CODE OF PRACTICE ON MONITORING AND MAINTENANCE OF WATER-CARRYING SERVICES AFFECTING SLOPES

Environment, Transport and Works Bureau
The Government of the Hong Kong Special Administrative Region
Second Edition
November 2006

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FOREWORD

The first edition of this Code of Practice was published in 1996 which gave guidance on monitoring and maintenance of water-carrying services that might affect slopes. It was prepared under the direction of the Standing Committee on Slope Safety chaired by the then Works Branch in response to a recommendation made by Professor Morgenstern, an international geotechnical expert, in his report on the Kwun Lung Lau Landslide in 1994.

With the passage of a decade, the Geotechnical Engineering Office of the Civil Engineering and Development Department has conducted a comprehensive review with the objective of updating the Code to meet present day needs. In doing so, it has set up a Working Group comprising representatives from the Hong Kong Institution of Engineers, the Hong Kong Institute of Utility Surveyors and various government departments. It has also conducted wide consultation among professional bodies, property management companies, property development firms, consulting engineers, contractors and academics so that their valuable views could be gauged. This second edition represents the hard work of all concerned and I would like to take this opportunity to express my deepest gratitude to them.

We encourage all engineers and professional practitioners to implement the good practice presented in this Code. It is only through our concerted effort that we can eliminate failure of water-carrying services, thus significantly enhancing the stability and maintenance standards of slopes in Hong Kong.

(MAK Chai-kwong)
Permanent Secretary for
the Environment, Transport and Works (Works)

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1. INTRODUCTION

1.1 BACKGROUND

In this Code of Practice, water-carrying services refer to conduits, exposed or buried, used for carrying water. These include sewers, stormwater drains and water mains. Leakage of water from water-carrying services can be a serious risk to the stability of slopes and retaining walls even at some distance away, as in the case of the fatal Kwun Lung Lau Landslide of 23 July 1994 (GEO, 1994).

Professor Morgenstern in his report on the Kwun Lung Lau Landslide (Morgenstern, 1994) recommends:

> *"The Government should develop a program for direct monitoring and repair of buried services at housing estates and other developments in all cases where leakage might impact on slope stability. Priority should be given to older estates where loose fill is known to have been used in site development. Periodic inspection of buried services at hazardous locations should become mandatory. The appropriate period is best established by experience, but a five-year interval appears reasonable at this stage."*

The first edition of this Code of Practice was published in 1996 in response to this recommendation.

This second edition has consolidated experience gained in the past years on the monitoring and maintenance of water-carrying services, and lessons learnt from landslide incidents in which leakage of water-carrying services was involved. The landslide incidents and the lessons learnt are documented in the GEO Landslide Study Report No. LSR 7/2005 (Hui et al, 2005). The second edition has been prepared with the support of a Working Group comprising representatives from the Hong Kong Institution of Engineers, the Hong Kong Institute of Utility Surveyors and various government departments. The membership of the Working Group is given in Appendix A.

For ease of reference, in this Code, sewers and stormwater drains are collectively referred to as drains, and slopes and retaining walls are referred to as slopes.

1.2 OBJECTIVE AND SCOPE

The purpose of this Code of Practice is to give guidance on monitoring and maintenance of water-carrying services affecting slopes. Monitoring encompasses inspection and leak detection of water-carrying services. For guidance on slope maintenance, reference should be made to Geoguide 5 (GEO, 2003).

Chapter 2 describes the basic policies adopted for monitoring of water-carrying services affecting slopes. It gives recommendations on the frequency of monitoring.

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Chapter 3 provides guidance on the extent and planning of monitoring of water-carrying services. Methods for locating alignments of existing water-carrying services are discussed. The importance of record keeping is highlighted.

Chapter 4 provides guidance on monitoring of water-carrying services. It outlines some methods that are commonly used for inspection and leak detection of water-carrying services. This Chapter also highlights requirements related to safe implementation of monitoring and maintenance of water-carrying services.

Chapter 5 gives guidance on investigation of suspected leakage. It suggests a number of chemical and physical tests for assessing the source of leakage.

Chapter 6 describes the requirements for the personnel who carry out the inspection and leak detection of water-carrying services. It provides guidance on quality control on the monitoring of water-carrying services.

Chapter 7 describes some common methods of repairing water-carrying services.

Chapter 8 gives guidance on preventive measures to reduce the impact of leakage of water-carrying services on the stability of slopes.

Chapter 9 lists the sources of information that are relevant and useful to the readers.

1.3 MAINTENANCE RESPONSIBILITY FOR WATER-CARRYING SERVICES

Public water-carrying services such as drains and water mains are maintained by the Government of the Hong Kong Special Administrative Region (HKSARG).

For private water-carrying services, the maintenance responsibility rests with their owners, or is conferred to specific parties through legal instruments such as lease documents, conditions of grant, conditions of sale, and conditions of exchange issued by the Lands Department. The public may gain access to these legal documents at the Land Registry.

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2. BASIC POLICIES

2.1 GENERAL

Leakage from water-carrying services may cause failure of a slope even without any notable signs of leakage at the ground surface. Where the consequence of slope failure is high, i.e. a slope of consequence-to-life Category 1 or 2 as defined in Works Bureau Technical Circular No. 13/99 (Works Bureau, 1999), the water-carrying services should be monitored regularly to identify leakage, so that they could be repaired or replaced where needed.

Guidance on the assessment of the consequence-to-life category of a slope is given in Works Bureau Technical Circular No. 13/99 (Works Bureau, 1999) and GEO Technical Guidance Note No. 15 (GEO, 2004).

Drains affecting fill slopes should usually be monitored using Closed Circuit Television (CCTV) or other appropriate means at least once every five years. The frequency could be appropriately relaxed if the fill is known to have been adequately compacted such that significant ground movement is unlikely or if these water-carrying services could accommodate significant ground movement without leakage. The relaxed frequency should not be less than once every ten years.

Drains affecting other types of slopes should be monitored at least once every ten years, supplemented by an interim visual inspection.

Water mains affecting slopes should be monitored at least once every five years.

Monitoring actions should also be arranged on water-carrying services affecting slopes where there is evidence of suspected leakage, or when their existence is first identified. Examples of evidence of suspected leakage include reports of leaking drains from maintenance inspection of slopes, flow with foul odour from slopes, abnormal quantity of water flow in dry season, excessive ground movement, and possible disturbance by construction activities in the vicinity.

Drains or water mains requiring repeated repair or replacement may indicate ground movement which may be too gradual to be noticed visually. These instances, as well as the more obvious case of pipe ruptured due to ground movement, should be reported to the Geotechnical Engineering Office. This is a good practice that should be applied to all drains and water mains irrespective of location, i.e. whether man-made slopes or natural hillsides are affected or not.

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3. PLANNING AND RECORD KEEPING

3.1 WATER-CARRYING SERVICES TO BE MONITORED AND MAINTAINED

Leakage from water-carrying services on and in the area behind a slope affects the stability of the slope. There is no hard and fast rule on the extent of this area; it depends on the hydrogeological conditions of the ground, the nature of the slope, and the type of pipes. As a minimum, the area should be taken as a strip of land adjacent to the crest of the slope with a width equal to the maximum vertical height of the slope. The width of this strip should be extended where the water-carrying services are known to be leakage-prone, e.g. pipes that are intolerable of ground settlement or disturbance, or water-carrying services with a record of leakage.

Leakage from water-carrying services may travel far in the presence of preferential flow paths, as in the case of the Kwun Lung Lau Landslide of 1994 (GEO, 1994) (see Appendix B for the probable failure mechanism). Examples of ground conditions giving rise to preferential flow paths are loose fills and colluvial deposits overlying less permeable soil and decomposed rock. Taking the experience of the Kwun Lung Lau Landslide, all water-carrying services within a body of loose fill that extends to a slope should be monitored and maintained. Information on sizeable man-made slopes can be obtained from the Slope Information System maintained by the Geotechnical Engineering Office of the Civil Engineering and Development Department or from the maintenance manuals of the slopes.

3.2 PLANNING FOR MONITORING AND MAINTENANCE

3.2.1 Checking Past Records of Water-carrying Services

The first step in planning monitoring action in an area is to identify and locate all water-carrying services affecting slopes. Details of public water-carrying services can be obtained from various government departments, as described in Chapter 9.

Information of private water-carrying services may also be held by the owners or their agents such as the owners' corporations and property managers.

Information of water-carrying services should be verified by site inspections for obvious errors and possible uncharted or unrecorded water-carrying services in the ground. Where necessary, geophysical investigations and trial pits may be carried out to verify and update the plan and associated information. This is especially important for private water-carrying services, and those involving old developments where reliable records of the water-carrying services cannot be found.

3.2.2 Methods to Locate Existing Water-carrying Services

Visible utility installations on ground surface (e.g. valve chambers and manholes) can give some indication of the existence of water-carrying services and their alignment. The depth of the water-carrying services can be estimated by measuring the invert of the chambers,

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pits or manholes. Circumstantial evidence, such as abandoned old developments or squatter dwellings near the slope, may indicate the possible presence of uncharted or unrecorded water-carrying services.

Geophysical surveys such as electromagnetic induction and ground probing radar methods can also be used to locate water-carrying services. Relevant photographs of the electromagnetic type and radar scan type equipment are shown in Appendices C and D respectively.

The accuracy of detection equipment is affected by utility density, interference from other nearby utilities or objects, soil conductivity, soil moisture and soil temperature, unusual pipe dimensions and experience of the equipment operator. Detection equipment can offer some assistance in reducing damage to underground services but none of the equipment currently in use is infallible. In short, the geophysical survey methods described above can be a useful auxiliary tool for locating the alignment and cover depth of existing underground services provided that adequate number of trial pits are dug to verify the results.

Excavation of trial pits is the most reliable means to confirm the exact locations of the water-carrying services when their approximate locations are known. Attention is drawn to safety measures to ensure slope stability when excavating trial pits on or above a slope. Reference to Geoguide 2 "Guide to Site Investigation" (GCO, 1987) should be made in this regard.

3.3 KEEPING OF RECORDS

3.3.1 Inventory and As-built Records

To facilitate future monitoring and maintenance of all newly-constructed water-carrying services, accurate as-built records of these services should be produced.

For private developments, the Authorized Persons or Registered Structural Engineers or Registered Geotechnical Engineers should provide as-built records of the water-carrying services to the Buildings Department. These should include necessary updating of those building plans, drainage plans and site formation plans submitted to government departments. Such information should be incorporated in the slope and retaining wall record plans referred to in Practice Note for Authorized Persons and Registered Structural Engineers No. 168 (BD, 2002). Copies should be distributed to the developers as well as the owners' corporations and property managers who will take over the future maintenance of the water-carrying services.

For all newly-constructed drains handed over to the Government for maintenance, as-built drawings in diazo should be passed to the Drainage Services Department for retention and incorporation into the existing drainage record drawings. All manhole positions with details of reference numbers, cover levels, invert levels, diameters and the directions of all the connecting pipes should be shown on the drawings. A sample as-built record of constructed drains is given in Figure 3.1. For all other special installations and special manholes, as-built drawings showing the details of the above special drainage installations, and operation and maintenance manuals are also required. Electronic file of each as-built

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drawing in CD-ROM should be provided, if available. The hydraulic and structural calculations should also be provided to supplement the drawings.

For all newly-constructed water mains to be handed over to the Government for maintenance, as-built drawings in an agreed format should be submitted to the Water Supplies Department for incorporation into the existing water mains record drawings. A sample as-built record of constructed water mains is given in Figure 3.2.

3.3.2 Inspection And Maintenance Records

For works carried out during maintenance activities, as-built surveys should be carried out on completion of the works. All changes in levels, positions and sizes should be surveyed and the results should be incorporated into the drainage records.

