HKIUS 香港管綫專業學會

Hong Kong Institute of Utility Specialists

Non – profit Making Organization

Method Statement

For

Utility Mapping By Non-Destructive Methods

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Foreword

It's been more than ten years now since the disastrous landslip that occurred in Kwun Lung Lau on Hong Kong Island on 23 July, 1994. Since 1995, the Government of HKSAR has awarded tens of millions of dollars in contracts related to detection of leakage from buried water carrying services (BWCS) both on slopes and on the roads throughout the territory. As expected, this sequence of events generated an increasingly large pool of "Utility Specialists (US)", with most working almost independently, devoid of any standardized surveying methods, quality requirements (on survey results) and the "registration" of operation personnel in the market before the establishment of HKIUS in 2002.

In view of the availability of the multitude of method statements, specifications, training manuals, and the contracts documents produced for the vast number of underground utility survey contracts (by government and private projects), the following sections try to provide a comprehensive set of method statement, by addressing the following topics in general and where the abbreviation can be found in the Appendix:

(1) Standard Operation Procedure
(2) Standard Report Format
(3) Standard Safety Precaution

You are welcome to take reference to this method statement for your contract and in case you need further information, please send an e-mail to info@hkius.org.hk or call Ir Dr. King Wong.

Ir Dr. King WONG, FHKIUS, FIIUS, RPUS
黃敬 博士、工程師、管綫專業監理師(院士)、管綫專業監察師,

Editor in Chief

January, 2020

Ir Chun-keung NG, FHKIUS

伍振強工程師、管綫專業監理師(院士)

President, HKIUS (2019-2021)
January, 2020

Ir Prof Eric MA, GBS, JP, FIIUS

馬紹祥 教授、工程師、金紫荊星章、太平紳士、管綫專業監理師(院士),

President, IIUS

January ,2020

If any error or mistake is found in this particular specification, please kindly contact us.

Tel: (+852) 2967 0000 Fax: (+852) 2618 4500 Email: info@uti.hk

Table of Content

Utility Mapping (By Non-Destructive Methods)

1. Scope of the Works

The aim of utility survey/mapping is to locate and identify all underground services within the sites to be investigated. The condition of services is not required to be investigated in the survey. Excavation is excluded, except where necessary to open existing covers.

1.1 Pipe and Cable Locator Survey

Introduction

Pipe and Cable Locators have been used to locate underground utilities for more than two decades. It applies the theory of Electromagnetic Induction onto a metallic target line and hence an alternating current (the signal) will be generated. The signal will then transmitted to a receiver, which facilitates the location of the centre of the signal to be identified. With advancements in technology, it is now possible to locate the depth of the induced line with good accuracy by a well-trained operator.

Electromagnetic induction

A pipe and cable locator does not locate buried pipes or cables. It detects a magnetic field around the line created by an Alternating Current – A.C. – flowing along the line. This magnetic field forms a cylindrical shape around the line and is known as the ‘signal’.

It is possible to insulate against the flow of electricity, however, it is not possible to insulate against a magnetic field, and the shape of this field is not altered by cable insulation or by the presence of different soil types.

Alternating currents create the detectable magnetic field or signal because it does not only provides a field but also an oscillating frequency of reversals, and such generation which makes effectively positioning possible through the principle of electromagnetic induction.

Instruments for locating buried pipes and cables use the principles of electromagnetic induction in the following two ways:

(4) Locating the A.C. signal on a line with a receiver.
(5) By the transmitter remotely applying a detectable A.C. signal to the line.

An electric circuit has to be completed to allow a current to flow. Low powered signal source at the surface shall affect the detectability of current flow in a properly insulated buried conductor. The voltages available are shall be incapable of punching through insulation. And capacitance on A.C. circuits shall also affect the detectability of current flow.

Capacitance is the effect by which signals are able to jump across insulation. The mass of the surrounding soil acts as if there is a conducting layer around the conductor.

Signal frequency

The basic law regarding signal frequency can be summarized as follows:

'The higher the signal frequency, the greater the A.C. voltage and signal induced in the conductor and the greater the capacitance current flow'.

It would therefore appear that high frequency signals are more effective than low frequency signals.

However, because a high frequency signal flows to ground via capacitance more easily, it will not carry as far as the same strength of a low frequency signal.

A further drawback of high frequencies is the ease with which signals aimed along the target line can couple by mutual induction to other lines in the vicinity. This often makes it more difficult to trace a target pipe or cable in a congested area.

A large pipe or cable diameter increases the line's surface area that is in contact with the soil, therefore the signal leaks to ground. The same signal strength leaks away over a much shorter distance from a large pipe than from a small one.

The ability of the ground to pass current varies locally. Wet soil is a better conductor than dry sands, and the resulting capacitance effects will vary the apparent conductivity of the conductor. The effect of high ground conductivity is to make it easier to induce current flow and therefore a signal in a buried conductor because of the good return path. At the same time, the easy return means that the signal becomes lost along a short rather than a long length of conductor.

Conversely, low ground conductivity requires more energy to induce a signal onto a line, but it will then be detectable along a greater length of the conductor.

To successfully locate and trace each different type of pipe or cable, operators shall tune the devices to an optimum frequency for the survey.

Electronic Depth Estimation

A receiver with a twin aerial antenna uses the two aerials to measure depth in the same way that two eyes can judge a distance.

The signal strength at the bottom aerial is compared to the signal strength at the upper aerial. The receiver circuitry does the arithmetic calculations to provide a depth reading on the receiver display.

Locating Non Metallic Lines

All the techniques described so far have been based on the detection of signal currents flowing in a conducting, metallic line. Where plastic or concrete pipes, ducts and drains are concerned, there is clearly no way of detecting and tracing them electro magnetically unless a transmitter can be inserted into them or a tracer wire is laid along the line. This tracer wire can then have a signal applied to it in the same way as to a metal pipe or cable.

Locating a Sonde

A sonde transmitter is a small self-contained signal transmitter designed for inserting into non-metallic ducts, drains or sewers so that it may be located and traced with a receiver.

Although it is an ac signal, the magnetic field or signal produced by a sonde is different to the signal produced by the signal transmitter and described previously in this section.

The sonde produces a field distribution, which is not cylindrical as with a line, but is sausage shaped along the orientation of the aerial core. As a sonde is approached with a horizontal aerial, a rising signal will be detected as it comes within range. This will then fall off again to null, giving the impression that the peak signal over the sonde has been passed. But if the traverse is continued, the signal will rise again to a much higher level, the peak of which indicates the actual and exact position of the sonde. It will then fall to null again, followed by a small rise and then fade away. The small ghost peaks either side of the nulls may be misleading unless the peak signal is located.

A vertical aerial produces a single null response over the sonde but this null response is present along an axis at right angles to the sonde. For this reason a vertical aerial should not be used to locate a sonde.

2. Field Procedures

2.1 Safety Program

Confined Space Works

Staff entering manholes (due to the nature of works, manhole entry is not recommended for Utility Survey as information can be acquired by Sonde and in case of unable to survey due to silt or flow or any other dangerous possibilities, photographs will be taken for record purpose) would have been trained and have been awarded the certificate for confined spaces works in accordance with the Factories &Industrial Undertakings (Confined Spaces) Regulation enacted on 19 June, 2000.

Road Work Safety

When working on the carriageways, Temporary Traffic Arrangements will be coordinated in accordance with the Code of Practice for Signing and Guarding as issued by the Highways Department.

Personal Protective Equipment (PPE)

PPE such as safety helmet, safety harness, safety shoes, goggles will be always provided. Staff will take necessary precautions and utilize them when potential hazards are identified.

An emergency telephone list will be provided for the Team Leader, to make sure that the Utility Companies, Police Department and Fire Department can be contacted should the need arise.

2.2 Planning and setting up

Systematic planning will be undertaken for the commencement of the contract. A preliminary schedule will be arranged in accordance with the agreement signed between contractor and the client. Further information such as utility drawings will be prepared and corresponding action will be taken e.g. application for traffic permits according to the schedule. Letters will be sent out to the utility companies for acknowledgement.

An exhaustive search of the available utility maps will be completed in order to get an understanding of the potential layout of subsurface utilities. In fact, the client shall provide those records as part of their obligation and to minimize the time spent on the issue.

The preparation kit includes utility drawings; all necessary permits for field works and safety precaution procedures will be issued to the survey team before the commencement of field works.

A report team will be established who have a good understanding with reference to the requirements set out in the contract signed with the client.

Boundary Definition and Visual Inspections

The site boundary will be confirmed and agreed on site by the client's representative. The site boundary will be marked with spray paint to provide on-site limits to the field crew and post-survey reference for any follow-up activity. This is facilitated by the use of a Total Station and arbitrary control points. Where possible manholes / valves / vaults / chambers will be opened in order to map their extents and depth. Sewers are also marked, where visible, for the direction and flow of drain tunnels, diameter and depth of each tunnel. Manhole covers and valves outside the immediate site boundary will also be opened, marked and traced if they contain services which enter the boundary area.

2.3 Electromagnetic Locating Survey

Electromagnetic location instruments (Cable/Pipe Locator) will be used to locate metallic pipes and tracer wires are laid for non-metallic pipes and drains where there is an access point within a reasonable distance (say 20 meters) from the site or on the route being surveyed.

All surface features relating to underground utilities, such as manholes, draw pits, inspection chambers and gullies, including all street furniture connected to pipes and cables such as lamp posts, illuminated road signs and bollards, telephone kiosks etc. will be recorded.

All known and all other recordable underground services within the site will be surveyed. However, the condition of services will not be surveyed.

Underground utilities will be located continuously and recorded in three dimensions at reasonable intervals and at each surface feature, change of direction. Where bands of cables/ducts are identified, the upper and lower outer cables/ducts will be traced in order to provide a cross section of the cable/duct band.

