HydroFoamer
Faster, Simpler, Safer

# Civil Works – Trenching

Position Paper

## 1 Introduction

HydroFoamer BV is a company that owns international IP covering the use of polyurethane foam as backfill for buried pipelines.

## 2 The Importance of Civil Works to the Concept

The HydroFoamer concept replaces low-cost gravel backfill with high-cost PU foam. However, although PU is more expensive by weight, a typical pipe using PU only needs a small fraction of the weight required by a pipe system stabilised by gravel. In addition, the speed at which PU foam can be produced in situ leads to a reduction in installation time.

The existing method of using compacted gravel as backfill almost always involves the use of material that must be transported to the installation site. This often requires improvements in infrastructure. A typical project, 1.6km of 500mm pipe, involves more than 15,000 tonnes of aggregate, meaning hundreds of return journeys by vehicles with axle weights of 8 tonnes. These logistical requirements involve the construction of roads and tracks sufficient to tolerate these loads, which have a quite heavy environmental impact. Licence conditions for hydropower development very often include limitations on such activities with which it is hard to comply.

**Typical small-scale hydropower penstock**
Length of penstock: 1.6 km Pipe Diameter: 500mm

| | Aggregate Backfill | HydroFoamer System |
|---|---|---|
| **Length of Project** (installation days) | 40 work days | 4 work days |
| **Number of Truck Loads** (x2) | **400** x 40t dumper truck loads<br>16,000 tons of material | **2** x 40t dumper truck loads<br>75 tons of PU component |
| **Cost** (per length foot) | €420 | €200 |

Production of PU foam is carried out by the HydroFoamer robotic spray crane, contained in a standard 20' shipping container, which can either be mounted on a trailer, a modified truck chassis, or even a trench crawler such as the Terramac RT14. The HydroFoamer allows foam to be produced in 12 metre sections, at approximately 1 length metre per minute. PU foam components, MDI and polyol, are supplied in 900L IBC containers, which can be transported to the production site from a main road access on vehicles with much lower axle weights, such as ATV trailers. For the same typical project, the total weight of foam required is 75,000KG, or 80 IBCs. Transport of so much less material involves a far lower level of environmental impact. Foam can be produced very quickly, with typical rates of 20KG / minute for a single pump. This equates to less than 4 days of machine time for our typical project.

As such, improvement of the 'pipe installation process', which is the essence of the HydroFoamer method, should thus be based on 'Theory of Constraints', rather than any other methodology. In order for civil works not to be the constraint, excavation would need to proceed at a pace of 53 linear meters or 65 $m^3$ per hour, on a single 7-hour shift pattern. This is currently above the likely output of existing plant used in Norwegian hydropower, given the geological make-up of the areas in which hydropower installations are built.

Norwegian hydropower construction is normally carried out by non-specialist teams from the area of the installation, experienced in general civil engineering works. Equipment is of good quality, but the volume of SHP projects available to each construction company does not justify specialist trenching equipment of the kind we believe should be used to bring about efficiency gains in the installation of hydropower pipelines.

## 3 Environmental Matters

Apart from the obvious direct reductions in environmental impact of avoiding several hundred dump truck journeys into the installation area, the PU foam method also facilitates production methods that have a lower on-site impact. This is due to speed of installation and reduced building footprint, which are related.

A typical SHP project involves opening the trench for the pipeline for a period of several months. The excavated material must either be transported away from the site, or sorted (due to regulations that prohibit the use of biological material in backfill) and used as top-level backfill. Norwegian regulations for trench work state conditions for trenches related to the length of time the ground is opened for work, the soil type and the depth of the trench. This invariably means that trenches must be dug in the classic 'V' configuration, with a slope angle of 45-53°.

