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What lies beneath - Mitigating the risk from buried services to geotechnical investigations

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ABSTRACT

Explorations of the ground for geotechnical purposes entail a risk of striking buried services. Without mitigation the risk of striking a buried service is greater especially in urban areas where the number of buried services is increasing plus a larger proportion of exploration is undertaken and value of those buried services is higher. Consequently the ground investigation industry needs to minimise those risks. This paper discusses a series of approaches for dealing with buried services and presents a protocol to eliminate, isolate or manage the risk. All good investigation practitioners will obtain the latest plans of utility networks but non-intrusive methods to clear services and use of a service locator specialist are also wise approaches. In the end however, the ground has to be penetrated and good practice has evolved to undertake some gentle initial probing of the upper layers before commencing the main exploratory effort, especially in the congested streetscape of the modern city. The paper discusses the merits of various probing techniques but the authors have found some form of hydro-excavation to be particularly effective. An alternative philosophy to utilities avoidance is positive identification, which can yield wider engineering and economic benefits as illustrated by examples. For major infrastructure investigations in the Auckland Central Business District, the authors present their experience of development of the advance excavation technique into the formation of a Ground Access Portal (GAP) that consists of a vertical void held open by a polythene tube through which follow-on drilling can take place.

Keywords: buried services, ground investigations, striking, risk, utilities, eliminate, isolate, minimise, manage, excavation.

1 INTRODUCTION

One of the key risks related to undertaking intrusive ground investigations especially in the urban environment is the striking of buried services. The effect of striking a buried service can be major as it can result in loss of business for the surrounding business that can equivalent to hundreds or millions of dollars of lost revenue. This paper provides an outline of the following:

- Risks of undertaking intrusive ground investigation is today's environment
- A protocol to manage the risk of striking buried services
- The procedure for the identification and location of buried services
- Assessment of excavation techniques
- Observation on legal and management aspects

A case study is presented of a technique that was developed for a major project in central Auckland where the risk of encountering buried services was extremely high.

2 RISK OF STRIKING BURIED SERVICES

If a buried service is severed or otherwise disrupted by exploration activity there is the loss of service provision and the requirement to reinstate that provision. Both of these come at a cost; the loss of the value of that service to connected users and the effort required to be spent in order to reconnect the service.

In addition to these straightforward costs, striking of buried services brings additional risks, particularly from health and safety aspects, as indicated by Table 1. A search through the internet will reveal some spectacular examples of what can go wrong from such an incident, e.g. the opening up of sinkholes, evacuation from flood or catastrophic fire and explosion. Closer to home there are examples of costly contamination clean-ups, death and serious injury.

Table 1: Increasing risks from striking buried services

Utility	Key Risks[1]	Recent Trends and exacerbating factors
Fresh water supply	• Flood • Subsidence	• May be under high pressure – flood may be swift. • Marked head losses may affect wide area • Use of plastic pipes – may be easier to cut • Some installation by trenchless methods
Stormwater	• Flood • Subsidence • Contamination	• Some installation by trenchless methods.
Sewerage	• Flood • Subsidence • Contamination • Health hazard • Methane (as gas)	• Some installation by trenchless methods. • Leakage may cover wide area • Clean up costly
Electricity	• Electrocution • Power cuts & surges • Fire	• Undergrounding • Multiple service providers
Lighting	• Compromise safety	• Widespread and shallow
Gas	• Toxic • Explosion	• Use of plastic pipes – may be easier to cut • Some installation by trenchless methods • May be under high pressure – can be catastrophic
Fuels	• Toxic • Explosion • Contamination	• Clean-up costs very high
Communications	• Business disruption • Dramatic downstream losses	• Traditional telephone wires giving way to buried copper cables • Fibreoptic cables becoming the new norm • Lack of signature to detect fibreoptics • Some installation by trenchless methods • Extremely delicate – not always in ducts • Installed by a plethora of parties

Note: [1] In addition to the standard risks of loss of service provision and requirement to reinstate after severance

3 INCREASING RISKS FROM RECENT TRENDS

As society develops, the value of the loss of these services is increasing substantially (Table 1). Whereas in the past there may have been a level of acceptance of such disruption, increasing recognition of responsibilities and rights translates to a higher potential loss to anyone deemed responsible for having caused such a disruption.

