	12	54	67	89	1.83	193	3.95	$94,763	$129,689	$224,452
1989	193	3.9	10	55	67	75	1.55	163	3.34	$90,475	$109,630	$200,105
1990	163	3.3	8	57	67	67	1.37	145	2.96	$87,845	$97,371	$185,216
1991	145	3.0	7	59	67	62	1.27	134	2.75	$86,296	$90,199	$176,495
1992	134	2.7	7	60	67	59	1.22	128	2.63	$85,454	$86,553	$172,007
1993	128	2.6	6	62	67	58	1.19	126	2.58	$85,075	$84,690	$169,765
1994	126	2.6	6	64	67	58	1.19	125	2.57	$85,002	$84,070	$169,072
1995	125	2.6	6	66	67	59	1.20	127	2.59	$85,133	$85,242	$170,384
1996	127	2.6	6	68	67	60	1.22	129	2.64	$85,404	$86,604	$172,006
1997	129	2.6	6	70	67	61	1.25	131	2.69	$85,765	$88,447	$174,212
1998	131	2.7	7	72	67	62	1.28	135	2.76	$86,195	$90,610	$176,806
1999	135	2.8	7	74	67	64	1.31	138	2.83	$86,676	$93,010	$179,686
2000	138	2.8	7	77	67	66	1.35	142	2.91	$87,194	$95,594	$182,788
2001	142	2.9	7	79	67	68	1.39	146	2.99	$87,713	$98,320	$186,033
2002	146	3.0	7	81	67	70	1.43	150	3.08	$88,319	$101,190	$189,509
2003	150	3.1	8	84	67	72	1.47	155	3.17	$88,910	$104,170	$193,080
2004	155	3.2	8	86	67	74	1.51	159	3.27	$89,540	$107,250	$196,790
									Net Present Value			$2,719,447

No Program Evaluation

Year	Leaks	New Leaks	Leaks Located	Total Leaks	Total Leakage (MGD)	Cost Water	Cost Repair	Total Cost
1984	596	48	30	614	12.6	$413,470	$7,898	$421,367
1985	614	49	31	632	13.0	$425,474	$8,134	$433,608
1986	632	50	32	650	13.4	$438,650	$8,378	$447,029
1987	650	52	33	670	13.8	$451,810	$8,630	$460,439
1988	670	54	34	690	14.2	$465,364	$8,889	$474,253
1989	690	55	35	712	14.6	$479,325	$9,155	$488,480
1990	712	57	36	733	15.0	$493,705	$9,430	$503,135
1991	733	59	37	755	15.5	$508,516	$9,713	$518,229
1992	755	60	38	778	15.9	$523,771	$10,004	$533,776
1993	778	62	39	801	16.4	$539,484	$10,304	$549,789
1994	801	64	40	825	16.9	$555,669	$10,614	$566,282
1995	825	66	41	850	17.4	$572,339	$10,932	$583,271
1996	850	68	42	875	17.9	$589,509	$11,260	$600,769
1997	875	70	44	902	18.5	$607,194	$11,598	$618,792
1998	902	72	45	929	19.0	$625,410	$11,946	$637,356
1999	929	74	46	956	19.6	$644,172	$12,304	$656,477
2000	956	77	48	985	20.2	$663,498	$12,673	$676,171
2001	985	79	49	1015	20.8	$683,403	$13,053	$696,456
2002	1015	81	51	1045	21.4	$703,905	$13,445	$717,350
2003	1045	84	52	1077	22.1	$725,022	$13,848	$738,870
2004	1077	86	54	1109	22.7	$746,772	$14,264	$761,036
								$5,408,320

Annex 3E. Economic Analysis of Leak Detection*

General

Leakage represents a physical loss of water, but the control of leakage entails some cost and normally can be justified only in relation to the cost of producing the water saved by leakage reduction. Additional savings may be achieved if leakage control results in lower costs of sewerage and sewage treatment. Where water resources are limited, the simple analysis of cost of water saved in relation to the cost of leakage control is not the sole justification for active control. Furthermore, the active control of leakage entails improved control of the water system and is of direct benefit to management and thus to the cost of supplying water.

Leaving aside these associated aspects not readily assessable in economic terms, it is relatively simple to undertake a cost/benefit analysis of leakage control and thus to determine future policy regarding the degree of control to be exercised. The cost of leakage is reflected in (a) the variable element of operating costs and (b) the capital costs of new works, to the extent that the construction of new works may be deferred. When an authority has a large surplus production capacity and major distribution works, and does not foresee incurring large capital costs in the near future, increased expenditure on leakage control may be less justified. Nonetheless it must be remembered that a reduction in leakage can help to increase revenue by increasing water sales.

Cost of Leakage

Unit cost of leakage = unit operating cost + unit capital cost

Unit Operating Cost

To calculate the unit operating cost (marginal cost) of water, one is concerned only with those water sources where production costs would be reduced by reducing leakage. Normally the large gravity source or the locally pumped source will produce the least costly supply and will be retained. Bulk supply sources or more recent and more remote pumped sources may entail more expensive pumping and treatment costs where reduction in output will be of greatest benefit. When reductions can be foreseen at more than one source it is necessary to calculate the weighted average of the variable operating costs at each source.

To calculate operating costs, fixed costs that are not affected by variations in quantity produced must be included. The normally calculated total operating costs of water from each source station are not relevant. Variable operating costs include electricity for pumping and chemicals for treatment. Other variable costs usually are not significant.

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Operating Costs

To calculate electricity costs if there is no power meter, use the following formulae:

$$\text{power input} = 1.73\ \frac{\text{x volts x amps x power}}{1{,}000}\ \text{factor}$$

$$\text{and } \underline{\text{unit pumping cost}} = \text{power}\ \frac{\text{input x kwh unit}}{\text{volume pumped } (m^3/h)}\ \text{charge}$$

$$\underline{\text{unit treatment cost}} = \frac{\text{annual chemical costs}}{\text{annual quantity of treated water}}$$

NOTE The operating costs are reduced to currency unit/m^3

Inflation factors should be ignored because they will apply more or less equally to labor and other costs of leakage control.

Capital Costs

Normally projections are made for five-year periods, but they can be made for a more extended period if large expenditures such as new source works or transmission mains are likely. It is necessary to estimate for each year the capital expenditure for source works, treatment works, pump stations, service reservoirs, transmission mains, primary distribution mains, and distribution reinforcements. The capitalized fixed costs of operating the future new works must be added to the capital costs. These costs are estimated by reference to the fixed costs of existing similar works; annual costs are capitalized by applying the factor $(1 + r)/r$, where r is the discount rate. For example, for a 5 percent discount rate the factor is 21.

The future capital costs are entered for the appropriate year as shown in an example in Figure 3E-1. The diagonal lines in the table provide for insertion of the simple capital sum and a sum modified by applying multipliers (in the range 0 to 1) as indicated below. Where a project cannot be deferred for some good reason, it may be wholly or partially omitted and in this analysis a "demand multiplier" should be applied.

Where a new project will satisfy demand for a long period ahead, its cost should be increased using a capacity multiplier, derived from Figure 3E-2. Using Figure 3E-2 the total discounted capital cost (TDCC) can be obtained, and the unit capital cost is then calculated from the formula:

$$\text{Unit capital cost} = \frac{\text{TDCC} \times r^2}{(1+r) \times 3.65 \times d}$$

r = the discount rate
d = the projected annual rate of increase in demand

FIGURE 3E-1

TYPICAL EXAMPLE FOR CALCULATION OF TOTAL DISCOUNTED CAPITAL COST (TDCC)

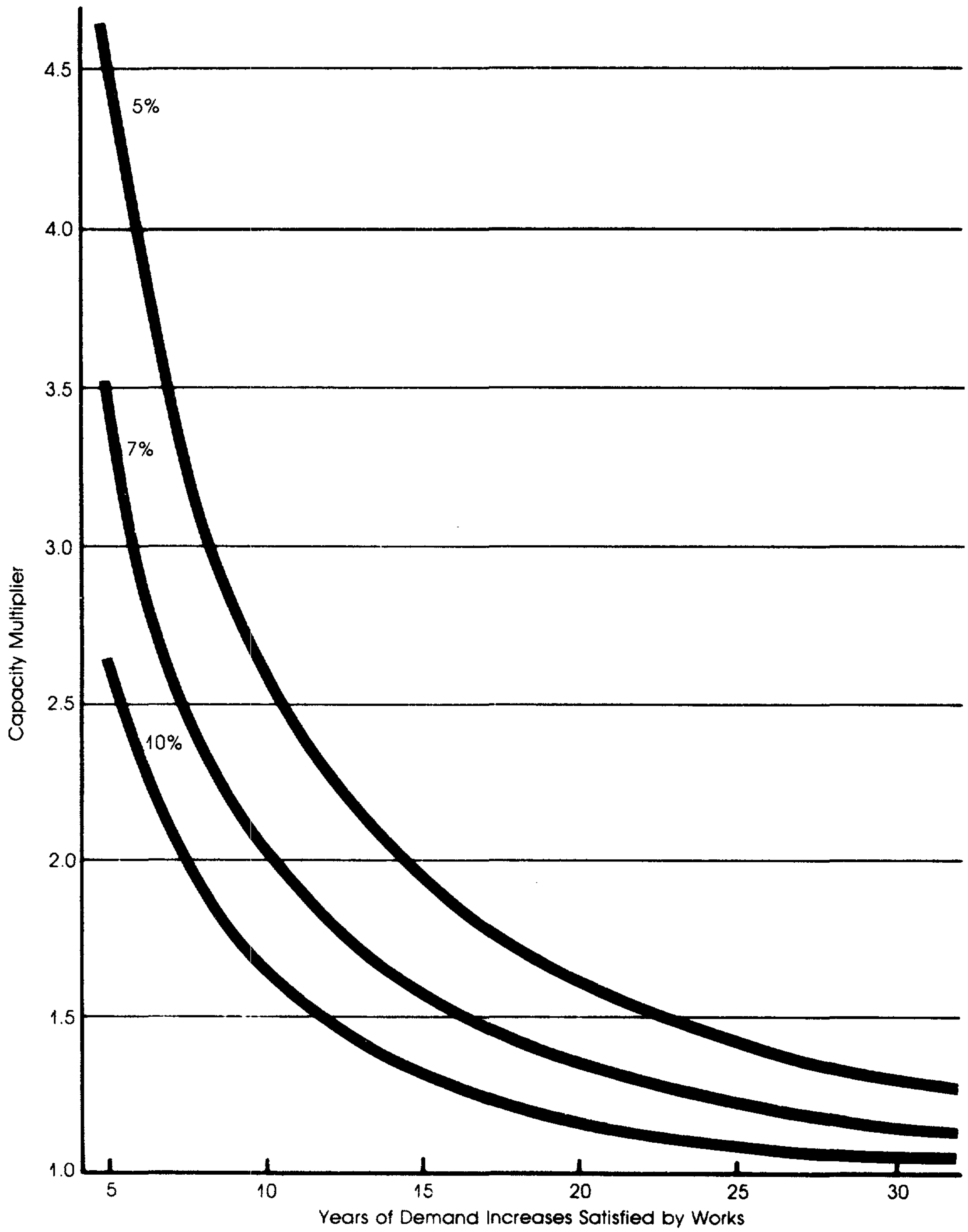
Costs of Capital Works (x £ 1000) — Actual / Modified

Year i	Storage and Distribution Extensions ii	Pumping Station Mods iii	Treatment Works Extension iv	Mains Strengthening v	Source Works vi	Trunk Main vii	viii	ix	x	xi	Total Modified Capital Cost (x £ 1000) xii	Discount Factor (5%) xiii	Discounted Capital Cost (x £ 1000) xiv
0 79	178 / 338	82 / 156	6 / 6								500	1.00	500
1 80	74 / 141	63									204	0.95	194
2 81	106 / 201		79 / 85	96 / 128							414	0.9	377
3 82			6 / 6	98 / 130							136	0.86	117
4 83			178 / 191								191	0.82	157
12 91					500 / 1075	370 / 796					1871	0.56	1048
13 92						5x21 / 226					226	0.53	120
Demand Multiplier	1.0	1.0	0.5	0.7	1.0	1.0							
Capacity Multiplier	1.9	1.9	2.15	1.9	2.15	2.15							

Total £ 2,513,000

World Bank—30891:1

FIGURE 3E-2
Capacity Multipliers for Various Discount Rates



World Bank—30505:3

Cost of Leakage Control

Having determined the extent of leakage and the unit cost of leakage, management has to set a realistic target for leakage control. This may be a reduction of UFW from say 40 percent to 30 percent (or it may be expressed in liters per property hour as given by net night production). The cost of improved leakage control based on increased labor and equipment then has to be estimated based on the type of control proposed. The results must be monitored to ensure that the target is being achieved without the cost of control being exceeded. The step-by-step procedure proposed in this document ensures that improved control is maintained within the economic limit justified by the saving in cost of water produced.

Costs of leakage control can vary greatly depending on: labor costs in the particular country; extra costs for night work; and above all, the condition of the system at the outset. If the system has become very run-down due to negligible input on proper operation and maintenance, the preliminary cost of putting the system into reasonable condition could form a considerable part of the total.

Assuming that such preliminary work is charged to general operation and not to the waste detection program, typical costs of various components would be in line with those noted in Annex 3C.

The costs of associated repairs should be readily determined from existing records but, failing that, might be based on: a team of five, plus a driver; repairs to pipe (five hours), to service (three hours), to valve or hydrant (two hours).

General Comment

The initiation of active control can be expected to show a considerable financial return but, as the program is developed and leaks are repaired, the results gradually become less rewarding. The law of diminishing returns applies, and it is advisable to repeat the economic analysis at regular intervals using updated cost projections to ensure that increasing efforts are fully justified. It must not be overlooked that the most important part of control is to repair rapidly the leaks when they are located. For a detailed discussion the reader is referred to Standing Technical Committee Report No. 26 on Leakage Control Policy and Practice published by the U.K. National Water Council.

Annex 3F. Draft Typical Terms of Reference for Consultants

Background

(Brief description of the Authority's organization and supply system.)

Objectives

The Authority proposes to undertake a study of the whole distribution system from source stations to consumers' fittings with a view to reducing the unaccounted-for water (UFW) and improving control of the system. The UFW appears to be excessive partly due to defects in consumers' meters and certain illegal practices and partly because of losses by waste including underground leakage.

The aim is to reduce metering losses by about not less than 15 percent within a period of three years and losses caused by all forms of waste by about 25 percent within a period of five years.

The Authority proposes to appoint consultants to assist in various aspects of the study in order to implement the procedure required to undertake the improvements necessary to enable the above objectives to be achieved and leave in place a sustainable organization. Consultants will also be hired to make such additional reductions in UFW in future years as may be economically justified. The attached "Working Guidelines" are provided for your review and comments. The Guidelines would then form part of the terms of reference.

Consultants will be required to assist the Authority in the following aspects of the work:

1. The setting to work and calibration of production meters and large consumption meters, including the correct installation of new meters where required and the regular monitoring of all water delivered by these meters.

2. The reassessment of total UFW.

3. A survey of all illegal connections, followed by the removal or the metering of such connections.

4. A sample survey of the accuracy of consumers' meters and of any irregularities in meter reading in order to assess (a) the total loss attributable to metering deficiencies and (b) the actual unit domestic consumption in different social conditions and supply areas.

5. The allocation of total UFW between metering losses and physical losses due to waste.

6. The training of selected members of the Authority's staff in the practical and administrative aspects of reducing waste.

7. A review of all aspects of metering practice, including possible privatization, incentives to improve performance and, if required, design and supervision of extensions to the meter repair shop.

8. A review of present waste control practices and an econonmic study of alternative methods for improved waste control, followed by advice on future policy.

9. The survey and remapping of the complete network of mains and consumer services and the establishment of a system to ensure continuous updating.

10. The physical separation of the network into isolated districts serving about 10,000-to-20,000 properties.

11. The measurement, monitoring, and evaluation of rates of flow into the whole system and into each isolated district to facilitate the determination and subsequent control of total waste in each district.

12. The establishment and operation of an active waste detection and repair organization, including the tracing of leaks and all forms of waste by appropriate methods.

13. The institution and enforcement of bylaws for the control of waste water by establishment of a plumbing inspection division or other appropriate measures.

14. A network analysis of the distribution network to determine the status of amount operating conditions.

15. A preliminary economic study of the least-cost network reinforcement required to meet demand foreseen in existing planning proposals for the next ten years.

16. Continued advice, training and management services for a period of (three?) years.

Submissions

Consultants with experience in the relevant administrative, financial, operational, and maintenance problems are invited to submit proposals for undertaking all (or any) of the above, including provision of the necessary services, equipment, and labor for:

Phase I Works covering a period of up to one year, and
Phase II Works covering a further period of four years.

Consultants should consider collaboration with local consulting companies in order to achieve greater understanding of local conditions and also to disseminate knowledge and experience more widely to achieve more permanent improvements in the maintenance of the supply.

The proposals for labor, equipment, and time required (a) by the consultants and (b) by the Authority are to be itemized for each of the works described in the following sections.

Scope of Consultants Services

Phase I Works

Large Meters. In some cases, production meters exist for measuring flows of treated water from certain works but are not operating satisfactorily and large consumer meters may be under recording or be completely inoperative causing significant revenue losses. All meters have to be inspected and, where practicable, put into working order and calibrated at all relevant flows from the station. The calibration should, preferably, be undertaken by measurement of volume changes on suction or delivery tanks, or alternatively, by discharge through test meter or such other means as may be agreed upon by the Authority. Where meters cannot reasonably be put into working order or where meters do not already exist, new meters are to be purchased and installed at the Authority's expense in such a way as to minimize interference with the supply of water. Sufficient meters are to be purchased and installed to enable the total rate of flow from all source works into the distribution system and use by large consumers to be measured at all times.

Reassessment of UFW. Having determined the true figure for total quantity of water produced and delivered into the system, it remains to calculate the total quantity that can be accounted for in supplies to the consumers. Two factors must be kept in mind: (a) the quantity supplied to consumers or used for public purposes but not metered and (b) the lack of correlation between the dates of reading various consumers' meters. A study is required of the seasonal or other variations in accounted for water compared with the water produced. The total UFW for the supply area can then to be calculated as a percentage of the water produced. A survey is also required of the number of properties in each district so that UFW can also be calculated in terms of quantity per property per hour. Comparisons should be made of these quantities in the different districts.

Illegal Connections. (Normally applicable only when domestic supplies are metered.) A sample survey must be undertaken of the total number of properties receiving water supply compared with the number of metered connections. This survey should cover different social areas separately to determine the extent of illegal domestic supplies and variations between different areas. It must cover supplies afforded by neighbors through temporary house connections as well as permanent connections. The survey must show the number of inhabitants (as well as properties) receiving an illegal supply. In addition, the survey must cover industrial premises, which may have some unmetered, as well as metered, connections. Where consultants propose to use aerial sewage students or local labor for such surveys, their proposals must be detailed for independent checking to minimize fraud or other inaccuracies in data obtained. Consultants are also required to advise on appropriate steps (bylaws, tariffs, etc.) to be taken to minimize the reconnection of illegal supplies that have been cut off and to ensure that all connections are and remain metered.

Sample Meter Accuracy and Domestic Consumption. A study of the accuracy of existing meters should be made, based on testing a 1 percent random sample of installed meters by means of a portable test meter. The site data must include data on the number of inhabitants served from each meter and the setting of the consumers' control valve when first examined. The accuracy tests must especially include calibration at the flow rate for this normal valve setting, as well as for very poor flow rates. The Authority's meter readers and other assistants will be made available as necessary for locating meters and other assistance.

The accuracy of meters should be recorded for each manufacturer and type of meter as well as (where the Authority's records are available) the time that has elapsed since the meter was (a) last read and (b) last changed. In addition, information from the last two meter readings for all the meters tested is required to determine total metered consumption through the meters tested, total consumption per capita per day, and, where possible, comparable figures for different districts and different social groups. This study must also investigate any possible irregularities in meter reading, estimate the total effect of any such irregularities, and advise on measures to be adopted to reduce the problem. It should also be aimed at determining the extent of water wastage, including underground leakage, on the consumer's premises.

Nonphysical UFW. Consultants will be required to determine from their surveys of meter accuracy, illegalities, and irregularities the actual quantities of water being delivered to consumers and thus, how much of UFW is attributable to metering deficiency. By deduction from total UFW, that part of UFW attributable to leakage should be calculated.

Training and Equipment. Consultants are required to provide specialized training of not less than 20 weeks for (six?) of the Authority's employees in all aspects of waste detection, leakage repair, and prevention of waste, including inspection of consumer's plumbing and fittings. This training should be undertaken by the consultants' staff in association with employees of a water authority in a developed country. It should include lectures on theoretical aspects but should be particularly devoted to practical training under working conditions using traditional methods as well as more modern equipment for leak detection. This training abroad should be followed by further training by the consultant on the Authority's works. It initially should include assistance on the works described in Sections 4.1 - 4.5 and 4.8 of the Working Guidelines and, later, on the proposed Phase II Works. Consultants must provide the specialized leak detection equipment required initially and the specifications for all additional equipment required for implementation of the proposed policy.

As part of the extended training, consultants are required to establish a pilot waste meter district, which will be regularly monitored and studied by all trainees.

Metering Practice. Following the sample tests on consumer meter accuracy, a review is required of present metering practice. This review should focus on the type, diameter, and manufacture of meters in current use; the required level of meter testing, repair, and replacement for effective operation; the possible alternative use of flow limiters for domestic consumers to ensure continued water conservation; and means to simplify maintenance, operation, and billing procedure. The quality of the water supplied, particularly the suspended solids, and the potential for improvements in quality by better maintenance of the network (including increased flushing, rehabilitation by cleaning, and relining of pipework) are all factors to be taken into account.

