BS 8005 : Part 1 : 1987

UDC 628.21/.24

British Standard

Sewerage

Part 1. Guide to new sewerage construction

Evacuation des eaux usées
Partie 1. Guide des égouts neufs

Entwässerung
Teil 1. Leitfaden für neue Abwasserleitungen

Foreword

This British Standard has been prepared under the direction of the Civil Engineering and Building Structures Standards Committee and is directed at general engineering practitioners who may either be embarking on a career in sewerage or be dealing with a particular aspect for the first time. It is not intended to be exhaustive in any field but sets out to present guidance on basic principles and good practice, indicating where a more detailed and comprehensive study may be made. BS 8005 supersedes and enhances CP 2005 : 1968, which is withdrawn, although some of the material incorporated is a restatement of the earlier text.

BS 8005 gives guidance on the planning, design, construction, operation and maintenance of works to convey sewage, including storm sewage, surface water and trade effluents to a sewage treatment works, tidal waters or other final place of disposal. Recommendations are given for the repair, renovation and replacement of sewers.

Many end users of this British Standard, such as governments, public authorities, sewerage authorities and consultants, issue their own recommendations and specifications for sewerage which BS 8005 is intended to complement rather than replace.

BS 8005 : Part 0 directs the reader to sources of more detailed information, particularly on important and specialized fields such as health and safety. It should be regarded as supplying essential background information for the other Parts of BS 8005.

BS 8005 is to be published in six separate Parts, as follows.

Part 0. Introduction and guide to data sources and documentation

Part 1. Guide to new sewerage construction

Part 2. Guide to pumping stations and pumping mains

Part 3*. Guide to sewers in tunnel

Part 4. Guide to design and construction of outfalls

Part 5*. Guide to rehabilitation of sewers

It has been noted that substantial one-part codes and guides take a long time to revise and if they are reviewed at infrequent intervals, they tend to become out of date quickly, especially in a field where technological development is rapid. It is intended therefore to keep a constant watch on new developments and to update BS 8005, Part by Part, as soon as the work can be justified.

BS 8301 sets out recommendations for building drainage and, while it relates generally to smaller pipelines, there is some overlap between it and BS 8005. BS 6297 gives recommendations for the design and installation of small sewage treatment works and cesspools.

Apart from Part 0, which is directed more specifically at the UK sewerage field, BS 8005 is for use both in the UK and, in appropriate circumstances, overseas.

Suggestions for the improvement of any Part of BS 8005 will be welcomed by the Secretary of CSB/5 at 2 Park Street, London W1A 2BS.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

* In preparation.

Contents

Section one. General

1 Scope

This Part of BS 8005 provides guidance on the materials, design, construction, testing, surveying, operation and maintenance and repair of new sewers.

NOTE. The titles of the publications referred to in this standard are listed on the inside back cover.

Other standards publications not referred to in this standard, but dealing with closely associated subjects, are listed in appendix A.

References are made to other sources of authoritative information. These will be found throughout the text, indicated by bracketed numbers thus [21] and are listed in appendix B.

2 Definitions

For the purposes of this Part of BS 8005, the definitions given in BS 892, BS 4118, BS 6100 and BS 8005 : Part 0 apply, together with the following.

2.1 catchment area. The area of a watershed discharging to a sewer, or watercourse.

2.2 flow attenuation. The process of reducing the peak flow rate in a sewer system by redistributing the same volume of flow over a longer period of time.

NOTE. This can be achieved by on or off line storage within the sewerage system, or by above ground storage before flows enter the sewer.

2.3 inverted siphon. A pipe or conduit where the soffit drops below the hydraulic gradient and in which the sewage flows under pressure of gravity.

2.4 nominal size (DN). A numerical designation of the size of a pipe, bend or branch fitting, which is a convenient round number approximately equal to a manufactured dimension.

NOTE. 'Nominal bore' is the approximate internal diameter of a unit as declared by the manufacturer. This quantity is quoted with units (mm) whereas nominal size (DN) is quoted without units.

2.5 percentile peakedness. The departure from the mean value of a storm profile, expressed as a percentage.

2.6 rainfall. Natural precipitation of water in any form, such as rain, snow, hail, etc., the rate of which is measured in millimetres of water per hour.

2.7 renovation. Methods by which the performance of a length of sewer is improved by incorporating the original sewer fabric, but excluding maintenance operations such as isolated repairs and/or silt removal.

2.8 roughness value (K_s). A measure of the resistance of the surface of a pipe or channel under turbulent flow which is expressed in millimetres.

NOTE. This value is based on the diameter of uniformly graded sand grains which would give the same resistance to flow.

3 Abbreviations

Throughout this Part of BS 8005, the abbreviations given in BS 5775 and BS 5555 have been used, together with the following.

ABS	Acrylonitrile butadiene styrene
BMR	Bending moment resistance
BOD	Biochemical oxygen demand
BRE	Building Research Establishment
CF	Compaction Fraction
CIRIA	Construction Industry Research and Information Association
COD	Chemical oxygen demand
DN	Nominal size
DoE	Department of the Environment
DWF	Dry weather flow
GRC	Glass reinforced concrete
GRP	Glass reinforced plastics
HDPE	High density polyethylene
MDPE	Medium density polyethylene
NJHSCWS	National Joint Health and Safety Committee for the Water Service
NWC	National Water Council (now defunct and replaced by WAA, but remain listed publishers of some references)
PE	Polyethylene
PIMP	Percentage impervious
PR	Percentage run-off
SOIL	Soil impermeability index
SRPC	Sulphate-resisting Portland cement
TRRL	Transport and Road Research Laboratory
UCWI	Antecedent catchment wetness
WAA	Water Authorities Association
WASSP	Wallingford computer program
WRc	Water Research Centre

4 Planning

4.1 General

The UK is served by a comprehensive sewerage network which has been developed over many years to satisfy the demands of society in a changing environment. In many areas of the country, urban expansion is now limited, regeneration of derelict inner areas requires urgent investment, the population level is stable or declining and the infrastructure is ageing.

Sewerage planning should determine how best to rehabilitate and extend the existing system to serve future needs.

Structure plans and local plans can assist the planning and design of new, improved and extended sewerage systems. The allocation of land use and the policies for development should be determined for each catchment area. This information will influence the assessment to be made of the extent of impervious areas and the consequent calculation of surface water run-off, and will provide assistance to forecast population changes and foul sewage flows.

The planning horizon will inevitably differ from the various potential lifespans of the many sewers and associated structures within the catchment area. Sewerage planning and design should take account of the impact of changing land use and future alternative developments.

4.2 Population and water usage statistics

4.2.1 *Population statistics.* An accurate assessment of population is essential in determining the probable flows in a sewerage system.

The official statistics of the Registrar General refer to areas defined by local authority boundaries, but are useful as a check on estimates made by other means.

Planning statistics can be of assistance since they frequently give local information on the average occupancy rate of domestic dwellings. When multiplied by the number of residential properties obtained by physical count, these can provide a fairly accurate assessment of population.

In holiday resorts or other areas where there is an occasional or seasonal influx of people, such a means of estimating is not possible. Peak population may be assessed only by sampling typical areas during the holiday or peak season and extending the densities thus estimated to the whole area under consideration. Registers of accommodation maintained by many local authorities, Tourist Boards, etc., together with information that can frequently be obtained from the local planning department, may be of value.

Where provision needs to be made for future population in areas not yet developed or due for redevelopment, information should be available from the local planning authority on areas scheduled for development and on the scale and intensity of development intended. Planning policies are subject to regular review and the designer should consult the local planning authority to assess the likelihood of future changes in policy.

4.2.2 *Water usage statistics.* The water supply authority can provide a fairly accurate assessment and forecast of the consumption of water in any particular area; this will have a direct relationship to the likely flows for foul sewerage purposes.

Commercial and industrial premises and public buildings such as hospitals and schools, which obtain a supply of water from public sources, are usually metered. After making due allowance for water use in any industrial process, the figures of consumption can provide a useful guide to the anticipated flows of waste likely to arise from such premises.

Some private and commercial undertakings obtain water direct from private abstractions from rivers, canals, wells or boreholes; these should be taken into account in assessing the possible discharge of foul sewage.

4.3 Trade effluents

Most industries require water for processing or other purposes; much of this water, after use, will be discharged either to public sewers or direct to natural waters.

Such discharges, which may contain a wide variety of matter in solution or suspension, are termed trade effluents. They range from essentially clean but warm water, to strong solutions of organic or inorganic chemicals or suspensions of solid matter. They may be coloured and may have strong odours or other offensive characteristics. They may differ markedly from typical domestic sewage and their discharge to sewers often raises special problems, either as a result of their individual constituents, or in combination with other sewage. These problems include:

(a) the effects which they may produce on the internal condition and hydraulic capacity of sewers, including effects on the fabric of the sewers and ancillary structures;

(b) the danger to men working in sewers;

(c) the effects they may have on sewage treatment processes and works or other means of disposal, and

(d) their effect on receiving waters when inadequately treated.

There is close relationship between all these problems and they all need to be taken into account when planning sewerage.

Quantities and strengths of trade effluents are difficult to predict as trade practices vary as a result of changes in industrial throughput, technological developments and changes in the occupation of premises. In areas of existing industrial development, information can be obtained from records or investigation of existing discharges and consultation with the dischargers. Where industrial sites are undeveloped, planning policies may identify the nature and size of proposed developments which, together with information on trade effluents from similar industries, will enable an assessment to be made of the likely future discharges. (See 4.1.)

The discharge of trade effluents to a sewer is likely to be subject to conditions governing the quality and quantity of the effluent discharged. Compliance with such conditions may require the discharger to undertake pre-treatment of the effluent before discharge.

4.4 System planning

4.4.1 *General.* System planning within a catchment area or river basin should consider the sewerage network, storm sewage overflows, pumping installations and the receiving sewage treatment works, and the effects of their discharges on receiving water courses. Hydraulic performance of the whole system has to be considered to ensure that additions or modifications to the system do not result in overloading and/or premature operation of overflows. Where sewage is pumped consideration should be given to the effects of the pump discharge rates on the downstream parts of the system.

4.4.2 *Sewerage rehabilitation.* Where, as in the UK, a very high proportion of the population is served by existing public sewerage systems the objective has to be to optimize the existing system and to determine what adaptations or improvements are necessary to meet future needs.

The philosophy of sewerage rehabilitation contained within the WAA/WRc 'Sewerage rehabilitation manual' [1] has been accepted by the UK Water Industry as the strategy for rehabilitation of the existing sewerage network. (See BS 8005 : Part 5*.)

4.4.3 *New developments* (see also BS 8005 : Part 0). When consideration is given to the allocation of land for development, the authority responsible for sewerage should be consulted regarding the constraints which may be imposed as to sewerage provision.

Site plans should include areas reserved for future routes for sewers including any necessary pumping stations and treatment plant, allowing sufficient room and access for construction and subsequent operation and maintenance.

Sewers to serve new development should be constructed in the highway, land to be used for highway purposes, or public open space. Guidance on the location of sewers can be obtained from 'Provision of mains and services by public utilities on residential estates' [2].

The owner of the development may wish the sewers to be adopted as public sewers by the appropriate sewerage authority under the terms of the Public Health Act 1936. It is recommended that adoption be by prior agreement under the provisions of Section 18 of the Act and for this purpose 'Sewers for adoption — a design and construction guide' [3] has been published by WAA.

Sewers needed to connect developments with the existing public sewerage system can sometimes be requisitioned from the appropriate water authority in England and Wales using the provisions of Section 16 of the Water Act 1973.

4.5 Public relations

Good public relations are important in the design, construction and operation of sewerage systems. This Part of BS 8005 draws attention to the necessity for close liaison between developers, land users, local authorities, statutory undertakers and others who may be affected by new sewerage schemes. Such liaison and consultation should not be restricted to that required under appropriate legislation. Persons and organizations affected by the proposals should be consulted as early as possible in the planning stage and such liaison should continue for the duration of the work. Property owners affected should be made aware of the implications of the works proposed and of their own rights under statutory procedures.

Construction of sewers often has a serious effect on the movement of traffic and pedestrians and can cause severe disruption to the activities of a community. Diversions or other activities should be planned with the persons affected, the police and other authorities well in advance of actual construction. Advance information should be posted to the persons concerned and the general public should be made aware by public meetings, public notices, or through the press and radio.

Attention is drawn to legislation and regulations dealing with issues such as traffic signing, health and safety, planning and noise which may apply during construction. A recognized point of contact should be identified for the use of persons affected by the scheme to deal with matters arising during the work.

Attention is also drawn to legislation and regulations which may apply during operation and maintenance activities to minimize any nuisance and inconvenience. Sewerage authorities should make public the address and telephone numbers of persons to be contacted in the event of routine enquiries, complaints or emergencies. Such arrangements should also cover out of office hours.

Owners of private sewerage systems should also ensure that occupiers of the properties they serve, together with the local authority and emergency services are aware of whom to contact in cases of emergency or malfunction.

Whilst a properly designed, operated and maintained system should normally have little effect upon the general public, there will be occasions when as a result of routine operation and maintenance or as a result of emergencies there will be some impact. This impact may be limited to a few individuals but may also affect very large numbers of people. Careful location of chambers can help to minimize the disruption caused by maintenance activities. Those persons responsible for sewerage and associated work should strive to minimize the nuisance and inconvenience caused by their activities by careful pre-planning, consultation and dissemination of information. Appropriate operational procedures and communication arrangements should be planned to ensure rapid action and good public relations.

* Under preparation.

Section two. Materials, components and appliances

5 Materials, components and appliances

5.1 General

This clause deals with materials for which there are current British Standard specifications and with other materials in common usage in sewerage. Users should refer to manufacturers when reference is made to the latter. The use of new materials is to be encouraged provided that sufficient information on long-term performance is available to enable a minimum service life to be defined with confidence.

5.2 Rigid and flexible pipes, joints and fittings

5.2.1 *Factors affecting choice of pipe materials.* The choice of pipe will be influenced by the hydraulic and structural design and particularly whether it is a gravity sewer or pumping main. The nature of the effluent to be carried and of the ground water will affect the choice of both pipe and joint. The diameter and length of the pipes available, the ease of cutting, the simplicity of the jointing system and the availability of fittings are among the factors to be considered, along with ease of unloading and positioning in the trench without damage to the pipe or any coating.

Flexible joints are generally available and are recommended. They accommodate degrees of straight draw, angular deflection and axial displacement or shear without loss of watertightness. In certain circumstances rigid joints are required; these are made by caulking a compound or working a cement mortar into the joint, or by bolted flanges or by welding the pipes together.

5.2.2 *Rigid pipes*

5.2.2.1 *General.* Rigid pipes do not deform appreciably under their design load and the materials show a linear, brittle stress-strain behaviour. The ability of a rigid pipe to support the total load transmitted to it is established by reference to actual crushing tests.

5.2.2.2 *Asbestos-cement pipes.* For use with gravity flow for sewerage and drainage applications, asbestos-cement pipes and fittings with flexible joints should comply with BS 3656 which specifies the strength classifications for pipe diameters from DN 100 to DN 2500, in pipe lengths of 3 m, 4 m and 5 m. Half and quarter length pipes are available.

For pressure pipelines, asbestos-cement pipes and flexible joints should comply with BS 486, which specifies the hydrostatic classification for pipe diameters from DN 50 to DN 2500 in pipe lengths of 3 m, 4 m and 5 m. Asbestos-cement bends are available for diameters up to DN 225. Cast iron fittings are also available.

5.2.2.3 *Clay pipes.* Vitrified clay pipes and fittings for use with gravity flow under atmospheric pressure should comply with BS 65. They are available in nominal diameters from DN 75 to DN 1000, and in lengths up to 3.0 m. The following classifications of pipes are available:

(a) normal, i.e. suitable for all drains and sewers;

(b) surface water;

(c) perforated, suitable for French drains and land drains;

(d) extra chemically resistant.

Three crushing strength classifications of pipes are given in BS 65, and there are equivalent bending moment resistance (BMR) classifications for preferred sizes up to DN 225. Requirements are set down for fittings and for flexible mechanical joints according to the type of pipe with which they are used.

Perforated pipes and associated non-perforated fittings normally have integral flexible joints; these pipes are available in lengths up to 2.0 m.

5.2.2.4 *Concrete pipes**. Precast concrete pipes and fittings of circular cross section for the conveyance of sewage or surface water under gravity, should comply with the appropriate Part of BS 5911.

BS 5911 : Part 1 specifies requirements for flexibly jointed pipes in nominal diameters DN 150 to DN 3000 in standard lengths 0.45 m to 5 m (3 m for pipes DN 600), in three strength classes for sewage or surface water (and for jacking pipes).

BS 5911 : Part 3 specifies requirements for pipes with ogee, rebated joints, in nominal diameters DN 150 to DN 1800, in standard lengths 0.45 mm to 2.5 m, in three strength classes, used principally for land drainage and surface water and for headings.

Precast glass composite concrete pipes, strengthened by continuous alkali-resistant glass fibre rovings, are covered by DD 76 : Part 1 (see note 1). These pipes are available for sewage under gravity flow in diameters from DN 150 to DN 1800, lengths from 0.45 m to 5 m, and in three strength classes. Flexible in-wall rebated joints are used with elastomeric joint rings complying with BS 2494.

NOTE 1. DD 76 : Part 1 has been reviewed and is being converted to a full British Standard as Part of BS 5911.

Precast concrete pipes strengthened by chopped zinc-coated steel fibres are covered by DD 76 : Part 2. The pipes and fittings are suitable for sewage or surface water under gravity, and are available in nominal diameters from DN 375 to DN 1200, in three strength classes, in lengths of 0.45 m to 2.5 m. Joints are generally of the flexible, spigot and socket type, but in-wall design is also catered for.

NOTE 2. DD 76 : Part 2 is being reviewed to see whether it can be converted to a full British Standard as Part of BS 5911.

5.2.2.5 *Box culverts.* Precast concrete box culverts for foul sewers, storm sewers, storm water retention tanks, manholes and wells for pumping stations at atmospheric pressure, are manufactured in a range of sizes from 1.0 m to 6.0 m spans with various internal heights between 0.5 m and 3.0 m and effective lengths between 1.0 m and 2.0 m to suit weight limitations. Box culverts are designed individually to suit specific loading situations. They are not currently covered by a British Standard and details should be obtained from the manufacturer.

* Where appropriate in this Part of BS 8005, the term concrete pipes can be taken to include concrete box culverts (see 5.2.2.5).

5.2.2.6 *Grey iron pipes.* Grey iron pipes and fittings should comply with BS 437 and with BS 4622 and are manufactured in the size range DN 50 to DN 225; BS 437 makes provision for centrifugally cast pipes with flexible joints in lengths up to 5.5 m. Flexible joints for these pipes should comply with BS 6087.

Pressure pipes and fittings with flexible or flanged joints should comply with BS 4622. Pipes with flexible joints are available in 5.5 m lengths and those with flanged joints in 4 m lengths.

Fittings complying with BS 437 can be jointed directly to BS 4622 pipes with lead caulked joints in the smaller diameters (DN 100 and DN 150 only).

5.2.3 *Flexible pipes*

5.2.3.1 *General.* Flexible pipes deform under load and the extent of this deformation depends upon the stiffness of the pipe and the compaction of the immediate surround fill. The materials for these pipes show ductile stress-strain characteristics.

5.2.3.2 *Corrugated metal pipes.* Corrugated metal pipes are manufactured in steel in diameters from DN 150 to DN 2600 and in lengths from 6 m to 9 m. They are jointed by corrugated or dimpled coupling bands and various types of bituminous coatings are available. These pipes are not covered by a British Standard and details should be obtained from the manufacturers. Two forms of corrugation are available for the pipe as follows.

(a) Helically corrugated pipes, available in sizes from DN 150 to DN 1500 made from galvanized steel sheet complying with BS 2989, grade Z2, coating type G600. The helical joint is formed by a locked seam.

(b) Annularly corrugated pipes, available in sizes from DN 1000 to DN 2600 made from steel complying with BS 1449 : Part 1, grade 3, condition HR. Longitudinal joints are rivetted and the pipes are galvanized in accordance with BS 729.

5.2.3.3 *Ductile iron pipes.* Ductile iron pipes and fittings should comply with BS 4772 and are manufactured in a range from DN 80 to DN 1600. Ductile iron pipes with flexible joints are manufactured in nominal lengths of 5.5 m for DN 80 to DN 800 inclusive and nominal lengths of 8 m for DN 900 to DN 1600 inclusive. Ductile iron pipes are suitable for both pressure and non-pressure applications. A class of pipe (class K9) is available for general purposes but other classes can be supplied. Pipes with flanged joints are manufactured in 4 m lengths.

5.2.3.4 *Unflanged corrugated liner plates.* Unflanged corrugated liner plates are generally used to form culverts, pedestrian tunnels and similar structures which are subsequently backfilled externally. To promote long life the plates and fittings are supplied galvanized. Plates are supplied with longitudinal corrugations and curved to the required profile.

5.2.3.5 *Glass reinforced plastics (GRP) pipes.* GRP pipes and fittings should comply with BS 5480 : Parts 1 and 2, in sizes DN 25 to DN 4000. Pipe lengths range from 3.0 m to 12.0 m although the 6.0 m length is the most common. GRP pipes are suitable for sewers working under gravity flow or working under pressure. The pipes have flexible joints and are available in eight pressure and stiffness classes.

Fittings for use with GRP pipes are manufactured of GRP, steel, or ductile iron, and are suitable for the same applications as the pipes.

5.2.3.6 *High density polyethylene (HDPE) pipes.* HDPE pipes should comply with BS 6437 in the range of outside diameters from DN 16 to DN 500 and in a series of pressure ratings from 2.5 bar* to 10 bar. The manufactured lengths of pipes vary from 10 m to 12 m. Joints can be fusion welded or mechanically coupled.

5.2.3.7 *Unplasticized PVC pipes.* Unplasticized PVC pipes and fittings with flexible mechanical or rigid solvent welded joints for gravity flow pipelines should comply with BS 4660 for nominal sizes DN 110 and DN 160 and with BS 5481 for nomin..l sizes DN 200 to DN 630. These standards provide for a wall thickness to diameter ratio selected for the buried sewer application. In accordance with international standards, plastics pipes are designated by their outside diameters in recent British Standards.

Unplasticized PVC pipes for pressure applications such as pumping mains should comply with BS 3505 or BS 3506. Pipes complying with these standards are identical except that BS 3505 contains additional clauses relating to water quality. BS 3506 specifies a range of pipes up to nominal size 24 in four pressure classes. Unplasticized PVC pipes used for intermittent sewage pumping mains should be of not less than class C (9 bar) nominal working pressure in accordance with BS 3506.

Unplasticized PVC pipes are normally available in lengths up to 6 m with either push fit mechanical joints or plain ended for use with couplers. Joints and fittings for unplasticized PVC pressure pipes should comply with BS 4346 : Parts 1 and 2.

Reference should be made to BS 5955 : Part 6 and CP 312 : Parts 1 and 2 for further guidance on the use of unplasticized PVC pipes and fittings.

5.2.3.8 *Acrylonitrile butadiene styrene (ABS) pipes and polypropylene pipes.* ABS pipes should comply with BS 5391 and are manufactured in nominal sizes of 3/8 to 8 and in lengths of 3 m to 9 m. Polypropylene pipes should comply with BS 4991 in lengths of 6 m.

* 1 bar = 10^5 N/m² = 0.1 mPa.

5.2.3.9 *Steel pipes.* Steel pipes and specials for sewerage should comply with BS 534; this covers welded and seamless pipes, specials and joints in an outside diameter range of 60.3 mm to 2220 mm.

5.3 Manhole sections

5.3.1 *Precast concrete sections.* Precast concrete circular manhole components are manufactured for assembly into complete manholes; they should comply with BS 5911 : Part 1. Precast concrete box culvert units are also manufactured for construction as manholes complete with step irons.

5.3.2 *Plastics.* Plastics manhole components include chambers and shafts. A concrete surround may be required in conjunction with these units.

5.4 Manhole covers and frames

Ductile iron and grey iron manhole covers and frames should comply with BS 497 and are in three grades for heavy, medium and light duty (grades A, B and C respectively).

5.5 Materials for bedding and backfill

5.5.1 *General.* The classification in figures 1 and 2 provides a practical method of specifying pipe bedding materials for the range of pipes commercially available.

5.5.2 *Granular materials for pipe bedding.* Generally it will be impractical to use two granular materials in the same trench, and possibly within the same contract. The choice of bedding materials is therefore to some extent a compromise. Granular materials should be durable under the influence of ground water.

Materials should be compacted to give maximum load-bearing capacity. As compaction at the sides and over a pipe is difficult to achieve without special apparatus, a single-sized bedding material may be preferred. If good compaction can be achieved, well-graded materials can be compacted to a minimum void ratio to provide a higher load-bearing capacity.

A compaction fraction (CF) test may indicate that alternative granular materials would be acceptable; material with a CF greater than 0.15 requires extra care in compaction. Details of the CF test are set out in appendix D.

In wet soils the migration of fine soil particles with ground water into the voids of granular bedding may be prevented by surrounding the granular material with filter fabric.

Granular materials for pipe beddings should comply with the following.

(a) Nominal single size aggregate complying with table 4 of BS 882 : 1983 as follows:

DN 100	10 mm size
DN 150	10 mm or 14 mm size
DN 200 to DN 300	10 mm, 14 mm or 20 mm size
DN 375 to DN 525	14 mm or 20 mm size
DN 600 and above	14 mm or 20 mm or 40 mm size

(b) Graded aggregate complying with table 4 of BS 882 : 1983 as follows:

DN 100	14 mm to 5 mm
DN 150 to DN 525	20 mm to 5 mm, or 14 mm to 5 mm
DN 600 and above	40 mm to 5 mm, 20 mm to 5 mm, or 14 mm to 5 mm

(c) Granular material having a CF value not greater than 0.3 for pipes less than DN 300 and 0.2 for pipes DN 300 and above when tested in accordance with appendix D. The maximum particle size should be as follows:

Less than DN 600	20 mm
DN 600 and above	40 mm

It should be noted that rounded materials, especially single sized, may not form stable beds for pipes of DN 300 and above. The greater the proportion of fines in the material the greater is the care needed in compaction.

5.5.3 *Selected fill.* Selected fill should preferably consist of uniform soil, free from stones larger than 40 mm, clay lumps larger than 75 mm, tree roots, rubbish, organic matter and frozen soil.

5.6 Concrete

NOTE. This clause covers in situ concrete. Precast concrete products are covered by various British Standards.

