.5

AD

SAFE WATER 2000 - Global Consultation on Safe Water and Sanitation for the 1990s, New Delhi, India, 10-14 September 1990

ADVANTAGES OF REHABILITATION OVER REPLACEMENT

The preparation of this Paper was commissioned by the Asian Development Bank, Manila, Philippines at the request of the Collaborative Council of ESAs for circulation at the Global Consultation. The Paper was prepared by North West Water International Ltd., Manchester, United Kingdom and represents their findings and views on the matter and do not necessarily reflect the position of the Asian Development Bank.

Any inquiries may be addressed to Messrs. Barrie Shore and David Young, North West Water International Ltd., P.O. Box 49, Oakland House, Talbot Road, Old Trafford, Manchester M16 OQY, United Kingdom. Tel: (061) 848 0683; Telex: 665682; Facsimile: (061) 872 5581. Additional copies may be obtained from the Water Supply Division, Asian Development Bank, P.O. Box 789, Manila, Philippines 1099.

SAFE WATER 2000 - Global Consultation on Safe Water and Sanitation for the 1990's, New Delhi, India, 10 - 14 September 1990

Advantages of Rehabilitation over Replacement

1. PREAMBLE

The levels of finance currently being mobilised by the water sector are, even at current per capita costs, insufficient to achieve modest rates of expansion. Furthermore effective use is not always made of available monies and inappropriate service standards, design parameters and assets are frequently adopted and provided. If best use is to be made of the limited financial resources available, rehabilitation of water services to give acceptable standards of service which consumers are prepared to pay for, is best pursued through a strategy involving the development of asset management planning rather than the generally uneconomic practice of total renewal and replacement.

The benefits of rehabilitaton and associated asset management planning can be clearly demonstrated. Firstly cost. By considering options to renewal, the most cost effective and technically viable solution can be chosen. Secondly, additional benefits are likely to accrue arising from greater rate of expansion in the sector for the level of finance available; deferment of investment by phasing rehabilitation; more effective use of resources; improved operations and maintenance along with a greater return on investment and better value for money.

This paper looks at the current situation regarding investment together with the benefits of developing rehabilitation programmes and asset management plans. It develops this concept by comparing a hypothetical consumer related business where people generally expect and are prepared to pay for the product and contrasts it with the water sector where almost universally the product is looked upon as a free god given right. Standards of service and asset performance are key elements in developing investment programmes for the water industry and optimal use should be made of existing facilities and assets by rehabilitation where practical.

Above ground requirements for rehabilitation are easier to deal with, since operation and maintenance needs are more readily discernible and obvious. The paper concentrates on the more difficult and expensive underground assets but makes the point that asset management plans for above ground installations should be developed using the same approach.

Implementation of rehabilitation systems demand that certain key areas are addressed; political, institutional and financial where attitudes need to be changed; technical, research and development and training - where opportunities of providing cheaper and more efficient new technological developments ought to be grasped.

Other attitudes which need to be changed are those related to people. Engineers and Technicians gain great personal satisfaction from the construction of new projects and politicians derive equal satisfaction from 'opening' them. Attitudes need to be changed so that greater emphasis is placed on operations and maintenance and this will be particularly difficult in developing countries where this type of work ethic is often absent.

The paper then goes into some detail on underground rehabilitation and renovation, including newer technologies, decision making and cost.

This paper is in two parts - Sections 2 to 4 inclusive are aimed at those with a political, social and economic interest and Sections 5 to 9 leads on from here into technical aspects. This is not to say, however, that policy decision makers should stop reading at the end of Part I. They should in fact satisfy themselves that Part II, and the appendix, which deals with implementation of rehabilitation technology together with most importantly attitudes of people, is practical and achievable to such an extent that approved policies can be implemented. Whilst the paper deals with rehabilitation of water services in general, sections 5 to 9 and the appendix concentrate on water distribution and the rehabilitation of underground assets, since 85% of investment in water services is underground. Guidelines on selection of rehabilitation methods are provided and similar guidelines could have been developed for sewerage, sewage treatment and water supply.

PART I

2. INTRODUCTION

In the past the provision of water supplies has been looked upon by generations of people as a God given right. This God given right was the means of ensuring an adequate standard of life and health and was often provided to people without thought of cost or value. However, the provision of adequate amounts of clear, pure, wholesome water entails high cost, particularly when one not only supplies the basic needs of the population, but also supplies increasing amounts to urban industry and commerce.

The supply of increasing amounts of water to people is very expensive and vast amounts of funds are required to enable the required standards of service to be met. In the past much of the money required was given in the form of government subsidies either directly or through external financing or loaned at low interest rates by one of the many global funding agencies. The available funding for water supply projects is now being carefully monitored and the water supply sector now has to compete with other sectors for the available funds.

The level of funding currently mobilised by the sector are, even at current per capita costs, insufficient to achieve even a modest rate of growth. Additionally, in the past those providing the services often did not make effective use of resources available and too frequently inappropriate design levels of service or design criteria were adopted.

Against this background it is likely that in future investment choice (level of service, size and timing of investment) may be more closely linked to the customers willingness to pay a for a sustainable service and as a consequence users may have to bear a greater proportion of the cost than previously, by conventional tariff systems supported by metering, billing, and collecting improvements or, where this is inappropriate, through alternative methods of cost recovery.

Thus the future financial status of the water sector depends upon concerted efforts by funding institutions, government and local water undertakings to address the problems of 'value for money' on investments and ensuring that maximum benefit in terms of levels of service are achieved for minimum cost.

This paper is directed at the policy makers within the major institutions, economic and financial planners, technical staff and politicians and suggests a way forward in ensuring that value for money is obtained within future funding in the water sector.

3. WATER INDUSTRY MANAGEMENT

People expect to pay for most 'public' services for instance, electricity, gas and telephones. Equally they expect to pay for other services, consumer products and essential items. Perhaps at this stage we ought to compare a general consumer related business, manufacturing a product, with the water industry, and analyse their respective needs.

General Consumer Related Business

In running any successful business the information needed to ensure effective management can be broken down into four main areas. These are customer, product, manpower and physical assets. Both financial and physical data is needed in all these areas. This allows management to run the business on a day to day basis as well as medium and long term planning.

In the case of the customer we need to know if the product is in line with his needs. Also is the design and cost up to standards of expectation and price? Clearly in today's terms an outmoded, overpriced, poor quality product leads to financial disaster. A manufacturing company needs therefore to engage in market research. This establishes customer needs and market demand, together with feedback on quality and price.

As far as product is concerned there is the need to establish a technically satisfactory production system in both quality and financial terms. Considerable effort has to be applied in this area if the company expects products of a consistently high quality and standard.

Manpower is a readily recognisable area of concern, particularly today when costs are so high. Any business needs to have the optimum level of skilled, well trained and motivated staff. Information on manpower is of paramount importance.

The fourth area, physical assets are readily recognisable in a manufacturing industry context. However, although vital, in water services it has historically often been overlooked. Any manufacturing company has physical assets in two main forms. Firstly, machinery which consumes power and needs maintenance and which ultimately will need replacing at fairly defined intervals. Secondly, fixed assets, generally in the form of buildings, which similarly have running and maintenance costs, together with the need for longer term replacement.

Information from these four areas is used to:-

* determine customer need
* establish product quality and control
* determine manpower requirement
* assess the consumption of fixed and mobile assets
* fix the product price
* reviewing the overall business.