The practice for replacement, repair, and testing of meters should be examined and recommendations should be made as to possible incentives for improved output and changes in frequency of reading, replacement, and associated extensions of repair and testing shop facilities. A special study should be made on large meter installation, calibration and maintenance practices.

Attention is to be given to possible privatization of meter reading and billing, which may also include privatization of meter installation, maintenance, testing, and repairs.

Depending on the conclusions and recommendations reached in regard to metering practice, the consultant may be required to design and supervise the construction of extensions to, and management of, meter repair and testing shop facilities.

Waste Detection and Repair Policy. In collaboration with the Authority, consultants are required to (a) review present waste control practices, (b) consider alternative, systematic methods required to meet target reductions in physical UFW, (c) examine the costs of waste detection methods, (d) undertake an economic study of alternative methods, and (e) advise on the policy to be adopted and the administrative and organizational changes to be made for the policy to be implemented, including the establishment of a practicable bonus scheme to stimulate enthusiasm among the inspectors and other personnel engaged in the works.

Phase II Works

Network Survey and Remapping. Existing maps of the distribution network are probably no longer accurate; many valves, hydrants and fittings have been covered over and can no longer be found; many are not operative. Specialized services are required, using electronic methods, to trace all mains and service connections and to plot on new maps to a scale of 1:1,000 showing correct sizes, materials, positions, and depths of all pipelines at 33 meter intervals. The maps are also required to show topographical details with ground elevations to 0.1 meter accuracy at all major pipework connections and otherwise at about 100 meter intervals. This work is to be undertaken in sections beginning with the older parts of the network and eventually covering the whole network.

An organization should be established to ensure that all future extensions, reinforcements, and modifications are recorded as constructed and that all relevant data is transferred to the new maps.

The adoption of a computer mapping system should be considered and approved by the Authority.

Pressure Zones and Districts. The existing boundaries of pressure zones and districts should be examined with a view to reducing any excessive pressure that may exist and increasing pressure where supplies are inadequate. This process should also ensure that the rates of inflow to each district can be monitored at all times. Where districts have not been established, they should be set up; normally they should not contain more than about 20,000 properties. First, the proposed district boundaries should be determined. When they have been approved by the Authority, a project for installing the necessary valving, metering, and modifications should be designed and specified; construction should be supervised and, finally, tested to demonstrate integrity. The district is to be surveyed demographically, and a monitoring system is to be established and maintained in collaboration with the Authority to enable changes in unit and total consumption to be regularly evaluated.

Waste Detection Division. Consultants are required to advise on the setting up (or the re-constitution and enlargement) of active waste detection and repair services. Appropriate organization and staffing, designed to implement the proposed policy as determined by the economic study undertaken in Section 4.8. of the Working Guidelines should be included. Consultants are also required to provide management services to assist in the operation of this division for a period of about four years and to ensure its continued operation thereafter, as may be dictated by economic policy, so as to increase the control of all forms of waste water. The consultant's duties should include, but not be limited to, a review of, and advice on, current procedures for applications for new water services and on customers' internal service and plumbing repairs.

Bylaws. The Authority proposes to request the Government to introduce legislation for the introduction of (or alternatively to reactivate the operation of) bylaws for the control of waste water. Consultants are required to advise on all aspects of the implementation of this policy, including the provision of a plumbing inspectorate to ensure compliance with required standards of fittings and plumbing and with the specifications for all new main laying and repair works. Particular emphasis has to be placed on public relations and, if necessary, on proposed enforcement methods that may be necessary to ensure compliance with the bylaws.

Network Analysis. In order to improve operation and control of the overall program; that is, to extend control of UFW and to determine least-cost network reinforcements to meet planned expansion of the supply, the Authority proposes a computer analysis of the existing network. Following the network survey in Section 4.9 of the Working Guidelines, consultants are required to undertake the necessary network analysis and to ensure correct calibration that represents current conditions. It is expected that certain anomalies may be discovered and that modifications of the network may be advisable in order to simplify operation or reduce the range of operating pressures and thus to reduce waste. Consultants are required to examine all possible modifications and, subject to an economic study, to advise on and to design and specify works for metering those changes that are justified. The network analysis is amply justified to achieve effective control of UFW as well as improved knowledge and operation of the system.

Network Reinforcement. A natural corollary not strictly related to UFW control is the use of the network analysis for least-cost reinforcement of the network in order to meet planned expansion of water supply. This work may be conveniently included in the terms of reference for consultants, who also may be called upon to design and supervise the construction of new main laying work and to ensure improved standards, thus preventing perpetuation of excessive underground leakage.

Continued Advice on Maintenance and Associated Management Services. The Authority is aware that the problems of excessive UFW are only one example of inadequate attention to maintenance of all parts of the system resulting mainly from lack of sufficient trained and experienced personnel. The aim is to correct this situation by improving the training of personnel at all levels and thus improving the management and organization so that a higher level of service and a more reliable supply of water is made available to meet future needs. Consultants are required to maintain a presence of experienced operators working in the Authority for a period of about three years after the conclusion of the contract covering the above works. These operators are to be engaged in in-house training of personnel, advice to the Authority on improvements of operation and maintenance, and ultimately in achieving independence of consultant assistance.

Reports

Consultants should provide the Authority with monthly progress reports during Phase I works, together with a separate report at the conclusion of each of the itemized works.

Consultants are required to prepare, in consultation with the Authority, monitoring indicators and a reporting system designed to provide clear information on the physical achievements and overall progress completed during Phase II works. At the conclusion of these works a comprehensive report is to be furnished giving full details of all data collected and all accomplishments.

The reports should have a succint executive summary (both in English and the local language) which should have clear conclusions and recommendations.

All reports are to be presented in English (30 copies) and in the local language. The number of local language copies should be decided in consultation with the client.

SECTION 4

EXTENDED ACTION PROGRAM FOR REDUCING NONPHYSICAL LOSSES

4.1 General

In the past, some authorities have had serious problems with meters owned by consumers, and this practice has hopefully now been superseded. The consumers' meters must therefore be owned by the authority, which will set an appropriate rental charge to cover the initial cost, installation, and maintenance costs. The choice of meter type depends on the quality of the water but, for all large industrial or small domestic purposes, rotary piston meters are normally preferable to inferential turbine (multijet or single jet) meters because of their greater accuracy. The meters should in most cases, be protected by additional strainers to limit erosion or seizing of the moving parts. However, if the water supplied contains large quantities of sediment, sand, or rust it will seriously interfere with rotary piston meter performance and life. There could then be a justification for using inferential turbine meters.

4.2 Domestic Meters

Domestic meters are normally 15 millimeters in diameter, but some authorities have standardized on 22 millimeter diameters because of past low pressure problems. Rotary piston meters are normally constructed to comply with I.S.O. 4064/1; inferential (turbine) meters should comply with American Water Works Association Standard C-708. (European Economic Committee and other acceptable standards also exist.)

Meters are subject to gross inaccuracy at low flow rates and this inaccuracy increases with age long before the meter fails completely (see Section 3.10).

Where past supplies have been discontinuous, the practice of installing very large storage tanks to cover periods of deficient supply has evolved. This has encouraged the practice of throttling the supply so that the tanks are filling slowly over most of the 24-hour period, with the result that underregistration prevails at all times. A special charge could therefore be considered for consumers with individual storage tanks. If at all possible, the authority should aim to purchase all large tanks and provide smaller replacements once a continuous supply under pressure can be assured. Alternatively, the tank could become redundant, or its capacity could be reduced with volume displacers; such as concrete blocks or bricks.

Recent research has shown that for all normal requirements 15 millimeters is unnecessarily large. It provides for normal flow rates of 1,500 liters per hour (the 22 millimeter diameter will pass up to 5,000 liters per hour) whereas 750 liters per hour is adequate where there is indirect plumbing and could be obtained with 10-12 millimeter diameter meters. The same findings were reported from Brazil, where smaller prototype meters with 15 millimeter diameter outlets have been produced. Tests show that, whereas with 15 millimeter diameter meters the average underregistration of new meters in normal use exceeds 5 percent, with smaller diameter meters of 750 liters per hour rating, the average underregistration is about 2 percent.

The "small body" domestic meter with a rated flow of 750 liters per hour may be used in the future to minimize underregistration at low flows, but initially it should be tested on a small scale. The problem is that the moving parts have smaller clearances and the meters may therefore be more prone to failure with water that contains excessive matter in suspension, which cannot be eliminated by protective screens. Such meters are in production at a slightly higher cost, which would be offset by increased water sales and, in any event, this extra cost might be reduced by increased orders. Selection and procurement of water meters is a complex matter and requires assistance from specialized consultants.

When an authority reports that say 25 percent of its meters are inoperative, it is probable that at least another 25 percent are recording only a fraction of the flow. When a meter is not operating, the practice is to charge based on an estimated flow. This estimate is based on registration recorded before the meter failed, and so is likely to be a very low estimate.

Lack of proper maintenance of meters is thus a prime cause of nonphysical loss.

4.3 Large Meters

In most cities, whether or not domestic supplies are metered, a very large proportion of the water consumed is sold through relatively few large diameter meters for bulk supplies to neighboring authorities or to industry, commerce, military camps and large government institutions or other public entities. It is of great importance to ensure that these large quantities are being recorded correctly; as they are few in number this is a relatively easy task. The first and most essential task is to site check whether these meters do record normal and low flows within the normally accepted tolerance of ± 2 percent. To ensure this, the meters must be tested frequently (at least annually) for accuracy. They must also be changed, cleaned, repaired, adjusted as necessary, and shop tested before reinstallation. These tests must be undertaken at both very low flows and normal flows. Although accuracy at low flows is difficult to ascertain, low flows may persist for long periods and represent large quantities of water. The larger the meter the more frequently it should be site tested and, if necessary, changed for shop refitting and testing. Depending on the quality of the water, routine replacement of the very large meters every two years may be found cost effective.

The size of the meter should be appropriate to the maximum rate of demand without unacceptable loss of pressure. When demand is very high, compound metering may be necessary. Industrial demands fluctuate with business cycles; where a decline in business activity and in the rate of demand has occurred, a change to a smaller meter may be warranted. Otherwise, an unnecessarily high proportion of the flow may be subject to excessive underregistration.

An independent historical check should, if possible, be carried out to ascertain how consumption relates to the volume of business. If at any time the increased activity is not reflected in increased consumption, an explanation should be sought. Likewise, an increase in metered demand without a corresponding increase in business activity should be investigated. It could be due to a major leakage or other type of waste on the consumer's premises. Irrespective of changes in demand, an independent check is justified to confirm that the size of the present meter corresponds to the maximum and minimum rates of flow recorded.

The site testing of these meters may be by isolation and timed volume change in the consumer's private storage. If this is not possible, provision should be made when the meter is installed for a spot test at any time by discharge to waste through a test meter. Valves closed for this purpose must be checked to ensure that they shut off flow effectively.

The choice of manufacturer and type of meter is important. For most purposes displacement meters are favoured for greater accuracy but, where failure of supply could have serious repercussions (for example, at a hospital or where expensive material is being produced), local storage is essential. If not possible, an inferential turbine meter would be required, which probably would be less accurate at low flows.

4.4 Meter Reading Procedure

While the maintenance of meters, including changing, repairing, and testing, normally falls within the duties of the distribution manager, the reading of the meters, together with billing and collection of charges, is the job of the financial manager. A common procedure is for the authority's area to be divided into meter districts; each meter reader covers a block of properties within that district. Sometimes there is provision for interchange of blocks between the different readers.

Quite often meters are read and accounts sent out at bimonthly or quarterly intervals. The actual reading dates are spread over the whole quarter, but the period between readings is about 90 days. For this reason, a comparison between production and consumption figures over a short period is not valid unless special correlated readings are made for that purpose.

Although the reading of domestic meters is reasonable at bimonthly or quarterly intervals, this may not be the case for the larger industrial meters. Investigations will show whether it is not more cost effective to read the larger meters every month. This not only would permit improved collection, but would also ensure that any defective large meters are replaced with minimum delay. The larger the meter, the more frequently it should be read.

Meter failures frequently result from excessive grit and rust particles in the water. This usually occurs because mains are not being flushed systematically. Flushing is most effective from washouts discharging to drains, ditches, or culverts, but flushing from hydrants is necessary where washouts do not exist. (Hydrants are essential on all dead ends of mains and should be spaced about every 100 metres.)

Irregularities in meter reading procedures can be rapidly detected if computerized accounting is introduced and programmed to throw up such anomalies. Failing that, frequent spot checks by management may be necessary.

Concentrate on large meters and institute program of (a) more frequent reading according to size; (b) regular (annual) testing on-

site or replacement; and (c) critical examination of records and follow-up. Consider monthly reading and quarterly testing of meters 3 inches in diameter and over.

Study general meter reading procedure and results. Undertake spot tests by management for sample study of reliability of meters and meter readings. Undertake sample survey of illegal connections in selected areas. Take steps to eliminate irregularities and anomalies.

Establish a program for regular (four-to-five year) meter changing and testing. Commence color coding or similar identification method. For this purpose a sample study of the meter condition is required; it also detects any installation problems.

Examine records of meter failures and failure to register low flows. Consider standardization appropriate to the operating conditions of type, and normal domestic diameter to minimize low flow errors. Examine a mains flushing policy and water treatment procedures to improve water quality and reduce meter failures. Alternatively, consider the use of "flow limiters" instead of meters. A pilot study should be made because some flow limiters are useless under conditions of low pressure. Determine policy and purchase additional or replacement meters necessary to meet future need. A local university might be approved to undertake these tasks as a research project.

NOTE: The reading, billing, and collection procedures, including costs, should at this time be reviewed by management, with technical assistance as necessary, and designed to improve data retrieval, as well as to highlight leakages on consumers' premises, and reduce irregularities, underregistration, and illegalities.

4.5 Meter Repairs and Testing

The procedure of changing meters at regular intervals requires the existence of a meter repair shop for cleaning, repair, and testing of defective meters. To be effective, the annual output of reconditioned meters must be about 25 percent of the total number installed (and 50 percent or possibly 100 percent of the total number of large meters).

If the current capacity is inadequate, the location of the site in relation to the center of demand, traffic problems, and journey times should be reviewed before expansion is planned. Having established the best location, capacity may be determined on the basis of two-to-three square meters for every meter to be serviced per day. This space will allow for receiving old meters, cleaning, repairing, painting, storage, testing, and dispatch, as well as office space for records and storage for new replacement meters.

It is essential to ensure that accurate testing is done at very low rates. For domestic meters and indirect tank supply plumbing arrangements, a low rate would be about 15-to-20 liters per hour; for larger meters, proportionate increases in minimum test flow are allowable. The recorded flow should not show more than ± 2 percent difference from the flow as measured by tank volume changes.

One test line may be expected to cover about 50 domestic meters a day. Many of the meters will require only cleaning but experience indicates that between 10 percent and 20 percent will probably require repairs.

It is recommended that all meters be painted a distinctive color to denote the year they were reconditioned. This will help to ensure that all meters are changed at regular intervals.

A study of the records of meter breakdowns and repairs is a necessary preliminary to the formulation of policy on the selection, installation, and maintenance of meters. If no records are available, they must be started as soon as practicable. Records should be kept on cards or in a form by which data can be rapidly retrieved to show manufacturer, type, size, frequency, and nature of failures that have occurred.

If records show very frequent failures because of suspended solids in the water, the use of modern flow limiters through which the flow rate remains fairly constant over a wide pressure range should be considered, and a pilot study should be made.

A study of output per person may be necessary in order to ensure that an expanded meter workshop is designed to minimize the cost of repairs. This study should include the cost of meter replacement, including transport to the workshop.

Study meter repair and testing shop procedure and capacity. Amend procedure as necessary to ensure testing at very low flows. Consider incentives for improved output of testing and repair. Study output per person and future manpower requirements. Study records of meter failures and establish necessary data retrieval procedure for reducing failures. Design any necessary expansion of meter testing and repair workshop.

4.6 Boundaries of Districts

The disparity between boundaries of meter districts and distribution districts often causes problems. Because of this difference, no accurate comparison of district production and demand can be made. This problem may be overcome by a one-off survey that allows the distribution district number to be entered on each meter account so that, with computerized billings, meter consumption for each distribution district can be readily totalled. Where billing is not computerized, correlation of boundaries becomes a much more difficult task that could entail physical changes in the boundaries of meter districts and even of meter readers "blocks."

Moreover, if changes in distribution zones are required in order to reduce leakage by reducing pressure on consumers' services, a change in the meter reading district boundary may become necessary. Such changes may not be easy to achieve.

Examine all possible means of correlating meter consumption statistics with distribution district boundaries, including any necessary boundary changes.

4.7 Review and Further Action Program

After consideration of the various factors involved in providing and reading consumers' meters, as well as any associated needs for additional or replacement meters and facilities for the servicing of meters, it is time to evaluate any improvements that have been effected and to consider any additional changes that appear necessary. Such changes might include: further modifications of the meter reading procedure, upgrading the meter reader's responsibilities and rewards; arrangements for replacing meters; meter workshop practices and requirements for expansion; training existing employees and recruitment and training of additional employees. Any training required for upgrading responsibilities may best be undertaken in-house by existing employees, but technical assistance from an external source could also be of great value. Against any associated increase in costs will be set the improved revenues already experienced and additional revenue foreseen.

Future improvements will require extensions to capital works and increased labor costs. In addition, provision should be made in the estimates for establishing a pilot metering area where ideal conditions are maintained, in order to determine the maximum increase in revenue that may be achieved and any other associated operational improvements. This pilot area should, if possible, be the same as that selected as a pilot waste water district (see Section 5.9).

At this stage, estimates of further costs envisaged and budget approval must be obtained.

Monitor and evaluate results and budget for further actions.

Expand meter testing and repair shop; recruit and train any additional employees required.

4.8 Incentives

Some meter readers may have no duties other than to read meters, but frequently they also distribute bills and collect payments. Although it is responsible work, it is normally not well paid. Some countries have found that one of the best incentives is to provide a good uniform which also adds to the public respect for water, and for the water authority. Beyond this, it may be asked whether the meter reader's responsibilities could be increased and her salary improved accordingly. It bears repeating that the meter reader is probably the only employee of the water authority who actually meets the consumer and is therefore a potential public relations spokesperson. She is in the best position to notice waste of water as well as leakage; she could, more easily than anyone else, locate illegal connections. Could she be paid a bonus for reports on wastage, leakage, or illegal connections, and could the bonus be related to the resulting reduction in UFW? Given proper training a meter reader could record readings intelligently in relation to population and usage on a property and note any unusual variations in consumption patterns. She could certainly receive complaints and report them; she might even be able to deal with some of them. Could she not also be trained to change defective meters instead of just reporting them? Would it be cost effective to combine her duties with detailed leak detection?

Alternatively, meter readers, inspectors, and fitters might be formed into loose teams for joint action. The word "loose" is important because frequent interchange would help to reduce any meter reading anomalies, inaccuracies, or irregular practices.

One other incentive that has been tried is giving discounts on water bills for leaks reported by the consumer.

4.9 Women Meter Readers

It has often been suggested that women should be employed as meter readers. Admittedly there could be problems in many countries (in Muslim countries it would not be possible) but it is a proposal that merits serious consideration. In China, for instance, it would probably be wholly acceptable. After all, meter readers operate during normal working hours, and it is the women of the household whom they can usually expect to meet. Women meter readers may be more acceptable to the consumers. It has been suggested that the particular abilities of women make them more conscientious in such tasks and that they would have the eye for domestic detail which might reveal irregularities in the readings and which might escape the notice of a man.

One of the unfortunate traditions is that the meter reader is on a low salary scale -- possibly so low in some countries that dishonesty is encouraged. It may be that, in some countries, the low salary would be sufficiently attractive to recruit women. No doubt it would have to be tried on a small scale and one possibility that could be explored would be to include women as part of a team as suggested in Section 4.8.

Any change in meter-reading procedure contemplated following considerations such as described here and in Section 4.8 should be initiated in a pilot area. Such pilot areas should preferably be the same areas selected for investigation of physical losses (see Section 5.9).

Examine all possible incentive schemes to encourage employees' enthusiasm for improved metering, while retaining in-house procedure. Consider improved status and possible rewards to meter readers for reporting defective meters, leakage, irregularities, illegal connections, and so on. This activity should be under continual review and could well begin much earlier (see Section 2.2.3). Remember that, because the meter reader is the only employee known to the public, improved public relations must begin there.

Examine the possible employment of women meter readers who are interested: (a) as the major users of water, to ensure its availability at all times and at low production costs by reduction of waste and (b) as keepers of the domestic purse, to ensure equitable payments by all consumers.

Select one or more possible pilot metering areas for correlation with pilot waste water district. Pilot area networks must receive

intensive cleaning, regular flushing, and generally improved maintenance to determine the effect on meter failures.

4.10 Meter Reading by Contract

In countries where the provision of public water supply is privatized, underregistration and other domestic metering problems appear to have been largely eliminated. There may be political objections to the privatizing of any part of a public service, but where the public service is already failing to produce equitable charges such objections might possibly be overruled. In other countries there may be no such objections, and there such a policy should be considered. Much depends on the terms of the contract. One suggestion is that payment to the contractor should depend on the total quantity of water recorded from meters for which a charge can be made. This does invite a contractor to overrecord consumption and, particularly where a meter has failed, to record an unreasonably high estimate. There is, then, a risk of producing bad public relations that the authority will wish to avoid. Independent spot checks might overcome such objections.

In this connection, recent research on the accuracy of small meters has shown that new meters by one manufacturer recorded objectionably high at low flow rates, with the result that some consumers would probably be overcharged. Such factors indicate that management needs to carryout overall inspection of any contract to ensure that it is being implemented fairly.

