Technical guide:

information and advice for the successful planning and execution of horizontal directional drilling works

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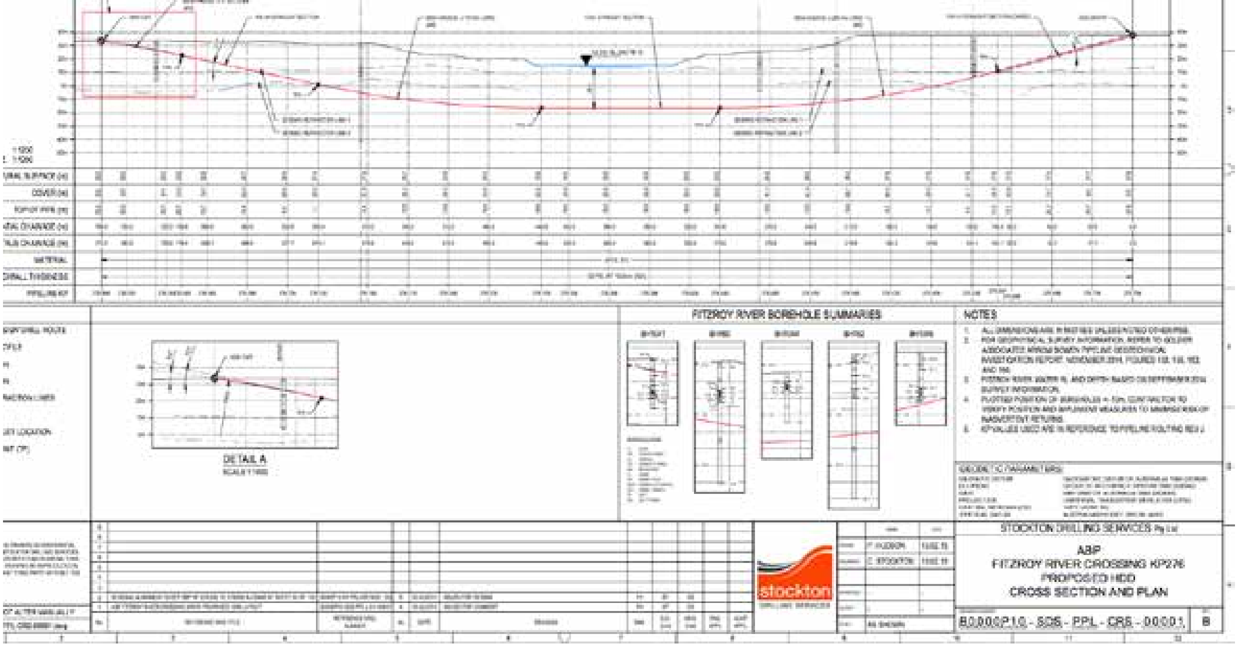

SO...WHAT EXACTLY IS HDD?

Horizontal Directional Drilling (HDD) is a trenchless method of installing pipeline or conduit and cables underground , along a predetermined path, by the use of specialised drilling equipment. This approach provides a flexible way of installing pipes and cables where conventional open cut methods are not permitted, practical, or environmentally or economically viable.

HDD is very useful in built up urban areas or where various obstacles or terrain, such as shore approaches, swamps and river crossings lie along the proposed route. By using HDD, the pipeline or cable land disturbance is only required at the entry and exit point and the pipeline or conduit is installed underneath the obstacle.

Trenchless technology allows for the installation or rehabilitation of a pipeline, conduit or casing between a given entry and exit point without any disturbance to the natural surface between those points. When new assets are installed using trenchless technologies, a tunnel is installed by directional drilling, microtunnelling, auger boring or impact moling. These different techniques allow for a great variety of distances, depths and diameters to be installed whilst minimising social and environmental impacts. HDD is usually employed when the required installation depth and length exceeds the boundaries of the other trenchless installation methods. HDD is most commonly used for road, river and shore crossings.

In order to take full advantage of the benefits offered by HDD and produce designs that can be efficiently executed in the field, design engineers should have demonstrated working knowledge of the process, including both industry capabilities and limitations.

The HDD process is usually undertaken in three distinct stages:

- Pilot hole drilling
- Reaming or hole opening
- Pipe installation

The first stage consists of directionally drilling a small diameter pilot hole along the pre-determined pathway. In the second stage, the pilot hole is enlarged by successive reaming and cleaning passes. When the hole is of the suitable diameter and condition, the pipe is pulled back or thrust into the fluid filled bore.

KEY BENEFITS OF HDD

HDD has become increasingly versatile in its application and progressively more reliable in its execution. Today, the question is not "Why use HDD?" but rather "Why not use HDD?".

The key benefits of employing HDD include:

- Access for construction equipment is only required at either end of the crossing
- Disturbance is only required at the entry and exit points and not for the entire crossing length
- The limited work footprint required at either side of an installation allows it that it can cater for all weather working conditions
- Due to a constrained work site, it can be easily adapted to a 24-hour program to safeguard the works schedule
- Due to the static position of major plant, safe access and egress, the site can be developed for worker safety – no deep pits or shafts are required and all work is performed above ground
- Alternative tooling and mud formulations allow for all soil conditions to be drilled
- Unforeseen ground conditions can be quickly addressed by changing the tooling and drilling fluid formula with limited cost and schedule impact
- HDD can be used along with other technologies such as retractable tunnelling and direct pipe to overcome instability problems, such as cobbles and cohesiveless soils
- Flexibility in the profile design allows for engineers to develop creative solutions to difficult geometries, including compound bends and steep entry and exit angles, with the only limit being the minimum radius of the installed pipeline material

In order to take full advantage of the benefits offered and use HDD for increasingly difficult crossings, HDDs should be designed and planned by experienced personnel who have proven working knowledge of the process, including both industry capabilities and limitations. Designs should be constructible and be able to be efficiently executed in the field.