5.6.1 *Cement.* Cement for use in sewerage work should comply with BS 12, BS 146, BS 1370, BS 4027, BS 4246 or BS 4248.

NOTE. This clause does not apply to cements used for jointing plastics pipes (see 5.9).

The commonly used cements are ordinary and rapid-hardening Portland cement. High alumina cement complying with BS 915 should not be used for structural (load bearing) work.

Where sulphates are present, reference should be made to BS 8110 (see also 5.17).

5.6.2 *Aggregates.* Aggregates should comply with BS 882 or BS 1047. Where tests are required they should be carried out in accordance with BS 812.

5.6.3 *Water.* Water should be clean and free from significant amounts of deleterious matter, either in suspension or in solution. Where sampling and testing of water is required this should be carried out in accordance with BS 3148. If the water is suspect, test cubes should be made with the proposed water and their setting times and strength development compared with cubes made with water of approved quality.

5.6.4 *Steel reinforcement.* Steel reinforcement for concrete should comply with BS 4449, BS 4461, BS 4482 or BS 4483. Steel for prestressed concrete should comply with BS 4486 or BS 5896.

Whenever possible, the bending dimensions and scheduling of bars for reinforcement should comply with BS 4466. The cover of concrete over all steel reinforcements should be as set out in BS 8110 or BS 8007 as appropriate.

5.6.5 *Concrete mixes*

5.6.5.1 *General.* Concrete mixes should be specified in accordance with BS 5328. The requirements relating to permitted concentration of chlorides in concrete should be as recommended in BS 8110.

5.6.5.2 *Admixtures.* Admixtures, if permitted, should comply with BS 5075. Calcium chloride or admixtures based thereon should not be used for concrete containing steel, or where sulphate-resisting Portland cement (SRPC) is to be used.

5.7 Cement mortar

5.7.1 *General.* A mortar mix of 1:3 cement/sand ratio is suitable for the following purposes:

- brickwork;
- rigid joints for clay or concrete pipes;
- joints for precast concrete manhole sections;
- rendering of inverts and benchings.

5.7.2 *Cement.* Cement for use in mortar should be as described in 5.6.1.

5.7.3 *Aggregates.* The fine aggregate for mortar should consist of sand complying with BS 1199 and 1200, or BS 882, grades M or F.

5.8 Cementitious grouts

5.8.1 *Cement.* Cement for use in cementitious grouts should be as described in 5.6.1.

5.8.2 *Pulverized fuel ash.* Pulverized fuel ash should comply with BS 3892 : Part 2.

5.8.3 *Aggregates.* The fine aggregate for cementitious grouts should consist of sand complying with BS 882, grades M or F.

5.9 Solvent cements

Solvent cements for unplasticized PVC pipes and fittings are specified in BS 4346 : Part 1 for pipes and fittings to BS 3505, BS 3506, BS 4346 : Part 2 and BS 5481. Solvent cements for jointing pipes to BS 4660 are specified in BS 6209 but cements complying with BS 4346 : Part 1 are also suitable.

5.10 Bricks and blocks

Bricks should be class B engineering type complying with BS 3921. Concrete bricks or blocks should comply with BS 6073.

5.11 Step irons

Step irons should comply with BS 1247 in malleable cast iron and in spheroidal graphite iron (ductile) and be galvanized. There are four basic patterns, i.e. general purpose, precast concrete manholes, round bar corner and harpoon.

5.12 Ladders

Fixed ladders should meet the dimensional requirements of BS 4211 except that stringers should be not less than 65 mm × 20 mm in section and rungs 25 mm in diameter. When made of low carbon steel they should be protected by hot dip galvanizing in accordance with BS 729.

5.13 Safety chains

Safety chains should be made of low carbon steel or of stainless steel, 10 mm nominal size, short-link, smooth welded chain to BS 4942 : Part 2. When made of low carbon steel they should be protected by hot dip galvanizing in accordance with BS 729.

5.14 Handrails and handholds

Handrails and handholds should be at least 25 mm in diameter. Low carbon steel tube and bar should comply with BS 1387 and BS 4360. They should be protected by hot dip galvanizing in accordance with BS 729.

5.15 Valves

Guidance on values is given in BS 8005 : Part 2.

5.16 Gullies

Gullies should comply with BS 65, BS 437 or BS 5911 : Part 2 as appropriate.

A gully usually incorporates a trap, or a sump, or both, to retain detritus. The top should be fitted with either a grating or a sealed cover. Connections should be made below the grating or cover. Gullies may be specially designed to suit selected locations and the volume and nature of the flow. They can also incorporate means of access for rodding the branch drain beyond the trap.

5.17 Resistance to chemical attack

5.17.1 *General.* Pipes and joints in materials referred to in 5.2 are generally suitable for use in sewers and drains conveying surface water, foul sewage and trade effluent which may legally be discharged to public sewers. The soil in which the sewer is to be laid may be corrosive to certain pipe and/or jointing materials and this may affect the choice of materials. Where a sewer or drain is liable to carry untreated and corrosive trade effluents, further consideration should be given to possible protective measures. Liquids at elevated temperatures are likely to be significantly more aggressive than those at ambient UK temperatures. General guidance is given in table 1.

5.17.2 *Concrete and materials containing cement.* Normal domestic sewage is not aggressive to Portland cement concrete or cement composite. Attack may however exceptionally occur as a result of aggressive ground water (see BRE Digest No. 250 [4] and BS 8110), or from discharges from hospitals or industrial processes from illegal discharges, or from sewage if it becomes septic.

Table 1 is intended to give general information and, in those cases where it is shown that concrete may be attacked, specialist advice should be obtained.

The cement content, the water/cement ratio and the compaction will have considerable effect on the resistance of concrete to chemical attack. A dense, high quality, well compacted concrete is very resistant to attack. Concrete pipes which comply with BS 5911 are normally resistant to attack by sulphates in solution, as the concrete in the pipes has a high cement content (about 400 kg/m^3), a very low water/cement ratio (0.30 to 0.35) and is well compacted by the pipe-making process. For additional protection SRPC should be specified.

5.17.3 *Protection of ductile iron.* Where conditions are particularly aggressive, additional protection should be considered (e.g. the site fitting of polyethylene sleeving complying with BS 6076 or factory application of zinc coating).

BS 4772 details the standard protection for ductile iron pipes. In sizes DN 80 to DN 800 the pipes are zinc coated externally, prior to bitumen coating internally and externally. For sizes DN 900 to DN 1100 the pipes are cement mortar lined and coated externally with bitumen material. All size pipes and fittings can, if required, be cement mortar lined. The bitumen should comply with BS 3411, type II or BS 4147, type I.

5.17.4 *Protection for grey iron pipes.* The standard protection for grey iron pipes is as follows:

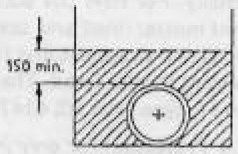
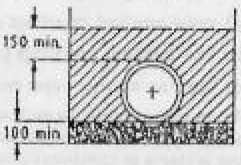
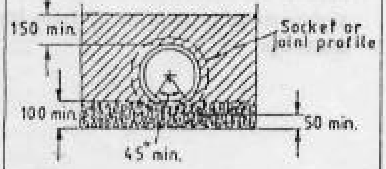
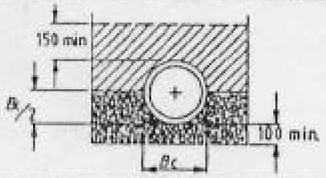
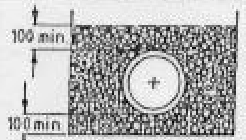
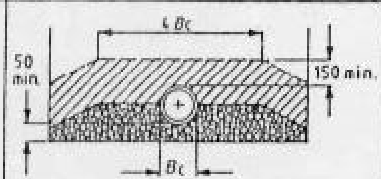
(a) cold applied coatings complying with BS 3416; or

(b) hot applied coatings complying with BS 4147; or

(c) zinc or epoxy type coatings as described in BS 5493.

NOTE. In some aggressive soils or where aggressive chemicals are being discharged it may be advisable to use additional protective coating systems or combinations of those listed above.

5.17.5 *Protection for steel pipes.* BS 534 describes internal and external protection systems for steel pipework for sewerage.

Figure	Bedding class		Bedding factor*	Comments
1a	D		1.1	Pipe laid on trimmed trench bottom.
1b	N		1.1	Pipe laid on a flat layer of granular material with CF† not greater than 0.3.
1c	F		1.5	Pipe laid on a flat layer of granular material with CF† not greater than 0.2. Illustrated after settlement.
1d	B		1.9	Pipe laid on granular material to half diameter with CF† not greater than 0.2.
1e	S		2.2	Pipe fully surrounded by granular material with CF† not greater than 0.2.
1f	B (example)		1.9 (example)	Construction as in figures 1b, 1c, 1d and 1e, except that when the trench width exceeds four times the outside diameter of the pipe barrel, the granular material may be sloped down from that width to the trench formation.

All dimensions are in millimetres.

KEY.

Selected fill — Granular material

B_c is the external pipe diameter.

NOTE 1. 5.5.2 gives recommendations for granular material for bedding.

NOTE 2. 5.5.3 gives recommendations for selected material for sidefill and initial backfill.

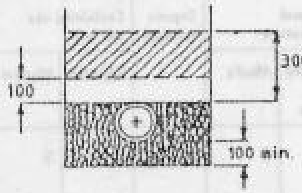
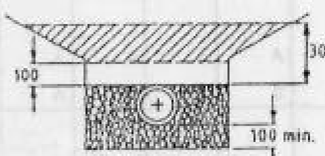
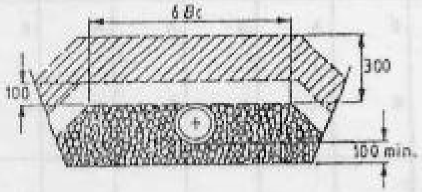
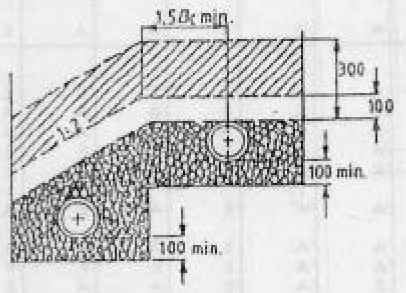
NOTE 3. 12.6.3 to 12.6.6 and 12.9 detail pipelaying procedures for beddings.

NOTE 4. Where there are sockets, these should be not less than 50 mm above the floor of the trench.

* Bedding factor = the ratio of the strength of the pipeline on the specified bedding to the specified crushing strength of the pipe.

† See appendix D.

Figure 1. Beddings for rigid pipes

Figure	Type of trench		Comments
2a	Typical		Pipe surrounded in granular material except above the crown where selected fill may be suitable (see 12.9.2.2).
2b	Vee		A sub-trench should be dug as shown, with construction as in figure 2a.
2c	Wide		Construction as in figure 2a except that when the trench exceeds six times the outside diameter of the pipe barrel, the granular material may be sloped down from that width to the trench formation.
2d	Stepped dual		Construction as in figure 2a for top pipe.

All dimensions are in millimetres.

KEY.

Selected fill — Granular material — Granular material or selected fill containing no stones larger than 40 mm.

B_c is the external pipe diameter.

NOTE 1. 5.5.2 gives recommendations for granular material for bedding.

NOTE 2. 5.5.3 gives recommendations for selected material for initial backfill.

NOTE 3. 12.6.3 to 12.6.5 and 12.9 detail pipelaying procedures for beddings.

NOTE 4. Where there are sockets, these should be not less than 50 mm above the floor of the trench.

Figure 2. Beddings for flexible pipes

Table 1. Chemical resistance of materials (for general guidance) (See also relevant information in clause 5)

Group	BS no.	Material and applications	Trade effluent							Soil	
			At normal temperature		Organic solvents	Containing oils and fats		At sustained high temperature*		Soil environment containing	
			Acids and septic sewage	Alkalis		Vegetable	Mineral	Acids	Alkalis	Sulphates	Acids
Ceramic	65 1196	Clayware pipes and fittings	S	S	S	S	S	A	A	S	S
	3921	Bricks and blocks of fired brick-earth, clay or shale	S	S	S	S	S	A	A	S	S
Concrete	5911 6073	Concrete pipes: Concrete masonry units Ordinary Portland cement	E	A	A	E	A	E	A	A	E
		Sulphate-resisting Portland cement	A	S	A	A	A	E	A	S	A
Asbestos-cement	486 3656	Asbestos-cement pressure pipes and joints Asbestos-cement pipes, joints and fittings (gravity) for sewerage and drainage	E	A	A	E	A	E	A	A	E
Metals	534	Steel pipes and fittings	E	A	A	A	A	E	E	E	E
	437 4622 4772	Grey iron pipes and fittings (gravity) Grey iron pipes and fittings (pressure) Ductile iron pipes and fittings	E	A	A	A	A	E	E	E	E
Plastics	4660 5481 3505 3506	Unplasticized PVC: gravity drain and sewer; pressure	S	S	E	A	A	E	E	S	S
	5480	GRP	A	A	E	A	A	E	E	A	A
Jointing materials (other than Portland cement and iron and steel components (see 5.2))	2494	Rubber: natural (NR)	A	A	E	E	E	E	A	A	A
		chloroprene (CR)	S	A	E	A	A	A	A	S	S
		BUTYL (IIR)	S	S	A	A	A	A	A	S	S
		styrene-butadiene (SBR)	A	A	E	E	E	E	A	A	A
		butadiene/acrylonitrile (NBR)	A	A	E	A	A	E	A	A	A
		ethylene propylene terpolymer (EPDM)	A	A	E	A	E	A	A	A	A
		ethylene-propylene copolymer (EPM)	A	A	E	A	E	A	A	A	A
		†Bituminous compositions	A	A	E	E	E	E	E	A	A
		†Polyester resin	S	A	E	A	A	E	E	S	S
	1972 1973 3284 6437	Polyethylene	A	A	A	S	A	A	A	S	S
		†Polyurethane	S	S	A	S	A	A	A	S	S
		†Polypropylene	S	S	A	S	A	A	A	S	S
		†Epoxy	A	S	E	E	A	E	S	S	A

KEY
A Normally suitable.
E Need expert advice, each case to be considered on its own merits.
S Specially suitable.

* It is not possible to defined 'high temperature' in respect of this range of materials and manufacturer's advice should be sought.

† There is no suitable British Standard for these jointing materials. The classification given to them in the table assumes that the formulations and methods of curing employed are those appropriate for pipe jointing.

NOTE. It is important to take account of quantities and concentrations of all types of chemical likely to be encountered.

Section three. Design

6 Basic principles

6.1 General

The design of a sewerage system is influenced by the local topography, the extent and character of development, the existing and future flows from adjacent catchments, together with the suitability of the point of discharge of any proposed sewer, and the location and adequacy (both hydraulic and structural) of any existing sewerage system.

6.2 Sewerage systems

6.2.1 *The different systems.* There are three different systems as follows.

(a) The separate system (sometimes known as the totally separate system) carries foul sewage (domestic sewage and trade effluents) by an individual system of sewers to a sewage treatment works or outfall point. Surface water from roads, footpaths, roofs and other paved areas is collected in an independent system of surface water sewers and discharged into convenient natural watercourses or soakaways, except in industrial areas where there is a high risk of pollution.

(b) The partially separate system is one in which foul sewage, together with some surface water, usually but not necessarily from roof or yard drainage, is collected by one sewer and the balance of the surface water is collected in another sewer or discharged direct to a watercourse or soakaway.

(c) The combined system is a one pipe system which carries all the foul sewage and surface water to a sewage treatment works or outfall point.

6.2.2 *Choice of system.* The sewerage system to be used depends on both technical and financial considerations, and on the requirement of the water authority. In the UK, the separate system is normally adopted for new development, but if much of the existing sewerage is either combined or partially separate, this may determine the choice of system. The hydraulic design of a combined system is more closely associated with surface water sewerage than with foul sewerage.

During the redevelopment of urban areas, or when sewers are being reconstructed, the opportunity may arise to construct a separate system to replace an existing system of combined or partially separate sewers, and this may be more economical than the provision of additional combined sewerage capacity.

The choice of a sewerage system depends on a number of factors as follows.

(a) In a separate system, surface water sewerage can sometimes be separated into a number of smaller catchments, each with its own discharge to a watercourse. This will limit the overall pipe size and could show a saving in capital cost, but there will be the additional maintenance costs of the two systems.

(b) With a separate system of sewers, the foul sewer is normally laid at a lower level to facilitate house connections. The laying of a foul sewer below the surface water sewer will also minimize the risk of discharge of foul sewage to a watercourse in the event of damage to the surface water sewer, or of any cross connection between the two. Care is needed to avoid incorrect connections when there are two separate sewers.

(c) Combined sewers can provide a means of control of pollution of watercourses as a large part of the surface water run-off will be passed through the sewage treatment works. Additional quality control can be obtained by the installation of oil/petrol traps and grease traps.

(d) A combined sewerage system needs to be large enough to carry storm run-off (see 9.4) but should also work at a self-cleansing velocity during dry weather conditions.

(e) If a part of the surface water run-off can be discharged directly to a local watercourse or to soakaways, the partially separate system should be considered.

(f) With combined or partially separate sewerage systems, storm sewage overflows may be considered to enable flows from storms to be diverted when the design run-off is exceeded (see 7.3).

(g) The amount of surface water in combined or partially separate sewers will increase the hydraulic capacity required at pumping stations and at sewage treatment works. The additional capital investment and operational costs need to be taken into account when comparing alternative proposals.

6.3 Preliminary investigations

6.3.1 *General.* The scope of site investigations work and the methods employed are covered by BS 5930. Particular attention should be paid to the topography and the nature of the subsoil. Specialist investigations are necessary if there is a possibility of the land being subject to mining subsidence or other ground instability.

6.3.2 *Topography.* An examination of contour maps enable preliminary lines for sewers and pumping mains to be established so that the general feasibility of the proposals can be determined before details are prepared. It is important to use Geological Survey data in conjunction with contour maps when a choice between deep open cut and tunnel is indicated.

6.3.3 *Ground investigations.* Ground investigations should be planned in the light and knowledge of site conditions already gained and of the probable disposition and depths of excavation. Where problems are known to exist, appropriate measures to determine their character and magnitude should be allowed for in any contract.

A preliminary ground investigation for a projected sewer or pumping main may be necessary to determine the feasibility of the engineering work involved or to assess the nature and scope of the main site investigation. In the latter case, the preliminary investigation facilitates the preparation of bills of quantities. The preliminary investigation should, in conjunction with information gained from other sources, reveal any parts of the site which require particular attention in the main site investigation.

In determining whether to arrange for a preliminary site investigation in advance of a main ground investigation, the designer should take into account the cost implications and the disturbance and inconvenience, to land owners and others, of having two separate investigations.

Trial pits (hand or machine dug) should be opened up as a matter of course on a site investigation, unless conditions make it impractical, to gain information about the uniformity or otherwise of soil in the mass. Such detailed information cannot be ascertained from boreholes.

6.3.4 *Existing services.* The positions of all existing services should be ascertained as accurately as possible. The records of the relevant public and private bodies should be examined and consideration given to their possible inaccuracy. Exploratory holes should be excavated where necessary. The details of proposed roadworks and other development on the route of the new sewers should also be examined.

6.3.5 *Existing surface water drainage.* The lines and levels of all existing drains, ditches and watercourses should be ascertained. When these are to be drained into a new surface water sewerage system, their drainage areas should be determined and surveyed. The relevant drainage authority should be consulted.

6.3.6 *Infiltration.* In cases which involve the connection of an old system of sewers (which is not to be reconstructed) to a new system, the infiltration of groundwater to the old system may be of significance and should be estimated by observation of the night flow. This should preferably be done when the ground water table is high.

It may be possible to control infiltration by maintenance, renovation or elimination of wrong connections. This could alleviate the need for, or reduce the capacity of, additional sewers. However it is necessary to show that there is a reasonable probability of abatement and that the necessary works are cost-effective. Infiltration abatement schemes on public sewers have on certain occasions caused a rise in the water table which simply transferred the infiltration source to the private drains.

Notwithstanding the advances in pipe materials and jointing systems, some allowance for infiltration into completely new systems should be made where pipelines are laid below the ground water table. There is always some risk of infiltration through building drainage connections, where the small scale and the piecemeal nature of the work render quality control particularly difficult.

6.3.7 *Soil samples.* Sampling and testing of soil should be undertaken in accordance with the recommendations of BS 5930, with the extent and nature of tests being related to the nature of the ground and the form of construction under consideration. A site investigation can only cover a relatively small part of the lengths of sewers under consideration and may not identify all variations in ground conditions. Similarly samples and tests may not always be representative of all materials on site. On investigation, if the ground conditions are found to be variable or of a dubious nature, the advice of an expert should be sought.

6.3.8 *Ground water.* The existence of ground water will be of particular importance and steps should be taken to identify ground water levels, including seasonal variations. Sampling and testing should be carried out to identify conditions which may be corrosive to materials used.

6.4 Financial and engineering assessment

6.4.1 *General.* The financial and economic aspects of the various options open to the designer should be considered alongside the technical, operational, manpower, social, energy conservation and other factors before reaching a decision as to the preferred solution.

Both capital investment and operational costs should be evaluated on the basis of the best information available and options should be compared using cash flow discounting or other techniques as may be appropriate. Due consideration should be given to the accuracy of the various assumptions made in developing the scheme and the sensitivity of the appraisal to errors in these or to changes arising in the future, including the effects of possible differential inflation.

6.4.2 *Staging of schemes.* Due to the practical difficulties in duplicating deep sewers in urban areas and the considerable economies of scale in sewer costs, it is often necessary to provide capacity to deal with any possible future flows arising from development of the drainage area.

In rural areas, where development is uncertain, or where space is available or can be reserved, development of sewers can be planned in stages according to the relative costings of alternative schemes. Staged construction should be considered particularly when sewers can be laid at minimum depth or where lengths of pumping main are needed.

6.5 Layout of sewerage systems

6.5.1 *Economy in the design of sewers and sewer connections.* While sewers should generally be kept as short as possible, and unproductive lengths avoided, care should be taken not to restrict potential development. The route and depth of a new sewer should always take account of land where there is the possibility of future development.

Where main sewers are laid at considerable depths or under main highways having expensive foundations and surfaces, it may be cheaper or more convenient to lay shallow rider sewers to receive the local house connections, and to connect the riders at a small number of convenient points into the main sewer.

6.5.2 *Depths of sewers.* Sewers should be laid at depths which will accommodate not only all existing properties but also any future properties likely to be erected within the area which the sewers are designed to serve; in certain cases, the depth of basements may need to be borne in mind.

The depth of a sewer will have a significant effect on the cost of its construction. The depth, in conjunction with other factors such as the nature of the ground, presence of groundwater and the proximity of foundations, services, etc., may influence the form and method of construction enough to justify the adoption of alternative layouts with longer lengths of sewer where practicable.

6.5.3 *Gradients of sewers.* The most economical design of sewers is obtained when they follow the natural falls of the ground. Sewers should, however, be laid at such gradients as will produce velocities sufficiently high to prevent the deposition of solid matter in the invert. For surface water sewers this can usually be achieved by ensuring that gradients are sufficient to give full bore velocities of at least 0.75 m/s. For foul and combined sewers this minimum velocity should be exceeded daily, which can be achieved by laying the sewers to a gradient which will give a velocity of 1.0 m/s at full bore flow.

6.5.4 *Pumping stations.* Circumstances which may make the pumping of foul or surface water sewage either necessary or advisable include the following:

(a) avoidance of excessive depths of sewer;

(b) the drainage of low lying parts of an area;

(c) the development of areas not capable of gravitational discharge to an adjoining sewerage system, a sewage treatment works or an outfall;

(d) overcoming an obstacle, e.g. a ridge, a watercourse, a railway, or for avoiding an inverted siphon;

(e) the correction of difficulties in a sewerage system resulting from mining subsidence;

(f) the provision of sufficient head for operation at a treatment works;

(g) the centralization of sewage treatment;

(h) raising sewage to storage tanks.

These points should be considered alongside the long-term energy commitments and the capital cost.

The output from a pumping station is normally irregular, particularly during the early life of the station when the flow in the sewers may be substantially below the design flow. The effects of this irregular flow should be taken into account in relation to the flow in downstream sewers and at any treatment works, the premature operation of overflows and the possibility of septicity of the sewage in pumping mains. The discharge from a pumping station may, however, provide a beneficial flushing effect in the sewers.

Site selection should take account of the possibility of flooding, limiting nuisance or damage caused by overflow in the event of mechanical or power failure and the effect on the general amenity of an area from noise or smell.

Pumping operations may be concentrated at one point or occur at a number of strategic points on a drainage system. Alternatives should be considered and cost comparisons made with due regard given to the capital investment and operational costs which pumping will entail.

NOTE. The design of sewage pumping stations and pumping mains is considered in detail in BS 8005 : Part 2.

6.5.5 *Vacuum sewerage.* In a vacuum sewerage system a vacuum is induced and maintained in the pipe system by means of central vacuum pumps and a reservoir. The vacuum pulls sewage through the system to a central collection chamber where it is disposed of using gravity or conventional pumping.

This type of system is not really new insofar as installations can be traced back to 1868 in Holland. But these older installations were very complex, requiring two pipe systems and special vacuum traps at all connections. It is only in recent years that a reliable pneumatically operated vacuum interface valve has been developed which allows the use of single pipe systems drawing the sewage from strategically placed collection sumps to which conventional gravity house drains and sanitary fittings can be connected. This has simplified the pipework, and means that operation and maintenance is a little more complicated than conventional systems and that the cost of installation and operation is competitive with other more normal systems.

Vacuum mains are relatively independent of gradient and the depth of cover can usually be the minimum 1 m to 1.5 m needed for protection. They are a viable alternative to gravity and conventional pumped systems, particularly the former in situations where the terrain is flat, there is a high groundwater level, unstable soils, rock, a requirement for a narrow trench and underground obstructions, although it should be remembered that continuous vacuum pumping will be required.

The vacuum sewerage system has been installed in a number of locations in East Anglia and is being considered in other locations. Pipes are of plastics and can vary in size from 75 mm to 200 mm in diameter, although larger diameters are under consideration.

NOTE. The installation of vacuum sewerage in the UK is described in the paper entitled 'Vacuum sewerage' by Stanley and Mills [5], presented at the International Conference on the Planning, Construction, Maintenance and Operation of Sewerage Systems on 12-14 September 1984.