Neglect in any area can lead to inefficiency and higher costs with the inevitable lowering of profits or even company failure.

Water Industry

The present day water industry should (irrespective of whether it is a state run organisation, privatised business or a social service), in operational management terms be run on the same lines as any efficient manufacturing company. In saying this it is recognised that a monopoly situation may exist. However, as far as efficient operational management is concerned this should not, in general terms, be a significant issue. The need for information in the water industry follows the same lines as described earlier.

First we need to know what the customer expects. Is it necessary to provide water at certain pressure, volumes, quality for all or part of the day? Are customers satisfied with the standard of service we provide both in product terms, customer services and the prices we charge? The customer needs to know what we offer and we should remove any false expectations of standards particularly, if for cost reasons, a low standard is to be provided. The clear parallel is market research. Until we tackle this area the complaints of poor service at too high a cost will remain.

Secondly, the demands for improved product quality are increasing. Therefore detailed information is needed both on water quality, production and cost. However, almost universally a high quality product is transported through poor condition distribution systems. This leads to a lower quality product being delivered to the customer together with a high unaccountable loss during delivery. A manufacturing industry would probably call in the police in similar circumstances!

Thirdly, we need information on levels, skills, training costs etc. of our manpower. It is inevitable that as technology improves and customers' expectations of service and charges harden, there will have to be reductions in manpower together with corresponding improvements in their skills and performance.

The fourth area, physical assets, has often been overlooked in the past. It is only when fixed assets appear to be at the end of their useful life that attention is focused on them. Information on customers, product and manpower, is often transient. However, information on fixed assets is long lived. Indeed within the water industry there is masses of information, much of it going back to the last Century.

Traditionally the water industry's solution to problems has been to invest in new assets, whether this be in terms of pumping stations, treatment works or underground pipelines. These investments have been built to last, with life expectancy in some cases of 100 years.

During this time little maintenance has been provided, particularly to underground assets and indeed the ageing assets have in many cases become obsolete and outdated well before the end of their design life. This has led to problems of operational efficiency and reduced levels of service to customers.

If we were to look for a moment at a manufacturing industry, in order to maintain its competiteveness in the market place new investment would be required from time to time. This investment would not be in the provision of new buildings nor in the wholesale reprovision of equipment, but the necessary machinery which would have a fairly short design life in order that the company could take advantage of new technology as it developed. Extensions would be more usual to existing plant where additional resources were required rather than taking the drastic step of demolition and rebuilding on a grand scale.

Why should the water industry be any different? In the past, replacement of assets has often been the only available solution to problems, but not any longer. Over the past few years new technology has been established in the Developed World which has led to new materials, equipment and techniques for rehabilitation being developed. These are now revolutionising the water industries construction methods on a worldwide basis.

The use of rehabilitation techniques as a solution to problems particularly in underground assets, is probably the most efficient and economic solution available - not only in terms of capital monies expended but also in terms of other more intangible benefits. For instance research has shown that social disruption caused by replacement of underground assets by conventional means, are equal or greater than construction costs. Indeed, where rehabilition is a technically satisfactory alternative to replacement there is no economic case for replacement.

Do these arguments hold good in developing countries where in many cases the cost of labour is cheap and technology high. The answer to this is yes. With large above ground assets such as sewage treatment plants or water treatment works, technology is an integral part of the process design and operation. The use of cheap labour on such sites is limited with a greater use of skilled personnel and expensive equipment. Rehabilitation of these assets is almost inevitably economically viable.

Turning now to underground assets, it is probably true in small rural communities with shallow mains running through unmade ground, that replacement may be the economic option. However, in urban areas with deeper mains laid under heavily trafficked roads, rehabilitation is the answer. This is particularly true for sewers where the cost of the pipe represents 5% of the cost of the asset in replacement schemes in urban areas. The remaining 95% of the cost is incurred in excavation and reinstatement. Additionally this takes no account of the social disruption caused by deep excavation such as disruption to traffic, noise, dust, disruption to business.

4. ECONOMIC BENEFITS OF REHABILITATION

The rehabilitation of assets whether below ground or above ground can be defined as the repair, renovation, maintenance, replacement and efficient operation of these assets in terms of system or asset management. The economic benefits that accrue from rehabilitation are many and are described in some detail below, with examples where appropriate.

Capital Costs

The capital cost of carrying out a major scheme is obviously one of the major considerations when considering investment. One of the major advantages in rehabilitation is the fact that capital investment is minimised. This minimisation of costs is achieved whilst meeting design levels of service. When considering above ground assets rehabilitation techniques should always be considered as a first alternative. Rehabilitation solutions to the problems of quality and quantity can prove very effective. For example by utilising existing treatment plant structures but by using different technology it was possible to uprate a water treatment plant in Malaysia from 90 MLD to 180 MLD at less than one fifth of the cost of a new works.

Such techniques can also be applied to sewage treatment works where new technology and automation can provide additional capacity and a better quality of effluent without the need for major rebuilding. With underground assets, both water mains and sewers, the picture is identical. The Appendix to the paper contains details of costs of various methods of rehabilitation and shows that rehabilitation can show substantial savings on replacement. These savings are proportionally appropriate both in developed and developing countries.

Other Financial Aspects

Rate of return on investment can be looked at from two different aspects - internal and external rate of return. An example of internal rate of return would be improved operational efficiency on works. The provision of a combined heat and power installation on a sewage treatment works can drastically reduce electricity and power costs, giving a rate of return on investments in some cases of less than 3 years. That is to say the money saved in three years operations will more than pay the cost of the initial investment. External rate of returns would include such aspects as leakage control. Rehabilitation of the distribution system can reduce leakage or non revenue water by as much as 40%. This additional water is then available for re-sale to new or existing customers. Implementation of leakage control policies have shown rates of return of as little as five years. However, it should be pointed out that external rate of returns are dependant on a suitable and effective charging policies. Deferment of capital costs and the ability to stage works is also an important consideration when assessing the benefit of rehabilitation works. Again by the rehabilitation of underground assets and reduction in leakage major investments on new sources can be avoided. Cases have shown that expenditure of $10M on leakage control can offset the need for new resources at $100 million and this example is not exceptional. It is also far easier to stage rehabilitation works than new works. Carrying out rehabilitation work in stages can reduce financing or borrowing requirements.

Other Aspects

Looking at rehabilitation on a national rather than an individual project level is also interesting. By prudent investment in rehabilitation projects, monies can be made available for other urgent work. This leads to good housekeeping with available resources being used as efficiently as possible perhaps in water or other sectors. Major replacement schemes can have a huge impact on the infrastructure of the area, in terms of the resources necessary to service that scheme. Rehabilitation schemes do not need such a level of back up support thus releasing resources for other important tasks. Other benefits include increased operational efficiency, better maintenance and management of assets - all of which help to keep costs down. As can be seen the economic benefits of rehabilitation are immense. These benefits apply to above ground as well as below ground assets. However, in view of the fact that 85% of investment takes place below ground this paper will now concentrate on the need for, and development of, rehabilitation strategies for below ground assets.

PART II

5. THE NEED FOR A REHABILITATION STRATEGY

The fixed assets of a manufacturing industry usually comprise its production machinery and buildings. Certain parts of the machinery have a very short life and are replaced on a day to day basis, whereas the machine itself may have an overall life measured in thousands of running hours. Generally machine life is fairly determinate and can, in financial terms, be confidently written down over this period!