THE CURRENT LANDSCAPE

Since trenchless technologies such as HDD, were first introduced in Australia, the price of using these methodologies has become increasingly more affordable. At the same time, the expertise and reliability of HDD contractors has increased, and so the use of HDD in pipeline construction has become widespread.

In fact, today, very few pipelines are built that do not include directionally drilled crossings somewhere along the route. For example, the recent installation of an 180km pipeline in Victoria used HDD to complete over 80 crossings of roads, rivers, drains, sensitive habitats and difficult terrain.

For oil and gas projects, the design process is driven by a risk based approach, whereas for some utility projects, price tends to be the driving factor. Oil and gas projects proceed through a number of development phases that allow risks to be fully evaluated, both before and after tender. This ensures the design evaluation process is driven by best for project outcomes. Adopting this risk-based approach ensures, good safety, environmental or quality performance.

INTRODUCING CHARLES STOCKTON

UK-born Charles Stockton, Managing Director of Stockton Drilling Services, has been a part of the HDD sector in Australasia since 2003.

Charles graduated with civil engineering degree from Loughborough University in the UK before joining the family business Stockton Pipelines. Stockton Pipelines pioneered the development of HDD in the UK in the 1990s, with Charles managing the drilling side of the operations. Charles was part of the first HDD drilling crew in the UK, and in those early, pioneering days, he worked with crews to meticulously plan and execute HDD crossings across the country and northern hemisphere. They successfully completed a number of complex projects discovering and developing innovative solutions along the way, which are now part of normal HDD operations.

During his tenure at Stockton Pipelines, Charles became an industry leader, and received three drilling awards from the UK Society for Trenchless Technology for new technologies and projects of special interest.

Two years after arriving in Australia, Charles established Stockton Drilling Services, a premier engineering consultancy specialising in HDD and other trenchless pipeline installation methods, bringing his wealth of experience to the Australian market.

The company's client base includes companies in the oil and gas, water, electrical, mining, communications and pipeline engineering industries; local and state government departments; and HDD and pipeline contractors. Charles received the Engineers Australia Environmental Award for his part in Chevron's Gorgon Project, which required nine shore approaches to be constructed by HDD on the hostile west coast of Barrow Island in Western Australia.

Charles has a team of highly experienced project engineers, managers, supervisors and HSEQ personnel, who provide a range of services including concept evaluations, feasibility studies, engineering design, project management, quality control, risk management, HSE services and pipeline mapping.

Stockton Drilling Services personnel ensure the quality of planning and construction of their HDD projects by using a risk-based design approach, mentoring both clients and contractors on the use of industry recognised best practice.

In response to industry need, Charles developed a HDD quality control package that has already had excellent outcomes for ExxonMobil, QGC and APLNG. As part of the HDD quality control package, Stockton Drilling Services provide FEED engineering and quality control inspection services during construction.

Major projects that Charles has provided engineering services for include:

- Esso, Longford Liquids Pipeline
- Chevron, Gorgon Gas Project
- ExxonMobil, Longford Gas Conditioning
- QCLNG/APLNG, Narrows Crossings
- Arrow Energy, Curtis Island LNG and Bowen Pipeline Projects

WHAT ARE THE CURRENT CAPABILITIES OF HDD?

As an installation method, HDD has been used for more than thirty years now on projects around the world. The capabilities of HDD equipment have grown considerably over this time period.

In the industry today, there certainly appears to be a recognisable trend developing – longer drills. Nowadays, pipelines are being installed in lengths of up to (and even in excess of) 4.5km by HDD.

Advancements such as intersect technologies (which allow crossings to be drilled from both sides meeting in the middle), larger capacity drilling rigs and the availability of pipe thrusters to aid pipe insertion, have all allowed for much longer lengths to be regularly and reliably achieved. Of particular note is the use of intersect drills, which has effectively allowed drill lengths to be doubled overnight.

The industry is also able to competently install pipelines of significant diameters, with steel pipelines of up to 48-inches being regularly installed with HDD. It's important to note that end users rarely require diameters over this size to be installed. Once the diameter does become larger than 48 inches, the construction of a concrete tunnel is generally advocated as lower risk, and accepted as the norm.

It is reasonable to infer that lengths of 4.5km of 12-inch pipe and 2.5km of 42-inch pipe are now well within industry capability.

This capability will allow for greater flexibility in construction options, and clients should be incorporating this advancement into their concept designs and studies.

I believe the HDD industry will drill longer yet, aided by further developments such as:

» Industry-specific software for analysing drill pipe pressures, fatigue and stress
» Telescopic casing to provide hole support whilst reducing torque and drag
» Mud programs and modelling for better hole cleaning and hole support, and
» Equipment advancements including telescopic rigs for faster tripping times

HDD will also continue to adapt and expand into new markets as new demands emerge. For example, HDD can be used to place a permeable membrane in an exact underground position to allow for the introduction or removal of fluids. This process can then be used to control water flows, as was employed by Stockton Pipelines to control groundwater levels associated with the construction of the Cardiff Bay Barrage. A similar process may also be used for applications including mine dewatering and extraction of minerals rich sands.