As time goes on more services are being buried underground. There is a trend away from unsightly cables being suspended from poles and pylons. New services are being added to the mix, most importantly communication lines. Furthermore the era of single public entities being responsible for each major type of service is giving way to multiple organisations offering alternative supplies.

Even when an organisation owns a service, it may well have been installed by a third party contractor and today the asset owner may have subcontracted the management of the asset to another organisation.

The plethora of entities responsible for installation, maintenance and management carries the risk of lack of clarity of who knows what is where.

More advanced materials are being used to form utilities and new methods of installation are adding to these risks. For example metal pipes are replaced with plastic and copper cables with fibre optic. The new materials are harder to locate but easier to damage. Whereas traditionally utilities were buried in backfilled trenches, nowadays a number are being installed by directional drilling with minimal surface expression.

As a consequence of these trends geotechnical practitioners need to be highly vigilant, well organised and thorough to reduce these risks when scoping, managing and conducting exploration programmes.

4 PHILOSOPHY OF RISK MITIGATION

Risk mitigation is the understanding of what the actual risk is and what the factors are that what drive it. The key things that drive risk in terms of buried services are:

- What environment is the work being undertaken in – green field verses urban
- Is the location in the public or private section
- What information is available e.g. as-built drawings
- If records are available, are the accuracy/correct

Each of those drivers directly control the risk of encountering a buried service during a geotechnical investigation and they can only be controlled by risk mitigation. The practice of controlling risk is by controlling the hazard which is done by the hierarchy of elimination, isolation and minimisation, as legislated in the Health & Safety Act (New Zealand Government, 1992). As illustrated by Table 3, the priority approach is to see if it is possible to eliminate the hazard by using an alternative approach. With buried services, the first step up from trusting in blind luck is to adopt a hazard minimisation strategy. Due to the risks and the lack of reliability of records, it is strongly recommended that the best approach is to isolate the hazards – either explore in locations that have been proven not to have services there or to positively identify buried services and explore at a distance.

Table 3: Application of hierarchy of hazard control to locations of buried services

Control	**Example**
Eliminate	• Make use of published records or borehole logs from previous projects • Use non-intrusive methods to obtain information – geological mapping, remote sensing, geophysics
Isolate	• Positively identify the locations of buried services on site • Physically clear an exploratory hole position of any services
Minimise	• Find out what services should be in the vicinity • Select exploratory locations away from services on plan • Adopt an offset from service

5 PROTOCOL TO MANAGE THE RISK

Following the above philosophy, we have developed a protocol to manage the risk of striking buried services, which is presented in summary as a flow diagram in Figure 1.

The first stage is to undertake a study to assess the risk of encountering buried services. The extent of this study will depend on whether the investigation is being undertaken within public property or in private property, since there may be a difference in rigour in recording the presence of buried services depending on whether the site is in the public domain or not. Utility plans need to be sought in either case.