The classic method of installing pipeline calls for compaction of graded aggregate. This process leads to very long installation times. PU foam can be covered within 1 – 6 hours, depending on the amount installed and climate conditions. We believe that it should therefore be possible to open and close sections of ground within 24 hours, thus avoiding one of the key 'triggers' in the Norwegian trenching regulations, and thush highly-secured 'V' trenches. The effect on the environmental impact of each project will be dramatic. In conversations with Kjetil Solberg, Chief Engineer of the Environment Section of NVE North in Narvik, he indicated that a construction method that could demonstrate such a reduction in environmental impact would attract promotion from NVE. Indeed, the licence conditions that NVE impose often include onerous and costly requirements for ameliorative measures, for restitution of the landscape. So, apart from direct cost reductions as a result of lowered construction costs, there is an associated reduction in post-project restitution.

## 3.1 Quantifying Environmental Impact from Construction Activities

There are many facets to the analysis of the ecological impact of construction in hydropower. This paper does not address subjects such biological diversity or effects on local water quality. Here, we assign a value to the area of terrain affected and the length of time the trench itself and the area in which civil works take place are affected. This is because out conversations with the regulator's environmentalists gave no objective rules for judgement of environmental impact, so we must make our own. Although this is a serious exercise, it should also be seen as an attempt to quantify a strictly non-quantifiable impact.

Values are accorded for area affected (the construction area either side of the pipeline tracé) and the volume of excavated material, and the length of time that each are impacted. No attempt is made to add the environmental cost of road / track building required to transport in graded aggregate, which is often as damaging as the pipeline itself.

The assumption is that the Construction Path (also known as a Construction Row) for the classic / gravel method involves 3 x 4.5m widths plus the trench and HydroFoamer is 2 x 4.5m widths plus the trench. This is because the classic method requires:

- Trench (5m)
- Access road (4.5m)
- Excavated material storage (4.5m)
- Gravel storage (4.5)

… whereas the HydroFoamer does not need gravel storage.

### 3.1.1 Comparison of Methods

| | **Classic** | **HydroFoamer** |
|---|---|---|
| Trench Form | 53° | 45° |
| Excavated Material m3 / LM | 4.49 | 4.00 |
| Construction Path Width (m) | 18.48 | 13.72 |
| Number of days open (1600m) | 80 | 4 |
| Total Area Affected (1600m) m2 | 29,570 | 21,945 |
| **Total Impact (Area Affected * Days Open)** | **2,365,585** | **87,781** |

# 4 Operational Objectives

Norway is a large mountainous country, often with poor accessibility for hydropower projects. Indeed, this is one of the drivers behind the development of the HydroFoamer method.

In addition to basic accessibility and topography, geology is obviously critical to the speed at which civil works can proceed. As expected, there is a great deal of variability in Norwegian geology, and in actual 'soil types' and conditions in production areas. Conditions are generally much harder than would be expected in the areas for which 'trencher' technology was originally intended, with large amounts of solid rock that must be blasted. In most areas, there is a large proportion of Gneiss, in different forms, but also large amounts of glacial moraine at the levels at which we will be operating. Detailed geological reports are available for each project.

In essence, when rock is under the limit for blasting (± 110 MPa), then the objective is to have a civil works team that can excavate the 45° trench variant at an average of 25$m^3$ per hour. This can be using mainly a very large trencher / chainsaw, a drum cutter, hydraulic hammer and excavator bucket, or any combination, or equipment about which we don't know. Our research shows that a 55-tonne machine carrying the largest hydraulic hammer should achieve this rate of production. For softer conditions, other methods are more appropriate, but the composition of the civil works team should remain the same.

The absolute minimum that the concept requires is 11km of 500mm equivalent, annually per team. This equates to approximately 15,000 $m^3$ of excavation per year, or 10.7 $m^3$ per hour on a single 7-hour shift pattern. We would expect the kind of CAPEX which we envisage to show a considerably higher rate of return in the form of civil works production.

## 4.1 Mobilisation

A typical project should last 8 to 10 days. Mobilisation and demobilisation takes 1 – 2 days maximum, allowing a maximum period of 5 days between project end and start-up dates. This should allow 200 production days per year. Norwegian roads are often poor, but transporter systems should be standard.