All records of monitoring and subsequent maintenance works should be kept by the owner. Moreover, it is advisable to keep duplicate copies of all records by the agent appointed by the owner and/or the party required to maintain the water-carrying services. To avoid the loss of records of monitoring and subsequent maintenance for private installations due to change of ownership, a copy of the records should be kept by owners' corporations, maintenance agents and property managers. Consideration should be given to keeping such records in an electronic form for effective record management.

Comprehensive and accurate record-keeping is important for good maintenance management. The format of these routine monitoring and maintenance records should be designed to suit the particular circumstances in hand. These records may have to be completed in two stages, namely, on completion of routine monitoring and on completion of maintenance works.

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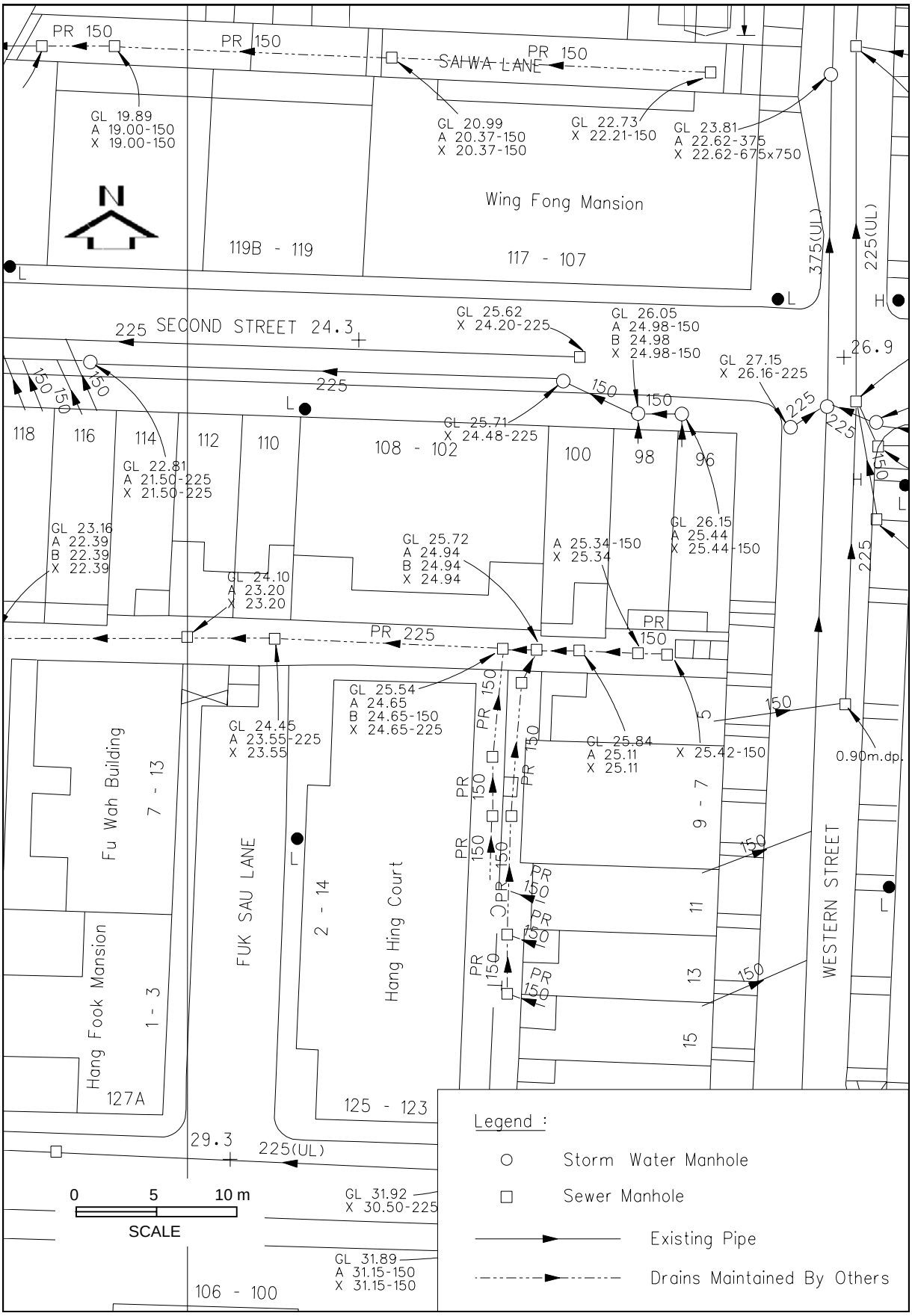

Figure 3.1 Sample As-built Record of Constructed Drains

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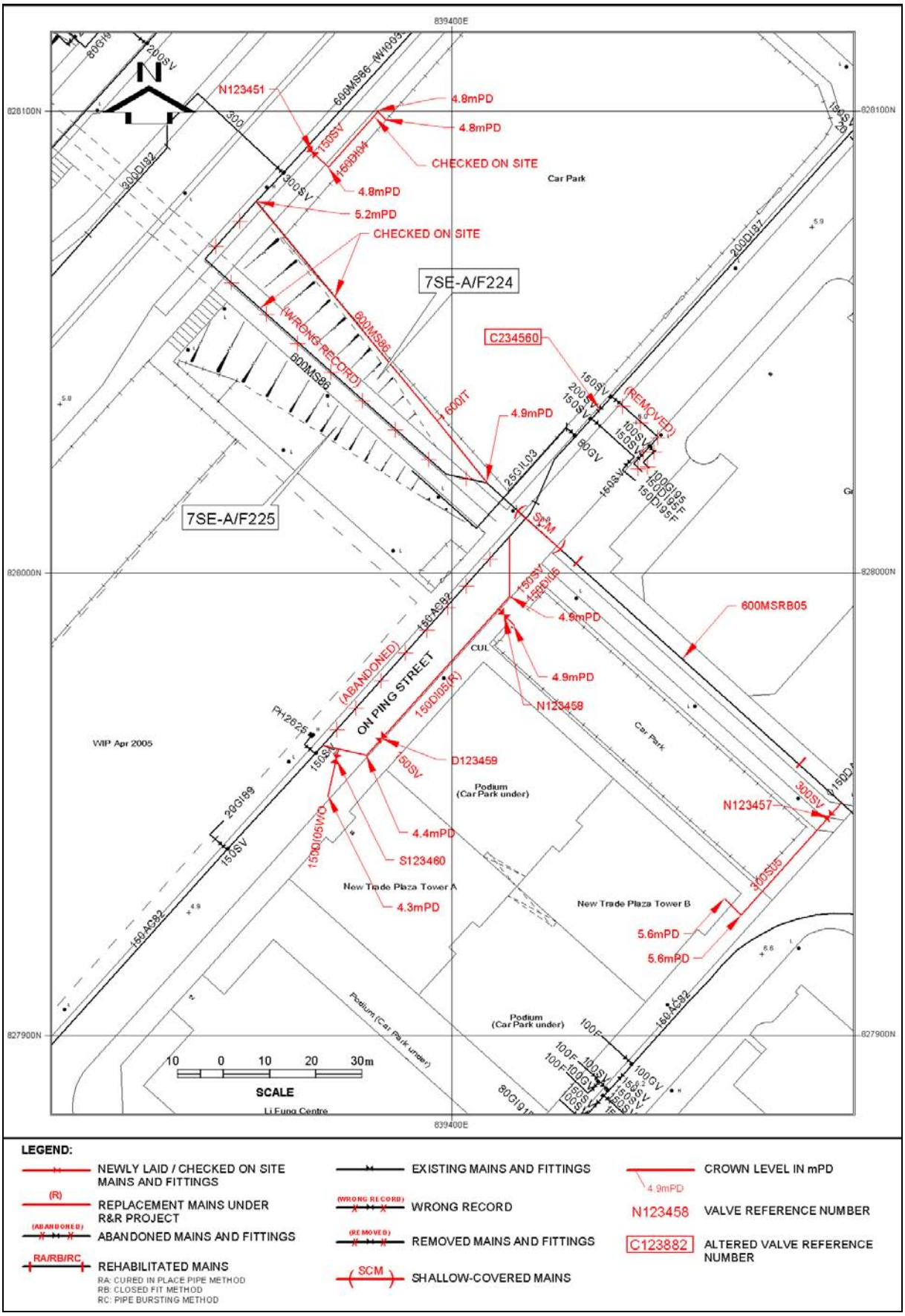

Figure 3.2 Sample As-built Record of Constructed Water Mains

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4. INSPECTION AND LEAK DETECTION

4.1 INSPECTION AND LEAK DETECTION FOR DRAINS

4.1.1 General

Drains should be inspected regularly for blockage, leakage and structural soundness. The condition of drains can be checked by inspecting the water levels and silt depth in manholes.

CCTV survey and other appropriate means should be arranged for the drains if blockage, leakage or reduced structural soundness is suspected.

4.1.2 Closed Circuit Television Survey

CCTV is considered to be one of the most effective methods for inspecting the physical condition of drains, including the internal structural condition, service condition, infiltration, joint movement or other signs which may indicate leakage. Most of the drainage contractors have the capability of carrying out CCTV inspections on pipes up to 1500 mm diameter. Some have the capability to inspect drains up to 3400 mm diameter.

CCTV cameras are capable of 360-degree pan, tilt and zoom, and some can incorporate an inclinometer so that the variations in gradient can be measured.

The water flow along the pipeline during the CCTV survey should be controlled, say to keep the water level below 30% of the maximum vertical dimension of the drain. Over-pumping may be carried out if the flow quantity is high. The CCTV camera should have suitable illumination and be capable of providing an accurate and clear record of the drain's internal condition. Pipes should be cleansed prior to the survey. However, an initial inspection may be necessary in some cases to detect any collapsed section prior to cleansing. Any leakage from the cleaning process would adversely affect the slopes in the proximity.

A sample specification for CCTV survey is given in Appendix E. Some examples of common types of pipe defects are shown in Appendix F. The adoption of the specifications and the defect coding system given in the Manual of Sewer Condition Classification (Water Research Centre, 2004), as well as the ranking score and defect grading systems given in the Sewerage Rehabilitation Manual (Water Research Centre, 2001), are recommended for reporting. If considered appropriate and necessary, the coded data should be provided in a standard electronic format for entry into a database system. The drain condition classification may be modified to suit the local conditions. In this regard, reference could be made to the Hong Kong Institute of Utility Surveyors' publications.

Should it be necessary to determine the priority of remedial works, though it is preferable to complete all works promptly, the scoring and pipe condition grading systems as detailed in the Sewerage Rehabilitation Manual (Water Research Centre, 2001) may be referred to.

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4.1.3 Water Testing

A water test on drains may be carried out to test their water tightness as per Clause 5.101 of General Specification (GS) for Civil Engineering Works, Volume 1 (HKG, 1992). The method of testing is described in Appendix 5.4 and Appendix 5.5 of the same GS (HKG, 1992).

4.1.4 Manhole Survey

The objective of manhole surveys is to check and verify the position of the manhole structure against any existing records, to record all salient features such as reference number, cover and invert levels of the manhole, and the diameters, flow directions and shapes of all the connecting pipes, etc. The survey should also assess the structural and surface condition of the manholes, and look for any evidence of leakage or infiltration. A sample specification for manhole survey is given in Appendix G.

4.1.5 Man-entry Inspection

For pipes with internal diameter exceeding 1500 mm or larger, man-entry inspection may be carried out if safety can be assured. However, it must be emphasised that working in a confined space can be hazardous, especially in foul sewers where lethal gas can be emitted by septic sewage and sludge. As such, man-entry inspection to foul sewers should be discouraged. In the event that no alternative is available, proper arrangements should be made to ensure the safety of the person entering the pipe.

4.2 LEAK DETECTION FOR WATER MAINS

For public water mains, the Water Supplies Department uses mechanical and electronic leak detectors, noise loggers and leak noise correlators to locate or pin-point possible leaks. Leak detection equipment is shown in Appendix H. A sample specification for leak detection works is given in Appendix I.