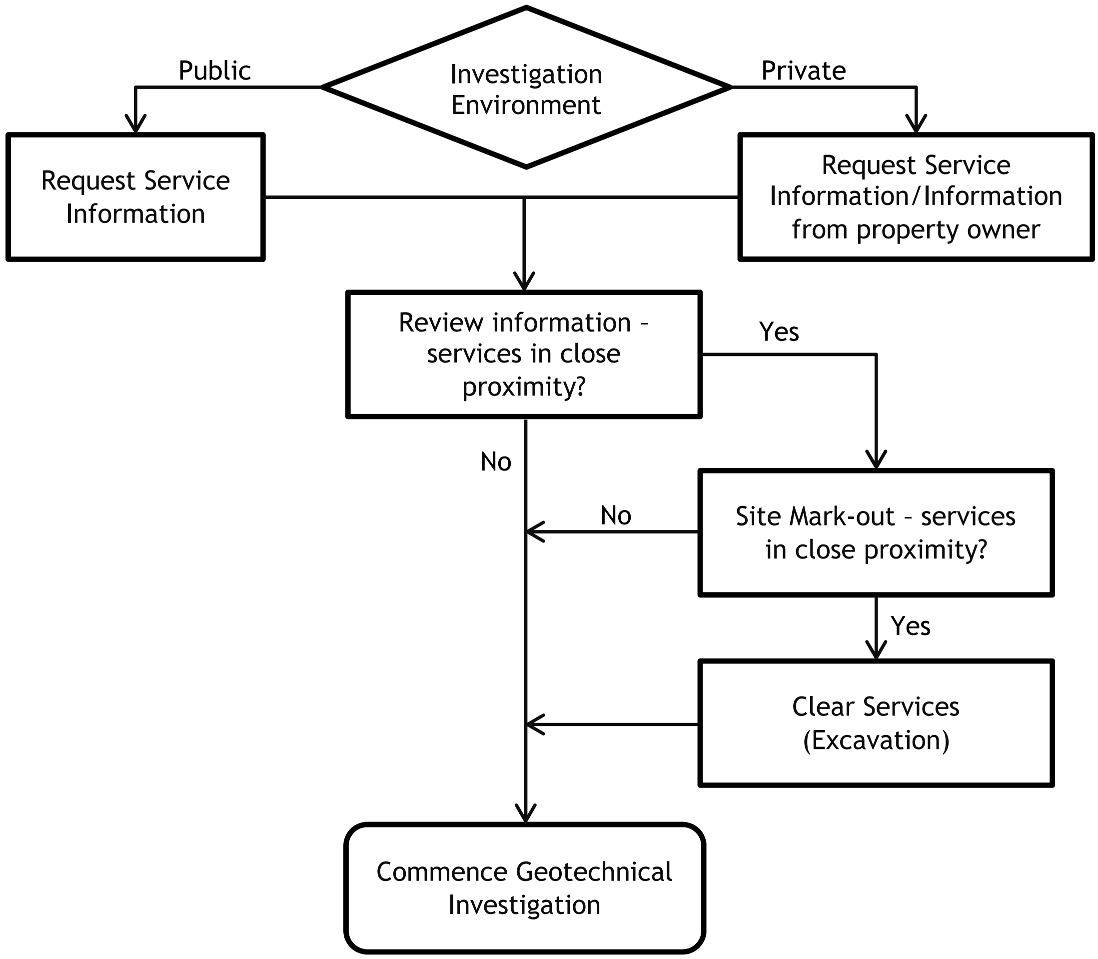

Figure 1. Summary protocol for services avoidance in advance of exploration work

To minimise the likelihood of striking a buried service a combination of identifying if a buried service is in close proximity of the investigation location and either physically locating it or working within a void that has been cleared to a depth greater than that of the service is required.

6 LOCATION OF BURIED SERVICES

The locating of the actual positions of buried services consists of two main stages: obtaining and reviewing as-built information and physically locating the positions of the buried services on-site.

6.1 Obtaining and Reviewing As-built Information

Obtaining as-built information from utility providers is undertaken in two ways, either by contracting them and requesting the information or by gaining access to their Geographic Information System (GIS). In New Zealand, the requests to the individual utility provider is undertaken using a single on-line tool called ‘Before U Dig’, which automatically contacts each of the registered asset owners on your behalf requesting the information for the area of interest. The information is then provided either via e-mail or mail directly by the Asset owner in the form of either specific plans or instructions on how to obtain the information e.g. GIS viewer.

If an asset owner has a GIS portal that contains as-built information access if normally gained directly via the internet or an external portal. The GIS interface allows the requestor to locate their area of interest on an aerial photograph and to see what buried services are located at or around the proposed investigation site. A number of the GIS systems also allow additional information on the buried services to be obtained e.g. diameter of a pipe, material type, purpose of the asset, as well, as allowing plans to be printed that can be taken into the field.

Once the as-built information has been obtained, a desktop review of the information needs to be undertaken to determine if a specific investigation location is in close proximity to the location of a known buried service. In the situation that it is identified that no services are present, there is still a risk that an unknown service may be present and precaution needs to be taken as any service that is strike could result in either serious harm or death.

6.2 Physically Locating Buried Services

When it is determined that services are in close proximity to the investigation location, the next step in the process is to get the asset owner to mark out the locations of their assets on the ground surface. This normally consists of the asset locations being physically marked on the surface using paint to indicate the proximity centre of the asset plus or minus a margin of error. The marking out of the services can be either undertaken by the asset owner, a specialist underground service locator or using Ground Penetrating Rader (GPR). Once the physical location of the buried service has been determined, the excavation method for either the locating or clearing the service can be determined. The method of excavation is dependent on several different elements, which are:

- The type of geotechnical investigation work scheduled to be undertaken
- The type of surface cover e.g. grass, sealed pavement
- Available workspace
- Density of buried services

The three common excavation techniques that are used for geotechnical site investigation work are outlined below.