ESSENTIAL FACTORS FOR A SUCCESSFUL HDD INSTALLATION

When undertaking a HDD installation, the key factors for consideration that often come to mind are geotechnical conditions, alignment geometry, installation constraints, and pipe strength rating. While these are all important, there are three other key factors that Clients and Contractors should take into account for a successful HDD installation.

D_O_N_'T_ _T_A_K_E_ _S_H_O_R_T_ _C_U_T_S_ _

After spending 25 plus years working on major HDD projects around the world, there is one golden rule that comes up time after time, and that is: don't take shortcuts. Do the right thing first time, every time.

If you speak to any experienced driller or superintendent who has worked on large-scale projects they will all tell you the same thing – don't take shortcuts.

Quite often site crews start to feel pressure from both the client and their own head office if they start to fall behind program.

Typically there is a reason that the schedule is slipping, and generally it is not inefficiencies or inexperience. It is more likely that the initial program was unrealistic or didn't correctly factor in some of the challenges or risks of the project, such as site constraints, geology or weather conditions, or complying with client requirements.

This is the time when crews will then be tempted to try and save time by initiating a shortcut that they know isn't good practice, but they think they can get away with. This is when small problems start to compound.

As most people have experienced with drilling, the stars very rarely align and you must make your own luck. Sticking to best practice and avoiding short cuts, even when all those around you are screaming for more progress, does this.

LEARN LESSONS

In larger companies with multiple crews, each driller or superintendent will tend to have their own way of doing things; their own favourite tooling configurations, preferred mud formula and site layouts.

Each supervisor will often be reluctant to heed the advice of other supervisors, until they too have learned the lesson firsthand.

This type of process can be hazardous and costly for the company (and the client). Even though each crew will be having these types of discussions on site about what is working for them in this particular condition and evaluating their performance, this valuable knowledge is rarely captured formally and is unlikely to be shared throughout the organisation.

If they are not doing this already, contractors should start to hold lessons learnt sessions at the end of each project to start developing their own rule book of best practice, that they can then rollout and employ throughout the company.

Only by continually evaluating performance can you start to achieve a professional outcome each and every time you go to site.

This feedback loop should also include head office to help them plan, create more accurate scheduling and develop more accurate pricing.

MAKE QUALITY DECISIONS

Quality decisions can only be made if a company encourages open dialogue throughout all levels of the organisation.

If the the Project Manager is dictating the course of action without first hearing and evaluating what others have to say, it will rarely be a good-quality decision. Supervisors should use reasoning, including the evaluation of facts and figures, over intuition.

To make a good-quality decision you should:

- Define the problem clearly
- Evaluate achievable alternatives
- Collate meaningful reliable information
- Determine required outcomes
- Use logically correct reasoning to commit to a course of action

INTEGRITY, MAINTENANCE AND SAFETY IN HDD OPERATIONS

ntegrity, maintenance and safety on HDD projects have come a long way, with more clients and contractors now aware of their importance on sites, and equipment designed to take these into account.

INTEGRITY AND MAINTENANCE

Due to this difficulty of accessibility and repair, a HDD section is usually designed with different parameters to a mainline, including being hydro-tested separately prior to insertion, and the use of increased coating thickness such as an abrasive resistant overcoat where deemed necessary. So not only is the HDD string pre-inspected, it is also then subject to a current drain test on completion of the pullback and prior to the tie-in to mainline to ensure the coating integrity of the HDD section. These additional quality checks, both before and after installation of steel pipelines, ensure the HDD section is unlikely to be the location of future integrity concerns.

If a defect exists which could potentially lead to a leak, the increased burial depth of the pipeline, which generally will be greater than 10m when installed by HDD, does provide added safety. Adversely the increased burial depth, along with the terrain being crossed – which may include a waterway or sensitive environment – makes dig up and repair prohibitive in most cases requiring the section to be replaced.

The coating system for the HDD's is required to be tolerant to coating damage during installation. Results of comparative testing have previously indicated that the coating thickness is directly related to the level of damage likely to be experienced during installation. For this reason, the preferred coating system for the HDD crossings should consider overall coating thickness that can be applied. Where it is likely the coating will encounter sections of gravel, rock and sand during insertion, it is recommended the outer layer is considered as a sacrificial wear/abrasion coating with the base layer providing the anti corrosive protection.

Initially the HDD pipe section must be pulled over rollers and supports which create the over-bend for the pipe to enter the bore at the correct angle. For this phase of the works the coating should have good gouge resistance from potential contact with rollers and supports and also have flexibility to allow for the temporary over-bend radius to be formed.

In the next phase the pipe is pulled through the bore. A wide variety of geology maybe encountered including alluvium consisting of sand, clay and gravel or bedrock, which should all be well defined in the site geological investigations. For sections in sand and rock the coating should have good wear resistance. For the sections in gravel the coating should have good gouge / shear protection and impact resistance as there's a potential the pipe will be pulled through unconsolidated sections which have partially collapsed.

In *Design and Coating Selection Considerations for Successful Completion of HDD Crossing* by A.I. Williamson and J.R. Jamerson, 3LPE performs well for abrasion, flexibility and impact but is ranked lower for gouge resistance. The 3LPE performed very well in the impact resistance test which is design to represent damage from falling rock. In the abrasion test the 3LPE also showed better performance than the other coatings. The polyethylene coatings appear to better resist wear due to the lubricity of the polyethylene particles compared to the harder nature of the particles from the other coatings.