Water mains, exposed or buried at shallow depth without any paving, can be inspected visually at the ground surface along their alignments; any leakage will cause apparent localised wet spots. Valve chambers can be inspected for any signs of leakage. Closing the upstream valve will immediately reduce the rate of leakage.

For water mains within private lots, private owners should engage experienced personnel to carry out leak detection. Water meters may be installed at the check meter positions of the water mains to detect leakage while keeping all outlets closed.

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4.3 SAFETY MEASURES

Like other construction activities, all personnel involved in planning and undertaking monitoring and maintenance of water-carrying services should comply with all safety and health related legislations, codes of practice and guides relevant to the works, to ensure the safety of the workers as well as the public. Reference should be made to the Factories and Industrial Undertakings Ordinance (HKSARG, 1997a) and Construction Sites (Safety) Regulations (HKSARG, 1997b) in this regard.

Working within the confined spaces associated with drains can be hazardous. The gases emitted by sewage can be lethal. Drains may contain industrial wastes making it impossible to predict what gases may be present. Injuries may occur by falling, slipping or misuse of tools and equipment. Sewer workers are also subject to the additional hazard of the sudden inrush of high flows, especially under adverse weather conditions, or a sudden release of toxic, corrosive or hot liquid. In this regard, reference should be made to the Code of Practice: Safety and Health at Work in Confined Spaces (LD, 2000) and the guidelines laid down by the relevant departmental safety manuals and rules to ensure a safe working environment. Safety precautions for diving should be in accordance with the Code of Practice: Safety and Health at Work for Industrial Diving (LD, 1998). Whenever it is difficult to ensure a safe working condition for man-entry inspection, CCTV inspection should be used instead.

Additionally, for monitoring and maintenance of the water-carrying services that involves activities along the roadside, all relevant legislations, codes of practice and guides relevant to the works should be complied with, to ensure safety of the road users and minimal disturbance to the traffic. Reference should be made to the Land (Miscellaneous Provisions) Ordinance (HKSARG, 1997c) in this regard.

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5. INVESTIGATION OF SUSPECTED LEAKAGE

5.1 GENERAL

When leakage of water-carrying services is suspected to be affecting a slope, in the form of localised seepage on the slope surface, field observations and tests on the seepage water would help to identify the likely source of the seepage.

5.2 OBSERVATIONS ON SEEPAGE WATER

The physical characteristics of leakage may give some clues to the type of water sources as follows:

(a) Sewage pipe leakage - turbid, smelly, continuous, white grey slime; could swell out in large quantity if from a large diameter rising main.

(b) Stormwater drain leakage - clear, leaking during and after rainy days.

(c) Salt water pipe leakage - clear, continuous, leakage confined to isolated spots, contains high chloride content.

(d) Potable water pipe leakage - clear, continuous, leakage confined to isolated spots.

In comparison, natural groundwater seepage is usually clear, almost continuous particularly during the wet season and seeping over a large area below a certain level.

The above characteristics assigned to leakage and natural groundwater seepage are broad generalisations, not hard and fast rules. Further verifications will be necessary for the avoidance of doubt. Such verifications include, but are not limited to, laboratory chemical tests as well as physical tests on site.

5.3 CHEMICAL AND PHYSICAL TESTING

When leakage is suspected to originate from either a fresh water supply system or a salt water supply system, confirmation tests should be undertaken on site as follows.

A diethyl paraphenylene diamine (DPD) tablet is used for testing fresh water supply systems. The tablet is dissolved in the water sample contained in a cell of standard volume. Normally, the development of a slight pinkish colour in the water sample will indicate the presence of chlorine in the water and hence the possibility that it is from a fresh water supply system. The degree of pinkness of the water may be used to give an indication of the concentration of chlorine present in the sample by comparison with a colour comparator.

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A chloride test (Merck) strip is used for testing salt water supply system. All the reddish brown reaction zones of the strip are immersed in the water sample for about 1 second. Normally, the discolouration of the reddish brown reaction zones will indicate the presence of chloride in the water and hence the possibility that it is from a salt water supply system. The colour pattern of the reaction zones may be used to give an indication of the concentration of chloride in the water by comparison with the colour rows of the label on the test strip bottle.

In general the above tests are adequate for the identification of the nature of water source from a fresh or salt water supply system. However, the results can be misleading if the fresh/salt water samples have been contaminated at the source. In case of doubt, reference water samples should be collected from the fresh/salt water supply system nearby, for parallel chemical tests in the laboratory with samples of the seepage water.

Apart from the possibility of contamination of groundwater seepage, the accuracy of the test results will depend on the sampling procedures. It is desirable that samples should be taken by experienced personnel, and laboratories accredited by the Hong Kong Laboratory Accreditation Scheme (HOKLAS) should be used to carry out the chemical tests.

It is also possible to identify the source of leakage by carrying out some simple physical tests on site. For drains, a dye test can be performed to check for leakage. Suitable dye solution is added to the flow through an upstream manhole and observations may be made as to whether or not any dye appears in the discharge.

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6. QUALITY CONTROL ON MONITORING OF WATER-CARRRYING SERVICES

6.1 TRAINING AND EXPERIENCE REQUIREMENTS FOR PERSONNEL

Monitoring of water-carrying services often requires the use of special equipment and demands judgment based on information available. Personnel taking part in the monitoring should be suitably experienced and trained. Table 6.1 gives indicative guidelines.

A trial test may be required to demonstrate the ability of the proposed teams and the suitability of the equipment and methods before commencement of the inspection and leak detection.

6.2 QUALITY CONTROL OF MANHOLE AND CCTV SURVEY

Since the recommendations for the subsequent repair works are based on the findings of the surveys, quality checks should be performed on the results of the inspection. The following quality check practices are recommended for surveys involving a large number of manholes and drains:

(a) validate data collected from surveys; and/or

(b) re-survey a number of randomly selected manholes and sections of drains that have been inspected.

Data validation for manhole surveys should include items such as missing data, inconsistent pipe sizes, inconsistent invert levels, connectivity, etc.

6.3 QUALITY CONTROL OF LEAK DETECTION FOR WATER MAINS

The quality of leak detection in locating leaks in a water main may be checked by exposing the section of water main at the suspected leak location for verification. In addition, the following quality check methods may be adopted for leak detection works carried out, depending on the scale of works:

(a) install identification tags randomly inside the valve chambers along the sections of water mains to be surveyed and request the contractor to report immediately on the findings of the tags during the course of the leak detection works; and/or

(b) re-survey a number of randomly selected sections of the water mains that have been surveyed either by an independent qualified leak detection specialist or by using alternative instrument, such as noise loggers, if appropriate.

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Table 6.1 Training and Experience Requirements for Personnel Carrying Out Inspection and Leak Detection of Water-carrying Services

Type of Personnel	Role	Minimum Training Requirement	Minimum Years of Practical Experience
Project Leader	Responsible for contract administration and preparation, checking and certifying of reports for compliance with the technical specification.	☐ Has attended training courses for relevant survey/detection methods and data management.	10 years in contract administration, preferably in works related to the inspection and leak detection of water-carrying services, and in data management.
Team Leader	Responsible for works arrangement and data processing including checking of raw data for quality and consistency.	☐ Has attended training courses for relevant survey/detection methods and data management.	5 years in works related to the inspection and leak detection of water-carrying services, and in data management.
Crew Leader	Responsible for supervising the field works and site safety.	☐ Has attended training courses for relevant survey/detection methods, and ☐ Possesses a valid training certificate for relevant survey/detection methods used.	3 years in works related to the inspection and leak detection of water-carrying services, and in data management.
Operator	Responsible for operating equipment and carrying out inspection and leak detection of water-carrying services using CCTV, MLD, ELD, noise logger and LNC.	☐ Has attended training courses for relevant survey/detection methods, and ☐ Possesses a valid training certificate for relevant survey/detection methods used.	2 years in works related to the inspection and leak detection of water-carrying services, and in data collection.

Acronyms: CCTV = Closed Circuit Television; MLD = Mechanical Leak Detector; ELD = Electronic Leak Detector; LNC = Leak Noise Correlator

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7. REPAIRING WATER-CARRYING SERVICES

7.1 GENERAL

When any drains or water mains behind slopes are found damaged or leaking, competent and experienced contractors should be employed to rectify them as early as possible.

7.2 REPLACEMENT/REPAIR BY OPEN EXCAVATION

In most cases, replacement of the defective water-carrying services by open excavation is usually the most cost-effective method and is the most direct way to make the repairs. Open excavation is normally used for repairing water mains. When replacing defective pipes by open excavation method, attention should be drawn to the following:

(a) diversion of the existing flow in case of drains;

(b) traffic condition;

(c) presence of underground utilities;

(d) safety measures to ensure slope stability for excavation for water-carrying services on or above a slope (reference should be made to "Guide to Trench Excavations (Shoring Support and Drainage Measures)" (HKSARG, 2003); and

(e) nuisance and inconvenience to the public.

Close liaison with the utility undertakers and traffic authorities is required before the replacement works are carried out so that the most suitable construction method and temporary traffic diversion and work requirements can be determined.

Replacement of and repair to defective water mains should be carried out in accordance with Section 23 - Water Supply Pipeworks of General Specification for Civil Engineering Works, Volume 3 (HKG, 1992), or any subsequent corrigenda, revisions and editions.

7.3 TRENCHLESS TECHNOLOGY FOR REHABILITATION OF DRAINS

Several trenchless methods of rehabilitation for drains are described in the following paragraphs though the list may not be exhaustive.

7.3.1 Joint Grouting

Joint Grouting is used where drains are leaking through the joints, but are otherwise

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structurally sound. Chemical grout is pumped into the pipe joint to fill the void surrounding the leaking joint in order to seal it.

For small pipes, the chemical grout is applied internally by an inflatable packer guided by a CCTV camera and the same packer is used to test for air tightness of the grouted joint. For large pipes, it may be more convenient to send people inside to carry out the grouting directly.

The equipment involved is generally simple, and the cost of remedial works is low when compared with the traditional replacement of drains. Its applicability, however, is limited to pipes suffering from open joints without other structural defects.

7.3.2 Relining Using Epoxy Impregnated Liner

Relining Using Epoxy Impregnated Liner Method uses a factory-fabricated lining tube to form a continuous lining inside the original pipe to be rehabilitated.

The polyester lining is impregnated with specially formulated resin in the factory. When delivered to site and installed, the liner is expanded so that it makes full contact with the interior of the defective drain. The temperature is increased inside the liner to cure and harden the resin. Any branch connections can be restored with a remotely controlled hole-cutting machine.

The method is generally applicable for pipes of all sizes, including oval and egg shaped pipes. It can negotiate smooth bends, but wrinkles may develop at sharp bends. It adds extra structural strength to the original pipe and offers good chemical and corrosion protection in all types of environment. The internal diameter of the pipe is reduced slightly by the thickness of the liner, but the liner provides a smooth surface to the pipe which may improve the flow capacity.

The equipment required for the method is sophisticated. Special equipment is required to ensure proper and even impregnation and to remove the air inside the polyester felt. Proper use of inhibitors and control of surrounding temperature are important to prevent premature curing before insertion. The set-up for insertion and heating is also demanding. The method is expensive, especially if only short lengths are to be lined.

The liner is placed inside the pipeline for installation by means of either “Pull-in Place” or “Air/Water Inversion”.

In the case of “Pull-in Place”, the liner is drawn into the existing pipe by means of winch cable. With the ends of the liner sealed, the liner is expanded by compressed air or water. Curing process uses steam or hot water.

In the case of “Air/Water Inversion”, the liner is inserted through an existing manhole by means of an inversion process and application of air pressure/water to fully extend to the next designated manhole. In general, the inversion and holding pressure should be about 1 bar and 0.5 bar respectively. Curing process shall be carried out in accordance with instruction of the liner manufacturer, e.g. using steam or hot water.

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7.3.3 Relining Using Pre-deformed Polyethylene Liner

Relining Using Pre-deformed Polyethylene Liner Method involves placing a factory made polyethylene liner inside the defective drain.