6.5.6 *Location of sewers.* To allow for adequate access to a sewer for maintenance and to keep maintenance costs to a minimum, the following factors should be considered:

(a) the position of other existing or proposed services;

(b) the proximity of existing buildings and their foundations and the nature of the road construction, in relation to the depth and size of the proposed sewer;

(c) the impact of the construction of the sewer and subsequent maintenance activities upon road users.

Where practicable, if the majority of development is along one side of a road, the sewers should be laid along that side. The duplication of sewers and the cost of laying these in the verge on each side of a main road should be compared with the cost of a single sewer with individual property connections from either side laid under the carriageway.

Where sewers are located under the carriageway, this will leave verges and footpaths available for services which are more likely to require repairs. However, if the sewer is at sufficient depth, it can be constructed in heading or tunnel to pass under existing services and its position will then only be affected by the requirements to locate manholes to avoid those services. In the case of new development, where the routeing of sewers along roads may be difficult or produce an uneconomic layout, it may be possible to lay them under public footpaths or pedestrian areas linking different parts of the development.

When areas are being improved or redeveloped and the existing sewerage system is combined or partially separate, the possibility of changing the system should be considered, together with the possible replacement of old sewers, or their relocation under new or improved paved areas.

6.5.7 *Septicity.* Septicity caused by the prolonged retention of sewage under anaerobic conditions should be avoided by limiting the time of retention in rising mains and siphons and by the provision of self-cleaning velocities in all sewers.

Septicity of sewage leads to offensive smells and difficulties in treatment. It is mainly caused by the retention of organic solids for long periods in an environment where there is a shortage of free oxygen. It may occur in lengthy sewerage systems, and in siphons and pumping mains where sewage may be retained for many hours particularly during the night.

Septic sewage may produce gases such as methane and hydrogen sulphide. When mixed with air in certain proportions methane is highly explosive. Hydrogen sulphide is toxic in high concentrations and in part-full pipes may be converted by micro-organisms on the damp crown of the pipe into sulphuric acid. This acid can cause serious corrosion of work constructed with Portland cement.

Hydrogen sulphide is formed under anaerobic conditions at low velocity of flow and warm temperatures. The rate of release is increased at points of high turbulence such as backdrops and the outlets of inverted siphons and rising mains. Corrosion can occur to susceptible materials at these points and downstream of them.

6.5.8 *Obstacles to sewer lines.* Other services, railways, waterways, major roads and similar structures frequently constitute serious obstacles in the layout of sewerage. Sewers are normally routed beneath such obstacles but, in certain cases, the relative levels may be such as to enable the sewer to be carried above the obstacle. If the sewer is of small diameter, permission may be obtained to sling it alongside an existing bridge structure. To carry a large diameter sewer, however, it will usually be necessary to construct a special pipe bridge. When constraints resulting from the span, headroom and access preclude this it will be necessary to drop the sewer below the obstacle.

The routeing of sewers under obstacles can result in considerable wastage of available fall as well as excessive depth beyond the obstacle. This wastage of fall may be reduced by the introduction of an inverted siphon (see 8.9). It may however be possible to effect an economy by choosing a route for the sewer which crosses the obstacle at a more favourable place, even if this entails an increase in its length.

7 Surface water sewerage

7.1 General

Surface water sewers are designed to collect and convey run-off generated within an urban area during rainfall, for safe discharge into a receiving watercourse. The magnitude of peak flows that have to be accommodated will depend primarily on the intensity of rainfall and the size and configuration of the paved areas. The topography, soil type and its permeability have also to be considered when estimating the flows emanating from unpaved areas, but these are generally small relative to the run-off from paved areas, particularly under UK conditions.

In the past, the most commonly used design methods have been the Rational (Lloyd Davies) Method and the TRRL Hydrograph Method [6]. Since 1981 these techniques have been updated by the methods in the Wallingford Procedure [7], developed by Hydraulics Research Station, with the assistance of the Institute of Hydrology and the Meteorological Office, under the supervision of the DoE/NWC Working Party.

With the older methods a design storm was selected and pipe sizes calculated to carry the resulting flows without surcharge. It was assumed that an adequate protection from surface flooding was thus provided. With the newer methods, the same approach is taken for sizing the pipes, but design can then be checked using a simulation program (WASSP–SIM) to establish the performance of the system under storms of longer return period. If an adequate protection against flooding is not found, the design should be adjusted. WASSP–SIM is principally used to check the hydraulic performance of existing systems. (See BS 8005 : Part 5*.)

7.2 Rainfall

7.2.1 *Performance criteria.* It is normally impracticable to avoid flooding from infrequent storms. A balance therefore has to be drawn between cost and the level of performance provided. Where the client authority has specified the performance criteria for protection against surcharge and flooding, these should be adhered to. For small schemes the criteria in table 2 have been suggested [3] for protection against surcharge and these should be used in the absence of alternative requirements.

Table 2. Storm return periods for design

Location	Return period
	Years
Sites with average surface gradient greater than 1 %	1
Sites with average surface gradient of 1 % or less	2
Sites where consequences of flooding are severe, e.g. existing basement properties adjacent to new developments	5

For larger schemes, following design, checks should be made using WASSP–SIM to ensure that an adequate level of protection against flooding will be present. These checks are particularly important on undulating or steeply sloping catchments. The client authority's requirements should again be followed, but in their absence a 30 year flood protection level should be assumed against surface flooding.

* In preparation.

7.2.2 *Design storms.* The Modified Rational Method (Wallingford Procedure) and its predecessor the Lloyd Davies Method assume mean rates of rainfall during the storm. The Hydrograph methods use a curve or storm profile which describes the distribution of rainfall intensities during the duration of the storm. Mean rainfall rates and storm profiles for the older methods are tabulated [6] together with adjustment factors for different geographical locations within the UK. For the Wallingford Procedure methods, profiles for typical summer storms are built into the programs. Geographical rainfall variations are taken into account. Alternative storm profiles may be appropriate as, for example, when the combined effects of sewer and river flooding are being studied and both winter and summer storms have to be considered. Guidance on storm profile construction should be sought from the Wallingford Procedure [7] and the 'Flood studies report' [8] or from the Meteorological Office.

7.3 Hydraulic design methods

7.3.1 *TRRL Hydrograph method.* The TRRL method was published in 1963. Subsequently modifications were made and incorporated in the second edition of Road Note No. 35 [6], and the techniques described there were the preferred method prior to the publication of the Wallingford Procedure.

Rainfall is entered in the form of a variable intensity hyetograph, which can be either an observed storm or a synthesized storm. The volume of run-off is determined by assuming 100 % run-off from drained impermeable areas, i.e. paved and roof areas, and zero contribution from all pervious areas (parks, gardens, etc.).

Surface run-off is represented by a time-area diagram with base equal to time of entry. The recommended value for time of entry is 2 min for normal urban areas, increasing to 4 min for areas which are large and/or have shallow gradients.

Time of flow down individual pipe lengths is calculated from pipe full velocities obtained using the Colebrook-White formula. To allow for temporary storage in the pipe, the input hydrograph is modified by routeing it through the reservoir formed by the pipe of the current design length. It is thus possible to obtain a discharge hydrograph for each pipe length in the system, from which both peak flow rates and volumes can be assessed.

The principal limitation of the TRRL method is its inability to model directly flow in surcharged pipes and therefore its unsuitability for modelling existing overloaded systems. Also the assumptions of 100 % and zero run-off are not considered to be a sufficiently accurate representation of actual percentage run-off rates.

7.3.2 *Modified Rational Method (Wallingford Procedure).* The Wallingford Procedure includes the following programs.

(a) WASSP–RAT: a modification of the Rational Method for design of sewer networks with catchments of less than 150 ha.

(b) WASSP–OPT: for optimum design of a new sewer network.

(c) WASSP–HYD: a hydrograph method for design and analysis of non-surcharged sewer systems.

(d) WASSP–SIM: a simulation model for existing and newly designed sewer networks, to check performance under severe storms.

WASSP–RAT is closely allied to the traditional Rational Method in that peak discharge is given by the equation:

$$Q_P = 2.78\,CiA$$

where

Q_P is the peak discharge (in L/s);

C is the coefficient (see note);

i is the average rainfall intensity (in mm/h);

A is the contributing catchment area (in ha).

NOTE. The coefficient C is the product of two other coefficients C_V and C_R. C_V is the proportion of rain falling on the catchment which appears as surface run-off, and is used in place of the previous assumption of 100 % run-off from paved areas. The routeing coefficient, C_R, is a simple means of allowing for surface routeing effects.

For the more sophisticated methods within the package the percentage run-off (PR) is estimated using a regression equation of the form:

$$PR = 0.829\,PIMP + 25.0\,SOIL + 0.078\,UCWI - 20.7$$

where

PIMP is the percentage of the catchment covered by impervious surfaces draining to sewer inlets;

SOIL is a soil impermeability index determined from maps provided in the Wallingford Procedure, Volume 3 [7];

UCWI is a measure of antecedent catchment wetness (in mm). It is calculated from soil moisture deficit and rainfall depth during the 5 days prior to the storm event.

Erroneous results are possible at low values of percentage run-off. A limiting condition is specified such that PR cannot be less than 0.4 PIMP.

Above-ground flow is routed through a non-linear reservoir of the form:

$$S = KQ^{\frac{2}{3}}$$

and which obeys the continuity equation:

$$\frac{dS}{dt} = I - Q$$

where

S is the storage on the ground surface (in m^3);

I is the input to the reservoir (net rainfall) (in mm/h);

Q is the outflow (in mm/h);

K is the storage-routeing constant.

In practice, to simplify the procedure the program compares the characteristics of each subcatchment to a matrix of nine standard run-off hydrographs and equates each subcatchment run-off to the most appropriate of the standard profiles.

Pipe flows are calculated on the basis of the Colebrook-White formula and the Muskingum-Cunge method is employed to evaluate storage-routine effects within the sewer system. WASSP–SIM also includes methods of assessing pipe flow behaviour under surcharged conditions.

7.3.3 *Choice of design method.* The Modified Rational Method has the advantage that it does not require access to a computer. To facilitate hand computation, a guide has been published as Volume 4 of the Wallingford Procedure [7]. The method can be used for straightforward design on developments up to 150 ha where time of concentration is up to 30 min and pipe size up to DN 1000. The data requirements for the Modified Rational and Hydrograph Methods are similar, so if there is access to a computer and the WASSP programs are available, the more accurate Hydrograph Method should be used for all but the simplest design. The Hydrograph Method should be used wherever WASSP–SIM is to be used, to check the level of flood protection available.

7.4 Balancing

7.4.1 *General.* The development of agricultural land for residential or industrial use will result in an increased rate of rainfall run-off. Unless this is controlled, it will increase the rate of flow in any surface water sewer or watercourse downstream of the development. If the increased run-off will overload the sewer or result in flooding, it is usual to provide some form of balancing on the surface water system of the new development to reduce the rate of discharge. It will generally be convenient to provide balancing on the new sewerage system, but in some circumstances, balancing of a watercourse could be more convenient.

Retention tanks or balancing reservoirs are used on surface water sewers and occasionally on combined sewer systems to accommodate temporarily that part of the peak flow which cannot be accommodated in the sewers downstream, and where increased overflow to receiving waters is unacceptable. The requirement to provide balancing may be set by the authority responsible for control of rivers, who will wish to consider the implications and approve all designs.

A proposal to provide balancing facilities should be based on a careful economic appraisal of the circumstances. The cost of a balancing reservoir (including the cost of land and the subsequent maintenance costs) should be compared with the costs of any improvements which would otherwise be required to existing sewers or watercourses.

7.4.2 *Design criteria.* The design should take account of the following:

(a) the maximum rate of outflow acceptable to the pollution control authority;

(b) the design storm (a balancing reservoir should be designed to deal with the run-off from a storm with a return period as required by the pollution control authority);

(c) the dimensions of the proposed balancing facility (there may be limitations in the area available or on the maximum depth of storage as required by the land drainage authority).

7.4.3 *Types of balancing.* Balancing of flows within the sewerage system can be provided by building in additional storage in the form of on-line or off-line tanks. For on-line storage an over-sized length of sewer can be installed.

Within the watercourse balancing can take one of two forms. An existing lake or pond can be used; balancing storage will then be obtained by arranging for an increase in water level during periods of storm. Alternatively, an area of land can be set aside to be flooded during time of storm; at other times this land can be used for recreational or similar use.

Careful consideration should be given to existing ground and water levels and to the effects of any excavation or banking. In particular, the safety of any existing or proposed properties should be considered. The Reservoirs Act 1975 will apply when the amount of water to be stored exceeds the minimum laid down in the Act.

7.4.4 *Storage capacity.* The required storage capacity of storage ponds on watercourses can be obtained by plotting the inflow hydrograph based on an appropriate design storm, together with an outflow hydrograph. The volume to be stored can then be calculated from the excess of inflow over outflow. Detailed advice is given in CIRIA Technical Note No. 100 [9].

The optimum size of retention tanks in sewerage systems can be derived using WASSP–SIM. An appropriate outlet throttle is assumed which gives the required carry-on flow. Various tank sizes can then be tested under a range of design storms. The critical storm duration will be found to be between two and four times the time of concentration of the upstream system. Storage tanks are installed more frequently to upgrade the performance of existing systems than as part of new systems, so for more detailed advice see the Sewerage rehabilitation manual [1].

7.5 Soakaways

A soakaway is a pit to provide soakage and storage capacity for run-off; its base and sides are open-jointed to facilitate the percolation of water into the surrounding subsoil. The pit can be filled with rubble, or a roof slab can be provided. If rubble is used, extra capacity should be provided to allow for this.

When the subsoil conditions are satisfactory, soakaways can be used to take the run-off from new development. Individual soakaways can be provided at each gully, downpipe, etc., or a number of drainage points can be connected to one soakaway. Prior approval from the authority responsible for groundwater protection is required before soakaways are installed and this may be withheld in Aquifer Protection Zones. Particular attention should be paid to the provision of oil spillage interception, in order to safeguard groundwater quality and also to protect the performance of the soakaway.

In ground with low permeability, it is necessary to provide storage capacity to retain the flows during prolonged or heavy rainfall. A capacity equal to 12 mm of rainfall over the area drained should be adopted. Its effective depth is measured below the invert of the lowest incoming drain. This can be achieved by the provision of one soakaway or a number linked at overflow level by piped seepage trenches. Similar trenches can be used to provide means of overflow from a soakaway.

8 Hydraulic design

8.1 Routeing of flow in sewers

The flow in a sewer usually varies with time, particularly in a storm water sewer or in a foul sewer at the diurnal peaks. A discharge hydrograph (i.e. a discharge-time record) taken at such a time would show that:

(a) the discharge rises from a base flow to a peak and then decreases to the base flow;

(b) assuming no lateral inflow, the peak discharge is less at successive locations along the sewer (this feature is termed attenuation);

(c) the time for which the discharge is greater than the base flow increases at successive locations along the sewer.

The computation of the changes in the discharge hydrograph along the sewer is called 'routeing': the most suitable method for routeing flow along sewers is that of Muskingum-Cunge which is used in the Wallingford Procedure [7] (see 7.3.2).

8.2 Recommended velocities in sewers

8.2.1 *Self cleansing velocities.* Sewers should be laid at gradients that will produce velocities sufficient to prevent permanent deposits of solids. A velocity of 0.75 m/s occurring sufficiently frequently is usually enough to maintain self-cleansing conditions to avoid long-term deposition of solids.

8.2.2 *Maximum velocities.* The erosive effects of high velocities are not as serious as formerly had been thought and there is thus no need on this account to place an upper limit on the velocity in a sewer. Nevertheless, other circumstances occur which need to be considered (see 8.6).

8.3 Hydraulic roughness value of sewer pipes and pressure mains

8.3.1 *Velocity equation.* Various equations have been developed in attempts to provide a scientific basis for the assessment of velocities of flow in channels and pipes. The formulae in use today include the following.

(a) *The Colebrook-White equation.* This is most commonly used in the design of sewers, providing an accurate basis of design, with experimental confirmation over a wide range of flow conditions. It is recommended as the first choice for the design of sewers.

(b) *The Manning equation and the Crimp and Bruges equation (Manning with a constant coefficient).* The Manning equation is widely used because of its simplicity. A special form of this, the Crimp and Bruges equation, is also still widely used, but incorporates a constant hydraulic roughness value. Manning and Crimp equations would be described as empirical.

(c) *Hydraulic Research Paper No. 4 equations.* This publication recommends use of the Colebrook-White equation and provides tables to simplify application of the equation to the range of sewer pipe sizes, gradients and roughness commonly encountered. The equation is presented in engineering terms for both pipe-full and open channel flow; factors to allow its application to non-circular pipes are provided. Methods for evaluation of the composite roughness of surfaces of dissimilar texture are also described.

Although the Colebrook-White equation is complex, design charts [10] and tables [11] are available. The exponential equations (Manning and Crimp and Bruges) do not have any theoretical basis and only apply to a limited range of conditions. They can be used where the flow is turbulent and where circumstances require an algebraic analysis; their simpler form gives them an advantage over the Colebrook-White equation. When using exponential equations, the appropriate coefficient and constant have to be selected [12].

8.3.2 *Roughness of sewers.* In order to use a velocity equation, it is necessary to estimate the roughness of the sewer. Whilst in theory the roughness is related to the height of the roughness elements of the pipe wall, in practice it is also influenced by other factors; these comprise the straightness of the pipe, discontinuities at the joints, free water surface at part-full flow, slime growths around the perimeter and sediment deposits on the invert.

In pipes carrying foul sewage, the roughness will be influenced to some extent by the pipe material, but will be primarily dependent on the slime that grows on the pipe surface below the water level corresponding to the maximum daily discharge.

A surface water sewer is unlikely to slime to any significant extent, but it is likely to contain deposits of grit on the invert. The roughness will depend on these and on the pipe material.

Recommended roughness values (K) for sewers are given in table 3.

Table 3. Surface water sewers: roughness values for new, well-aligned pipes free from deposits

Material	Recommended values of K
	mm
Brickwork	
Well pointed	1.5
Concrete	
Spun concrete pipes with 'O' ring joints	0.15
Precast concrete pipes without 'O' ring joints or having rough internal finish	0.30
In situ lined concrete tunnels	0.60
Asbestos-cement	
With 'O' ring joints, long pipe sections	0.06
Clayware (glazed or unglazed)	
With sleeve joints and 'O' ring seals	0.03
With spigot and socket joints	0.06
Polymeric materials (GRP, PE, unplasticized PVC)	
With chemically cemented joints	0.03
With sleeve joints and 'O' ring seals	

Recommended roughness (K) values for foul and combined sewers are given in table 4.

Note that the recommendations given in table 4 apply to new sewer design.

8.3.3 *Roughness of pressure mains.* Although a pressure main carrying sewage will slime, the amount and pattern of sliming will be different from that occurring in a gravity foul sewer.

8.4 Headlosses at manholes and bends

In addition to the energy losses that are induced by friction on the surface of the pipe, other losses will occur at manholes and bends as a result of sudden changes in velocity and in direction. These additional losses are usually small in relation to the frictional losses, and are not normally considered (see appendix E). The equation for the energy loss is usually of the form:

$$\text{energy loss} = \frac{kv^2}{2g}$$

where

k is the energy loss coefficient;

v is the mean velocity in sewer (in m/s);

g is the gravitational constant (in m/s^2).

8.5 Surcharging

A surcharged sewer is one where the sewage flows under pressure. This situation will arise when the incoming flow is greater than the capacity of the pipe when just full, or when the tailwater level is raised sufficiently to cause the sewer to run full when it would normally run only part full. The capacity of a surcharged sewer depends on the hydraulic gradient. If the hydraulic gradient is steeper than the invert gradient, the capacity will be greater than the capacity when just full. Surcharging is undesirable in systems carrying foul sewage and in surface water systems where there is a danger of flooding. However, it should be borne in mind that frequent surcharge of defective sewers will cause soil loss which could result in structural damage. The ability to simulate surcharging in sewers is contained in the Wallingford Procedure [7].

Table 4. Recommended roughness values for pipe and brick foul and combined sewers

Material	Recommended values of K
	mm
Pipe sewers	
Peak DWF* velocity typically exceeds 1.5 m/s	0.3
Peak DWF velocity typically exceeds 1.0 m/s	0.6
Peak DWF velocity between 0.76 m/s and 1.0 m/s	1.5
Brick sewers	
Peak DWF velocity typically exceeds 1.5 m/s	1.5
Peak DWF velocity typically exceeds 1.0 m/s	3.0

* Peak DWF = Dry weather flow diurnal maximum = 2 × DWF.

8.6 Sewers at steep gradients

There is no criterion for limiting maximum sewage velocities and consequently no technical reason to avoid steep gradients. In steeply sloping ground, economies in the cost of a sewerage scheme might result from laying the sewers at the prevailing ground slope. Smaller pipes can be used, and backdrop manholes can be eliminated. However, high velocities can introduce problems that are not normally encountered in the design of sewerage schemes. Consideration should be given to the following:

(a) air entrainment may produce bulking of the flow;

(b) the surface of the sewer can be damaged by cavitation (i.e. collapse of vapour bubbles formed at local areas of low pressure);

(c) the surface can be damaged by corrosion as a result of the release of hydrogen sulphide from septic sewage at places where the flow is highly turbulent, e.g. at a hydraulic jump;

(d) energy dissipation measures need careful consideration, particularly where the sewer is discharging into a watercourse or where the sewer gradient changes from steep to mild;

(e) special attention should be given to the safety of operatives;

(f) energy losses at bends and manholes may be significant;

(g) energy losses may also occur should standing waves form when the sewer is running part full.

NOTE. In theory a sewer flowing half full is steep when the velocity exceeds $2\sqrt{D}$ m/s, where D is the nominal pipe bore, and the above phenomena will not occur below this velocity. Some may not be significant until a considerably higher velocity is reached.

As a general guide [7] the engineer should examine the design to check whether any of the aspects listed above need to be taken into account, whenever the velocity when the pipe is flowing half full (in m/s) is greater than or equal to twice the square root of the nominal pipe bore (in metres).

8.7 Storm sewage overflows

The number of overflows in a sewerage system should be kept to a minimum commensurate with limiting the sizes of the sewers downstream. Overflows should not normally be installed on sewers less than DN 500.

For new sewers, the overflow setting should generally be according to the formula [13] :

$$Q = \text{DWF} + 1360\,P + 2E$$

where

Q is the flow retained in the sewer system (in L/day);

DWF is the dry weather flow draining to the overflow (in L/day);

P is the population served by the sewers upstream;

E is the average trade effluent flow (in L/day).

Variations in the types of predominant trade effluents may warrant adjustments to this formula.

Consideration has to be given to the capability of the receiving stream to take the environmental impact of the overflow discharge. For small streams the constant 1360 may need to be significantly increased. Similar increases for the constant 2 will be required for abnormal discharges of trade effluent. The relevant river pollution authority may have guidelines regarding minimum dilution ratios which should be followed and their advice should be sought in all cases where the overflow discharge is likely to make up more than 20 % of the receiving stream flow.

The hydraulic performance of overflows can be greatly improved by the provision of downstream storage in, for example, a length of tank sewer. The benefits of such provision can be tested using the WASSP–SIM program. The design of tank sewers will be covered in more detail in BS 8005 : Part 5*.

In the design of an overflow, steps should be taken to reduce to a minimum the discharge of floating solids to the receiving waters. Scumboards offer only a partial solution and where amenity considerations are important raked screens may be required. Again the river pollution authority's advice needs to be sought.

8.8 Backdrop and ramp manholes

Where a sewer connects with another at a materially lower level, a backdrop or ramp manhole may be constructed to drop the higher incoming flow to the level of the lower sewer and a common outlet (see 11.2.6).

The choice between constructing a backdrop manhole or laying a sewer more steeply should be decided on economic grounds.

8.9 Inverted siphons

Inverted siphons pose a potential maintenance problem and whenever there is a practical alternative, sewerage designs should be arranged to avoid them. They are necessary, however, on occasions to carry sewage flows under obstructions such as rivers, canals, major roads and railways. Because there is normally more grit in suspension (and on the invert) in a combined or partially separate system then in a separate foul system, to achieve self-cleansing conditions the design of siphons on those sewers is more critical than for siphons on separate foul systems. The siphon arrangement should be such as to minimize operational and maintenance difficulties arising from silting. Wherever possible, all siphons should be designed so as to be self-cleansing even during the lowest rate of flow. Where velocities in a siphon will be inadequate, some means of flushing will be necessary. On small siphons, this can sometimes be arranged by providing a penstock upstream of the siphon so that the sewage flow may be temporarily held back and suddenly released. The resulting flush may be sufficient to scour the siphon. Advantage may be taken of any other means of flushing available locally.

The layout should allow any siphon to be isolated for cleaning purposes. This can be arranged by providing penstocks or stop-boards at the inlet and outlet. Access for removing silt is essential. Short siphons are often best arranged with rising pipelines from a low inlet chamber where sediment will collect. This chamber is part of the siphon and has to be isolated together with the siphon pipeline.

On longer siphons, an independent washout chamber draining from the lowest point in the siphon system may be used to collect deposited material. On large diameter siphons, it is often convenient to enable the suction of a portable pump to be connected to this draw-off, and to connect the pump delivery to the draw-off valve on one of the other pipes, so that the contents of one pipe can be pumped directly into another.

Where access is desirable, hatch-boxes should be provided on the pipes for rodding, etc.

In the multiple-pipe siphon, the fore-bay should be so designed that the various pipes come into action successively. This can be arranged by the provision of a number of weirs which come into operation in succession as the flow rises. In this way, the heavy solids moving along the invert would be directed into the pipe which remains in continuous operation. The outlet end of a multiple-pipe siphon should be designed so that reverse eddies cannot carry solids back into the pipes which are not in use.

On most separate sewerage systems, two-pipe siphons will usually suffice, the first one taking up to the quantity which would give a self-cleansing velocity, and the second taking the remainder of the flow. This should ensure that the first pipe is self-flushing when the flow is near its daily maximum.

On larger sewers, three or more pipes will sometimes achieve better results, the flow being divided between them on the same principle as for a two-pipe siphon with all pipes designed to be self-cleansing.

8.10 Sewage retention tanks

Retention tanks should not be used on separate foul sewerage systems, except:

(a) at pumping stations where the sump is used to retain sewage flows to suit pump switching arrangements; and

* In preparation.

(b) at the inlet to small sewage works where large fluctuations in flow may impair the treatment process operations.