Direct connections will be made to gas and water valves without any damage to the utilities. All electrical utilities (lampposts, traffic lights, low / medium / high voltage electric cables and telecom cables) will be located by either inductive methods or where necessary the use of a signal clamp which makes no contact with any conducting material. Sewer manholes will never be accessed internally but rather examined by use of torches thus not requiring confined space entry and greatly reducing any chance of injury from harmful gases, rats, snakes, etc.

Drains or sewers will be surveyed by lifting covers and the path of the drain traced and located using an electromagnetic sonde.

The position of utilities will be marked for the surveyor to record the findings by undertaking a topographical survey and eventually forming a drawing in IDMS format.

Preferred Site marking standard

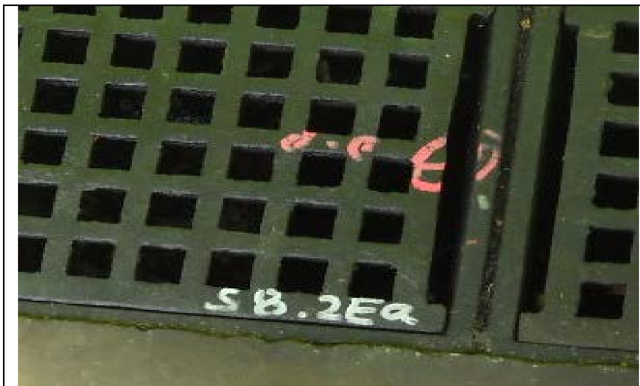
1) Site marking should be marked tidy.
2) Spray paint and marker can be used to mark.
3) Marker is preferred to spray paint, but if marker cannot mark on ground, spray paint is acceptable.
4) When marking on tile, marking should be marked as a small circle with point number.
5) Use marking in sharp colour such as red and yellow.
6) **Must not use marking in white on road in order to prevent affecting road marking which is also in white colour.**
7) Make the marking visible and as tiny as possible in order to reduce visual pollution.
8) Use paint remover to clear all markings after completion of work.

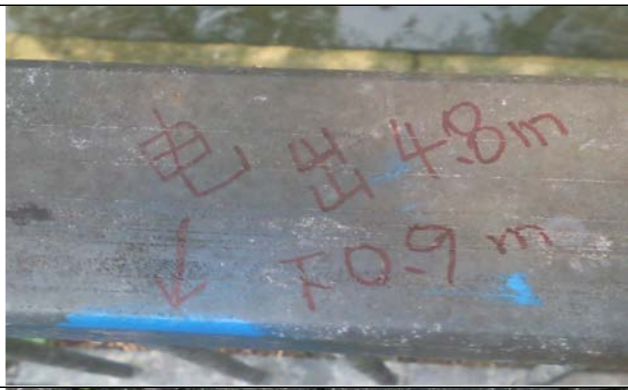
Site marking size:

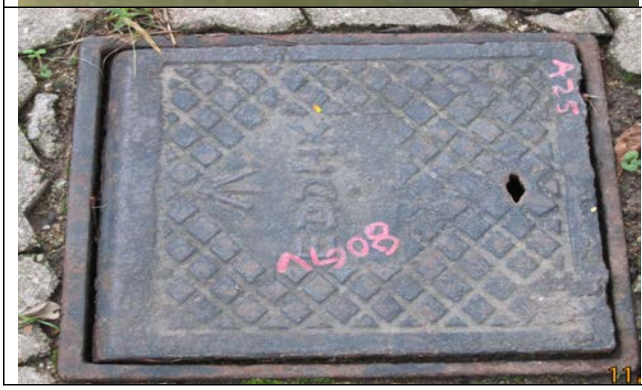
Site marking size should be within site/ property owner's acceptance. If there is no special request from the site/ property owner, site marking size should be as follow:

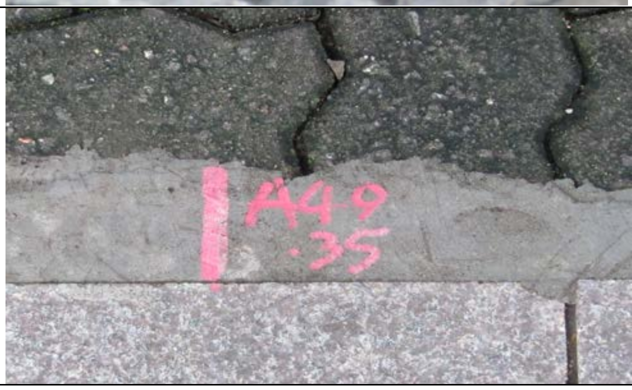
a) When using marker to mark on site, for each marking, the marking should be marked within A6 size (10.5cm x 14.8cm).
b) When using spray paint to mark on site, for each marking, the marking should be marked within A4 size (21cm x 29.7cm).

Samples of site marking (marker):

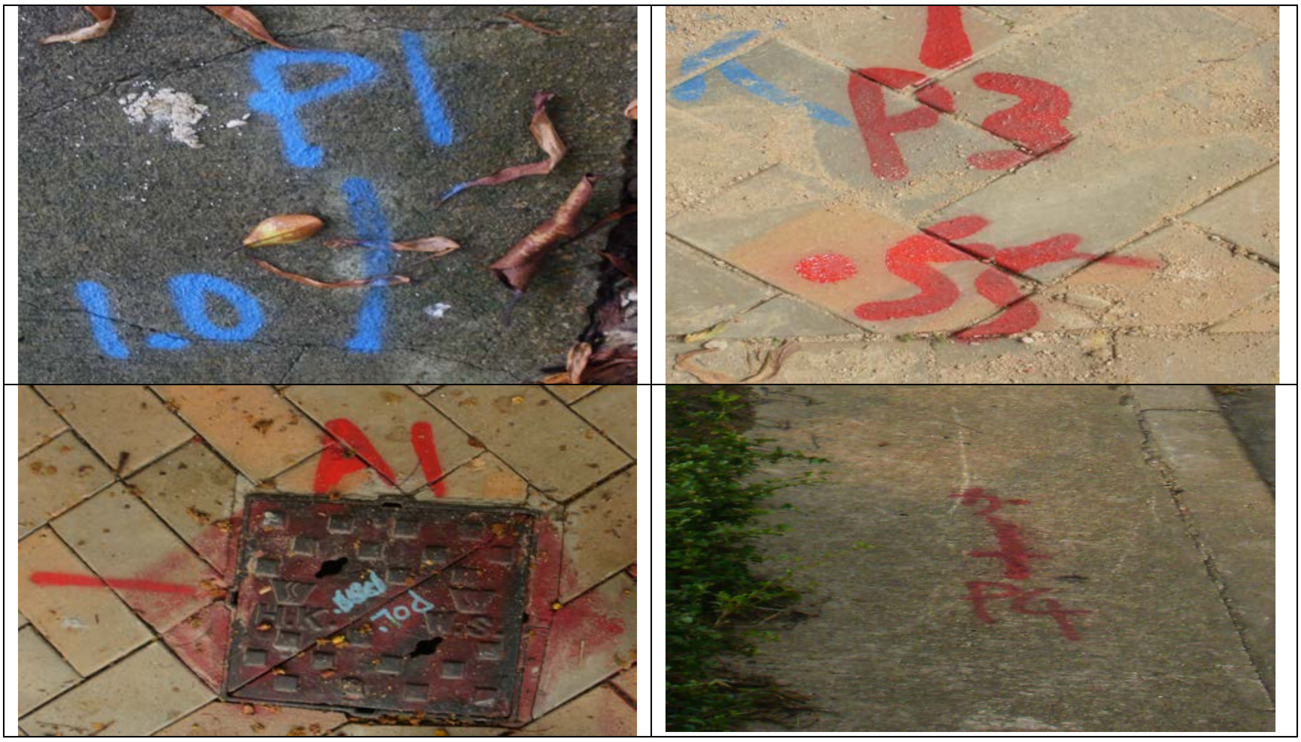




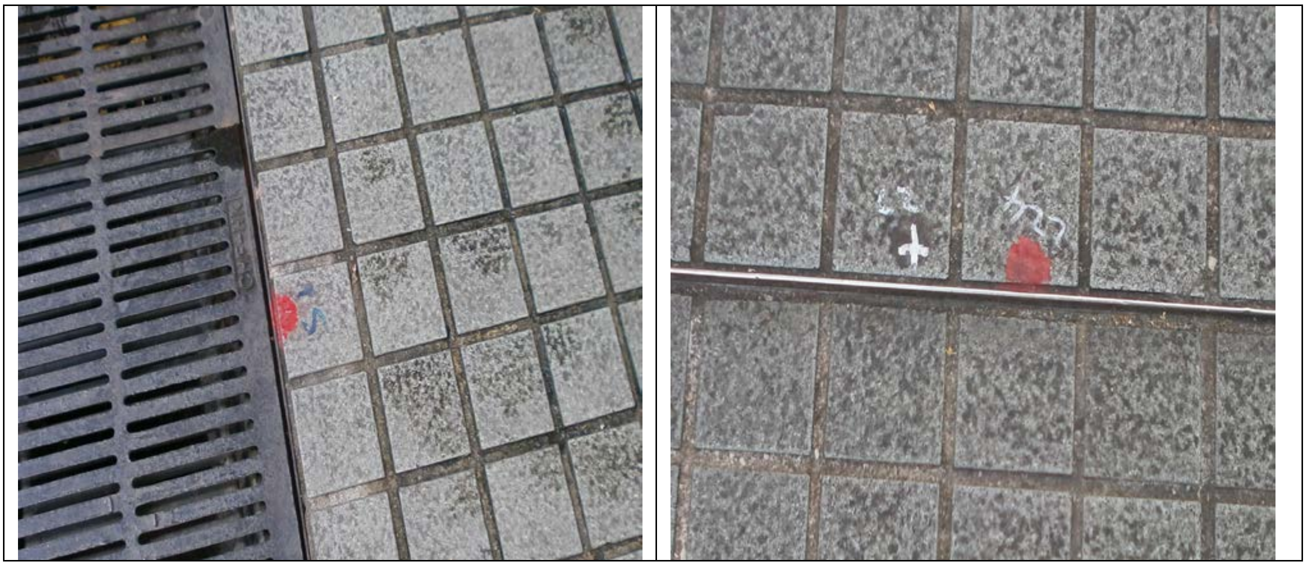




Samples of site marking (Spray paint):



Samples of site marking on tile:



Samples of utilities survey with photographs can be found in Appendix A3 in this method statement.