The liner is first deformed and pulled through the existing drain by winches. Water at high temperature and pressure is then used to cure and to restore the circular shape so that the liner fits snugly inside the old pipe.

The method is applicable for drains ranging in size from 100 to 450 mm diameter. It can only negotiate large radius bends, and is not as flexible as the epoxy impregnated liner. It can be used to seal joints and cracks, and to improve the flow characteristics and chemical resistance. However, the interior of the old pipe must be smooth, and without serious obstructions. The working space inside the manholes must be big enough to facilitate installation of the liner.

7.3.4 Relining Using Smaller Pipes

Relining Using Smaller Pipes Method involves pulling or pushing a thin walled pipe made of steel, glass reinforced plastic, high density polyethylene or other materials, through a defective drain. The size of the new pipe is smaller than the old pipe. The pipes are generally jointed by welding as they are pushed. The annular space between the new and the old pipes is grouted.

The main disadvantage of this method is the reduction in size, and that a large space is generally required at the inlet. It cannot go through even large radius bends. It works better for large diameter pipes where the reduction in size is less significant. Reprovision of branch connections is also difficult unless the drain is large enough for man access.

7.3.5 Pipe Bursting

Pipe Bursting Method employs a powerful hydraulic expander which progressively destroys and expands the old pipe as it advances itself through the pipe. The replacement pipe, generally of larger size, is pulled in behind the bursters.

The method has been used overseas, but potential applicability in Hong Kong may be limited because of the close proximity of other utilities which may be damaged during the process.

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8. PERMANENT MEASURES TO MINIMISE IMPACTS

8.1 ROUTING OF NEW WATER-CARRYING SERVICES

In routing new water-carrying services, they should be kept as far away as possible from the area within which leakage could affect slopes. Section 3.1 discusses the extent of such areas.

8.2 RESITING OF EXISTING WATER-CARRYING SERVICES IN SLOPES

When opportunities to re-route existing water-carrying services arise, the considerations in Section 8.1 apply. Such opportunities include upgrading of adjacent slopes or the repair or replacement of existing water-carrying services.

8.3 ADDITIONAL MEASURES FOR WATER-CARRYING SERVICES IN CREST AREA

Where new water-carrying services have to be so routed that leakage could affect slopes, Chapter 9 of Geotechnical Manual for Slopes (GCO, 1984) recommends measures to safeguard against the effect of leakage. These include taking into account the effects of possible water leakage in assessing the stability of the slopes, or enclosing the water-carrying services in ducting systems. Laying the water-carrying services on or above ground is another alternative.

Ducting to water-carrying services should be provided with proper drains. Standard drawings for ducting of water mains are available on the web site of the Water Supplies Department. Drains from ducting to sewers should not be discharged to open channels and natural streams where possible to avoid environmental nuisance. To facilitate regular inspection for discharge from ducting systems as recommended in GCO (1984), inspection chambers with safe access should be provided. Regular checks of the ducting system should be carried out to detect any flow in and leakage from it.

For slopes that could be affected by leakage from water-carrying services, raking drains could be installed to reduce the impact of leakage. Reference should be made to GEO Report No. 56 (Wong et al, 1999) for guidance on use of prescriptive raking drains in this regard.

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9. SOURCES OF INFORMATION

9.1 GENERAL

The Buildings Department maintains a list of registered building contractors in accordance with Section 8(1) of the Buildings Ordinance (HKSARG, 1997d). For any repairs of drainage works, building owners can employ registered building contractors to carry out the repairs which are simple engineering works to be completed by those experienced contractors registered in the list. The list of Registered General Building Contractors can be accessed from the Buildings Department's web site (http://www.bd.gov.hk).

It is a statutory requirement that only plumbers licensed by the Water Supplies Department should be employed to repair water mains within private lots. The Licensed Plumber Directory can be accessed from the Water Supplies Department's web site (http://www.wsd.gov.hk).

Directory of accredited laboratories as well as details relating to approved types of testing by individual laboratories and standards of testing are available at the Innovation and Technology Commission's web site (http://www.itc.gov.hk).

The Home Affairs Department manages the Building Management Resource Centres to assist building owners, residents, owners' corporations, mutual aid committees and management bodies in improving the standards of management, safety and maintenance of their buildings. The addresses of various District Offices can be accessed at the Home Affairs Department's web site (http://www.had.gov.hk).

Useful information relating to the maintenance of slopes and water-carrying services can be obtained from a number of organisations.

The Buildings Department provides updated information on the approved plans of private developments upon application by submitting an application form and payment of the prescribed fee, details are available in its web site (http://www.bd.gov.hk).

The Water Supplies Department maintains as-built records of public water mains. Reference should be made to its web site (http://www.wsd.gov.hk) regarding access to the relevant information.

The Drainage Services Department maintains as-built records of public drains. Reference should be made to its web site (http://www.dsd.gov.hk) regarding access to the relevant information.

The Architectural Services Department maintains drainage records for government properties. Reference should be made to its web site (http://www.archsd.gov.hk) regarding access to the relevant information.

The Housing Department maintains records related to water-carrying services within public housing estates. Requests for information or records held by the Department should

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be made by letter or application form obtainable from the public reading area of the Housing Department Library, all Housing Information Centres and all Estate Offices. Applications should be addressed to the Access to Information Officer, Housing Department, Housing Authority Headquarters, 33 Fat Kwong Street, Ho Man Tin, Kowloon, Hong Kong. Reference can also be made to its web site (http://www.housingauthority.gov.hk) regarding the list of records held by the Department.

The Geotechnical Engineering Office of the Civil Engineering and Development Department maintains a Catalogue of Slopes that registers sizeable man-made slopes within the Hong Kong Special Administrative Region. Up-to-date information on these registered slopes and retaining walls is contained in the Slope Information System, which can be accessed from the "Hong Kong Slope Safety" web site (http://hkss.cedd.gov.hk). The Catalogue of Slopes also contains information on disturbed terrain features and natural terrain hazard mitigation measures within the Hong Kong Special Administrative Region. Some popular GEO publications, GEO Technical Guidance Notes and summary of selected notable landslides can also be accessed from the "Hong Kong Slope Safety" web site. The Geotechnical Information Unit of the Civil Engineering and Development Department maintains ground investigation reports related to slopes.

The Lands Department is responsible for land administration. Information about land records, land boundaries, lease conditions and slope maintenance responsibility can be sought from the Lands Department. The Slope Maintenance Responsibility Information System (SMRIS) contains information on the maintenance responsibility for registered man-made slopes and retaining walls and can be accessed from the Lands Department's web site (http://www.slope.landsd.gov.hk/smris).

Engineer Inspection for Maintenance Reports and Maintenance Manuals for government man-made slopes and retaining walls are held by various departments responsible for their maintenance.

Records of property owners, lease documents and Deeds of Mutual Covenant are kept at the Land Registry, where the public can make a search of these records.

Information on gas, electricity, telephone and similar services, including both the locations and details of existing facilities and the provision of future services, is available from the corporations supplying the services.

The Hong Kong Association of Property Management Companies Limited may be consulted for general information about property management. The Association keeps a list of property management companies in Hong Kong and can be accessed from its web site (http://www.hkapmc.org.hk).

Information about training courses on CCTV surveys and leak detection works can be obtained from a number of organisations e.g. the Hong Kong Institute of Utility Surveyors at its web site (http://www.hkius.org.hk) and the Develop Training Group at its web site (http://www.develop-solutions.co.uk).

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APPENDIX A

WORKING GROUP ON REVISION OF CODE OF PRACTICE ON INSPECTION AND MAINTENANCE OF WATER-CARRYING SERVICES AFFECTING SLOPES - MEMBERSHIP AND TERMS OF REFERENCE

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WORKING GROUP ON REVISION OF CODE OF PRACTICE ON INSPECTION AND MAINTENANCE OF WATER-CARRYING SERVICES AFFECTING SLOPES - MEMBERSHIP AND TERMS OF REFERENCE

Group Members

Organization / Department	Representatives
Architectural Services Department	Ms Tak-wai Ping
Buildings Department	Mr Ying-kit Ma
Civil Engineering and Development Department	Mr Wai-keung Pun (Chairman) Dr Dominic O-kwan Lo (Secretary) (since Feb 2006) Dr Lok-sing Cheung (Secretary) (before Feb 2006) Ms Alice Ching-shan Lai (since Nov 2004) Dr Yat-fung Yu (before Nov 2004)
Drainage Services Department	Mr Kwok-keung Yung
Highways Department	Mr Andy Ho-tong Wong (since Jan 2005) Mr Chi-hang Leung (before Jan 2005)
Hong Kong Institution of Engineers	
(Civil Division)	Mr Victor King-yin Lo
(Geotechnical Division)	Mr Patrick Yiu-kwong Yong
Hong Kong Institute of Utility Surveyors	Dr King Wong
Housing Department	Mr Fu-keung Chan Mr Eddy Leung
Water Supplies Department	Mr Sek-kui Yeung Mr Tat-kong Chung (since Apr 2005) Mr Kam-shing Lai (before Apr 2005)

Ad-hoc member

Environment, Transport and Works Bureau	Mr Michael Mein-kai Chang (since Jan 2006) Dr Alex Chi-on Li (before May 2005, Oct to Dec 2005) Mr Kwong-yin Choi (May to Sep 2005)

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Terms of Reference

1. Consolidate experience on inspection and maintenance of water-carrying services affecting slopes.

2. Provide technical input and comments on the revision of the Code of Practice.

3. Review the existing practices of maintenance of water-carrying services and frequency of inspections affecting slopes to further improve the cost-effectiveness.

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APPENDIX B

PROBABLE FAILURE MECHANISM OF THE KWUN LUNG LAU LANDSLIDE

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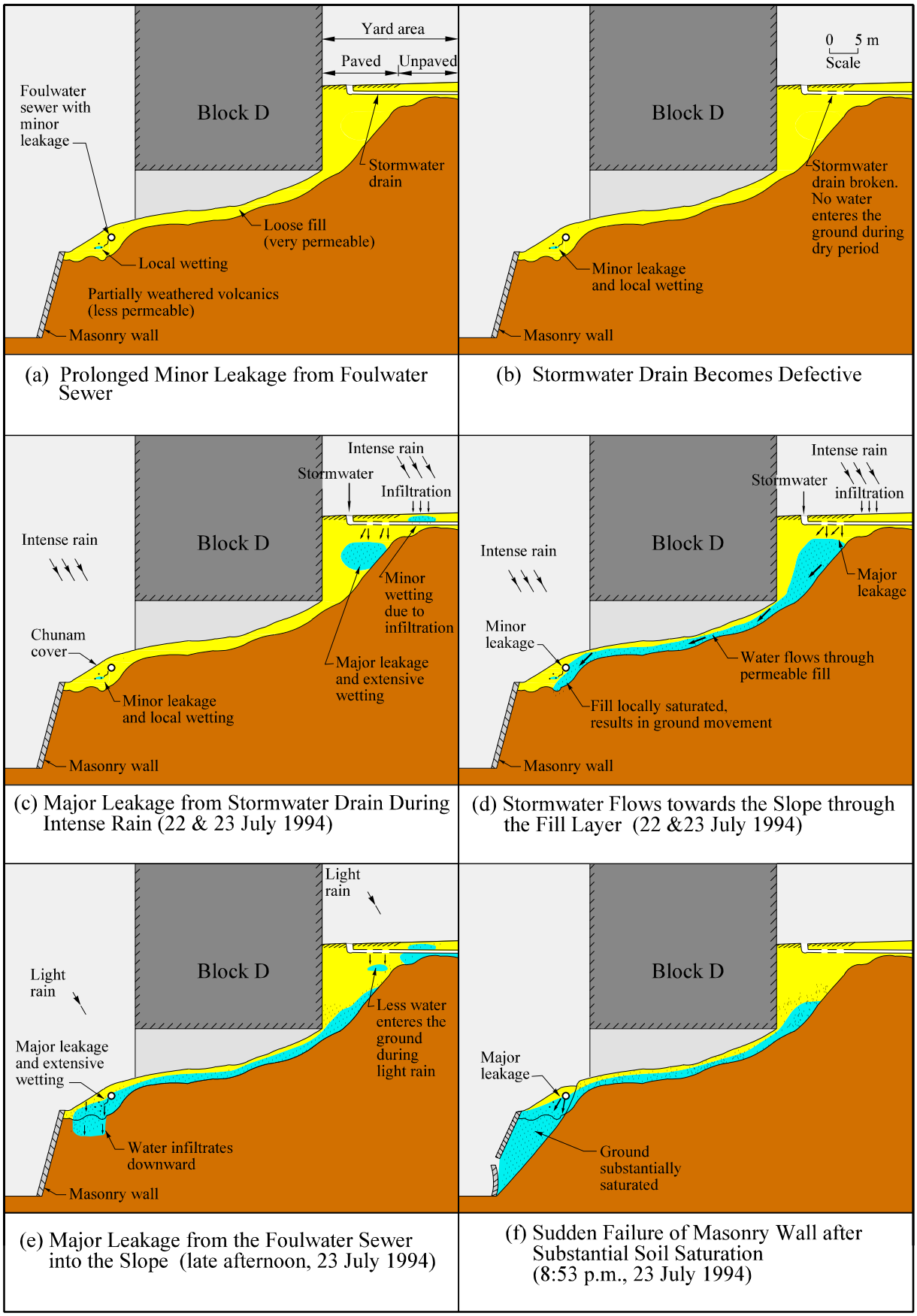
PROBABLE FAILURE MECHANISM OF THE KWUN LUNG LAU LANDSLIDE