The inclusion of a retention tank in the sewerage system (see also 8.7) may cause sewers to surcharge when the tanks are in use and this has to be taken into account in the hydraulic design to ensure that flooding is avoided.

8.11 Miscellaneous

8.11.1 *Ventilation arrangements.* Sewers should be ventilated to release sewer gases. Unventilated sewers may give rise to air locks or the emptying of domestic siphon traps when the sewers are running full.

In recently developed urban areas, sewers will normally be adequately ventilated through the domestic waste pipe stacks and the house connections to the sewer. Exceptions to this are likely if unventilated stub-stacks are used in domestic plumbing in single storey development or where all sanitary facilities are on the ground floor. Older properties are usually equipped with external waste traps, thus providing no sewer ventilation*. It is not normally necessary to provide forced sewer ventilation systems in the UK.

Ventilator covers are not normally advised in urban areas, but may be needed on main sewers where rider sewers are used.

Ventilation columns are required in urban areas where house connections are unventilated. They are also required on deep trunk sewers where house connections discharge to a parallel local collection sewer. In rural areas, the lengths between house connections may be ventilated by open manhole covers, provided these are located more than 20 m from inhabited properties; where the sewers run at the edge of the road, open covers are not advisable and ventilation columns may be required.

Sewers should generally be ventilated as follows:

(a) at the head manholes in a gravity sewer system;

(b) at about every 500 m;

(c) at pumping stations;

(d) at manholes where pumping mains discharge.

Columns should rise to at least 900 mm above the top of the highest opening window and should be at least 3 m away horizontally and preferably much more. The top of each column should be equipped with a wire cage.

8.11.2 *Sewer flushing.* Wherever possible, sewers should be designed to achieve self-cleansing conditions. Frequent sewer cleaning may be necessary on flat sewers where the gradient is insufficient to achieve self-cleansing velocities. Portable high pressure jetting equipment is found to be more convenient than flushing and better able to lift deposited grit (see 17.3.1).

8.11.3 *Flow recording equipment.* The need for permanent flow recording in a sewerage system depends on the monitoring practice of the sewerage authority. Trade effluents may need to be measured and recorded for charging purposes; the meter should be placed on the drain at the premises.

Provision for temporary flow recording apparatus, flow sampling and direct analysis equipment should be considered at strategic points in new sewerage systems to provide the designer with flow data for engineering similar systems in the future. (See also 16.6.)

9 Foul and combined sewerage

9.1 Water consumption statistics

Existing water supply statistics (see 4.2.2) should be used to derive future water supply consumption and hence sewage flows. They will be invaluable in deriving flow patterns for daily consumption and indicating anticipated variations between different types of development. Figures for consumer wastage and distribution leakage are of particular importance in assessing sewage flows from such statistics. The overall capacity of the existing water supply system, together with projected additions, should be correlated with the capacity of planned sewerage schemes. Private water supplies obtained from boreholes, rivers, etc. that are likely to contribute to the sewerage systems should also be investigated.

9.2 Design flows: foul sewers

For foul sewers flow rates are usually based on either population and a rate of flow per head or, for new developments where such data may not be available, on the number of dwellings. For a new development the estimates used should be appropriate for a 30 year planning horizon.

For an upgrading scheme on an existing development, the ultimate foreseeable development of the sub-catchment area may be used (see 4.2.1).

The rate of flow per head may be based on local water supply statistics allowing for distribution losses and consumption that does not result in discharge to the sewers. Typical discharge figures for similar developments to those under consideration may also be used. In the absence of such data a figure of 220 L (based on 200 L plus 10 % infiltration) [3] may be assumed which multiplied by the population gives the average flow or dry weather flow (DWF).

Foul sewers are frequently designed to carry 4 to 6 x DWF, the larger figure relating to sub-catchments and the smaller to the trunk sewers. This takes account of diurnal peaks and the daily and seasonal fluctuations in water consumption, together with an allowance for extraneous flows such as infiltration. A figure of 4000 L per dwelling has been recommended for new development as an approximation to 6 x DWF [3].

* Building Regulations now do not recommend the use of external traps, but until about 1960 these were required under many building byelaws.

Where a scheme is to be developed in phases, consideration should be given to the likely flows following the initial stages of construction so that self-cleansing velocities are attained at times of peak flow each day (see 6.5.3).

Flow rates calculated from the DWF should not be used to design sewers that serve individual or small groups of buildings where flushes from individual appliances will give relatively high flows of an intermittent and irregular nature. In such circumstances the likely peak rate of flow should be derived from the probability study on the number and type of appliances connected (see BS 8301).

9.3 Design flows: combined and partially separate sewers

For combined and partially separate sewers, the design flow rate is made up of the storm flow, which is by far the predominant component, plus an allowance for foul sewage flows. The storm flow component should therefore be estimated using the methods outlined in clause 7. The foul sewage DWF is estimated as described in 9.2 and capacity allowed for 2.5 × DWF or 1500 L per dwelling unit [3].

As the foul sewage flows will be very much less than the design flow rates, particular consideration should be given to self-cleansing velocities during dry weather conditions (see 6.5.3).

9.4 Storm sewer overflows

The purpose of storm sewage overflows is to limit the quantity of storm sewage carried to sewage treatment works and to allow the discharge of diluted sewage to watercourses without causing undue pollution to the receiving water (see 8.7).

Overflows should only be installed on combined or partially separate sewerage where the flow in wet weather may greatly exceed the maximum foul sewage flows. They should not be installed on separate foul sewerage which should be designed to accommodate all foul sewage flows.

Each overflow should be located near a suitable watercourse to which the excess flows can be discharged.

The annually exceeded level in the receiving water should be below the weir level of the overflow to enable the overflow to operate and to avoid risks of the receiving waters discharging back into the sewers. To protect the system against larger floods, stop valves may be required. The receiving water should provide sufficient dilution to excess sewage flows in wet weather as required by the pollution control authority. The siting of overflow outlets should be chosen with regard to the effects of occasional polluted discharges. Particular consideration should be given to overflows from sewage pumping stations which will come into operation in the event of a failure of the pumping equipment.

Storm sewage overflows should only be considered where there is an overriding economic justification and the consequences of such discharges will not be prejudicial to the achievement and maintenance of the quality of the receiving waters, taking into account the needs of existing and potential uses of that water. The siting of any storm overflow should be determined after a proper appraisal of these factors. A decision will have to be taken as to the frequency of storms and the rainfall intensity to be catered for, the provision and type of storm overflows and any of the consequent pollution problems weighed against the increased costs of larger diameter sewers [13]. All available information should be obtained regarding levels, depth of water, quantity and velocity of flow, liability to flooding, purpose for which the water is used, its quality and any local conditions which might affect or be affected by a storm overflow, such as water supply intakes, ornamental waters, fisheries, etc. In the case of discharge to tidal waters, full account should be taken of tidal currents.

The pollution control authority should be consulted early with regard to the discharge of storm sewage from the sewerage system and any special setting of storm overflows required by that authority (see also BS 8005 : Part 0); the authority should be able to provide records of stream flows and other factors in support of their requirements. Storm sewage overflows should not be sited near to places where the public have access to the banks of a stream.

In order to avoid pumping, storm overflows should wherever possible be located at points in the system where a gravitational fall is available through the storm overflow pipe to the selected point of discharge, without fear of drowning the overflow weir at times when the water in the receiving river, stream, or surface water sewer is at its maximum flood or tidal level. If necessary, the overflow can be located at some considerable distance from the point of discharge.

When retention tanks are used they should be interposed adjacent to an existing storm sewage overflow so that, during periods of storm, the heaviest polluting matter is discharged to the tank via a low level weir. The normal overflow weir discharging to the watercourse should be retained in order to relieve the system of any excess storm sewage flows. These tanks can be entirely underground.

When a treatment tank is provided, it should be sited on the discharge pipe from the storm sewage overflow.

NOTE. These tanks have a storage function in retaining storm sewage which is later returned to the sewer when the sewer flow subsides. Under these circumstances, the storm sewage is returned to the system for treatment and there is no discharge to the watercourse. Larger storm flows will fill the tanks and cause overflow to the watercourse but the storm sewage discharged will have received some treatment by settlement.

9.5 Trade effluents

The rates of flow of trade effluent depend upon the industry and the process from which it emanates, and no general rules on quantities of flow can be laid down.

The forecasting of future flow rates of trade effluent during the life of the sewerage system is often difficult. It is dependent, among other things, upon the policy of the sewerage authority. Problems can be minimized by the following measures.

(a) The occupiers of premises should ensure that the processes which they adopt will reduce, as far as possible, the total quantity of waste-water produced.

(b) As much as possible of this total flow should be returned to the premises for re-use.

(c) The remaining waste-water should be discharged to the sewer at a steady rate rather than as a surge.

(d) The outflow from a factory should preferably take place only during low flow periods in the sewerage system (e.g. at night). Where appropriate this will be covered by any consent agreements to discharge.

(e) Consideration should be given to the possibility of high temperature in effluents and their effect on the corrosivity of pipe materials (see table 1).

Typical figures prepared by the Water Authorities Association Water Council Water Information Centre relate waste discharges from particular industries to product output and/or to the number of workers employed. When reviewing the discharges from a large number of small industries, the approach should be based on the number of workers. This has obvious practical advantages, bearing in mind the degree of uncertainty about the type of industry.

Medium and large industries should be reviewed individually, noting the methods of working as well as the average daily water consumptions. Continuous processes or processes where three shift working is adopted, usually give rise to sector inevitably produce uncertain trade effluent discharge whereas batch processes, single shift working, and intermittent cleansings and flushings (possible secondary to the principal process) can give rise to peak discharges many times greater than average. As a consequence of the emptying down of tanks, or the storage capacity provided within the establishments, the instantaneous discharges may sometimes greatly exceed the maximum rate of supply.

The unknowns inherent in planning for the industrial sector inevitably produce uncertain trade effluent discharge predictions. In the absence of firm development plans, sewer capacities should be provided which allow for present discharges to be increased in proportion to the spare production capacity existing within the factory or possible expansion on a site.

When planning for future industrial development in which the types of industry are unknown, some authorities require designs based on a domestic element of 0.6 L/s·ha for an average DWF, plus a trade element. The peak flow for the latter is frequently taken as 2 L/s·ha for normal industries and 4 L/s·ha for wet industries or for small sites.

The control of trade effluent discharges is referred to in BS 8005 : Part 0.

9.6 Pumped discharge

Where a sewer receives a pumped discharge it should be capable of receiving the output from all the pumps in the station discharging together at the total head that would apply if the wet well were filled to ground level. This excessive flow is one that can occur either:

(a) upon power supply after a mains failure; or

(b) after repairs to the station if the attendant should inadvertently switch on all pumps whilst the wet well is full.

This is generally a problem with pumps that have a steep characteristic curve, as is normal with submersible type pumps.

10 Structural design

10.1 General

The computed load method based on the work of Marston, Spangler and others should normally be used for all sewerage design. To provide against the effects of settlement and soil movement, sewers should be provided with flexible joints. See 'A guide to design loadings for buried rigid pipes' [14].

Sewers laid within highways should have a minimum cover of 1.2 m in order to avoid interference with other underground utility pipes and cables. The beddings of pipelines with 1.0 m or less of cover require precautions to be taken besides those needed to resist the loads acting upon them. Otherwise sewers should not be laid at such a depth as to foul the line of any land drains, and at no point should they be so shallow as to interfere with cultivation. Cover over the highest part of the pipeline structure of 0.9 m will normally satisfy this.

10.2 Design method for rigid pipes

The design involves the computation of the total effective external load on the pipe caused by the worst combination of fill load and surface loads likely to be imposed simultaneously on any particular length of sewer, and the selection of a rigid pipe having a crushing test strength which, together with the class of bedding to be used, will provide sufficient supporting strength to carry the maximum load with an adequate factor of safety.

Simplified tables and design charts have been published [15], which indicate certain standard methods of construction.

Various standardized methods of bedding are used, and it is recommended that the bedding factors set out in figures 1 and 2 should normally be adopted. Allowance should be made for any specific requirements contained in national specifications or those of the authority under whose jurisdiction the work falls.

10.3 Factor of safety method

This method uses a factor of safety which differs from usual practice in that it is applied not to the calculated loads based on the properties of the soils to be encountered, but to predicted loads derived from experimental work. Further, the value of ground support utilized in the design method may be less than that which occurs in practice.

Where the calculation of supporting strength is based on the crushing strength specified in the relevant British Standard for pipes of the various materials and where the maintenance of this strength is supported during manufacture by a properly controlled quality assurance system, it is recommended that a factor of safety of 1.25 minimum should be applied to the calculated design load.

For concrete pipes, BS 5911 : Part 1 specifies maximum works test loads and in addition, for reinforced concrete pipes proof works test loads of 80 % of the maximum; in calculation a factor of safety of 1.25 for maximum or 1.0 for proof should be used. The use of factors of safety should not be regarded as a substitute for the maintenance of proper site control and supervision. On the other hand, hidden safety factors should not be included, without proper reference to them.

10.4 Design method for box culverts

Box culverts are required to withstand the worst combination of the effects of fill and surcharge loads. They are individually designed to the requirements of the relevant highway, rail or water authority and are not manufactured to standard class strengths as in the case of pipes. Surcharge loading specification is to BS 5400 : Part 2 and structure design to either BS 8110 or BS 5400 : Part 4.

10.5 Design method for flexible pipes

Unplasticized PVC, PE and other thermoplastics pipes, thin-walled steel pipes and GRP pipes are commonly occurring examples of flexible pipes. Flexible pipes support loads by soil/pipe interaction, and so the surrounding fill is an essential part of the support structure and proper regard should be paid to its selection, placing and compaction.

Pipes up to about DN 600 are usually laid according to empirical rules. The wall thicknesses in the British Standards for such pipes for use for underground non-pressure applications are chosen on the basis of experience with the assumption that pipes will be installed so as to limit the amount of ovality that will develop in service to a (usually) 5 % decrease in vertical diameter. For concrete-lined steel pipes a limit of 2 % is desirable. Care should be taken to observe any usage limitations (e.g. temperature) set out in the relevant British Standard.

Since the consistent control of compaction of soil around pipes, particularly in the smaller sizes, is not easy to ensure, it is preferable to employ a granular surround of material requiring the minimum of tamping to achieve a satisfactory density (see 6.5 and figures 1 and 2).

Care is needed to identify situations where the pipes may be subjected to considerable external hydrostatic head and/or internal vacuum (greater than 6.0 m head) or where the soil may be rendered unstable by water, since the lateral support afforded to the selected surround material by the adjacent soil may then be inadequate. In cases of doubt, pipes should be used having a wall thickness (stiffness) capable of resisting the long-term external hydrostatic pressure without buckling in the absence of soil restraint.

Computed load design methods may also be employed particularly for pipes over about DN 600. These methods are directed towards the following:

(a) the determination of the maximum external loading; and

(b) the selection of a suitable pipe wall thickness (stiffness).

The latter, taken in conjunction with a specified degree of compaction of the surrounding bedding and adjacent soil material, should maintain the degree of pipe deformation within prescribed limits without risk of wall buckling or of causing unsafe strains in the pipe wall.

Ductile iron pipes are flexible and are commonly used for pumping mains and in cases where extra strength is required. This may be to resist high external loads, such as traffic loads, where there is no alternative but to place the sewer near to the road surface, or when full vacuum conditions may exist.

There are publications that summarize the results of work on flexible pipe design and the conclusions to be drawn from it [16, 17, 18, 19]. See also BS 5955 : Part 6 regarding the use underground of thermoplastics pipes.

10.6 Particular cases

10.6.1 *Sewers passing below and through structures.* The routeing of sewers below or through a building or structure should be avoided wherever possible but if not it is essential to allow for the effects of differential settlement.

The walls of manholes and other structures generally will be subject to settlement differing from that of the pipe. Differential settlement can be accommodated by means of flexible joints. The risk of shear fractures is considerably reduced by the provision of a flexible joint, located as close to the face of the structure as is feasible, compatible with the satisfactory completion and subsequent movement of the joint.

In cases where differential settlement is expected, the length of the next pipe (rocker pipe) away from the structure should be kept short. The length of rocker pipe should be approximately 0.5 m to 0.75 m for pipes up to DN 450 and 1 m for pipes up to DN 750.

Where considerable differential settlement is expected, several rocker pipes should be laid and the designed gradient may need to be increased locally so as to reduce the likelihood of a backfall developing.

Where it is not necessary for the pipe to be built into the structure the effects of differential movement may be overcome by the use of a lintel, relieving arch or sleeve in the structure, leaving a gap of not less than 50 mm around the pipe. The gap should be effectively sealed to prevent the entry of gas, gravel or rodents. This is particularly relevant when working on reclaimed land. Particular care should be taken to identify and fill any abandoned sewers, drains or conduits before building work is commenced [20]. The designer should take due note of the proximity of other underground services.

10.6.2 *Two sewers in one trench.* Where two sewers are laid at different levels in the same trench the bedding material should be well compacted over the full trench width above the lower pipe to provide a stable bed for the upper pipe. Side fills of the upper pipe should also be well compacted to ensure full and continuing support under the haunches [14].

10.6.3 *Sewers on piles, piers or walls.* Where there is no alternative to laying sewers on beams supported either on piles, piers or walls the loads will be considerably higher than usual due to subsequent differential settlement of the fill. It will usually be necessary to support pipes with reinforced concrete bedding or surround designed as a beam to carry the sum of the highest possible loads over the spans between supports. A flat-top T-beam should not be used without the addition of pipe bedding.

If differential settlement of the supports is possible, flexible joints in the sewer, extending through all concrete work, should be formed over the edges of each support.

10.6.4 *Mining subsidence.* Undermined ground is displaced downwards and simultaneously inwards towards the centre of the subsided area. The damage caused by ground movement depends partly on the vertical component of displacement and partly on the horizontal component. The vertical component, resulting in lowering of the ground, causes differential subsidence or tilt. Its effect on sewers may be to increase or decrease their gradients by up to 1 in 50 in extreme cases. A more typical change of gradient might be about 1 in 400.

The horizontal component resulting in change of length (strain) accounts for most of the damage to sewers. Such strain may amount to 0.8 % or 1 % in exceptional cases over shallow workings, but is commonly 0.25 % or less. It may be compressive or tensile. The intensity of ground strain varies from point to point and may range from zero through maxima of compression and tension and back to zero in only a hundred metres. The amounts of strain likely to occur at various points on a given site can nevertheless be predicted with reasonable accuracy.

Every site needs to be considered separately and for advice on the precautionary measures to be adopted, it is advisable to consult the Area Surveyor of British Coal in the case of coal mining, and the company responsible in the case of other minerals.

Government departments and local authorities can obtain advice from the mineral valuers of the Inland Revenue.

11 Manholes

11.1 General

11.1.1 *Structural design of manholes.* Manholes and other pipeline structures should be designed to carry the worst combination of superimposed and ground loading. Foundations should be designed to carry all the imposed loads. The chamber walls and base should be designed to take into account also any lateral loading and/or hydrostatic upthrust.

11.1.2 *Spacing of manholes on sewers not more than* 1.0 m *in diameter.* As smaller sewers cannot easily be entered for cleaning or inspection a manhole should be built at every change of alignment or gradient, at the head of all sewers or branches, at every junction of two or more sewers, and wherever there is a change in size of sewer. In exceptional difficulties in routeing, to accommodate angles less than 15° a slow bend may be sited on the sewer immediately upstream of a manhole. Manholes should not be positioned further apart than 100 m, beyond which it is not practicable to use drain rods or some form of pipe scraper. However, where high pressure jetting equipment is used for maintenance, and other circumstances are favourable, this maximum can be increased to 150 m or 180 m.

11.1.3 *Spacing of manholes on sewers more than* 1.0 m *in diameter.* Where a man can enter a sewer for inspection it is not necessary to have a manhole at every change in alignment. Where the sewer is curved in plan the manhole should preferably be located in such a manner that visual inspection of the sewer is possible between manholes, even if this leads to a manhole being built on the curved sewer. Manholes should be placed at every significant change in gradient or size of the sewer, and at major junctions.

The spacing of manholes on large sewers should be governed by the following:

(a) the distance which silt or other obstruction may have to be conveyed along the sewer to the nearest manhole for removal;

(b) the distance which materials for repairs can be conveyed through the sewer;

(c) ventilation requirements for men working in the sewer.

In general a spacing of 180 m to 200 m on straight runs is a suitable figure, although on sewers of 1.8 m diameter and over, laid in heading or tunnel, this could be increased to distances up to 300 m. Due consideration should always be given to ventilation and the safety of men working in the sewer.

The use of breathing apparatus may be necessary in any sewer and the working range of breathing apparatus should be taken into account. When breathing apparatus is necessary for access into a sewer, manhole spacings over 200 m are undesirable.

11.2 Types of manhole

11.2.1 *General.* At a change in diameter of sewers, and where conditions permit, the soffits or crowns of the two sewers should be at the same level.

11.2.2 *Straight-through manholes.* The simplest type of manhole is that built on a straight run of sewer with no side junctions.

11.2.3 *Junction manholes.* A manhole should be built at every junction of two or more sewers, and the curved portions of the inverts of tributary sewers should be, wherever possible, within the manhole. To achieve this with the best economy of space, the chamber may be built either rectangular or circular. To avoid surcharging of a connecting sewer, its soffit should be at the same level as that of the main sewer, wherever conditions permit. However, this may restrict the gradient of the connecting sewer and prove to be uneconomical. The flow from branch connections should merge with the main flow at the smallest angle practicable. To achieve this, bends may be necessary.

11.2.4 *Side-entrance methods.* In large sewers, or where owing to the existing services, gas, water, etc., it is difficult to obtain direct vertical access to the sewer from ground level, the access shaft should be constructed in the nearest convenient position off the line of the sewer, and connected to the manhole chamber by a lateral passage.

In tunnelled sewers the shaft and lateral passage may be used as a working shaft, the tunnel being broken out from the end of the heading; alternatively the shaft and passage may be constructed after the main tunnel is complete, provision having been made in the tunnel lining for breaking-in from the access passage.

The floor of the side-entrance passage should fall at about 1 in 30 towards the sewer and should enter the chamber not lower than the soffit level of the sewer. In large sewers where the floor of the side-entrance passage is above the soffit, either steps or a ladder should be provided to reach the benching. A removable handrail or safety chains should be provided for the protection of the user.

11.2.5 *Deep manholes.* Deep manholes should be provided with rest chambers, or platforms not more than 6 m apart vertically. Access openings in successive landings should preferably be staggered to limit the height of an accidental fall from the access ladder but separate openings should be provided, suitably protected by trap doors directly below each other for the movement of materials and tools.

The landings and platforms and access openings should be of adequate size to accommodate at least two men with safety harness; and to minimize the risk of falling they should be provided with handrails where possible.

11.2.6 *Backdrop manholes*

11.2.6.1 *General.* Where a sewer connects with another sewer at a significantly lower level, a manhole may be built on the lower sewer incorporating a vertical or nearly vertical drop pipe from the higher sewer to the lower one. This pipe may be outside the chamber and encased in concrete, or supported inside the chamber, which should be suitably enlarged. Access should be provided to the higher sewer and to the vertical drop pipe for men to inspect and to maintain the sewer. If the drop pipe is outside, a continuation of the sewer should be built through the chamber wall and the vertical drop pipe continued up to an access cover at ground level, and encased in concrete. If the drop pipe is inside, it should have adequate and accessible means for rodding. The diameter of the backdrop should be more than sufficient to discharge the maximum flow from the incoming pipe.

11.2.6.2 *Small sewers (about* DN 300 *or less).* The backdrop on small sewers pipe should terminate at its lower end with a plain or rest bend turned so as to discharge its flow at 45° or less to the direction of the flow in the main sewer. An external pipe should be surrounded with 150 mm of concrete.

Where the difference in level is less than 1.8 m a ramp is often preferable; a rodding eye should be provided as for a backdrop.

Backdrop manholes may be avoided by constructing the sewer between two manholes at the steepest gradient compatible with laying and bedding of the pipes.

11.2.6.3 *Larger sewers and deep drops.* Backdrops on larger sewers should incorporate some form of water cushion to dissipate energy. A method of doing this is to discharge below the water level into a stilling bay of adequate capacity controlled by a weir.

In the case of sewers over 450 mm in diameter the drop in level may be accomplished by one of the following methods.

(a) *A ramp.* A ramp formed by gradually increasing the grade of the last length of the upper sewer to about 45°, or by constructing a similarly graded channel or culvert leading from the high level to the low level sewer. A water cushion at the foot of the ramp is desirable.

(b) *A cascade.* A cascade (a steep ramp composed of steps) over which the flow is broken up. A pipe connecting over the two levels is often concreted-in under the steps to allow small flows to pass without trickling over the steps.

In cascades and ramps, adequate headroom, steps, handrails and chains should be provided for the safety of operatives.

11.2.6.4 *Vortex backdrops.* For high volume flows, vortex backdrops can be useful but the design is complex and specialized. The inlet to the drop shaft takes the form of a vortex chamber. Spin is imparted in the stream entering the chamber, and a rotational eddy is set up. The design requires that there be a continuous air core down the drop shaft.

The establishment of the geometrical properties of the throats and lips of the vortices is thus an essential part of the calculations for this type of backdrop manhole. The vortex chamber requires very precise design and construction; the noise which can stem from a vortex needs to be considered, particularly in built up areas.

11.2.7 *Hydrogen sulphide in manholes.* Hydrogen sulphide will be released from sewage at points of high turbulence, e.g. backdrops. Adequate ventilation should be provided and the materials of construction chosen with care.

11.2.8 *Dual and crossing manholes.* Where surface-water and foul sewers are laid in the same trench, the surface-water sewer is often laid at a higher level than the foul sewer. A manhole can be built to give access to both sewers by normal construction on the foul sewer, the surface-water being carried through the chamber in a pipe. The same type of construction can be used for two independent sewers which cross each other at an angle. A bolted inspection cover should be provided on the higher pipe.

11.2.9 *Catchpits.* Catchpits are chambers on surface water sewers installed to retain silt and constructed as manholes but without benchings. A floor level below the lowest pipe invert is used to form a sump, which will require periodic cleaning.

11.2.10 *Lampholes.* Lampholes are needed only in exceptional circumstances where larger access is impracticable. If they are necessary they should be constructed with a vertical pipe, usually DN 225, from the sewer to ground level. The cover and frame should be bedded on a concrete slab arranged for example by use of sleeving, so that traffic loads on the cover are not transmitted to the vertical pipe and thus avoid the risk of the shaft being pushed into the sewer.