Any contract for which payment is based on results should probably include all aspects of metering, including the remapping of service connections. The selection, installation, maintenance, repairs, and testing of meters would have to be included, along with meter reading and possibly invoicing as well. If illegal connections have not already been surveyed and eliminated (see Section 3.7) this work could also be included in the contract.

In spite of the attendant difficulties, privatization has an appeal which cannot be ignored. A cost/benefit study should be undertaken, for which assistance by a consultant may be required. If studies indicate that privatization is justified, implementation of such a policy should preferably be in stages. The plan could begin with operations in one pilot meter district alone for at least one year. After monitoring and evaluating the results, future policy can be decided.

Undertake, in-house or by consultant, a cost/benefit study of privatizing all meter reading (and possibly billing), using an incentive type of contract. The contract may or may not include meter testing and repair, and the survey and remapping of consumers' services, including illegal connections.

Subject to the results of the study, implement policy of contract metering by starting in only one district.

Monitor and evaluate achievements. Make policy decisions on all further consideration of improvements to metering and any associated billing procedures.

4.11 Three-Year Program

The task force must be instructed to prepare and maintain a program for identifying the extent of the nonphysical losses and for reducing these losses to an acceptable figure within a period of two to three years (see Annex 2A). This program will begin and will extend over the same period as that for the reduction of physical losses. Likewise it will be essential to continue excercising control over the ensuring period for the nonphysical losses to be eliminated.

SECTION 5

EXTENDED ACTION (FIRST FIVE-YEAR PLAN) FOR REDUCING PHYSICAL LOSSES

5.1 Existing Conditions

5.1.1 Organization for Leakage Control: A Reappraisal

During the "immediate action" period an attempt should have been made to check basic data as well as possible with the equipment available; to set up a division within the authority to carry out preliminary tests of the system and the equipment; to develop a program for further action based on preliminary economic analysis; and to develop an overall future strategy for additional control of UFW.

If the strategy is aimed at further pursuit of leakage control, the first step may be a more detailed review of present conditions prior to taking appropriate actions. Following the completion of the initial investigations and immediate works, there should be more confidence in: the accuracy of measurements of the quantities of water produced and distributed; the percentage inaccuracy of consumers' meters; and the revised estimates of actual consumption for domestic, commercial, and industrial purposes. These figures will have revealed the extent of nonphysical losses and, by deduction, of physical losses as well. Policy has been determined as to how much additional effort will be exerted initially in reducing "physical loss" by improved detection methods and repairs of leaks.

Assuming there has been a "passive" leak detection program in the past -- that is, locating, pinpointing, and subsequent repair of leaks reported by the public -- it now has to be decided whether the existing personnel, equipment, and organizational arrangements should be retained and expanded or supplanted, to comply with future policy needs.

It is likely that existing employees will have some, and possibly a great deal of, experience in detecting leaks, combined with a wide knowledge of the system. Often the inspectors have some equipment for locating mains and valves, as well as simple listening sticks, stethoscopes, geophones, or other electronic amplifying equipment; they may also have a modern correlator. They may have some, or a great deal of, experience and knowledge in locating leaks by use of the equipment. (Sounding techniques, insofar as it is possible to describe them, are discussed in Annex 3B.)

For any effective improvement to be made in leakage control, employees must be well screened. Those selected for retention should be provided with some incentive, such as an appropriate uniform, which is of much assistance for the necessary entry on to private premises.

A review of the current repair organization is required at this stage. This review should cover not only leak detection, but also the repair situation, including delays between detection and repair and details of any current backlog in repairs.

It has been stated that, with the introduction of an improved detection process, demand for repairs will increase. But the immediate backlog will be relatively short-lived and, once it has been dealt with, the existing repair staff will probably be able to handle any problems. This is not necessarily true, however, because if physical losses (measured as a percentage of net production) appear to have been fairly steady over recent years then, as the system has expanded the actual number of unrepaired leaks has increased. In such conditions the repair staff has not been adequate.

With the introduction of improved detection, then, a permanent increase in repair staff will probably be required. But the short-term need may best be met by employment of contract labor, as long as adequate supervision is provided and good standards are ensured. Sufficient plant must also be provided.

At this point, a preliminary estimate should be made of the probable labor requirements for dealing with the increased volume of leakage likely to be found.

> **Review existing procedures for leak detection reporting and repairs. Consider all possible improvements using only existing employees, including more intensive visual inspection particularly in dry conditions and in periods when pressures are high (see also Annex 3). Determine the extent of delay in repairing reported leaks and take action to reduce any backlog including, if necessary, temporary additional contract or other labor. Review existing equipment and assess needs. Intensify repair organization as necessary to deal with extra leaks detected. This may be needed only temporarily, until the backlog of leaks found disappears.**

5.2 Mapping, Records, and Network Analysis

(See also Section 3.8.4)

Control of UFW entails the continual repetition of a series of simple, logical processes and tasks to obtain increasingly accurate detailed data that facilitate ever-more-efficient detection of deficiencies. Mapping is no exception; it is a continuing process required for meeting the needs of system expansion and new demand.

Maps and records should already have been given some attention, and hopefully some updating and improvement has begun. These preliminary improvements can now be examined, and decisions can be made regarding further improvements required, particularly regarding how much can be done in-house and the extent to which specialized contractors should be brought in for assistance (to locate buried valves, map all mains and services, and so on). The future computerization of mapping should be kept in mind for any contract work. In any case, mapping should include elevations of all valve and hydrant covers and other key points for future computer network analysis.

Many records may have been kept that apparently have no permanent value. Yet with a little expansion or modification they may be useful. For instance, a continuous record of leaks detected and details of repairs carried out will show the existing time delay, although otherwise such records may never be used. If these reports were cross-referenced by street, a valuable record would be built up to show where leaks are concentrated and the cost of individual repairs. Such data would be useful in determining when complete refurbishment of a section of the system would be justified. Computerization of records would, of course, make data retrieval simpler. It is reported that in Holland costly individual repairs may be replaced by computerized data retrieval followed by wholesale system replacement.

With the completion of district metering and the monitoring of results, little more can be done to improve the leak detection process without accurate mapping of the network. The mapping that is required is not just geographical. For logical leak detection, knowledge is required of the material and age of all pipework, valves, and fittings. This information must be built up slowly by studying old records.

Such information is also required as part of the normal operation of the undertaking and is invaluable for developing computer network analysis. A network analysis may be required at this stage for other purposes, such as economical network reinforcement. Remapping could also be of enormous benefit for modifying zone or district boundaries.

Review progress on whatever remapping of the distribution network is necessary, beginning in the areas where the greatest leakage and metering problems are expected. Remapping should include finding, exposing, marking, and numbering all valves. This work may best be done in conjunction with remapping of consumers' service connections. Consider having all remapping completed by private contractor (covering also the possibility of computer mapping in the future). This work should be done at the same time as the work outlined in Sections 2.3.6 to 2.3.11.

5.3 Future Training, Labor, and Equipment

Where a program of intensified leak detection is proposed, training with an authority in a developed country is invaluable, even when employees already have some experience. Training centers exist in many developed countries where collaboration with water authorities will provide intensive practical training covering a wide range of equipment and methods (see also Section 3.8.3.iii).

In the first instance, training might be limited to three or four carefully selected employees who will be directly engaged in leak detection and one engineer or technician. The latter can then play a key role in organizing the intensified service and recruiting and training additional inspectors.

If this is not feasible, an alternative might be to engage some other authority or a specialized consultant/contractor to undertake all additional training "on the spot," providing any additional equipment required as part of the training. The training might also be related to a contract for the first phase of leak detection.

Such training should facilitate an assessment of the additional labor and equipment required to fulfill short-term, and possibly long-term, policy. Suitable equipment is manufactured by a number of the developed countries under various trade names. Most LDCs have technical connections with one or more developed countries and can obtain details of equipment available from the consulates.

Arranging for such training is one of the first steps to be taken in implementing a program for improved leak control.

> **Arrange for additional training in leak detection of employees selected from existing leak inspectors as well as one engineer/technician suitable for providing future extended training. This training may be on the spot, but initially should include training with a foreign water authority. (See also Annex 5A.) Purchase additional equipment considered essential. Establish stores inventory for all tools and equipment.**

5.4 Technical Assistance

When an authority is unable to devote the time of its own staff to a detailed study of the economic justification for and the establishment and operation of an active leak control program, there is a clear need for assistance by foreign consultants (which may include a foreign water authority). When this is necessary, it is essential for the associated contract to include a major item for training an adequate number of the local staff to continue the program.

It must be stressed that leak control is not a short-term actvity which once begun can then come to an end. Experience shows that unless the control program is perpetuated indefinitely, soon after cessation the UFW figure is as high as ever. The need for appointing a competent, long-term consultant to assist the authority should be seriously considered.

A key part of any contract with a consultant is the establishment of an effective permanent organization in the authority and a commitment to continue advising the authority on the detailed solutions of problems encountered during the first year or longer. Of equal importance is provision by the authority of a sufficient number of suitably motivated, intelligent, and qualified "counterpart" employees to undertake on-the-spot training and take over the operation at the end of the consultant's contract.

The organization must be established either before or at the very beginning of the consultant's contract, if it is to be fully effective. There are far too many consultant's reports scattered around the world recommending institutional changes, personnel training, purchase of equipment, and overall programs for improved leak control that have never been implemented and are at best coated with dust -- or at worst, lost.

In order to avoid this it is often better for an authority to set up an organization with the help only of an individual consultant for initial advice and subsequent follow up as necessary to help renew enthusiasm and initiative as well as to overcome difficulties.

If considered desirable, apply for and obtain a very brief preliminary study and advice from external source such as (a) foreign water authority, (b) individual expert, or (c) Bank or other technical assistance. This study is to assess short-term needs and to advise on action program from time to time.

5.5 Pressure Reduction (see also Section 6.3)

During the immediate action program there should have been some preliminary tests of the effect of pressure reduction on leakage. It is only recently that the impact of increasing pressures has been fully appreciated. Previously it was assumed that the leakage flow would follow the orifice formula, in which the flow is proportional to the square root of the pressure. Evidence is now clear that in most areas the pressure flow relationship curve does not follow this formula; instead, it normally curves in the opposite direction, which is much more serious. This phenomenon appears to result from the flexing of splits and similar openings so that the orifice size increases with pressure. The emphasis is now placed very firmly on effective control of leakage by making all practicable reductions in pressure (see Figure 3-3).

This may be achieved by means such as installing pressure reducing valves (PRV's); utilizing break pressure tanks to increase the number of different pressure zones; reinforcing the network to minimize friction losses and permit operation with reduced working pressures; changing the service connections to mains operating at lower pressure; or introducing speed control or other means of reducing night flows from pumps.

PRV's may be installed in a leading main adjusted to be fully open and to provide no reduction in pressure at times of peak flow but to operate as flows are reduced, thereby preventing the build-up of pressures during the night. Better control is achieved by means of telemetry-controlled PRVs.

In some cases, zone boundaries may be changed to reduce excessive pressures.

Every possible means must be considered for effecting reductions in pressure, but unless the effectiveness of any change can be accurately measured, there will be no way of making a cost/benefit study of any proposal. Measures adopted must therefore follow accurate pilot studies or temporary tests introduced by manual valve throttling or other means. There is, of course, a strict limit to the number of changes that can be justified in economic terms. Regular monitoring of pressures in all parts of the district should be instituted so that the results of pressure modifications may be evaluated. In the first place, any tests undertaken during the Immediate Works program for measurement of pressures and night flows in a pilot area may be extended to other areas.

Make every effort to reduce all excessive pressures in the distribution network at all times of day and night. First reductions should be by selecting and isolating a pilot area, and monitoring the effect by meter. Pressures and resulting leakage frequently increase at night, and reductions in night pressure may be achieved by simply installing in-line pressure reducing valves (PRVs) without

significantly reducing the daytime pressure necessary to ensure continuous supplies. A careful survey of fringe areas to zones and reconnecting of service connections can be rewarding. Interzonal leakage must be strictly controlled.

5.6 Monitoring District Flows

An initial check on net production should have been made as part of the immediate action program. Further checks are required not only of net production for the whole system, but also of the separate zone and district flows, at regular intervals at least four times a year and preferably much more frequently. The initial flow figures were, at best, estimated; but every effort must now be made to install meters to record or at least indicate flows over a 24-hour period into each zone or district.

When a district is first established, all waste detection should be concentrated in that district and consumers' meters should be checked in order to determine the bases for demand and consumption. As conditions improve over the years, these bases may be lowered. But they are needed at this point for comparison with the flows recorded each time the district demand is monitored.

Regular monitoring of district flows is the simplest method of locating leakage areas and, if inspectors are concentrated in those areas, of effectively controlling leakage. Even where an authority has introduced waste meter districts over the whole system, there are times when inspectors are not able to monitor the "waste" districts. In such cases, control can be effectively exercised through evaluation of district meter flows. One important method of improving control, particularly where waste-water districts cannot be operated, is to gradually break down the main district into smaller districts, each of which can be metered.

Where district meters have not yet been installed, they should now be regarded as essential. Once installed, the meters must be tested for accuracy at least once a year. Any necessary improvements should be made in metering, in order to facilitate regular monitoring of flows (see Annex 5B).

Isolation valves between zones should be checked regularly to ensure that they are not "letting by" at any time. Valves between districts should not be "letting by" during flow tests. It is likely that this will entail considerable work on valve reconditioning -- or scrapping and replacement. Pressure checks both inside and outside the boundary are necessary to test valve integrity and to ensure that there are no unknown cross-connections.

District meters must be of a size suitable for measuring the whole range of flows with reasonable accuracy. They are normally installed on a bypass but, where this is impracticable, turbine meters inserted under pressure are very valuable. They should be integrating and recording as well as indicating, unless it is found that standards of maintenance are such that the simpler indicating meters are more reliable. A common size meter for small districts is 6 inches; for larger districts, two or more entry points with 6 inch meters may be better than using a larger meter.

The presence of large private tanks and indirect plumbing may limit accurate testing to low demand periods, when flows can be monitored to give meaningful results of net night flows. But tests made at times of high demand can also provide valuable information and should be undertaken when feasible.

Check the 24-hour variation in production for the whole system and, as it becomes increasingly possible, for separate districts. (See also Annex 5B.) This normally has to be done during a period when demand is low, and when it may be expected that all private tanks will have been completely filled during the earlier part of the night.

5.7 Minimum Night Flows

Data on inflows to each zone or district are of inherent value since variations in these flows over successive periods will help to reveal hidden losses. But these gross night flows cannot be strictly correlated with losses, because they will almost certainly include night consumption by industry or public services, such as hospitals.

The aim is to determine the night-flow rates, if possible including variations throughout the night, for all the large meters in each district. Normally, where there is legitimate night consumption it is possible to arrange for this to be recorded by the consumer who, if properly approached, will appreciate efforts to reveal possible leaks or waste in his network. Unmetered night consumption by public lavatories, street cleaning, and so forth must also be estimated.

Having determined the figures for nondomestic consumption during the night and deducted this figure from the gross inflows for each district and for the system as a whole, the net night flow can be determined and expressed as a percentage of average demand or in liters per property per hour. This figure will vary for different districts and for different authorities depending on a number of factors, including the average night pressures in the areas where leaks are prevalent. It should not be greater than 25 percent of average in any system. It should be possible to reduce the figure below six liters per property per hour (4.3 cubic meters/property/month) by intensive waste control measures, but the target in an old system is unlikely to be less than ten liters per property per hour.

The minimum net night flow is likely to be the best indicator of whether or not there is excessive leakage.

Retest production meters (or estimates). Repair or install additional meters as necessary. Install additional meters at all treated water and source pump stations, service reservoirs (inlets and outlets), and boosters. Test for leakage in (a) service reservoirs and (b) transmission mains. Begin regular monitoring of production and district flows.

Take sample readings on all large consumers' meters to assess industrial and commercial night consumption for the whole system. Adjust the total night production flows to determine the net (domestic) night demand and express as a percentage of production. This figure should not exceed 25 percent (or 10 liters per property per hour). Repeat for each district.

5.8 Inspectors for Valve and Hydrant Operation

The inability to operate valves effectively is probably the most difficult problem to be overcome when introducing any form of active leak detection.

Frequently this stems from low standards of construction for the initial main laying and the perpetuation of low standards in the repair works following mains fractures. Great care must be exercised to prevent the entry of stones or, during repairs, to remove stones and debris from inside pipelines. All too often one sees main laying or repairs in progress with no attempt at protection of open ends and no subsequent high rate flushing out of the system through washouts. When stones and grit are not removed, they inevitably become trapped in the valve seatings and prevent effective closure.

If valves are operated carelessly, with excessive force, and no attempt is made to dislodge grit by repeated careful opening and closing against high flow discharges, the usual result is a valve with a bent or broken spindle, which is quite inoperable. Similarly, the attempted operation of a larger valve by one person produces an eccentric force and, again, a bent spindle.

Another problem arises from lack of care and discipline in the operation of valves. When valves are shut off for repairs, closing one valve on each side of the repair will normally suffice. But if they will not close effectively, then more remote valves must be closed until the flow can be shut off. The problem then is to remember, when the repair is finished, to open all the valves that have been shut off. This problem is compounded when some of the valves in the system close clockwise and some counter-clockwise, since it becomes difficult to determine which valves have been reopened.

Unless rigid discipline is exercised many valves in a system are left closed, with the result that flows and pressures are reduced, supplies fail, and the quality of the water in "dead" lengths of main deteriorates.

A further difficulty arises when, as a result of road resurfacing, valve covers are broken or valves are covered over and lost. Frequently there are no valve marker posts to assist in relocation. Similar problems occur with buried hydrants.

These problems usually occur when the responsibility for valve and hydrant operation and maintenance is not clear. Experience shows that it is essential that all such operations be undertaken by a limited number of experienced and responsible employees, who may be graded as senior or "district" inspectors.

Experienced, older employees should be trained as senior inspectors and given the sole responsibility for operating and maintening valves and hydrants. No repair gangs should have valve keys among their tools. A senior inspector's main responsibility should be to personally ensure that valves are operated correctly, with labor assistance as necessary. They should also ensure that valves are maintained in proper working order, complete with marker posts, and are repaired or replaced when found to be leaking or in any way defective. An inspector should ensure that valves are not damaged or lost when road works are in progress. Finally, inspectors must protect the mains generally against damage by operations of other utility workers or during road reconstruction.

These inspectors are likely to be more than fully occupied. Yet at certain periods they may have time to undertake leak detection in the area they are controlling.

Before active leak detection can proceed very far, considerable effort will probably be required to find, map, mark, and change all defective valves, beginning with those required to isolate zones and districts effectively. This may prove to be a mammoth task, but the effort required will be amply justified by the improved operation and control of the system.

In some systems the number of valves may not be sufficient to exercise proper control. It may also be found that there are insufficient washout valves or hydrants to permit flushing of the system, either on a regular basis or following shutdowns for the repair of leaks.

In fact, one of the serious problems for leak inspections in some systems is the absence of any direct contact points. Valves are buried; hydrants are sparse; and there are no stop taps on consumers' services except those adjacent to meters situated on private premises not accessible at night. The first essential step in such cases is to restore, and if possible expand, the installation of valves and hydrants.

> **Select top grade district inspectors to have the sole responsibility for all maintenance and operation of valves, including initial location and subsequent guarding of surface boxes (see Section 2.4.5). During the same period install district (or zone) meters. Ensure that districts can be isolated permanently or, if this is not operationally possible, at least temporarily for test purposes. Concentrate leak detection and repair in districts that appear to have the most leakage. Always measure and record the quantity of leakage detected and stopped.**

5.9 Pilot Waste Meter Districts

In developed countries the monitoring of district flows and the consequent concentration of active leak detection in areas with high night flows has been shown to be economically justified, where the marginal cost of water exceeds about $0.022 per cubic meter. This figure is likely to be very different in developing countries, depending on the cost of labor and production.

For any developing country authority, the economic assessment of the cost of active leak detection in relation to the benefit in marginal cost of water saved -- an assessment based on preliminary estimates of net production flows and actual consumption -- has probably justified the provision of district meters and the monitoring of district flows.

As the regular testing of meters and monitoring of flows proceeds, the extent of physical losses in each district can be estimated with ever greater accuracy. At this stage, certain information is required to justify the breaking down of each district into a number of waste-meter districts in order to further concentrate leak detection activity. This information can be gathered by establishing a pilot waste-meter district.

The pilot waste-meter district should be located in an area where there is considerable leakage. For test purposes, it must be isolated from the rest of the network; thus it is essential that all isolating valves be operating effectively. The area chosen should, preferably, be one of the areas selected for accurate measurement of actual consumption (see Section 4.10).

It may be found that to ensure effective valve operation the simplest course is to replace all valves in and around the pilot area. In the process, care should be taken to flush out all the mains thoroughly in order to remove grit and stones.

The area chosen should be operating under a high working pressure at all times and should serve about 1,000 properties. If the area includes a number of nondomestic meters, the night flows through these meters should be readily determinable. Other factors for consideration are demographic levels, ages of mains and services, and previous history of leaks.

The aim is to be able to isolate the pilot area and to supply it through only one connection. To accomplish this, a waste meter of size appropriate to the maximum and minimum flow ratio and a PRV should be installed on a bypass.

The rate of flow into the area must be measured over a 24-hour period. By comparing the flow with the total metered consumption, total physical loss can be determined. As an exercise, this flow can be repeated with the PRV set and maintained at varying lower pressures in order to determine the effect on unmetered physical losses, and consumption.

The pilot area should then be subjected to nighttime "step tests" to determine the night flow to each street, or sub-area. (For details on step tests, see Annex 5C.) This will locate those parts of the area producing the greatest leakage and enable leak detection to be concentrated in those limited areas. Repeated tests, leak detection, and repairs will demonstrate how much water has been saved and indicate both the threshold for acceptable leakage and the cost of detection and repair.

