# THE TECHNICAL AND ECONOMICAL EFFECTIVENESS OF DRY DIRECTIONAL DRILLING IN URBAN UTILITY INSTALLATIONS

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ABSTRACT

Three significant case histories show how dry directional drilling makes it possible to install underground utilities with remarkable technical and economical results. 1. Metroweb and Fastweb projects for TLC cables installation in eight of the major Italian cities. 2. Hydro Quebec project for the connection of 1,000 houses to the electrical backbone in Hampstead. 3. ENEL experimental project in Florence (Tuscany) for the installation of electrical cables in the most beautiful Italian artistic cities. The paper contains a description of the basic principles of Dry Directional Drilling technology and shows the most significant technical and economical data related with the aforementioned case studies.

**Keywords:** Dry Directional Drilling, DDD, Underground utility installation, Trenchless technology with very low environmental impacts, Electrical wiring, Telecommunication cabling.

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## INTRODUCTION

Dry Directional Drilling is a high productivity trenchless technology with very low environmental impact, used, for the most part, in the installation of underground utilities. Further to an appropriate stage of evaluation and testing, some companies involved in the construction and management of telecommunication and electric networks concluded that the Dry Directional Drilling technology was inexpensive and effective, especially when used in urban area installations, both if compared to traditional open-cut trenches methods and to traditional directional drilling techniques (wet boring).
Dry Directional Drilling brings several advantages such as:

- high productivity in various soil conditions
- no use of drilling fluids in the liquid state
- it is less expensive than other installation methods
- negligible environmental impacts

## 1. BACKGROUND

Dry Directional Drilling represents today an advanced stage of the earlier “dry boring” technique, tested in the UK, in the early ‘80s. The dry technique differs from traditional directional drilling techniques because it replaces drilling fluids in the liquid state (bentonite mud, water) with compressed air at low pressure. The tools used in the drilling stage are rotating-percussive, but they can be either rotating or rotating-percussive in the back reaming stage.
The Dry Directional Drilling technology to which we are referring in this paper, was developed in Italy in 1996 and was put on the market by a group of Italian-Canadian companies (SE).
The stages involved in the pipe installation by means of DDD, are the same as traditional directional drilling techniques and they are:

- pilot boring
- back reaming
- pullback

Nevertheless, from a technical point of view, there are remarkable differences that make DDD rather different from traditional directional drilling methods.
DDD is a technique of soil displacement and compaction since, during the principal drilling stages (pilot boring and back reaming), soil is mostly displaced and compacted rather than removed, as it usually happens for the wet directional drilling. The rock drilling is an exception, since the material to be drilled is previously pulverized and then removed by the air flow, circulating in the bore-hole.
While operating in cohesive soils (even in presence of large sandy and gravelly particle-size fractions), the displacement and compaction of the soil (enhanced by the percussive action of the down the hole tools), help generate self-sustain phenomena of the hole (“*arch effect*”).

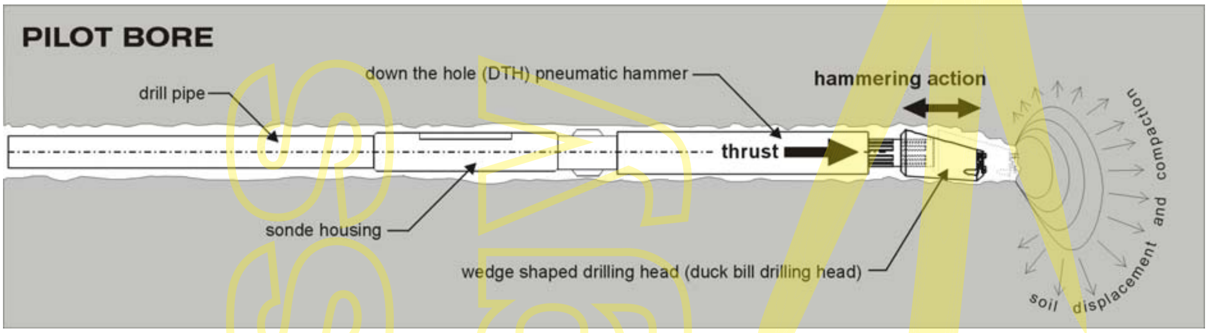


Figure 1 – Displacement and compaction of the soil during the pilot bore stage.