2.4 Topographical Survey

The Land Surveyor will map the position of the found utility alignments marked on site, data recording is via onboard data logging facility using specially designed survey data collection software.

The utility information is transferred to digital format and presented in a utility drawing at (1:100 or 1:200 scale) in DWG/DGN/IDMS format. Cover levels and invert levels are related to the arbitrary control point and the Hong Kong Principal Datum.

The depth below ground will be annotated at each surface feature and at significant changes of depth. The depth of metallic lines will be shown as - 0.68d - with a cross mark on the respective line. Depth of metallic lines, which were located, by Pipe and Cable Locators are referenced to the centre of the pipes/cables.

Where cable/duct bands are identified, notes will be included, showing the number of cables/ducts and configurations.

Where a bundle of cables are found, a carpet of cables will be marked on the drawing with the outer cables show on each side of the bundle.

3. Quality Assurance and Quality Control

3.1 Electromagnetic Induction Data

The locator data will give real-time information from which the result will be a spray-painted mark on the ground identifying the service type by colour, the direction of service, and the depth to the centre of service. No post-survey processing is required. The located information is recorded by undertaking a topographical survey using a total station. Any interpretation on the part of the locator operator will be made on site. There are occasions when the signal to noise level is not adequate enough to make a confident locate due to congested areas, presence of reinforcement bars in the road or concrete, deteriorating utility condition or interference from other local sources. In these situations, the location is based on the operator's experience and his understanding of the site layout based on existing maps, if available. Any field notes and maps will be checked after the field program to confirm that all buried services are located. Any missed utilities or sections were checked with the locator operators to confirm that the existing situation is not different from that indicated on the maps. If a conflict still remains, a second site visit will be instigated to confirm or correct any discrepancies.

3.2 Total Station Survey Data

The topographic survey data will be downloaded to a desktop computer, edited for field errors, then attributes added to each separate feature. The results will then be checked against the existing utility maps and to re-confirm all existing buried services, which were mapped on site. Utilities will be shown at a scale of 1:200 or 1:100 and services will be shown to actual scale, except where otherwise noted.

The drawings will be presented relative to an arbitrary control point set on site and all survey datum levels will be referenced in relation to the Hong Kong Principal Datum. It is important to note that the electromagnetic-induction-located data is referenced as depth to centre of the service, Radar Survey results are referenced as depth to the top of the anomalies and Sewer/Drains are referenced as the depth to invert of the pipes.

3.3 Drawing Editing

Drawings will be submitted in IDMS format. Alignments will be shown in different colors for different type of utilities and depth will be marked at an interval of around 10 meters on the plan. Information recorded by the surveys will be compared with the existing utility plans. Any doubts will be clarified by a site re-visit.

3.4 Report Writing

A technical report will be accompanied with the drawing this will state the findings and difficulties encountered on site. Photographs illustrating the progress and any problems encountered will be included in the report for the client's reference and comments.

It is expected that the client will return the marked up reports with their comments within 14 days from the date of submission. Otherwise, it will be regarded as approved by the client. Any other activity beyond this may induce additional costs as we may need to re-mobilize teams from other destinations.

4. Survey Accuracy

4.1 Control Accuracy

Well defined points of detail will be surveyed to less than ±60mm root mean square error, on the ground, when compared with co-ordinates determined by precise measurement from the nearest control point (90% of a representative sample of well defined points will be within ±100mm).

Spot heights on hard surfaces will be correct to better than ±10mm root mean square error, when compared with heights determined by precise levelling from the nearest bench mark (90% of a representative sample of spot heights will be within ±165mm) OR (0.1D which ever is higher (D = Depth of Buried Pipes)).

Additional tolerances shall be permitted for features without sharply defined edges and spot heights on soft surfaces.

4.2 Accuracy of Location and Survey for Normal Case

Underground services, which can be located without excavation, such as cables and connected metal pipes, which can be located by surface detection equipment, the Pipe and Cable Locator, and drains shall be located and surveyed to the accuracy given below:

Underground services will be located continuously and recorded in three dimensions at intervals not exceeding 5m at discrete areas or at intervals not exceeding 10m for survey along road, and at each surface feature, change of direction and bifurcation.

The position and level of locatable services, at the recorded points and intervals defined above, will be related to grid control points and bench marks to better than +100 mm root mean square error on the ground. (For normal case, 90% of a representative sample of points on locatable services will be within ±165 mm or 0.1d (depth) whichever is bigger.

Positions and levels shall be related to the specified grid and datum and will normally be related to the centre of pipes, ducts or cables, and inverts of sewers and drains.

(1) The position and level of locatable services, at the recorded points and intervals not exceeding 1 meter, shall be related to the control survey stations to better than

(2) The position and levels shall be related to the Hong Kong 1980 Geodetic Datum and shall normally be related to the centre line of pipes, ducts or cables, and inverts of sewers and drains.

(3) Any known underground services or information which cannot be surveyed to the accuracies stated above, other than by excavation, shall be entered in unique AutoCAD layers defined as “unreliable”.

(4) Where full details of underground services cannot be determined without excavation, these details shall be deduced from the utility undertakers’ record drawings and entered into the drawing in a unique AutoCAD layer defined as “Record”.

(5) Wherever access is available from the surface, depth to the underground services shall be checked as a means of calibrating the survey work. Positions of exact measurements shall be noted as attributes in the drawings.

5. Discussion on Findings

Utilities Survey (Pipe and Cable Locator Survey)

The Electromagnetic Induction Locators will be utilized to locate metallic utilities and the Sonde will be used to locate non-metallic utilities. The utilities to be located include Water Pipes, Gas Pipes, High and Low Voltage Cables (includes E & M, Street Lighting and ATC Cables), Telecom Cables, Foul and Storm Drain Pipes (including Box Culverts). Within the limit of the survey equipment (3 metres in depth for direct buried metallic pipes, 4.5 meters for using double depth antenna and 6 meters for non-metallic pipes with proper access point), at least 90% of the representative sample will be located to an average accuracy of higher than 90% of the representative sample. The rest of the utilities, which could not be identified, may be due to one or more of the following factors:

(1) Manhole covers unable to be located due to manhole covers being buried, which making sonding or locating not possible. In this case, the utilities' alignment will be located instead based on the next closest manhole cover;

(2) Manhole covers unable to be opened due to aged rust or other matters, making sonding not possible. In this case, attempts will be made to locate the next closest manhole to trace the pipe back to the unopened manhole (even though the next manhole cover may be far away from the survey area);

(3) Pipe connected by non-metallic materials, in part of the metallic pipe, makes locating not possible or very difficult. In this case, assumptions will be made to connect the pipe once the alignments from both ends have been located. A line called "unreliable" will be marked;

(4) Pipes or cables are buried in the same level and are very close (say an inch or even in contact) to each other making identification of each pipe and cable not possible. In the case, it will be assumed that the pipe of a larger diameter is indicated.

(5) Pipes or cables are located at the same or very close vertical layer. In this case, the first layer will be located and reported.

References

(1) 16/WSD/97, Leakage Detection of Buried Watermains Affecting Slopes - Stage I, Water Supplies Department

(2) 3M Cable Locator User Manual

(3) American Standard of Testing Materials (ASTM) D6432-99, Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation

(4) Code of Practice on Monitoring & Maintenance of Water Carrying Services Affecting Slopes, ETWB (2006), Hong Kong SAR Government.

(5) Constitution, Hong Kong Institute of Utility Specialists, 2010.

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(7) DC96/19, Investigation of Sewers and Drains Behind and Adjacent Fill Slopes and Retaining Walls, Drainage Services Department.

(8) King Wong(2009), Hong Kong Conduit Condition Evaluation Codes(HKCCEC) The Code of Practice on Conduit Condition Evaluation using CCTV in Hong Kong, 4th Edition,UTI

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(11) Particular Specification for Utility Survey, HKIUS, 2011.