Water distribution's comparative fixed assets are supply zone networks, not the individual pipelines, which could be compared to the nuts and bolts of the machine. Supply zone networks require day to day maintenance, including the repair of bursts and replacement of short lengths of pipe. However, here the similarity ends, since the wholesale replacement of the supply network is unlikely to take place all at once. Some pipelines may be abandoned after 10 years, others 100 and some may last even longer which after 150 years service are still as good as new. In overall terms, therefore, it is difficult to determine other than a broad brush estimate of replacement costs. Estimates could be made of average lives of pipelines, as well as average replacement costs but these all lead to doubtful historical accounting values. The UK water industry has carried out such an historical accounting exercise and it is estimated that $2 billion needs to be spent on the water distribution network to bring it back to a satisfactory condition in North West England alone. World wide this cost will run into many billions of dollars.

Is this amount correct? What are the confidence limits of the estimate? The answer to these questions is that there is a fair degree of uncertainty and a fresh approach to long term financial planning is called for.

With any asset which has long but indeterminate life, we need to know the likely reinvestment over a period of about twenty years. This is probably the planning horizon, since beyond this time there can be little confidence in the probability of events. Accordingly, we need to prepare a plan showing the physical works required to bring the network back to a steady state where predetermined service standards can be met. This asset management plan can be reviewed at five year intervals to give firmer indications of investment requirements.

The essential elements to be considered for long term investment strategy are:-

1. A statement of standards and policies. For this paper an indication of some parameters is included in Table 1. These would be modified to suit local circumstances.

2. A schedule of Distribution assets, which for ease of handling is broken down into supply zones.

3. The principal components, condition and performance of supply zones relative to standards and policies. This will involve:-

   a) collecting performance data on structural condition (bursts and leakage) and hydraulic performance of the component pipelines.

   b) undertaking surveys in supply zones to determine water quality and pressure changes in distribution

   c) within each supply zone undertake a pipeline material condition survey on strategically important mains.

4. A programme of capital works over a given period of time to meet identified shortfalls in performance and condition.

An equally essential component is to monitor the effectiveness of such a programme to ensure the objectives are being met.

Table 1 - Standards of Service

Standard	Value
Pressure	Min 15 metres at normal daily peak demand.
Flow	Min 20 L/min at stop tap
Interruptions	Max 1 per year of 12 hour duration.
Reliability	Ability to cope with loss of source works for 24 hours.
Water Quality	Compliance with WHO standards
Water Quality	Consumer - 95% satisfied. (For example 6% may not like the taste of chlorine - or the lack of it!)
Economic	Net cost saving of programme.
Design & Operation	To accepted Standards and Manuals.

This methodology relies on a regular detailed monitoring of system performance and asset condition. The cost of this could be thought to be high but in all probability this data is already being collected. If inspection and investigation are applied selectively concentrating on areas of greatest need, and if frequencies are based on previous results, then costs can be shown to be well below the resulting benefits. Furthermore, there is the added bonus of spin-off for day to day operational management. These include better day to day management of the system, a greater understanding of the system and more efficient operation.

Of paramount importance in this approach is the need to prepare and update asset inventories. In the longer term a computerised system is the easy way to achieve this.

6. DEVELOPMENT OF A REHABILITATION STRATEGY

The Need for Rehabilitation

Corrosion occurs in all water mains to varying extents. This is one of the contributory factors which leads to failures, leakage, poor water quality and reduced flows. Where problems occur, consumers experience a poorer quality of service than they would normally hope to receive and expect and additionally the undertaking is faced with increased operating costs. This situation is faced by most water undertakings throughout the world, particularly where a well developed system has been allowed to decline through lack of investment, maintenance or poor management. The implications of these facts is that rehabilitation can and should be justified on the basis of overcoming existing or expected shortfalls in service to the consumer, or on the basis of savings in operating costs. More specifically, situations in which rehabilitation can be justified fall into six main categories, three affecting current problems and three which do not.

Table 2 - Justification of Rehabilitation

Current Service Problems

1. Poor water quality - internal condition of network
2. Poor pressure - internal condition of network
3. Interruptions - structural condition of network.

Problems not Affecting Current Service

4. Potential service problems - change in demand, water source, flow regime, operating practice.

5. High cost of ownership - leakage, repairs, pumping, cleaning. This is usually related to operational activities.

6. Severe consequences of failure - key role mains where the consequences of failure are unacceptable.

It is recognised that poor water quality and pressure may be down to a number of reasons such as inadequate treatment, leaking mains, intermittent supplies or simply poor design. The initial studies undertaken when developing the Asset Management Plan will quickly identify the source of the problems.

Implementing a Rehabilitation Programme

Experience has shown six key areas which have to be addressed if a rehabilitation programme is to be successfully prepared and implemented:-

* Political
* Institutional
* Charges
* Technical
* Research and Development
* Training

Again, it should be obvious that none of these areas can be dealt with overnight but that a start, however subjective, needs to be made on them all. Some aspects of these key areas need further consideration.

Political

Improvements to levels of service and the repair of years of neglect on systems costs money. The cost of a rehabilitation programme is, however, far less than replacement costs for the network and social and economic costs are also greatly reduced. However, a rehabilitation programme is likely to involve considerable expenditure in the longer term, with the consequential effects of borrowing/charging. If a long term Asset Management Plan is produced with alternatives on standards and timing, politicians, both local and central, as well as customers can clearly see the choices facing them and take decisions on a course of action. The choices they have, must clearly be linked to the financial consequences. From experience it is vital to ensure that both customer and political support is given to a rehabilitation programme if it is to be successfully implemented.

Institutional

Rehabilitation should not be confined to pipe networks. Perhaps as great a reason as any for rehabilitation need at present, is the lack of management of systems in the past. If we are to meet tomorrow's exacting demands then organisational development must continue apace, to ensure that an effective and efficient structure can meet the rehabiliation challenge. Traditionally organisations have employed fewer people. At the same time computer systems, information systems, telemetry, communications and other technology has helped in the higher service standards which have been achieved and with increased efficiency.

Charges

In many developing countries, commercial, industrial properties and domestic consumers properties are metered and pay by measure. In some parts of the world water bills are governed by property valuation. Irrespective of how people pay and this topic has been widely debated, tariff structures must satisfy the following criteria:-

* Adequacy
* Fairness - including ability to pay
* Simplicity
* Enforceability

People are generally happy to pay for gas, electricity, telephones, transport etc., but there are many who see water as a God given free gift and are not happy with the prospects of paying for the small element managed by man! On the other hand if the small element managed by man fails, even for a short period, they are quick to let everyone know. Increasing charges against such a background is difficult and yet through careful planning and implementation of rehabilitation programmes this cost can be kept to a minimum. At the same time rehabilitation vis a vis replacement will reduce borrowing needs and customers will pay for a more efficient service. Customers are happier paying for a service which they perceive to be efficient and meeting their required standard of service.

Technical

The need for urgent action faces many authorities throughout the world in respect of water distribution rehabilitation. Ideally AMP's should be the first step so that the correct level of resources can be invested into a system at the correct time. In practice this is hardly likely to be the case and immediate action, however subjective, is often demanded where obvious failures have occurred. Under these circumstances a parallel approach should be taken with Asset Management Planning preparation proceeding abreast of firefighting action. This approach is necessary in many cases and during the early phases renovation and relining equipment needs to be developed as well as many other technologies. These technologies are described in more detail in the Appendix.