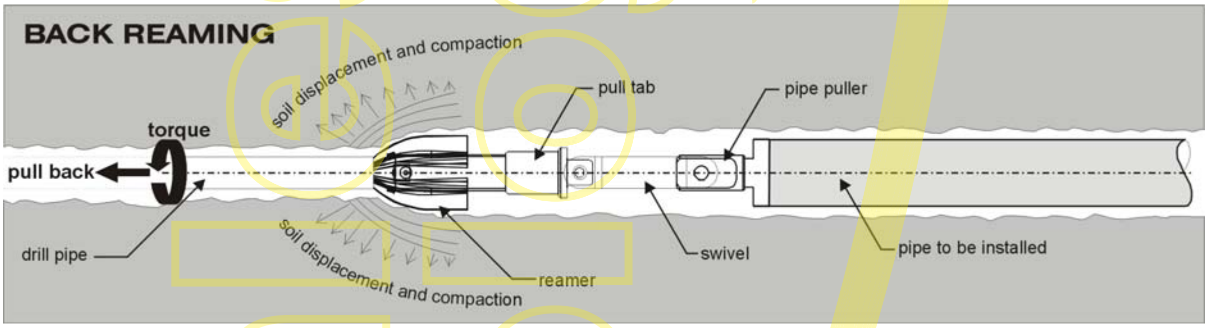


Figure 2 – Displacement and compaction of the soil during the back reaming stage.

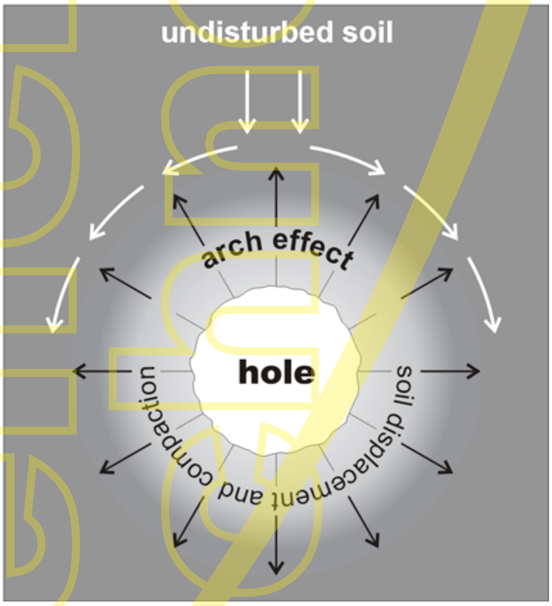


Figure 3 – Self-sustain phenomena of the hole ("*arch effect*").

The phenomena originating in DDD can be easily observed when drilling in soils in which traditional directional drilling methods usually bring about the hole collapse.

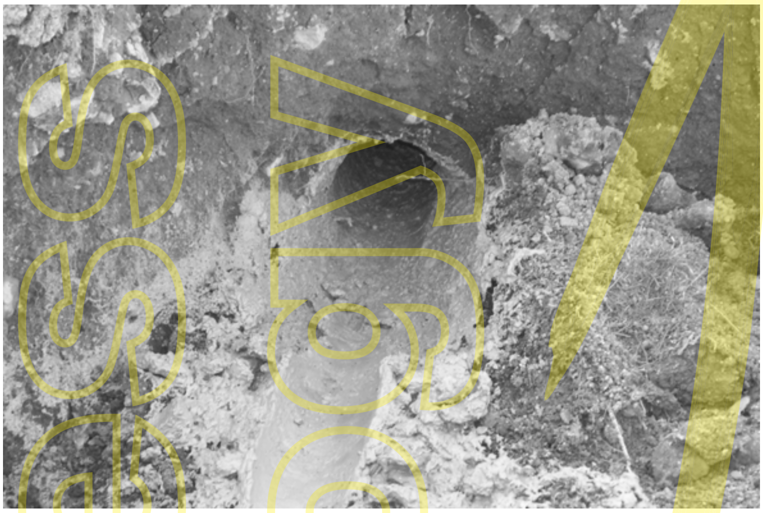

Figure 4 – Self-sustain phenomena of the hole.