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(14) W. Lai, S. Tsang & K. Wong, Applications of Ground Penetrating Radar in Civil Engineering Works, 2004

(15) Work procedures for Utility Survey, HKIUS, 2011

Appendix

A1 Abbreviations

Company/ Organization	
Code	Description
BD	Buildings Department, HKSARG
CEDD	Civil Engineering and Development, HKSARG
DSD	Drainage Services Department, HKSARG
EMSD	Electrical and Mechanical Services Department, HKSARG
EPD	Environmental Protection Department, HKSARG
HA	Hong Kong Housing Authority, HKSARG
HKIUS	Hong Kong Institute of Utility Specialists, HKSARG
HKURC	Hong Kong Utility Research Centre
HyD	Highways Department, HKSARG
LandsD	Lands Department, HKSARG
LD	Labour Department, HKSARG
PolyU	The Hong Kong Polytechnic University
UTI	Utility Training Institute
WRc	Water Research Centre
WSAA	Water Services Association Australia
WSD	Water Supplies Department, HKSARG
WTI	Water Training Institute
Others	
Code	Description
%	Percentage
BMP	Bitmap (Picture Format)
BWCS	Buried Water Carrying Service
CCE	Conduit Condition Evaluation

Company/ Organization	
CCE(CCTV & ME)	Conduit Condition Evaluation(Closed Circuit Television & Man- Entry)
CCES	Conduit Condition Evaluation Specialists
CCTV	Closed Circuit Television
CD	Compact Disc
CL	Cover Level
COP	Code of practice
CP	Competent Person
DN	Nominal Diameter
DP	Design Pressure
DVD	Digital Versatile Disc
e.g.	Exempli Gratia
GIS	Geo-Information System
EPR	Environmental Protection Requirements
etc.	et cetera
GL	Ground Level
H	Height
HKCCEC	Hong Kong Conduit Condition Evaluation Codes
HPWJ	High Pressure Water Jetting
hr	Hour
Hz	Hertz
ICG	Internal Condition Grade
ID	Internal Diameter
IDMS	Integrated Data Management System
IL	Invert Level
ISO	International Standards Organization
JPEG	Joint Photographic Experts Group (Picture Format)

Company/ Organization	
kHz	Kilo- Hertz
kPa	Kilopascal
m	Meter(s)
ME	Man Entry
MHICS	Manhole Internal Condition Survey
mm	Millimetre(s)
Mpa	Megapascal
MPEG	Motion Picture Experts Group (Video Format)
MS	Method Statement
MSCC	Manual of Sewer Condition Classification, UK
OHSAS	Occupational Health and Safety Assessment Series
PPE	Personal Protective Equipment
ppm	Parts per million
PS	Particular Specification
PSI	Pound Per Square Inch
QA/ QC	Quality Assurance/ Quality Control
Ref.	Reference
RMSE	Root Mean Square Error
RPUS	Recognized Professional Utility Specialist
RTO	Recognized Training Organization
SCG	Service Condition Grades
SOPs	Safe Operator Procedures
SPF	Sun Protection Factor
SPG	Structural Performance Grade
SRM	Sewer Rehabilitation Manual
STP	System Test Pressure
TTA	Temporary Traffic Arrangement

Company/ Organization	
US	Utility Specialist
VHS	Video High Speed
W	Width
WLD	Water Leakage Detection
WO	Works Order
WP	Work Procedure

A2 Requirements for Personnel Carrying Out Inspection

Training and Experience Requirements for Personnel Carrying Out Inspection (HKIUS standard, 2011)

Title	Role	Minimum Training Requirement	Minimum Years of Practical Experience	Qualification
Project Leader	Responsible for contract administration and preparation, checking and certifying of reports for compliance with the technical specification.	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ Has attended training courses for relevant survey/detection methods, and Possesses a valid training certificate for relevant survey/detection methods used	10 years in contract administration, preferably in works related to the inspection, survey and in data management.	Either: M/FHKIUS, RPUS plus CP, CW or MHKIE/ R.P.E. plus CP, CW and relevant training in RTO (e.g. PolyU, UTI) for surveys and data management
Deputy Project Leader	Responsible for assisting project leader and acting the post of project leader when project leader temporary not with the team	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ Has attended training courses for relevant survey/detection methods, and Possesses a valid training certificate for relevant survey/detection methods used	10 years in contract administration, preferably in works related to the inspection, survey and in data management.	Either: M/FHKIUS, RPUS plus CP, CW or MHKIE/ R.P.E. plus CP, CW and relevant training in RTO (e.g. PolyU, UTI) for surveys and data management
Team Leader	Responsible for works arrangement and data processing including checking of raw data for quality and consistency.	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ Has attended training courses for relevant survey/detection methods, and Possesses a valid training certificate for relevant survey/detection methods used	5 years in works related to the inspection, survey and in data management.	M/FHKIUS, RPUS, CP, CW
Crew Leader	Responsible for supervising the field works and site safety.	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ 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, survey and in data collection	O/MHKIUS, CP, CW
Operators	Responsible for operating equipment and carrying out inspection and survey.	➢ At least 35 hours of CPD every year ➢ At least 14 hours for refreshment training in every three years ➢ Relevant training in RTO (e.g. PolyU, UTI) for surveys and data collection ➢ 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, survey and in data collection.	AMHKIUS, CP, CW