(Adopted from Figure 12 of the Report on the Kwun Lung Lau Landslide of 23 July 1994, Volume 2, GEO (1994))



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APPENDIX C

ELECTROMAGNETIC TYPE DETECTION EQUIPMENT

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ELECTROMAGNETIC TYPE DETECTION EQUIPMENT

Electromagnetic type detection equipment comprises a hand-held detector and a matched portable signal generator. For metallic pipes, cables or non-metallic pipes with tracing tapes or wires, the output signal from the signal generator is either directly connected to the buried services using suitable connectors, or induced onto the services by placing the generator on the ground surface directly above the services. The hand-held detector then picks up the signal and the position at which it is the strongest will indicate the position of the buried services. If the pipe is non-metallic, the output signal can be radiated by a small transmitter inserted into and pushed along the pipe from which the signal can be picked up by the detector. Relevant photos are shown below:

Plate C1 Locating Buried Services by Electromagnetic Type Detection Equipment

Plate C2 Components of Electromagnetic Type Detection Equipment

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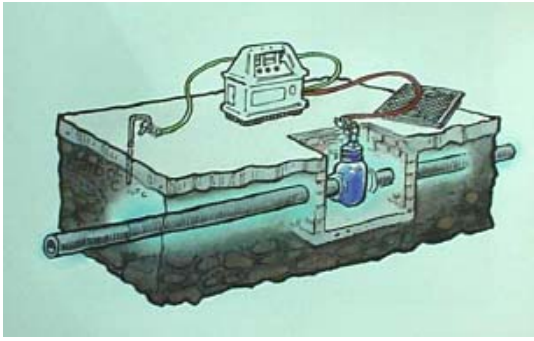
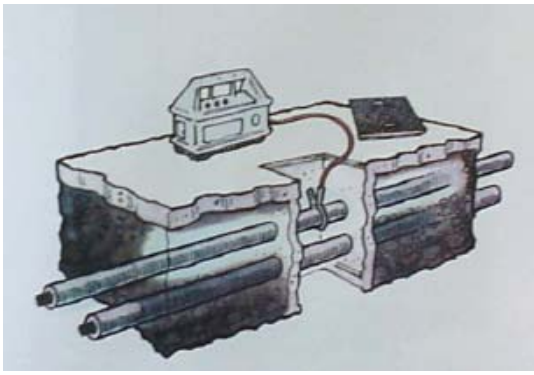
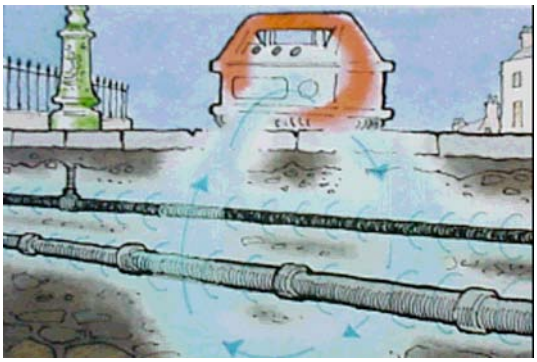
Plate C3 Receiver Display Panel



Direct Connection



Clamp Connection



Induction

Plate C4 Different Set-up of Electromagnetic Type Detection Equipment

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APPENDIX D

RADAR SCAN TYPE DETECTION EQUIPMENT

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RADAR SCAN TYPE DETECTION EQUIPMENT

Radar scan type detection equipment or ground probing radar is the technique which employs radio waves to map structures and features buried in the ground. This method may require the survey of a large area in order that different and congested services can be distinguished.

Plate D1 Ground Probing Radar (Courtesy of Radiolocation Ltd.)

Plate D2 Ground Probing Radar on Slope (Courtesy of the Hong Kong Institute of Utility Surveyors)

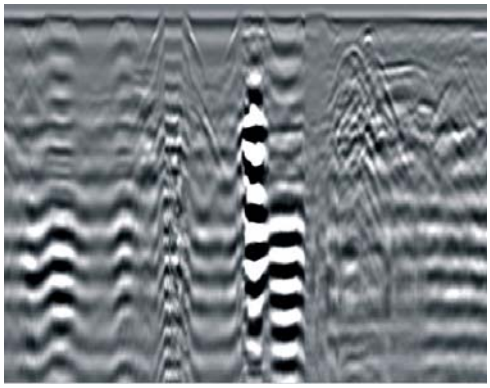

Plate D3 Ground Probing Radar Output (Courtesy of the Hong Kong Institute of Utility Surveyors)

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APPENDIX E

SAMPLE SPECIFICATION FOR CLOSED CIRCUIT TELEVISION SURVEY

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SAMPLE SPECIFICATION FOR CLOSED CIRCUIT TELEVISION SURVEY

1. Scope of CCTV Survey

The Contractor shall produce an updated full and accurate record of the existing sewers and drains within the Survey Extent of each site as part of the reconnaissance and CCTV surveys. From this updated record, the Contractor shall produce a corresponding schedule of the pipes to be surveyed in a format to be agreed with the Client or his representative.

The Contractor shall note that the purpose of CCTV survey is the inspection and accurate assessment of the conditions of the internal fabrics of the sewers and drains. CCTV survey shall be required for all sewers and drains up to an internal dimension of 1500 mm in any direction while man-entry survey will be required for internal dimensions exceeding 1500 mm in any direction.

2. Method Statement

The Contractor shall produce a method statement for CCTV survey including all operational requirements such as safety procedures, provision of ventilation, reporting of conditions by coding, identification of intruding utilities and taking of condition photographs. The method statement shall also cover all quality assurance and control procedures including data validation procedures. The method statement shall also take due cognizance of all relevant safety requirements with respect to confined spaces and be agreed with the Client or his representative in advance of any sewer and drain survey works.

3. Survey and Operational Equipment

CCTV cameras with a pan and rotate head shall be used to enable the internal conditions of junctions and connections to the sewers and drains to be inspected closely.

The CCTV equipment shall be capable of surveying a length of sewers or drains up to 350 m where entry to the sewers or drains may be obtained at each end and up to 30 m by rodding, or up to 150 m where a self-propelled unit is used where entry is at one end only. The equipment shall be maintained in full working order and shall be fully calibrated in accordance with the manufacturer's recommendation.

Each survey unit shall contain a means of transporting the CCTV camera in a stable condition through the sewers or drains under inspection. Such equipment shall ensure the maintained location of the CCTV camera on or near to the central axis of a circular shaped sewer or drain. Where the CCTV camera is towed by winch and bond through the sewers or drains, all winches shall be stable with either lockable or ratcheted drums. All bonds shall be steel or of an equally non-elastic material to ensure the smooth and steady progress of the CCTV camera. All winches shall be inherently stable under loaded conditions.

Each unit shall carry sufficient numbers of guides and rollers such that, when surveying, all bonds are supported away from the sewers or drains and manhole structures

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and all CCTV cables and/or lines used to measure the camera's location within the sewers or drains are maintained in a taut manner and set at right angles, where possible, to run through or over the measuring equipment.

Each unit shall carry a range of flow control equipment, as opposed to over-pumping equipment, for use in controlling the flow during the survey. A minimum of one item of each size of equipment ranging from 100 mm to 900 mm diameter inclusive shall be carried.

In many locations, it is anticipated that access to the slopes may be difficult for the normal type of vehicle mounted CCTV survey equipment. A complete range of CCTV survey equipment shall be available to enable difficult locations such as steep pipes and steep slopes to be surveyed.

The Contractor is required to control the water flow of the pipeline during CCTV survey, say to keep the water level at below 30% of the maximum vertical dimension of the sewers or drains. Over-pumping may be carried out if instructed. In case water level cannot be reduced, alternative method such as Sonar shall be considered.

4. Camera Position

Wherever prevailing conditions allow, the camera shall be positioned to reduce the risk of picture distortion. In the case of circular or regular shaped sewers and drains, the camera lens shall be positioned centrally within the sewers or drains. In the case of egg shaped sewers and drains, the camera lens shall be positioned vertically above the invert at a height two-thirds of the vertical dimension of the sewers or drains. In all instances, the camera lens shall be positioned looking along the axis of the pipeline. A positioning tolerance of ± 10% of the vertical pipeline dimension shall be allowed.

5. Camera Speed

The speed of the CCTV camera in the sewers or drains shall be limited to 0.l m/s for sewers and drains of diameters less than or equal to 200 mm, 0.15 m/s for diameters exceeding 200 mm, or such other speed as agreed with the Client or his representative to enable all details to be extracted from the video tape recording.

The advancement of the camera shall be "stopped" to ensure that an accurate and clear record is taken whenever defects are being noted on the coding sheet.

6. Linear Measurement

The CCTV monitor display shall incorporate an automatically updated record in metres and tenths of a metre of the meterage of the camera position from the cable calibration point, which is also called "adjusted zero".

The Contractor shall use a suitable metering device which enables the cable length to be accurately measured; this shall be accurate to ±1% or 0.3 m whichever is the greater.

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When requested by the Client or his representative, at any time during the course of the CCTV survey, the Contractor shall demonstrate that the tolerance is being complied with using one or both of the following methods as the Client or his representative shall select:

(a) Use of a cable calibration device.

(b) Tape measurement on the surface between edges of manholes.

If the Contractor fails to meet the required standard of accuracy, the Client or his representative shall instruct the Contractor to provide a new device to measure the meterage. The Client or his representative may at his discretion instruct, in writing, the Contractor to re-survey those lengths of sewers or drains previously inspected with the original measuring device using the new measuring device.

7. Data display and Video Recording

A data generator shall electronically generate and clearly display on the viewing monitor and video recording a continuous record of the following information:

(a) Automatic update of the CCTV camera's meterage position from "adjusted zero".

(b) Location (street name/slope reference).

(c) Pipeline dimensions.

(d) Manhole or Sewer/drain length reference numbers.

(e) Date of survey.

(f) Direction of survey.

(g) Time of start of survey.

(h) Pipeline classification (sewers or drains).

(i) Name of company and operator.

The size and position of the data display shall be such as not to interfere with the main subject of the picture.

The Contractor shall demonstrate the correct adjustment of the recording apparatus and monitor by use of the test tape or other device approved by the Client or his representative. The Contractor shall then demonstrate satisfactory performance of the camera by the recording of the appropriate test device at the commencement of each day for a minimum period of 30 seconds.