It is worth mentioning the use of additive mixtures in Dry Directional Drilling.
The additive mixture is principally made up of water and of a foam agent to which polymers can be also added. Additives are generally used in a proportion of 1 part of foam agent and/or polymers out of 1,000 parts of water. The obtained additive mixture is atomised in the air flow and its quantity generally does not exceed 20gal/hr (90 lt/hr). This is the reason why, this process essentially remains a dry process. For further details about the DDD technology, see the references.

## 2. THREE SIGNIFICANT CASE STUDIES

The following are three significant case studies in which the use of DDD brought remarkable advantages either from a technical and an economical point of view.

### 2.1. Metroweb and Fastweb projects for TLC cable installations – ITALY.

Milan is one of the biggest and most dynamic Italian cities where different economical activities concentrate. In this city, the demand for utility installation is huge and still growing (15% of the entire TLC cabling activity of Italy in the year 2001).
The first coordinated plan for the installation of underground cables for telecommunication, traffic light systems and public lighting, in the city of Milan, was passed in 1999. At that time, the plan already provided that around 900 km of installations were made in the central urban areas, for the telecommunication network alone. In 1999, the telecommunication companies involved in the cabling plan were about nine, half the number of firms now existing. Metroweb (www.metroweb.it), that is one of these firms, was formed from the telecommunication department of AEM (in the beginning, a firm owned by the municipality of Milan), and soon after it stood out from the competitive scene, developing its business and deciding to extend the cabling investments not only to the city of Milan, but also to 7 other big Italian cities such as, Rome, Naples, Bologna, Turin, Genoa, Reggio Emilia and Padua.
The tests for the installation of pipes by using directional drilling began massively in 1998. All major Italian directional drilling companies took part to the first test phase, using all

available directional drilling technologies. Metroweb, which was then starting its activity, gained more and more importance until it became first operator in the city, in terms of contracted works.
By the end of the year 2000, the Metroweb network was made up of 2,060 km of installations, of which 560 km had been made during the year 2001 alone.

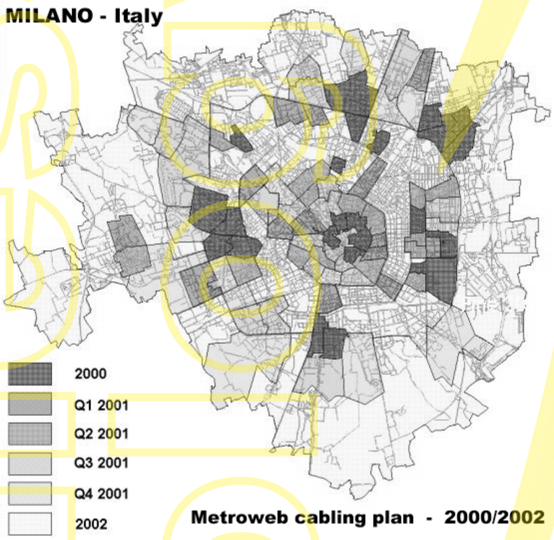


Figure 5 – Metroweb cabling plan in Milan, Italy.
*(courtesy of Metroweb, Italy)*

According to Metroweb technical managers, the size of the project called for a more cost-effective directional drilling technology with a lower environmental impact.
On the basis of the research that was carried out by comparing the data of hundreds of directional drilling jobsites in Milan, Metroweb chose the Dry Directional Drilling technology, because of the following reasons:

- smaller jobsites
- no risk of cellar and underground telephone and electric booths flooding
- remarkable directional precision
- capability of drilling through any kind of soil and under any circumstance.

The reasons of their choice were not only technical but also economical. Actually, installing by Dry Directional Drilling was less expensive than open-cut trenching, even if only speaking in terms of construction costs. Briefly, not only did DDD enabled a reduction of the generalized costs (interferences with transportation infrastructure; social, environmental and risk costs) but also gave to the contracting firm (Metroweb) the opportunity to economize on the direct costs.
The installation of pipelines was more complicated in Milan underground because of the following factors:

- environment complexity: limited areas, heavy vehicle traffic, short-term work permissions released with very short notice, installations made from and to underground hollow spaces;

- underground complexity: large presence of pre-existing utilities and walls;
- lithological nature of the underground: presence of gravels in a clayey matrix.