Research and Development

The past ten years has seen dramatic changes in rehabilitation techniques, renovation equipment and methods, as well as materials, equipment and other associated technology. A number of these systems have been developed and research and development continues, particularly in the areas of pipeline renovation and in computer systems. The need for this work to run in parallel with rehabilitation is essential if optimum results are to be achieved. Pure research in the highly practical field of distribution rehabilitation is hardly likely to be worthwhile. This technology needs to be applied wherever rehabilitation is planned.

Training

At the beginning of a programme the number and skills of both the staff and manual workforce is hardly likely to be sufficient to meet the objectives. Training needs have to be identified over the full range of activities to be undertaken, from the initial contact with the customer through to high technological training of scientists and engineers. Training centres, together with appropriate staff and courses need to be established and these should be supplemented by on the job training with trainers moving to any location in the region.

7. IMPLEMENTATION OF REHABILITATION - ASSET MANAGEMENT PLANNING

A primary need is a long term plan for the proper management of underground assets. This plan, the 'Asset Management Plan' has the following broad aims:-

* To establish a long term spending assessment.
* To establish and implement a plan for water main rehabilitation
* To establish and implement a plan for system management on a zone by zone basis.
* To help establish and implement leakage control policy

This cannot be achieved overnight and it may be necessary to approach the plan on a statistically stratified basis. Equally there may be a need to prioritise work programmes.

There then is the problem of which renovation solution should be used. Are they technically viable? Can comparative costs be reasonably made? Which choise is most suitable? These questions have been answered for sewerage, sewage treatment water supply and distribution and the appendix to this paper deals with the development of AMP's. Descriptions are included of modern renovation techniques for water mains as well as decision making for selection of the most appropriate technology. It is recognised, however, that some methods are not necessarily available everywhere at present.

8. BENEFIT OF REHABILITATION

The benefits of the development of rehabilitation strategies and Asset Management Planning can be seen in many areas. Not least, of course, is the cost of the scheme. By taking time to consider carefully the options available at the commencement of a project one can be certain that the solution obtained is the most technically viable yet cost effective solution for that project. Cost comparisons are difficult in terms of straight savings in cash. The selection of the most appropriate techniques to renovate and rehabilitate supply zones will lead to more efficient use of monies thus enabling more projects to be undertaken to the wider benefit of the general populous. The use of rehabiliation in project appraisal will lead to the following additional benefits.

* Levels of Investment - greater rate of expansion will be available in terms of coverage for the level of finance currently mobilised within the water sector.

* Effective use of the resources available will be assured.

* The correct design levels of service will be adopted.

* Cost recovery will be easier

* Operational efficiency will be improved.

* Maintenance of existing systems will be improved.

* Knowledge of the system will be greatly enhanced.

* There will be a greater return on investment with much greater value for money.

* A more reliable service will be provided to the customer. Increased knowledge of the system will lead to a greater understanding of problems and their solutions.

* Economic benefits will accrue from the ability to defer large scale capital investment and to enable staging of work to take place. Rehabilitation work can be phased to enable deferrment of capital expenditure.

* The development of asset management plans will enable detailed knowledge of the system to be developed and all financial expenditure to be carefully planned and phased.

9. CONCLUSIONS

Financial, economic and institutional constraints are going to play a greater role in the selection and implementation of projects in the water sector. It is essential that the technical and economic viability of a project be confirmed at the appraisal stage in order that value for money is obtained. The use of Asset Management Planning and modern rehabilitation techniques has many benefits which have been described in detail in this paper. The use of the techniques described should always be considered during the appraisal of any project. Their use will ensure that the most technically viable yet economically and financially correct solution to problems in the water supply sector will be achieved. Rehabilitation and asset managemenmt planning should always be considered as a first alternative to water sector problems.

APPENDIX 1

IMPLEMENTATION OF REHABILITATION - ASSET MANAGEMENT PLANNING

Development of Zone Plans

There are the two urgent needs as described in section 6 of the main paper. These are the short term need to try to hold the situation and prevent further deterioration of service and, perhaps more importantly, the need to determine a long term plan for the proper management of the underground assets. This plan, the 'Asset Management Plan' has the following broad aims.

* To establish a long term spending assessment.
* To establish and implement a plan for water main rehabilitation.
* To establish and implement a plan for system management on a zone by zone basis.
* To help establish and implement leakage control policy.

The plan would need to contain the following items :

* The long term operating and customer standards of service.
* A schedule of the system broken down on a zone by zone basis.
* An assessment of the performance of each zone in relation to the defined standards.
* Estimates of the cost of rehabilitation works over a period of say 20 years.

Clearly in urban areas such a plan cannot be developed overnight and time is needed to develop such detailed asset management plans. The approach to be adopted is better if it is attempted in a statistically stratified manner. This will give meaningful results within a shorter period. The technical approach to zone surveys, including the steps to be taken, is as follows.

* Develop schematic and Inventory - it is essential to develop a schematic model for each zone and an inventory of apparatus.

* Condition and Performance Data - data must be collected on all available information on condition and performance of the systems.
* Mains Pressure Systems - measured at high points and at normal peak demand to enable pressure contour plans to be drawn.
* Survey of communication pipes - their condition etc..
* Water Quality analysis
* Water Colour analysis
* Customer Surveys

Using data collected from the above, reports can be prepared to enable rehabilitation requirements of each zone to be identified and estimates and prioritised implementation programmes prepared.

Prioritising of Work

It is generally agreed that work should be programmed on the basis of need, that is those areas suffering from the poorest levels of service should be resolved first. It is also sensible, where practical, that when work is carried out in part of a zone then the work should include all aspects to bring that area to the design standards of service. That is the work may include reinforcement work and valve installation as well as mains refurbishment and service replacement, although it may be necessary to complete work in another part of the zone before the full range of standards is met. However, provided the survey and modelling work has been carried out at zone level then it will be clear how the work in a particular scheme fits in with a strategy for the zone as a whole and how the standards will be met after future schemes have been completed.

Since the detailed information needed to compare individual schemes across the whole region may not be available a two tier prioritising system is adopted. The first tier is at zone level and dictates the order of priority in which zones are investigated and schemes identified. The second tier is then a ranking of these schemes for inclusion in the capital programme.

Both these ranking schemes are based on a points scoring procedure.

Points System for Prioritising Survey

Work - Tier 1

The scoring system for ranking the zones for surveys is based on information that is readily available, to avoid extra burden on staff in collecting ancillary information at this stage of the investigation. The water quality and standard of service information is the basis of the first level ranking.

These measures include interruptions, pressure, flow and water quality compliance. The water quality compliance figures are those measured at the tap. Any non-compliance with directives could therefore be either as a result of the treatment plant or the distribution system. This would be determined during the investigation stage.

The sensitivity of the zone selection to the scoring system can be tested by varying the value of the unit scores.

Points System for Prioritising Capital

Works - Tier 2

As a result of the survey work, information on the performance of the network against standards of service, water quality, and many other measured parameters is available. The information is also more detailed, including information at more than one threshold, for example, information on pressure every 5 metres and not just at 15m. The surveys also identify schemes to resolve problems in various parts of the zone.

In order to objectively prioritise work on the basis of need it is necessary to again use a point scoring system. Points are awarded to each property according to the level of service currently being experienced and those points increase with poorer service.

Once the schemes have been prepared they are added to the pool of schemes already identified from the survey and other zones. The worse ones would be selected for inclusion in the Capital Programme. The list of outstanding schemes should be reviewed each year as new schemes are defined as further zones are analysed. In this way a scheme to solve a severe problem in a part of what is otherwise a zone with few problems would leapfrog to a high rank.