11.3 Detailed design of manholes

11.3.1 *General.* Where practicable, the invert should be of the same material as the sewer. Where this is not practicable, preformed channels of other materials or concrete with a granolithic finish may be used. Pipes should be built into manholes as construction proceeds.

The benching should rise vertically from the springing to at least the height of the soffit of the sewer, where it should turn over with a nosing of about 25 mm radius and rise at a gradient of about 1 in 30 to the water of the chamber. In shallow manholes it may be desirable to decrease the level of the benching to not less than half pipe height in order to give more adequate headroom. For pipes up to DN 450, benchings should be provided on each side of the sewer.

All manholes on sewers of DN 600 diameter and over should be provided with a safety chain or bar for placing across the mouth of the outgoing sewer when men are at work. Handrails should be provided on the edges of benchings, and at platforms, etc., from which a man might fall into the sewer.

If a manhole is in agricultural land, the chamber walls (in shallow manholes) or shaft walls (in deep manholes) should, if possible, be built up to about 0.6 m above natural ground surface and mounded on all sides with earth. Alternatively, the chamber may be covered with a concrete slab, the top of which should be at least 600 mm below ground level.

The burying of manhole covers should be avoided if possible, especially at changes of direction. For buried covers, careful reference measurements need to be made to some fixed points to enable them to be located quickly and accurately. They should be sited, if possible, near to hedges or other boundaries of fields.

Below the groundwater table special precautions should be taken to minimize infiltration, especially where a concrete surround is not otherwise required.

11.3.2 *Sizes of manholes*

11.3.2.1 *Sizes of chamber for shallow manholes (i.e. without a shaft).* The minimum size of chamber in which a man can work efficiently and safely is 1.2 m on the line of the sewer and 0.75 m across, and for circular chambers 1.05 m diameter. For practical purposes the size of masonry rectangular chambers should be increased to avoid the undue cutting of bricks.

For very shallow manholes on sewers of less than DN 500 where there is less than 1.0 m headroom above the benching, maintenance from within the chamber will be impracticable. A length of at least 900 mm in the direction of the main sewer and a width sufficient for a 230 mm wide benching on each side should suffice to enable a man to work from the ground surface or partly within the manhole.

11.3.2.2 *Sizes of chambers for deep manholes (i.e. with a shaft).* The dimensions of a deep manhole will depend on the size and depth of the sewer; the chamber should preferably be large enough to provide a benching or landing of sufficient size to accommodate two men.

The width of the chamber should be such as to allow benchings at least 230 mm wide on each side of the channel and wherever possible there should be not less than 2 m of clear headroom above the benching. In manholes on sewers of DN 500 and over, one benching should be wide enough for a man to stand on, i.e. at least 400 mm.

If the sewer is constructed in a heading or tunnel, the manholes will often be located at the access or working shafts, and the manhole chamber may then be constructed of a size to suit the working shaft, or vice versa.

11.3.2.3 *Sizes of shafts and entries.* In determining sizes, regard should be paid to the dimensions of the maintenance plant likely to be used in the sewers. The minimum size of rectangular access shafts should be not less than 900 mm × 840 mm. Access shafts of circular section should be not less than 900 mm diameter where ladder access is provided. Where sufficiently small breathing apparatus will be used, 675 mm diameter access shafts with step irons are permissible for manholes on sewers less than 1.0 m in diameter.

Manhole covers should have a minimum clear opening dimension of 600 mm for sewers less than 1.0 m diameter, except for very shallow manholes where this dimension may be 550 mm. Manhole covers on sewers 1.0 m diameter or greater should have a 600 mm × 600 mm clear opening with a minimum diagonal dimension of 700 mm.

11.3.3 *Manhole access.* Step irons should be built into brickwork or be cast into concrete. They should be uniformly spaced vertically and horizontally at a maximum of 300 mm centres measured from the face of the manhole, and should be staggered. Brick access shafts may be provided with corner type step irons instead of the general purpose type.

Ladders can be used with any form of construction and are easier to remove when necessary. Lightweight removable ladders may be used on manholes less than 5 m in depth where they can easily be inserted and secured from the surface. This practice may be used to deter unauthorized access to the sewer.

Fixed ladders should be used in preference to step irons, especially for depths over 3.5 m, because they are easier to use when wearing heavy boots. Ladders should not rise more than 6 m without provision of an intermediate platform, which should preferably break the line of the ladder. Adequate clearance should be provided around the ladder to ensure safety in use. Clearances at the back of any rung should be not less than 225 mm to allow for foot room; and on the user's side of the ladder this should be not less than 650 mm. Stringers should be adequately supported from the manhole wall at intervals of not more than 3 m. They should not be built into the wall but bolted to built-in cleats to facilitate renewal.

It should be possible to reach the top rung of a ladder or the top step iron with the feet when sitting on the edge of the opening in the frame. Thus the top rung or step iron should be within 450 mm of the top of the frame. For shafts of 900 mm diameter or greater, and where 550 mm or 600 mm clear opening covers are used they should be positioned so that the edge of the opening in the frame is vertically above the top rung of the ladder or the front edge of the step iron.

The access shaft of a manhole in a road should be brought up to a suitable level to allow a manhole cover and frame to be bedded at road level. A maximum of three courses of regulating engineering brickwork or precast concrete manhole cover sealing rings may be used. The frame for the cover should be carefully set to road level in cement mortar, or proprietary quick setting resin mortar, care being taken to set the frame to fit the camber of the road. The reduction from the dimensions of the chamber to those of the shaft should not be in the road construction depth.

Where larger covers are used it will not be possible to enter the manhole safely without one or more handholds. These may be in the form of bars built into the sides of the shaft beneath the cover frame or formed in the frame itself; where a ladder is used these may form an extension to the top of the ladder.

11.3.4 *Brick manholes.* Brick manholes (chambers and shafts) should be built in English bond with engineering bricks or Special Purpose concrete bricks; where pressed bricks with a shallow frog may be used, these should be laid with the frog uppermost. To ensure watertightness, horizontal and vertical joints should be well filled and flush pointed before the mortar for the next course is spread.

Brick relieving arches should be turned over pipes DN 300 or larger where they pass through the chamber walls, the arches being turned on properly formed centres in separate rings. Alternatively a reinforced concrete lintel may be used.

Chambers should be covered by one of the following methods.

(a) By means of a concrete slab reinforced to carry the weight of the ground above and all probable superimposed loads. An in situ slab should be not less than 150 mm thick. Alternatively precast slabs may be used.

(b) By a brick arch turned over the chamber in one direction; in the other direction the brickwork may be corbelled inwards, or a concrete lintel may be used.

(c) In large manholes, brick arches at different levels and in both directions may be used to effect the reduction in size.

At the top of an access shaft, brickwork should be corbelled on three sides (two sides only where corner step irons are used) to reduce it to the size of the opening in the cover frame, and such as to provide easy access on one side to the step irons or ladder.

Where necessary, the cover frame should be bedded on brickwork, in which adjustment to correct road or surface level can be made.

11.3.5 *In situ concrete manholes.* The general dimensions and requirements for in situ concrete manholes are similar to those of brick manholes. The construction should be in accordance with the recommendations of BS 8110.

11.3.6 *Precast concrete manholes.* Precast concrete sections are available by means of which 150 mm adjustments may be made to the depths of chambers and shafts. Manholes of precast units can be rapidly constructed. Precast base units with or without benching are also available. Joints between chambers, taper and shaft units are usually rebated, ogee or tongued and grooved and these may be sealed with cement mortar or a proprietary mastic. In the latter case, precautions may be required to prevent tilting of the units. There are systems available for rubber ring joints between units and between pipes and units, but these are not in common use. Below the groundwater level, a proprietary mastic or a double seal manhole joint in cement mortar may be used. It is essential to ensure that the first unit is truly vertical, and if the joint is of the rebated or ogee type, be laid with its spigot upwards; if the joint is of the tongued and grooved type the socket should face upwards. A taper unit or reducing slab is used to reduce the chamber diameter to that of the access shaft with its cover slab. To bring the cover to the finished level a maximum of three courses of engineering brickwork or precast concrete manhole cover rings may be used; these should be set in cement mortar consisting of 1 part cement to 3 parts sand.

Tapers or reducing slabs should not be used until a 2 m height of full size chamber has been constructed above the benching level. In these cases a shallow manhole should be constructed with a cover slab placed directly on the chamber units. In deep manholes, rest platforms may be formed by inserting a cover slab, which may be suitably modified, within the chamber. Cover and reducing slabs and rest platforms may be bedded directly into chamber and shaft units, without the need to form a flat top or bottom joint. Jointing materials are described above.

Side entry manholes are available for use on pipes of 1200 mm diameter and above. They should be provided with a minimum 150 mm surround of 20 N/mm^2 concrete, extending the full length of the main pipe including the side entry.

Concrete surrounds to circular manholes are not normally necessary but they may be required to provide stability in made or otherwise unstable ground. In certain applications it may be deemed more satisfactory to use a lean mix concrete as a backfill material where compaction would be difficult or impossible. Segmental manholes, especially those sunk as caissons, should be provided with grout holes so that voids may be filled.

Box culvert units are also manufactured to be installed vertically as manholes, complete with step irons as required. Joints are rebated and sealed with either cement mortar or a proprietary mastic. Cover slabs may be provided in precast or in situ concrete.

Special precautions should be taken where there is a possibility of the soil or ground water having a deleterious effect on Portland cement (see BS 12).

11.3.7 *Manholes of other materials.* Where the linings of shafts sunk for access to tunnelled sewers are of a permanent nature these may be used as manholes. When the lining is of segments of concrete or cast iron these may form the manhole walls without a further lining. In certain conditions of corrosive ground, groundwaters and effluents, it may be desirable to construct manholes using non-corrodible materials such as PE, unplasticized PVC and GRP. Where these materials are being considered, the manufacturer's advice should be sought regarding structural stability and chemical resistance properties.

Section four. Construction

12 Construction of sewers (see also BS 8004 and [21]

12.1 Setting out sewers in trench

The centreline and top width of trench should be accurately set out, marked and referenced.

Temporary bench marks should be established in stable positions where they are unlikely to be disturbed. The transference of levels by straightedge and spirit level is not recommended and should be avoided where possible.

On flat gradients the work should be set out and frequently checked by instrument.

When sight rails are used, they should be strong, planed true, painted in contrasting colours and fixed on rigid posts. As a check on accidental displacement of a sight rail, at least three rails should be provided on each gradient, placed at intervals to allow easy viewing from one to another. The centreline of the sewer, or its offset, should be indicated on the sight rail and the height of the rail from the invert level of the sewer should be a simple dimension (e.g. 2 m, 2.25 m, 3 m).

The lengths of travellers used between sight rails should be checked at frequent intervals. Travellers should have projections to rest on inverts.

The use of lasers, which can be set up either in the pipe or in or over the top of manholes, leads to greater speed and accuracy of laying. Care should be taken that the target is placed accurately in relation to the true invert, especially in large diameter pipes. The setting up of the laser should be checked regularly during construction [22].

12.2 Excavation

The nature of the ground as revealed by the site investigation, the depth of the trench, and the avoidance of damage to existing (or proposed) structures or underground works, will determine the choice of the method of excavation and the type and strength of support required to the trench sides during construction.

Excavation in rock may require the use of explosives. Rock is usually self supporting, but silts, all granular materials, peat, marshy ground and made ground will require close sheeting and ample bracing. Stiff clays, cemented sands and gravels and marls are relatively stable under dry conditions, but where necessary adequate trench support should be provided to ensure stability and safety. Care should be taken in all types of ground under wet conditions and where there is a high water table. Steel is generally to be preferred for close sheeting. The depth of any penetration of sheeting below the bottom of the excavation will be determined by consideration and special precautions may be needed against boils and blows (see BS 6031 and BS 8004).

Supports should be designed so as to permit progressive withdrawal as the backfill is placed, and the spacing of struts and walings should suit the individual lengths of the pipes to be laid. Under suitable conditions, use may be made of drag-boxes, trench shields or unit box systems of support made of metal or GRP. These provide protection to the pipelaying and backfill processes and are either dragged or leap-frogged along the trench line as the work progresses; they may not prevent lateral ground movement and consequent damage. With mechanical excavations in any soil requiring support, whether the trench is close sheeted or not, the cross bracing should be placed progressively as close to the excavating machine as possible. Where ground conditions permit, trench support should not extend below the top of the pipe bedding to avoid disturbance of the bedding during removal.

In bad ground above the permanent water level, timber may rot, and when it is known that the support needs to be left in, the use of steel or reinforced concrete is preferable. Trench supports left in, which cross the sewer either above or below the pipes, need to be kept well clear of the pipes otherwise they may constitute hard spots and cause fracture of the pipes.

The interruption of buried services is undesirable and may be dangerous. Every effort should be made to locate these accurately through the statutory undertakers or local authority before commencing excavation. Trial pits to confirm locations should be hand dug. All pipes, ducts, cables, mains or other services exposed in the trench should be effectively supported, or diverted if necessary. Attention needs to be paid to the temporary and permanent support of these services to avoid subsequent damage. Care should also be taken to minimize ground movement which may damage services alongside the trench.

12.3 Ground stabilization

Under certain conditions where trenching would be extremely expensive or impossible, tunnelling methods may be preferable (see BS 8005 : Part 3*). Alternatively, consolidation of the strata may be undertaken prior to the excavation and this can be done by injecting chemicals to produce a gel, by freezing, or by injection of suitable stabilizing agents, e.g. cement. The choice of method and the material is a matter for specialist knowledge. The cost of such methods may be justified where essential work could otherwise be inhibited by soil conditions, or by the presence of existing structures (see BS 6031).

12.4 Dewatering

Where the proposed excavation formation level is below the groundwater table and the grading of the surrounding ground is suitable, it may be desirable to lower the groundwater table locally by pumping during the period of the excavation. The pumping out of water can also carry with it fine material in suspension. This may cause subsidence of existing structures by loss of fines or water or both and it should be carried out under expert advice. Dewatering is usually only possible in soils coarser than silt (i.e. 0.06 mm) with less than 10 % passing a 75 μm sieve. Exceptionally, some coarse silts (0.02 mm) may dewater.

Dewatering may be carried out:

(a) by pumping from a series of well points sunk adjacent to the line of the excavation;

(b) by pre-laying a perforated horizontal disposable tube in the most suitable permeable stratum adjacent

* In preparation.

to the proposed excavation; pumps are then connected to vertical risers placed at suitable intervals;

(c) by installing a number of deep wells; these can be at greater intervals than well points.

In the first case, tubes approximately 50 mm to 70 mm diameter with perforated metal tips are inserted into the ground by hand by jetting (pumping water down the tubes); each is then coupled to a header tube leading to a vacuum lift pump capable of lifting water from 6 m to 7 m. The vertical tubes may be disposable.

Horizontal tubing, usually of ribbed plastics and covered with a filter sleeve, is inserted into the ground by a self-propelled trenching machine. At intervals to suit the permeability of the strata and the pumping capacity, a non-perforated riser is brought to the surface for connection to a vacuum lift pump.

Deep wells should be formed by drilling and installing a perforated tube some 250 mm to 300 mm diameter to a depth considerably below trench formation level. Suitable filters are essential to prevent excessive removal of fines and may consist of sleeves or graded stone within the bore. At the bottom of the well a pump should be installed capable of lifting water from a greater depth than would a vacuum type pump.

12.5 Preparation of trench

Uniformity of support for a sewer is essential and the trench bottom should be carefully trimmed to the required depth and gradient to provide the proper formation level. A soft or uneven formation should be removed to an economical depth and the resulting cavity refilled with a material which will give uniform support. If rock is encountered at formation level, this may also have to be removed and similarly replaced, except where concrete bedding is to be provided.

Where dewatering is necessary and where this can be effected by the use of sub-drains, these should be constructed below formation level and covered with gravel or broken stone up to formation level. Sub-drains can be laid at one or both sides of the trench discharging to pump sumps clear of the trench line. Where possible sub-drains should be grouted up after pipelaying is complete. Where the flow of water is too great to be dealt with by means of sub-drains, other methods should be considered (see 12.4). (Reference should also be made to BS 6031 and BS 8004.)

12.6 Pipe laying and jointing

12.6.1 *Handling and storage.* Pipes are prone to damage in transit and should be examined on delivery for defects liable to affect jointing, anti-corrosive properties and strength. Damaged pipes should be rejected. Pipes should be handled carefully with suitable equipment.

Where pipes are to be stacked, they should be arranged so that the sockets and spigots are not loaded and excessive loads are not carried by pipes lower in the stack.

Rubber joint rings should be stored in an unstressed condition away from sunlight, oils and sources of ozone such as fluorescent lights and electric motors.

12.6.2 *Inspection of pipes preparatory to laying.* All pipes, fittings and rubber joint rings and preformed mastic seals should be carefully inspected prior to use, special attention being paid to joint surfaces, grade of mastic seal and protective coatings and linings.

12.6.3 *Pipe laying: general.* Pipe laying should start at the downstream end, the pipes being normally laid with the sockets upstream.

12.6.4 *Laying pipes on trench as formation.* Where the design permits and if the nature of the ground is such as to allow it to be trimmed to provide a uniform bearing, rigid pipes may be laid on the trench formation. Socket holes should be as short as practicable and should be scraped or cut in the formation, deep enough to give a minimum clearance of 50 mm between the socket and the formation.

If the formation has been over-excavated and does not provide continuous support, low areas should be brought up to the correct level by placing and compacting suitable material.

After the formation has been prepared, the pipes should be laid upon it true to line and level within the specified tolerances. This should be checked for each pipe, and any necessary adjustments to level should be made by raising or lowering the formation, always ensuring that the pipes finally rest evenly on the adjusted formation throughout the length of the barrels. Adjustment should never be made by local packing.

12.6.5 *Laying pipes on granular bed.* The trench should be excavated to a depth such as to allow the specified thickness of granular bedding material to be placed beneath the units. Any mud should be removed and soft spots either removed or hardened by tamping in gravel or broken stones. Rock projections, boulders or other hard spots should also be removed.

In soft clay, disturbance of the trench bottom should be minimized by placing a layer of blinding material about 75 mm thick. Such precautions may also be necessary in bad weather and for wet ground conditions.

Granular bedding material should be placed to the correct level and should extend to the full width of the trench. Socket holes should be formed at each joint position. These need to be deep enough to prevent the weight of the pipe and the load upon it bearing on the socket or coupling and should be a minimum of 50 mm deep leaving 50 mm of granular bedding material beneath the joint. Bedding material should not be compacted in these socket holes. Care needs to be taken not to allow bedding material to enter the joint and become trapped during jointing. In the case of box culverts this may be achieved by placing strips of hardboard or similar material under each joint prior to jointing.

Pipes should be laid directly on the granular bed and should then be adjusted to correct line and level within the specified tolerances, i.e. the pipe invert levels should be constructed to a tolerance of ± 20 mm subject to the proviso that the pipe gradient should not be less than 90 % of that required in the design. Sidefill of either granular material or selected backfill material, depending upon the bedding specified, should be placed and compacted evenly on either side of the pipe taking care not to disturb the line and level. For box culverts the granular bedding (minimum depth 200 mm) has to be prepared to the correct line and level as subsequent adjustment is not practicable. A thin blinding layer of fine material may be provided so that disturbance of the bedding material is minimized during jointing. It is important to ensure compaction of the bedding to a density corresponding to the natural trench bottom.

Measures to prevent migration of fine material from pipe bedding should be undertaken where the pipeline is below groundwater level.

12.6.6 *Laying pipes with concrete bed, bed and haunch, or surround.* Where in situ concrete bedding is required, the trench bottom should be prepared to give a firm foundation as described in 12.5, using a blinding layer if necessary. The level of this formation should allow for a depth of concrete under the pipe barrel of 0.25 D, where D is the nominal pipe bore, or 100 mm, whichever is the greater. The pipes should be supported clear of the trench bottom by means of blocks or cradles placed under the pipes immediately behind each socket and just clear of each spigot, or at both sides of the sleeve, where sleeve joints are used.

The blocks should extend the full depth of the bedding which should be cast monolithically. Free standing blocks may be used if they are of a suitable size which will not tilt or rock when pipes are added to the line. A minimum layer of compressible material should be placed between the support and the pipe to permit the barrel of the pipe to rest uniformly on its bed after normal setting shrinkage of the concrete has occurred. Expanded polystyrene or impregnated fibre building board are suitable for this purpose.

The concrete bed should extend equally on each side of the pipe to a width of 1.25 B_c or B_c + 200 mm, whichever is the greater, where B_c is the outside diameter of pipe barrel, and should not be placed until the pipework has been inspected and deemed satisfactory.

Where flexible joints are employed, the overall flexibility of the pipeline should be maintained by the provision of flexible joints in the concrete. These should be formed through the full cross section of the concrete by providing compressible materials at least 20 mm thick (or that required to ensure the flexibility of the pipe joint), such as expanded polystyrene or impregnated fibre building board, at the face of each pipe socket or at one face of each sleeve. This is to ensure that any subsequent flexing occurs only at a pipe joint.

Care should be taken as follows:

(a) in the placing of concrete, that the pipes or lateral construction joints are not displaced and flexibility of the joint is not impaired; and

(b) to avoid excessive shear loads developing at joints, especially immediately below road surfaces.

For box culverts the trench bottom should be formed to an approximately uniform load and compaction and a flat apron of non-structural concrete at least 75 mm thick cast on, on which the inverts are laid and given uniform support. If a thicker apron or reinforced concrete slab is used, special measures should be taken to ensure uniformity of support.

12.7 Jointing pipes

12.7.1 *Flexible joints.* The pipe manufacturer's instructions regarding the making of the joints should be followed closely. Only sliding ring joints should be lubricated, using the lubricants recommended by the manufacturers. The correct sealing rings should be used in jointing; if the rings are supplied separately from the pipes, care should be taken not to mix up different sizes.

Most types of flexible joint can be made in wet conditions, but it is preferable not to attempt jointing when the pipes are under water. The jointing faces and sealing rings should be clean and free from oil, grease, tar, mud or sand particles, prior to placing the joint ring on the spigot or in the socket or collar as specified.

When joints cannot be made manually, mechanical pulling devices should be used. Any disturbance of the pipe bed should be minimized, and made good. The specified gap should be left between the end of the spigot and the shoulder of the next pipe to permit movement. With some rolling-ring types of joint there is a tendency for the ring to unroll and with small pipes, unless the pipe is temporarily held in the trench, to force the spigot of the last pipe laid out of the socket in which it is engaged. With rolling-ring joints the pipe being laid should not have its axis inclined to that of the pipe to which it is being joined, during the pulling-in of the joint.

Box culvert joints are usually made with a preformed mastic seal. The joint seals have to be prepared with a primer which first has to dry. The mastic seal which is supplied either in strips or a roll is then applied to the socket, ensuring full continuity at the joints. Box culverts may be supplied with a caulking groove for secondary sealing or to provide a smooth joint.

12.7.2 *Rigid joints.* While flexible joints are quicker to make and preferred, the older traditional rigid joints are still available with some pipe materials and for joining dissimilar pipes. Care should be taken to ensure that where they are used this is consistent with the overall design of the pipeline. If it is necessary to make the occasional rigid joint in a flexibly jointed pipeline, the rigid jointed section should be kept as short as possible.

Cement mortar for joints should not be richer than 1 part cement to 2 parts sand and preferably in a ratio of 1:3. The ends of the pipes should be wetted immediately before jointing and the joints kept damp and protected from the sun and wind until covered by the initial backfill. The interior of the pipe should be examined as each joint is made and any intrusions of mortar or gaskin removed before further pipes are laid.

Concrete pipes with ogee or rebated joints are normally jointed with mortar but they cannot usually be made completely watertight by this means alone.

Rigid solvent-cement joints and welded joints are available for certain unplasticized PVC and ABS pipes. Rigid fusion-welded joints are available for polyethylene pipes.

12.8 Ancillary items

12.8.1 *Junctions.* Junctions should be inserted at intervals as required for present or future connections, during the construction of the sewers. All junctions which are not immediately connected to laterals should be closed with durable purpose-made watertight caps. The position of each junction should be carefully measured and recorded in a junction book and on the plan of the works.

When in situ junction connections are required the main pipe should be cut and a junction arm in the form of a purpose-made saddle attached. A concrete surround to an in situ junction is necessary and should finish at the joint of the junction arm. Only purpose-made saddles are recommended and there should be no protrusion of the junction pipe into the main pipe. The diameter of the saddle connection should be normally at least one size less than the diameter of the sewer.

12.8.2 *Gullies.* Gullies should be set vertically and to the correct level; when necessary they should be surrounded in concrete, care being taken to prevent flotation.

12.9 Backfilling

12.9.1 *General.* Care and attention should always be given to the placing and compaction of backfill, particularly where it forms part of a load-supporting system, e.g. under roads.

12.9.2 *Sidefill and initial backfill.*

12.9.2.1 *Rigid pipes.* As soon as possible after completion of the bedding or surround, selected fill should be placed by hand and carefully compacted between the pipes and trench sides and brought up in 150 mm to 250 mm layers to at least 150 mm of compacted material above the pipe crown, taking care to avoid uneven loading and damage to the pipe.

Where mortar joints or concrete beddings are used, sufficient time should be allowed for them to gain strength to avoid damage during the backfilling operation.

12.9.2.2 *Flexible pipes.* The sidefill for flexible pipes other than ductile iron should be of the same granular material as that used for bedding (see 5.5). It should be taken to at least the level of the pipe crown and be carefully compacted. (The load carrying capacity of the pipes depends very largely on the compaction of the sidefill to provide the resistance to lateral deformation.) Selected backfill should then be placed and carefully compacted in layers to give at least one 150 mm layer above the pipe crown.

In most cases, for ductile iron pipes, tamped excavated natural material from the trench will be suitable for backfill. In instances of excessive depths, high vehicular loading or super loading from buildings, etc., or very poor soil properties it may be necessary to bring in a graded granular backfill.

12.9.3 *Main backfill.* The main backfill may be started after the initial backfill has been placed and when any concrete bedding or surround has achieved an initial crushing strength of at least 14 N/mm^2.

When practicable and safe to do so, trench supports should be removed as the filling proceeds. Particular consideration may need to be given where, for safety and stability, sheet piles or modular box supports have to remain until backfilling is substantially completed.