A3 Samples of utilities survey with photographs

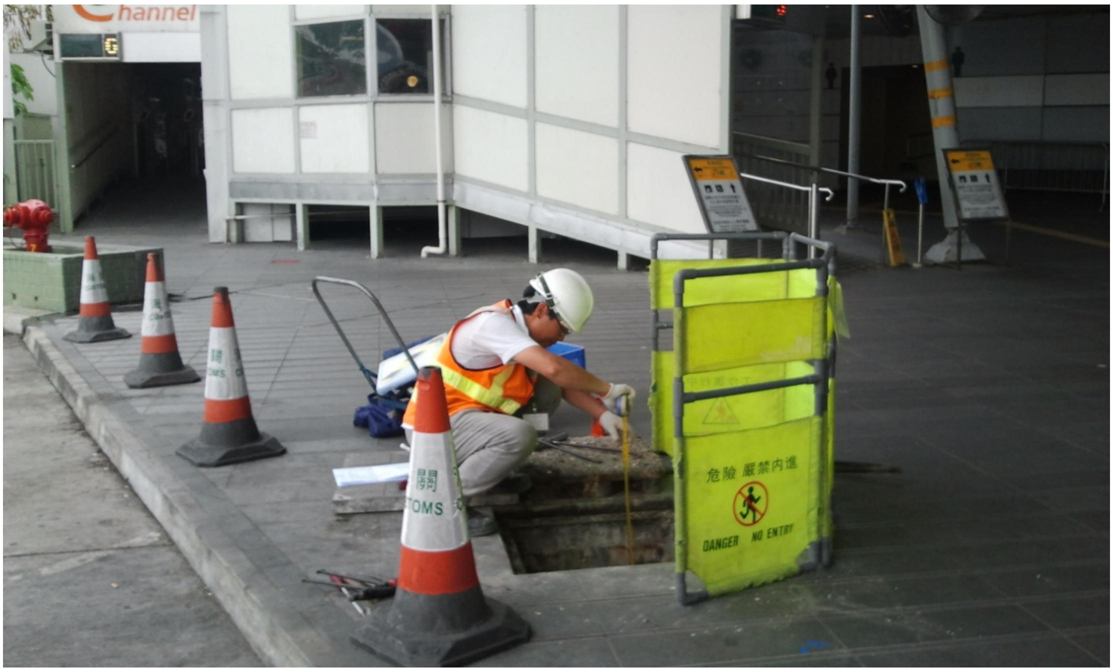

Fig. 1 Manhole depth measurement

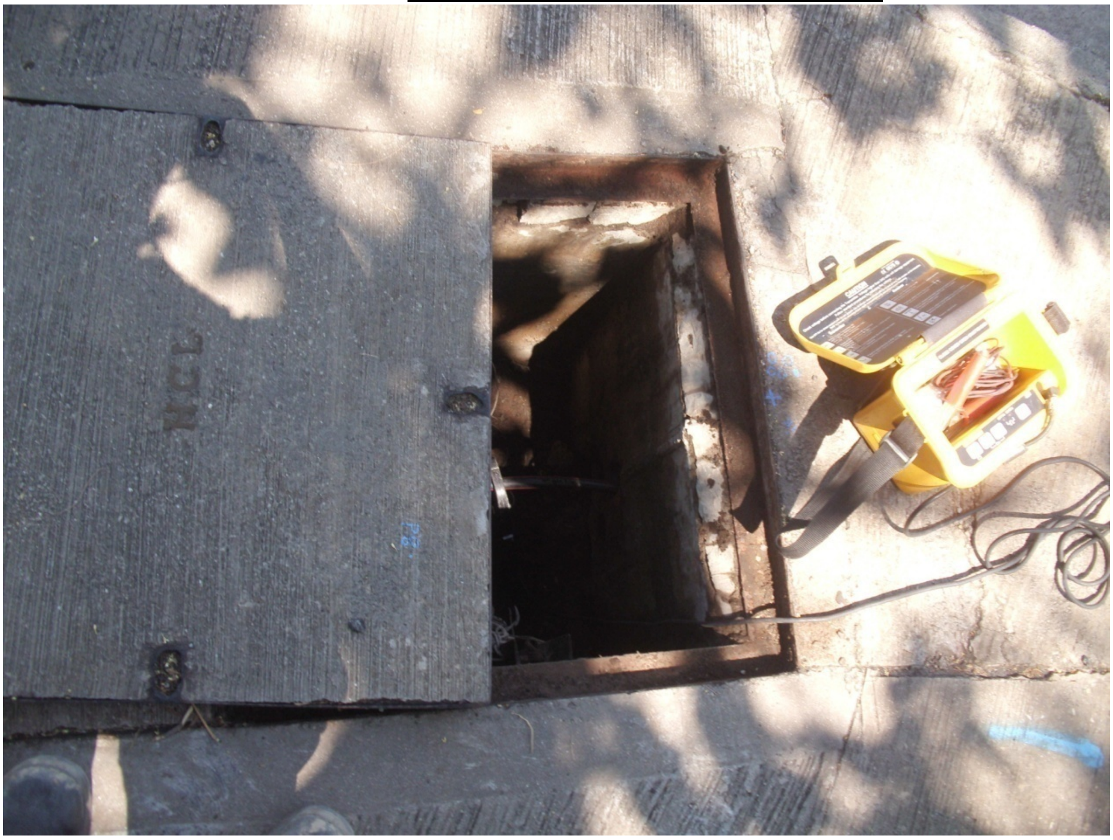

Fig. 2 Locator setup at manhole

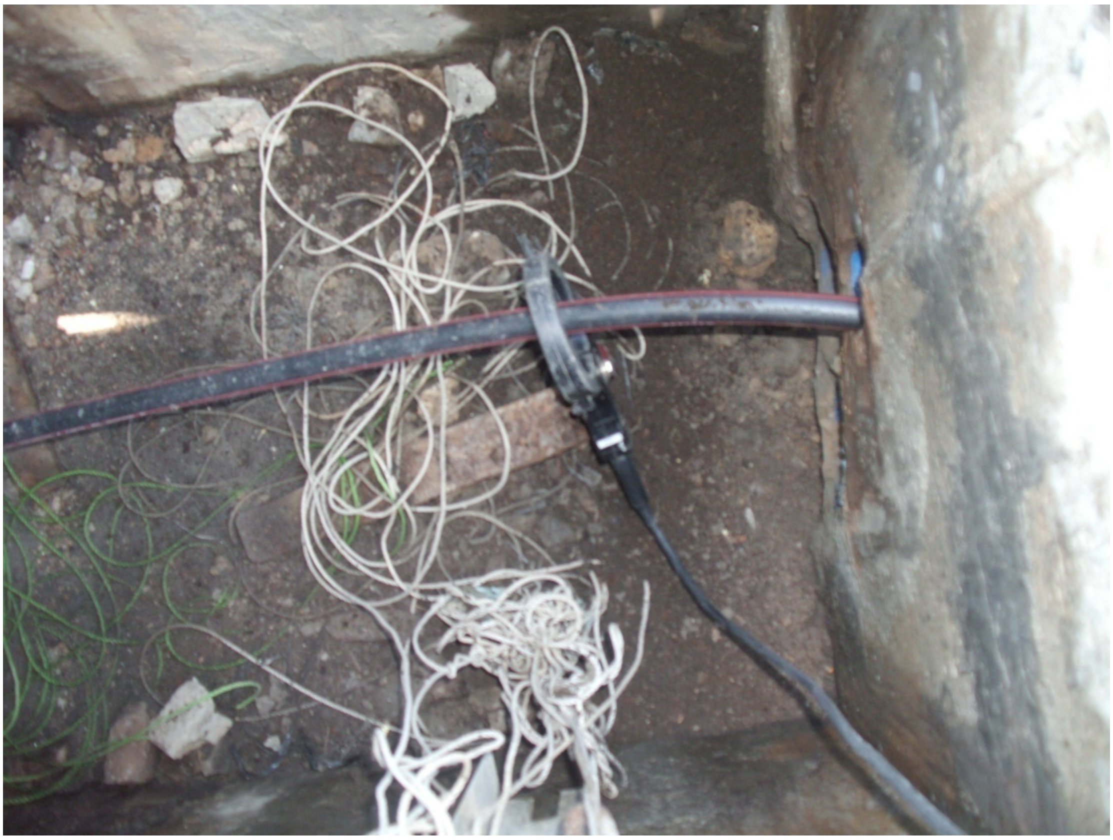

Fig. 3 Locator setup at manhole

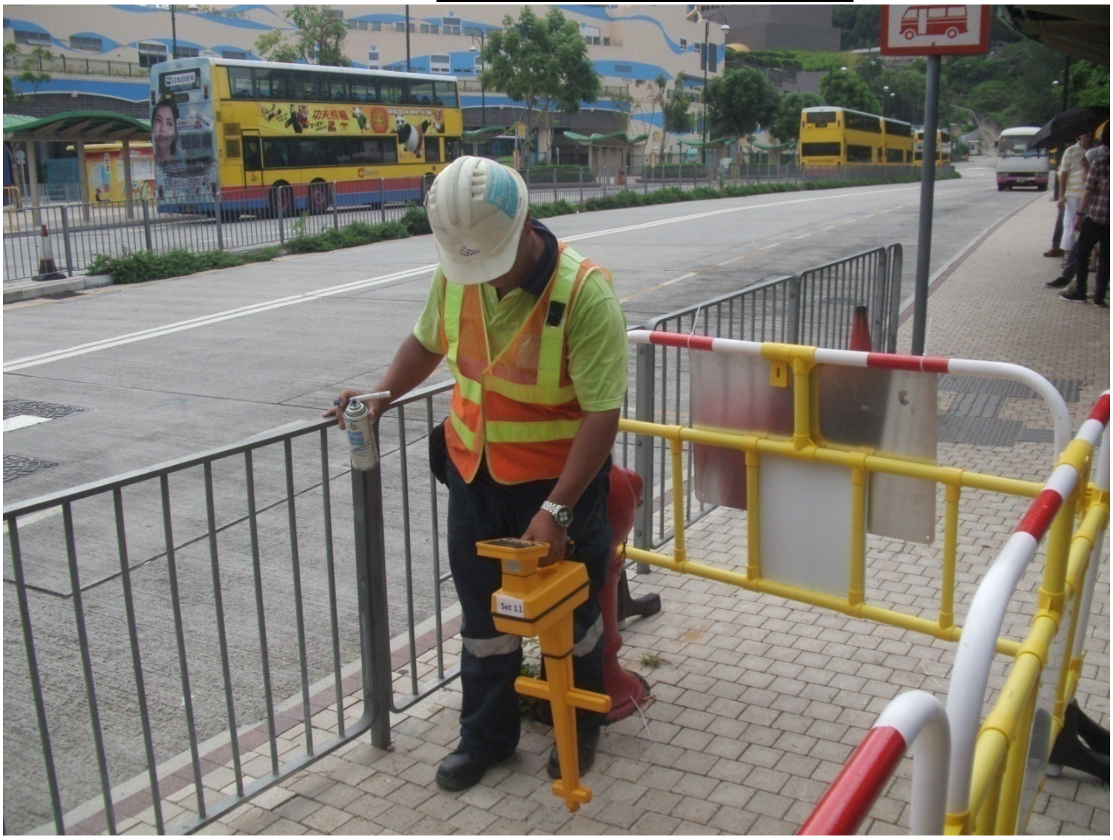