Whilst this ranking system was developed within the UK it is perfectly relevant worldwide and provides an easy way to assess needs and developed prioritised programmes of work. This ensures that value for money is obtained with limited finance being targetted into essential areas.

MODERN RENOVATION TECHNIQUES

Just as any industry requires its manufacturing equipment to be modern and efficient, so the water industry needs to use modern and efficient techniques in renovating and rehabilitating its pipelines and systems. The use of these techniques will drastically reduce costs and give value for money solutions. Selection of the most suitable technique for a given circumstance is essential for cost effective rehabilitation. A brief description of available technique is detailed below. They fall into three categories :-

* Non structural methods including relining.
* Non structural methods with leakage control.
* Structural methods including replacement.

Cement Mortar and Cement Mortar Replacement Scrape and Line

Renovation using cement mortar relining has been used since the early 1930's, the amount being done annually, until about 5 years ago, being relatively small. The lining technique provides effective protection to ferrous pipelines and prevent internal corrosion and tuberculation, and improves hydraulic capacity. Of paramount importance is the condition of the main to be relined since whilst the lining will prevent further corrosion of the internal surface it will not prevent external corrosion nor will it add appreciably to the strength of an already weak pipe. Cement mortar lining is likely to be beneficial where :-

* internal corrosion is causing significant hydraulic or water quality problems.
* the present condition of the pipe and the rate of external attach suggests a worthwhile life after renovation.

Pits are sunk on to the main at 100 to 150 metres intervals and a power boring machine clears out the encrustation. Debris is removed to the reception pits by flushing out with water.

A high speed spinning head is pulled through the pipe at a constant velocity applying a uniform thickness of cement mortar lining on to the internal surface of the pipe. Bends of up to 22.5^{o} can be accommodated and the process does not block ferrules. The pipe is returned to service usually within 24 to 36 hours.

For diameters less than 150mm the lining thickness should be 4mm, between 150 and 450mm, 6mm thickness and above 450mm, 9mm. Tolerances for these linings should be +2 -0mm.

For small diameter pipes of less than 350mm the cost, including the high level of temporary supplies so that disruption to service is minimised, is around 30% of replacement cost or 15% if social disruption, loss of business to industry etc., is taken into account.

There can of course be problems with the process, most are caused by bad workmanship and inexperienced operatives. Skill training is therefore an essential part of this process. Problems can also be experienced where very soft waters can raise pH levels to 9 or 10 for some time after renovation. This leads to complaints of taste and interference with industrial process. In these circumstances alternative renovation methods should be looked at.

Epoxy Mortar Scrape and Line

Epoxy resin is being developed as an alternative lining material to cement, but at the time of writing has not received full approval. Full approval is expected shortly; the concern is over the leachate of diamines.

The process is very similar to cement mortar lining but requires a higher degree of skill and more sophisticated equipment since essentially two polymers are mixed at the spinning head.

The advantages are that the lining can be relatively thin 2mm maximum, the hydraulic capacity is similar to the original pipe, no pH problems occur, service connections are rarely blocked, and accelerated life tests show a life of at least 40 years. In consequence this process offers great future potential.

New Materials

The traditional main laying material of cast iron was replaced after the second world war with newer ductile iron and asbestos cement. Since 1960 uPVC has taken part of the market bu the more recently introduced polyethylenes are now paying a significant role.

In the mid 1960's the Gas Industry were looking for a material for gas distribution purposes. Because of the explosive nature of gas they were aiming for a material which was tough, flexible, long lived, pressure sustaining, weldable so as to be jointless and hence leakproof, corrosion resistant, etc., indeed all the characteristics one would like to see in a water main. In conjunction with British Petroleum they developed medium density polyethylene which is in fact an alloy of polyethylene, butone and hexene and is modified rather than midway between low and high density. MDPE is flexible, strong, tough, stress crack resistant, not subject to brittle failure, has a high defect and damage resistance, weldable, etc.. However, the basic resins are relatively expensive and if the walls are too thin it may kink. Today MDPE is more expensive than plastic, is significantly cheaper than iron up to the 375 mm break even point, but has the outstanding advantage of being jointless with the consequential effect on leakage. The pipe is lightweight, delivered in coils up to 180mm diameter, has a low friction factor, is coloured blue for water, yellow for gas, black for sewers, etc., and a full range of weldable fittings, ferrules, tees, flanges etc., are available. The material has been used by the Gas Industry since 1968 and by the Water Industry worldwide for the past five years.

The introduction of this material has made possible a number of rehabilitation methods.

Sliplining

Sliplining involves the drawing of a new MDPE pipe into an existing water main. Lengths of pipes up to several hundred metres at a time can be installed, and large radius bends in the existing line can be accommodated. Sliplining can be used to rehabilitate a main structurally and would be appropriate in circumstances where the existing main is suffering from external corrosion.

Sliplining requires the providing and the scraping of existing mains and can be carried out with an annulus as small as 3mm, because of the low friction value this kmay not necessarily result in a loss of hydraulic capacity when compared with the existing main.

Pipeline Insertion Method (PIM) or Size for Size Replacement

Replacement moling is similar to sliplining except that, prior to insertion of the polyethylene lining pipe the existing main is broken out using a percussive mole. By oversizing the mole a pipe larger than the original main may be installed but this sometimes has an effect on other services and the highway surface. The mole consists of a horizontal reciprocating hammer acting within a cylinder fitted inside a tapered head. The head may be fitted with "stress raisers" to increase the breaking force exerted on the pipe. The reciprocating action provides both forward motion and radia force to shatter the existing pipeline and compress the pipe fragments into the adjacent soil, which itself is consolidated.

The progress of the mole can be slowed down or even stopped if concrete surrounds the old main or if ductile iron or steel pipes are encountered. It can deal with cast iron, concrete and asbestos cement easily as well as short lengths of plastic pipes, but tends to push long lengths of plastic pipeline forward causing them to 'snake' rather than burst. At present the size limitations for water mains is up to 200mm and in the range 75 to 150 the price is little more than cement mortar lining. In consequence more of this work is being undertaken. The advantages are little disruption to the surface, low reinstatement costs, lengths of 100 metres completed within a day and returned to service, increased capacity, new jointless pipes and low cost compared to replacement. The system is now well tried and tested and has been used in the Water Industry for some 3 - 5 years.

Blind Moling

An adaptation of this system is moling in new pipes where none exist at present. In this case a small diameter mole usually 40mm is driven through on the line required. A larger diameter moling system is then introduced and a new pipe forced through the pilot hole. The small moles can also be used for service crossings under highways or through drives and gardens into private houses and industrial complexes. Again these systems rely on the use of MDPE and cost a fraction of conventional mainlaying.

Narrow Trenching

Machines have now been developed using rock wheel cutting chain trenching principles. The rate of progress is approximately 1 metre/minute. Plastic in strings or MDPE in coils is lowered into the trench and backfilled. Excavation disturbance and reinstatement is minimised and consequently the cost is little more than cement mortar lining.