Backfill should be built up in even layers not exceeding 300 mm, each layer being thoroughly compacted before further fill is added. Guidance on the selection of compacting equipment, with techniques and appropriate layer thicknesses for various types of soil is given in BS 6031. The aim is to compact the fill as nearly as possible to the same density and moisture content as that of the undisturbed soil in the trench sides, but this is rarely achieved in practice and some subsequent settlement usually occurs. The compacting equipment should be such as to ensure that the pipes are not overloaded during the filling.

The use of concrete as backfill under roads can be damaging both to the pipe and the road, particularly in clay soils.

12.9.4 *Backfilling around manholes.* The method of backfilling and compacting around manholes should be generally as for trenches. Care should be taken to raise the fill equally all round the manhole shaft to avoid unbalanced lateral loading. Care is also necessary in placing the fill around free-standing manhole shafts which have been constructed in advance of an embankment (e.g. in a valley which is to be filled in subsequently); end-tipping of the fill in the vicinity of the manhole should be avoided. Where there is a structural risk, precast concrete manholes should be surrounded with concrete 150 mm or more thick, possibly reinforced, depending on the loading conditions.

12.10 Trenchless construction

Trenchless construction is any means of constructing new, or rehabilitating existing pipes underground without excavating an open trench. It includes renovation and the existing and imminent new techniques in that field are described in the 'Sewerage rehabilitation manual' [1]. There are a number of other techniques available for trenchless construction and most of these are described in the Conference Papers for No-Dig 85, First International Conference and Exhibition on Trenchless Construction for Utilities, organized by the Institution of Public Health Engineers and held on 16-18 April 1985 [30]. In addition the WRc has completed two studies of trenchless construction. The first, a review of current methods and development needs; the second, a detailed comparative study of the economics of the methods. Reports on these studies are available from WRc Engineering, Swindon. Further work is proceeding in conjunction with CIRIA and the results will be published in due course.

Section five. Testing and surveying

13 Testing of sewers

13.1 General

Sewers should be tested and inspected for infiltration and exfiltration to acceptable limits.

Initial testing should be applied before any sidefill is placed. This will facilitate replacement of any faulty pipes or joints revealed by the test. Testing after placing backfill will reveal any leakage due to subsequent damage or the displacement of joints.

For the final acceptance test the line should be tested from manhole to manhole. Any short branches may be tested concurrently with the main line but branches over approximately 10 m long should be tested separately.

13.2 Choice of test method

There are two test methods which are relatively simple and technically acceptable; these are based on the loss of either water or air.

As sewers are designed to carry liquids, the water test is to be preferred, but under site conditions an air test is usually quicker and more economical.

13.3 Air test

13.3.1 *General.* The air test is easier to carry out than the water test and does not have the problem of providing and disposing of large quantities of water. It provides a rapid test which can be carried out after every third or fourth pipe is laid. This should prevent a faulty pipe or a badly made joint passing unnoticed until it is revealed by a test on a completed length. To replace a faulty pipe or remake a joint in the middle of a pipe run is a time consuming and costly operation. A smoke test can indicate the location of a failure.

13.3.2 *Procedure.* The following test procedure should be adopted.

(a) Seal the ends of the pipe and any junction pipes. Note that pipelines should not be left with plugs in where there is a risk of the trench filling with water before it is backfilled, or flotation may occur.

(b) Attach a U-tube (manometer) and a means of applying the air pressure to one of the plugs.

(c) Apply pressure either by mouth or by a hand pump to achieve a pressure slightly more than 100 mm of water in the U-tube.

(d) Allow about 5 min for stabilization of air temperature.

(e) Adjust air pressure to 100 mm of water.

Without further pumping, the head of water should not fall by more than 25 mm in a period of 5 min.

13.3.3 *Factors affecting the test.* There are several possible contributing factors that could affect the apparent failure of the air test. These include the following:

(a) temperature changes of the air in the pipe due to direct sunshine or cold wind acting on the pipe barrel;

(b) dryness of the pipe wall;

(c) leaking plugs or other apparatus.

If there is a dramatic fall in pressure then either the pipeline is faulty or the end plugs or other apparatus are leaking. If the failure is marginal the pipeline should not be condemned on the air test alone and the contractor should be given the opportunity of applying a water test.

It should be noted that an air test on a backfilled pipeline where the water table is above the pipe soffit is not an effective test.

13.4 Water test

13.4.1 *General.* Gravity sewers up to and including DN 750 should be tested to an internal pressure represented by 1.2 m head of water above the crown of the pipe at the high end of the line. The test pressure should not exceed 6 m head of water at the lower end and if necessary the test on a pipeline can be carried out in two or more stages. The test pressure should be related to the possible maximum level of groundwater above the sewer.

When pipes larger than DN 750 are to be tested, expert advice and special equipment may be needed.

13.4.2 *Procedure.* The following test procedure should be adopted.

(a) Fit an expanding plug, suitably strutted to resist the full hydrostatic head, at the lower end of the pipe and in any branches if necessary. The pipes may need strutting to prevent movement.

(b) Fit a similar plug and strutting at the higher end but with access for hose and standpipe.

(c) Fill the system with water ensuring that there are no pockets of entrapped air.

(d) Fill the standpipe to requisite level.

(e) Leave for at least 2 h to enable the pipe to become saturated, topping up as necessary.

(f) After the absorption period measure the loss of water from the system by noting the amount of water needed to maintain the level in the standpipe over a further period of 30 min, the standpipe being topped up at regular intervals of 5 min.

The rate of loss of water should be not greater than 1 litre per hour per metre diameter per metre of pipe run.

13.4.3 *Factors affecting the test.* Excessive leakage may be due to the following:

(a) porous or cracked pipes;

(b) damaged, faulty or improperly assembled pipe joints;

(c) trapped air being dissolved;

(d) defective plugs;

(e) pipes or plugs moving.

13.5 Joint test for large diameter pipes

For man entry sewers special equipment is available to test joints or short sections of pipe in situ.

13.6 Infiltration

After backfilling is completed and after the groundwater level has stabilized, the sewer should be checked for infiltration. All live inlets should be sealed and the line inspected from the manholes. Any flow from the pipeline coming into the manholes or within the manholes themselves should be investigated to establish its source.

In small pipes the point of infiltration may be located visually with light and mirror or with an inflated rubber plug. When conditions justify it a television camera can be used.

The sewer may normally be acceptable if the infiltration does not exceed 1 litre per hour per metre diameter per metre of pipe run, although this will depend on the judgement of the engineer and the extent of exfiltration shown by the water test.

13.7 Freedom from obstruction

As the work progresses the sewer should be checked for obstructions by visual inspection or by inserting a mandrel or 'pig' into the line. A television camera can also be used.

13.8 Straightness

A sewer should be checked for line and level at all stages of construction. Methods of checking include the following:

(a) surveyor's level and staff;

(b) sight rails, boring rods and travellers;

(c) laser beams with sighting targets;

(d) lamp and mirrors.

13.9 Soundness tests for ancillary works

13.9.1 *General.* Recommendations given in this guide for the materials, design and construction of manholes, and similar underground chambers should ensure a high level of resistance to water penetration, both inwards and outwards.

Manholes should be so constructed that no appreciable flow of water penetrates the permanent works.

Where construction work has been effectively carried out, visual inspection may be sufficient for acceptance without testing. Inspection should always be made to reveal any possible weaknesses in the structure and particular attention should be paid to the following:

(a) step iron and ladder housings;

(b) benchings;

(c) pipes entering or leaving the structure;

(d) joints in brickwork or blockwork (see 11.3.4);

(e) joints between sections of the structure.

If required, the inspection should be followed by testing (see 13.9.2 to 13.9.6).

13.9.2 *Reasons for testing.* There may be a need for testing to be carried out in any of the following cases:

(a) for petrol interceptors, suction wells and similar structures;

(b) where unsatisfactory features have been revealed by inspection, e.g. where there is reason to believe that materials or workmanship have been inadequate;

(c) in locations where there is fissured chalk or rock, or pervious subsoil;

(d) where frequent surcharging of the manhole is likely.

13.9.3 *Test head.* Manholes less than 1.5 m in depth to invert should be filled with clean water to the underside of the cover and frame located at ground or surface level. Where the depth to the channel invert is 1.5 m or greater, the test head should be not less than 1.5 m. The test head for petrol interceptors, suction wells and similar underground chambers should be not less than 0.5 m above the invert of the highest connection to the chamber.

Where the chamber is located in ground subject to pore pressure, the test head should be the mean water table level based on seasonal variations or test heads previously specified, whichever is the greater.

13.9.4 *Test procedures.* Tests should not be carried out until structures have reached sufficient strength to sustain the pressure from testing.

The external faces of a structure should not normally be backfilled or concrete surrounded before the chamber is filled with water to the specified test level. Adequate stability should be ensured during the period of test and subsequent concrete placement and backfilling.

For the tests fit a bag stopper in the outlet of the manhole and expanding plugs or bag stoppers in all other connections. Secure all plugs and stoppers to resist the full hydrostatic head and provide means of safely removing the outlet bag stopper from the surface.

Fill the manhole with clean water to the required test level and allow to stand for at least 8 h for absorption, topping up the level as necessary. Carry out the tests as rapidly as possible.

NOTE. These tests should show that the construction is substantially watertight. Work is continuing in order to quantify this term and an amendment to this Part of BS 8005 will be issued as soon as possible.

13.9.5 *Maximum permissible water loss.* The acceptable water loss will vary with site conditions and is a matter for further research. In the meantime, the criterion for acceptance should be that no appreciable flow of water should penetrate the permanent work. Where water can be observed issuing from the outside face of the structure at an identifiable point or points, such leakage should be stopped.

13.9.6 *Testing of watertight structures.* Sumps, suction wells, mud and oil interceptors, petrol interceptors, oil separators, septic tanks and cesspools should be tested for watertightness as described in 13.9.4 but over the full height to surface level and without measurable loss of water after 30 min.

14 Surveying existing sewerage systems

14.1 Objectives

14.1.1 *General.* Surveys of both sewers and manholes are undertaken for several reasons. The nature and detail of the data to be collected will depend on the objective, and may influence the method of recording findings.

Common objectives are as follows:

(a) to investigate causes of poor performance, or of suspected deterioration (e.g. frequent blockage, smell complaints, pipe fragments in manholes);

(b) to locate and inspect sewers prior to a change in their use, or in the use of the surface above them (with the objective of executing necessary repairs);

(c) to inspect sewers prior to adoption (see BS 8005 : Part 0);

(d) to record the condition of a sewer immediately prior to adjacent workings (with the objective of attributing liability for any associated damage) using the NWC classification of Sewer Defects STC No. 25 [23];

(e) to create and periodically update sewer records, following STC No. 25 [23].

Internal sewer surveys may be classified as either operational (or service condition) surveys, or as structural surveys.

14.1.2 *Operational surveys.* Operational surveys are carried out to provide information on the following:

(a) the necessity for, and nature and frequency of, cleaning;

(b) possible structural weaknesses which may be indicated by the type of sediment (inflow from voids, rubble, bricks, etc.);

(c) tree root systems which might cause blockages;

(d) sediment which may indicate bad or flat construction even though the sewer may be sound;

(e) the necessity for major jetting and cleansing operations;

(f) heavy concentrations of debris indicating the possibility of collapse;

(g) the presence of noxious gases indicating sediment and septicity problems which could lead to fabric deterioration.

14.1.3 *Structural surveys.* Structural surveys provide information on the following:

(a) possible renewal or renovation costs;

(b) major defects which can lead to collapse;

(c) the condition and life of sewer fabric.

Jetting to clear the sewer may weaken the structure, but may more readily disclose structural defects.

14.2 Survey methods

14.2.1 *General.* Several methods of surveying are available. The choice should be influenced by objective, costs and sewer diameter.

14.2.2 *Man-entry surveys.* The decision to permit personnel entry into sewers for surveying purposes should be based on safety considerations rather than a minimum limiting diameter.

The surveyors will require adequate lighting at a level in excess of 10 lx which may be supplied from portable battery packs or from a supply cable at less than 50 V. Distances from the point of entry are normally measured using a tape anchored at a suitable datum point.

Observations, together with their circumferential location and distance along the sewer, can be tape-recorded. This eliminates the difficulties associated with writing under cramped and dirty conditions.

Monochrome or colour photographs may be taken and their locations carefully recorded. It is advantageous if the camera incorporates facilities for imprinting reference numbers and other information on frames by way of data banks.

As an alternative the survey can be recorded on video tape via a suitable portable low light-level television camera.

14.2.3 *Photographic and cine surveying using remotely controlled cameras.* Photographic and cine cameras which operate under remote control are available for sewer surveying. Their prime application is in smaller sewers. They are commonly modifications of more conventional equipment. The cameras are encased in a watertight container incorporating flash illumination. Operation is through a length of cable from a control box. Flash bulbs should not be used where there is a risk of explosion.

Cameras are winched through the sewer, exposures being taken at regular intervals, or at locations along the sewer suspected to be of interest. A leading and trailing winch cable is normally employed such that the camera can be retracted if progress becomes impossible. It is usual to estimate the distance travelled into the sewer by coloured markers at regular intervals along the signal cable or by a cable measuring device. The length of sewer that a camera can negotiate in one pass is only limited by the length of cable that can be threaded and the number of exposures/frames on the film in use. In practice it is advisable to bring cameras to the surface regularly to check and remedy lens fouling. The principal disadvantage of these types of survey is that their success cannot be assessed until the film has been processed. In practice many exposures can be wasted owing to lens submersion and fouling. Care has to be taken that all exposures are referenced to the correct length of sewer, and to their distance along it. Referencing of batches of exposure can be on a chalk board carrying the relevant location details (e.g. date, road name, manhole reference). Individual exposures are usually referenced to their position in a sewer, by compilation of a site report. In most systems an exposure counter is incorporated on the surface to facilitate this procedure. However, unless the system also incorporates facilities for alpha-numeric marking of exposures, referencing is dependent solely on the sequencing of exposures within the film. Cine and photographic surveys are capable of producing sequences of high definition colour pictures. Cine film can be replayed on a frame by frame basis so that the pictures can be interpreted and a report produced. Where specialist cameras are not available, useful results can be obtained using conventional flash photography from manholes.

14.2.4 *Lamping surveys.* Observers with safety lamps entering adjacent manholes can check for unobstructed vision along the connecting length of sewer. Mirrors held at a suitable angle in the manhole invert enable the surveyor to achieve this inspection from a squatting position.

The length of sewer over which the procedure is effective is dependent on diameter. In sewers of less than 300 mm diameter it is difficult to distinguish a circle of light over distances in excess of 30 m. In older systems, lamp-holes were often included between manholes; many of these have been abandoned, or replaced by manholes.

Although useful detail can only be observed for a limited distance along a sewer, the surveyor is frequently able to decide whether further action is required. In particular, lamping should be regarded as a useful preliminary to other more costly surveying techniques in as much as the desirability of pre-cleaning and/or flow diversion can be established.

14.2.5 *Television surveys.* The use of specialist closed-circuit television equipment for sewer surveying is widespread [24]. The technique is usually associated with the inspection of smaller sewers, although if illumination is adequate it is equally amenable to sewers of man entry proportions where entry is undesirable on safety grounds.

The camera is either winched through the sewer or driven through mounted on a self-traction device. Whilst the latter eliminates the task of line threading which may incur a significant part of survey cost, tractor surveys in silted sewers may cause abandonment through loss of traction.

There is great variation in the extent of service offered by contractors and in the sophistication of equipment supplied by manufacturers. Survey contracts should be let under a detailed specification and conditions of contract and should be properly supervised on site.

14.2.6 *Manhole surveys.* Manholes are an integral part of a sewerage system, and should preferably be surveyed at the same time as the downstream length of sewer. Data collected should include the following:

(a) dimensions;

(b) fabric;

(c) cover, ladder or step iron details;

(d) service condition;

(e) structural condition;

(f) date and time of survey;

(g) levels of the manhole cover, and of the invert of connecting sewers (to Ordnance Survey Newlyn Datum);

(h) a plan showing the geometry of connections and directions of flow;

(i) location information (e.g. a manhole reference number);

(j) Ordnance Survey grid reference of manhole cover centre;

(k) position of sewer centreline in relation to manhole cover centre.

It is convenient to store collected information on a standard data sheet. Photographs of manholes and their covers are often useful and these should be cross-referenced to the manhole data sheet or affixed to it.

14.2.7 *Line and level surveys*

14.2.7.1 *General.* BS 8005 : Part 0 summarizes legislation defining the duty of local authorities to maintain sewer maps.

14.2.7.2 *Sewer line.* The position of all manholes along a length of sewer can be determined by referencing the manhole covers to permanent features of detail on the ground (i.e. buildings, fences, kerb lines, etc.) which are shown on Ordnance Survey large scale maps. Buried manholes might be found by using metal detectors and all taped measurements should be to the nearest 10 mm.

In rural areas the manhole positions can be plotted on to 1/2500 scale maps giving a positional accuracy of ± 1 m, and for urban areas on to 1/1250 scale maps giving positional accuracy of ± 0.15 m. National Grid coordinates can then be determined for each manhole cover centre by scaling from the appropriate map.

The sewer centreline should be determined in relation to each manhole centre and plotted as an approximate line between manholes. If required, the true line of the sewer between manholes can be determined by a number of methods; e.g. by electrolocation; sighting with powerful lamps through the sewer between manholes and by reference to 'as constructed' drawings. In the case of man-entry sewers, distances can be measured through the sewers between manholes, recording the chainage of starts and finishes of bends, centrelines of incoming sewers and pipes, etc.; the resulting information should be plotted on to the appropriate map.

All information recorded in the field should be properly indexed and cross-referenced for future use.

In man-entry sewers, precise line and level surveys can be carried out using conventional surveying instruments and the resultant survey plotted to a scale of 1/200 or larger. Surveys of this nature will determine the position of the sewer in relation to surface detail to an accuracy of ± 0.1 m of true position. These surveys are not generally required for record purposes but for civil engineering design purposes; precise location is required for reconstruction, foundation design, etc., or where the sewer is to be built over.

14.2.7.3 *Sewer levels.* Sewer invert and cover levels should be related to Ordnance Survey Newlyn Datum latest available values. An accuracy of ± 25 mm should be aimed at for all sewer levelling.

Cut marks can be established on manhole frames directly over the sewer invert if possible, and the distance from cut mark to sewer invert is measured very accurately down the manhole shaft. In shallow sewers the invert level may be read directly whilst surface levelling is being carried out.

At side-entry or off-set manholes the cut mark is established and a datum point can be put in the gallery floor directly below it. The distance from cut mark to datum point is carefully measured; this point is then used to determine the sewer invert levels.

The level of the centre of each manhole cover should be recorded and in the case of tilted covers, the lowest point. All levels should be read in the field and booked to the nearest millimetre; they may, however, be recorded to the nearest 10 mm on the sewer map. All information recorded in field books should be properly indexed and cross-referenced.

14.3 Recording survey information

Survey information may be produced/stored in the form of written reports, photographs, slides, cine film, audio tape recordings, video tape recordings, plans, and in the several methods of computer storage (e.g. floppy disc, solid-state memory). Where storage on more than one of these media is employed, information should be cross-referenced within the systems. It is useful if referencing is based on the module of a single manhole and its downstream length of sewer. (For symbols see appendix G).

In addition to the condition data obtained from surveys, data may exist on the sewer environment (e.g. bedding type, traffic loading, groundwater conditions) and on sewer performance (e.g. flow data, blockage frequency, maintenance costs). This information should be stored in conjunction with condition data, or cross-referenced to it.

Written reports suffer from the following disadvantages:

(a) they cannot be readily updated following sewer alterations or deterioration;

(b) the abstraction of quantitative summary information (i.e. based arithmetically on survey contents) is tedious;

(c) they are produced in a multitude of styles using non-standard terminology to describe observations.

An advantage of written reports is simplicity and lower capital cost. Steps can also be taken to overcome the problems of non-standard format and technology by the use of rigid definitions and nomenclature for commonly observed defects.

Pictorial evidence from surveys can be expensive to produce, but can help to overcome problems associated with operator interpretation. However, unless video tapes, photographs, etc., are produced in conjunction with a comprehensive survey report, their use in the quantitative comparison of sewer condition is very limited. The reviewing of video/cine coverage of surveys can be time consuming.

Computer storage of survey data used in conjunction with a standard system of nomenclature and a simple coding procedure to facilitate input, has the following advantages.

(1) Surveys can be readily updated.

(2) Summary information useful to the ranking of sewers in order of the cost effectiveness of remedial action can easily be abstracted.

(3) Survey and summary reports can be readily reproduced in a variety of formats suitable for various levels of use (e.g. site applications, resource planning).

(4) Sewer condition data can readily be stored and used in conjunction with environment and performance data.

(5) Data can be stored on a suitable medium on site, and can be available for input direct to computer. This avoids the costs associated with the manual production of reports.

(6) Subsequent survey information may be easily compared to monitor progressive deterioration.

Section six. Operation, maintenance and repair

15 General

15.1 Adoption of sewers

In England and Wales sewers for construction on a development site may be offered for adoption to the sewerage authority by agreement under Section 18 of the Public Health Act 1936 prior to the commencement or alternatively using the provisions of Section 17 of the same Act after completion.

Reference should be made to the WAA document 'Sewers for adoption' [3] or to the specification prepared by the sewerage authority.

In Scotland sewerage authorities are responsible under the Sewerage (Scotland) Act 1968 for providing sewers. In practice they may enter into an agreement with the developer who will lay the sewers to the sewerage authorities' specification. On completion, the sewerage authority, if satisfied that the sewers have been laid to their requirements, become owners of, and responsible for, the sewers.

In addition to a detailed inspection of the sewers to ensure that they have been constructed or repaired to the specification and are clear of silt and other debris, all step irons, ladders, landings, guard rails and chains should be checked to ensure that they are securely fixed and set in the correct position. Safety chains or hinged bars should be parked clear of normal flows. Manhole covers should be correctly set and their frames properly bedded. A check should be made to ensure that any previously live connections have been remade.

The performance of a new or repaired sewer should be monitored for a period. In the case of surface water sewers or storm relief sewers the flow conditions should be monitored by inspection during the first few storms and particularly during any major storms occurring in the first year of its service. All statutory undertakers and those directly connecting to the sewer should be advised when the sewer has been put into use. Those responsible for sewer operation and maintenance, pumping stations and treatment works should be notified beforehand of the date when the sewer will be commissioned and advised as soon as it has been put into use.

Final inspection of sewers and manholes constructed under a contract should be made before the completion of the maintenance period in order that any defects can be remedied before the conclusion of the contract.

All drawings of works as executed should be kept. All inspection records should be kept for at least 12 months after completion of the works. Sewer maps should be updated in respect of new sewers, removed sewers and closed sewers.

15.2 Operation

Operation involves the regulation or diversion of sewage, for example, by the following:

(a) starting or stopping of pumps;

(b) inserting dam boards or cloughs;

(c) the regulating penstocks, valves, weirs, etc.;

(d) the use of balancing or storm sewage treatment tanks.

15.3 General maintenance

The term maintenance when used in a general sense, covers all the tasks carried out to keep the sewerage installation in such a condition that the system performs its functions satisfactorily. The national assessment [25] defines the tasks as follows.

(a) *Maintenance.* The systematic inspection and cleaning of a sewer, including minor repairs but not involving reconstruction of the main structural fabric or altering of the original dimensions. Maintenance includes joint repairs, renewal of inspection covers, step irons, etc. and sealing of cracks when the structural fabric is not impaired.

(b) *Repair.* The repair of the main structural fabric of the sewer and the reconstruction of short lengths, but not the reconstruction of the whole of the pipeline considered as an entity, nor work involving significant alteration of the dimensions, location, or depth of the pipeline as originally constructed.

(c) *Renovation.* The operation of effectively improving the condition of an existing sewer by in situ techniques such as will provide for a substantially increased life. Renovation may or may not improve the structural strength of the pipeline.

Structural renovation systems reduce the size of the existing sewer by a larger percentage than non-structural techniques and the loss in capacity should be considered. However, minor reduction in size may be offset by the improvement in hydraulic efficiency.

NOTE. The subject of rehabilitation will be dealt with in BS 8005 : Part 5* and is covered in detail in reference [2].

(d) *Renewal.* The reconstruction of the whole structure of a sewer as an entity to the same dimensions as the original pipeline, but not necessarily in precisely the same location.

(e) *Replacement.* The construction of a new sewer either in the same location as the original sewer or in a new location so that the fundamental purpose of the original sewer will be incorporated in the functions of the new sewer. Replacement can include a proportion of improvement or development work.

* In preparation.

15.4 Remedial works

Remedial works (see clause 17) may be required if:

(a) the sewer is structurally unsound, i.e.:

(1) fails to support or retain the soil in which it is constructed;

(2) is inadequate to support the superimposed loads from buildings or traffic, etc.;

(3) allows infiltration or exfiltration to an extent which causes leaching away of, or damage to, the soil surrounding the sewer and/or reduces the hydraulic capacity available for the performance of its function;

(4) deforms or collapses to the extent that restrictions to flow or blockages occur.

or

(b) the hydraulic capacity of a sewer has been reduced by:

(1) siltation;

(2) loss of gradients (settlement);

(3) encrustation;

(4) tree root penetration;

(5) badly formed connections;

(6) deformation of cross section of sewer;

(7) hydraulic conditions elsewhere in the catchment, such as restricted outlets to rivers, backing-up caused by the connection of additional sewers.

or

(c) structural defects have been caused by:

(1) increased structural loading from engineering works, buildings, roads, earthworks and natural or artificially introduced ground movements;

(2) increased hydraulic loading;

(3) infiltration of groundwater;

(4) exfiltration of sewage;

(5) deterioration of materials;

(6) chemical attack on materials;

(7) erosion of materials;

(8) inadequate design;

(9) unsatisfactory construction.

16 Operation

6.1 Records

6.1.1 *General.* Records should be kept so that an dequate service to the community can be provided with ue regard to safety. This objective will normally ecessitate a reasonably comprehensive record system, ie statutory maps being supplemented either by additional iformation shown on them or by additional document- ion which is referenced to them.

ecords of sewers should be in two forms as follows:

(a) location records: to state clearly the position, size, level, material, function and age of the apparatus;

(b) condition records: to record the condition and operational history of the apparatus, including the results of inspections and surveys and all maintenance and repair work carried out.

For additional information on the uses and form of records, together with associated statutory and financial aspects, see STC Report No. 25 [23]. Records connected with manhole surveys are referred to in 14.2.6. For symbols used in records see appendix G.