This investigation will be invaluable in determining the extent to which other waste-meter districts should be established in order to optimize the benefits from improved leak detection. Where operating pressures are very low, however, waste meter districts are not practicable.

> **Select one or more pilot areas and install a waste meter, making sure that all valves can be effectively closed. Undertake regular tests of 24-hour and night flows and, if possible, regular step tests. (See Annex 5C.) Initially, test monthly for training purposes; later every six months.**

5.10 Night Domestic Consumption

In Section 5.6, reference was made to the variations found for net night flow in different systems and in different districts of the same system. When domestic consumption is not metered, it is not easy to proceed further in investigating the variations. Although the differences have to be accepted, pilot tests on selected waste meter districts can enable an authority to arrive at reasonably cautious targets for the future.

Where domestic consumption is metered, providing the accuracy of the meters is known, the variations in average per capita consumption between districts can be determined. This figure can then be related to net night consumption in order to arrive at a reasonable target. To make this calculation, some boundary adjustment of meter reading records, or "walks," may be necessary.

These comparisons will help also to reveal possible sampling on other errors in arriving at meter inaccuracies. They will also facilitate a reassessment of the proportions of UFW attributable to physical and nonphysical losses.

Study the 24-hour total production of water in relation to average total metered consumption in each district. For this purpose, boundary adjustments may have to be made to meter consumption records.

5.11 Waste

Wasted water, or simply waste, is an all-embracing term that includes leakage. In countries where domestic water is not metered, waste -- whether the willful failure to turn off taps or drips due to defective fittings -- is normally regarded in the same light as water leaking underground from fractured or corroded pipes and joints. Physical action can be taken by the authority to reduce the latter but the former can be prevented only by (a) the strict application by bylaws designed to prevent the use of bad workmanship and fittings and (b) by public support, through the proper operation and maintenance of private fittings. The waste inspector is responsible for preventing waste in every sense, which includes supplying and fitting approved equipment and checking that it is being used properly, as well as finding leaks. Some authorities provide free re-washering of cold taps in order to improve inspection and to educate the public in the prevention of waste.

In countries where domestic supplies are metered, there has been little concern over waste other than leakage. The view has been that consumer waste is metered and serves to increase the revenue. This view is probably not justified because, whereas normal consumption occurs only for brief periods, waste from fittings as well as leaks on private service pipes may involve only small flows, they are continuous and thus may amount to a significant volume. These small flow rates will almost certainly not be registered on any meters, except during periods of actual consumption. They are therefore of great importance and merit the same close attention as underground leaks from the authority's own system. Recent surveys in developing countries have revealed as high a percentage of defects and leakage in private pipework, even where metered, as on public mains and services. Notices to property owners to repair leaks are often ineffective.

It has been supposed that when an authority has completed a project and has surplus water, waste by consumers is actually of financial benefit to the authority. But this is only true if it is recorded on the meter.

In many developing countries it will be found that: bylaws, if they exist at all, are honored only in the breach; there is no compulsory control or registration of plumbers to ensure a reasonable standard of workmanship or limitation on illegal practices; there are no effective standards for private plumbing fittings; and overflows and drips go unnoticed. Some authorities are better organized and have insisted that all overflows discharge outside the building -- preferably into the public street. Normally, however, such restrictions are confined to authorities in countries where domestic supplies are not metered and where the need for waste control is better appreciated.

Where bylaws exist, they have to be put into practice. After publicizing, repeatedly checking, and serving notices, it may be necessary to resort to publicized prosecution. Where bylaws do not exist, the attention of the central government of the country must be brought to bear on this issue.

(Typical bylaws, not generally applicable without modification, are provided in Annex 5D.)

The cooperation of the public is probably more valuable than the strict application of bylaws, but both will only be established over a long period by education and the gradual improvement of social standards. A public education program should be considered by management.

Inspectors must be trained to appreciate that their work includes discovering waste as well as leakage.

Re-estimate the proportions of UFW due to metering deficiencies and waste.

Review problems of water waste, both public and private, and determine action to be taken by improved education and public relations as well as by strict application of bylaws. Review existing bylaws and make changes as needed. Where bylaws do not exist, prepare legislation for approval by government. (See Annex 5D.)

Experience shows that most leakage problems are due to innumerable small leaks on service connections. Even when domestic consumption is metered, small leaks can often be found on consumers' pipework. Correcting this problem is usually the responsibility of the householder, upon whom notice should be served to take action within a certain number of days. If no action is taken, faults should be rectified at the householder's expense. Repairs are a time-consuming and tedious task. Concentrate the leak detection and repairs in districts where night line tests suggest the greatest leakage losses occur. Do not expect that correlators or other modern equipment will normally solve the problem, though they may be invaluable for locating certain leaks. Monitor and evaluate for a trial one-or-two-year period. Pinpoint possible areas where complete renewal of a network may be the most economical solution.

Make an economic study of the reduction already made in leakage achieved thus far. If this part of the UFW (that is, excluding an estimated amount for underregistration of consumers' meters) is still greater than 12 percent, review the procedure to determine (a) possible improvements in control without changing the basic control method; (b) additional potential savings by introducing waste meter districts or by complete replacement of all mains and services in selected streets (see also Annexe 5B).

Re-examine policy and budget.

Annex 5A. Training

Most large authorities in developing countries will have a few employees who are engaged in locating the source of leaks. They frequently have some equipment for locating pipes and valves, and they should be familiar with the sounding process referred to in Annex 3B. Most of their technique will have been picked up gradually and may, or may not, be effective. Their equipment is often antiquated but may still be effective; it may have been updated and may even include a modern correlator. Up-to-date training may already have been provided by suppliers of equipment. More often than not their experience has been limited, their equipment is outdated, funds have not been provided for improved performance, and most importantly, there has been little interest or enthusiasm from management. The employees have lacked discipline or control and, without these, have suffered from boredom and frustration.

To transform this passive control into some form of active control, a new spirit of enthusiasm--backed by funds--has to be implemented. The best start is to arrange for about three selected employees to be transferred for a period of up to ten weeks to a developed country where they will be given special training using modern equipment and will work with trained inspectors employed by another water authority.

If two or more employees working in the area of repairs could under go similar training, it will be advantageous to the Authority. They can learn to appreciate the standards of workmanship required to ensure the best possible repair under difficult conditions.

If possible, one of the employees selected should be an engineer or technician with an aptitude for teaching. She should then undertake the selection and some training of additional employees required to build up the organization in the area of effective leakage and waste control.

This initial training of a few selected employees should be part of an ongoing program. As the division expands, one of the incentives for new recruits should be the potential to be selected for training abroad.

Overseas training should normally provide short, formal courses at specialized training centers that include:

(a) theory of leakage control;

(b) practical demonstrations and experience in the use of a wide variety of equipment; and

(c) maintenance of and simple repairs to all equipment.

This should be followed by a lengthy period of hands-on operational work during the daytime and at night, covering all forms of active control including recordkeeping and analysis of results. This hands-on experience should include electronic detection of pipelines and cables, experiments on measurement of waste under different pressures, and flow measurements. It should also include tapping mains under pressure, insertion of pitot and turbine flow meters, repairs to pipes and services, flushing mains and sterilization, testing valves to ensure tight shut-off, the use of portable test flow meters, pressure gauges and recorders, and setting up a district metering system and a waste meter district.

Annex 5B. District Metering for Control of UFW

When the manager of a water authority is satisfied as to the total volume of water being put into his distribution network, his next aim should be to learn more about how this water is being distributed. The overall objective is to supply the water as economically as possible. To fulfill this goal, the manager and his staff must have detailed knowledge of how the system performs.

The quickest way to obtain this knowledge is to divide the network into separate "districts" of a convenient size such that the flow to each district is permanently (or temporarily for test purposes only) supplied through one or more meters. These districts may be separate pressure zones or may serve separate areas at the same pressure. The essential point is that the district can be completely isolated, except at the metered entry points.

Ideally the district should include 5,000 to 10,000 properties but, if the authority has no previous experience with districts, it may be more convenient to begin with larger districts and then, as knowledge and control of the supply improves, to break these down to smaller districts. It is simplest if the supply to each district is through only one meter, but if this is not practicable, the use of two or three meters is acceptable. Where the network is based on a ring main supply, the permanent isolation of districts may not be easy.

The meters must be accurate, so they must be tested frequently using a portable test meter fitted to a hydrant. If possible, they should be installed on a bypass, but if they have to be installed on a main conveyor that cannot be easily shut down for the necessary installation of valves and fittings, the alternative is to install either a pitot meter coupled to a transducer (for accurate reading of low flows) or else a small turbine meter. Both of these meters can be inserted under pressure without shutting off the supply. Meters fitted on a bypass are normally the 6" or 8" diameter turbine type or larger, as necessary to measure the maximum flow without excessive loss of pressure. They must not be so large that low night flows are not measured accurately. Regular monitoring will show management how the system is working, what changes are taking place, and what actions have to be taken to meet new demand.

For purposes of UFW control, the aim of this procedure is to monitor regularly the flow to each district over a 24-hour period. If this is not possible, then monitoring can take place during the night hours only. The net supply of water must take into account the gain or loss of water in any service reservoir within the district. It goes without saying that structures such as reservoirs, boosters, and PRVs must be operating satisfactorily, and management must be aware of any reservoir leakage. The district should first be monitored quarterly, then monthly, and later weekly; only exceptionally is more frequent monitoring required.

The records will consist of meter reading books or cards showing variations over 24 hours, or at night only, at monthly or weekly intervals. Graphs of meter readings should be kept to highlight variations. Nondomestic use in each district can be recorded separately and any variations in domestic use, which will include all leakage, will be evident. Domestic use could be translated to liters per property per hour, and the figure for each district compared. Any anomalies can be investigated and, if caused by excessive leakage, will serve to concentrate leak detection activities.

Of particular importance in this comparison will be the average pressure in each district. It must be expected that leakage losses will be higher in those districts with higher main pressures. Pressure variations in each district have to be determined and regularly monitored using pressure recorders installed at strategic points. A lower than expected night pressure is often an indication of extensive leakages.

Having established a district, every possible step should be taken to locate and repair all leakage in that district in order to determine night flow threshold conditions. These may be varied later as monitoring is continued, district comparisons are made, and records are built up.

The regular monitoring of districts and the breaking down of the system into smaller and smaller districts may be found more cost effective than the introduction of small waste meter districts with frequent night step-tests.

Annex 5C. Step-Testing in Waste Meter Districts

Before carrying out step-tests on a waste district, it is essential to go through a checklist to ensure that:

(a) a map of this district has been prepared and is correct (see Figure 5C-1);

(b) a program of the procedure has been prepared, complete with timing instructions for valve operation;

(c) each valve shown on the plan can be found, is operable, is correctly set, and can be closed "drop-tight";

(d) all large meter locations are known and, where necessary, consumers have been notified of shut-down;

(e) the police and fire service have been notified;

(f) all supplies for hospitals and essential services are maintained;

(g) all employees have the necessary maps, instructions and equipment including flashlights, watches, valve keys, cover keys, pressure gauges, fluorescent jackets, and two-way radios;

(h) the waste meter clock is correct and all watches are time-checked.

Incidental equipment for normal repair operations should be available on the spot.

It is essential that any new program be well rehearsed in daylight before proceeding with a night test. Security of personnel should be given special attention. Typical records of waste meter district tests are given in Figures 5C-2 to 5C-8.

There are various types of step-tests, such as the three noted below:

(a) Christmas Tree - This is the standard method extended to give a reverse opening sequence. This extension may not be practical in situations where low night flows are of very short duration.

(b) Open and Close - This is a method where each section is turned off and on again for a brief period so that the supply is interrupted for only a short time. The results are much more difficult to analyze but the procedure may be necessary to better maintain supplies for essential services.

(c) Double Locking - For this test, as the metered supply is cut off to a section an alternative supply is made available from outside the district. This is ideal where it can be arranged but requires more labor and an assurance that all valves, not only the boundary valves, close drop-tight.

When conducting such tests it may be desirable to have in mind that: it is impracticable to find and repair all leaks; it may be uneconomical to repair large numbers of small leaks. Figures for acceptable leakage vary but generally in old districts in the United Kingdom flows of up to four liters per property per hour are acceptable, whereas in newer districts lower figures apply.

In many old urban areas, when beginning to practice active leak detection in this way, it will probably be difficult to achieve minimum net night flows less than 10 liters per property per day unless the average pressure is relatively low. If operating pressures are too low, step-testing will probably not be a practical method of leak control. Experience shows that in many districts where waste water meter districts have been established it is more cost effective to treat the meters in the same way as district meters; that is, to monitor the 24-hour flows frequently, evaluate changes that occur, and concentrate leak detection accordingly. Further concentration of activities to single streets is often not justified especially where labor is plentiful and not expensive.

Figure 5C-1. PLAN OF WASTE DISTRICT

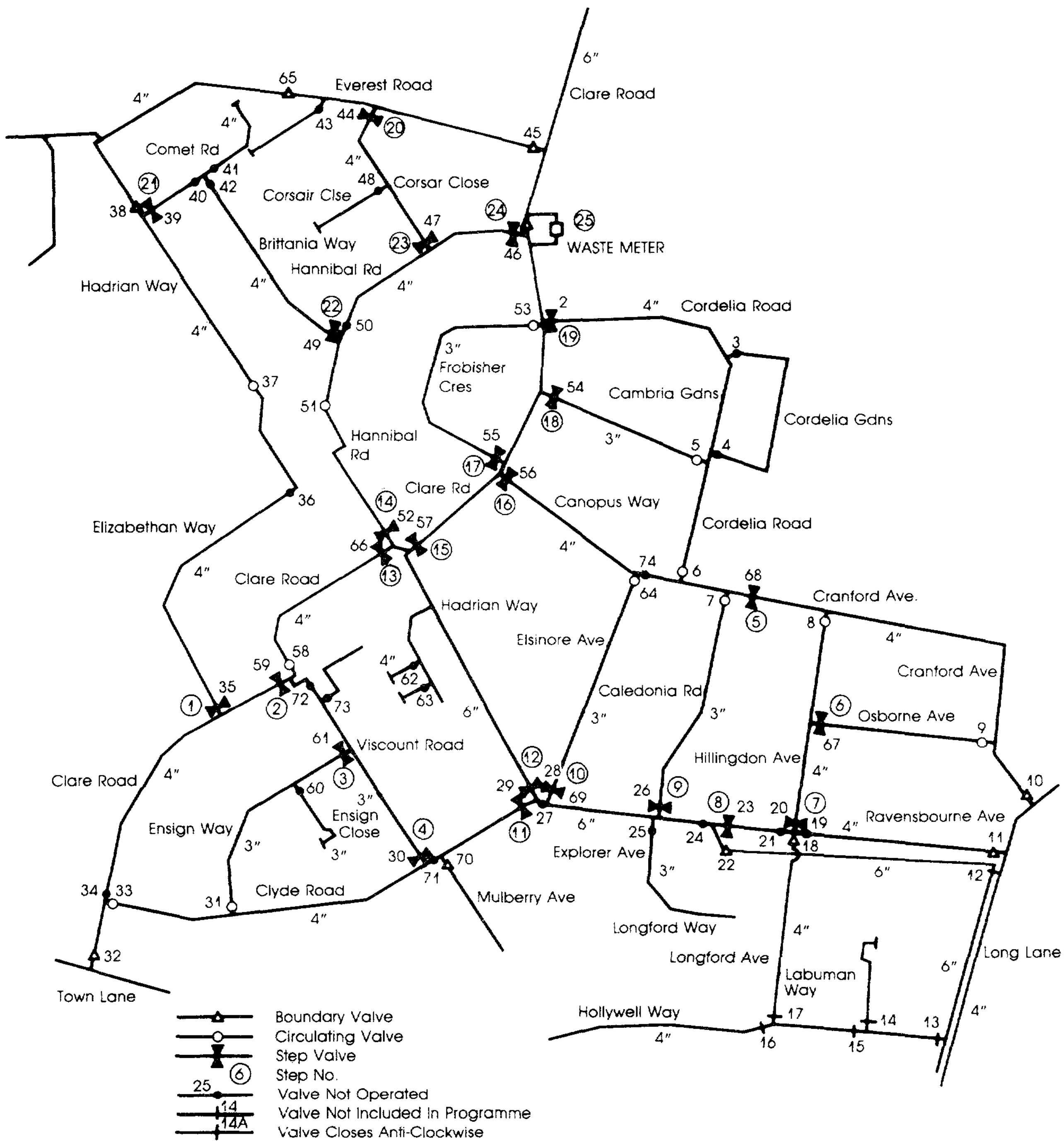


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Figure 5C-2. Typical Step Test Chart

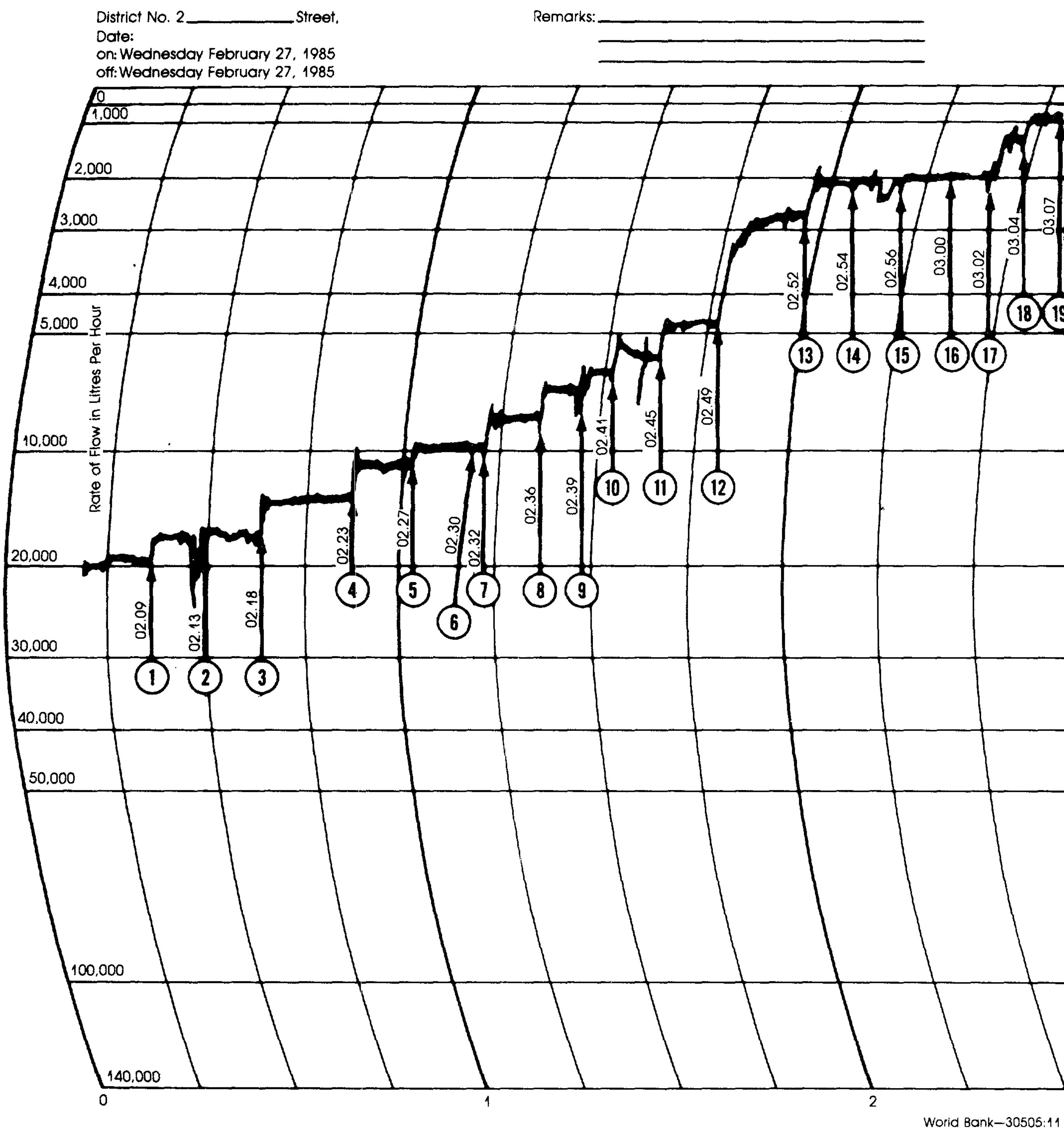

Figure 5C-3. Meter Reading Report

NON-DOMESTIC
METER READINGS: ____________________ WASTE METER DISTRICT NO: ____________________

Walk Number	Serial Number	Meter Size	Consumer	Meter Location	Initial Reading			Second Reading			Consumption	Average Hourly Consumption
					Date	Time	Reading	Date	Time	Reading		

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Figure 5C-4. Leakage Report

WASTE DEPARTMENT
DEFECT SUMMARY WEEK-ENDING ____________

Waste District Number	Date of Works Instruction	Address or Location	Works Instruction Number	Nature of Leakage or Defect
Leakages/Defects Reported During Week				
Leakages/Defects Repaired During Week				
Leakages/Defects Outstanding From Previous Weeks				
Consumer Side Leakages Reported During Week				
Consumer Side Leakages Repaired During Week				
Consumer Side Leakages Outstanding From Previous Weeks				