It is difficult to say which of these tests (the gouge resistance, abrasion or impact resistance) best replicates the conditions downhole and it is likely to be a combination of all of these properties. Ideally the coating should be tough but not too hard where it has the potential to also become brittle.

SAFETY

Even though drilling crews are generally well established and familiar with all aspects of the work, management and supervision should continually use tools such as pre-start discussions, JHA's, SWMS and 5x5 to maintain crew focus on potential impacts from stored energy. These may be in the form of suspended loads, high pressure mud and hydraulic hoses, or rotating drill pipe and pipe tongs, to name a few. Crew should be trained to continually look for and identify these potential impact and then implement ways to prevent injury or damage.

HDD operations rely heavily on implementing safe working procedures and having sufficient experienced and trained personnel on site to manage the frequent lifting operations. During a pullback or during tripping drill pipe it may be necessary to lift pipe clear from the rig and stock piled them every two minutes for duration of several hours often in wet and slippy conditions. This process has the potential to become hazardous if clear systems of communication are not established and maintained.

HDD operations have the advantage that the sites are static and therefore allow for greater control of the work area. This allows for the site layout to be planned prior to mobilisation and include considerations such as a prepared hardstand; cables and hoses routes that can be buried or suspended; personnel access and egress that are clearly defined; include the use of bunds under static equipment; all of which allows for personnel to be familiar with their work environment.

The safety culture on HDD sites, like pipelines, has come a long way and all personnel now realise safety as a core value, not just a set of rules to be obeyed. Stockton Drilling Services is proud to have recently provided HDD Clients Representative for a pipeline project that installed over 18km and 70 HDD's with three maxi rigs and three mini rigs without incident.

DEALING WITH FRAC-OUTS

A ‘frac-out’ is the unintentional return of drilling fluids to the surface during horizontal directional drilling (HDD).

A frac-out occurs when the down hole mud pressure exceeds the overburden pressure (i.e. shallow or loose sections of the bore), or the fluid finds a preferential seepage pathway (such as fault lines and fractures, infrastructure or loose material).

These fractures can be natural or induced by over-pressurising the formation.

It is relatively common for a frac-out to occur on a HDD project. Most frac--outs, however, are usually minor, within construction right of way and close to the bore entry or exit.

VARYING LEVELS OF SERIOUSNESS

The seriousness of a frac-out depends on where it occurs. If the frac-out occurs in an environmentally or culturally sensitive area (which you are generally trying to avoid by using HDD), there is reason for concern.

The drilling fluid itself may not be toxic, but the fine particles can smother plants and animals, particularly in an aquatic environment. If a saltwater polymer fluid is used, the salt can also impact on freshwater systems and terrestrial vegetation. Neighbouring landowners do not appreciate frac-outs on their land.

In most states a frac-out outside of the working area is generally considered a “reportable incident”. In Victoria all frac-outs must be reported to the regulator within two hours.

Frac-outs may also damage infrastructure or nearby services. There are reports of sections of roads rising, nearby water pipelines failing as the frac-out washed away the bedding sand, power boxes filling with fluid and vegetation disappearing into a sinkhole caused by a frac-out.

On the other hand, the frac-out may be small (less than 20L), occur within a disturbed or non-sensitive area and be easily contained and cleaned up. In these cases, there is no lasting impact or damage and no real reason for concern.

These frac-outs are still better avoided as they utilise resources and time in the cleanup and reporting.

Generally with frac-outs, the perception and association with other industries means the perceived threat is far worse than reality.

PREVENTING FRAC-OUTS WITH GEOTECHNICAL INFORMATION

There are a number of steps that can be taken to prevent a frac-out from occurring.

The first step is to assess the risk of frac-out prior to drilling. This can be done using specially designed software (e.g. DGeo Pipeline by Deltares) or pressure calculations.

These methods compare the maximum allowable fluid pressure against the expected drilling fluid pressure.

To ensure they are reliable, they require detailed information on the soils, drilling fluids and bore profile, and should be conducted by experienced personnel.

The modelling will predict if and where frac-outs are likely to occur, if profile changes are required (e.g. increasing the depth), the maximum drilling pressures (the driller can then set alarms at these pressures) and if other management strategies are required.

In some cases it may be necessary to install casing at the entry point where reduced cover and bearing pressure exists, or drill pressure relief wells to give the fluid a controlled place to go.

The modelling also allows for the optimum pilot hole bottom hole assemblies to be configured for the formation, allowing the correct bit size to be selected for the drill pipe dimensions.

During drilling, contractors should continually monitor the drilling fluid properties i.e. mud weight, viscosity, gel strength, volume and pressure, to prevent frac-outs.

They can also include a pressure sub for real-time down hole pressure monitoring by the driller, allowing actual annular pressure readings to be obtained in real-time and then plotted against the modelled values.

If any unexpected variations or trends are observed then drilling should immediately cease and the cause investigated.

Common causes include a restricted or blocked annulus created by a buildup of cuttings which requires mechanical agitation and fluid flow to re-suspend and remove the blockage.

Contractors should be prepared with frac-out contingency plans and response equipment such as sand bags, vac-trucks and the like in place. Regular inspections should also be conducted along the drill path during pilot hole drilling.

Both contractors and client can take steps to prevent frac-outs, especially in sensitive areas, by undertaking adequate assessment and planning before drilling, and ensuring sufficient controls and monitoring are in place during drilling.

AVOIDING DAMAGE DURING HDD INSTALLATIONS

There are risks when undertaking a HDD installation, especially in urban areas where the risk of damaging underground and aboveground facilities greatly increases. However, there are several things that can be done to help mitigate risks and avoid damage to the installed pipeline.