6.2.1 Hand Excavation

Hand excavation is the use of hand tool i.e. shovel, hand auger to form a small excavation that extends to below the depth that services are likely not to be present i.e. 1.5m. The excavation is then normally used as the void that the investigation work is undertaken within.

6.2.2 Mechanical Excavation

Mechanical excavation is the use of mechanical equipment e.g. hydraulic excavators to form an excavation/trench to either clear or locate the position of buried services. Due to the nature of the investigations that are to be undertaken, either a single trench or multiple trenches need to be undertaken to allow for buried services to be located. Either a single trench can be used to clear services or multiple trenches can be used to identify a safe area clear of services to undertake investigations.

Multiple trenches in a ‘L’ shaped configuration can be used to clear services and the actual investigation in this situation can be undertaken from the ground surface as the investigation position can be located within the area within the zone between the two trenches.

6.2.3 Hydro Excavation

Hydro-excavation is a non-mechanical, relatively non-destructive excavation technique that uses pressurised water and an industrial strength vacuum to simultaneously excavate and evacuate soil. The technique uses a high pressure water blaster to break up the underlying compacted soil into loose materials that along with the water can be removed using a powerful truck mounted vacuum system.

7 ASSESSMENT OF EXCAVATION TECHNIQUES

Table 4 below compares different aspects of the excavation techniques and indicates their advantages and disadvantages.

Table 4: Comparison of Excavation Techniques

	Hand Excavation	**Mechanical Excavation**	**Hydro Excavation**
Investigation Type	• Boreholes • CPTs	• Boreholes • Test Pits • CPTs	• Boreholes • Test Pit • CPTs
Advantages	• Small Excavation	•	• Minimal damage to services • Speed • Variable size
Disadvantages	• Limited type of investigation	• Excavation size	• Not suitable for contamination investgiations
Risk	• Damage to services due to wrong type of auger used	• Damage to services by the teeth of the bucket	
Cost	• Low	• Medium	• Medium to high

Each of the excavation techniques have their advantages and disadvantages as well as their associated risks and costs. Each of the techniques need to be reviewed along with the information obtained from the asset owners to determine the best technique for the environment and the type of investigation that is being undertaken. The assessment of the different excavation techniques shows that hydro excavation provides the best overall excavation technique when dealing with buried services but carries a cost factor that for smaller projects may not be acceptable.

8 OBSERVATIONS ON LEGAL AND MANAGEMENT ASPECTS

The protocol and techniques discussed above will help considerably in risk reduction. However these can be compromised if there is lack of clarity about who is responsible for what or if excessive time pressure is applied and operatives are rushed into making snap decisions. Further aspects that it is recommended are considered are listed in Table 5. Other aspects that need to be considered are:

- The importance of determining who makes the final call as to commencing an exploratory operation (e.g. issues a permit to excavate) at a particular location should not be underestimated
- Do they have the complete set of facts to hand in order to make that decision?
- Can they see that all steps have been taken in order to get to that stage?
- Who bears responsibility if something goes wrong?
- Is everything correctly documented?

Table 5 – Contractual and managerial factors to mitigate the risk of striking buried services

Factor	**Explanation**
Responsibility	• Clarify lines of responsibility • Confirm who is responsible for determining the precise position of an exploratory hole – “X marks the spot” • Confirm whose decision it is to switch on the exploratory plant at that particular location • Confirm who is responsible for determining the site presence or absence of services • Identify who will be responsible (at fault) should a service be struck
Contractual arrangements	• Clarify who is contracted to whom e.g. NZS3910 • Are legal documents in place to confirm arrangements? • Have legal arrangements been nullified or compromised by some action/inaction?
Costs	• Who will bear costs if a service is struck? • Are the relevant parties/insured adequately?
Programme	• Has adequate time been allowed to ensure appropriate steps taken to avoid compromising services?