World Bank—30505:8

Figure 5C-5. Property Report

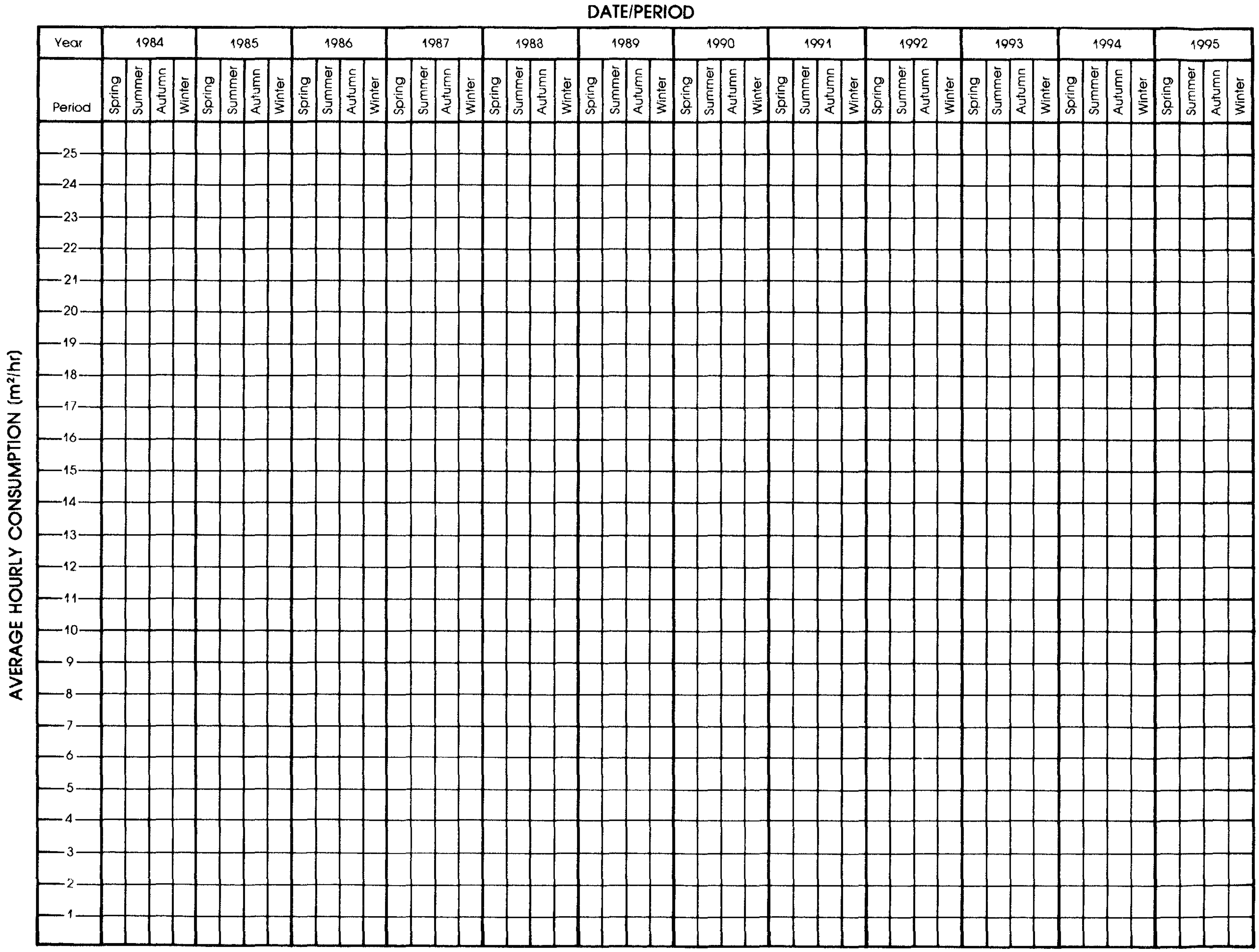
PROPERTY SUMMARY: ______________________ (WASTE) DISTRICT NUMBER: ______________________

Road/Street Etc.	Date	Number of Services	Length of Main	Un-Metered Properties							Metered Properties						
				Houses	Bungalows	Flats	Shops	Offices	Industrial	Others	Domestic	Shops	Schools	Churches	Public Houses	Industrial	Others

World Bank—30505:13

Figure 5C-6. Consumption Report

(WASTE) DISTRICT NO.________________
METERED CONSUMPTION



World Bank—30505:10

Figure 5C-7. Whole Area Report

DIVISION WASTE CONTROL STATISTICS

YEAR ENDING—31/3/1985 WHOLE AREA

Month	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
WWM Areas Open Runs	2	7	5	6	3	4	4	2		3		
WWM Areas Step-Tests	1	3	3	1	2	3	2		1		2	1
Total Saving on WWM Areas Litres/hour	6000	9893		3240		18,350	17.025			6000	57.600	
Calculated Daily Saving Ml/d	0.120	0.198		0.065		0.367	0.340			0.120	1.152	
Average Daily Supply for the Month Ml/d.	115.849	117.211	122.753	119.533	113.702	111.696	107.236	106.819	107.411	112.147	111.354	112.810
Savings as a % of Average Daily Supply	0.11	0.17		0.06		0.32	0.30			0.11	1.02	

Total Water Supplied 1984/1985: 41 322 969 Ml
Average Daily Supply 1984/1985: 113.214 Ml/d.

Total Savings 1984/1985: 110.108 l/h.
Calculated Daily Savings: 2.362 Ml/d

% of Total Water Supplied 2.09%

World Bank 30505:7

Figure 5C-8. Night Flow Report

GRAPHIC RECORD OF NIGHT FLOW
(WASTE) DISTRICT NO.____________________

MINIMUM NIGHT FLOW

Scale in m³	Date of Open Reading
100	
90	
80	
70	
60	
50	
40	
30	
20	
10	

NET NIGHT FLOW

Scale in m³	Date of Open Reading
100	
90	
80	
70	
60	
50	
40	
30	
20	
10	

World Bank—30505:9

Figure 5C-9

Step-Test Summary: Waste District Number: 1 ______________ Road

Date Time	Total Consumption	StepValv Number	Location of Valve	Close A (anti-) or C (clockwise)	Drop Recorded Litres	Properties		Litres/ Property/ Hour	Metered Consumption	Remarks
						Unmetered	Metered			
4-9-1984		START								
02-52	5,400	1	On Pavement ______________ Rd.	A	100					
Used As A C.V.	—	2	On Pavement ______________ Ave	A	—					
02-56	5,400	3	On Pavement ______________	A	NIL					
03-00	4,800	4	On Pavement (Ashtray) ______________ End Road	A	600					
03-05	4,600	5	In Roadway Rd. ______________ Rd.	A	200					
03-09	4,450	6	In Roadway , Junction of ________ Lane ________ Rd.	A	150					
03-13	4,400	7	In Roadway ______________ Rd.	A	50					
03-18	4,200	8	In Roadway Opposite ______________ Rd.	A	200					
03-21	3,850	9	In Roadway, Junction of ________ Rd. ________ Lane	A	350					
03-24	3,750	10	On Footpath at River Bridge ______________ Rd.	A	100					
03-28	3,750	11	On Pavement Opposite ______________ Rd.	C	NIL					
03-33	3,750	12	In Roadway O/S Kay's Corner ______________ Rd	A	350					
03-37	3,800	13	In Roadway, Junction of ________ Ave. ________ Park Rd.	A	600					
03-41	2,600	14	In Roadway, Junction of ______________ Park Rd.	A	200					
03-44	2,420	15	In Roadway ______________ Ave	A	180					
03-47	2,320	16	In Roadway (Ashtray) ______________ Ave.	A	100					
03-51	2,000	17	In Roadway, Junction of ________ Ave. ________ Ave.	A	320					
03-53	950	18	In Roadway, Junction of ________ Ave. ________ Ave.	A	1050					
03-56	630	19	In Roadway, Junction of ________ Rd. ________ Ave.	A	320					
03-59	500	20	In Roadway, Junction of ______________ Rd.	A	130					
04-01	NIL	21	At Meter Position ______________ Rd.	A	500					
		22								

World Bank—30505:12

Figure 5C-10

WASTE DETECTION SUMMARY

Reservoir Zone	W.D. No:	District or Zone	Location	Original Property Count	Original Min. Night Flow (litres)	Date	Original Min. Night Flow (l/p/h)	Original Classification	Revised Property Count	Revised Min. Night Flow (litres)	Date	Revised Min. Night Flow (l/p/h)	Revised Classification	Step Test Date	Remarks
	28														
	29														
	30														
	31														
	32														
	33														
	34														
	35														
	36														
	37														
	38														
	39														
	40														
PARK	41														
	42														
	43														
	44														
	45														
	46														
	47														
	48														
	49														
	50														
	51														
	52														
	53														
	54														

World Bank—30505:15

Annex 5D. Typical Bylaws for the Prevention of Waste or Misuse of Water*

The following bylaws are for use in the U.K. and are suitable when the plumbing system is indirect; that is, the majority or possibly the whole of the supply is delivered to a private storage tank. When the plumbing is direct and there is no private storage tank these bylaws would have to be modified accordingly.

BYELAWS made under

Authority for preventing waste, undue consumption, misuse, or contamination of water supplied by them.

Interpretation

1. In these byelaws, unless the context otherwise requires— Definitions

"ballvalve" means any float-operated valve for controlling the inflow of water to a cistern;

"British Standard" means a standard or specification issued by the British Standards Institution ;

and **"British Standard Code of Practice"** means a code of practice issued and available as aforesaid.

"building" means any structure (including a floating structure) whether of a permanent character or not, and whether movable or immovable, and without prejudice to the generality of the foregoing, includes any caravan, vessel, boat or houseboat;

"capacity" in relation to a storage cistern means the capacity of the cistern measured up to the highest level the water can reach when the ballvalve or other device for controlling the inflow of water is fitted or adjusted in the manner required by paragraph (d) of byelaw 40, or, where paragraph (e) of byelaw 41 applies, by that paragraph;

"closed circuit" means any system of pipes and other water fittings through which water circulates and from which water is not drawn for use, and includes any vent pipe fitted thereto but not the feed cistern or the cold feed pipe;

"corrosion-resisting material" means any material which is highly resistant to any corrosive action to which it is likely to be subjected in the circumstances in which it is used;

"cylinder" means a cylindrical closed vessel capable of containing water under pressure greater than atmospheric pressure;

"distributing pipe" means any pipe (other than an overflow pipe or a flushing pipe) conveying water from a storage cistern, or from a hot water apparatus supplied from a feed cistern, and under pressure from that cistern;

"feed cistern" means any storage cistern used for supplying cold water to a hot water apparatus, cylinder or tank;

"overflowing level" in relation to a warning or other overflow pipe of a cistern, means the lowest level at which water can flow into that pipe from that cistern;

"service pipe" means so much of any pipe for supplying water from a main to any premises as is subject to water pressure from that main, or would be so subject but for the closing of some stopvalve;

"stopvalve" means any device (including a stopcock and stop tap), other than a draw-off tap, for stopping at will the flow of water in a pipe;

"storage cistern" means any cistern, other than a flushing cistern, having a free water surface under atmospheric pressure, but does not include a drinking-trough or drinking-bowl for animals, including poultry;

"tank" means a non-cylindrical closed vessel capable of containing water under pressure greater than atmospheric pressure;

"the undertakers" means the Authority;

"warning pipe" means an overflow pipe so fixed that its outlet, whether inside or outside a building, is in a conspicuous position where the discharge of any water therefrom can be readily seen; and

"water fittings" includes pipes (other than mains), taps, cocks, valves, ferrules, meters, cisterns, baths, waterclosets, soil pans and other similar apparatus used in connection with the supply and use of water.

Compliance with British Standards

2. (1) Any requirement in these byelaws that a water fitting shall comply with a British Standard shall—

(a) be construed as requiring compliance with that Standard only in so far as the Standard relates to the size, nature, materials, strength and workmanship of that fitting; and

(b) be deemed to be satisfied, notwithstanding that the fitting does not comply with that Standard in so far as it relates to those matters, if the fitting is not less efficient and suitable in relation to the purposes for which these byelaws are made than a fitting which does comply with that Standard in so far as it relates to those matters.

(2) Where any requirement of any such Standard relating to any of those matters conflicts with a specific requirement of these byelaws the latter requirement shall prevail.

Application

Application of byelaws generally

3. No person shall—

(a) use a water fitting for the purpose of conveying or receiving water supplied by the undertakers, or cause or permit a water fitting to be used, or to remain arranged or connected so that it can be used, for that purpose, in contravention of a provision of any of the following byelaws, that is to say, byelaws 7, 7A, 8, 10 to 12, 14 to 26 and 28 to 58A, or if the fitting, or its mode of arrangement or connection, or its situation, contravenes, or is not in accordance with, such a provision, or if the fitting is not equipped, provided with fittings or accessories, protected or supported in accordance with or if it is equipped or provided with fittings or accessories or in contravention of, such a provision; or

(b) arrange or connect a water fitting, or cause or permit a water fitting to be arranged or connected, so that it can be used for the purpose aforesaid, in contravention of, or in a manner or in a situation which contravenes, or is not in accordance with, a provision of any of the said byelaws, or if the fitting contravenes, or is not in accordance with, such a provision; or

(c) alter a water fitting used for the purpose aforesaid, or cause or permit a water fitting to be altered, so that it contravenes, or is not in accordance with, a provision of any of the said byelaws; or

(d) disconnect a water fitting used for the purpose aforesaid, or cause or permit a water fitting to be or remain disconnected, otherwise than for the purpose of repair or renewal, if, as a result of the disconnection, a provision of any of the said byelaws by virtue of which the fitting is required to remain connected will be contravened.

Savings for fittings lawfully fitted

4. (1) None of these byelaws (with the exception of byelaws 7, 10(4) and 24) shall have effect so as to require any person to cease to use, or to arrange, connect, disconnect, alter, dismantle or renew any water fitting lawfully used or capable of being lawfully used on any premises immediately before the byelaw first applied in relation to those premises, or to remove any fitting or accessory from such a fitting or to refit such a fitting in a different situation, or to provide any equipment, fitting, accessory, protection or support for a water fitting then used or capable of being used on any premises where the absence of the required equipment, fitting, accessory, protection or support was not then unlawful, unless, by reason of the damaged, worn or otherwise unserviceable condition of the water fitting, its faulty arrangement or connection, its situation, equipment, fittings or accessories or the absence of the required equipment, fittings, accessories, protection or support, it causes or permits, or is likely to cause or permit, waste, undue consumption, misuse, erroneous measurement or contamination of water, or reverberation in pipes.

(2) Where, for a reason mentioned in the preceding paragraph, any of these byelaws (other than byelaws 7, 10(4) and 24) has effect as mentioned in that paragraph, or where byelaw 7, 10(4) or 24 has such effect, and any work is rendered necessary by that byelaw, compliance therewith may be postponed for such time as is reasonably required for the carrying out of that work.

Closed circuits

5. Of the following byelaws, only byelaws 6 – 8, 10 – 16, 23, 26, 29(3), 31, 59 and 60 shall apply in relation to any water fitting forming part of a closed circuit.

Fittings used for industrial or research purposes

6. Where water is–

(a) taken by meter and discharged into a storage cistern; and

(b) discharged into the air not less than 150mm above the top edge of the cistern; and

(c) conveyed from the cistern for use for industrial or research purposes,

and it is not reasonably practicable for any one or more of the following byelaws (other than byelaws 7 and 8) to be complied with in relation to any water fitting supplied with water from the cistern, that byelaw or those byelaws shall not apply in relation to that fitting.

General provisions

Unserviceable fittings and fittings not mentioned in the byelaws

7. A water fitting falling within either of the following paragraphs, that is to say–

(a) any pipe, pipe fitting, draw-off tap, draining tap, stopvalve, ballvalve, float, cistern, cylinder, tank or flushing apparatus or any bath, wash basin, sink, soil pan or similar appliance, being a fitting which is damaged, worn or otherwise unserviceable, or connected or arranged in a faulty manner; and

(b) any fitting not specified in the preceding paragraph, whether or not damaged, worn or otherwise unserviceable, or connected or arranged in a faulty manner,

shall not be used, or be or remain so connected that it can be used, if, notwithstanding that its use or connection does not contravene any of the following byelaws, it causes or permits, or is likely to cause or permit, waste, undue consumption, misuse, erroneous measurement or contamination of water supplied by the undertakers or reverberation in pipes.

7A. Water fittings of dissimilar metals shall not be used, or be or remain so connected that they can be used, for the purpose of conveying or receiving the same water, unless–

Deterioration through electrolytic action

(a) the circumstances are such that deterioration of any of the fittings through electrolytic action is not likely to occur; or

(b) effective measures are taken to prevent such deterioration.

8. (1) No pipe or cistern used for conveying or receiving water supplied by the undertakers shall convey or receive, or be or remain so connected that it can convey or receive, water not supplied by the undertakers:

Connections which could cause contamination of mains water

Provided that where the water supplied by the undertakers to any cistern is discharged into the air not less than 150mm above the top edge thereof, this paragraph shall not apply to that cistern or to any pipe conveying, or any cistern receiving water therefrom.

(2) In the preceding paragraph, "water not supplied by the undertakers" includes, and "water supplied by the undertakers" does not include, water supplied by the undertakers which has been used.

(3) No pipe or cistern used for conveying or receiving potable water shall convey or receive, or be or remain so connected that it can convey or receive, non-potable water;

Provided that where the potable water supplied to any cistern is discharged into the air not less than 150mm above the top edge thereof, this paragraph shall not apply to that cistern or to any pipe conveying, or any cistern receiving, water therefrom.

(4) In the preceding paragraph "non-potable water" means water supplied by the undertakers for non-domestic purposes only, and as being unfit for drinking or culinary purposes, and "potable water" means any other water supplied by the undertakers.

(5) No service pipe or pump delivery pipe drawing water from a service pipe shall convey water from–

(a) a distributing pipe; or

(b) a pump delivery pipe drawing water either from a distributing pipe or from a storage cistern.

(6) No pump or other means of increasing pressure shall be installed in a service pipe for the purpose of increasing pressure or rate of flow in or from a service pipe or a fitting or appliance connected to that pipe.

Taps for drinking water

9. (1) In any premises (not being premises to which section 57 of the Factories Act 1961 applies, or premises to which section 11 of the Offices, Shops and Railway Premises Act 1963 applies or which, by or under that Act, are excepted or excluded from the application of that section) in which water is supplied by the undertakers for domestic purposes, the supply being separately chargeable, the person for the time being entitled or authorised to do so shall provide a draw-off tap in a position convenient for drawing drinking water on a service pipe or a pump delivery pipe drawing water from a service pipe:

Provided that where, by reason of the height at which the water is required to be delivered or of some other circumstance, it is not reasonably practicable to provide in the premises a service pipe or a pump delivery pipe drawing water from a service pipe, the tap may be provided on a pump delivery pipe or distributing pipe drawing water exclusively from a storage cistern which–

(a) is a closed vessel having a tightly fitting access cover bolted or screwed in position;

(b) is properly maintained and, where necessary, suitably lined or coated to preserve the potability of the water;

(c) has an air inlet and an overflow pipe or pipes all suitably screened;

(d) is, where necessary, insulated against heat; and

(e) is supplied exclusively from a service pipe, or from a pump delivery pipe drawing water either from a service pipe or from a storage cistern which is a closed vessel equipped, maintained and supplied as aforesaid.

(2) This byelaw shall not have effect so as to require any person to provide a tap on a pipe which was in any premises immediately before this byelaw first applied in relation to those premises if the omission to provide the tap on the pipe was not then unlawful.

(3) No pipe on which a tap is provided in compliance with this byelaw shall be so placed that the water in the pipe is likely to become warm before reaching the tap.

Protection from damage from frost

10. (1) Every water fitting, whether inside or outside a building, shall be so placed as to reduce to the greatest extent which is reasonably practicable the risk of damage to it from frost.

(2) Every water fitting (other than an overflow pipe) which, notwithstanding compliance with the preceding paragraph, is likely to suffer damage from frost shall be effectively protected from such damage.

(3) The requirements of the preceding paragraphs shall be deemed to be satisfied if the location, protection and insulation of the fittings are in accordance with the recommendations in that behalf in Sections three, four and five of the British Standard Code of Practice CP 99: 1972 "Frost precautions for water services".

(4) In every building and in every part of a building the supply to which is separately chargeable the water fittings on the downstream side of each stopvalve required by byelaw 24 shall be so arranged that they can be drained to prevent damage to them from frost, and shall be fitted with such draining taps (if any) as may be reasonably necessary for that purpose.

Protection from damage from other causes

11. Every water fitting, whether inside or outside a building, which is so placed as to be liable to damage from some cause other than frost shall be effectively protected from such damage.

Accessibility of fittings

12. Every water fitting in, on or under a building shall be so placed as to be readily accessible for purposes of examination, repair, replacement and operation, except where compliance with this requirement is not reasonably practicable or is inconsistent with the provisions of byelaw 10 or 11:

Provided that this byelaw shall not prevent–

(a) the enclosing of any pipe or any fitting thereon in a chase or duct if the pipe and fitting are reasonably accessible for such purposes; or

(b) the embedding of any pipe or pipe fitting in the fabric of a building so far as may be necessary for the efficient operation of any system of space heating.

Disconnection of disused pipes

13. If a water fitting is disconnected and is not within 28 days reconnected or replaced, the person supplied with water by the undertakers shall disconnect any pipe or part of a pipe which conveyed water supplied by them to that fitting and is not required to convey such water to any other fitting.

Pipes

Support of pipes

14. Every pipe shall be adequately supported and shall be so arranged as to avoid any air lock or reverberation.

Depth of pipes laid underground

15. Every pipe laid in the ground shall, unless it is under a building of a permanent character, at no time be less than 750mm nor more than 1.35m below the surface of the ground, measured from the top of the pipe to the ground surface.

Provided that if it is not reasonably practicable for a pipe or some part of a pipe to be not less than 750mm below the surface of the ground, that pipe or part shall be at the greatest depth below the surface of the ground that is reasonably practicable, and in every such case the pipe shall be given adequate waterproof insulation and protection against damage from causes other than freezing.