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8. Picture Quality

The CCTV camera shall have suitable illumination and shall be capable of providing an accurate and clear record of the sewers' or drains' internal condition.

A test device for the CCTV equipment shall be submitted to the Client or his representative for approval and made available on site throughout the Contract enabling the tests specified below to be checked.

The test card shall be the Marconi Resolution Chart No. 1 or its derivatives with a colour bar, clearly defined with no tinting to show the following colours:

- White
- Yellow
- Cyan
- Green
- Magenta
- Red
- Blue
- Black

At the start of each and every working shift, the camera shall be positioned centrally and at right angle to the test card at a distance where the full test card just fills the monitor screen. The card shall be illuminated evenly and uniformly without any reflection.

The electronic systems, television camera and monitor shall be of such quality as to enable the following to be achieved:

Shades of grey

The grey scale shall show equal changes in brightness ranging from black to white with a minimum of five clearly recognisable stages.

Colour

With the monitor control adjusted for correct saturation, the six colours plus black and white shall be clearly resolved with the primary and complementary colours in order of decreasing luminance. The grey scale shall appear in contrasting shades of grey with no tint.

Linearity

The background grid shall show squares of equal size, without convergence/divergence over the whole of the picture. The centre circle shall appear round and have the correct height/width relationship (+/-5%).

Resolution

The live picture must be clearly visible with no interference and capable of registering

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a minimum number of TV lines/picture height lines. The resolution shall be checked with the monitor colour turned down. In the case of tube cameras this shall be 350 lines and in the case of CCD type cameras 250 lines.

Colour consistency

To ensure that the camera shall provide similar results when used with its own illumination source, the lighting shall be fixed in intensity prior to commencing the survey. In order to ensure colour constancy, generally no variation in illumination shall take place during the survey.

9. Focus/ Iris/ Illumination

The adjustment of focus and iris shall allow optimum picture quality to be achieved and shall be remotely operated. The adjustment of focus and iris shall provide a minimum focal range from 150 mm in front of the camera's lens to infinity. The distance along the sewers or drains in focus from the initial point of observation shall be a minimum of twice the vertical height of the sewers or drains. The illumination must be such as to allow an even distribution of the light around the sewer/drain's perimeter without the loss of contrast, flare out of picture or shadowing.

10. Photographs and Video Prints

The following photographs and video prints are required:

(a) A general condition of the pipeline shall be taken at a distance of not more than 20 m after the previous photograph.

(b) All defects, both structural and service conditions of sewers and drains. Where a defect is continuous or repeated the photographs shall be taken at the beginning of the defect and at not less than 5 m intervals thereafter.

(c) All junctions, connections defective or other appropriate features.

Photographs shall be taken during CCTV survey to illustrate degree of mortar loss, size of a crack or fracture, size of a void or any other quantifiable defect and a suitable metric scale shall be included in the clearly focused photograph. When a photograph is taken to illustrate mortar loss, the scale shall be inserted in the joint between the bricks. Where a photograph is taken to illustrate a specific defect it shall occupy the central part of the photograph and be clearly in focus and accurately reflect the defect.

Photographs shall be provided either:

(a) As screen captures from the CCTV records in a commonly

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recognised digital format (preferably “jpeg”) on CD-ROM.

(b) As durable hardcopy. The size of photographs and video prints shall be agreed with the Client or his representative, and shall be supplied in a suitable album. The negatives shall be supplied in suitable plastic negative holders. Each plastic negative holder sheet shall be clearly cross referenced to the report.

Video prints shall clearly show details and accurately reflect what is displayed on the monitor, and shall be clearly identifiable in relation to the location (minimum requirement includes manhole start and finish numbers or sewer/drain length reference numbers), survey direction, meterage, print number, date and time when the print was taken. The annotation shall be clearly visible and in contrast to its background, and shall have a figure size no greater than 5 mm, and be type printed. The annotation shall be so positioned as not to interfere with the subject of the print.

11. Site Coding Sheets

Each sewer or drain length surveyed shall be recorded on a separate coding sheet in the format agreed with the Client or his representative. The site coding sheets shall be completed by an operative at the time of the survey, and shall forward copies of these sheets to the Client or his representative each day.

12. Survey Report

Upon the completion of all required surveys of the sewers and drains, the Contractor shall submit two copies of a report, which shall be computer validated and machine printed, and presented in accordance with the format agreed with the Client or his representative. The report shall contain/comply with the following:

(a) A plan showing the location of the pipe surveyed.

(b) A summary of ranking scores for both structural and service conditions of sewers and drains surveyed.

(c) A summary of manhole references, sewer or drain lengths surveyed, diameter/section details, summary ranking scores for cross referencing the manhole survey results to demonstrate that no sewers or drains are missing from the survey.

(d) Survey data, conversion of coded defect into scores and grades shall be provided in one of the commercially available software packages agreed with the Client or his representative.

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(e) Forms A to D as shown in Figures E1 to E4.

13. Quality Control Procedures

The Contractor shall submit a method statement detailing a quality control system to the Client or his representative for approval prior to the commencement of the survey. The system is to gauge the accuracy and consistency of the CCTV survey reports produced by a survey team. The minimum level of accuracy to be attained in the quality control system shall be given in the specification and agreed with the Client or his representative prior to commencement of the survey.

The Client or his representative shall audit periodically the control system and be present when assessments are being carried out. When requested by the Client or his representative in writing, the Contractor shall provide to the Client or his representative sufficient details and information for this audit assessment.

The Contractor shall check all header information and detail information to ensure that the entries are correctly entered, alpha or numeric symbols are correctly used and all compulsory boxes filled in.

Should any report fail to achieve the minimum level of accuracy for a particular sewer or drain length, the Client or his representative shall require the Contractor to re-code and re-submit the report. If the accuracy check fails, the Contractor shall repeat the full quality control check on other surveys carried out by the same survey crew. If any further failures are found to be outside the tolerances in these additional checks, the process will be repeated until an acceptable standard is reached. Any reports that have failed should be re-coded by another survey team.

On completion of the survey or completion of a batch of no more than 100 pipes, whichever is less, the Contractor shall provide a survey team, excluding the team who originally worked on the batch of surveys to be tested, to undertake the quality control tests under the supervision of the Client or his representative. The quality control test shall consist of a re-survey of 1% of the surveys or a minimum of 1 survey where there are less than 100 surveys within the batch to be tested. Surveys to be tested will be selected by the Client or his representative and checked against the results obtained by the Contractor in the initial survey. The Contractor shall supply a copy of the results of the re-survey to the Client or his representative for the comparison of the two sets of results to confirm that the original survey was carried out in accordance with the requirements of the Contract.

The Contractor shall check the CCTV tape produced during the re-survey against the original tape and investigate any anomalies, especially the pipe references in the header data, and to establish the reason for any anomalies found. The Contractor shall report the findings of the check to the Client or his representative.

The test shall be deemed to have failed the quality control check if any item of data falls outside the tolerance requirements or if key header data is found to be incorrect.

If the survey fails to meet the quality control check, the Contractor shall repeat the full

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quality control check on 10 pipes, 5 pipes each side (in terms of the original order of surveys carried out by the survey crew in question) of the pipe, which failed the check. If any further failures are found to be outside the tolerances in these additional checks, the process will be repeated until either a test passes or all pipes within the batch have been re-surveyed. The Client or his representative may remove any survey team whose quality control results repeatedly fall below the required minimum levels of accuracy from the survey.

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FORM A

Summary of Works										
LOCATION			CONTRACT NO.		TAPE NO.			SHEET NO.	DUTY	
MANHOLE NO.		PIPE			MANHOLE (FROM)			GRADE		
FROM	TO	LENGTH	SIZE	MATERIAL	I.L.	C.L.	DEPTH	SERVICE	STRUCTURAL	REMARKS

Figure E1 Form A - Summary of Works (Courtesy of the Hong Kong Institute of Utility Surveyors)

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FORM B

LOCATION
DUTY

Summary of Defects

LOCATION					**URGENT**	PIPE										SERVICE CONDITION								MISC	
SHEET	VIDEO	MANHOLE FROM	MANHOLE TO	METER		SURFACE DAMAGE SPALLING	CRACKED	FRACTURED	BROKEN	HOLE	Defective Connection / Junction	DEFORMED	COLLAPSED	JOINT DISPLACED	OPEN JOINT	ROOTS	INFILTRATION	ENCRUSTATION SCALE	SILT	GREASE	OBSTRUCTION	WATER LEVEL (+20%)	LINE	SURVEY ABANDONED	CAMERA UNDERWATER
TOTAL																									
GRAND TOTAL																									

Figure E2 Form B - Summary of Details (Courtesy of the Hong Kong Institute of Utility Surveyors)

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FORM C

MANHOLE NO. DEPTH				SIZE	MAT.	DIR.
FROM	DEPTH	TO	DEPTH			

DATE : **VIDEO TAPE NO.**
Name of Operator

LOCATION :
Slope Ref.(if Applicable)

PIPE DUTY

SHAPE

ORDER NO.

Video No. Hrs Mins Secs	Photo No.	Chainage (metres)	Cont. Defects & Extra Lines	LETTERS Class	Type	Description	NUMBERS Dia of JN/CN (mm)	Clock at to	Intrusion Etc (mm) %	Remarks (Information in this column will not be input to computer)
H 0 1 2 3	5 6 7	9 10 11 12 13	15 16	17	18 19	20 21	23 24 25	27 28 29 30	32 33 34 35	- Punch Column No. -

Signature of Operator:

Figure E3 Form C - Site Coding Sheet for CCTV Survey (Courtesy of the Hong Kong Institute of Utility Surveyors)

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FORM D

CCTV Survey Photographs

	Photograph No. : 1
	Location :
	Manhole / Pipe Reference:
	Chainage:
	Size:
	Comments:

	Photograph No. : 2
	Location :
	Manhole / Pipe Reference:
	Chainage:
	Size:
	Comments:

	Photograph No. : 3
	Location :
	Manhole / Pipe Reference:
	Chainage:
	Size:
	Comments:

Figure E4 Form D - CCTV Survey Photographs (Courtesy of the Hong Kong Institute of Utility Surveyors)

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APPENDIX F

EXAMPLES OF SOME COMMON TYPES OF PIPE DEFECTS

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EXAMPLES OF SOME COMMON TYPES OF PIPE DEFECTS

(Courtesy of the Hong Kong Institute of Utility Surveyors)

Plate F1 Missing Piece of Pipe Wall

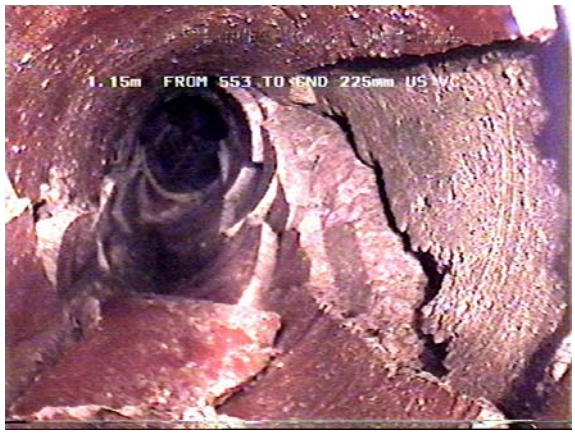

Plate F2 Collapsed Pipe

Plate F3 Water Infiltration into Pipe

Plate F4 Longitudinal Fracture

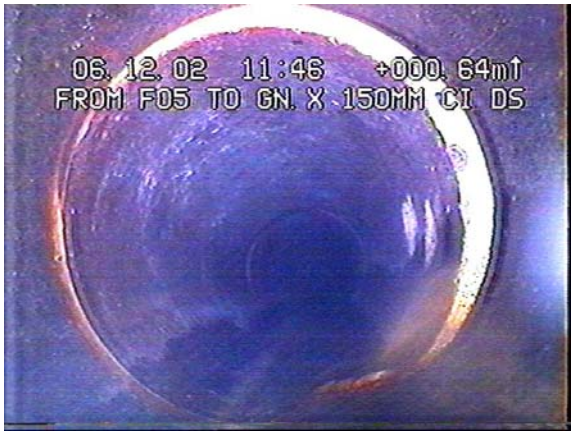

Plate F5 Joint Displaced under 1.5x Pipe Wall Thickness

Plate F6 Joint Displaced over 1.5x Pipe Wall Thickness

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Plate F7 Open Joint Displaced over 1.5x Pipe Wall Thickness