16.1.2 *Statutory obligations.* In England and Wales the statutory requirements for sewer records are contained in Section 32 of the Public Health Act 1936, which, by virtue of the Local Government Act 1972, places the responsibility for keeping records on to district councils. Section 32 is not specific with respect to content and does not require all sewers to be recorded. Section 32 will be satisfied by a district which keeps deposited a map showing the location of all post-1937 sewers and all pre-1937 sewers which are reserved for foul or surface waters only. Section 32 does not require records of sewers to be kept unless a declaration of vesting, or an agreement to make such a declaration has been entered into.

In Scotland, Section 11 of the Sewerage (Scotland) Act 1968 defines the duty of sewerage authorities to maintain maps.

16.1.3 *Other drainage systems.* Highway drains and watercourses are not public sewers and accordingly there is no statutory duty to show them on sewer maps, although in some areas they may form an important part of the system of drainage. In evitably this leads to ambiguity where such conduits are interconnected with public sewers because the records will not normally indicate the reason for the omission of pipelines. In many cases, (for example, where it is necessary to consider connections, maintenance, or building over) establishing the ownership and status of the conduit is of prime importance. A rapid determination of status is essential when an emergency arises, for example when it is necessary to trace a source of pollution. The inclusion on the public sewer map of certain non-public drains or sewers is therefore recommended, provided their status is suitably indicated.

16.1.4 *Basic or master records.* The basic or master record is normally an Ordnance Survey plan or is a reduction or enlargement thereof. There are, however, a few instances of as constructed drawings forming the master record. Whilst detailed 1/500 scale maps may be necessary in certain parts of Metropolitan areas, the Ordnance Survey plans generally in use for statutory purposes are the 1/1250 and 1/2500 series; smaller scale maps such as the 1/10560 and 1/10000 are used for forward planning or indexing uses. Master record drawings normally provide details of the line, size, type of sewer, manhole locations and depths.

The most common methods of preparing master record drawings, and of storing and labelling them, are in STC Report No. 25 [23]. Symbols for use in the maps are given in appendix G.

16.2 Safety considerations

16.2.1 *Statutory requirements.* Statutory requirements are identified in BS 8005 : Part 0.

16.2.2 *Health, training and information.* It is essential that every employee concerned with operation and maintenance work in the sewerage industry should be of the necessary standard of health and should be adequately trained to perform his particular function efficiently and without risk.

From the bibliography in appendix B, attention is directed particularly to the first reference, 'Health and Safety Guidelines No. 2' entitled 'Safe working in sewers and at sewage works' [26], published by NJHSCWS for general guidance.

For staff employed in pumping stations, special emphasis should be placed on a sound knowledge of safety precautions in the operation of relevant plant and machinery. (See BS 8005 : Part 2.)

Where an employee's duties involve working in sewers and associated confined spaces, the primary consideration is his state of health. This could extend not only to defects in hearing, eyesight and sense of smell but also to physical deformities, susceptibility to claustrophobia, nervous or mental disorders and any inherent weakness which constitutes a hazard for the particular operation. It is essential that a system is established which regularly monitors the health of such employees.

Types of training will vary depending on the requirements of the operational function, but in view of the potentially high degree of risk to employees when entering and working in sewers and confined spaces, adherence to the following aspects of training is essential:

(a) provision of safe systems of work;

(b) the use of equipment for testing and monitoring the atmosphere;

(c) the use of respiratory protective equipment;

(d) basic first aid;

(e) escape and rescue procedures.

It is recommended that a Medical Instruction Card should be given to every employee likely to come into contact with sewage. This card should give occupational information about the individual and a list of the basic precautions to be taken by the employee against the risk of leptospirosis.

In addition, all employers should issue an illustrated booklet containing information about known operational hazards, how they can be avoided and the most effective methods of dealing with them. Current legislation should be referred to, where appropriate, and the booklet should be updated regularly.

16.2.3 *Procedure.* Whenever a manhole or sewer is to be entered consideration should be given to:

(a) reviewing the information available about the sewer and its appurtenances;

(b) the size of the gang required to carry out the work and to effect rescue if necessary;

(c) the system of communication between members of the gang when one or more are below ground;

(d) the equipment necessary for safe and effective working, including gas detection and rescue gear;

(e) the procedures for dealing with emergencies.

Proper maintenance of all working and safety equipment is essential.

16.2.4 *Danger to workmen in sewers.* This subject is covered comprehensively in the 'Report on the enquiry into serious gas explosions' [20] and 'Health and Safety Guideline No. 2' [26]. It is considered essential to highlight here the most common dangers, their causes and the appropriate remedial measures, but not to the exclusion of the more detailed recommendations given in the reference documents.

(a) *Physical injuries.* Injuries to men descending through manholes and working inside sewers arise mainly from falls, slipping, dropping tools, cuts or scratches from sharp edges and the use of incorrect or faulty tools. In most cases the remedies are obvious and unless appropriate action is taken to report and repair the causes (e.g. damaged step irons and ladders with irregular surfaces), accidents may recur.

The discipline of vacating such a workplace immediately to apply first aid cannot be over-emphasized. The use of anti-tetanus injections as a primary safeguard should be rigidly enforced. The fact that a minor injury caused underground may result in a major rescue operation, if incapacity ensues, should be emphasized regularly.

(b) *Dangerous atmospheres.* Entry should not be made or permitted into a confined space unless the atmosphere has been tested by an authorized competent person having relevant local knowledge of the system or installation. A safe result has to be obtained before entry is attempted and arrangements made thereafter for the continuous monitoring whilst persons are in the confined space. Alternatively suitable breathing apparatus has to be provided and used. Such apparatus should comply with the requirements of BS 4617 : Parts 1, 2, 3 and 4 as appropriate.

Table 5 lists the most common hazardous gases likely to be encountered in sewers, their basic properties, main hazards and methods of detection.

Other gases may be present as a result of accidental spillage or discharge of unauthorized trade effluents causing hazards by generation of toxic or explosive fumes. A pre-survey of an industrial area, where sewer work is necessary, may give valuable information as to what substances are likely to enter the sewers both in controlled and accidental circumstances. Guidelines on identification of such substances, e.g. colour, odour, may be obtained. Advantage should be taken of improved detection devices continuously being developed.

Table 5. Common hazardous gases

Gas	Properties	Hazard	Method of detection*
Carbon dioxide	Colourless Odourless Heavier than air Non-flammable	Displacement of oxygen Mildly toxic	Flame of safety lamp decreases if concentration is sufficient to reduce the oxygen content of the air
Carbon monoxide	Colourless Odourless Lighter than air Flammable Toxic	Toxicity Flammability	Flame of safety lamp increases in height
Chlorine	Yellow-green colour Choking odour Much heavier than air Non-flammable Toxic	Toxicity	By smell
Hydrogen sulphide	Colourless Rotten-egg odour Heavier than air Flammable Toxic	Toxicity Flammability Impairment of the sense of smell by high concentration	Moistened lead acetate paper goes brown in atmosphere containing hydrogen sulphide
Methane (constituent of natural and reformed gas)	Colourless Odourless Lighter than air Flammable	Flammability Explosion	Flame of safety lamp increases in height
Petroleum Diesel vapour	Colourless Paraffinic odour Much heavier than air Toxic Flammable	Toxicity Flammability Explosion	Flame of safety lamp increases in height

* The detection methods listed are based on the conventional safety lamp with acetate paper holder. Other commonly used methods include electronic monitoring and testing devices and air sampling methods.

Attention is particularly directed to the atmospheric dangers which arise at the junction point of two or more sewers containing effluents which react together and generate fumes. A similar danger may arise if a person walking through the sewer disturbs sediment in the invert and releases harmful gases. Account should be taken of gases heavier than air which consequently dispel slowly if normal venting methods are used.

When the oxygen content in the atmosphere falls below a minimum level of 17 % owing to displacement by other gases, normal monitoring systems sound an alarm and personnel are required to vacate the area immediately. The normal method of rectifying the situation is to improve the ventilation. Rapid improvement by injecting oxygen or hydrogen peroxide is not advised owing to the increased fire and explosion risk such action may create.

Effluents from the brewing and food industries are likely to create oxygen deficient atmospheres.

(c) *Other hazards.* Other hazards present in sewers include the following.

(1) *Flooding.* Circumstances leading to flooding in sewers and manholes are dealt with in 16.5.

(2) *Bacteriological infection.* Special vigilance should be kept for any signs of infection developing into Weil's disease (Leptospiral Jaundice), which requires immediate treatment. A suitable barrier cream protecting hands and forearms before entering a sewer will provide protection to slight cuts and bruises. However, no person with an open cut or wound should be allowed to enter a sewer.

(3) *Accidental discharges.* In addition to controlled trade effluent (16.3), malfunction of industrial plant or transport accidents may result in accidental discharges of hazardous materials into sewers. Such discharges should be notified to the appropriate authority immediately.

Table 6. Sources of hazards in effluents	
Source	Substance causing hazard
Metal refining, plating, etc.	Cyanides
Cleaning metal components	Phenols, chlorinated solvents*, acids, alkalis
Dry cleaning	Chlorinated solvents*
Motor trade	Paint solvents Petrol/diesel
Papermaking, dye works, acid manufacture, Refrigeration plant	Sulphur dioxide
Breweries and food factories	Oxygen deficiency
General: hospitals, laboratories, power stations, etc.	Steam discharge Radioactive substances

* Chlorinated solvents are trichloroethylene, perchloroethylene, trichloroethane.

16.3 Trade effluent control

16.3.1 *Objectives of trade effluent control.* The objectives of control are to prevent trade effluent discharge to sewers which may cause the following:

(a) risks to personnel employed therein (see tables 5 and 6);

(b) damage or harm to the sewerage system together with increased maintenance costs;

(c) interference with the effective and economic treatment of the sewage;

(d) unacceptable effects on water resources or the environment generally from the products of treatment, in the form of effluent or residues;

(e) unacceptable storm sewage discharges to watercourses.

Trade effluent control also provides data for use in the design of future sewerage and sewage treatment works, and ensures that the trader pays a fair charge for the services rendered for the reception, conveyance, treatment and disposal of his effluent.

Consent to discharge is issued by the water authority. The conditions are designed to ensure that the effluent complies with the above objectives. They should also include the following:

(1) the provision and maintenance of an inspection chamber or manhole to enable samples to be readily taken;

(2) if considered necessary, the provision and maintenance of such meters as may be required to measure the volume and rate of discharge of the effluent.

A consent may also include conditions for the provision and maintenance of apparatus for determining the nature and composition of the effluent, the keeping of records of volumes discharged, etc., and the making of returns and giving any other information regarding the effluent.

16.3.2 *Sampling.* Sampling is required to monitor the following:

(a) the trade effluent discharging into a public sewerage system, both for control and charging purposes;

(b) any overflow within the system that could lead to a direct discharge to a watercourse;

(c) the discharges from surface water sewers.

Sampling can be continuous, intermittent, or occasional. The choice will be dependent upon the following:

(1) the nature of the effluent, and its potential for effect on personnel, the sewerage system, treatment works and receiving environment;

(2) the method of establishing the trade effluent charge.

At present there are a number of parameters, i.e. pH, temperature, dissolved oxygen, conductivity, rate of discharge and volume, that can be monitored continuously. Other parameters such as nitrate, total ammonia, chemical oxygen demand (COD), biochemical oxygen demand (BOD) and suspended solids do not lend themselves to continuous monitoring and, if required, need to be determined in the laboratory.

There are two methods of automatic sampling, as follows.

(i) The effluent is pumped to the sampler and a known volume deposited in the bottle. This method usually requires a power supply, either mains or battery.

(ii) The release of a pinch valve enables a sample of effluent to be drawn into an evacuated bottle. This method can be used in sewers and enclosed spaces.

An alternative method of sampling, commonly used, is by manual 'grab' or 'snap' samples which can be extended over a pre-determined period of time.

16.4 Rodent control

The environment of a sewer provides an ideal habitat for a rat. The main dangers associated with rats are as follows:

(a) they exploit existing defects in the sewer and their burrowing activity can undermine its stability;

(b) they carry disease, the most serious being Weil's disease (leptospirosis) and Salmonella (food poisoning).

The objective should be to control the infestation to a level which is considered acceptable. This will only be achieved by developing a planned campaign of poisoning in sewers, private drainage systems, buildings and other breeding areas. Rat infestation of sewerage systems is a universal problem and the knowledge, strategy and health requirements are subject to continual change. In England and Wales the Local Health Authority and the Ministry of Agriculture, Fisheries and Food should be approached before any action is taken. The equivalent authorities in Scotland are the Local Environmental Health Officer and the Department of Agriculture and Fisheries for Scotland.

A classification system should be established dividing the infested areas into three categories which represent high, medium and low infestation. Classification may be established from past records but if they do not exist, or the rat population is believed to have changed, a test baiting system should be set up.

Having established the areas of high infestation an overall treatment strategy should be developed. This should be as extensive as possible. As complete extermination is extremely unlikely, treatment should be on a regular basis, the time period being established by the results achieved. Attention should be paid to treatment on boundaries between authorities and programming should be coordinated by adjacent authorities. Close collaboration is essential between responsible departments for the control and monitoring of actions taken to be effective.

The following two types of poison are in use at present.

(a) Acute poison which requires only a single dose to cause death. Examples of acute poisons are sodium fluoroacetate and sodium fluoroacetamide.

(b) Chronic poisons which have to be administered in small amounts over a period of time, e.g. anticoagulants such as Warfarin and Nacumin.

16.5 Storms and emergencies

Emergencies may occur during heavy storms or they may be the result of a sudden rush of water caused by faulty flap-valves, fractured sewers or watermains, unexpected discharge from swimming baths, reservoirs or factories, breakdown of control equipment and the uncoordinated operation of control equipment.

There are basic considerations which should be examined in order to develop, plan and coordinate adequate emergency provisions, and which include the following.

(a) *Hazard records.* An up-to-date set of plans of each sewerage system should be readily available. They should clearly show the normal flow conditions with flows, water levels and overflow provisions indicated. Hazardous and emergency conditions should be highlighted and the safe limits of operation clearly identified. The worst conditions experienced should also be recorded.

(b) *Weather conditions.* Staff should have access to accurate meteorological information and local weather forecasts.

(c) *Communications.* Good communications are essential, particularly during storm and emergency conditions. Normal VHF mobile radio and telephone systems may need to be expanded during an emergency. Fire, Police, Ambulance, Plant Hire and Military services should be considered when developing emergency procedures.

(d) *Emergency training and equipment.* Emergencies arising from severe weather conditions call for special precautions against flooding, electrical faults and structural damage. Rescue operations should be within the scope of the normal emergency cover, but special equipment such as mobile pumps, generators and cranes may be required. Staff should receive special training in mock emergency conditions.

(e) *Accident procedures.* The risk of injury to staff involved in storm and emergency operations is likely to increase, and first aid, rescue and transport facilities should be available at their specified locations before emergency operations commence.

16.6 Flow measurement

16.6.1 *Objectives.* Continuous or intermittent measurement of flows into, within, or out of sewers may be required for the following purposes.

(a) To check that discharges into a sewer, or from a sewer, to receiving streams comply with consent standards. Whether continuous or occasional measurements are taken will depend on the nature and variability of the discharge and on the degree of dilution in the receiving stream.

(b) To ascertain the variations of flows within foul sewerage systems and to locate sources of extraneous water (inflow or infiltration). Measurements should be taken and comparisons made with the base flow. These measurements should be taken when the water table is high (during the winter), or during a rainstorm to detect inflow, and for at least 24 h after to detect infiltration.

(c) To monitor flows within combined or surface water sewer systems during the passage of a rainstorm to calibrate mathematical flow models.

(d) To monitor the discharges from storm water overflows.

16.6.2 *Techniques.* A variety of techniques can be used for flow measurement as follows.

(a) *Critical depth flumes.* Critical depth flumes will give accurate flow measurement so long as backwater effects from downstream constrictions are not present and silt deposits are not allowed to build up. They can take the form of purpose-built structures or insertions placed within the pipe. They will generally be permanent or semi-permanent structures. Depth is measured and converted to flow using a theoretical rating curve with, where possible, in situ checks. The main disadvantages of critical depth flumes are the cost of installation, the reduction of sewer capacity they cause and head loss through the flume.

(b) *The monitoring of depth.* The accuracy of flow measurement achieved depends on the flow characteristics of the gauging site. Flow should be normal at all depths (i.e. the water surface is parallel to the sewer invert) and the hydraulic roughness should be stable. The sewer chosen should, therefore, not be affected by any backwater from obstructions or gradient changes upstream or downstream, the water surface should be smooth, and the measuring section should not be prone to silting. Such conditions are found more frequently within a sewer barrel rather than within the manhole invert. The depth can be measured as follows:

(1) using an automatic probe which senses the water level;

(2) acoustically, by recording the time it takes for a sound pulse to travel from the transmitter to the water surface and back to a receiver (both restricted to manhole or open channel application);

(3) by the measurement of hydrostatic pressure on a bubbler device or pressure transducer located in the sewer invert. The depth of water can be related to flow by either incorporating it into an open channel hydraulic formula, or by measuring velocity and calculating the flow. A depth of water/flow relationship is achieved by simultaneously measuring the depth and velocity over a range of flows.

(c) *Continuous measurement of depth and velocity.* Where backwater effects make the monitoring of depth alone unreliable, velocity and depth are measured simultaneously enabling discharge to be calculated. The measured velocity is related to a mean velocity by:

(1) assuming the measured velocity multiplied by a constant coefficient equals the mean velocity;

(2) establishing a rating curve and a velocity/depth discharge relationship (see (b) above);

(3) measuring velocity at a number of locations in the sewer reach such that the mean velocity can be directly calculated from the observations.

NOTE. With reference to telemetry and computer control of operation, see BS 8005 : Part 2.

17 Maintenance

17.1 General

Sewerage systems require maintenance to avoid nuisance, to safeguard public health and to safeguard the structural integrity of the component parts of the system.

Maintenance of sewerage systems includes planned inspection, follow-up maintenance and crisis work.

17.2 Inspections

Sewers of small diameter located at nominal depths in low risk areas where the effects of collapse or blockage are localized and of limited economic consequence (e.g. in a housing estate), can be inspected and maintained on a crisis method of operation. This crisis method of operation will generally give a steady workload on the sewerage maintenance organization with over half the work being of the crisis type.

Such an approach cannot be justified, however, on the structurally and hydraulically vulnerable parts of the sewerage system where the overall consequences of serious dilapidation are far reaching. In such circumstances a procedure of planned inspection and follow-up repair and maintenance is required. Such locations are as follows:

(a) pumping stations;

(b) storm water overflows;

(c) siphons;

(d) penstocks;

(e) problem sewers;

(f) structurally suspect sewers.

A system of planned inspection and routine maintenance is also required for building support structures (e.g. pipe bridges) and grounds.

Minor cleaning and maintenance should be carried out at the time of inspection and the need for more major works should be reported for further attention. Inspection of sewers should be carried out by remote control methods, e.g. closed circuit television, except in the case of large, man-entry sewers which are suitable and safe to enter.

17.3 Routine maintenance

17.3.1 *Cleaning work.* Regular cleaning and removal of deposits by jetting, flushing, winching, running, blow-boarding or rodding techniques is required in some sewers and at siphons and overflows.

Blockages can be dealt with by either rodding or jetting. Jetting can result in the complete removal of a blockage whereas rodding can be merely making a waterway through, which will often quickly reblock. Jetting downstream of a cleared blockage is desirable to ensure that the restriction has not been simply pushed forward.

Jetting becomes less effective as the sewer size increases and the standard machines are not effective at diameters of 600 mm and above. Rodding is slow and dirty.

Catchpits and storm tanks form part of some sewerage systems. They require desludging at intervals.

17.3.2 *Structural maintenance.* Maintenance works required to older sewers include repointing of mortar joints, replacement of defective brickwork and pressure grouting with cement grout. Renovation may also be required and this may include one of the various types of lining available to give structural strength to the sewer.

The location and filling of voids outside, and sometimes at a distance from, the sewer and ancillary structure may also have to be undertaken to preserve its structural integrity.

Some brick sewers are beyond economical repair or are grossly hydraulically overloaded and need to be replaced. Others are being replaced as redevelopment takes place in inner city areas. A considerable proportion, however, will need to be kept in service by adequate maintenance.

17.3.3 *Minor repairs and general housekeeping.* Apart from sewer cleaning work and structural maintenance, a certain amount of minor repairs and housekeeping work will always be required to manholes, manhole covers, overflow chambers, outfalls, etc., such as replacing worn covers, step irons, ladders and safety chains and repairs to manhole benchings.

17.3.4 *Mechanical and electrical maintenance.* In addition to the routine operation inspection and maintenance of mechanical and electrical equipment (pumps, motors, screens, penstocks), more detailed inspection and maintenance should be carried out at less frequent intervals. This will involve major overhaul of the plant from time to time.

17.3.5 *Buildings, superstructures and grounds.* Buildings and grounds are an inherent part of many pumping stations, storm tanks and overflows. Ground maintenance (grass cutting, etc.) can be carried out by sewer operatives. Superstructures include overground pipes and pipe bridges. These require painting and repairs as appropriate.

17.4 Crisis work

17.4.1 *General.* Crisis work consists of clearing blockages and collapses, mopping-up operations and dealing with electrical and mechanical breakdowns.

17.4.2 *Clearing blockages and collapses.* Blockages and collapses occur sporadically with no fixed pattern and can happen in areas:

(a) with old sewerage systems;

(b) subject to mining subsidence;

(c) with sewers laid at minimum gradients;

(d) with sewers which have been blocked by tipping of rubbish.

Sewers which block frequently in the same place should be identified, and cleaning should be carried out on a planned basis to avoid a breakdown in service.

17.4.3 *Mopping-up operations.* Mopping-up operations result from flooding and irregular discharges from storm overflows. Blockages, full or partial sewer collapses, and the general inadequacies of some sewerage systems can also be responsible.

17.4.4 *Mechanical and electrical breakdown.* When the breakdown of mechanical and electrical control equipment occurs a sewer maintenance organization should be able to undertake necessary repair work. The frequency of the occurrence of such breakdowns is dependent in some degree on the level of inspection and routine maintenance.

17.5 Major blockage and collapse

The first line of attack with any blockage should be use of rods, either hand or power operated, and/or high pressure jetting equipment. Where a blockage is due to collapse of the sewer fabric such an occurrence is often accompanied by visible settlement of the ground surface. The collapse of a sewer, however, may not always result in complete blockage, and settlement of the ground surface is often the first indication of trouble below.

Whenever a major blockage or collapse is encountered all practicable investigations should be carried out to ascertain the extent and nature of the problem by use of CCTV, remote photography or lamping techniques or in large diameter sewers, direct visual inspection from inside the sewer, if possible.

The most usual method of repair involves excavating from the ground surface, although it may occasionally be possible to bore out a blockage with hydraulic or compressed-air driven equipment from adjacent manholes. Where the blockage or collapse is in a deep sewer, the use of tunnelling techniques as an alternative to direct excavation should be considered, although this can be difficult through collapsed ground on the line of the sewer.

Dealing with a major blockage or collapse often results in disruption of traffic and inconvenience to frontagers. The following procedures and measures may need to be taken.

(a) Provision of equipment for overpumping, or diversion of flow.

(b) Provision of an adequate system of ground support including, where necessary, geotechnical measures such as dewatering, ground freezing and chemical stabilization.

(c) Notification to police, fire and highway authorities regarding the arrangements of necessary traffic regulation and road closures.

(d) Notification to all frontagers and arrangement of any practicable and appropriate measures to alleviate inconvenience.

(e) Notification to other statutory undertakers, location of plant and arrangement of necessary diversions or supports.

(f) Notification to the appropriate authority where damage to buildings may occur.

(g) For sewers not in the highway, notification of land owner/occupier and negotiation of suitable access and working arrangements. In the case of public sewers in England and Wales formal notice under Section 287 of the Public Health Act 1936, or Section 15 of the Water Act 1973 where appropriate. In Scotland, clause 48 of the Sewerage (Scotland) Act 1968 should be consulted.

(h) Where public sewers are involved, compensation may be payable for damage caused by an authority by reason of the exercise of any of their powers in clearing the blockage or repairing the collapse.

(i) Property surveys to assess the existing structural condition of property adjacent to the point of collapse and on the route of diverted traffic.

17.6 Chemical attack

17.6.1 *General.* The fabric of sewers may be attacked by aggressive chemicals which may be acidic or alkaline. The attack may be internal (usually from trade effluents) or external (e.g. from sulphates or tip leachates).

17.6.2 *Internal attack.* Internal attack occurs in two distinct patterns as follows.

(a) *Direct attack by an aggressive effluent.* Examples of this are as follows.

(1) The degradation of cementitious material by acids such as sulphuric and hydrochloric acid, which are used extensively in industry, and by hydrofluoric acid from glass processes.

(2) Corrosion of metal safety chains, ladders, penstocks, step irons, manhole covers and pipes. Where there is no protection this will occur under normal conditions in the sewer environment but is exacerbated by aggressive chemicals.

(3) The glazing of clay pipes may be affected by fluorides (from glass processes) at relatively weak pH values.

(4) High alumina cement may be attacked in pH values greater than 9 and if caustic alkalis are present. Use of high alumina cements are not advised in warm wet conditions whether or not alkalis are present (see 5.6.1).

(b) *Attack by the formation of a chemical within the sewer itself.* The most common problem of this type is the effect on concrete sewers of the formation of hydrogen sulphide, within the sewage or sewage sludge, from sulphate under anaerobic conditions. This happens frequently in sewage pumping systems with a high retention period and in flat sewers and chambers where sludge settles and remains undisturbed for long periods. Release of sulphide into the air (for instance at the outfall manhole of a rising main) results in micro-biological oxidation of the hydrogen sulphide to sulphuric acid on the aerobic surfaces. The process, which is assisted by the organism Thiobaccillus Concretivorus, results in the replacement of aluminates and hydroxide in the cementitious material by sulphate and can occur after long periods and over considerable distances downstream of the point of discharge of rising mains containing septic sewage. The consequential loss of strength causes progressive failure, which is accelerated once reinforcement has become exposed.

17.6.3 *External attack.* External attack generally occurs as sulphate attack of cementitious materials by high sulphate bearing ground water. Leachates from coal and mineral working tips or tips containing industrial waste may exhibit low pH values resulting in the attack of cementitious materials.

17.6.4 *Prevention of chemical attack and remedial measures.* Prevention of chemical attack may take three distinct forms as follows.

(a) At the design stage, by the use of a resistant material and by the avoidance of structural forms and conditions which may cause, for example, septicity or turbulence.