	• Is no party pushed to make a call to explore without putting in place appropriate safeguards
Supervision	• Who is supervising the works? • Who can make a call on site to react in case of suspicion of services? • Are service plans on site?

9 CASE STUDY

For the Auckland City Rail Link project, Aurecon New Zealand Ltd was engaged by Auckland Transport to scope and deliver two stages of geotechnical investigation along the proposed alignment for the underground rail link between Britomart Station and the Mt Eden Rail Station. One of the major health and safety issues for the investigation works was working within the complex network of buried services and the effects that striking a buried service would have on surrounding stakeholders. A concept was developed to provide the geotechnical drilling contractors with a portal that they could undertake their work via which was clear of buried services, it consisted of a cylindrical tube installed in the ground vertically with an access cover at the surface. The solution was named the Ground Access Portal or "GAP" for short.

The GAP consisted of a 200mm inside diameter PVC liner (constructed of a length of PVC drainage pipe) that was installed in a void between buried services to a minimum depth of 1.5m below the existing ground level (Figure 2). The void between the outside of the PVC liner and the installation excavation was backfilled with granular material that met the requirements of the asset owners and a lockage access cover was installed flush with the existing ground level. The inside of the PVC liner was not backfilled and provided a void for the drilling rods to work through.

Following the development of the GAP, it was identified that the use of traditional methods of excavation would not be appropriate due to the following requirements:

- Minimum footprint for excavation works due to physical site restrictions
- Excavation depth needed to be a minimum of 1.5m but could be up to 3m deep
- The technique needed to be time efficient due to time restrictions
- Technical needed to cause minimal or no damage to the buried services, if encountered.

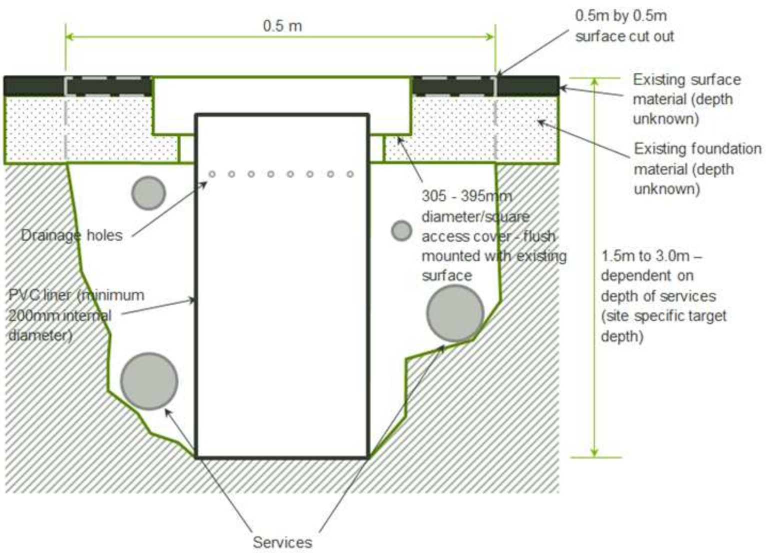

Figure 2. Schematic arrangement of a Ground Access Portal (GAP)

It was identified that hydro-excavation was the only excavation technique that could fulfil the requirements for the work due to it being a non-mechanical and non-destructive excavation technique. AS hydro excavation is a precise excavation technical, it means that the actual excavation formed only needs to be slighter that the outside diameter of the GAP. The technique also ensured that minimal damage occurred to any buried services encountered and in the situation that there was not adequate space between buried services to install the GAP, the excavation could be extended quickly to find a suitable position for the GAP.

10 CONCLUSIONS

The following are the key conclusions from our assessment of the risks associated with undertaken intrusive geotechnical investigations:

i. The exploratory work undertaken for geotechnical investigations exposes the project and all associated parties to risks from striking buried services.
ii. Due to a number of recent trends, these risks are increasing.
iii. Careful consideration is required to develop a safe practice to reducing these risks.
iv. A practical protocol is presented that demonstrates a viable approach to risk reduction.
v. Both obtaining as-built information and physically locating or clearing a void without services needs to be undertaken to minimise the risk of striking a buried services during a geotechnical investigation.
vi. Several different excavation techniques can be used to physically locate/clear services but they need to be considered along with the environment that the work is being undertaken in and the type of investigation.

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