Plate F8 Spalling of Pipe Wall

Plate F9 Connection Defect in Pipe

Plate F10 Connection Defect with Intruding Pipe

Plate F11 Roots of Less Than 10 mm Thick

Plate F12 Roots of over 10 mm Thick

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Plate F13 Root Mass Causing Sectional Area Loss

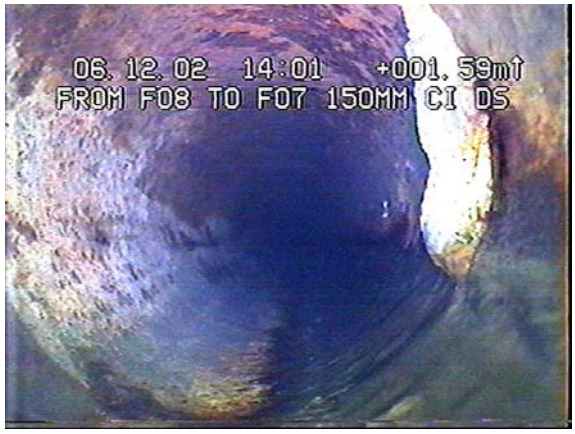

Plate F14 Deposition of Dissolved Salt on Pipe Wall

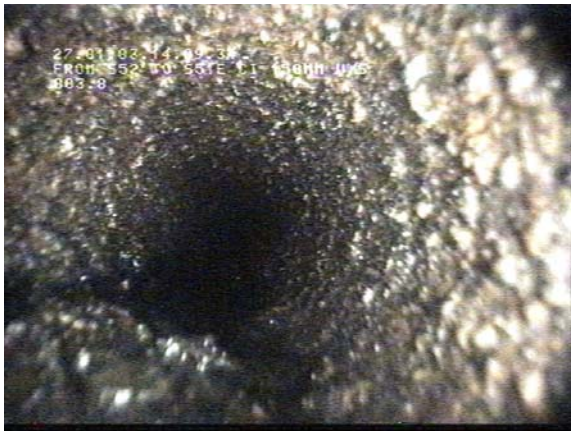

Plate F15 Heavy Scale on Pipe Wall

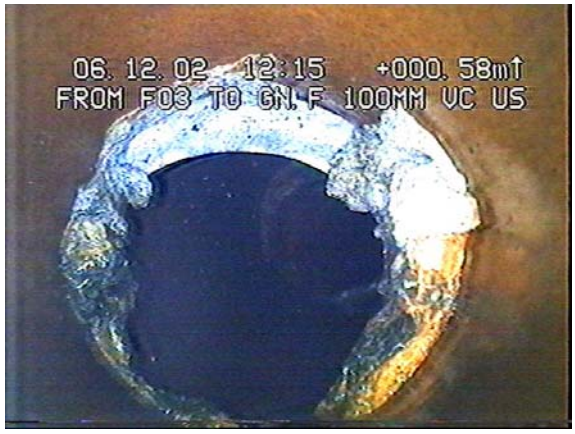

Plate F16 Heavy Encrustation on Pipe Wall

Plate F17 Line Deviation of Pipe to the Right

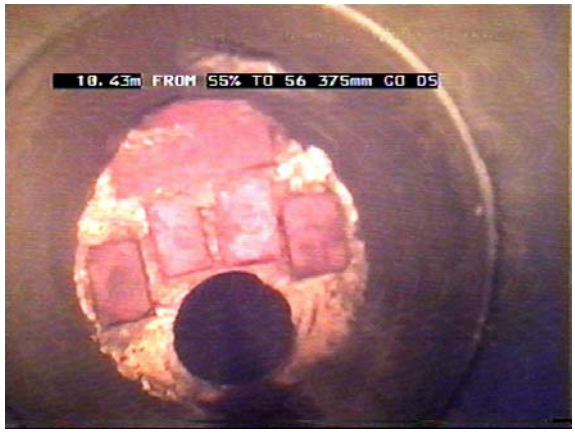

Plate F18 Pipe Dimension Change

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Plate F19 Pipe Material Change

Plate F20 Bulging of Pipe Lining

Plate F21 Vermin Encountered in Pipe

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APPENDIX G

SAMPLE SPECIFICATION FOR MANHOLE SURVEY

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SAMPLE SPECIFICATION FOR MANHOLE SURVEY

1. Scope of Manhole Survey

The Contractor shall carry out a survey of manholes within the Survey Extent for each of the slopes. The survey shall include manholes on both sewers and drains as identified or agreed with the Client or his representative.

The objective of the manhole surveys is to record all salient features, obtain evidence of the structural and surface condition of the manholes, evidence of leakage or infiltration, record and verify the position of the manhole structure against the supplied layout plans.

2. Method Statements

The Contractor shall submit a detailed method statement for the manhole survey. The Contractor shall submit separately a detailed method statement for working in confined spaces, in accordance with the latest Factories and Industrial Undertakings (Confined Spaces) Ordinance. The Contractor shall be responsible for accessing the survey area and carrying out risk assessment and obtaining the relevant permits related to traffic management.

The Contractor shall also submit a method statement for the Contractor's data management system for the approval of the Client or his representative. The Contractor shall host and maintain all checked data on a secured database to be accessed by the Client or his representative.

3. Equipment

The Contractor shall equip the team undertaking the manhole survey work with the following:

(a) Equipment for easing and lifting manhole covers.

(b) Confined space safety equipment.

(c) Road safety equipment.

(d) Personnel protective equipment, PPE.

(e) Spirit level, bent rod and measuring tape.

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4. Accuracy of Survey Data

The standard of accuracy required in the survey and completion of manhole record cards shall be as follows:

(a) All textual information shall be correct.

(b) All measurements shall be accurate within the following tolerances:

- Grid references	± 1 m
- Location measurement	± 300 mm
- Levels	± 25 mm
- Relative levels of pipe inverts within the chamber	± 20 mm
- Pipe sizes	± 20 mm
- Box-culverts	± 20 mm
- All other dimensions	± 50 mm

Levels shall be referenced to Survey Bench Marks, the locations and values of which are obtainable from the Lands Department.

Grid references shall be supplied in the Hong Kong 1980 Grid format.

5. Data Validation

The Contractor shall download the survey data and photographs onto their data management system. The Contractor is responsible for checking and validating the data to make sure that no inconsistencies appear in the survey data. These shall include, but are not limited to, checking for:

(a) Missing data (invert levels, cover levels, diameters).

(b) Inconsistent pipe sizes (e.g. downstream pipe smaller than upstream pipe).

(c) Inconsistent invert levels/reverse gradients (e.g. downstream invert level above upstream invert level).

(d) Inconsistent pipe materials.

(e) Connectivity.

6. Manhole Record Card

The Contractor shall obtain all relevant data to complete the manhole record cards. In particular the Contractor shall include a location sketch and a general layout of the manhole. An example of a fully completed manhole record card showing the total data to be captured is shown in Figure G1.

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The Contractor shall provide a minimum of two photographs for each manhole (i.e. one showing the general location and the other showing an internal condition). An example is shown in Figure G2.

7. Reference System

The Contractor shall ensure that each new manhole has a unique reference and is not duplicated in the original datasets provided at the start of the project. The Contractor shall also maintain consistent references for each asset (i.e. an asset shall not be given two different numbers). The Contractor is recommended to assign references to the assets in accordance with the latest reference system adopted by the Drainage Services Department.

8. Connectivity Testing

The Contractor may use smoke, dye testing or electronic methods to determine connectivity of manholes.

9. Quality Control

On completion of the survey or completion of each 100 manholes, whichever is less, the Contractor shall supply completed manhole record cards and a copy of the relevant portion of the map in respect of those manholes to the Client or his representative for checking on site.

A site check comprising a re-survey of 5% of each batch of 100 manholes, or a minimum of 1 manhole where there are less than 100 manholes in the batch, submitted by the Contractor is recommended. The manholes to be re-surveyed shall be randomly selected by the Client or his representative and checked against the results obtained by the Contractor in the initial survey. The re-survey shall be deemed to have failed if any item of manhole measurements falls outside the tolerances in Section 4.

10. Abandonment and Re-scheduling of Manhole Survey

Abandonment of the survey of a manhole may be considered by the Contractor subject to the agreement of the Client or his representative in any or a combination of the following circumstances:

(a) Risk to Contractor's equipment.

(b) Inability to locate the manhole.

(c) Inability to gain access to the manhole once located.

(d) Risk to Contractor's operations due to unsafe condition of manhole.

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(e) Inability to survey from the manhole due to blockage, silt or high water level.

(f) Inability to gain access to the manhole due to possession of the site by a third party.

In cases (a), (b), (c) & (d), the Contractor shall, if possible, take photographs of the situation causing abandonment. In case (e), the Contractor shall carry out cleaning works, ventilation, flow control or other measures as necessary to complete the survey. In case (f), the Contractor shall first re-schedule his works to minimise the effects of the possession of a site by a third party. Arrangements shall be made to re-visit the site and liaise with any relevant third parties in order to complete the survey.

In all cases, the Contractor shall report the matter to the Client or his representative as soon as possible and report the same in the survey report.

11. Survey Report

The Contractor shall submit two copies of a report to the Client or his representative upon completion of the survey. The report shall include, but not limited, to the following:

(a) Location plan including all assets (e.g. manholes, pipes, catchpits and other ancillaries) with connectivity delineated.

(b) Completed manhole record cards.

(c) Data validation check sheet.

(d) Corresponding electronic data in the format agreed by the Client or his representative.

(e) Any other matters that may have affected the results of the survey.

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MANHOLE RECORD CARD

NODE REFERENCE	MH 11
Hong Kong GRID	824606 N / 830685 E
DRAINAGE AREA CODE	ESK
Slope Ref.	7SE-C/F128
SURVEY DATE	14-Feb-05

GRID REFERENCE	HK3024767652														
LOCATION	Kwai Shing West Estate														
YEAR LAID			STATUS	HD	FUNC-TION	S	NODE TYPE	M		(diam)					
COVER	SHAPE	D	HINGED	N	LOCK	N	DUTY	H	SIZE (mm)	575	X	575	TOXIC ATMOSPHERE	N	
SHAFT	SIDE ENTRY	N	REGULAT COURSES	0	DEPTH (mm)	450			SIZE (mm)	565	X	550	EVIDENCE OF VERMIN	N	
CHAM	SOFFIT	T	STEPS	1	LADDERS	0	LNDGS	0	SIZE (mm)	760	X	745	CONSTRUCT CODE	I	

DEPTH OF FLOW (mm)	DEPTH OF SILT	HEIGHT SURCH (mm)	COVER LEVEL (mPD)
0	1.0	1.0	60.98

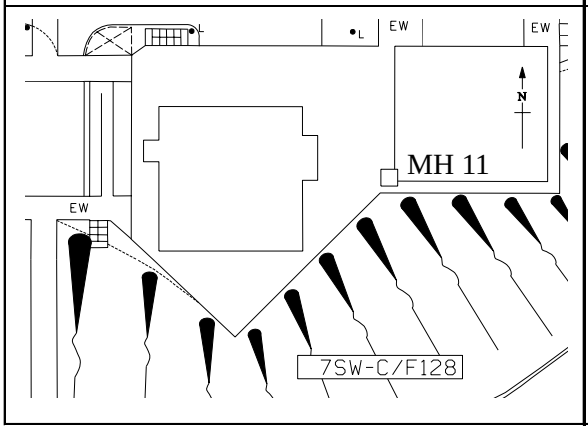
		UPSTREAM REFERENCE	PIPE SHAPE	(diam)	PIPE SIZE	BACKDROP DIAM (mm)	PIPE MATERIAL	LINING	DEPTH OF COVER	INVERT LEVEL (m)
INCOMING PIPES	A	GNA	C	225	X		CO		1.34	59.64
	B				X					
	C				X					
	D				X					
	E				X					
	F				X					