Protection of pipes from corrosion and contact with contaminating substances

16. (1) No pipe or pipe fitting shall be laid, installed or allowed to remain in or on the ground unless it is either of a corrosion-resisting material or effectively protected from external corrosion.

(2) No pipe shall pass into or through any ashpit, manure pit, sewer, drain, cesspool, refuse chute or any manhole connected therewith.

(3) No pipe shall be laid, installed or allowed to remain in or on any foul soil or other substance which could cause contamination of the water in the pipe unless it is impracticable for the pipe to be elsewhere and all necessary measures are taken to avoid any risk of contamination of the water in the pipe.

(4) No pipe made of any material susceptible to permeation by any gas or other substance which could cause contamination of the water in the pipe shall be laid, installed or allowed to remain in a position where such permeation could reasonably be expected to occur.

Dezincification

16A. Every water fitting and every component of a water fitting on any pipe below ground which may be in contact with water shall be resistant or immune to dezincification. Provided that this requirement shall not apply to any fitting or component of any fitting in a closed circuit.

Pipes of lead, wrought iron and steel not to be used

17. No service pipe, pump delivery pipe or distributing pipe, or pipe fitting connected to any such pipe, shall be of lead, wrought iron or of steel other than stainless steel unless: -

either

(i) the circumstances are such that contamination of water or deterioration of any such pipe or pipe fitting is unlikely to occur; or

(ii) effective measures are taken to prevent such contamination of water or deterioration of such pipe or pipe fitting.

Provided that this byelaw shall not prohibit the use of a pipe or pipe fitting of wrought iron or steel which: -

(a)(i) forms part of a fire sprinkler or other fire fighting installation from which water is drawn only for fire fighting purposes; and

(ii) is kept charged with water through an automatic alarm valve or is charged with water only when fire occurs; or

(b) is used in connection with the supply of water for the purpose of building, demolition or constructional work while the work is in progress, or for any other temporary purpose during a period not exceeding one month or such longer period not exceeding three months as the undertakers may approve in any particular case.

Pipes of cast iron

18. (1) Every service pipe, pump delivery pipe and distributing pipe of cast iron shall be capable of withstanding a hydraulic test pressure of not less than double the pressure to which the pipe will be liable to be subjected under working conditions.

(2) Every such pipe and every pipe fitting on any such pipe shall comply with British Standard 4622: 1970, "Grey iron pipes and fittings" or with British Standard 4772: 1980, "Specification for ductile iron pipes and fittings.";

(3) Where pipes are laid in ground, the surface of which is not suitable for heavy traffic loads, such pipes shall be not less than Class C of the said British Standards 1211: 1958 and 2035: 1966 provided that this byelaw shall not apply to a pipe laid in ground unlikely to be subjected to vehicular traffic.

Pipes of steel

19. (1) Every service pipe or pump delivery pipe of steel (other than a pipe to which paragraph (2) (a) of this byelaw applies) and every distributing pipe of steel in contact with the soil shall comply with the requirements for heavy tubes in British Standard 1387: 1967, "Steel tubes and tubulars suitable for screwing to BS21 pipe threads".

(2) Every steel pipe not in contact with the soil which is of either of the following descriptions–

(a) a service pipe or pump delivery pipe which–

(i) forms part of a fire sprinkler or other fire fighting installation from which water is drawn only for fire fighting purposes; and

(ii) is kept charged with water through an automatic alarm valve or is charged with water only when fire occurs; and

(b) a distributing pipe,

shall comply with the requirements for medium tubes in the said British Standard 1387: 1967.

(3) Every malleable cast iron pipe fitting connected to any steel pipe not prohibited by byelaw 17 being a service pipe or pump delivery pipe (other than a pipe to which paragraph (2) (a) of this byelaw applies) or a distributing pipe shall comply with the relevant

requirements of British Standard 143 & 1256: 1968, "Malleable cast iron and cast copper alloy screwed pipe fittings for steam, air, water, gas and oil", and every cast iron pipe fitting connected to any pipe to which paragraph (2) (a) of this byelaw applies shall comply with British Standard 1641: 1950, "Cast iron pipe fittings for sprinklers and other fire protection installations", or with the relevant requirements of the said British Standard 143 & 1256: 1968.

(4) Every pipe fitting of wrought iron connected to any steel pipe not prohibited by byelaw 17, being a service pipe, a pump delivery pipe or a distributing pipe shall comply with British Standard 1740: Part 1: 1971, "Wrought steel pipe fittings (screwed BSP Thread): Part 1: Metric Units" and every pipe fitting of steel connected to any such steel pipe shall comply with either the said British Standard 1740: Part 1: 1971 or with British Standard 1965: Part 1: 1963, "Butt-welding pipe fittings for pressure purposes: Part 1. Carbon Steel".

(5) Every pipe and every pipe fitting to which any of the preceding paragraphs of this byelaw applies shall be effectively protected from–

(a) external corrosion; and

(b) internal corrosion, unless it is a pipe or fitting which–

(i) forms part of a fire sprinkler or other fire fighting installation from which water is drawn only for fire fighting purposes; and

(ii) is kept charged with water through an automatic alarm valve or is charged with water only when fire occurs.

(6) Reference in this byelaw to "steel" shall not include stainless steel.

Pipes of copper

20. (1) (a) Every service pipe, pump delivery and distributing pipe of copper connected by means of screw joints shall comply with British Standard 2871: Part 2: 1972, "Copper and copper alloys. Tubes: Part 2: Tubes for general purposes", and the thread of every screw in any such joint shall comply with British Standard 61: 1969, "Thread for light gauge copper tubes and fittings".

(b) Every copper alloy pipe fitting for a copper pipe having a screw thread which complies with Table 1 and 2 of the said British Standard 61: 1969 shall comply with British Standard 66 & 99: 1970, "Cast copper alloy pipe fittings for use with screwed copper tubes".

(2) (a) Every service pipe, pump delivery pipe and distributing pipe of copper which is connected by means of capillary or compression fittings or by silver brazing or bronze or autogenous welding and is laid in the ground shall comply with British Standard 2871: Part 1: 1971, "Copper and copper alloys. Tubes: Part 1: Copper tubes for water, gas and sanitation," Table Y.

(b) Every such pipe of copper which is not laid in the ground shall, if connected by capillary or compression fittings, or welding comply with the said British Standard 2871: Part 1: 1971, provided that pipes to Table Z shall not be bent or connected other than by capillary fittings or non-manipulative type compression fittings.

(c) Every capillary fitting and compression fitting on any service pipe, pump delivery pipe or distributing pipe complying with sub-paragraph (a) or (b) of this paragraph shall comply with British Standard 864: Part 2: 1971, "Capillary and compression tube fittings of copper and copper alloy: Part 2: Metric Units", provided that every compression fitting shall be of Type B if the pipe on which it is fitted complies with British Standard 2871: Part 1: 1971: Table Y, and is laid in the ground.

(d) Where any pipe complying with the said British Standard 2871: Part 1: 1971 is connected by bronze welding by gas the welding shall comply with British Standard 1724: 1959, "Bronze welding by gas".

Pipes of asbestos cement

21. (1) Every service pipe, pump delivery pipe and distributing pipe of asbestos cement shall be capable of withstanding a hydraulic test pressure of not less than double the pressure to which the pipe will be liable to be subjected under working conditions, and shall comply with British Standard 486: 1981, "Asbestos-cement pressure pipes".

(2) Where pipes are laid in ground, the surface of which is not suitable for heavy traffic loads, such pipes shall be not less than Class 25 of the said British Standard 486: 1981, provided that this byelaw shall not apply to pipes laid in ground unlikely to be subjected to vehicular traffic.

Pipes of other materials

22. (1) Every service pipe, pump delivery pipe, distributing pipe and pipe fitting not being a pipe or fitting of a material specifically mentioned in byelaws 17 to 21 shall be capable of withstanding a hydraulic test pressure of not less than double the pressure to which the pipe will be liable to be subjected under working conditions, and shall be of material the nature, thickness and strength of which is suitable in the circumstances in which the pipe or pipe fitting is to be used.

(2) Every such pipe of polythene shall comply with British Standard 1972: 1967, "Polythene pipe (type 32) for cold water services", or with British Standard 3284: 1967, "Polythene pipe (type 50) for cold water services".

(3) Every such pipe of unplasticized polyvinyl chloride shall comply with British Standard 3505: 1968, "Unplasticized PVC pipe for cold water services". Where pipes are laid in ground, the surface of which is not suitable for heavy traffic loads, such pipes shall be not less than Class C of the said British Standard 3505: 1968 provided that this byelaw shall not apply to a pipe laid in ground unlikely to be subjected to vehicular traffic.

(4) Every such pipe of stainless steel shall comply with British Standard 4127: Part 2: 1972, "Light gauge stainless steel tubes. Part 2. Metric Units".

Fittings in closed circuits

23. Every water fitting forming part of a closed circuit shall be of suitable material and capable of withstanding a hydraulic test pressure of not less than double the pressure to which the fitting will be liable to be subjected under working conditions.

Taps and Valves

Stopvalves on pipes supplying buildings

24. (1) Every pipe supplying water to a building (except a pipe conveying water from one building to another building the supply to which is not separately chargeable and which is within the same curtilage) shall be fitted with a stopvalve inside and as near as is reasonably practicable to the point where it enters that building.

(2) Every pipe supplying water to a part of a building which is a part to which the supply is separately chargeable shall (unless the pipe passes through that part to another such part) be fitted with a stopvalve inside and as near as is reasonably practicable to the point where the pipe enters that part.

(3) Where a pipe supplies water to a part of a building which is a part to which the supply is separately chargeable and passes through that part to another such part, every branch pipe connected to that pipe in the first-mentioned part shall be fitted with a stopvalve as near as is reasonably practicable to the point of connection.

(4) Where a pipe supplies water to a part of a building which is a part to which the supply is separately chargeable and passes through one or more of such parts to another, it shall be so placed that, before entering the first of the parts, it passes through a place, whether inside or outside the building, to which the occupier of each of the parts has access, and in that place the pipe shall be fitted with a stopvalve as near as is reasonably practicable to the point where it enters the building.

(5) Every pipe conveying water from a building to another building the supply to which is not separately chargeable and which is within the same curtilage as, but has no direct access from, the first-mentioned building shall, subject to paragraph (6) of this byelaw, be fitted with a stopvalve inside and as near as is reasonably practicable to the point where it leaves the first-mentioned building.

(6) Where it is not reasonably practicable to fit a stopvalve inside the first-mentioned building, the said pipe shall be fitted with a stopvalve inside and as near as is reasonably practicable to the point where it enters the other building.

(7) No stopvalve fitted in accordance with any of the preceding paragraphs of this byelaw shall be a plug cock or plug valve.

Stopvalves on outlet pipes from storage cisterns

25. Every draw-off pipe from every cold water storage cistern of a capacity exceeding 18 litres shall be fitted with a stopvalve as near to the cistern as is reasonably practicable.

Provided that, where such a draw-off pipe is connected directly to a hot water storage cistern, cylinder or tank in such a way that it is not reasonably practicable to fit a stopvalve on that pipe, a stopvalve shall be fitted on every draw-off pipe from the hot water cistern, cylinder or tank, as near thereto as is reasonably practicable.

Location of draining taps

26. No draining tap shall be buried in the ground, or so placed that its outlet is in danger of being flooded.

Standpipes

27. No person shall erect or set up, or allow to remain erected or set up, a standpipe for conveying water supplied by the undertakers which is used by the occupants of more than one building, separately occupied part of a building or tent unless the pipe is provided with a non-concussive self-closing tap and a stopvalve.

Drinking troughs

28. (1) Every pipe supplying water to a drinking-trough or drinking-bowl for animals, including poultry, shall be fitted with a ballvalve or some other not less effective device for controlling the inflow of water, so designed as to prevent overflow, and every such ballvalve, or device shall be effectively protected from damage, contamination and unauthorised interference:

Provided that this paragraph shall not apply to a pipe if

(a) the water in the pipe flows by gravitation from a storage cistern; and

(b) the trough or bowl to which the pipe supplies water is placed at such a level as to prevent overflow.

(2) No such trough or bowl shall be supplied directly from a service pipe or pump delivery pipe drawing water from a service pipe unless the inlet is fixed at a distance above the top edge of the trough

or bowl which –

(a) is sufficient, having regard to the design of the trough or bowl and the use to be made of it, to prevent contamination of the water in the service pipe; and

(b) is in no case less than 25mm.

Draw-off taps

29. (1) Every metal bodied draw-off tap shall comply with the relevant requirements of British Standard 5412: 1976, "Specification for the performance of draw-off taps with metal bodies for water services".

(2) Every plastics bodied draw-off tap shall comply with the relevant requirements of British Standard 5413: 1976, "Specification for the performance of draw-off taps with plastics bodies for water services".

(3) Every draining tap shall comply with British Standard 2879: 1980, "Draining taps (screw-down pattern)", or with the relevant requirements of British Standard 1010: Part 2: 1973, "Draw-off taps and stopvalves for water services (screw-down pattern). Part 2. Draw-off taps and above ground stopvalves".

Stopvalves

30. (1) Every above-ground stopvalve not exceeding nominal size 2 shall comply with the relevant requirements of the said British Standard 1010: Part 2: 1973.

(2) Every underground stopvalve not exceeding nominal size 2 shall comply with British Standard 5433: 1976, "Underground stopvalves for water services".

(3) Every stopvalve exceeding nominal size 2 shall comply with the relevant requirements of British Standard 5163: 1974, "Double flanged cast iron wedge gate valves for waterworks purposes".

Operation of stopvalves

31. Every stopvalve shall be so placed that it can be readily operated by the means by which it is designed to be operated.

Ballvalves

32. (1) Every ballvalve of the piston type shall comply with British Standard 1212: Part 1: 1953, "Ballvalves (exluding floats): Part 1: Piston type" and every ballvalve of the diaphragm type shall comply with either British Standard 1212: Part 2: 1970, "Ballvalves (excluding floats): Part 2: Diaphragm type (brass body)", or British Standard 1212: Part 3: 1979, "Float operated valves (excluding floats): Part 3: Diaphragm type (plastics body) for cold water services".

(2) Every ballvalve not of the piston type or the diaphragm type shall comply with such of the following requirements as are relevant –

(a) every high pressure valve shall close against a working pressure of 14 bar, every medium pressure valve against a working pressure of 7 bar, and every low pressure valve against a working pressure of 3 bar; and every high pressure, medium pressure and low pressure valve, not being a valve having an interchangeable orifice seating, shall have the letters "H.P.", "M.P." or "L.P." cast or stamped on the body of the fitting, or shall be otherwise clearly identified as a high, medium or low pressure valve, and every valve shall, while held mechanically in the closed position, be capable of withstanding a pressure of 20 bar;

(b) the component parts of every valve of a nominal size not exceeding 50 mm shall be of a suitable and corrosion-resisting material and the lever shall be made of such material as will ensure that it does not bend under working conditions; and

(c) every valve wholly or partly of ferrous metal of a nominal size exceeding 50 mm shall–

(i) be provided with a flange on its inlet suitable for a nominal pressure of 16 bar complying with British Standard 4504: Part 1: 1969, "Flanges and bolting for pipes, valves and fittings. Metric series: Part 1: Ferrous";

(ii) have all parts of ferrous metal protected against corrosion by coating, or by galvanising in accordance with British Standard 1387: 1967, "Steel tubes and tubulars suitable for screwing to BS 21 pipe threads", and

(iii) have all ferrous working surfaces lined or faced with, and the orifice seating made of, a suitable and corrosion-resisting material.

(3) Every ballvalve float shall comply with British Standard 1968: 1953, "Floats for ballvalves (copper)", or with British Standard 2456: 1973, "Floats (plastics) for ballvalves for hot and cold water", or with the requirements of the said British Standard 1212: Part 2: 1970 so far as they relate to floats of materials other than copper and plastics.

Storage cisterns

Placing of storage cisterns

33. Every storage cistern from which water is drawn for domestic purposes shall be so placed and equipped that the interior thereof can be readily inspected and cleansed, and no such cistern shall be so placed and equipped that the water therein is liable to contamination.

Support and covering of storage cisterns

34. (1) Every storage cistern shall be adequately supported and, if water for domestic purposes is drawn from it, shall be suitably covered but not so as to be airtight.

(2) Every cover shall effectively exclude light and shall be rigid with overlapping edges so constructed that it cannot easily be dislodged and shall be of material which will not contaminate any condensate.

Avoidance of flooding, buried or sunken cisterns

35. (1) No storage cistern shall be so placed that it is in danger of being flooded.

(2) No such cistern shall be buried or sunk in the ground unless –

(a) there is sufficient space around and beneath it for the purposes of maintenance and the detection of leakage; and

(b) either–

(i) it is a closed vessel with a tightly fitting access cover bolted or screwed in position, and an air inlet and overflow pipe or pipes all suitably screened;

or

(ii) its inlet pipe discharges into the air not less than 150 mm above its top edge:

Provided that sub-paragraph (a) of this paragraph shall not apply in relation to a concrete cistern designed and constructed in accordance with the relevant recommendations in British Standard 5337: 1976, "Code of practice for the structural use of concrete for retaining aqueous liquids".

Materials for storage cisterns

36. (1) Every storage cistern shall be watertight and of adequate strength and shall be constructed of galvanized iron or steel,copper, polythene, polypropylene, asbestos-cement, concrete or some other not less suitable material, but not lead.

(2) Where the cistern is not made of a corrosion-resisting material it shall be effectively protected from corrosion.

British Standards for storage cisterns

37. (1) Every storage cistern of mild steel shall comply with the requirements for Grade A or Grade B cisterns in British Standard 417: Part 1: 1964, "Galvanized mild steel cisterns and covers, tanks and cylinders, Part 1. Imperial Units" or British Standard 417: Part 2: 1973, "Galvanized mild steel cisterns and covers, tanks and cylinders. Part 2. Metric Units". Where Grade B cisterns are installed they shall be suitably protected against corrosion where necessary.

(2) Every storage cistern of asbestos cement shall comply with British Standard 2777: 1974, "Asbestos-cement cisterns".

(3) Every storage cistern built up of cast iron plates shall comply with British Standard 1563: 1949, "Cast iron sectional tanks (rectangular)".

(4) Every storage cistern built up of pressed steel plates shall comply with British Standard 1564: 1975, "Pressed steel sectional rectangular tanks".

(5) Every storage cistern of polythene or polypropylene shall comply with British Standard 4213: 1975, "Cold water storage cisterns (polyolefin or olefin copolymer) and cistern covers".

38. (1) Where in any house there is a cold water storage cistern which is not connected to any other such cistern its capacity shall not be less than— **Capacity of storage cisterns in houses**

(a) 115 litres, if it is not used as a feed cistern;

or

(b) 230 litres, if it is used both as a feed cistern and for other purposes.

(2) Where in any house there are two or more cold water storage cisterns connected together, the sum of their capacities shall be not less than—

(a) 115 litres, if none of them is used as a feed cistern;

or

(b) 230 litres, if they are together used both as a feed cistern and for other purposes.

(3) In this byelaw "house" means premises separately occupied as a private dwelling.

39. (1) Every pipe supplying water to a cold water storage cistern shall be fitted with a ballvalve or shall have some other not less effective device for controlling the inflow of water so designed as to prevent overflow: **Storage cisterns to be fitted with ballvalves**

Provided that where two or more cold water storage cisterns at the same level are connected together this paragraph shall not apply to a pipe used only to connect one cistern to another.

(2) Every such pipe, whether fitted with a ballvalve or not, other than a pipe used only to connect one cistern to another, shall be fitted in such a position that it discharges at a level higher than the overflowing level of the overflow pipe or, if there is more than one overflow pipe, the highest overflow pipe, by not less than the diameter of the said overflow pipe, unless there is an effective means of preventing the siphonage of water back through the inlet.

(3) Where a ballvalve is fitted to a cistern, the size of the orifice, the size of the float and the length of the lever shall be such that, when the float is immersed to an extent not exceeding half its volume, the valve is watertight against the highest pressure at which it may be required to work.

(4) Every ballvalve shall be securely and rigidly fixed to the cistern which it serves.

Warning pipes on storage cisterns holding not more than 4.5 cubic metres

40. Every cold water storage cistern which would hold not more than 4.5 cubic metres if filled to the top edge shall comply with the following requirements–

(a) it shall be fitted with an efficient warning pipe of a corrosion-resisting material and with no other overflow pipe;

(b) no warning pipe shall rise in level outside the cistern;

(c) the internal diameter of the warning pipe shall be greater than the internal diameter of the inlet pipe and in no case less than 19 mm; and

(d)(i) when the cistern is first installed; and

(ii) when the existing ballvalve or other device for controlling the inflow of water to the cistern is repaired or readjusted; and

(iii) when a new ballvalve or other device is fitted,

the ballvalve or other device shall be so fitted and adjusted that the highest level the water can reach is lower than the overflowing level of the warning pipe by not less than 25 mm, or the internal diameter of the warning pipe, which ever is the greater.