The five most important things to think about are as follows:

PILOT HOLE PROFILE

The as drilled profile of the bore will have an effect on the pull force and abrasion the pipe is exposed to during pullback.

This may be in areas where doglegs (rapid change in direction) have been created, which often occur at formation changes from soft to hard or hard to soft, or where radii of the pipe have not been maintained.

The driller's log, the steering engineers log and survey data should be examined on completion of the pilot hole to identify any potential areas that could be out of specification or cause potential problems during reaming and insertion.

HOLE REAMING

The speed of the reaming pass should be calculated to ensure the correct pump volume has been used for the given penetration rate.

For example, the cut volume of a 24-inch ream following a 12-inch pilot hole is approximately 2m^3. If the solids being removed are measured at 20 per cent of mud volume and pump rate is 1,000Lpm, then the ream should take ten minutes (1,000 x 0.2 x 10 = 2,000 L) (2m^3).

The driller's log should indicate the time per joint, and the mud logs/test report should indicate the percentage of solids in the mud returns. Also, as a rough guide, a volumetric check of the cuttings stockpiled on site can be equated against the complete hole volume.

MUD PROPERTIES

On completion of the pilot hole, and once the bore is open at both ends, the fluid must be configured to adequately suspend the cuttings indicated in the geotechnical investigations. The fluid viscosity and velocity must be tailored to create sufficient carrying capacity to facilitate the removal of the largest anticipated cutting size.

Cuttings suspension and transportation should be observed at the entry pit, and often cuttings will be deposited directly after exiting the bore.

This implies the fluid velocity, along with the viscosity (gel strength), is important in cuttings transport, but as soon as the velocity decreases after exiting the bore the cuttings fall out of suspension.

Mud logs and test records should be examined regularly to appreciate optimised fluid properties that were employed for each reaming stage, and their ability to suspend and remove coarse grained cuttings such as sand and gravel.

CLEANING PASS

It is good practice to conduct a cleaning pass with a under gauge barrel reamer after completing the reaming pass. For example, the barrel I would recommend for a 24-inch hole would be 20-22-inches. A smaller barrel would not correctly identify problem areas and potentially skip over or under any cuttings beds/restrictions/instability.

This pass should be used to gauge the condition of the bore and its readiness for pipe insertion.

Sometimes it will be observed that sections generate higher drill string torque, which would indicate cuttings, collapse or hole shrinkage. The driller should then swab back through the section to ensure hole stability before completing the pass. If any concerns remain, an additional cleaning pass can be re-run.

PULLBACK

The pipe must be correctly aligned with the borehole and enter the HDD central to the hole at the correct angle. A overbend plan should be developed to confirm the position and height of the supports and ensure that the pipe bend radius is maintained.

For large diameter steel pipelines and HDPE or FPVC pipes, the buoyancy of the pipe should be considered, as it displaces the drilling fluid from the bore. It may be necessary to fill or partially fill the pipe to create neutral buoyancy to reduce drag and therefore the insertion force and potential coating abrasion.

SHORE CROSSINGS WITH HDD

Working in the nearshore environment, especially on Australia's exposed coastlines, can be very challenging and inhospitable for both land-based and water-based construction equipment. Neither construction method is ideally suited to construction in the shallow, tidal, high-energy zone; it is too shallow for marine vessels, which risk grounding, and too deep and exposed for land-based work, which risks flooding and equipment damage. This is the zone that neither the offshore contractor or the onshore contractor are ideally placed to manage – it is not their normal working environment and iIt is this challenge that makes shore crossings very interesting to design and construct.

Up to 15 years ago, these crossings would have required large-scale open battered excavations onshore, which would connect to a piled cofferdam through the surf zone, followed by a dredged channel offshore. A concrete-coated pipe section would be floated into position using floatation devices and hydraulic winches. The process was very susceptible to adverse weather conditions and tidal variations, as well as presenting numerous challenges for managing worker safety and large-scale disturbance to the environment.

By using HDD to construct a shore crossing, you are totally eliminating the requirement for works to be constructed in the nearshore environment. Using HDD allows for the crossing length and depth to be increased, which positions the rig back on level land, and also allows for the exit to be beyond the surf zone. The rig can be placed well behind the dune system, preventing impact to the dune and any flora and fauna within the coastal corridor, e.g. shorebirds and turtle nesting areas.

The pipeline can be prefabricated onshore and thrust through the bore from entry to exit. Alternatively, the HDD rig can be used to pull back the pipeline from offshore if the pipe is fabricated by a laybarge or towed offshore from a spool base/launching area. This is especially convenient if the product pipe is HDPE, which will float without the use of external buoyancy control measures.

UNDERSTANDING THE CHALLENGES

Selecting an appropriate exit location. The exit point needs to be selected to provide appropriate conditions for positioning subsea structures or providing a suitable transition to the offshore pipeline. The exit location must provide sufficient water depth to allow safe vessel access and anchoring, as well as diving operations.

Obtaining reliable, cost-effective offshore geotechnical information. For shorter crossings it may be possible to interpolate onshore and nearshore boreholes, but for longer crossings it is extremely important to develop an understanding at the exit topography and geology. This is critical for developing the HDD methodology, determining whether the hole will be forward reamed or back reamed, and if the pipe will be thrust or pulled into the bore.