Polyethylene (PE) Lining

One of the characteristics of MDPE is its plastic memory. This is used in the PE lining process. In this system a prewelded lining pipe is squeezed through a die at a controlled stress. Before the pipe has chance to expand again, it is pulled through the old pipe to form a tight integral lining. The system is in its infancy but promises to be twice as fast to install as cement mortar lining, gives a smoother finish and better flow characteristics, can be thin or thick walled to suit pressure requirements and hopefully after further development should be cost comparable. A number of development projects are underway in ranges of 75mm to 120mm diameter, and the system offers potential solutions to the renovation of many trunk mains and aqueducts, some of which are now at least 150 years old.

SELECTION OF APPROPRIATE TECHNOLOGY

The choice of the most suitable rehabilitation technique is of course vital to the success of any rehabilitation project. Decision making is based upon four criteria.

* Technical rules
* Flow carrying rules
* Scheme details
* Costs

Briefly these are described below:-

Technical Rules

As discussed, each of the rehabilitation methods currently used has certain physical or technical limitations constraining its application. In addition there are constraints applied by authorities which perhaps might reflect results of trials, insufficient training or knowledge of the technique by their staff, or even that, say, above a particular size the method, although technically viable, will never be the least cost option in the present market.

Flow Carrying Comparisons

For a given set of circumstances a set of technically viable methods will affect the flow carrying capability of the rehabilitated pipe to differing extents, eg. a pipe sliplined with MDPE will reduce the carrying capacity more than lining the pipe with epoxy resin. Each of the set of methods is compared on the basis of flow carrying capability. This is not an absolute comparison, as differing pipe sizes and thicknesses of lining etc. are being considered together. Thus the set of technically viable methods is modified in light of the flow carrying capability required from the rehabilitated pipe.

Scheme Details

Next is a consideration of the scheme details. That is constraints applied by the nature of the scheme itself as distict from the method. Examples would be say to limit the size of a narrow trenching contract to say a minimum of 500m due to the high establishment costs of the specialist machinery required. Another example would be to opt for a no dig technique say where service or traffic were known to be a particular problem. Below is a checklist of the factors that should be considered and which may affect the actual choice of rehabilitation method.

* Metreage - certain specialist techniques cannot be cost effective in short lengths (say less than 500m).
* Subsoil - Chemical contamination, aggressive subsoil etc. can reduce the performance of the rehabilitated pipework.
* Access - will the techniques chosen comply with the vehicle and pedestrian access requirements of the scheme?
* Traffic - will the techniques chosen comply with the traffic management requirements?
* Services - certain replacement techniques can damage nearby services. Narrow trenching costs are sensitive to density of service crossings. Have these costs been included and compared?

* Environment - are there any restrictions regarding noise, disposal of arisings, disposal of cleaning water etc. Consider the impact of thescheme on the area, will techniques chosen produce an acceptable standard of reinstatement?
* Customer Standards - what is the comparative effect of the techniques chosen on our customers - are there any additional method specific costs to be considered.

Unit Cost

The least cost method is then determined by comparing unit costs of each of the set of technically viable methods. These costs are constantly being updated and comprise historic data from previous contract work. Any discounting for reduced asset life can be introduced.

Details of typical decision charts follow

APPENDICES

FIGURE 1 — LIMITATIONS OF REHABILITATION TECHNIQUES

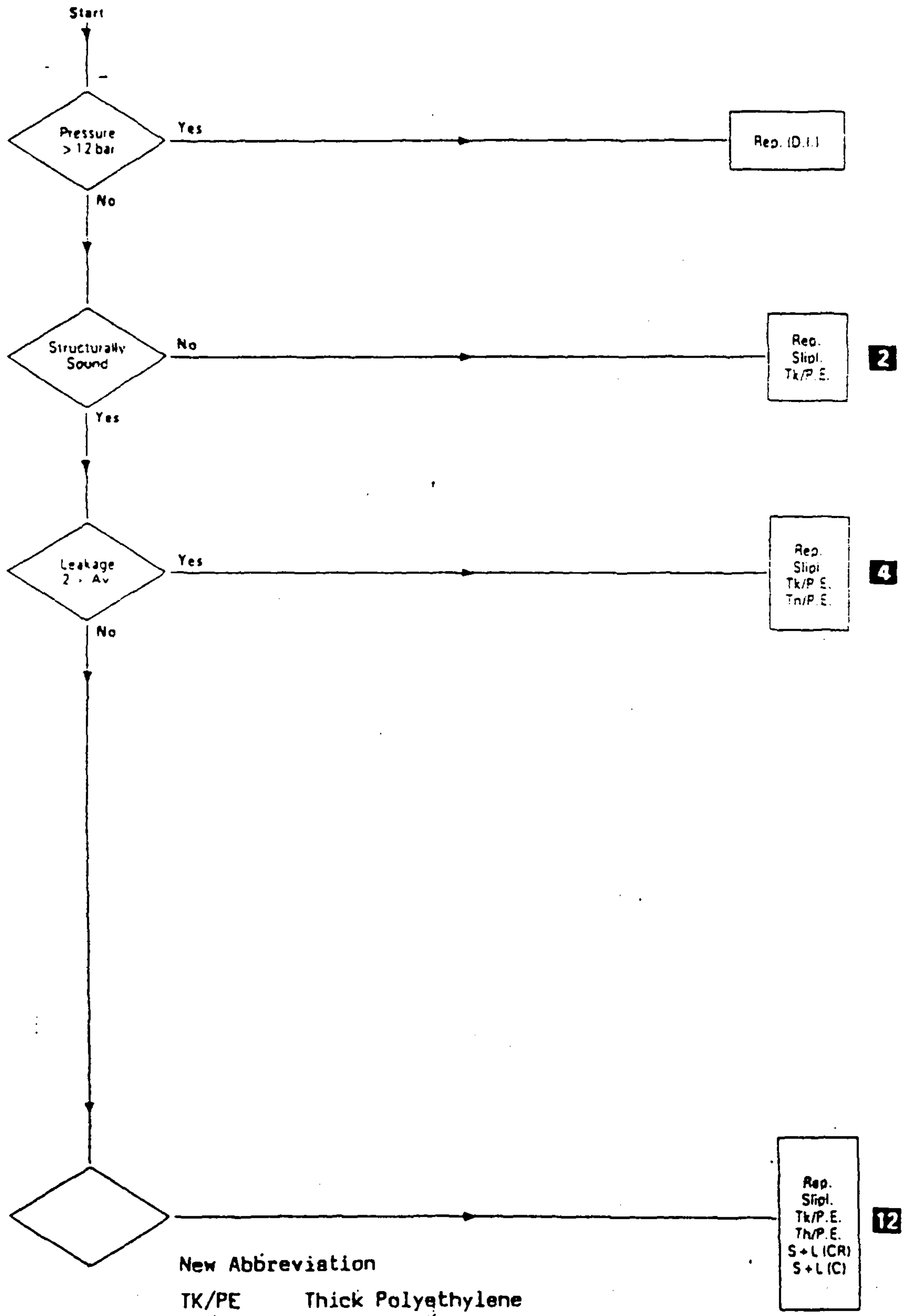
	TECHNIQUE	NO-DIG TECHNIQUE	SIZE LIMITATIONS IN N.W.W. ON REHABILITATED PIPE	WATER QUALITY LIMITATIONS	CAN EXISTING MAIN BE UPSIZED	DOES TECHNIQUE RESULT IN REPLACEMENT OF FERRULES/TRANSFER OF SERVICES	PHYSICAL CONDITIONS THAT CAN AFFECT SUCCESS OF TECHNIQUE	COMPARATIVE SIZE OF ACCESS PIT	REPLACED PIPE MATERIAL
STRUCTURAL REPLACEMENT	PIPELINE INSERTION METHOD (P.I.M.)	YES	MAX: UP TO 200 nb MIN: 75 nb	NONE	YES	YES	REPAIR COLLARS + FITTINGS DUCTILE IRON + PLASTIC PIPES CONCRETE SURROUND + HARD GROUND SHALLOW COVER	LARGE	M.D.P.E.
	SLIPLINING	YES	MAX: SUBJECT TO PIPE AVAILABILITY - NONE MIN: 75 nb	NONE	NO	YES	LOCAL RESTRICTIONS/DIRECTION CHANGE LEAD FISHES BURIED FITTINGS PROTRUDING FERRULES	LARGE	M.D.P.E.
	P.E. LINING (THIN OR THICK)	YES	MAX: SUBJECT TO PIPE AVAILABILITY - NONE MIN: 75 nb	NONE	NO	YES	LOCAL RESTRICTIONS DIRECTION CHANGE LEAD FISHES BURIED FITTINGS PROTRUDING FERRULES	LARGE	M.D.P.E.
	CONVENTIONAL OPEN TRENCHING	NO	MAX: NONE MIN: NONE	NONE	YES	YES	SERVICES SUBSOIL CONDITIONS ARTIFICIALLY HARD MATERIAL	N/A	UTILITY POLICY
	NARROW TRENCHING BY NARROW BUCKET	NO	MAX: UP TO 300 nb MIN: NONE	NONE	YES	YES	SERVICES SUBSOIL CONDITIONS ARTIFICIALLY HARD MATERIAL	N/A	M.D.P.E. U.P.V.C.
	NARROW TRENCHING BY SPECIAL MACHINE	NO	MAX: UP TO 300 nb MIN: NONE	NONE	YES	YES	SERVICES SUBSOIL CONDITIONS SETTS SIZE OF SPECIAL MACHINE	N/A	M.D.P.E. U.P.V.C.
	MOLE PLOUGHING	NO	MAX: UP TO 150 nb MIN: NONE	NONE	YES	YES	UNSURFACED GROUND ONLY	N/A	M.D.P.E.
	SMALL DIAMETER MOLING (SERVICE PIPES)	YES	MAX: UP TO 75 nb for 63 nb SERVICE MIN: 45 nb for 25 nb SERVICE	NONE	N/A	N/A	SERVICES SUBSOIL CONDITIONS ARTIFICIALLY HARD MATERIAL	SMALL	M.D.P.E.
NON-STRUCTURAL WITH LEAKAGE CONTROL	P.E. LINING (THIN)	YES	MAX: SUBJECT TO PIPE AVAILABILITY - NONE MIN: 75 nb	NONE	NO	YES	LOCAL RESTRICTIONS/DIRECTION CHANGE LEAD FISHES BURIED FITTINGS PROTRUDING FERRULES	LARGE	M.D.P.E.
NON-STRUCTURAL LINING ONLY	CEMENT MORTAR SCRAPE AND LINE	YES	MAX: NONE MIN: 75 nb	CAUSES INCREASE IN pH IN LOW ALKALINITY WATER	NO	NO	LOCAL RESTRICTIONS/DIRECTION CHANGE LEAD FISHES BURIED FITTINGS PROTRUDING FERRULES	MEDIUM	N/A
	CEMENT MORTAR REPLACEMENT SCRAPE AND LINE	YES	MAX: NONE MIN: 75 nb	CAUSES INCREASE IN pH IN LOW ALKALINITY WATER	NO	NO	LOCAL RESTRICTIONS/DIRECTION CHANGE LEAD FISHES BURIED FITTINGS PROTRUDING FERRULES	MEDIUM	N/A
	EPOXY MORTAR SCRAPE AND LINE	YES	MAX: UP TO 200 nb MIN: 75 nb	STILL AWAITING FINAL APPROVAL	NO	NO	LOCAL RESTRICTIONS/DIRECTION CHANGE LEAD FISHES BURIED FITTINGS PROTRUDING FERRULES	MEDIUM	N/A

