LOCATING UTILITIES – A CRITICAL COMPONENT IN DREDGE PLANNING CASE STUDY: GAS LINES IN THE PROVIDENCE RIVER

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ABSTRACT

Defining the presence and location of existing utilities is a critical component during the planning of marine construction and dredging projects. Many times engineers are faced with the challenge of relating current survey data with aged utility permit and construction documents, often without the corroboration of professional surveys or as built plans. In the absence of definitive data, engineers must not neglect sound engineering judgment when advising a project owner as to how to deal with the potential conflicts, barriers and/or limitations such utilities often pose on a project.

The following case study came from the application of a utility for the design and permitting of a proposed Natural Gas Marine Terminal at a deep-water port that was also undergoing improvement dredging. During the course of the dredging project it was learned that there were three ten-inch diameter, high-pressure gas lines traversing the Harbor that crossed the mid-point of the proposed terminal. After researching the plans of record on the subject gas line, the USACOE found that the originally permitted burial depths of the pipeline conflicted significantly with two electronic surveys that had been performed. The survey showed that if the Federal Channel and the proposed berth were dredged to a depth of –12.5 m (41 ft) MLLW, there would be insufficient cover over portions of the pipe to meet DOT requirements. Because of the disparity of between the various surveys, and the fact that recent surveys showed the pipelines to be significantly shallower in depth than the permits allowed, the USACOE determined that the survey data of record was too ambiguous to be relied on, and as such it could not dredge much of a 46 m (150 ft) wide corridor/ buffer directly over the pipeline route. In order for the new terminal project owner to proceed with its plan it became necessary to accurately determine the depths of the pipes in accordance with the USACOE directive, and to accurately identify areas where the pipes might be out compliance. Several electronic methods of locating the pipes were attempted; however, because of site constrictions and the pipeline configuration, functionally repeatable results could not be obtained.

Because electronic surveys had not produced consistent results, the owner and the USACOE turned to more conventional methods, which included unearthing portions of the pipe. There was much concern on the part of all parties that any unearthing of the pipelines in the marine environment would cause damage or leaks in an area where they would be very difficult to repair. In response to this concern CLE Engineering, Inc. and CRC Company, Inc. developed a means to unearth the pipeline and physically identify it in order to locate it horizontally and vertically with a high degree of accuracy.

The process of physically uncovering the pipes was one of the biggest challenges. Because of the large disparity between surveys, the depth of excavation could vary from as little as 1.75 m (6 ft), to as much as 5.5 m (18 ft) below the existing harbor bottom. Water depths also made the process difficult, as the areas of the most critical verification surveys depths ranged from 10 to 12 m (34 to 40 ft), with the addition of as much as 1.5 m (5 ft) of tide.

This paper will review the options for submerged pipeline surveys, the accuracies of each and discuss a project that ultimately physically uncovered and located three pipelines and determined the actual locations and depths of burial.

Keywords: pipeline location, utility locations, utility surveys, pipeline inspections, dredge design

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INTRODUCTION

The U.S. Corps of Engineers (USACOE) was in the process of performing improvement dredging of the Federal Channel in the Providence River to a design depth of –12.5 m (41ft) Mean Lower Low Water (MLLW), plus .6 m (2 ft) of allowable overdepth. The project plans included, and took into account the position of three 25.4 cm (10 in) diameter steel gas pipelines that crossed the river. The original permits for the pipelines indicated that it had been buried to a depth of –15 m (50 ft) MLLW, which would have provided adequate coverage under the DOT regulations. During the course of the dredging project it was learned that the actual records of the pipeline installation (in 1954) were fragmented – and in fact there were no realistic as-built surveys of the pipes. After considerable study, the USACOE determined that the originally permitted burial depths of the pipeline conflicted significantly with two more recent "electronic location" surveys, which were performed by the pipeline's owner. Because of the disparity between these surveys, and the fact that recent surveys showed the pipelines to be significantly shallower in depth than the permits allowed, the USACOE determined that the survey data of record was too ambiguous to be relied on, and as such it could not dredge much of the 46 m (150 ft) wide corridor directly over the pipeline route. This area became known as the "no-dredge" zone and it extended 126.5 m (415 ft) into the Federal Channel from the Western channel limit, and 93 m (305 ft) into the Federal from the Eastern channel limit. Pursuant to this issue, the USACOE sent a directive to the pipeline owner to either provide a functionally accurate, certified survey of the pipeline, and if the pipeline were out of compliance with permits, to correct or remove same. Providing a "functionally accurate, certified survey" was defined by the USACOE as physically locating and identifying each of the three pipes, in a number of locations, surveying its position at these locations, then having a Registered Professional Engineer certify the locations. Because of the conflicting record data, electronic and/or sonic methods of pipeline location were not considered acceptable means of survey.

CLE Engineering, Inc. (CLE) had provided engineering and surveying services for a number of components of the project. CLE had also conducted the research to determine the location of the three (3) 25.4 cm (10 in) diameter steel gas pipelines installed under the Providence River. CLE was requested to develop and conduct a survey that would satisfy the USACOE's requirements. This project was problematic in that it required that the pipes be uncovered in a number of locations, at water depths exceeding 17 m (55 feet) and because the issue occurred at the time of the winter heating season, the pipelines could not be de-pressurized for more than a short time during the investigation. This meant that the pipes had to be uncovered and measured for depth while live and in use which required that a number of safety related issues be addressed. Also, because the pipeline owner was concerned about the long-term life of the pipe, an excavation methodology need to be devised that would guard the pipe and coating against any possible damage during the excavation process.

METHODOLOGY

Attempts to Locate the Pipes by Electronic Methods

The history of electronic pipe location attempts began in 1995 when the pipeline owner contracted with a diving company to perform a survey using a combination of electronic and conventional hand probes. This party produced a plan and profile of the pipeline crossing, however because of a significant error in the vertical datum applied; the pipe appeared much deeper on the profile than it actually was. Since there were no plans for dredging of the river on the horizon at that time, the utility owner did not have any reason to look for a problem and the drawing was simply placed in the file. During that same time period, another company performed an electronic pigging survey of the pipe's interior, however the pig's electronics were limited and the pig only recorded pipe interior condition, length and approximate location of bends, thus it was of little help identifying the pipe's physical location. It was not until the beginning of the dredge project in 2003 that anyone had reason to look more closely at the 1995 survey.

As part of an area study relating to an ancillary dredging project, CLE requested that the utility owner provide copies of any plans and/or surveys of the pipe. When CLE reviewed the 1995 survey it became apparent that there was an obvious datum error that when an approximate correction was applied, placed significant portions of the pipeline within the dredging template. The USACOE was notified of the problem, and in turn they classified the suspect areas as a "no dredge zone" until the problem could be resolved. This prompted the need for follow-up surveys to attempt confirmation of the pipeline burial depth. The utility owner re-contracted the same diving company to return and re-survey the pipeline, this time under the observation of the USACOE. The diving company employed essentially the same methods as they had used in the 1995 survey, however this time using better tidal correction data. The resultant profile was completed and when the profiles were compared, they showed essentially the same burial depths as the (corrected) original survey. CLE was then contracted to locate a more sophisticated electronic location system to survey the pipeline. However, the search became problematic, in that the configuration of the pipeline valve pits, and several abrupt bends in the pipeline crossing prohibited the use of more accurate "tracking" pigs (due to the length of the pig). The search however did lead to one company, StarTrak Pigging Systems, who had a technology whereby the pipes were isolated electrically, and then a "loop wire" was added across the waterway, connecting the extreme ends of the underwater crossing. Thereafter a signal generator was connected to produce an electro-magnetic field on the pipeline. The signal was then traced by running a survey boat back and forth across the pipeline at 6 to 15 m (20 to 50 ft) offsets, recording bottom depth, pipeline horizontal position and pipeline burial depth. The system data was calibrated be physically probing and locating the pipe in a few known locations where the pipe burial was minimal. The survey resulted in a pipeline plan and profile that again differed considerably from earlier surveys. The most dramatic difference was found in the pipe alignment, whereby the StarTrak survey showed the pipe's alignment bowed about 15 m (50 ft) to the south of the "straight" alignment shown on both the as-built trench plan as well as the diver surveys. The new StarTrak survey also showed the estimated pipeline depth profile to be very close to the original trench survey (albeit somewhat different in several locations) and considerably different than the diver surveys of 1995 and 2004.

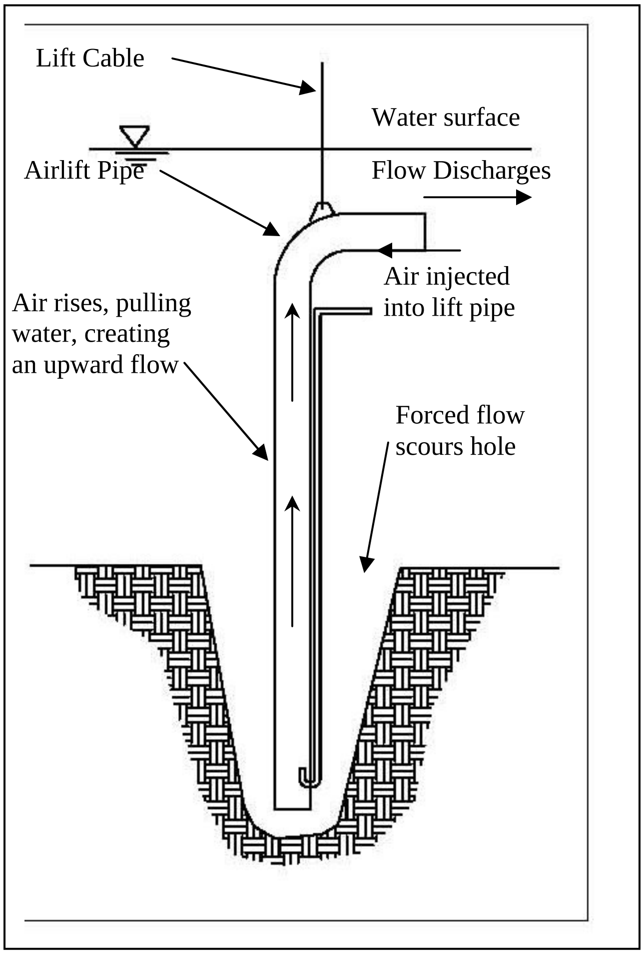
Nonetheless, there remained a number of unresolved disparities between the various plans and surveys. There was the (1) original Permit Plan, (2) the informal trench survey by the original installation contractor, (3) the 1995 diver survey, (4) the 2004 diver survey and (5) the 2004 StarTrak survey. Even though the StarTrak survey appeared to be the most accurate and reliable of all, the USACOE, in concurrence with CLE agreed that because of the potential risk to public safety, some form of physical confirmation survey should also be performed to assure all parties of the actual pipe location. It was also determined that no dredging would be done within 23 m (75 ft) of the pipeline corridor until the location was physically confirmed.

General Description

There was much concern on the part of all involved parties that any unearthing of the pipelines in the marine environment would cause damage or leaks in an area where they would be very difficult to repair. In response to this concern, CLE and CRC Company, Inc. developed a means to carefully unearth each pipeline and physically locate it with a reasonably high degree of accuracy. The methodology, proposed in the permit applications to the USACOE, Rhode Island Coastal Resources Management Council (CRMC), and the Rhode Island Department of Environmental Management (DEM) was modified slightly in the field as existing conditions dictated. In general the following procedures were followed:

The plan was to remove silt and clay materials overlaying the pipeline in selected various locations and the pipe was to be identified and then physically surveyed at these locations. Proper surveys conducted under these conditions would determine the precise vertical and horizontal position within 15 cm (0.5 ft) tolerance vertically and under one meter horizontally. The pipeline was to be exposed in a number of locations within the Federal Channel as well as both the East and West U.S. and RI Harborlines, dependent on field conditions such as the presence of rip rap or unstable side slopes.

The process of physically uncovering the pipes was one of the biggest challenges. There was a high degree of concern by all parties that the pipelines not be damaged in the process of uncovering them. Unfortunately, this precluded most of the common, more productive methods of marine excavation. Methods that utilized clamshell buckets or cutterhead-suction devices were ruled out. Because of the large disparity between surveys the depth of excavation could range from as little as 1.75 m (6 ft), to as much as 5.5 m (18 ft) below the existing harbor bottom. Water depths also made the process difficult, as the areas of the most critical verification surveys depths ranged from 10 to 12 m (34 to 40 ft), with the addition of as much as 1.5 m (5 ft) of tide. It was determined that the most viable and safe method to uncover the marine sediment and clay from over the pipes was to use a marine "airlift".



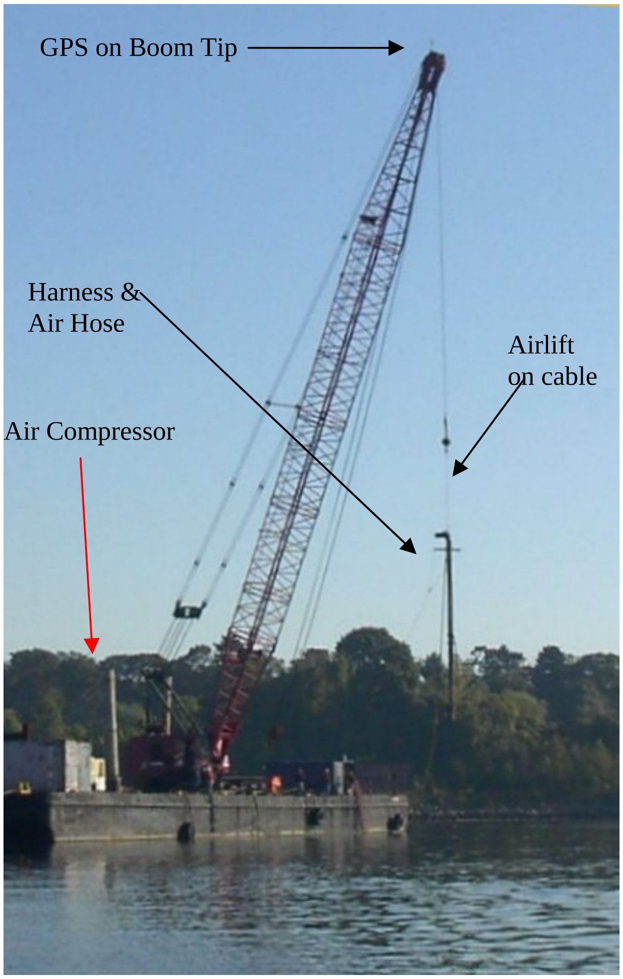


Figure 1: Simplified diagram of how air lift works

Figure 2: Airlift suspended from cable, preparing to be lowered into water to begin excavation

An airlift is a dredging tool that works by injecting compressed air through a small diameter pipe (5 cm or 2") at the bottom of larger diameter pipe (30 cm or 12"). The air is injected into the bottom of the larger pipe that is positioned vertically on the river bottom by use of a cable suspended from a barge-mounted crane. The advantage of the airlift is unique in that it has the ability to scour and remove marine sediments without the need for hard digging devices, such as clamshell buckets. Instead, the air injected at the bottom of the airlift pipe rapidly rises up to the top of the pipe and the bubbles of the air stream and create a forced upward flow of water and air within the pipe. The airlift utilizes the velocity of the combined flow to agitate and liquefy marine soils, and literally suction them up the pipe and away from the area of intended excavation. Accidental abrasive damage to the pipe and coating system was prevented by the use of a rubber shoe fastened to the bottom of the airlift. Like a giant underwater vacuum cleaner, the airlift gently removed the soils overlying the pipes until they were exposed. This same technology is often used for underwater excavation of delicate archeological sites.

There were 21-targeted areas where the pipe was to be located. At each location an area of exploration was targeted, then as each hole was excavated, a diver would enter the hole to attempt physical location of the pipe. Because clouds of suspended sediment remained in the excavation, diver visibility was non-existent once the diver entered the hole. From that point on all pipe location inspections were strictly done by feel. Unfortunately, the marine soils covering the pipes varied considerably in consistency, ranging from gelatinous muck the moderately stiff marine clay. This caused a large variety of excavation formations, each of which had to be individually verified for stability progressively as the diver entered the excavation. Only professional divers, with backgrounds in what are known as “black water” penetrations, with surface supplied air, emergency air and radio communication were employed.

Detailed Work Sequence

CRC Company, Inc. towed a12 m by 49 m (40 ft by 160 ft) barge equipped with a Model 4100 Manitowoc crane, plus two 37 cubic meters per minute (1,300 cubic feet per minute (CFM)) air compressors, with three outfitted cabins to serve as all weather enclosures for men and equipment. There were facilities for diver operations, Electronic position monitoring, and equipment storage.

Barge and Airlift Positioning

CLE Engineering was tasked with the responsibility of providing positioning for both the barge and airlifting operations. Both functions were critical to the investigation effort, the first system being required to properly position the barge in relation to the alignment of the pipeline, and the second system to accurately position the airlift over projected pipe locations.

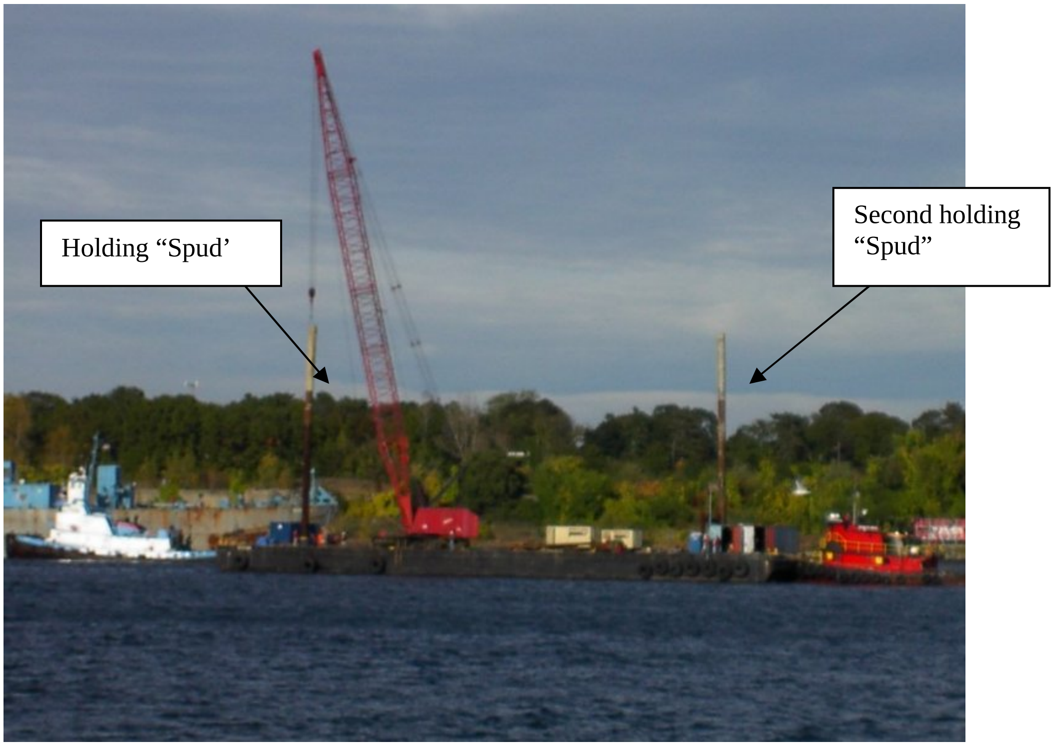


Figure 3: Crane barge being pushed into position adjacent to pipeline, note crane is about to lower and “set” one of two holding spuds

The method determined to be the most reliable for holding the barge in place during airlifting was the use of spuds, which consisted of two large 76 cm (30 in) diameter pipes. Spuds were determined to have an advantage as they had far less tendency to slip or drag such as anchors might, and they confined barge movement (drifting) to a few feet while on station. The negative feature required setting the spuds near the exact limits of the designated “no-spud” zone, which was 23 m (75 ft) from the anticipated center of the pipeline corridor. This was complicated because it was learned that there was not only a disparity in the pipe’s depth, but there was also a significant disparity in where the pipes laid with respect to its permitted alignment. (One of the earlier electronic surveys showed the pipes bowing as much as 15 m (50 ft) off line to the south of the previously designated corridor.) As such, the position of the pipeline in relation to the no-spud zone changed as the work approached the center of the river, to a point where it was within a few feet of the southerly “no spud” limit, which in turn made barge positioning extremely critical in these areas. The positioning system for the barge was a CSI Vector Pro antenna (heading accuracy to ½ degree and submeter positioning) integrated with HyPack Software®. This was necessary in order to identify the position of both spuds in relation to the "no-spud" zone before they were set into the bottom. The airlift positioning system was a single antenna (Trimble AG312) GPS with sub-meter accuracy. The boom tip GPS also served a second function, acting as a redundant system to confirm the position of a spud before it was set. Barge and airlift positioning systems were monitored by a CLE Engineer using a tracking computer with two monitors. Each showing the anticipated pipeline locations, the barge position and alignment as well as the airlift position, all in real time. One monitor was located with the computer, and a second monitor was located in the cab of the crane. Prior to the start of work, the entire system was calibrated against known control, including the existing pipeline valve boxes. During the progress of the project the location of each test excavation was logged and the location of the hole was recorded on the screen.

As a precautionary measure, during the initial exploratory phase of the investigation the pipeline owner opted to shut off the flow of gas through the pipelines to allow testing of the work and safety plans. Because neither the horizontal location nor depth of the pipes were known with any degree of surety, it was determined to start exploration in shallow water on the East side of the river, where the pipe was known to have only a few feet of cover. This plan served two purposes, it allowed for relatively quick test pit excavation to obtain projected pipe depth, and the shallow water allowed for better visibility, making identification in inspection of the pipe easier. Conversely, soil conditions in this area turned out to be a relatively stiff marine clay, which made uncovering the pipes difficult. This material was not only difficult and slow to excavate, but the sidewalls of the excavation stood at a very steep slope. As such, while the initial penetration hole of the airlift took only a short time, it took a considerable amount of time for that airlift to widen the hole to a size where the diver could safely enter the hole. Because of these difficult soils the initial contact with the first pipe required the excavation of numerous "dry" holes, and took almost two days to accomplish. Once the pipes were finally found, and upon removal of the overburden from above the pipelines in the shallow trench, a diver equipped with a video camera entered the excavation and confirmed a pipeline had been located. In order to confirm the find, and determine if the diver was on the north, middle or south pipeline, personnel were positioned in the closest manhole that could provide land access to the pipes. The diver then "sounded" the pipe by tapping on the metal surface allowing the shore personnel to listen on each pipe for the tapping, then to report back to the barge. The diver then held a survey rod on the top of the pipe that extended above the water surface. The prism at the top of the survey rod was located by CLE surveyors on shore utilizing a theodolite and electronic distance meter, a method that would provide the most accurate and reliable position data. The elevation of the top of the pipe relative to MLLW and its location relative to the Rhode Island State Plane coordinate system was then determined. A secondary redundant verification method was also used, wherein the location of the pipe was noted by the airlift positioning system and its depth was noted relative to the water surface elevation as read from the survey rod while it was held on the pipe.

Once an accurate position of each pipe was ascertained, it was possible to project each individually known pipe alignment ahead a few hundred feet to the next area of exploration, so as to reduce the search area for the next station. For the locations of the pipelines in deeper water it became necessary to locate a point on the cable suspending the airlift that was a known distance from the bottom of the airlift, then to place the air lift directly over the pipeline and shoot a hand held prism held on the mark with land based survey equipment. The secondary method used the distance from the known point to the water surface as measured by CLE from their survey boat, and the GPS location of the airlift.

Operations within the Federal Channel were more restricted than work outside of the channel, in that freight traffic navigating the channel had to be considered. At the end of each day's work, in consideration of maritime safety, the barge had to be moved from its working position, and relocated to a place near the edge of the channel out of the way of shipping. In addition, the excavation areas had to be surveyed at the end of each day, to ensure that any shoals crated by the airlifting did not protrude above the published navigation depth, where they could create a grounding hazard. CLE also conducted hydrographic surveys during the excavation process to document the river bottom topography and to note the conditions before and airlifting. This data was collected to provide defense against potential shoaling claims from the dredging contractor.

Upon completion of the final pipeline location on November 2, 2004 CRC backfilled the open test pits that remained over the pipelines in the shallow areas.

OBSERVATIONS

The results of the pipeline survey were graphically presented on a plan prepared by CLE. CLE engineers were on board the barge each day to position the barge and airlift as well as log the daily operations. CLE surveyors also performed daily hydrographic surveys and provided supply and transportation between the barge and the shore. Copies of the daily survey data in the form of fathometer rolls and raw survey data was held in storage by CLE.

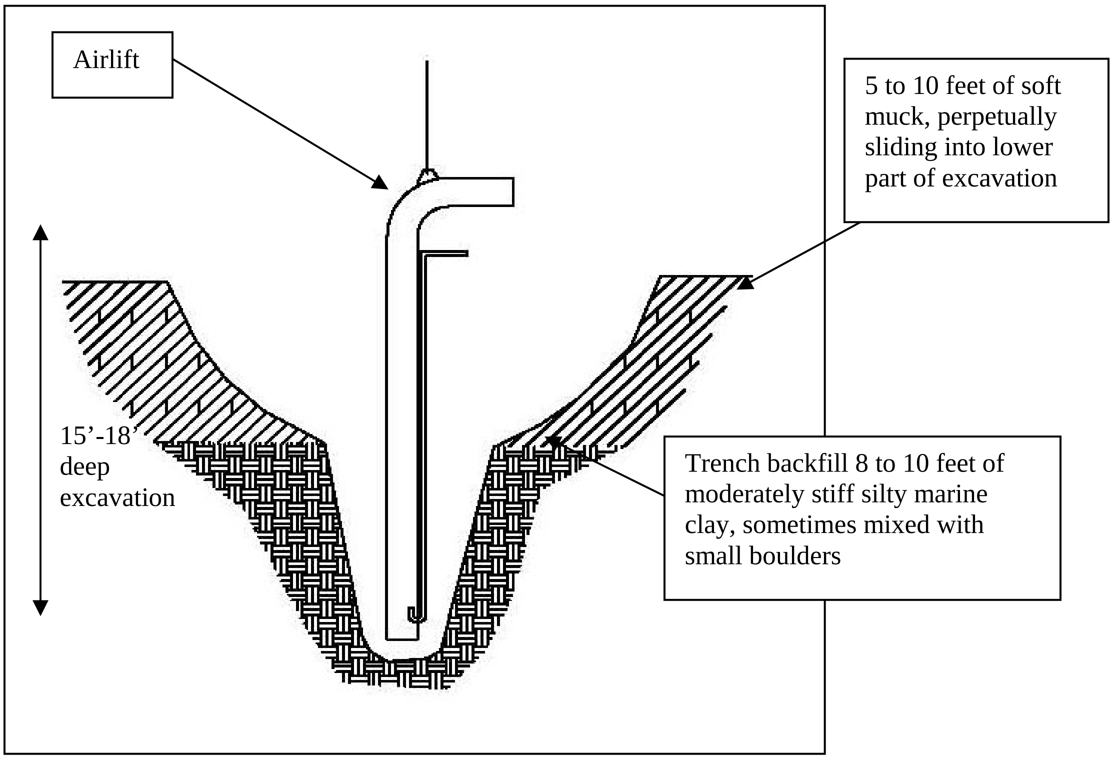


Figure 4: Typical Air lifted exploration hole

Generally speaking most of the exploratory holes developed the funnel shape shown in the above figure. Soils on the Western limit of the channel were found to be considerably softer, and to deeper depths than the Eastern two thirds of the channel. The stratification of the marine soils overlying the pipes caused a number of problems, including a persistent sloughing of the soft muck in the upper surface layers into the smaller lower excavation. At times a second soft layer was found near the pipeline depth, this tended to create a "bell hole" at the bottom of the excavation, which had to be stabilized before a diver could enter the excavation.

The pipeline inspection revealed a number of noteworthy conditions that differed significantly from prior documentation of record.

- In general the pipes were found to be at or close to the design grade of –15 m (50 ft) MLLW, except in two locations. About 26 m (85 f)t of pipe was found to be above the design grade on the Eastern shore, the shallowest pipe depth was at –13.6 m (44.7 ft) below MLLW, or about 1.6 m (5.3 ft) above the minimum permitted depth, in addition 7.5 m (25 ft) of this section was above the elevation required to allow the minimum 1.2 m (4 ft) of cover required for excavation of the new channel depth. Because of this encroachment, the Eastern 30 m (100 ft) of the Federal channel was not dredged for the 46 m (150 ft) length of the "no-spud" zone. On the Western limit of the Federal Channel about 95 feet of pipe was also found to be above grade, the shallowest pipe was found to be –15.1 m (49.7 ft) below MLLW, or about 0.09 m (0.3 ft) above the minimum permitted depth. This condition did not encroach on the minimum 1.2 m (4 ft) cover requirement, and thus did not affect the Federal dredging.
- In general the StarTrak electronic survey proved to be most accurate of the electronic location methods. In the western no dredge zone the actual pipeline depth was found to be approximately 0.5 m to 0.9 m (1.5 ft

to 3 ft) higher than indicated by StarTrak, which was close to StarTrak's claimed vertical accuracy of 0.6 m (2') ±.

- The StarTrak horizontal position survey proved extremely valuable in locating the pipe, and it proved to be the most accurate with respect to preceding methods, especially with respect to predicting the actual "bowed" alignment of the pipes. Further, because of the large disparity between the permitted pipe alignment, and the actual alignment, if the StarTrak alignment survey had not been available for initial guidance, pipeline location operations would have required considerably more time.
- While traces of gravel were found from time to time in the pipeline excavation, in no instance did CLE note the presence of measurable quantities of gravel backfill in the pipeline trench. (Gravel bedding and cover had been indicated on various plans and documents of record that were reviewed prior to the pipeline excavation.)
- The backfill material over the pipelines in the east side of the Federal Channel was found to be a moderately stiff marine silt and clay that held almost vertical side slopes. Conversely, the backfill material over the pipelines on the extreme West side of the Federal Channel was much softer (almost soupy), as such it would not hold a reliable side slope; this required that excavations be much larger. Concentrations of 0.3 m (12 in) boulders were found in a number of locations on the Western exploration area, which also made excavation more difficult. Not only did the boulders tend to lodge in and clog the air lift, but their presence made hand probing by the divers much more difficult.
- There was no evidence of typical marine coating on any of the pipes, such as heavy taping or concrete jacketing, nor was there any evidence of the cast iron jackets referred to in permit documents. Oak staves or strapping of unknown length, measuring roughly 5 cm by 5 cm (2 in by 2 in) were found along the long axis of a few of the pipelines in a few of the Eastern locations. The original intended purpose of this wood is not known.
- Two wooden piles were found protruding from the bottom in the vicinity of the first pipe excavation. It is assumed that these piles were either range markers or devices originally used to hold the pipes on line while they were being pulled across the river.
- The pipes were found to be out of compliance with respect to the 3 m (10 ft) separation shown on permit drawings. The middle pipe was found to encroach on the southern pipe, and in fact was laying directly on top of the southern pipe for a significant percentage of the route. It is possible that the middle pipe actually crosses over the South pipe somewhere on the eastern third of the channel, then re-crosses back over the South pipe about 150 m (500 ft) east of the Federal channel limit.
- The pipelines were found to be south of their design locations by as much as 15 m (50 ft). Based on projections it could be as close as 6 m (20 ft) to the southerly limit of the Federally designated "No Spud Zone".

The figures below show typical trench conditions that were anticipated from documentation of record, versus what was actually found from field exploration.

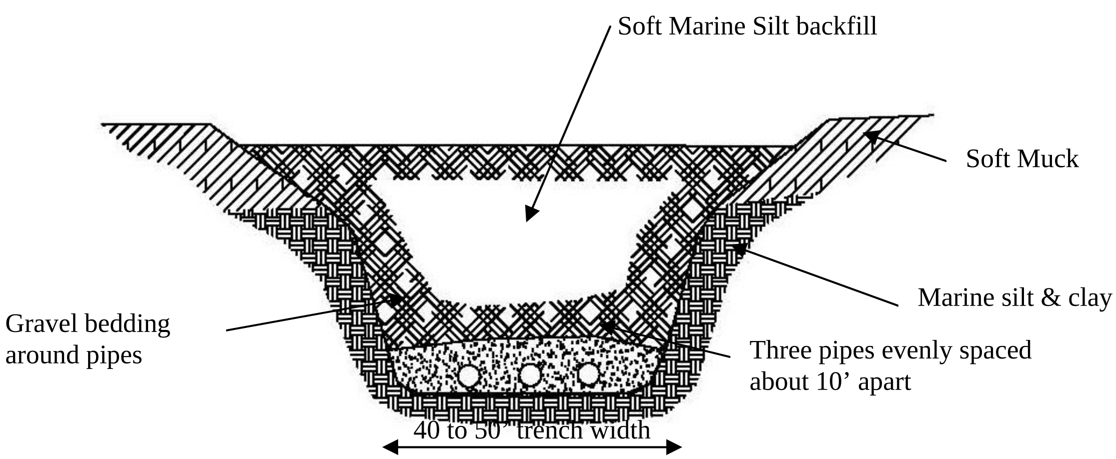


Figure 5: Expected pipe placement and burial conditions based on documentation

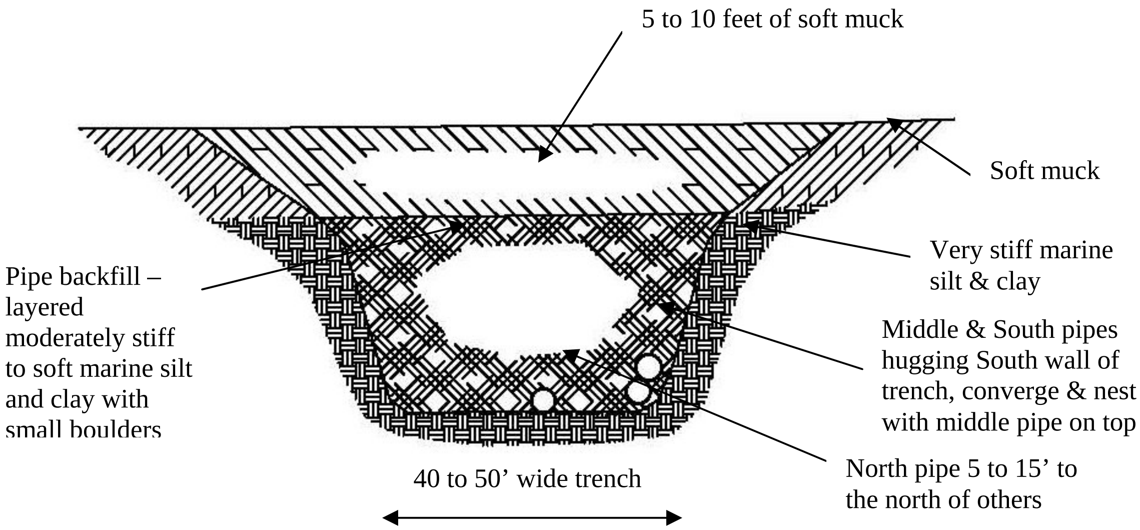


Figure 6: Typical pipe trench conditions found during investigation

CONCLUSIONS

Based on the results of the CLE gas pipeline survey of October 2004, it was determined that the gas pipelines in the Western no dredge zone, were found to be much deeper than the earlier electronic surveys, yet slightly above the minimum design depth. Pipes lying East of the Western Federal channel limit were found at depths of –15.1 m to –15.8 m (–49.7 ft to –52 ft) MLLW, approximately 29 m (95 ft) of the pipe’s alignment was above the permitted grade of –15.2 m (50.0 ft) MLLW. The CLE survey also indicated the gas pipelines in the Eastern no dredge zone were at or below the –15.2 m (50.0 ft) MLLW permitted depth except for about 26 m (85 ft) of pipe alignment, which was found to be above the design grade. This non-compliant area was the Eastern most section of the pipe within the Federal channel. The shallowest pipe depth in this area was –13.6 m (44.7 ft) below MLLW, or about 1.6 m (5.3 ft) above the minimum permitted depth, in addition about 7.5 m (25 ft) of this section was above the elevation required to allow the DOT’s minimum four feet of cover required for excavation of the new channel depth. Because of this encroachment, the Eastern 30 m (100 ft) of the Federal channel was not dredged for the 46 m (150 ft) length of the No-Spud Zone. The USACOE was provided a certified copy of the CLE plan on November 5, 2004 after which they proceeded to direct the contractor for the Federal Channel dredging project to complete the specified work within the no dredge zones. Excepted from this order was the 30 m (100 ft) extending west from the eastern Federal Channel line, which extended for 23 m (75 ft) either side of the original pipeline corridor. All other areas were dredged on November 6th and 7th 2004 and the post-dredge survey was completed in January 2005

It should also be noted that because of the various problematic burial conditions discovered during the pipeline excavation, which included lack of pipeline coating, inadequate cover, and inconsistent pipe separation, the pipeline owner opted to institute a program to replace the pipes.