Fig. 4 Locating in progress

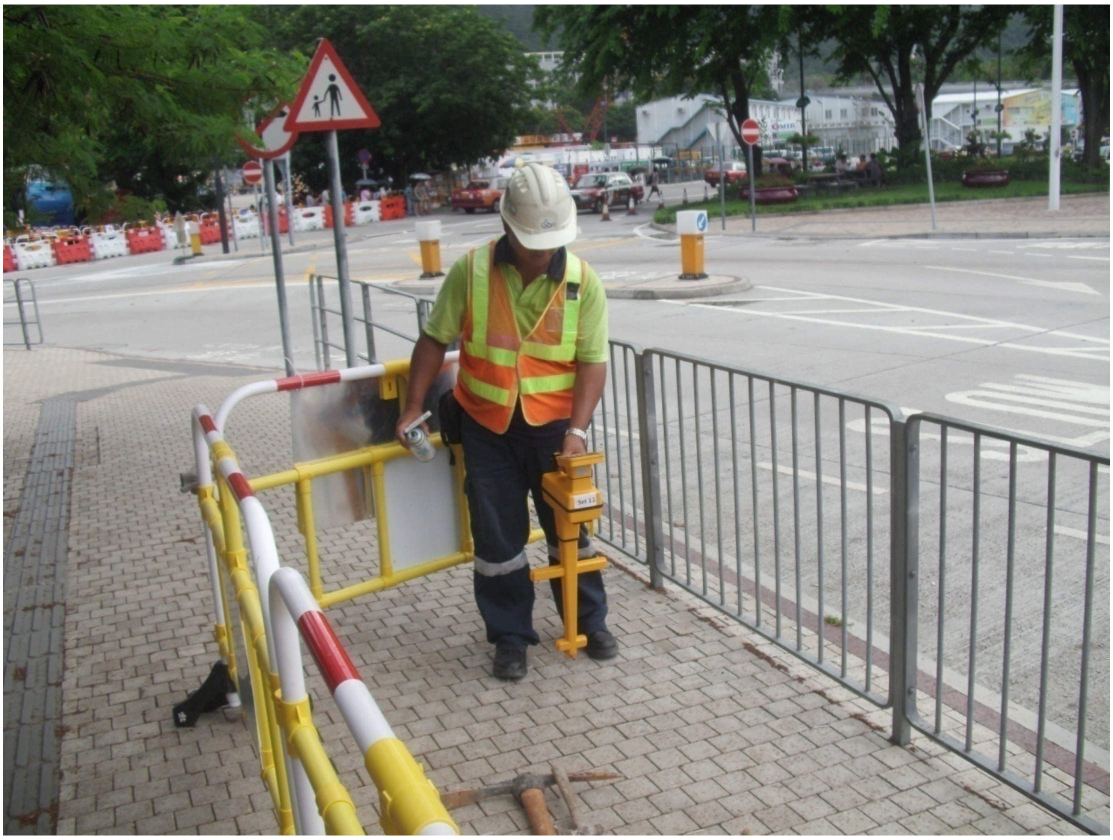

Fig. 5 Locating in progress

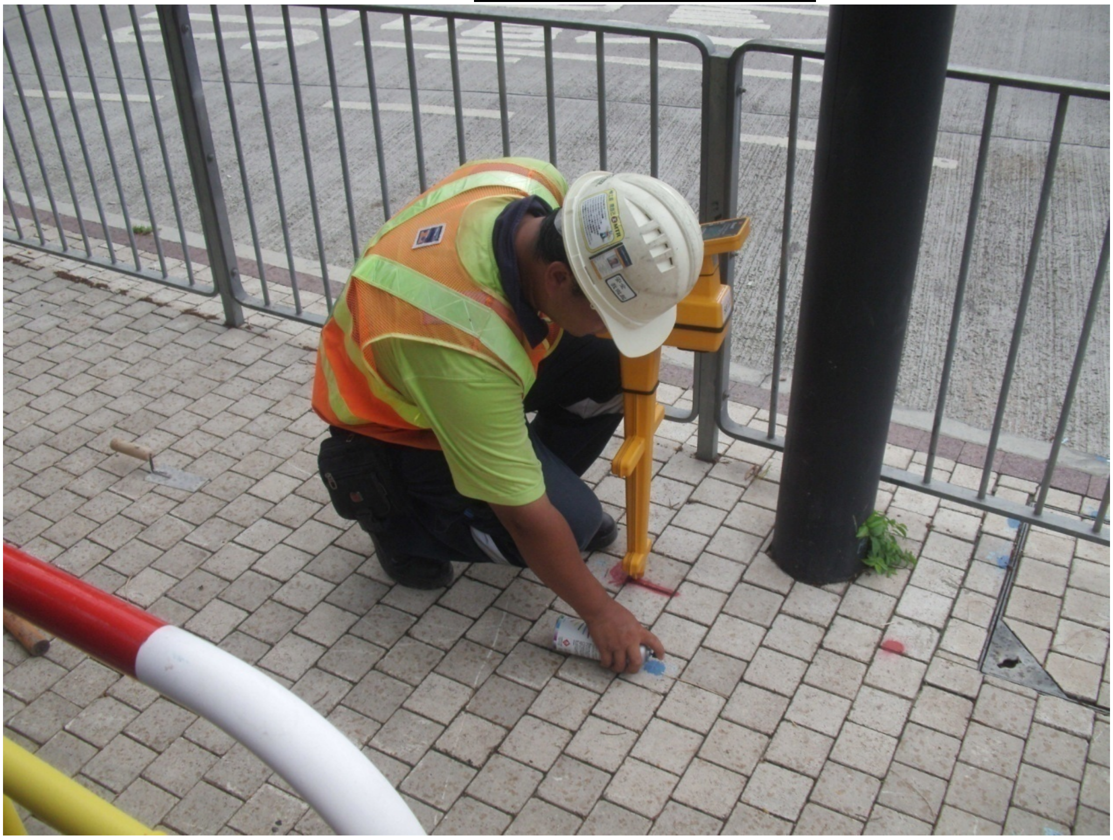

Fig. 6 Site marking in progress

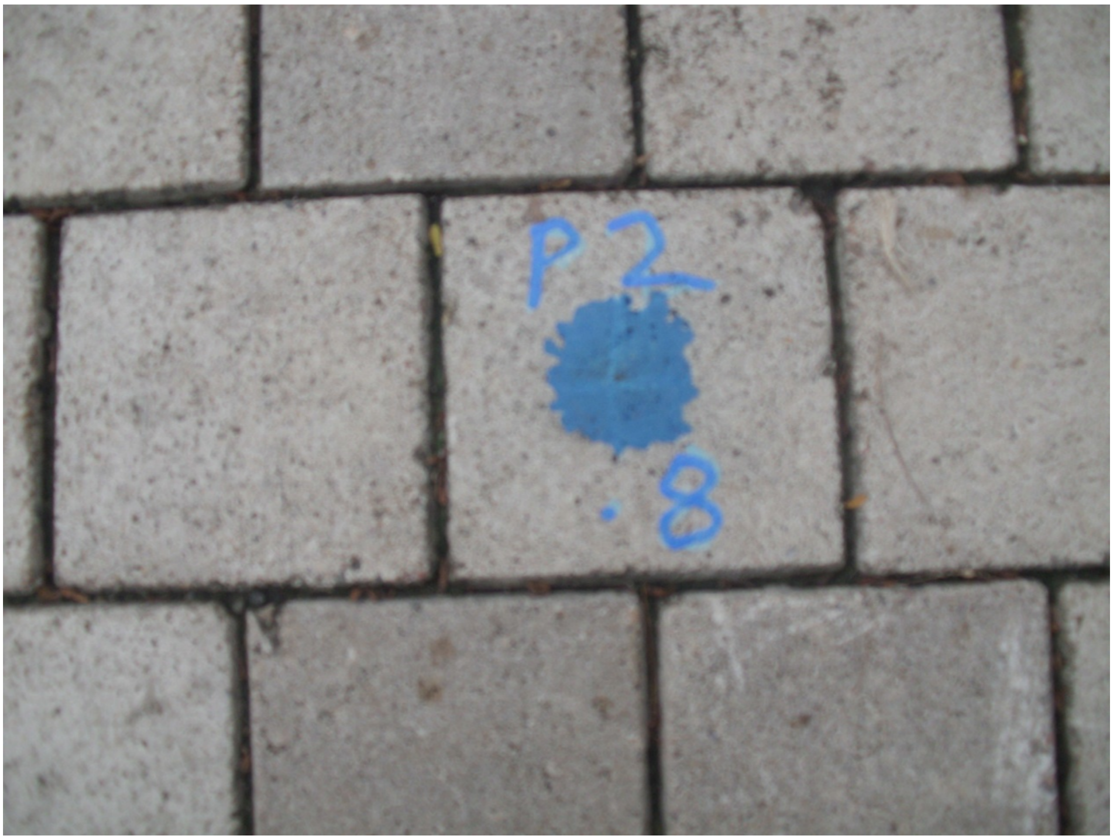

Fig. 7 Site marking

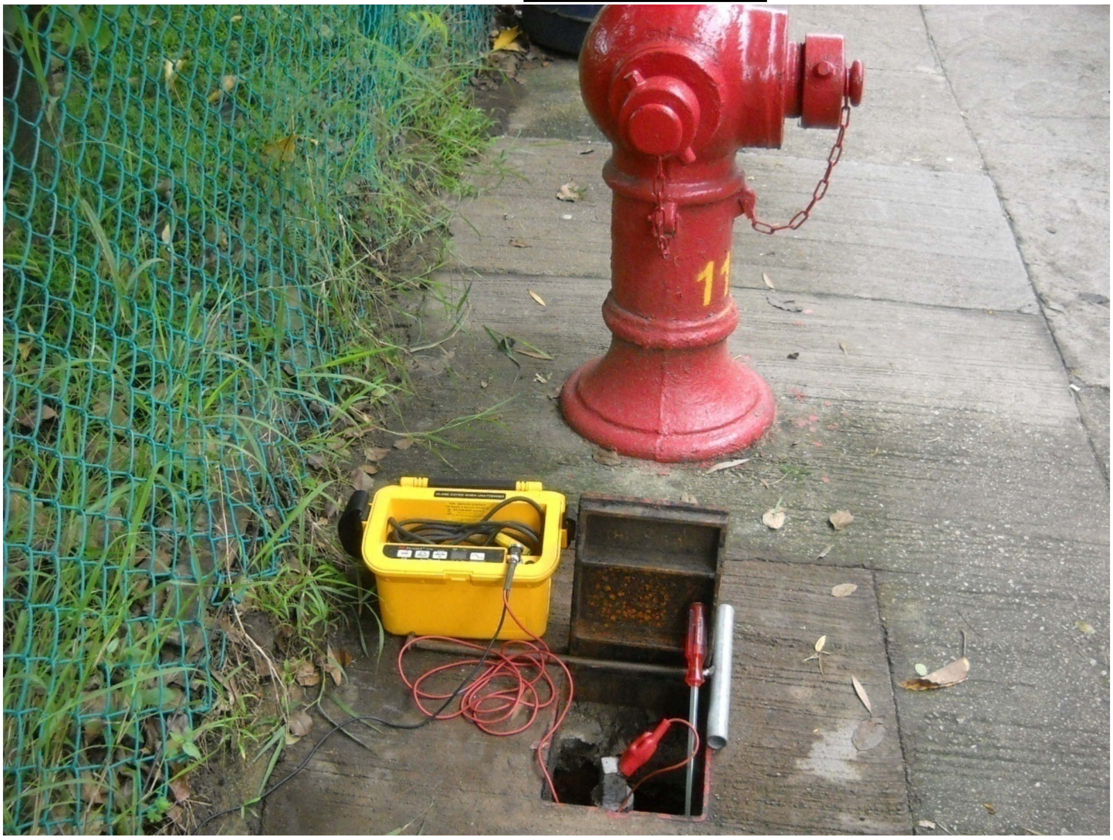