ABBREVIATIONS

M.D.P.E. – MEDIUM DENSITY POLYETHYLENE
U.P.V.C. – UNPLASTICISED POLY VINYL CHLORATE
PE – POLYETHYLENE
nb – NOMINAL BORE

FIGURE 2a — METHOD DECISION CHART

PART 1a TECHNICAL RULES (Diameter 200 mm and over)

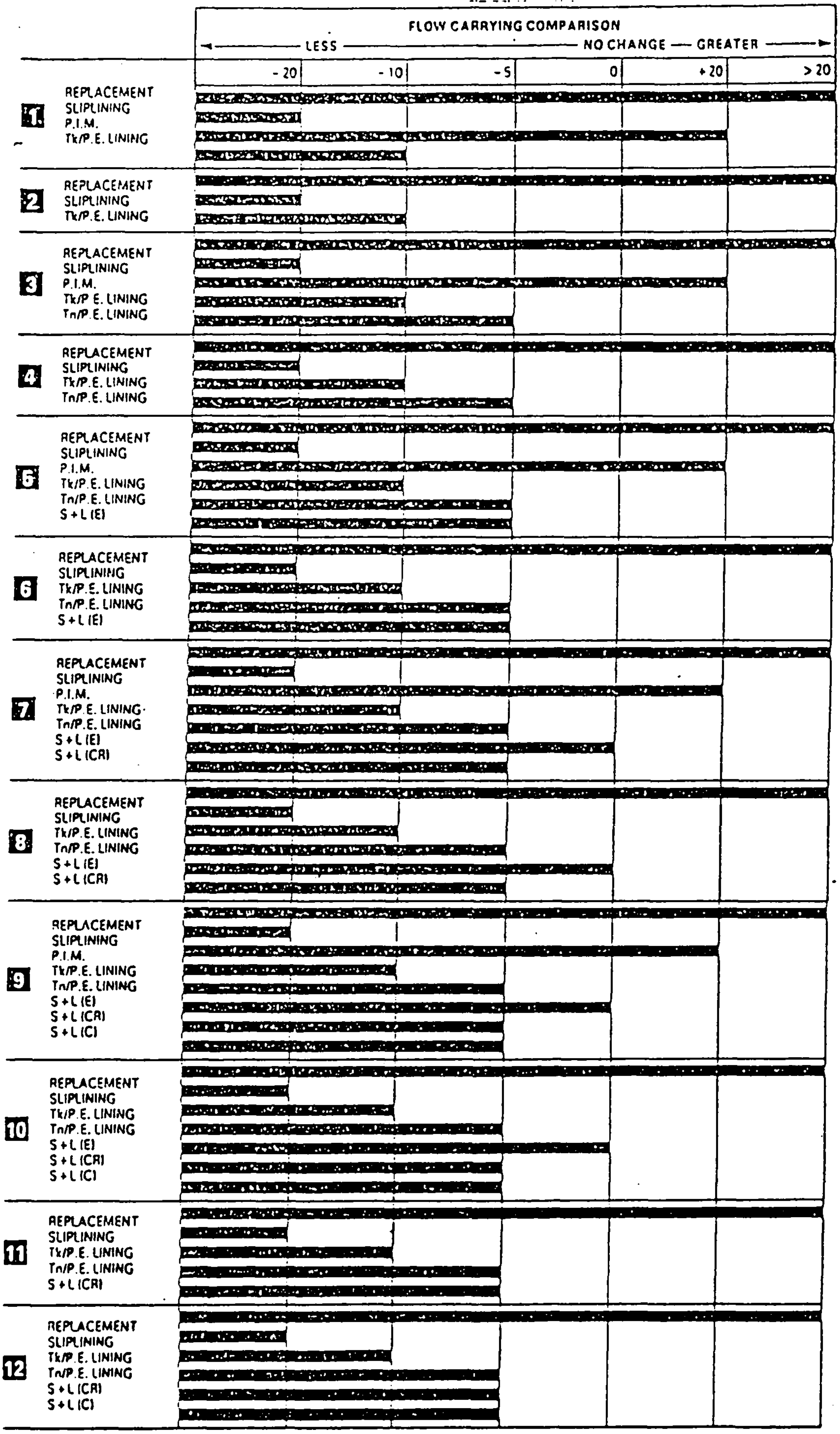


New Abbreviation

TK/PE	Thick Polyethylene
Th/PE	Thin "
DI	Ductile Iron
Rep	Replace
SlipL	Slipline
S & L	Scrape and Line