Metroweb overcame these problems by using the DDD technology and a very detailed planning procedure. Being the Metroweb project a very complex one, the planning procedure consisted of different stages such as:

- designing of an underground map based on:
    - radar surveys
    - ground surveys
    - collection of maps and data from the utility companies

- selection of the strip where the infrastructure has to be installed with observance of the safety distance
- calculation of the drilling paths

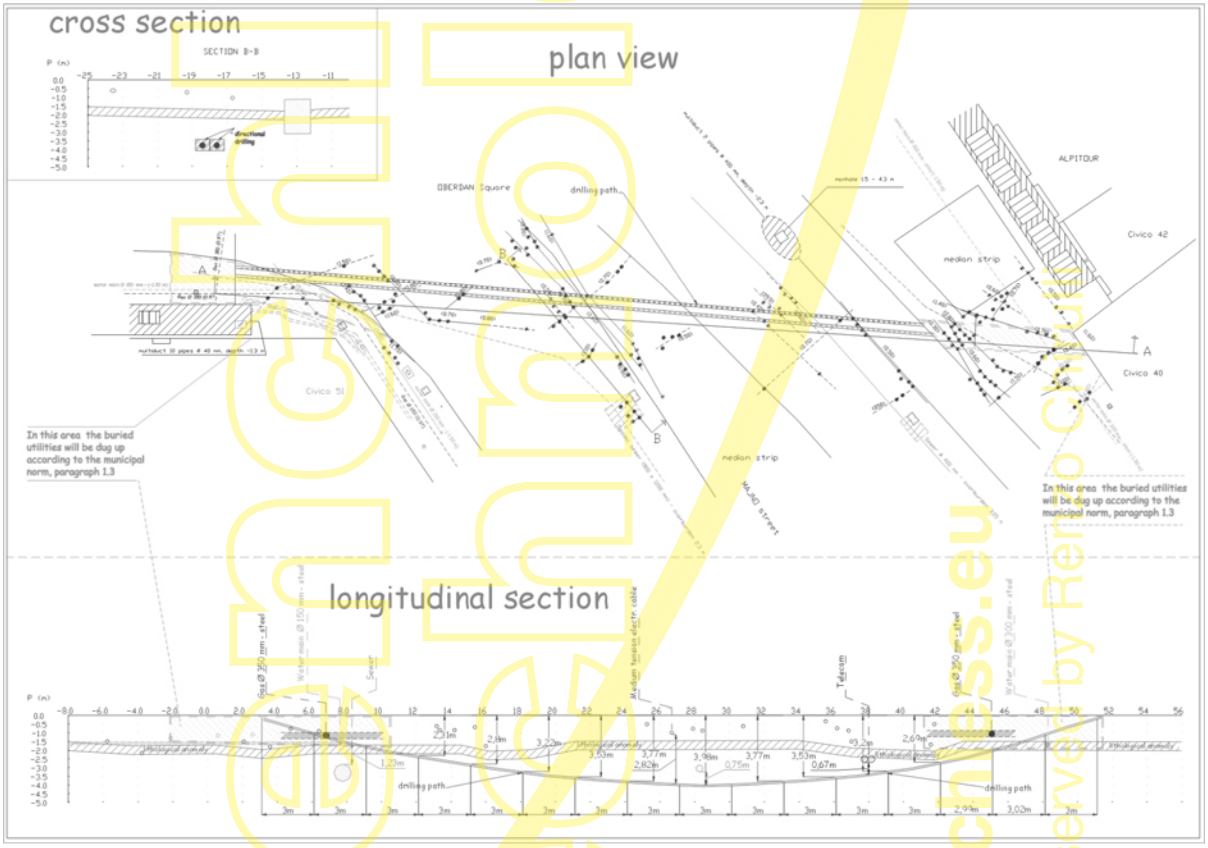


Figure 6 – Project printout of one of the hundreds of installations made by Metroweb in Milan *(courtesy of FRAES Srl, Italy)*

The situation of the 7 other cities in which Metroweb is operating, does not differ very much, in fact in some cases it gets complicated, as it happens in the city of Genoa, where the historic centre is one of the most complex from a morphological and lithological point of view (narrow and steep streets, rocky underground). Other complex cities are Bologna,

where there is one of the most beautiful historic centres in Italy and Rome where all the difficult conditions we listed so far concentrate.
In the first half of 2001, 200 jobsites and a total of 20,000 metres of networks have been already installed by using Dry Directional Drilling, in the city of Milan alone.
These figures are expected to double during the year 2002.
The projects were carried out by using both ground machines (from 12 to 24 t of pullback) and pit-launched machines (5 t of pullback). The objective was to install 2-in HDPE multiducts pipe made up of 9 to 16 ducts. The installation rate was between 20 and 80 metres per day.

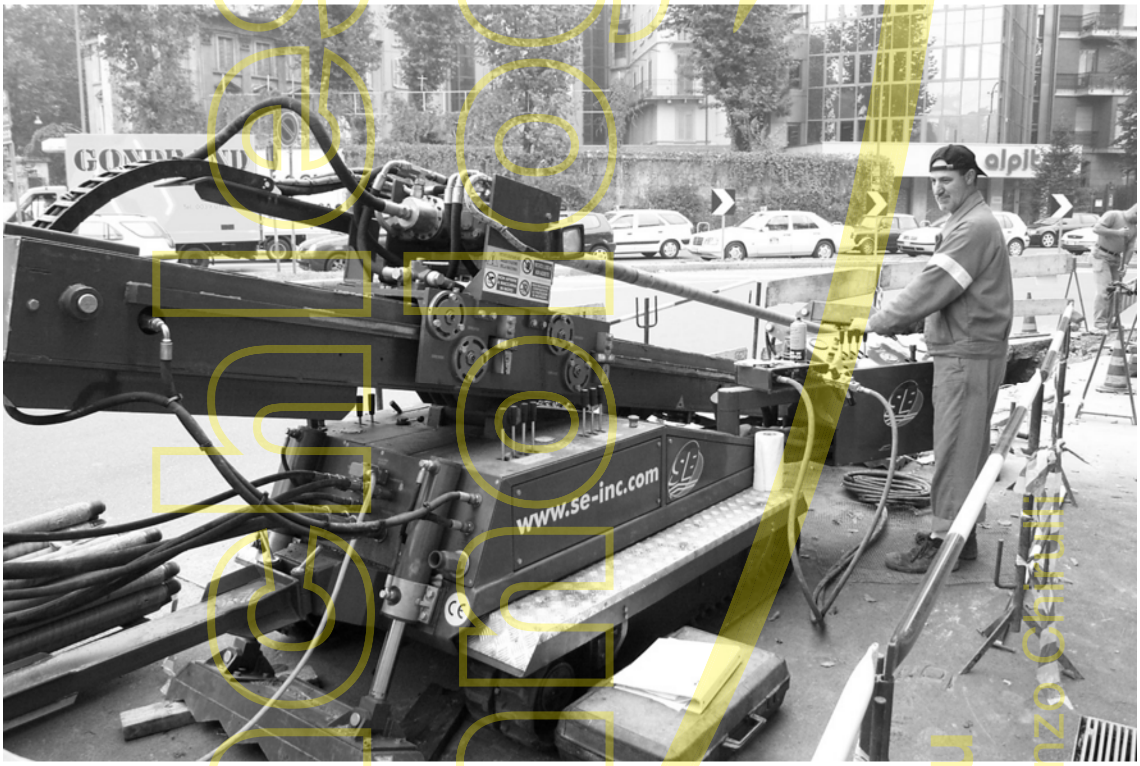


Figure 7 – A DDD 24t pullback force rig during an installation in Milan downtown.