Weather and sea conditions. Even though the majority of the works can be conducted onshore, marine vessels and divers will still need to be deployed during a number of critical stages of the operation. Having these windows well identified, and then having contingency planning for delays, is essential. Clearly setting out what conditions the marine vessels can operate in, and determining how this risk will be costed will be important to prevent cost escalation and potential disputes between parties.

Specifying and managing a marine spread. A key difference with an onshore HDD operation is that the pipe-side will be managed over water by a marine spread. Marine activities may include seabed preparations, diving, lifting and recovery of downhole tooling, winching, tow-out, alignment and hook up of pipe string, placement of clump weights/mattresses for temporary stabilisation, as well as flooding and gauging of the pipeline. It is essential to correctly scope the marine work, specify the vessel requirements and establish the responsibilities and operational parameters. This is where using HDD contractors or consultants with previous experience working with marine operations is critical.

Discharge of drilling fluids at the exit point. Some shore crossings are undertaken in sensitive marine environments and discharge of drilling fluids and cuttings from the bore hole is not desirable. One technique that has evolved is to drill the pilot hole and leave the bore closed just prior to exit or plug it with an inflatable plug. This then allows for the bore to be opened by forward reaming, and drill fluids are returned to entry for recycling rather than being lost to the ocean floor. The final section of the bore can then be reamed out using biodegradable fluids to limit any potential environmental impacts of the break through to the seabed.

EXPERIENCE MATTERS

Stockton Drilling Services has been involved with a number of complex shore crossings constructed in Australia over the past 15 years, including:

- Minerva Shore Crossings (two) in Victoria for BHP Billiton
- Gorgon Shore Crossings (nine) in Western Australia for Chevron
- Kupe Shore Crossings in New Zealand for Technip/Origin Energy
- Victorian Desalination Pilot Plant Shore Crossings in Victoria for Department of Sustainability and Environment
- Narrows Shore Crossings (four) in Queensland for APLNG/QGC
- Gladstone Harbour Crossing Feasibility Study for Arrow Energy
- Anglesea Water Reclamation Plant (WRP) Shore Crossing in Victoria for Barwon Water

Two projects that are interesting to note are the Gorgon Shore Crossings and the Anglesea WRP Shore Crossing Replacement.

The Gorgon Shore Crossings were constructed on a Class A Nature Reserve, and won the national Environmental Engineering Excellence Award at the Australian Engineering Excellence Awards in Canberra. Ian Pedersen, Chair of the National Engineering Excellence Awards Judging Panel, said "the uncompromising environmental commitment to this project suggests engineering construction techniques can be ecologically sensitive, allowing us to maintain our natural environment for the future".

The second project, which clearly indicates how the development of new construction techniques have allowed for improved design, is the Anglesea WRP Shore Crossing Replacement, located 25m above sea level on the Anglesea coastal cliffs. The previous outfall consisted of a 30m deep drop structure which transferred flows from the treatment plant level to the base of the cliffs. A 185m outfall pipe then discharged flows from the base of the drop structure to the ocean.

The outfall was constructed in 1995. Since construction, cliff erosion had exposed a section of the outfall pipe that runs through the base of the cliff, from the drop structure to the beach. The current rate of erosion is estimated at four meters every 10 years.

In May 2006, a rock fall crushed a section of the exposed pipe and emergency repairs were required. The pipe was repaired and a concrete block was formed around the exposed pipe. However, the cliff continued to erode further, exposing the pipe again, undermining the concrete block and placing the pipe at risk of failure again. The instability of the cliff and risk of further collapse meant it was too dangerous to carry out temporary repairs to the broken pipe.

As a result Barwon Water initiated a project which required the design and construction of a new outfall pipeline and associated works. Stockton Drilling Services provided engineering support and construction supervision for the project.

A geotechnical desktop assessment was undertaken to allow for the design of alternative preliminary drilling profiles, and to define the scope for further geotechnical investigations. The project team then undertook bathymetric surveys and seabed sampling of the works corridor to establish suitable exit point locations. Seabed profile, water depth, currents, geology and environmental impacts were then evaluated to determine the lowest risk and optimised length and location for the drill exit and diffuser installation.

Considering the peak flows from the water reclamation plant and installation forces, it was determined that a 450mm diameter HDPE pipeline would be required. The pipeline would extend 700m from within the plant boundary to approximately 500m offshore to a water depth of 15m, where a 16m-long diffuser would be installed. The pipeline was installed within three weeks of mobilising to site.

UTILISING HDD IN URBAN ENVIRONMENTS

The execution of HDD in an urban environment is technically the same as for an open environment. The main difference is not what is happening below ground, but what is happening on the surface.

BENEFITS OF HDD IN DEVELOPED AREAS

The key benefits enjoyed by both contractors and residents are the reduced amount of open trench excavation, reduced time of construction and reduced amount of reinstatement. Open trenching can be difficult and time consuming in an urban environment due to the need to expose, protect and support existing services that cross the alignment. Often these trenches, curbs, pavements and roadside easements are then prone to future settlement after open trench installation methods have been used, which is eliminated by using HDD. The use of HDD may be essential if a main highway, railway or infrastructure needs to be crossed.

HDD is commonly used for pressurised water supply, pressure or graded wastewater, electrical conduits, telecommunications, and gas supply networks.

TAKING THINGS INTO CONSIDERATION

The crossing design must take into consideration the increased density of infrastructure both above and below ground, including: road, rail, foreign services, foundations, power poles, and overhead cables. Undertaking a dial before you dig (DBYD) enquiry and site inspections should be used to identify all services. These services should then be proven by potholing of ground penetrating radar (GPR) to confirm their exact position and depth.