Fig. 8 Locator setup at pit

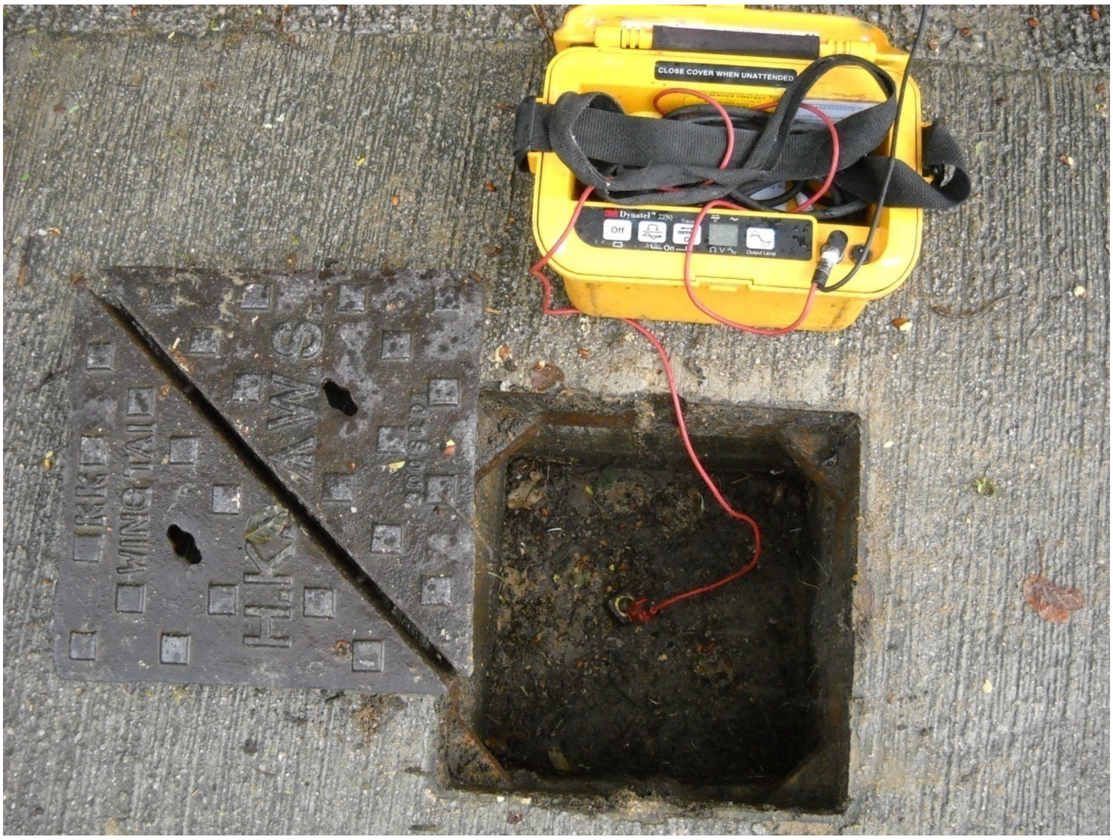

Fig. 9 Locator setup at pit

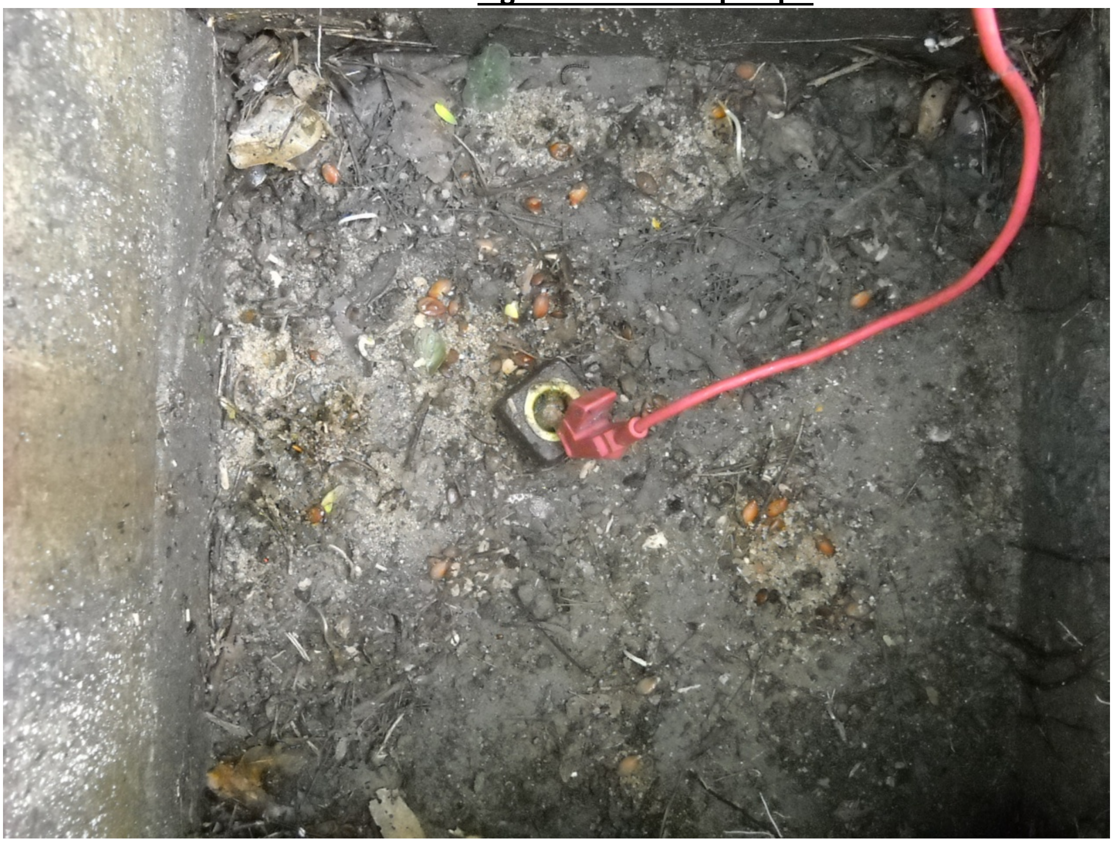

Fig. 10 Locator setup at pit

Fig. 11 Locating in progress

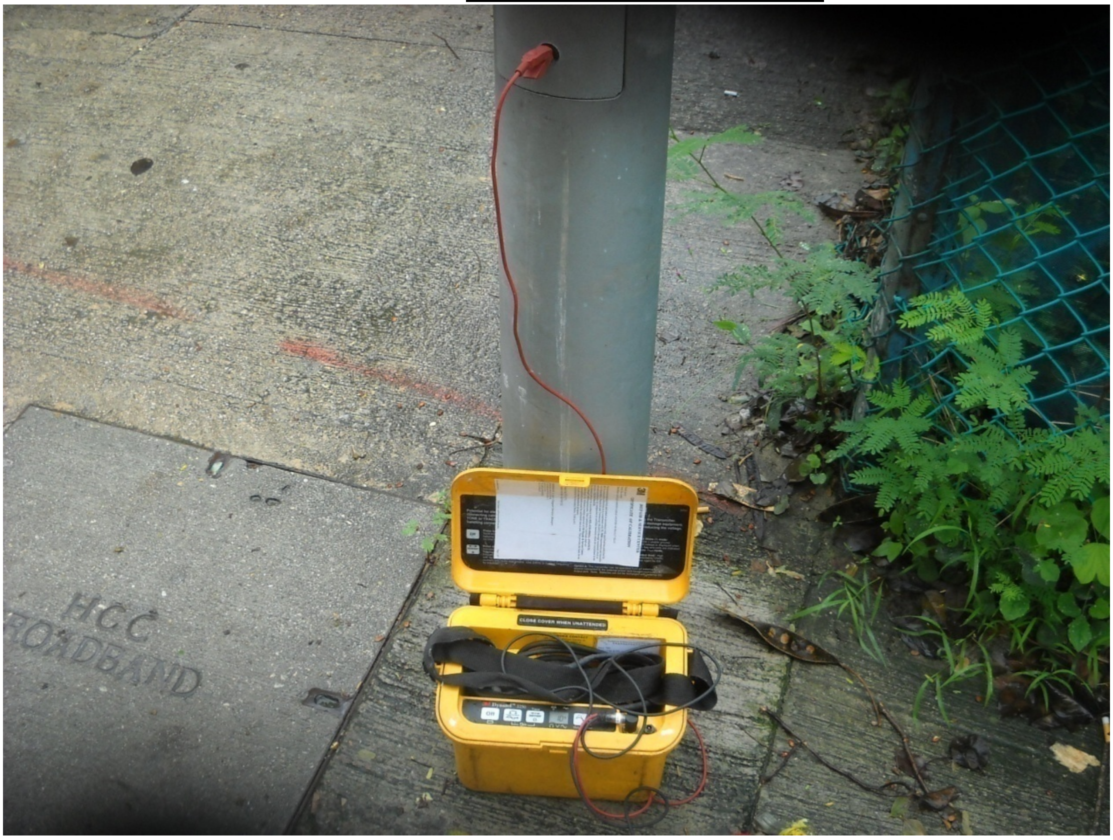

Fig. 12 Locator setup at public lighting

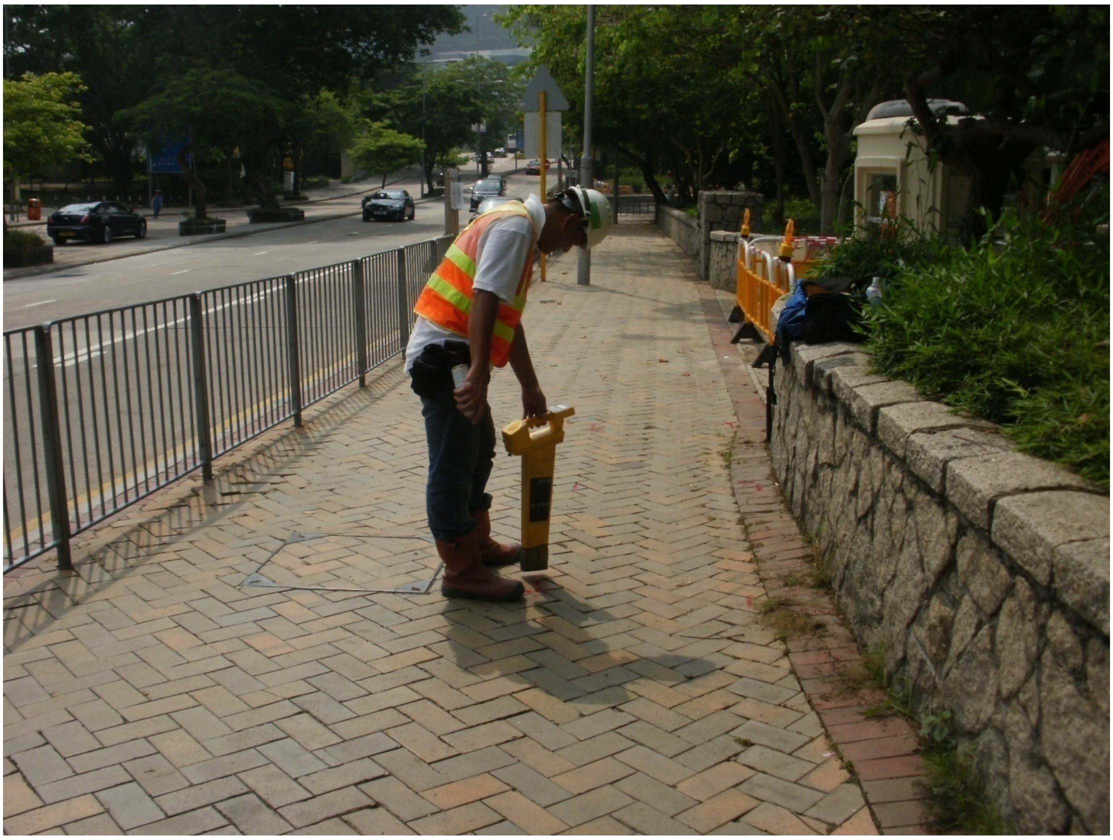

Fig. 13 Locating in progress

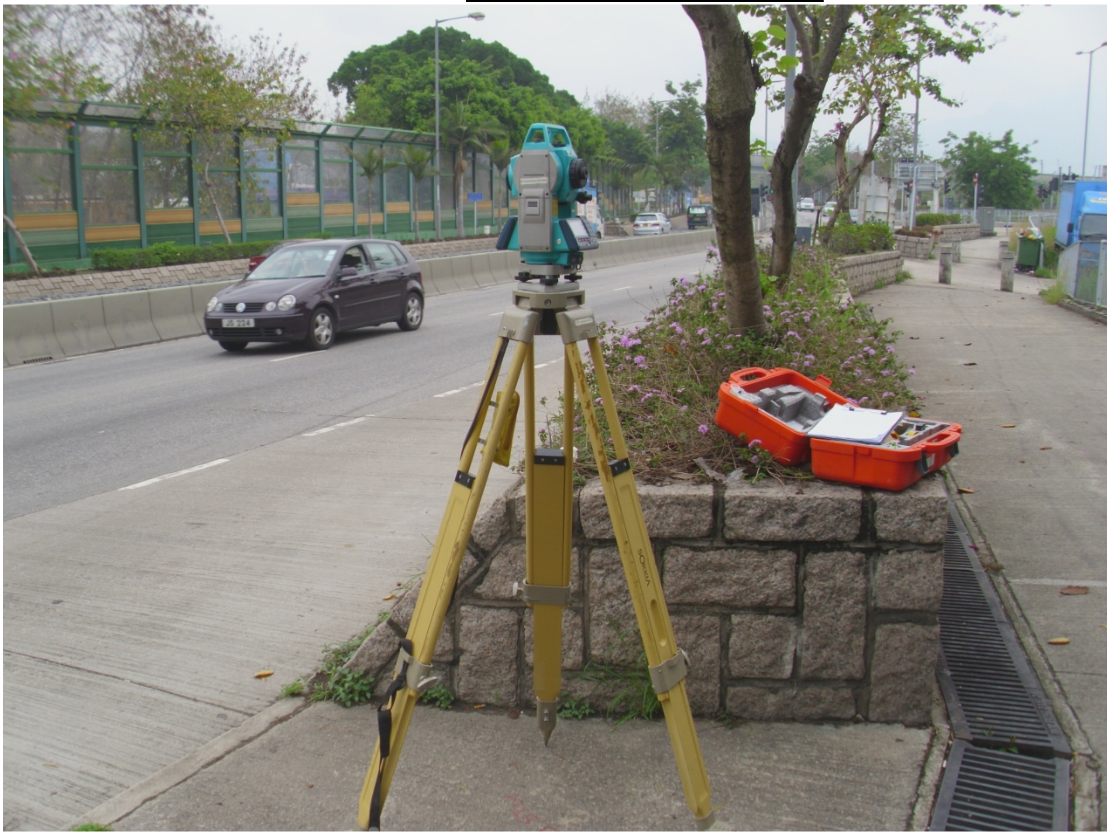

Fig. 14 Topographic survey in progress

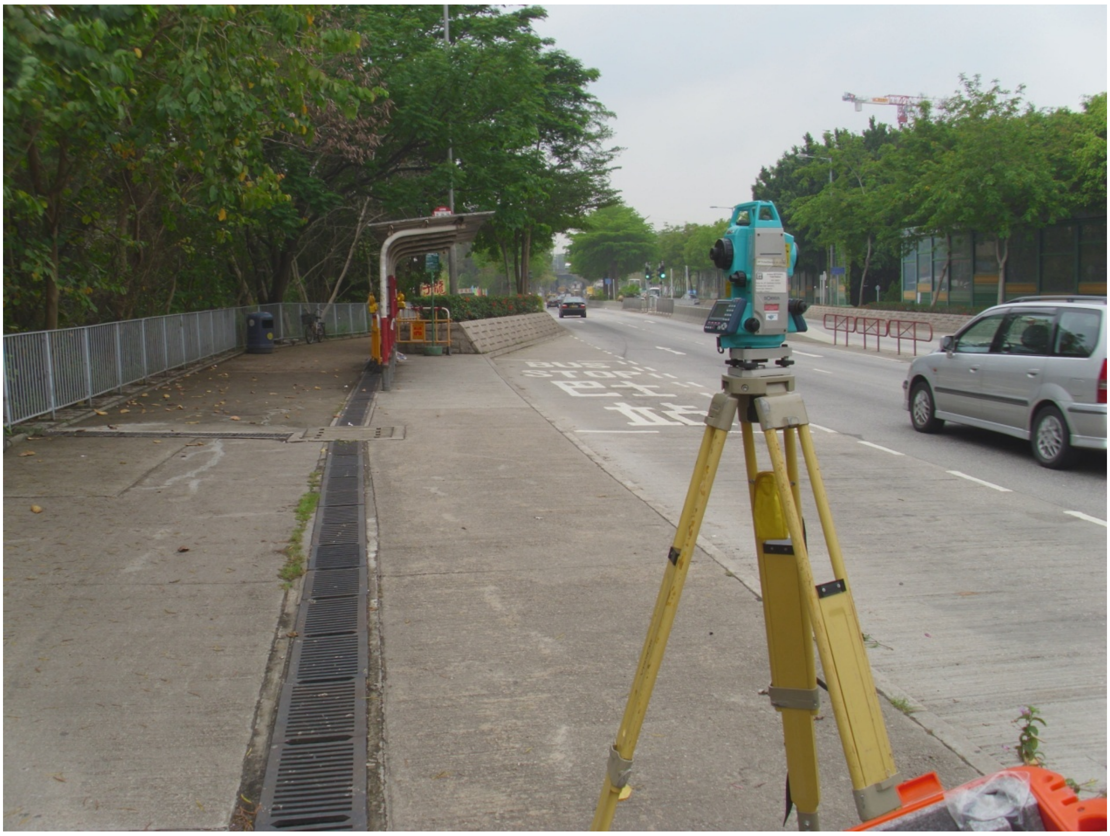

Fig. 15 Topographic survey in progress

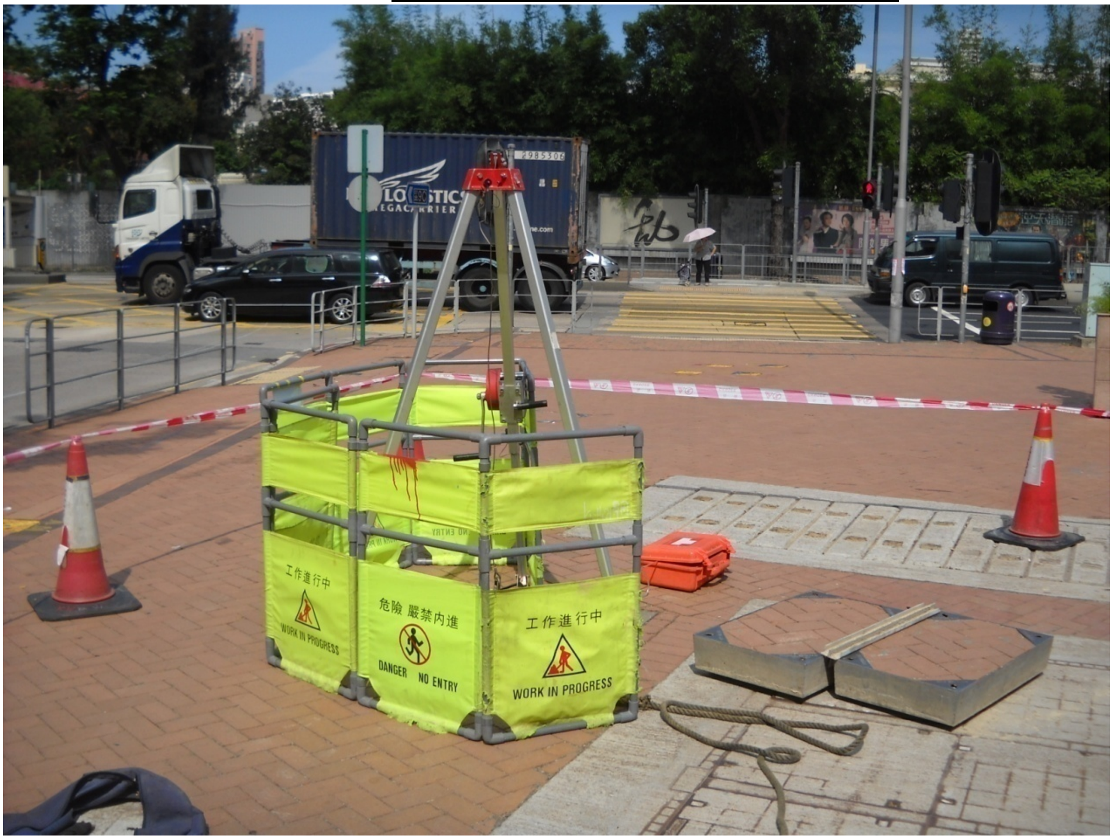

Fig. 16 Safety measurements setup