**2.2. HydroQuebec project – Hampstead, Qc – CANADA**

In January 2001, Hydro Quebec (www.hydroquebec.com) came into contact with the authors of this paper, to ask whether the DDD technology was suitable or not to carry out a project of electric wiring in the area of Hampstead (QC). The project consisted in connecting around 1,000 houses (a total of nearly 28 km of infrastructure) to a new electric backbone to be built in the Hampstead area.
After a preliminary analysis of the project, a decision was taken to test the DDD technology and therefore evaluate its economical and technical effectiveness for the project in question.
The tests carried out were related to:

- steereability in the pilot bore stage
- productivity

- assessment of the back reaming and pullback forces
- assessment of the interferences generated from 12 kV, pre-existing, underground electric power lines on the guidance system

The trial soil was made up of a clayey matrix with rocky erratics of volcanic origin (basalt, granite, blue rock). Erratics had variable sizes (in terms of weight) ranging from 1 to 100 kg, and every cubic metre of soil could contain erratics for a total of 200 to 400 kg.

Figure 8 – Erratics under various sizes in Hampstead soil.

Figure 10 – Rocky erratics of volcanic origin in Hampstead soil.

The pilot bore was carried out with a 3-in diameter hammer and a 90 mm wedge-shaped drilling head.
During the steereability test, the 60 mm outside diameter drill pipes, used for this purpose, reached the minimum bending radius of 30 m, which stands for a deviation of 3.33 % per drilled meter.

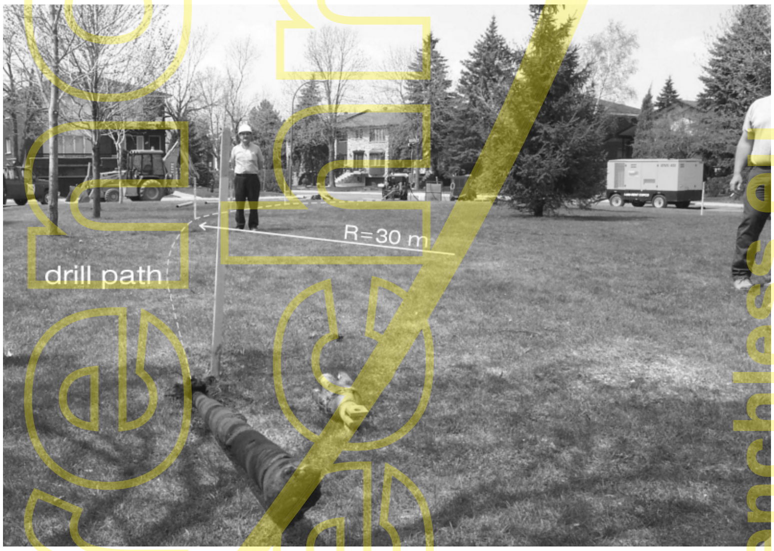


Figure 11 – Steereability test in Hampstead

The productivity test, carried out with 60 cm long (2 ft) drill pipes, provided a medium installation rate of around 15 m/hr (drilling and pullback operations through bent paths).

The same test, carried out in the same soil conditions by using 1m long drill pipes, provided a rate of nearly 22 m/hr.
The back reaming and pullback forces were assessed by testing the installation of 4-in outside diameter PVC pipes (Bore-Gard by Carlon). The back reaming and pullback stages were performed at the same time. The back reaming was carried out with a 4 cones rock reamer (180mm outside diameter). With the back reamer working, the assessed pullback force kept at a rate of around 20,000 to 23,000 N. With the back reamer out of the hole, the pullback unit force decreased at 25 N/m and the proof of it is that one man alone was able to pull the 33 m long pipe installed with his own bear hands.
The interferences generated from the 12 kV pre-existing underground power lines on the guidance system, were tested by performing a pilot bore (around 1 m clearance) parallel to the pre-existing power line, which showed that the percentage of error while measuring the depth remained below 2% of the nominal measure. No remarkable error was instead found in the pitch and tool face measurements. The guidance system used was a walk-over type Drill Track by Radiodetection.
Therefore, the tests provided more than satisfying results, convincing Hydro Quebec not only to use the DDD technology but also to buy some units that were specifically designed and produced to meet the project requirements.
The machines built to execute the project were: two SE 250 PL HQ which are pit-launched DDD systems with 6 t pull back and 2,500 max. Nm of torque. Each machine was equipped with an 80 HP power unit, powered with an air compressor at 125 psi and 350 cfm.

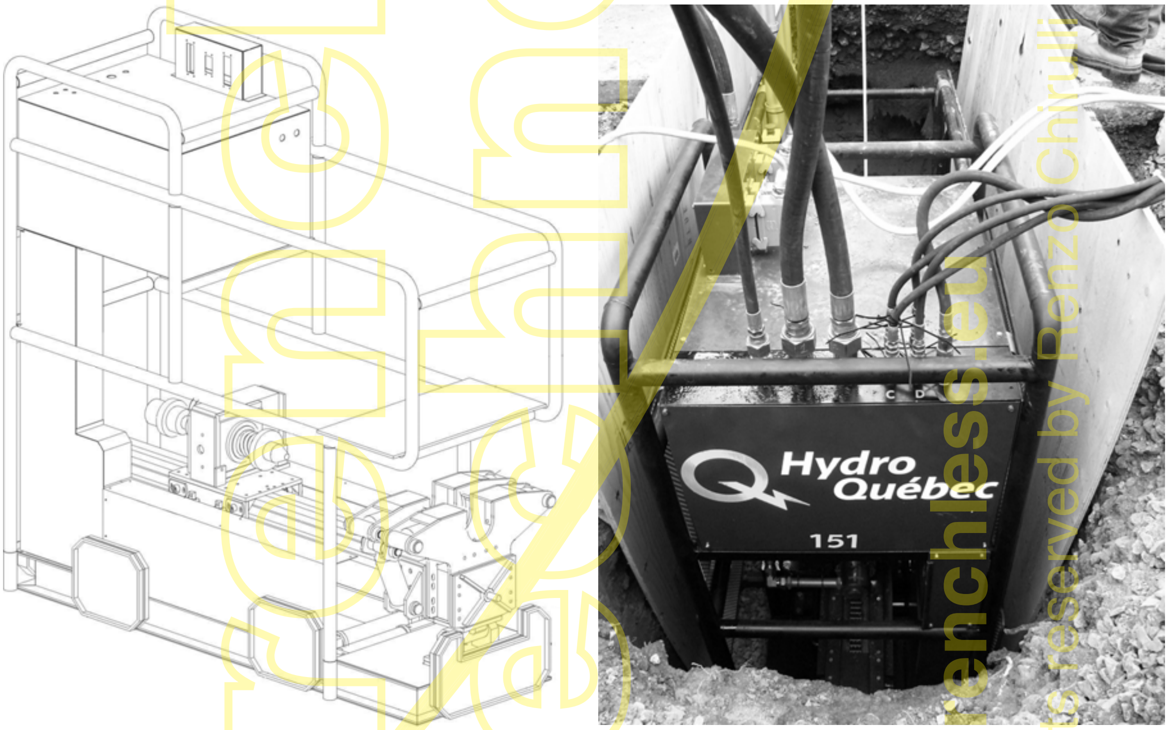


Figure 12 – DDD 6 t pullback force pit-launched rig – SE 250PL HQ
*(courtesy SE Industries Inc. – QC, Canada)*

Particular attention was also paid to organize the jobsite and to train the personnel to use the drilling machines, since Hydro Quebec required that each unit could install up to 3 connections per workshift (8 hours) totalling 120 meters per shift . This objective was successfully achieved.
Establishing a suitable work schedule was decisive to attain the expected results.
In the Hampstead project, the DDD technology brought remarkable results such as:

- elimination of any effect/operation caused by the use of drilling fluids in the liquid state (i.e. frac-outs, flooding of underground rooms, mud pumping from start/arrive pits)
- absolute drilling effectiveness in presence of rocky erratics

The Hampstead project is now in course of completion.