(b) Remedial measures, as follows:

(1) lining with such materials as polyethylene, polypropylene, GRP and various composites;

(2) renewal and replacement of the affected material; pointing, rendering and guniting are examples of this;

(3) the amendment of consent conditions and/or the pre-treatment or balancing of the effluent before discharge to the sewer to prevent further damage.

(c) Trade effluent control, by the setting of reasonable consent conditions and consequential monitoring of subsequent discharge.

17.7 Tree roots

Roots may travel great distances and depths in search of moisture. Sewers above the water table, having only minute cracks, leaking joints or poorly made side connections are prone to penetration by roots.

Having penetrated the sewer the root will grow to cause an obstacle and may eventually exert sufficient force to break the pipe.

The methods which exist for the removal of tree roots fall generally into two categories.

(a) *Mechanical methods.* A whole range of cutting tools exist that can be attached to rodding machines or winches which will cut or tear the roots from inside the sewer. Rotary cutting tools are also available that attach to high pressure jetting machines.

(b) *Chemical methods.* A range of herbicides is becoming available which will inhibit growth in addition to killing the roots already present. Two of these chemicals, metham and dichlobenil are being used in the USA and tests there have proved that such treatment is far more successful than mechanical removal.

Unless the tree is removed completely, it is only a question of time before regrowth occurs. Chemical methods are claimed to inhibit growth as well as to remove it thus increasing the time before the problem recurs.

Prevention of root penetration can only be achieved by sealing infiltrating joints and cracks, relining or relaying the offending section of pipe.

17.8 Ground erosion

Ground erosion forming voids or interstices is usually caused by infiltration of groundwater into a sewer, but it can be caused by water main leakage.

The loss of fines from the soil into the sewer is prevalent in strata formed of sands and silts. These conditions are usually associated with river valleys and old buried channels.

Unless the infiltration causing voids is prevented the loss of material from around the sewer may ultimately cause its collapse, damage to other services, or subsidence of the ground surface.

Remedial work to prevent infiltration should include grout filling of cavities around the sewer. This is a specialized operation which may be done from inside a man entry sewer or where smaller sizes are involved by lancing down from the ground surface.

17.9 Infiltration and exfiltration

17.9.1 *Infiltration.* The ingress of water into a sewer through cracks, leaking joints or badly made lateral connections may be from rain percolating through the soil during a storm or from the groundwater if the sewer is temporarily or permanently lower than the water table.

Infiltration can cause all or some of the following:

(a) increased operating costs at pumping stations and treatment works;

(b) earlier captial expenditure on new plant, such as sewerage, pumping equipment or sewage treatment works;

(c) increased incidence of flooding;

(d) more frequent operation of overflows;

(e) surcharging, resulting in damage to sewers and manholes;

(f) removal of fines from the soil causing voids to form around the sewer;

(g) encrustation.

The location and measurement of infiltration can be achieved by planned surveys of flow measurement or by observation of night flows following rainstorms. A suitable delay period is necessary after the rainstorm has passed to allow for inflow from rainwater connections to pass through the system.

17.9.2 *Exfiltration.* Water leaking out of a sewer through faults in the pipework will usually occur when the sewer is above the water table and it is surcharged, although a broken pipe may exfiltrate in all flow conditions.

The major problem is the pollution of groundwater and local streams or rivers. Exfiltration may also result in the loss of self-cleaning velocities and the deposition of solids within the sewer. This can result in an increase in maintenance costs.

The rise and fall of the local water table may cause reversals of exfiltration and infiltration. The effect of this may be a pumping action which can accelerate the formation of voids in sands, silts and clays.

Appendices

Appendix A. British Standards that are relevant but not referred to in the text

The following is a list of British Standards not referred to specifically in this Part of BS 8005, but of interest as they deal with closely associated subjects. A list of publications referred to in the text appears on the inside back cover.

BS 4	Structural steel sections
BS 78	Specification for cast iron spigot and socket pipes (vertically cast) and spigot and socket fittings Part 2 Fittings
BS 308	Engineering drawing practice
BS 350	Conversion factors and tables
BS 587	Specification for motor starters and controllers
BS 599	Methods of testing pumps
BS 1211	Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage
BS 1377	Methods of test for soil for civil engineering purposes
BS 2035	Specification for cast iron flanged pipes and flanged fittings

Appendix B. Bibliography

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Appendix C. Legislation affecting the rights or duties of public authorities in connection with sewers

NOTE. See BS 8005 : Part 0 for more detailed account of legislation.

C.1 England and Wales

Public Health Act, 1936
Public Health (Drainage of Trade Premises) Act, 1937
*† Rural Water Supplies and Sewerage Acts, 1944 to 1971
Water Acts, 1945, 1973, 1983
*† Public Utilities (Street Works) Act, 1950
*† Coal Mining (Subsidence) Act, 1957
*† Land Power (Defence) Act, 1958
Highways Acts, 1959 to 1971
Radioactive Substances Act, 1960
Highways (Miscellaneous Provisions) Act, 1961

Public Health Act, 1961
Pipeline Act, 1962
*† Water Resources Acts, 1963 to 1971
*† Town and Country Planning Act, 1971
*† Local Government Act, 1972
*† Water Act, 1973
Land Compensation Act, 1973
*† Control of Pollution Act, 1985 — Part 2
* Health and Safety at Work Act, 1974
* Dumping at Sea Act, 1974
Local Government Act, 1974
* Salmon and Fresh Water Fisheries Act, 1975
Land Drainage Act, 1976
Water Charges Act, 1976
*† Local Government (Miscellaneous Provisions) Acts, 1953 and 1976
Building Regulations, 1976

* Also relevant in Scotland (see C.2).

† Only part of the Act relevant to sewerage.

C.2 Scotland

All references marked with an asterisk in C.1 are relevant together with the following.

Burgh Police Scotland Act, 1892
Public Health (Scotland) Act, 1897
Land Drainage (Scotland) Act, 1930
Rivers (Prevention of Pollution) (Scotland) Acts 1951/1965
Land Drainage (Scotland) Act, 1958
Flood Prevention (Scotland) Act, 1961
Sewerage (Scotland) Act, 1968
Land Compensation (Scotland) Act, 1973
Building Standards (Scotland) Regulations, 1971 to 1975

C.3 Northern Ireland

Land Power (Defence) Act, 1958
Radioactive Substances Act, 1960
Water Act (NI) 1972
Planning (NI) Order 1972
Water and Sewerage Services (Northern Ireland) Order, 1973
Drainage (Northern Ireland) Order, 1973
Pollution Control and Local Government Order 1978
Dumping at Sea Act, 1974
Building Regulations (Northern Ireland) 1977
Health and Safety (NI) Order 1978

Appendix D. Compaction fraction test for suitability of bedding material

D.1 Apparatus

D.1.1 *Open-ended cylinder*, 250 mm long and 150 $^{+10}_{-5}$ mm internal diameter (150 mm diameter PVC pipe is suitable).

D.1.2 *Metal rammer*, with striking face 40 ± 1 mm diameter and weighing 0.8 kg to 1.3 kg.

D.1.3 *Rule.*

D.2 Procedure

Obtain a representative sample more than sufficient to fill the cylinder (viz. about 10 kg). It is important that the moisture content of the sample should not differ materially from that of the main body of material at the time of its use in the trench.

NOTE. To obtain a representative sample about 50 kg of the proposed material should be heaped on a clean surface and divided with the spade down the middle into two halves. One of these should then be similarly divided, and so on until the required mass of sample is left.

Place the cylinder on a firm flat surface and gently pour the sample material into it, loosely and without tamping. Strike off the top surface level with the top of the cylinder and remove all surplus spilled material. Lift the cylinder up clear of its contents and place on a fresh area of flat surface. Place about one quarter of the material back in the cylinder and tamp vigorously until no further compaction can be obtained. Repeat with the second quarter, tamping as before, and so on for the third and fourth quarters, tamping the final surface as level as possible.

Measure down from the top of the cylinder to the surface of the compacted material. This distance, in millimetres, divided by the height of the cylinder (250 mm) is referred to as the compaction fraction.

D.3 Intepretation of results

The relationships between compaction fraction and suitability for use is as given in table 7.

Table 7. Compaction fraction

Compaction fraction	Suitability for use as bedding
0.15 or less	Material suitable
0.15 or 0.3	Material suitable but requires extra care in compaction. Not suitable if the pipe is subject to waterlogged conditions after laying
Over 0.3	Material unsuitable

Appendix E. Energy losses at manholes and bends

E.1 Manholes

Table 8 gives values of energy loss coefficient, k, derived from experiments on manholes where the sewer is surcharged. The energy losses when the sewer is only just full (i.e. with the flow confined by the manhole benching) will be less than those obtained using these coefficients. When the manhole incorporates a junction, the energy losses will be increased and will depend on the geometry of the junction and on the flows in the branches.

Table 8. Energy loss coefficient, k, for manholes

Plan shape of manhole	Type of manhole		
	Straight through	30° bend	60° bend
Rectangular	0.10	0.40	0.85
Circular	0.15	0.50	0.95

E.2 Circular bends

Table 9 gives values of k for 90° circular bends, flowing full, for various ratios of bend radius, R, to nominal pipe bore, D.

Table 9. Energy loss coefficient, k, at bends

Bend radius/pipe diameter R/D	k
0.5	1.0
1.0	0.25
1.5	0.18
2.0	0.16
5.0	0.18
10.0	0.24

The values given in table 9 apply when the straight length of pipe downstream from the bend is greater than 30 pipe diameters.

E.3 Mitre bends

The energy loss coefficient, k, for a single mitre bend is given by:

$$k = 1.4 \frac{\theta^2}{90}$$

where

θ is the bend angle (in degrees).

Table 10 gives the loss coefficient for a 90° lobster-back bend comprising 4/22.5°, 3/30°, or 2/45° mitre bends.

Table 10. Energy loss coefficient, k, for lobster-back bends

ℓ/D	4/22.5°	3/30°	2/45°
	Loss coefficient k		
0.5	0.40	0.45	0.55
1.5	0.25	0.30	0.40
3.0	0.32	0.35	0.48
6.0	0.32	0.37	0.50

NOTE 1. ℓ is the centreline length of one of the individual short pieces of pipe (which are all of equal length) from which the bend is made. D is the nominal pipe bore.

NOTE 2. The values given are for a rough pipe; the loss coefficients for a smooth pipe will be approximately 75 % of these values.

Appendix F. Closed circuit television surveys of sewers

The components of a basic closed circuit television survey system are as follows:

(a) a purpose-built television camera housed in a robust cylindrical case to isolate it from the sewer environment;

(b) a light source, often forming an integral part of the camera;

(c) a multicore cable for a low voltage power supply to the camera, standard wave profiles to circuitry, and signals functions under remote control;

(d) a camera control unit for operation of camera lights and remote functions (e.g. focussing, aperture adjustment);

(e) a television monitor for viewing the survey (this is commonly incorporated within the camera control unit);

(f) a camera for taking still photographs of the monitor screen.

Portable systems are available which may be transferred to a small vehicle for site operation. These are not suitable for prolonged site application under all-weather conditions; a purpose-built surveying unit then becomes essential. A purpose built unit houses the camera control unit and television monitor in a clean area (darkened to aid viewing), wherein the survey operator can produce his report and control survey progress. Safety equipment, manhole cover lifting gear, generators for powering survey equipment, a winding drum to store the camera cable, winches and ancillary equipment will be housed in a separate area.

More sophisticated components which are incorporated into some systems and/or included in the service of some contractors include the following.

(1) A device to measure the distance progressed by the camera, and to provide a continuous display of this reading at the control unit.

(2) The facility to display alpha-numeric data on the television monitor. This is commonly used to display sewer diameter, location and a contract reference number. It may also be linked to a distance measurement device and incorporate a digital clock. Additional information such as sewer flow and survey direction may also be shown.

(3) A range of interchangeable viewing heads to tailor the camera optics and lighting to different sewer diameters.

(4) A video tape recorder with which to record an entire survey or relevant extracts.

(5) A self-traction device upon which to mount the camera as an alternative to towing through the sewer using a winch.

(6) In combination with the television camera, a remote control photographic camera.

The survey operator either controls survey progress directly in the case of tractor surveys, or via communication (often UHF radio) with a remote winch operator. The camera can be halted at points of interest, the operator recording his observation against the distance progressed and (if in use) the position reached within a spool of video tape. A written survey report should be prepared; the audio track of a video tape recorder may be used for a supplementary verbal commentary. The operator can take photographs from the television monitor; these are generally of lower definition than those taken from the insertion of photographic cameras into the sewer. In modern systems, the length of sewer negotiable in one pass is limited only by the distance a line can be threaded, or, in the case of tractor surveys, by the distance over which traction can be maintained. In older designs, distances may be limited by signal/power loss in cables and cable weight.

Appendix G. Symbols for use in record maps

G.1 General

The information in this appendix is taken from 'Sewer and Water Mains Records. Standing Technical Committee Report No. 25' [23] and shows the symbols, colours and abbreviations for use on 1/1250 and 1/2500 scale record maps.

G.2 Sewerage

Private sewer	Foul	0.2 mm chain dot line: 10 mm dashes 5 mm apart, dots centred between dashes
	Surface water	0.2 mm chain line: 5 mm dashes 3 mm apart
	Combined	0.2 mm continuous line
Public sewer (including Section 24*)	Foul	0.5 mm chain dot line: 10 mm dashes 5 mm apart, dots centred between dashes
	Surface water	0.5 mm chain line: 5 mm dashes 3 mm apart
	Combined	0.5 mm continuous line
Main (trunk) sewer	Foul	1.0 mm chain dot line: 10 mm dashes 5 mm apart, dots centred between dashes
	Surface water	1.0 mm chain line: 5 mm dashes 3 mm apart
	Combined	1.0 mm continuous line
Sewers over 1000 mm		Optional. Pencil shading between lines
Rising main	Foul	Arrow shows direction of flow
	Surface water	0.2 mm, 0.5 mm or 1.0 mm as appropriate
	Combined	
Abandoned sewer		
Proposed sewer		Pencil line. Style as appropriate
Elevated sewer		Line weight and style as appropriate
Culverted watercourse		5 mm dashes 3 mm apart. 0.2 mm, 0.5 mm or 1.0 mm according to importance
Highway drain		5 mm dashes 3 mm apart. 0.2 mm, 0.5 mm or 1.0 mm according to importance
Section 18/24 Sewer*		0.5 mm line. Style as appropriate
Direction of flow		
Easement		0.2 mm. Lines denote width of easement
Manhole	Foul and combined	
	Surface water	
Backdrop	Foul and combined	
	Surface water	
Side entry	Foul and combined	
	Surface water	
Blind shaft	Foul and combined	
	Surface water	
Vent		
Vent column		
Lamp hole		
Watertight door		
Flushing chamber	Man entry	
	Non entry	
Penstock chamber		
Damboards		

* Sections 18 and 24 are Sections of the Public Health Act 1936, dealing respectively with the local authorities' powers of requisition for adoption of sewers and with their powers to recover the costs of maintenance of the sewers.

Storm overflow (weir)
LS = Low side weir
HS = High side weir
SP = Stilling pond
VT = Vortex
SY = Syphon
SR = Surcharge relief

Cascade

Gauging point

Change in size other than manhole

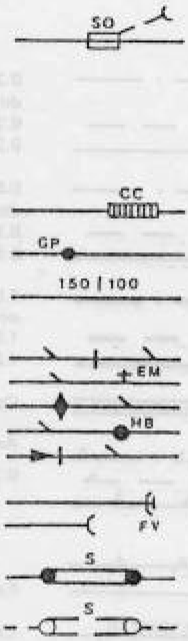
Valve
Emptying valve
Air valve
Hatch box
Reflux valve

(Emptying valve, Air valve, Hatch box, Reflux valve: on rising mains)

0.5 mm line

Flap valve
Outfall

Syphon
Foul and combined
Surface water



Use of colour
If it is required to adopt colour to enhance the presentation of the maps (e.g. Adoptions, PUSWA design, etc.) the following colours should be used.

Foul water sewer	— Brown
Surface water sewer	— Dark blue
Combined sewer	— Red
Watercourses	— Light blue
Building over/Easements	— Orange
Property not connected	— Yellow

Installations (All installations should be named and/or reference number quoted)

Pumping Station

Sewage ejector

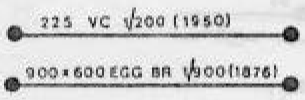
Sewage treatment works

Line delineates site boundary

Notes along pipelines

Circular pipeline

Other than circular



Diameter, material, gradient (year laid)

Dimensions, shape, material, gradient (year laid)

For pressure pipes see water mains

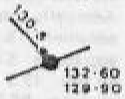
Names of sewers
The title of the sewer and branch should be shown in full whenever space permits, otherwise it should be abbreviated.

Dimensions
All pipe dimensions are to be nominal metric (e.g. 12 inches = 300 mm) excepting for imperial rising mains which should continue to be labelled in inches.

Levels

The cover level and invert level of the outgoing pipe should be printed alongside the manhole thus:

When an incoming pipe enters via a backdrop, the invert level should be written along the incoming pipe thus:



Levels should be in metres and related to Ordnance Survey (Newlyn) Datum

Reference Numbers

Reference numbers should be enclosed in an ellipse thus: (B14)

G.3 Materials

Alkathene	AK
Asbestos-cement	AC
Brick	BR
Cast Iron (pipes only) For plate construction add PL. For segment construction add SEG.	CI
Spun (Grey) Iron	SI
Concrete	CO
Concrete Segments Bolted or Unbolted	CS (B) or CS (U)
Concrete Box Culvert	CC
Ductile Iron	DI
Glass Reinforced Concrete	GRC
Glass Reinforced Plastics	GRP
Plastic/Steel composite	PSC
(Unplasticized) Polyvinyl Chloride	(u) PVC
Polyethylene	PE
Reinforced Plastics Matrix	RPM
Steel	ST
Vitrified Clay	VC

G.4 Linings

Cement	CL
Bitumen	BL
Resin	RL
Plastics	PL

When other materials are used for linings the suffix 'L' should be used.

Index

Publications referred to

BS 12 Specification for ordinary and rapid-hardening Portland cement
BS 65 Specification for vitrified clay pipes, fittings and joints
BS 146 Specification for Portland-blastfurnace cement
BS 437 Specification for cast iron spigot and socket drain pipes and fittings
BS 486 Specification for asbestos-cement pressure pipes and joints
BS 497 Specification for manhole covers, road gully gratings and frames for drainage purposes
BS 534 Specification for steel pipes and specials for water and sewage
BS 729 Specification for hot dip galvanized coatings on iron and steel articles
BS 812 Testing aggregates
BS 882 Specification for aggregates from natural sources for concrete
BS 915 Specification for high alumina cement
BS 1047 Specification for air-cooled blastfurnace slag aggregate for use in construction
BS 1194 Specification for concrete porous pipes for under-drainage
BS 1196 Specification for clayware field drain pipes
BS 1199 and 1200 Specification for building sands from natural sources
BS 1247 Specification for manhole step irons
BS 1370 Specification for low heat Portland cement
BS 1387 Specification for screwed and socketed steel tubes and tubulars and for plain end steel tubes suitable for welding or for screwing to BS 21 pipe threads
BS 1449 Steel plate, sheet and strip
Part 1 Specification for carbon and carbon-manganese plate, sheet and strip
BS 1868 Specification for steel check valves (flanged and butt-welding ends) for the petroleum, petrochemical and allied industries
BS 1972 Specification for polythene pipe (Type 32) for above ground use for cold water services
BS 1973 Specification for polythene pipe (Type 32) for general purposes including chemical and food industry uses
BS 2494 Specification for elastomeric joint rings for pipework and pipelines
BS 2989 Specification for continuously hot-dip zinc coated and iron-zinc alloy coated steel: wide strip, sheet/plate and slit wide strip
BS 3148 Methods of test for water for making concrete (including notes on the suitability of the water)
BS 3284 Specification for polythene pipe (Type 50) for cold water services
BS 3411 Method for the determination of the tensile properties of individual textile fibres
BS 3416 Specification for black bitumen coating solutions for cold application
BS 3505 Specification for unplasticized polyvinyl chloride (PVC-U) pressure pipes for cold potable water
BS 3506 Specification for unplasticized PVC pipe for industrial uses
BS 3656 Specification for asbestos-cement pipes, joints and fittings for sewerage and drainage
BS 3892 Pulverized-fuel ash
Part 2 Specification for pulverized-fuel ash for use in grouts and for miscellaneous uses in concrete
BS 3921 Specification for clay bricks
BS 4027 Specification for sulphate-resisting Portland cement
BS 4118 Glossary of sanitation terms
BS 4147 Specification for bitumen-based hot-applied coating materials for protecting iron and steel, including suitable primers where required
BS 4211 Specification for steel ladders for permanent access to chimneys, other high structures, silos and bins
BS 4246 Specification for low-heat Portland-blastfurnace cement
BS 4248 Specification for supersulphated cement
BS 4346 Joints and fittings for use with unplasticized PVC pressure pipes
Part 1 Injection moulded unplasticized PVC fittings for solvent welding for use with pressure pipes, including potable water supply
Part 2 Mechanical joints and fittings, principally of unplasticized PVC
BS 4360 Specification for weldable structural steels
BS 4449 Specification for hot rolled steel bars for the reinforcement of concrete
BS 4461 Specification for cold worked steel bars for the reinforcement of concrete
BS 4466 Specification for bending dimensions and scheduling of reinforcement for concrete
BS 4482 Specification for cold reduced steel wire for the reinforcement of concrete
BS 4483 Specification for steel fabric for the reinforcement of concrete
BS 4486 Specification for hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete
BS 4622 Specification for grey iron pipes and fittings
BS 4625 Specification for prestressed concrete pressure pipes (including fittings)
BS 4660 Specification for unplasticized PVC underground drain pipe and fittings
BS 4667 Breathing apparatus
Part 1 Closed-circuit breathing apparatus
Part 2 Open-circuit breathing apparatus
Part 3 Fresh air hose and compressed air line breathing apparatus
Part 4 Specification for escape breathing apparatus
BS 4772 Specification for ductile iron pipes and fittings
BS 4942 Short link chain for lifting purposes
Part 2 Specification for grade M (4) non-calibrated chain
BS 4991 Specification for propylene copolymer pressure pipe
BS 5075 Concrete admixtures
BS 5178 Specification for prestressed concrete pipes for drainage and sewerage
BS 5304 Code of practice. Safeguarding of machinery
BS 5328 Methods for specifying concrete, including ready-mixed concrete

BS 5391	Specification for acrylonitrile-butadiene-styrene (ABS) pressure pipe
BS 5400	Steel, concrete and composite bridges
	Part 2 Specification for loads
	Part 4 Code of practice for design of concrete bridges
BS 5480	Specification for glass fibre reinforced plastics (GRP) pipes and fittings for use for water supply or sewerage
	Part 1 Dimensions, materials and classification
	Part 2 Design and performance requirements
BS 5481	Specification for unplasticized PVC pipe and fittings for gravity sewers
BS 5493	Code of practice for protective coating of iron and steel structures against corrosion
BS 5555	Specification for SI units and recommendations for the use of their multiples and of certain other units
BS 5572	Code of practice for sanitary pipework
BS 5628	Code of practice for use of masonry
BS 5775	Specification for quantities, units and symbols
BS 5896	Specification for high tensile steel wire and strand for the prestressing of concrete
BS 5911	Precast concrete pipes and fittings for drainage and sewerage
	Part 1 Specification for pipes and fittings with flexible joints and manholes
	Part 2 Specification for inspection chambers and street gullies
	Part 3 Specification for pipes and fittings with ogee joints
BS 5930	Code of practice for site investigations
BS 5955	Plastics pipework (thermoplastics materials)
	Part 6 Code of practice for the installation of unplasticized PVC pipework for gravity drains and sewers
BS 6031	Code of practice for earthworks
BS 6073	Precast concrete masonry units
BS 6076	Specification for tubular polyethylene film for use as protective sleeving for buried iron pipes and fittings
BS 6087	Specification for flexible joints for cast iron drainpipes and fittings (BS 437) and for cast iron soil, waste and ventilating pipes and fittings (BS 416)
BS 6100	Glossary of building and civil engineering terms
BS 6209	Specification for solvent cement for non-pressure thermoplastics pipe systems
BS 6297	Code of practice for design and installation of small sewage treatment works and cesspools
BS 6437	Specification for polyethylene pipes (type 50) in metric diameters for general purposes
BS 8004	Code of practice for foundations
BS 8005	Sewerage
	Part 0 Introduction and guide to data sources and documentation
	Part 2 Guide to pumping stations and pumping mains
	*Part 3 Sewers in tunnel
	Part 4 Guide to design and construction of outfalls
	*Part 5 Rehabilitation of sewers
BS 8110	Structural use of concrete
BS 8301	Code of practice for building drainage
CP 312	Code of practice for plastics pipework (thermoplastics material)
	Part 1 General principles and choice of material
	Part 2 Unplasticized PVC pipework for the conveyance of liquids under pressure
DD 76	Precast concrete pipes of composite construction
	Part 1 Precast concrete pipes strengthened by continuous alkali-resistant glass fibre rovings
	Part 2 Precast concrete pipes strengthened by chopped zinc-coated steel fibres

* In preparation

This British Standard, having been prepared under the direction of the Civil Engineering and Building Structures Standards Committee, was published under the authority of the Board of BSI and comes into effect on 23 December 1987.

First published, as CP 2005, December 1968
First Part revision, as BS 8005 : Part 1,

ISBN 0 580 15991 4

The following BSI references relate to the work on this standard:
Committee reference CSB/5 Draft for comment 84/11181 DC

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Civil Engineering and Building Structures Standards Committee (CSB/–) to Technical Committee CSB/5, upon which the following bodies were represented:

Association of Consulting Engineers
Association of County Councils
Association of District Councils
British Ceramic Research Ltd.
British Coal
British Plastics Federation
British Precast Concrete Federation Ltd.
British Tunnelling Society
Clay Pipe Development Association Limited
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Institution of Public Health Engineers
Institution of Structural Engineers
Institution of Water Engineers and Scientists
Royal Institute of British Architects
Scottish Development Department
Trades Union Congress
Water Authorities Association
Water Research Centre

Amendments issued since publication

Amd. No.	Date of issue	Text affected

BS 8005 : Part 1 : 1987

British Standards Institution · 2 Park Street London W1A 2BS · Telephone 01-629 9000 · Telex 266933