Overflow pipes on storage cisterns holding more than 4.5 cubic metres

41. Every cold water storage cistern which would hold more than 4.5 cubic metres if filled to the top edge shall comply with the following requirements–

(a) it shall be fitted with an efficient overflow pipe or pipes of a corrosion-resisting material and, if none of those overflow pipes is an efficient warning pipe, with an efficient warning pipe or with some other device which effectively indicates when the water reaches a level not less than 50 mm below the overflowing level of the overflow pipe or, if there is more than one overflow pipe, the lowest overflow pipe;

(b) no overflow pipe shall rise in level outside the cistern;

(c) where a warning pipe but no other overflow pipe is fitted, the cistern shall comply with the requirements of paragraphs (c) and (d) of byelaw 40;

(d) where both a warning pipe and some other overflow pipe or pipes are fitted–

(i) the internal diameter of the warning pipe shall be not less than 25 mm; and

(ii) the cistern shall comply with the requirements of paragraph (d) of byelaw 40; and

(e) where the cistern is fitted with some device (other than a warning pipe) of the kind mentioned in paragraph (a) of this byelaw, then, on each occasion mentioned in paragraph (d) of byelaw 40, the ballvalve or other device for controlling the inflow of water shall be so fitted and adjusted that the highest level the water can reach is lower than the overflowing level of the overflow pipe or, where there is more than one overflow pipe, the lowest overflow pipe, by not less than 50 mm.

Hot water apparatus

Distance between hot water apparatus and draw-off taps

42. The length of any pipe conveying hot water from any hot water apparatus, hot water storage cistern, cylinder or tank, or flow and return system to any draw-off tap shall not exceed that specified in respect of that pipe, by reference to the largest internal diameter of any part of it, in the following table -

Largest Internal Diameter of Pipe	Length in Metres
Not exceeding 19mm	12.0
Exceeding 19mm but not exceeding 25mm	7.5
Exceeding 25mm	3.0

Position of outlets in relation to level of water in cylinders and tanks

43. No tap or other means of drawing water (other than a tap with a removable key for emptying the system) shall be connected to any part of a hot water system in such a position that by its use the level of the water in the hot water storage cistern, cylinder or tank can be lowered -

(a) below the level of the top of any pipe connecting the cistern, cylinder or tank to the apparatus in which the water in the system is heated; or

(b) more than one-half of the depth of the cistern or one-fourth of the depth of the cylinder or tank:

Provided that

(i) if the hot water system includes two or more hot water cylinders or tanks at different levels this byelaw shall apply only in relation to the lowest cylinder or tank; and

(ii) this byelaw shall not apply in relation either to an open vessel in which water is directly heated or to a hot water storage cistern, cylinder or tank forming part of a hot water system in which water is heated only under thermostatic control by electricity, gas or oil.

Hot water cisterns not to have ballvalves

44. No hot water storage cistern shall be fitted with a ballvalve unless such ballvalve is of material suitable for the purpose and complies in its construction and fitting with the provisions of byelaws 39, 40 and 41 as if the cistern to which it is fitted were a cold water storage cistern.

Outlets from feed cisterns to hot water apparatus

45. Every outlet from a cistern to hot water apparatus shall be at a distance of not less than 25 mm above the bottom of the cistern. Every pipe which delivers water from a feed cistern to a hot water apparatus not of the instantaneous type or to a hot water cylinder or tank shall deliver water to that apparatus, cylinder or tank only.

Hot water apparatus not to be connected directly to service pipe

46. Where any apparatus in which water is heated is supplied with cold water from a service pipe or a pump delivery pipe drawing water from a service pipe, the pipe shall not be connected directly to the apparatus but shall discharge into the air not less than 13 mm above the top edge of the apparatus:

Provided that this byelaw shall not apply in relation to a water-heater which—

(a) is of the instantaneous type; or

(b) is not capable of holding more than 15 litres,

if

(i) the working pressure to which the apparatus is subjected is no higher than that for which it is designed;

(ii) the apparatus (being a gas water-heater) is so constructed that no leakage between the gas and water spaces can occur;

(iii) the water space is completely enclosed and its contents have no contact with the atmosphere except through the outlet pipe or vent pipe; and

(iv) the water is discharged from the apparatus into the air at a level not less than 13 mm above the lowest part of the top edge of the bath, wash basin, sink or other appliance supplied therefrom.

Mixing valves

47. No mixing valve, pipe or other water fitting in which hot water and cold water are mixed shall be or remain so connected as to mix either

(a) water supplied from a hot water apparatus connected directly to a service pipe, or to a pump delivery pipe drawing water from a service pipe, with cold water not supplied directly from a service pipe or a pump delivery pipe drawing water from a service pipe; or

(b) water supplied from a hot water apparatus not connected directly to a service pipe, or to a pump delivery pipe drawing water from a service pipe, with cold water supplied directly from a service pipe or a pump delivery pipe drawing water from a service pipe.

48. Every pipe used for conveying hot water shall be of copper or some other corrosion-resisting material which is not less suitable.

Materials for hot water pipes

49. (1) Every hot water cylinder or tank shall be constructed of copper or some other not less suitable material and shall be adequately supported.

Materials for, and support of, hot water cylinders and tanks

(2) Where the hot water cylinder or tank is not made of corrosion-resisting material, it shall be effectively protected from corrosion.

50. Every hot water cylinder or tank to which any of the following British Standards applies, namely—

British Standards for hot water cylinders and tanks

417: Part 1: 1964,

"Galvanized mild steel cisterns and covers, tanks and cylinders. Part 1. Imperial Units";

417: Part 2: 1973,

"Galvanized mild steel cisterns and covers, tanks and cylinders. Part 2. Metric Units",

1565: Part 1: 1949,

"Galvanized mild steel indirect cylinders, annular or saddle-back type. Part 1. Imperial Units";

1565: Part 2: 1973,

"Galvanized mild steel indirect cylinders, annular or saddle-back type. Part 2. Metric Units";

699: 1972,

"Copper cylinders for domestic purposes";

1566: Part 1: 1972,

"Copper indirect cylinders for domestic purposes. Part 1. Double feed indirect cylinders";

1566: Part 2: 1972,

"Copper indirect cylinders for domestic purposes. Part 2. Single feed indirect cylinders";

843: 1976,

"Thermal-storage electric water heaters (constructional and water requirements)";

853: Part 1: 1960,

"Calorifiers for central heating and hot water supply. Part 1. Mild steel and cast iron";

853: Part 2: 1960,

"Calorifiers for central heating and hot water supply. Part 2. Copper", and

3198: 1960,

"Combination hot water storage units (copper) for domestic purposes";

shall comply with the relevant requirements of that Standard.

Capacity of hot water storage cisterns, cylinders and tanks

51. Every hot water storage cistern, cylinder or tank, unless forming part of a hot water system in which water is heated only under thermostatic control by electricity, gas or oil, shall be capable of holding not less than 115 litres:

Provided that if the hot water system includes two or more hot water cylinders or tanks at different levels, this byelaw shall apply only to the lowest cylinder or tank.

Baths, wash basins and sinks

Inlets and outlets of baths, etc.

52. (1) Every inlet to a bath, wash basin, sink or similar appliance shall be separate from, and unconnected with, any outlet therefrom.

(2) Every outlet for emptying a bath (other than a shower bath), wash basin, sink or similar appliance shall be provided with a well-fitting and readily accessible watertight plug or with some other not less effective device for closing the outlet:

Provided that this paragraph shall not apply in relation to -

(a) any appliance required by law to be fitted with an unplugged waste-pipe; or

(b) any appliance to which water is delivered exclusively by a fitting or fittings so designed and arranged as to be incapable of delivering water to that appliance or, in the case of a washing trough, any unit thereof at a rate exceeding 0.06 litres per second.

(3) Every fitting for delivering water to a washing trough shall be so designed and arranged as to be capable of discharging water to one unit of the trough without simultaneously discharging it to another or others.

(4) In this byelaw–

"washing trough" means a wash basin, washing trough or sink measuring internally 1,200 mm or more over its longest or widest part; and "unit", in relation to such a trough, means 600 mm of the length of the trough or, in the case of a circular or oval trough, 600 mm of the circumference thereof.

53. Every draw-off tap or other fitting (other than the flushing pipe of a flushing cistern) which discharges water into a bath, wash basin, sink or similar appliance shall be fitted in such a position that it cannot discharge at a level lower than 13 mm above the lowest part of the top edge of the appliance: **Position of taps on baths, etc.**

Provided that–

(a) this byelaw shall not require a fitting which incorporates a hand-operated hosepipe or to which such a hosepipe is attached to be so fitted that it cannot discharge through the hosepipe at a level lower than that level, if there is an effective means of preventing the siphonage of water back through every pipe conveying water to the fitting; and

(b) this byelaw shall not require any fitting to be so fitted that it cannot discharge at a level lower than that level, if every pipe conveying water to that fitting–

(i) draws water only from a storage cistern or from a cylinder or tank having a vent open to the atmosphere; and

(ii) is connected to the cistern, cylinder or tank at a level not less than 25 mm higher than the level of the lowest part of the top edge of the appliance; and

(iii) does not convey water to any draw-off tap or other fitting (other than a draining tap) which discharges water at a level lower than the last mentioned level.

Flushing cisterns

54. Every watercloset pan and every urinal shall be provided with a flushing cistern or with some other not less efficient and suitable flushing apparatus. **Waterclosets and urinals to be fitted with flushing cisterns**

55. Byelaws 39(1), (3) and (4) and 40 shall, with any necessary modifications, apply to flushing cisterns (other than automatic flushing cisterns) and flushing troughs as they apply to cold water storage cisterns. **Ballvalves and warning pipes on flushing cisterns**

56. No pipe, other than a flushing pipe leading only from a flushing apparatus, shall be or remain so arranged or connected that it can deliver water to any watercloset pan or urinal. **Pipes discharging to watercloset pans**

Provided that this byelaw shall not apply in relation to a warning pipe from which any water is discharged into the air not less than 150 mm above the top edge of the pan or urinal.

Design and arrangement of flushing cisterns for waterclosets

57. (1) Subject to the provisions of paragraph (2) of this byelaw no flushing cistern, flushing trough or other flushing apparatus serving a watercloset pan or pans shall be of such a design or be or remain so arranged that the volume of the flush or, in the case of an apparatus designed to give flushes of two different volumes, of the larger of the two flushes (excluding the water entering a cistern or trough during the flush) exceeds 9 litres (with the upward variation permitted by the British Standard specified in paragraph (3) of this byelaw).

(2) On and after the 1st January 1983, every flushing cistern, flushing trough or other flushing apparatus serving a watercloset pan or pans of the washdown type installed in domestic dwellings shall be of such a design and be and remain so arranged that it will give, at the choice of the user, a flush of one or other of two different volumes, of which the larger (excluding the water entering the cistern or trough during the flush) shall not exceed 9 litres (with the upward variation permitted by the British Standard specified in paragraph (3) of this byelaw).

(3) Every such flushing cistern and, so far as the requirements of the Standard would be appropriate in relation to flushing troughs, every such flushing trough shall comply with British Standard 1125: 1973, "WC flushing cisterns (including dual flush cisterns and flush pipes)", save in so far as that Standard prescribes the volume of the flush.

(4) Every watercloset pan shall be of such a design and be and remain so arranged and connected that after normal use its contents will be effectively cleared by one flush (being the larger of the two flushes in the case of an apparatus designed to give flushes of two different volumes) from the apparatus serving it.

Design and arrangement of flushing cisterns for urinals

58. (1) No flushing cistern or other flushing apparatus serving a urinal shall be of such a design or be or remain so arranged as to give a flush of more than 4.5 litres (with the upward variation permitted by one or other of the British Standards specified in paragraph (2) of this byelaw, whichever is appropriate) per stall or bowl or per 700 mm width of slab.

(2) Every such flushing cistern shall comply with British Standard 1876: 1972, "Automatic flushing cisterns for urinals", or with British Standard 1125: 1973, "WC flushing cisterns (including dual flush cisterns and flush pipes)", save in so far as the appropriate Standard prescribes the volume of the flush.

58A. (1) No automatic flushing cistern serving a urinal shall be or remain so arranged that it flushes the urinal automatically at intervals of less than twenty minutes. Operation of automatic flushing cisterns

(2) Every automatic flushing cistern serving a urinal shall be fitted with a time switch or some other not less effective device for ensuring that the cistern will only operate within such hours as are set on such time switch or device.

Notices to the undertakers

59. (1) At least 7 days before fitting or altering (otherwise than by way of repair or renewal) any water fitting used or to be used in connection with an existing supply of water from the undertakers, a person shall give to them notice in writing of his intention in that behalf. Notices to the undertakers

(2) At least 7 days before -

(a) back-filling any excavation in which a pipe used or to be used for conveying water supplied by the undertakers is laid; or

(b) laying such a pipe by mole-plough,

a person shall give to the undertakers notice in writing of the date on which he expects to begin that work, and shall not, without their consent, begin that work before that date.

Penalties

60. Any person contravening any of these byelaws shall be liable on summary conviction to a fine not exceeding the sum of £400 in respect of each offence and, in the case of a continuing offence, to a further fine not exceeding £50 for each day during which the offence continues after conviction therefor. Penalties

SECTION 6

EXTENDED ACTION (SECOND FIVE-YEAR PLAN) FOR REDUCING PHYSICAL LOSSES

6.1 Organizational Aspects

It has been suggested earlier that effective reduction of UFW may require a temporary major change in the water authority's organization. Such changes may cut across the pattern of promotion and the order of seniority of existing staff; but if inadequacy in the provision, supply, and sale of water has become inbred, there is probably no other way to produce short-term improvements.

After the immediate works program has been completed, any temporary change in the organizational pattern should have been reviewed. It may have produced so many problems in internal relationships that it cannot be maintained. But, if at all possible -- assuming that some initial success has been achieved in reducing UFW -- the change in organization should be confirmed and retained until completion of the first five-year plan. At this stage, the wheels should have been set in motion and any change which appears desirable on general grounds could be implemented without taking undue risks that control will deteriorate and UFW will increase. At this point, special attention should be paid to maintaining UFW at the reduced level and going through a period of consolidation. If a new source of water has been developed, pressure should improve, hitherto hidden leaks should show, and leakage losses should increase. The organization should be alerted to the impending situation.

Review the organization that has been set up for UFW control in the light of achievements; either confirm or make needed organizational changes as long as changes will not restrict further efforts toward controlling of UFW.

Where the marginal cost of water indicates that further reduction is justified, proceed by steps, first repeating the original program to check the accuracy of production metering and of estimates of public unmetered water consumption. Examine potential savings in waste offered by alternative methods of procedure.

6.2 Rechecking Data

When an active waste detection program has been developed over the initial period, subsequent activity is usually a process of refinement that follows the established pattern of testing, measuring, recording, and evaluating results in order to arrive at more accurate figures -- and lower figures -- for the losses.

In early years of the program, a special effort is normally required to achieve worthwhile results through reduction of UFW. The program has been designed to concentrate waste reduction in those areas where the highest losses occur. Thus, the results of earlier efforts are likely to be more dramatic and impressive than those achieved during the second five years.

Experience in developed countries shows that where only passive leakage control is exercised, the net night flow may be as much as 25 liters per property per hour. Even where authorities are well regulated, managed, and maintained, the figure is likely to be as high as 15 liters per property per hour. This is an indication of the level of leakage and waste but, since night pressures are normally much higher than daytime pressures, this level of waste is not continuous for 24 hours.

6.3 Pressure Reduction - Potential Savings in Waste

If, for instance, one assumes the night pressure for eight hours and the daytime pressure only half the night pressure for 16 hours, the losses during the night and day might be 25 and 10 liters per property per hour respectively and the average over 24 hours would then be 15 liters per property per hour. This corresponds to 360 liters per property per day; if there are four people per property, the loss would amount to 90 liters per capita per day. In many developing countries, the occupancy rate is higher and the per capita loss correspondingly lower.

Evidence suggests that if the average night pressure were reduced, for example, from 60 meters to 30 meters; the net night flow of 25 liters per property per hour would be reduced to 10 liters per property per hour. This appears to be a major impact, but it should be recognized that reducing the night pressure without a corresponding reduction in daytime pressure (which is likely to be quite impracticable) is of limited value. Thus every effort must be made to introduce continuous pressure reductions wherever possible. This may entail reinforcement of the distribution network in order to reduce friction losses and help maintain adequate pressures at the end of the line without excessive pressures at the beginning. Where significant pressure reduction cannot be achieved without excessive expenditure, leak detection by sounding and other modern methods, including correlators, are likely to be more cost effective. Another means that has been used to control operating pressures throughout the day is telemetry remotely controlled valves. Such sophisticated arrangements are unlikely to be available in most developing countries at present.

Examine possible further reductions in pressure, including the use of telemetry-controlled PRVs.

6.4 District and Waste Metering: Potential Achievements

Experience in developed countries suggests that with simple, annual sounding of the whole system, the net night flow can be expected to fall from 25 to 15 liters per property per hour, corresponding to an estimated reduction of 54 liters per capita per day. (With the high occupancy levels that prevail in most LDCs, per capita losses would be lower.)

If district metering were introduced, a further fall in net night flow from 15 to 11 liters per property per hour might be achieved corresponding, with four residents per property, to 40 liters per capita per day. If waste metering districts were introduced and combined with district metering, the figures might drop to eight liters per property per hour, or 29 liters per capita per day.

If, associated with these developments, the overall system operation and authority control were improved, higher reductions might be achieved. The lowest probable figure for net night flow would be six liters per property per hour, or about 20 percent of the original figure.

These figures can be used to assess the potential benefit at different levels of control, but some modifications might have been made in light of the authority's earlier achievements and experiences.

6.5 Service Reservoirs

It may be significant that in a fairly recent study undertaken in the U.K., it was shown that, although almost all service reservoirs had negligible leakage, 3 percent of those tested had daily leakages of as much as 12 percent to 30 percent of capacity.

If the leakage from service reservoirs has already been carefully checked early in the program, repeated checking is not normally required (unless there is evidence of ground movement, earthquakes etc.). If, however, there are any doubts about the accuracy of the early checks, a repeat is warranted. The most reliable method is to isolate the reservoir by closing inlet and outlet valves for a period of 24 hours and measuring any volume change through use of a hook. It is essential to ensure effective closing of the valves while the check is taking place. In order to maintain the supply to the consumer, bypass connections may have to be constructed.

Where supply conditions are sensitive, it may be found that a service reservoir cannot be isolated for any appreciable period because pressures on the district would become too low or the cessation of pumping would result in water shortage the following day. In such a case the only recourse may be to accurately measure inflow and outflow.

While this testing is taking place, the total supply from a reservoir to a particular part of the system may be checked by leaving the outlet valve open. If there is a long transmission main associated with the service reservoir, the volume of any leaks from the main may be deduced by changes in reservoir volume. This provides one valuable method of determining the night flow to a particular district.

Recheck leakage from service reservoirs and transmission mains.

6.6 Updating of Waste Detection

Along with refining leak detection techniques, management must also consider improved training of personnel using all types of equipment, as well as devising incentive schemes for increasing output. It has already been stressed that all waste saved must be quantified and recorded. Charts depicting the reduction over the years of net night demand for different districts can help to spur competition between groups of waste inspectors. These can be displayed on the walls of the inspectors' offices or made public by the media in order to stimulate public cooperation.

The main problem with reduction of UFW is that it is an irksome job and some motivation is required to sustain the levels of without and effective activity and to ensure that equipment is used. It is highly conscientiously desirable to monitor the overall effect of the combined efforts of the teams and from this to devise some form of reward. In one bonus scheme which has been operated successfully for some years, the annual trend in consumption per property has been graphed from past records (see Figure 6-1). When the consumption per property for the year is below the trend line associated saving in chemicals and energy is calculated and half of this saving is paid out to the employees engaged in inspection and repair work as a bonus. The breakdown of individual bonus payments is based on performance. As an alternative to a bonus incentive scheme privatization may be contemplated.

Completion of the relocation and remapping of the system, and of the process of replacing defective valves and installing additional valves and hydrants will facilitate the detection of leaks.

Finally, the extent of difficulties and the cost of tests carried out thus far, compared with the volume of waste saved in pilot waste meter districts, will determine whether an extension of waste meter districts throughout the system is likely to be cost effective. If such a program appears financially attractive, the establishment of additional waste meter areas will normally begin in the older districts, where waste appears to be greater and detection by sounding or any other method is more difficult and time consuming.

Reexamine possible improvements using additional training, equipment, labor, and incentives.