FIGURE 3 — METHOD DECISION CHART

PART 2 — FLOW CARRYING COMPARISONS

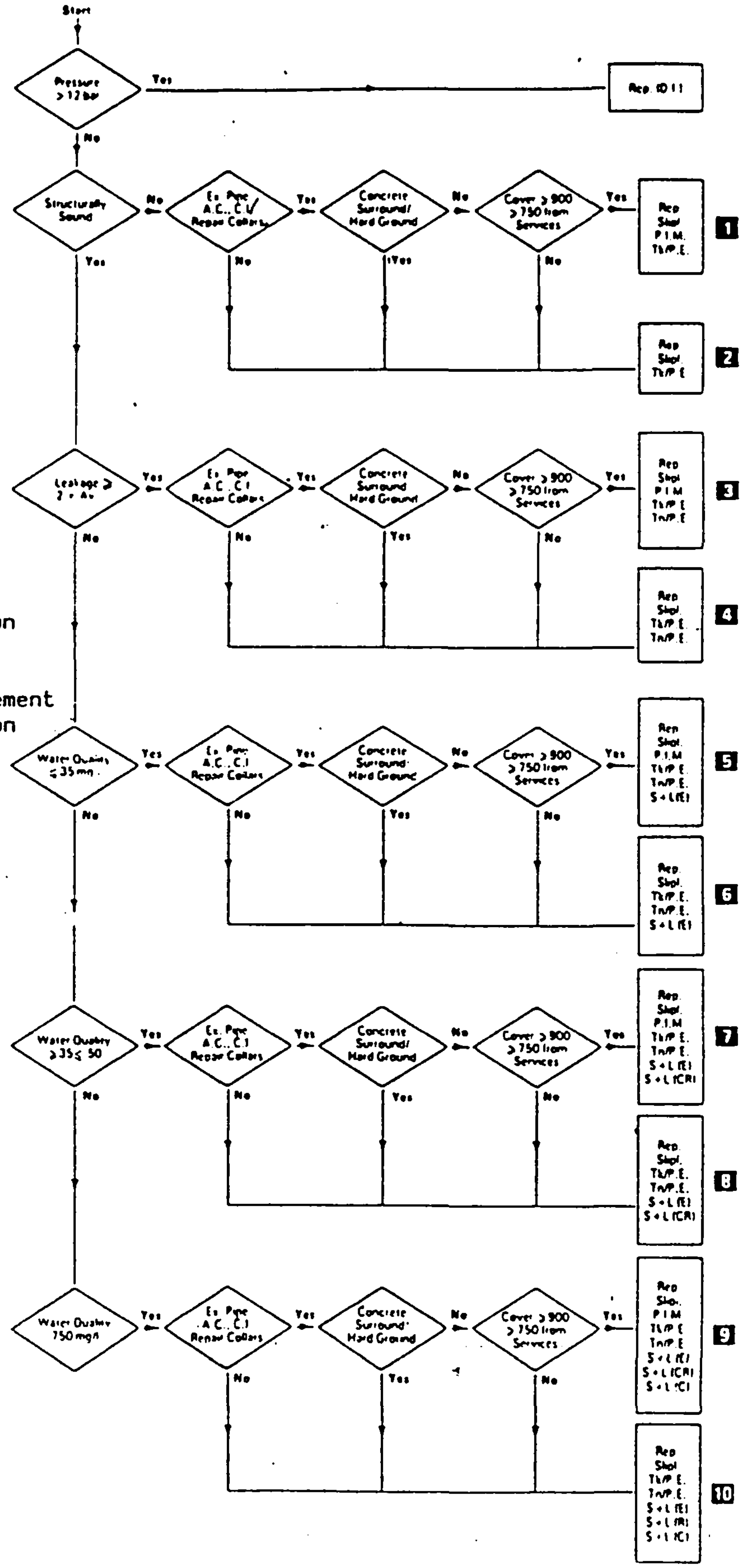


ABBREVIATIONS

P.I.M. — *PIPELINE INSERTION METHOD*
Tk/P.E. LINING — *THICK POLYETHYLENE LINING*
Tn/P.E. LINING — *THIN POLYETHYLENE LINING*
S + L (E) — *EPOXY MORTAR SCRAPE AND LINE*

FIGURE 2b — METHOD DECISION CHART

PART 1b TECHNICAL RULES (Diameter up to 200 mm)



New Abbreciation

Ex Existing
AC Asbestos Cement
DI Ductile Iron

FIGURE 4 – METHOD DECISION CHART

PART 4 – UNIT COST TABLE – TYPICAL EXAMPLE

£ Sterling
≐ $ 1.8 U.S.

	COMPARATIVE COSTS INCLUDING SHORT AND LONGSIDE SERVICE REPLACEMENT								
	TECHNIQUE								
	S+L(C) £1M		S+L(CR) £1M		S+L(E) £1M		NARROW TRENCHING (S) £1M	P.I.M. £1M	SLIPLINING £1M
DIAMETER (mm)		(1)		(1)		(1)			
80	N/A	N/A	N/A	N/A	N/A	N/A		45 (to 100 nb)	
100	42·5	46	43·5	47	48	51·5	46	44 (to 100 nb)	
125		47		48		51·5	55	53 (to 150 nb)	
150	43·5	47·5	44·5	48·5	49	53	59	51 (to 150 nb)	43
175		47·5		48·5		53		52 (to 150 nb)	48
200	44·5	48·5	45·5	49·5	52	54			53
225									58
250	49·5		51·5						63
300	52·5		54·5						73
350	52·5		54·5						83
400	54·5		56·5						
450	58·5		60·5						
COMPARATIVE COSTS EXCLUDING SERVICE REPLACEMENT									
80	N/A	N/A						28 (to 100 nb)	
100	22·5	26	23·5	27	28	31·5	26	27 (to 100 nb)	
125		26		27		31·5	35	36 (to 150 nb)	
150	23·5	27·5	24·5	28·5	29	33	39	34 (to 150 nb)	26
175		27·5		28·5		33		35 (to 150 nb)	31
200	24·5	28·5	25·5	29·5	32	34			36
225									41
250	29·5								46
300	32·5								56
350	32·5								66
400	34·5								
450	38·5								

NOTE: COLUMN (1) REPRESENTS THE DISCOUNTED COST OF THE TECHNIQUE OVER 40 YEARS AT 5% INTEREST REPLACED BY P.I.M. TECHNIQUE.