The presence of infrastructure may also prevent the use of traditional magnetic or walk-over steering systems and alternative steering solutions such as gyroscopic tools may be required.

Space is constricted, a smaller footprint is utilised, and equipment needs to be configured to individual sites to allow for efficient and safe drilling operations. On the pipe side, it becomes increasingly difficult to string long lengths of pipe in one continuous length, so alternatives need to be evaluated. These may include performing tie-in welds during insertion, or using HDPE, which is more flexible than steel and easier to handle. Also, pipe trailers can be utilised for smaller diameter coiled pipes.

The execution of the works should then consider any potential impacts on adjacent residents and businesses, including: traffic management, noise, dirt on roads, dust and light emissions. In such an environment these factors will usually result in restrictions on operations which need to be considered, e.g. restricted working hours, noise control, heavy vehicle movement restrictions.

The risk and potential impact of a frac-out can also be increased in an urban environment. Previous construction activities and installation of other services can reduce the bearing capacity of the soil or introduce pathways for fluid migration.

These crossing require a thorough scoping and risk assessment process to ensure that all potential risks are identified and controls and contingencies are in place. The crossing design needs to allows for safe access, appropriate space for equipment setup, suitable pipe handling methodology, and a profile design that provides adequate separation to all infrastructure and services, both present and future.

A VERSATILE SOLUTION

Due to the vast array of drilling rigs available today, HDD can be used for all types of pipe installation in urban environments [Is this statement really true?]. Compact, silenced, powerful rigs with automated rod loading, built-in power generation and on-board pumps all simplify the drilling operation and reduce the required footprint.

One of the most challenging urban environments I have worked in was, Bangkok, where we had to design and install 28km of 30-inch high-pressure steel pipeline by HDD.

The plan our design team developed was to drill the section as 16 crossings, each between 400m and 1600m long. Due to the rapid development and expansion of the city limits, there was no space available for pipe stringing. Once the project was underway imaginative strategies had to be developed, including welding and stringing on top of shipping containers, and floating strings out by threading them along the canal network of khlongs.

One of the most challenging urban environments I have worked in was in one of the world's most congested cities, Bangkok, where there are over eight million residents. Even though there is hardly space to walk, never mind drive a rickshaw, we had to design 28km of 30-inch high-pressure steel pipeline to be installed by HDD.

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THE IMPORTANCE OF GEOTECHNICAL INFORMATION

Around 90 per cent of HDD work happens below ground, so thorough and well thought out site specific geotechnical investigations are essential for planning any HDD project. Obtaining sufficient and correct geotechnical information can make or break a HDD project. The importance of defining the crossing geology should never be underestimated. This will allow for the profile, downhole tooling, drilling fluids and schedule to be accurately developed and costed.

Initially, a site visit and geological review should be undertaken to provide a geological overview of the area, which should then be used to determine the site specific investigations.

The site investigation needs to obtain sufficient reliable information to permit the safe and economic design of installation and permanent works. The investigation should be designed to verify and expand upon any information previously collected. Site investigations for all drills should include site inspection/surface investigation, topographic survey, identification of existing services and a geotechnical assessment.

Where the client undertakes the investigations, the HDD contractor should assess the completeness of the information provided and ensure it provides sufficient information for planning and execution of the bore.

Where further information is required, the HDD contractor should provide a proposal to the client outlining the objectives, requirements, and budget costs for any additional works required.

CONSIDERING THE BASIC GUIDELINES

Some basic guidelines for planning the scope of the geotechnical investigations include:

The level of geotechnical investigation required is a function of the length of the bore and the anticipated complexity of the subsurface conditions. While typical spacing is at least every 150–250m along the bore alignment, a minimum of two geotechnical boreholes is required for each bore where the bore length is greater than 300m.

Boreholes should be located to track stratigraphy and to detect the geological sequence, structure, and areas of significant change. When results indicate other anomalies or highly varying strata, then additional boreholes may be required.

The boreholes should penetrate through an elevation at least 3-5m below the depth of the proposed HDD profile to provide information for HDD design modifications, pilot hole deviations and ensure any potential rock formations have been identified.

Boreholes should be offset perpendicularly from the HDD centreline where practical by 10m.

Investigations should describe the soils and rocks encountered and recover samples for laboratory testing. Where soils are encountered, in-situ standard penetrometer testing sampling should be undertaken at selected depth intervals within the borehole.

Where frac-out modelling is required, the geotechnical parameters required for undertaking the modelling (e.g. unit weight, shear strength, friction angle, cohesion and Youngs Modulus) should be determined during the geotechnical investigation.

The likelihood of soil/groundwater contamination or acid sulphate soils should be determined prior to undertaking any investigations. If contamination is suspected (i.e. near electrical transformers, fuel storage, petrol stations, industrial land), samples should be tested for likely contaminants in accordance with the relevant guidelines for contaminated sites.

Boreholes should be backfilled to minimise the possibility of drilling fluid migration along the borehole during subsequent HDD operations. The upper 1.5m of land-based boreholes should be backfilled with the surrounding soil. Below 1.5m, a backfill mixture containing cement grout and a bentonite product to promote expansion is recommended. Cuttings from the drilling operation may be incorporated into the backfill mixture if considered beneficial.

A geotechnical report addressing the sampling program, laboratory analysis (including strength testing and particle size distribution), interpretation of geotechnical engineering properties, bore logs and a profile of the subsurface conditions shall be produced. Reduced levels of borehole data shall be included on the HDD profile drawings.

Probably 90 per cent of the work is happening below ground, so thorough and well thought out site specific investigations are the most basic and essential requirement for planning any trenchless construction project.

All formations can be drilled reliably if the soil conditions have been properly defined and considered during the design phase.

WHAT IS HOLDING HDD BACK?

For our industry to continue to grow we need to keep our minds open to new technologies and possible hybrid solutions between open and trenchless construction, such as ploughing and direct lay. Our industries currently coexist, but may well merge further in the future as new methodologies and possibilities develop.

HOW CAN WE IMPROVE THE REPUTATION OF THE HDD INDUSTRY SO THAT IT IS NO LONGER CONSIDERED HIGH RISK?

As our urban centres continue to grow and our demand for resources needs to be met, there will be continued growth for the HDD industry as long as contractors ensure clients the methods and practices are well engineered and reliable. For example, the Australian market has been slow to take advantage of new technology such as gyro surveying, which is widely used in other countries.

One recent application demonstrates its value and the need for accurate and independent confirmation of pipeline as-builts installed by HDD. A civil engineering contractor was engaged to construct a major road underpass and was in the process of drilling in the concrete piles when they severed a 300mm diameter conduit containing a 132kVA cable. According to the as-built supplied, they were more than two metres away from the three HDDs. We mobilised the next day and were able to survey the two remaining conduits, which contained the other phases.

We confirmed the position of the two remaining conduits to +/-150mm along the entire length of the crossing, therefore allowing the works to confidently proceed. In this case, they were lucky no-one was hurt and just had a major power outage to deal with. As most pipe bundles are installed with a spare, I would like to see all HDD crossings re-surveyed with the gyro tool to ensure pipeline owners and service suppliers have accurate and reliable as-builts. This will simply become more and more critical as HDD installed infrastructure continues to grow with population density.

I also feel that we, as an industry, need to increase the quality, reliability and performance of HDD services in Australia.

Our industry continues to expand, at all levels, and there should be a means to standardise performance and ensure product delivery. At the moment there are no real codes of practice that exist that are applicable to current practices and capabilities of the market. Often foreign or out dated references are used in contract documents; but these are rarely applied or used in earnest.

To give pipeline owners, engineers and contractors a valid and recognised guideline would greatly enhance industry performance, reduce construction risk and ensure best practices are employed. It would help put Australian construction practices forefront on the world stage, and would provide the fabric for the development of HDD QA/QC. Every other part of pipeline construction is regulated but often the most challenging part of the works, the HDD, is left without independent inspection and verification.

Stockton Drilling Services is hoping to help facilitate the pipeline industry and trenchless industry in working together to develop a code of practice/guidance note for the planning and execution of HDD projects in Australia.

THE FUTURE FOR HDD

HDD is now employed throughout the construction industry, and these days it's surprising not to see a small HDD rig at the side of the road anywhere a pipeline, cable or conduit is been installed in an urban environment.

It is no longer only for special sections, but an integral part of any pipeline routing and design.

There is a distinct split in the capabilities of HDD contractors; either operating mini/midi rigs and concentrating on small lengths and diameters; or operating maxi rigs (greater than 100 tonnes pullback capacity) for the installation of large diameter pipelines. These two very distinct fields mean that contractors are generally specialists in their own area but not necessarily in both. Therefore it is important that the right contractor, with the appropriate equipment and relative experience, is selected for any works.

Asset owners and builders must enhance the opportunities that trenchless construction offers if they are to stay competitive and embrace safer and more environmentally conscious pipeline construction. Whether you are evaluating a 50m section under a driveway or 4,000m section under an inhospitable coastline, HDD must be part of that evaluation.

HDD will become even more commonplace in the next five to ten years, and owners will need to engage specialist companies such as Stockton Drilling Services to ensure designs are optimised by recognised industry experts, who will ensure there is seamless alignment between the owner's requirements and the contractors capabilities.

In response to industry needs, Stockton Drilling Services has developed a HDD quality control package that has seen some excellent outcomes. HDD is the most technical and often the most challenging part of installing a pipeline, however unlike the other components, there are no inspection and quality controls. The process is often left solely to the contractor or client superintendent, who may have limited HDD experience.

Depending on the project phase, we provide the following:

» FEED engineering design – to ensure a technically feasible and efficient crossing is designed
» Contractor proposal reviews – to ensure the contractor's proposal is technically acceptable and adopts industry best practice
» Quality control inspection during construction – to ensure contractor compliance and quality control

Our expert HDD inspectors are employed by clients in a site-based role to monitor and review the HDD construction process. The technical specialists monitor progress, identify issues before they arise, provide guidance, assist with problem solving, evaluate technical proposals, and monitor breakdown stoppages.

The benefits include:

» Compliance with the scope, specification and industry best practice
» Environmental impacts are avoided or minimised
» Continual monitoring to ensure safe systems of work and equipment
» Avoidance or minimisation of schedule delays and cost impacts by ensuring risks are identified early and managed appropriately

I feel that we, as an industry, need to continue to push the quality, reliability and performance of HDD services in Australia. Whilst our industry continues to expand at all levels Stockton Drilling Services continues to strive to standardise contractor performance and safeguard product delivery

Meanwhile we should all continue to explore new business opportunities that utilise HDD industry capabilities in new or unconventional ways including water management, mining applications and energy sectors such as geothermic. Horizontal Directional Drilling continues to be an exciting industry for clients, engineers and contractors alike and one that we are very proud to be support.