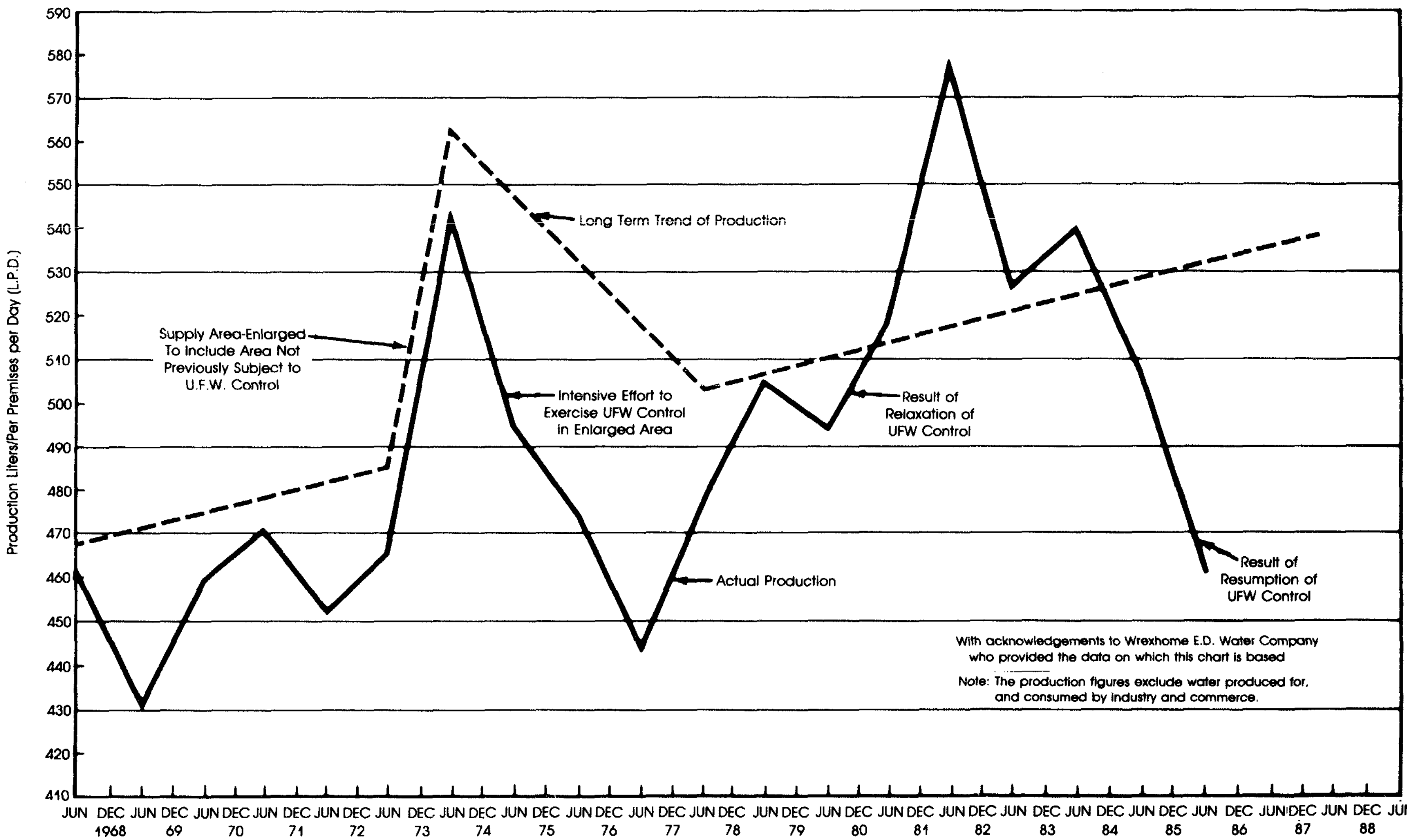
Introduce competitive spirit and appropriate rewards by monitoring, evaluating, and showing in chart form the achievements for each inspection group.

Consider the introduction of a bonus scheme based on savings in annual operating costs resulting from reductions in UFW.

Extend the pilot scheme for waste meter districts by stages, beginning in those sections where excessive leakage is expected. Step-test to measure night demand and locate demands in each street. Repeat tests every six months and compare results.

Alternatively or additionally, extend district metering by subdividing the original large districts and increase the frequency of monitoring districts. (see Annex 5B). Establish respect for bylaws by appointing plumbing inspectors to improve standards of consumers' internal plumbing, or by such other means as appear practicable. This could include adult education, publicity, legal action, and community involvement. The private sector could be given incentives for providing low-cost and efficient plumbing services.

Figure 6-1. RELATIONSHIP BETWEEN UFW CONTROL AND PRODUCTION



6.7 Public Relations

The build-up of a waste conscious outlook both within the authority and in the wider community has to cover a period of many, many years. Thus the major part of the long-term effort to control UFW must be based on improved public relations in the media and, more particularly, in the schools. The appointment of a public relations officer by the authority is an essential first step.

Management should ensure that schools are visited at least annually and that parties are taken to visit the water works. Every opportunity must be taken to demonstrate the losses that occur from wasteful use and the resulting cost that has to be met by the consumers.

In most industrialized countries, bylaws to cover such practice are normally in operation but in the LDCs, even where such bylaws exist they are normally ignored. Special attention is required to introduce such legislation where not existing and above all, to ensure compliance. The difficulties are paramount, but the first essential is to appoint plumbing inspectors to approve all new plumbing installations. In the long term, education to encourage public cooperation may be more valuable than legal enforcement.

6.8 Improved Construction and Repair Works (see Sections 7 and 8)

One sector that may need special attention is the building industry. Great efforts have to be made to educate the builders and plumbers in the value of improved plumbing practice covering both the equipment and its installation.

If leakage problems are to be reduced in the long term, renewed attention must be directed to improving standards of design and construction of both new works and repairs. The authority must ensure that the standards of work carried out in-house are above criticism. All contracted works must be inspected to ensure that they are, and will remain, leak-free. Mainlaying work done by contractors must be supervised by new works inspectors whose insistence on compliance with specifications will be fully supported by management.

- **Pay particular attention to improving the standard of construction of new works and repairs for mains and services and ensure that all work is properly inspected and may be expected to remain leak-free for years to come.**

- **Establish respect for bylaws by appointing plumbing inspectors to improve standards of consumers' internal plumbing, or by such other means as appear practicable.**

6.9 Improved Metering

Review the progress achieved by the extended action program for reducing nonphysical losses (Section 4) and make improvements in the meter changing program and in meter repair and testing procedures. Ensure that coordination between the consumer service departments and billing and collection departments is as close as possible. Coordination with the distribution and maintenance departments should also be ensured, so that meter blockages are reduced to a minimum and routine operation of valves and mains flushing programs proceed in an orderly manner. The meter procurement, repair, and testing programs should be fully operational and working satisfactorily.

6.10 Meter Reading

Review meter reading procedures; consider the effects of privatization, if already begun, and any other improvements.

6.11 Distribution System Mapping

Review progress in mapping of the system, including all new works, and update as needed.

SECTION 7

OPERATION AND MAINTENANCE IN RELATION TO CONTROL OF UFW

7.1 General

When first faced with the overwhelming difficulties entailed in accurately estimating UFW, water authority managers may feel a sense of hopelessness. Among the difficulties will be: the scarcity of trained administrators and engineers of high enough calibre to insist on keeping the pumping stations clean, let alone organize any day-to-day maintenance of pumping plant and meters; the high proportion of consumers' meters that are defective; the frequency with which they break down because of grit in the main; the impossibility of arranging for regular simple tests on equipment to deduce operating efficiency and accuracy; the obvious exposed waste by leakage from jammed air valves, or other sources; the inability to arrange for a shutdown of mains to stop such obvious wastes; the absence valves, hydrants, washouts, and associated marker posts.

There are so many jobs to be tackled and so few employees able to tackle them. There is a constant temptation to say: "It's impossible to begin UFW control until we have gone back a few steps and put the system into a condition where reasonably accurate data can be produced." An attempt has been made in these guidelines to show how, with patience, determination, organization, and adequate resources, it may be possible to overcome the immediate difficulties and gradually achieve UFW reduction as the necessary improvements in operation and maintenance are made. Unless there is a major input by a special task force, however, UFW will increase faster than any reduction that can be achieved by the proposed program.

It will be found in most cases that standards of maintenance inherited by the authority have not, in recent years, been retained. Looking around works, one occasionally finds a particular area where cleanliness and order reign in the midst of dirt, squalor, and degeneration. Where this is so, it is usually the achievement of a single employee. The solution to the problem then should be clear. The status and authority of those few, well-organized individuals should be recognized and increased. Their small areas of order have to be extended; they must be given sufficient help and an improved position to enable them to extend their influence over the whole works or the whole system. They may not be the most qualified or even the most experienced of the employees, but no matter. If something is broken or not operating correctly it has to be repaired or replaced. These men or women may have no idea how to make the repair but they have the impelling desire, the initiative, the patience, and the perseverence to find a way to get it done.

It has already been noted that a special task force should be created to control UFW. It may be that such a task force could be given wider powers, covering overall maintenance. A high level of UFW is only one aspect of inadequate maintenance of the system, and control of UFW cannot proceed very far until other maintenance deficiencies are eliminated. If the correct organizational decisions were taken during the preceeding five years, the operation and maintenance departments of the authority were strengthened as part of the UFW reduction program and should be ready to shoulder the responsibility of controlling UFW. This is the preferred course of action.

7.2 Source Stations

A program must be developed by management to cover operation and maintenance, including the regular testing of all plant and equipment, so that proper control of the system can be established. For station equipment, operational handbooks are normally provided by the manufacturers. It is necessary to aggregate these and to diarize, or possibly computerize, them so as to provide daily, weekly, and annual routines for the operational staff. Additionally, all gauges and meters have to be tested for accuracy at regular intervals. Often the equipment provided is inadequate. In one developing country where the works were recently inspected, there were major pumping stations with ten or more large pumps delivering into the system at 100 megaliters per day or more, but only one small delivery pressure gauge in operation for the whole installation -- and a guage that might, in fact, be showing readings 20 percent in error. Such a major error can occur when a gauge has not been fitted with a controlling stop valve to eliminate vibration.

In many major pump stations there are no suction gauges, no ammeters, no flow meters, but only perhaps a few voltmeters in operation. Since there are no means available for testing pump outputs or efficiencies, there is no way to operate the station in an energy efficient manner, or to decide when pumps should be replaced. It may also be found that pump characteristic curves have been lost -- and are even irreplaceable. With such problems to be overcome, it is nearly impossible to accurately estimate flows or total production. Many of these mechanical failures are a result of the failure to protect motors, meters, and other equipment from dust during building repairs and extensions.

> **The password is cleanliness. Operator training is a prerequisite of successful operation and maintenance. If problems of grit in the meters, valves not shutting off, etc., are to be minimized, it is essential that proper attention be paid to all maintenance works, particularly on main and service repairs, to ensure thorough flushing out after completion of repairs. Additional hydrants and washouts must be installed if required for this purpose.**
>
> **The guidelines refer to testing of production meters and alternative production estimates based on pump output. Testing of all meters and pumps is essential annually or more frequently, as indicated by results. Protection from dust during building alterations is often overlooked and is a common cause of failure.**
>
> **Pressure gauges and recorders sensitive to shock and vibration should be installed in duplicate. They rapidly become inaccurate and replacement is necessary whether for permanent installations or for portable use. Regular testing and calibration is required at least annually. All gauges permanently installed and operating should be throttled to minimize vibration.**

7.3 Distribution Networks

Distribution networks may have deteriorated in the same way as the machinery but, in the absence of testing facilities, it impossible to know.

Ignorance is bliss -- until major failures occur. Reinforcement of a network to improve pressures and flows is a matter of blind guesswork. Thus the greater part of an authority's capital investment is not based on a logical design process and is not being utilized in an effective manner. Improvements may be possible, but costs cannot be accurately estimated. Valves that have been left closed produce "no flow" sections in which excessive internal corrosion occurs. Failure to flush grit from the network can produce conditions where consumers' meters may fail only a month after installation.

The internal cleaning and relining of pipelines may extend their life considerably, reduce leakage, improve pressures, and extend the useful working life of valves and consumers' meters. Pressure tests on the network at regular intervals can reveal where such remedial action might be cost effective, but portable pressure gauges or recorders are rarely available in the Authority's stores. Pilot tests on such rehabilitation works are often justified and, if properly monitored for UFW before and after, can be evaluated for cost-effectiveness.

Very old networks may also be too small to provide adequate supplies. In such cases complete replacement of pipelines and consumers' services may be cost effective. This should be attempted first on a "pilot" basis, and the resulting reduction in leakage should be carefully measured. The effect on the life of meters should also be monitored, so that the project can be properly evaluated.

> **Although failures in transmission and leading mains are normally self-evident, regular inspection is desirable throughout their whole length to minimize failures. Total leakage tests of other mains is rarely possible except for special investigations. Maintenance includes inspection, full operation, testing of closure, and repairs of leaking glands, etc. on all valves. All air valves, PRV's, and hydrants should also be inspected, tested, and repaired.**
>
> **Examine possible cleaning and relining of distribution mains to obtain a clean system. In many circumstances internal cleaning and relining of mains may be desirable, but this normally calls for the employment of specialized contractors and should be done initially on a pilot scale.**

The problems involved in organizing the operation and maintenance of networks were raised in Section 5.8. This is a fundamental aspect of distribution network operation, and it is essential that the responsibility for valves and hydrants be clearly assigned to carefully selected individuals who are appointed as district inspectors. Their responsibility should include frequent surface inspections along the lines of all major transmission pipelines. Rapid action must be taken when potential problems arise due to construction works or unexplained changes in level, ground movements, or wetness. Inspectors should also be in charge of special operations such as the setting up of pilot areas for UFW control.

> **Reexamine potential improvements in operation and maintenance. One way of ensuring proper maintenance is to have "district inspectors" who have sole responsibility for all valve operations for the repair teams. They may also undertake waste inspection while repairs are in**

progress in the same locality. They are responsible for seeing that all valve boxes remain exposed during highway maintenance and after road repairs. They are responsible for all internal cleaning of mains, sterilizing and flushing after repairs and, finally, for seeing that all isolating valves remain closed and that all valves closed for repairs are reopened.

All valves must have marker posts and must be numbered and recorded on distribution plans. All failures and repairs must be recorded in a form that readily reveals operating conditions in each street.

When special pilot areas are established, preliminary flushing out of all pipelines and testing and replacement of all valves in the pilot area are required.

Following the detection of leaks by waste inspection teams, it is important to ensure that the leaks are repaired immediately and that the work is done and retested carefully in order to minimize the risk of further leakage occurring near the same place. Cases have been reported, for instance, where service pipes were leaking from old repairs that were made by using lengths of rubber hosepipe. It is also very important to ensure that any stones, grit, or extraneous matter that may have entered the network as a result of the leakage or the subsequent repair are removed both manually and by swabbing and flushing out before testing and sterilizing has been carried out. The cost of excavation, refilling, and surface reinstatement forms such a major part of the overall operational cost that every effort must be made to ensure that all repairs are tested to a very high standard.

Records must be kept in a form suitable for rapid reference, giving details of the dates and costs of repairs in each street. These will indicate when wholesale mains and service replacements are required, especially where there are extensive corrosion problems.

The cost of repairs to individual small underground leaks being relatively high, every effort must be made to ensure high quality workmanship, flushing out, and testing before excavations are refilled.

Every effort must also be made to eliminate any corrosion problems, particularly in the replacement and repair of services. (See World Bank Guidelines on Corrosion.)

SECTION 8

NEW WORKS IN RELATION TO UFW CONTROL

8.1 Design

Until now the design of new works, even in Bank projects, may not have made sufficient provision for active leak detection. All too often, no means appear to have been provided for measuring accurately the quantity of water produced. When new works are designed, everything must be done to ensure that:

- production meters are provided;
- pumps can be tested regularly;
- service reservoirs can be isolated for testing, cleaning, and repairs;
- reservoir inflow and outflow rates, as well as water levels, can be indicated conveniently;
- sufficient valves are fitted for shutting off new pipelines for repair purposes;
- tappings are provided in mains for inserting instrumentation to measure flows;
- washouts and hydrants are provided for charging and flushing out pipelines and sections of the network;
- valve and hydrant marker parts are fixed; district meters are provided on bypasses to record the pattern of distribution flows; pilot waste water districts can be readily set up for training and research on consumption, if not for active waste detection;
- accessible stop taps are provided on all consumer's services within the street boundary, complete with access chambers and cover plates to enable soundings to be made without entering private premises.

The adoption of new design valves in place of traditional sluice valves should be considered, because the former have no gate "slot" in which stones can lodge and they can be easily closed drop-tight after continued use.

Where the design is being undertaken by consultants, the authority must collaborate at the outset to ensure that these requirements are all included in the terms of reference.

Outline design must, at a minimum, include or make provision for:

(a) Simple tests on all pumps and production meters by isolation and volume measurements on clear water tanks or reservoirs and/or by discharge to waste through test meters. Installation of adequate indicators of pressure (suction and discharge), flows, amps, volts, r.p.m., and hour counters;

(b) Production meters at headworks to be supplemented by meters for delivery to, and discharge from, service reservoirs;

(c) Ample district meters or, at least the chambers and bypasses for later installation. For distribution extensions, smaller metered districts to be considered and allowances made in the layout. Adequate valves and hydrants to be provided for control, isolation, and flushing; as well as tappings for insertion of pitometers or turbine meters.

(d) Where waste water districts are justified, include chambers and bypasses, planning one meter to serve two or three districts.

8.2 Materials

In Bank-financed projects, the standards of design, specification, and construction have normally been satisfactory. The designs have ensured that materials appropriate to the conditions have been specified. But often a great deal of new work has been undertaken directly by the authority using local contractors, and the work has been supervised by local inspectors. In these conditions, less than adequate care has frequently resulted. In areas where galvanized steel services traditionally have been used, for example, the practice has been continued even though local conditions (such as a high water table) have resulted in rapid corrosion and excessive leakage.

Now that a variety of alternative materials is available, there is no reason for not using materials appropriate to local conditions. Where conditions are corrosive, much can be done to reduce deterioration by initial protective measures. Exposed metal fittings can be coated with a waterproofing paste or tape before trenches are refilled; this simple precaution can significantly prolong the life of pipework at little cost.

Political pressure to use local materials of inferior quality or thicknesses that do not comply with international standards may arise. Such pressures have to be resisted, in spite of the difficulties, if the manager is to reduce the costs of operation and maintenance.

Select materials to withstand local conditions (such as aggressive soils or corrosive water) and comply with international or other appropriate standards.

8.3 Equipment

Pumps and other equipment are normally selected after international tender. For larger items, the choice is made on the basis of least cost, taking into account efficiency and operating and maintenance costs. Other important considerations are suitability for purpose and interchangeability with existing equipment. Such factors are difficult to assess in financial terms and thus are frequently overlooked. But they must be considered, if operational costs are to be minimized. Moreover, the conditions in developing countries frequently do not permit adequate maintenance and correct operation of modern equipment that has been designed to meet the needs of more developed countries. The wisest choice is to initially select the simplest equipment, so that its continued operation is assured. For instance, before embarking on the purchase of large quantities of new domestic meters, the authority should consider the alternative of installing flow limiters, which are relatively simple to operate, and may be less liable to breakdown when water contains grit and rust, and are able to control water use at low cost.

If the continued use of domestic meters is justified, a limitation in the size of meters and in the number of different manufacturers will simplify repairs, testing, and stocking.

Select equipment appropriate to local conditions, particularly allowing for interchanging with existing equipment; minimizing stocks of spare parts; and simplifying operation, maintenance, and repair. Suitability for purpose should take precedence over investment cost. Simple operation is preferable to the most modern sophisticated plant, especially when labor is plentiful.

8.4 Training

One major problem common to developing countries is the shortage of skilled and semiskilled labor. This results in persistant failures due to the failure to maintain equipment properly. Even where relatively simple Venturi-type meters have been installed to indicate production, they have been misused and are frequently broken. One of the major tasks of management is to concentrate on the training of employees in the construction and maintenance of new works of all grades. Training schools are being established in many countries, and every opportunity should be taken to make use of all the available facilities. A continuing difficulty is that of adequately compensating public employees who have received training, who often move over to the private sector. The solution appears to be either improving pay structures or privatization.

Management may have to take the broad view in regard to losses of trained staff, because this factor helps to ensure that the contractor for new works can employ more skilled labor capable of improving construction standards.

Training of labor in construction standards is essential for obtaining satisfactory new works.

8.5 Construction

The materials for mainlaying contracts are frequently supplied under a separate contract. Great care is required in controlling the supply of materials to the contractor to ensure that unnecessary breakage is avoided. The contractor has to check all pipes and fittings when he takes delivery, and he then becomes responsible for any damage that occurs. All pipes must then be examined, "rung," or otherwise tested before laying. During the setting out, it must be ensured that adequate space between the mains and pipes, sewers, or other services crossing the line is allocated. Before laying, all pipes must be cleaned; they must be laid on a proper bed (preferably gravel) with a minimum cover of 1.0 meter.

If the pipes are made of ductile iron, and in corrosive conditions, polyethylene sheaths give valuable protection. If they are made of nonmetallic material, the laying of a tracer cable along the top will be of value later, in case records of the line are lost.

Jointing requires special cleanliness and care. Manufacturers' instructions should be followed for centering and lubrication of joints, and so forth. An end stopper must always be fixed to the end of the open pipeline to prevent entry of stones, debris or, in the case of large mains, fecal and other waste matter.

Tapping of mains, particularly under-pressure tapping, requires special attention to manufacturers' instructions. Metallic fittings should be protected with waterproofing paste or plastic tape to enhance their resistance to corrosion. Service pipelines should be installed at a minimum 0.7m depth and bent or laid so as to avoid strain at the junction with the pipeline. Special protection should be provided when joining dissimilar metals.

After the laying of pipes, the pipelines must be tested, normally to twice the working pressure. First they should be swabbed with plastic swabs as often as appears necessary to remove all debris that has inadvertently entered the line. Before testing, the sides and ends must be supported and at bends, concrete blocks should be provided. Testing should be carried out while the pipe joints are still exposed to view. Supervision of construction, particularly of local contracts, can present a special problem. In some cases local tenders are so low that proper construction necessitate a loss for the contractor. If the inspection is done locally, standards will decline. It is possible to see top grade pipes being laid so badly that the factor of safety against failure is less than 1.0 by the time the contract has been completed.

Local supervision of local contracts can also make it difficult to ensure that all variations from the original contract plans are recorded accurately and that proper record drawings are prepared showing the works as constructed.

It may be essential, in some cases, to insist on supervision by competent consultants to ensure adherence to contract conditions.

> **All construction must be required to comply with approved specifications. The same rigid specifications used for major contracts are required for small local contracts; the supervision and inspection of local contracts should be made the responsibility of a qualified consultant. For pipe-laying contracts, particular attention should be paid to the provision of temporary stopends in order to prevent stones and grit from entering pipes during construction. Proper standards of construction, including depth, trench pumping, alignment, bedding, jointing, refilling, testing, swabbing, disinfecting, flushing, and retesting of all pipelines are essential. Retesting at working pressure should follow the provision of services.**

Service connections should be bent to give flexibility and prevent excessive strain on tappings. Ferrules (corporation cocks) and, where appropriate, saddles should be provided. Main stop-taps with surface boxes should be fitted outside and adjacent to consumer's boundaries to give adequate night access for leakage sounding. Alternatively, surface boxes must be provided over the ferrules.

Complete records should be kept of all as-built work.

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