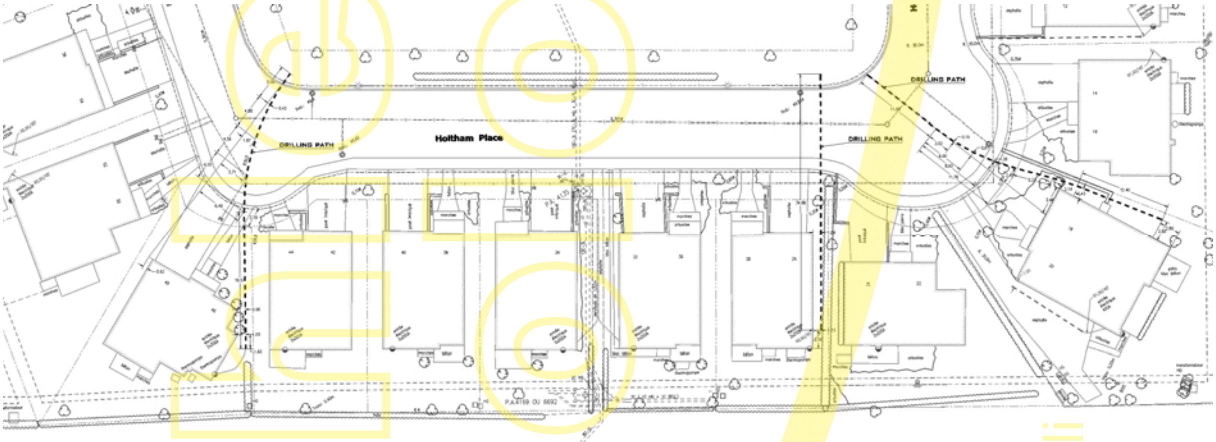


Figure 13 – Hydro Quebec Hampstead project – Some of the connections.

**2.3. ENEL experimental project in Florence, ITALY.**

Enel (www.enel.it) is the biggest Italian electric power company, with over 29 millions of customers, 43.000 employees, more than 20.000 km of high-tension lines, 331.000 km of medium- tension lines and a low-tension power line network of more than 700.000 km. Enel was owned in the past by the Italian government.
In order to serve new customers and replace old lines, Enel is constantly involved in wiring works for the medium-tension (up to 3 kV) and low-tension (up to 380 V) installations.
Among the cities where the difficulty of intervention becomes higher, there is Florence, which is one of the most beautiful cities in Italy.
Florence has one of the most complex historic centres, both for the existing structures and superstructures and for the many commercial and tourist activities, not to mention the heavy pedestrian and vehicle traffic.
In Florence, the underground is rich in finds, besides being full of pre-existing utilities. The narrow streets that characterize it, are paved with high value materials that are of a high historic value, which is the reason why they cannot be damaged.
This kind of complex but also beautiful environment, makes it very difficult and expensive to operate by open-cut trenching: in fact, all the operations have to be carried out manually in order to keep unaltered the pre-existing conditions as much as possible. Moreover, the

typical effects caused initially by digging operations (opening trenches, mounding diggings) and then by refilling trenches and restoring streets, are often incompatible with the activities that take place near the jobsites.
This is the reason why, in the year 2001, ENEL decided to test the Dry Directional Drilling technology to install underground cables in Florence.
The main restraints imposed were related to:

- the impossibility of damaging large portions of the streets hand-paved in the past with ancient stones
- the necessity of limiting as much as possible the inconveniences brought to the surrounding activities
- the necessity of accelerating works because of the short municipal permissions
- the limited size of the areas involved in the jobsite operations

Obviously, in addition to these reasons, ENEL wanted to test the DDD technique because it was also looking for a less expensive solution.
The test involved the installation of around 700 m of 4-in HDPE pipes, distributed in 4 different jobsites.
The installation operations made with the DDD system took a total of 30 days. The machines used for the jobs were a 5,6 m long and 1,5 m wide dry rig with 24 t pull back and a 1,5 m long and 0,60 m large pit-launched machine with 5 t pull back force.
Two were the most difficult jobs. The first one was performed near the famous "*Mercato di S. Lorenzo*" a typical tourist marketplace and the other one was carried out in a central street near the popular *Battistero* of Florence, for the connection of an underground medium tension booth, built to power a new store of the Benetton chain.
We estimate that the cost of installation for these applications was about 30% lower than the installation costs generated by open-cut methods.

Figure 14 – A DDD 5 t pullback force pit-launched rig during the pilot bore stage, operating in Florence downtown.

Figure 15 – The pullback operation.


Figure 16 – A DDD 5 t pullback force pit-launched rig operating in Florence downtown near the "Brunelleschi" dome.

## 3. CONCLUSIONS

Dry Directional Drilling proved itself to be a very competitive and effective technology, in various conditions, for technical and economical reasons as well. DDD makes it possible to extend the use of directional drilling to those situations and projects in which the traditional technologies are not suitable or effective.

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