		DOWNSTREAM REFERENCE				COND	CRITY			
OUTGOING PIPES	X	30247605	C	225	X	N	C	U	IS	1.33	59.65
	Y				X						

CONDITIONS (Y if attention required)	COVER	IRONS/ LADDERS	SHAFT	CHAMBER	BENCHING	OTHER
	N	N	N	N	N	N

REMARKS
PIPE A DEEPER THAN PIPE X

Location Sketch



Plan of Manhole

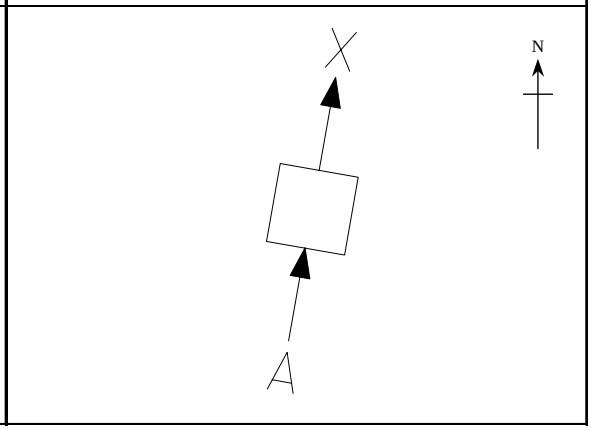


Figure G1 Manhole Record Card

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Manhole Survey Photographs

	Photograph No.: 30247608-01
	Location : 11SW-A/R304
	Manhole Reference : M/H 0835
	Description : Location photo
	Remark :

	Photograph No.: 30247608-02
	Location : 11SW-A/R304
	Manhole Reference : M/H 0835
	Description : Internal Condition photo
	Remark :

Figure G2 Manhole Record Photos

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APPENDIX H

LEAK DETECTION EQUIPMENT

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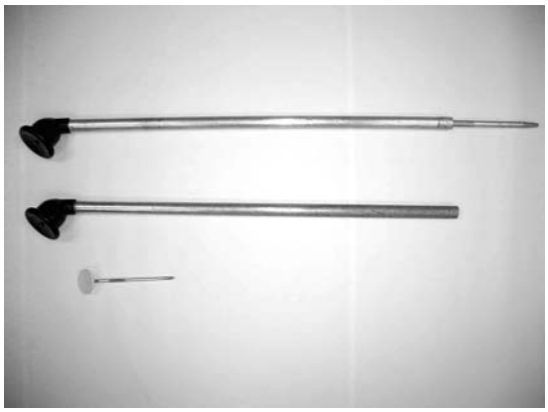
LEAK DETECTION EQUIPMENT

1. Mechanical Leak Detectors

A mechanical leak detector is a leak locating instrument which uses mechanical means to amplify the sound of a leak. It transmits the sound to the operator's ears through a hand held detector, which is in direct contact with the pipe, valves or fittings, ground/road surface or other contact points. Examples of such detectors include the listening stick and the geophone. Relevant photos are shown below:

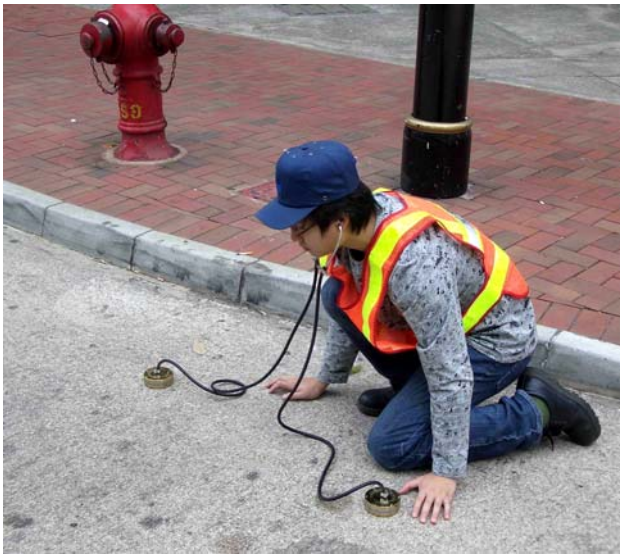


Listening Stick

Geophone

Plate H1 Mechanical Leak Detectors

Listening Stick



Geophone

Plate H2 Leak Pinpointing by Mechanical Leak Detectors

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2. Electronic Leak Detectors

An electronic leak detector (ELD) is a leak locating instrument which uses electronic means to amplify the sound of a leak. It consists of a ground microphone, a noise amplifier, headphones and frequency filters. The leak noise is amplified and transmitted to either headphones, a loudspeaker or an indicating meter electronically. Background noises can be removed by electronic frequency filters. By listening at regular intervals (above ground) along the line of the water main being surveyed, the user is able to identify both audibly (via the headphones) and visibly (from the indicating meter) where the strongest leak noise activity is located. Relevant photos are shown below:

Plate H3 Electronic Leak Detector

Plate H4 Leak Pinpointing by ELD

3. Noise Loggers

A noise logger is a leak location instrument, which is installed at valves or fittings along a section of water mains being surveyed. It detects and records the constant source of noise generated by a leak, usually over a 2-hour period. The results are analysed to identify whether there is a suspected leak in the section of a water main. Relevant photos are shown below:

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Plate H5 Noise Logger in a Valve Chamber

Plate H6 Downloading and Analysis of Noise Logger Results

4. Leak Noise Correlators

A leak noise correlator is one of the most sophisticated leak locating instruments. It consists of at least two accelerometer sensors, two hydrophones, and a correlator. The accelerometer sensors are attached to the contact points or valve spindles while the hydrophones are attached to the hydrants along the water main to be surveyed. The correlator analyses the leak noises collected by the two accelerometer sensors or the two hydrophones for locating the leak position. A correlation peak shows that a leak noise is present. Relevant photos are shown below:

Plate H7 Leak Noise Correlator

Plate H8 Leak Pinpointing by Leak Noise Correlator

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APPENDIX I

SAMPLE SPECIFICATION FOR LEAK DETECTION WORKS FOR WATER MAINS

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SAMPLE SPECIFICATION FOR LEAK DETECTION WORKS FOR WATER MAINS

1. The sections of water mains for leakage investigation are to be identified by or agreed with the Client or his representative.

2. The leakage investigation works to be performed by the Contractor shall include, but not limited to, the following:

   (a) Provision of all qualified staff, laborers, materials, equipment, devices and tools required to carry out the leakage investigation works.

   (b) All necessary co-ordinations, planning, relevant permit applications, preliminary inspections, reportings and surveys for the sections of water mains.

   (c) Submission of the leak detection plan prior to the survey/field works.

   (d) Visual inspection on exposed portions of water mains and valve pits/chambers along the water mains and on the slopes in the vicinity of the water mains.

   (e) Removal of silt and debris and dewatering of the valve pits/chambers so as to make the valves and other contact points accessible for inspection and for sounding/leak noise correlator surveys.

   (f) Making of additional contact points proposed or required for sounding/leak noise correlator surveys.

   (g) Locating the alignment of water mains by means of electromagnetic type and/or radar scan type detection equipment or other approved methods.

   (h) Leak detection and localizing by mechanical and/or electronic leak detection device, noise loggers, leak noise correlators or other approved methods.

   (i) Location of suspected leak by means of mechanical and/or electronic leak detection device or other approved methods to locate the suspected leak points.

   (j) On-site marking of suspected leak points.

   (k) Taking of record photographs.

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(l) Collection and testing of water samples from the seepage water in the slopes near the water mains when ordered by the Client or his representative.

(m) Submission of the leak detection report after completion of the survey/field works.

3. The leak detection plan shall include, but not limited to, the following:

(a) Composition of the leak detection team and qualifications and experience of the team members.

(b) Proposed method statements to be adopted for carrying out leak detection.

(c) Types, make and model numbers and details of the leak detection equipment to be used.

(d) The programme of the works.

(e) The data processing and reporting procedures.

(f) Other related works such as traffic management schemes.

(g) The quality management plans and safety plans for the required works.

4. The leak detection report shall include, but not limited to, the following:

(a) Names of the leak detection team members.

(b) Location of the survey.

(c) Date and time of the survey.

(d) Sketches showing the locations of the water mains surveyed and the locations of the suspected leaks, if any.

(e) Total length of water mains surveyed.

(f) Details of all survey setups together with relevant record photographs.

(g) Results of survey (including any graphical printout).

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(h) Interpretation and analysis of results with detailed explanation and supporting records to substantiate the findings and interpretation/analysis.

(i) Any problems encountered.

(j) Conclusion/recommendation.

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GEO PUBLICATIONS AND ORDERING INFORMATION
土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website http://www.cedd.gov.hk on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁 http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

Copies of GEO publications (except maps and other publications which are free of charge) can be purchased either by:

writing to
Publications Sales Section,
Information Services Department,
Room 402, 4th Floor, Murray Building,
Garden Road, Central, Hong Kong.
Fax: (852) 2598 7482

or
- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
- Visiting the online Government Bookstore at http://bookstore.esdlife.com
- Downloading the order form from the ISD website at http://www.isd.gov.hk and submit the order online or by fax to (852) 2523 7195
- Placing order with ISD by e-mail at puborder@isd.gov.hk

1:100 000, 1:20 000 and 1:5 000 maps can be purchased from:

Map Publications Centre/HK,
Survey & Mapping Office, Lands Department,
23th Floor, North Point Government Offices,
333 Java Road, North Point, Hong Kong.
Tel: 2231 3187
Fax: (852) 2116 0774

Requests for copies of Geological Survey Sheet Reports, publications and maps which are free of charge should be sent to:

For Geological Survey Sheet Reports and maps which are free of charge:
Chief Geotechnical Engineer/Planning,
(Attn: Hong Kong Geological Survey Section)
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5380
Fax: (852) 2714 0247
E-mail: jsewell@cedd.gov.hk

For other publications which are free of charge:
Chief Geotechnical Engineer/Standards and Testing,
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5345
Fax: (852) 2714 0275
E-mail: ykhui@cedd.gov.hk

讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外):

書面訂購
香港中環花園道
美利大廈4樓402室
政府新聞處
刊物銷售組
傳真: (852) 2598 7482

或
- 致電政府新聞處刊物銷售小組訂購 (電話：(852) 2537 1910)
- 進入網上「政府書店」選購，網址爲 http://bookstore.esdlife.com
- 透過政府新聞處的網站 (http://www.isd.gov.hk) 於網上遞交訂購表格，或將表格傳真至刊物銷售小組 (傳真：(852) 2523 7195)
- 以電郵方式訂購 (電郵地址：puborder@isd.gov.hk)

讀者可於下列地點購買1:100 000，1:20 000及1:5 000地質圖：

香港北角渣華道333號
北角政府合署23樓
地政總署測繪處
電話: 2231 3187
傳真: (852) 2116 0774

如欲索取地質調查報告、其他免費刊物及地質圖，請致函：

地質調查報告及地質圖:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
規劃部總土力工程師
(請交:香港地質調查組)
電話: (852) 2762 5380
傳真: (852) 2714 0247
電子郵件: jsewell@cedd.gov.hk

其他免費刊物:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
標準及測試部總土力工程師
電話: (852) 2762 5345
傳真: (852) 2714 0275
電子郵件: ykhui@cedd.gov.hk

MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2000).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.

GEOSPECS

Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 3	Model Specification for Soil Testing (2001), 340 p.

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 p.

GEOLOGICAL PUBLICATIONS

The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents