



## WATER INJECTION DREDGING

### WHY CONSIDER WATER INJECTION DREDGING?

Water Injection Dredging is a hydrodynamic dredging technique that should be taken into consideration as a cost-effective, environmentally sound solution to some specific dredging operations. Dredging works can be complex and costly, accounting for a substantial proportion of the budget of a maritime project. To effectively plan and execute a dredging operation, to be able to select the most appropriate dredging plant, requires extensive knowledge of the material to be dredged as well as the environmental circumstances of the site to be dredged. Since the mobilisation and capital costs of dredging plant are quite significant, choosing the wrong vessels and methods can have severe economic consequences.

Appropriate ground and environmental surveys are fundamental to the success of dredging operations, from both a technical and an economic perspective. Water Injection Dredging has very specific limitations but in the appropriate situation it also has very specific benefits.

### WHAT IS WATER INJECTION DREDGING?

Water Injection Dredging is a relatively new hydrodynamic dredging technique, developed by engineer R.N. Van Weezenbeek a little more than 25 years ago, which has been gradually gaining popularity for maintenance dredging. Since port authorities are continually confronted with the siltation of the harbours and access channels, regular maintenance dredging is a necessity to ensure safe navigation depths in these waterways. However, especially for smaller ports, the financial demands of dredging can become burdensome.

Generally speaking the larger the port project, the more cost-efficient dredging becomes using traditional dredging techniques – trailing suction hopper dredgers and cutters for

instance. But for the regular maintenance of smaller harbours, the technology of Water Injection Dredging can be an effective, economical and environmentally sound solution.

### WHAT IS THE THEORY BEHIND WATER INJECTION DREDGING?

Other types of hydrodynamic dredging techniques do exist, such as agitation dredging, during which sediment is dispersed vertically over the whole water column, and ploughing. In contrast, Engineer Van Weezenbeek introduced the idea of allowing sediments to flow horizontally out of a port taking advantage of natural processes and forces, while the fluidised sediment layer remains close to the water bed.

Based on his knowledge of the behaviour of sand-silt water mixtures, he proposed to use the principle of gravity-driven density currents. By fluidising the solid sediment layer into a density current, the material, under certain circumstances, will flow out of the port basin. A density current is the fluidised soil layer “on the move”. The main characteristic of Water Injection Dredging is that the horizontal transport takes place in the water column, by the combined forces of a pressure difference in the water and gravitational forces. This method eliminates the need for the traditional dredging methods of excavating and then transporting dredged material by hoppers or barges. Dredging becomes then a matter of initiating a density current.

After trials in the Netherlands confirmed that Van Weezenbeek’s theory worked, and indeed that the production levels were similar to those of a small trailing suction hopper dredger, construction was begun on a prototype Water Injection Dredger (WID) and by 1987 the first WID vessel *Jetsed* was operational.

*Pictured above: The WID Jetsed was the first prototype water injection dredging vessel. It has been updated and is still active.*

## WHAT ARE THE FEATURES OF A WATER INJECTION DREDGER (WID)?

With a water pump capacity of 852 kW and a maximum dredging depth of 23 m, the first purpose-built WID vessel *Jetsed* executed a number of small, in some cases still experimental, works. At present, the use of WID vessels globally is increasing, the fleet of WID vessels is growing and the Water Injection Dredging method has gradually become recognised as proven technology. As of June 2010, 22 Water Injection Dredgers were active, ranging from the *Maasmond* with jet pump diesel engine power of approximately 1200 kW to the smallest, the *Baldur* with 75 kW – with a wide range in between. The choice of a WID vessel is site-specific and will depend on various factors such as soil conditions, hydrodynamic conditions, transport distances and maximum operating depths. The dredging depth of WID vessels varies between 26 m to almost 0 m. The working speed is 1 to 2 knots although most WID vessels are able to sail faster in non-dredge mode. Portable WID vessels can be rapidly deployed to relatively remote sites when necessary.

## HOW DOES WATER INJECTION DREDGING WORK?

Water Injection Dredging is a technique in which a specially developed Water Injection Dredger injects large volumes of water at a low pressure into the sediment, using pumps with a series of nozzles on a horizontal jetbar. This fluidises the sediment by effectively overcoming the cohesion in fine-grained (cohesive) soils or internal friction of coarse-grained (granular) soils. This fluidised sediment then remains close to the river or channel bed, flowing down to deeper areas. Fluidised soil is also sometimes referred to as fluid mud, fluid bed or density cloud, but since the sediment remains just above the bed, the term “fluidised soil layer” is generally agreed to be a more apt description.

Staying close to the bed creates a density current that then, either by the force of gravity or through a natural or artificially created slope, flows downwards to deeper water. This all occurs with a minimum of disturbance to the equilibrium of the ecosystem. In this way, instead of mechanical transportation, nature takes care of the sediment transport, making Water Injection Dredging under certain conditions a very cost-efficient dredging technique.

## HOW IMPORTANT ARE SOIL CONDITIONS AT THE SITE?

As with all dredging projects, a complete understanding of environmental and ground conditions on-site is essential to a successful Water Injection Dredging project. In a Water Injection Dredging project, nature takes care of the horizontal transport of the sediment, which means that a density current needs to be created by the WID vessel. A relatively small window of suitable soil conditions exists for this process to occur. If the undrained shear strength of the in-situ material is too high, the jetting water will not be able to disintegrate the

sediment into individual particles. The soil will not fluidise and flow, but lumps of clay will form and quickly settle on the bed. If the average grain size in a non-cohesive (granular) soil is too high, sediment may settle too quickly and the flow will only continue over short distances. Soil conditions for both events – the fluidisation of the soil and the horizontal transport by nature – must be favourable for both of these to occur.

Coarser-grained materials (sands) have a higher settling rate than finer-grained material (silt and clays). Performance in fine-grained sediments is reduced as cohesion and consolidation increase. Highly plastic (i.e., fat) clays cannot be effectively dredged using Water Injection Dredging and it is also not applicable to dredging rock.

## WHAT IS THE INFLUENCE OF SITE-SPECIFIC BATHYMETRY AND GEOMETRY?

The use of Water Injection Dredging as a possible technique also depends on the site-specific bathymetry and geometry. The production rates will be influenced by the water depth, the dredge template and the bathymetric features and site geometry of the sediment deposition areas as well as characteristics of the transport path of the density current.

The definition of site geometry is the overall arrangement of the entire dredging area. This includes the area where shoaling material is removed (the dredge template), the density current transport path, and the area where sediment is supposed to settle (deposition area) after being transported in the density current. In other cases, the fluidised soil layer enters a High Energy Environment, where the hydrodynamic conditions are such that the fluidised sediment layer is dispersed in the water column and the sediment particles are being mixed with the naturally occurring particles in the system. The sediment is brought back into the natural system of sedimentation, transportation and deposition.

## WHY IS WATER INJECTION DREDGING ESPECIALLY SUITED TO MAINTENANCE DREDGING?

The specific characteristics that typify maintenance dredging make Water Injection Dredging a suitable technique. For instance, maintenance dredging involves variable quantities of material, which can range from thin to thicker layers. The sediments to be dredged are the most recent layers which have formed in navigation channels and harbours. Maintenance is a recurring activity, usually in a dynamic environment, where sedimentation and erosion are on-going occurrences even as dredging is taking place.

## WHAT ARE THE ENVIRONMENTAL IMPACTS OF WATER INJECTION DREDGING?

As mentioned above, the main difference between Water Injection Dredging compared to traditional dredging techniques is that the dredged material is transported horizontally in (the lower part of) the water column along the water bed. This results in the following specific circumstances:

- an increased quantity of sediment goes into (the lower layers of) the water column;
- the rate of sediment input in the natural system at the dredging area is increased;
- the sediment is transported by natural phenomena to the final destination (settlement location) through the density current;
- the rate of sedimentation in the deposition areas may vary if the natural conditions vary;
- dredged sediments remain within the ecosystem, which can be an important advantage.

## SHOULD WATER INJECTION DREDGING BE MONITORED?

As with all dredging activities, monitoring is an essential step that should be taken to ensure that the sought-after results are being achieved without detriment to the environment. Monitoring programmes for Water Injection Dredging should include:

- Operational monitoring, which evaluates the ongoing dredging process. This supports and guides the contractor in the execution of the work.
- Contractual monitoring, which evaluates whether the operation is meeting the contractual obligations to the client stipulated in the contract.
- Environmental monitoring, which establishes whether or not all requirements in environmental impact assessments are being met, those set out by stakeholders as well as the government.

## CAN WATER INJECTION DREDGING BE COMBINED WITH OTHER FORMS OF PLANT?

Yes, in fact Water Injection Dredging is often combined with other dredging technologies and this combination of technologies can often operate with increased efficiency. For instance, at the Port of Calais in northern France, most of the maintenance dredging work is done by trailing suction hopper dredger (TSHD). However, Calais is the closest port in France to Great Britain. The daily ferry traffic from Calais across the English Channel is considerable: The distance is merely 34 km and every 15 minutes one of the ferry terminals is occupied. Maintenance of these ferry terminals is crucial but using a TSHD at these ferry terminals is practically impossible because of the very busy ferry traffic. The most suitable option here is a self-propelled WID which is flexible and manoeuvrable compared to most TSHDs.

In addition, because a major part of the sediments is fine material and the difference in the exploitation depth between the terminals and the adjacent basins is large, the WID technique seems to be particularly effective. The slope to deeper water from the ferry terminal to the basin provides a good evacuation route for the fluidised sediment layer. By the force of gravity only, the fluidised sediments are re-shifted on a small scale towards the adjacent basin. Clearly, as these basins



*Water Injection Dredging in Mumbai proved to be a cost-effective technique to level the seabed.*

are also subjected to port traffic, the sediments accumulating there should also be removed. And since there is more space to manoeuvre in the basin and larger quantities of sediment, a TSHD can then be deployed as the most appropriate plant.

At Calais the most efficient sequence has proven to be to first deepen the basins by a TSHD to the dredging target level; then dredge the ferry terminals with WID. This provides the optimum efficiency and lowest costs. Water Injection Dredging may thus provide either a stand-alone dredging solution or a complement to traditional dredging methods.

## WHAT ARE THE ADVANTAGES OF WATER INJECTION DREDGING COMPARED WITH OTHER DREDGING METHODS?

Water Injection Dredging can provide clear advantages under certain circumstances compared to other dredging techniques:

- Since WID vessels are smaller in size, they are easier to mobilise than some other dredgers like trailers and cutters. The really smaller containerised WID vessels can even be transported by road.
- This manoeuvrability means that a WID vessel can operate in an access channel or port without impeding cargo and other vessels passing by. This makes Water Injection Dredging a suitable option for locations with high vessel traffic (such as the Calais ferry terminals).
- Auxiliary equipment is in most cases not required during Water Injection Dredging. This means that neither pipelines, boosters, a reclamation area with dry equipment nor a disposal area are needed. Without all this extra plant and facilities, the organisation of the project is far less complicated which can lead to considerably lower costs.
- Also, by using a relatively small amount of auxiliary plant Water Injection Dredging can offer a relatively rapid excavation alternative because the WID vessel can start working as soon as it arrives on site.
- The number of crew members required onboard a WID vessel is relatively few which also adds to the financial feasibility of the technology.

- Another cost reduction is achieved because soil is not removed from the bed and loaded into a hopper or transported through discharge pipelines to a placement area during the Water Injection process, but remains in its natural environment.
- This horizontal transport is also more environmentally friendly not only compared to trailers and cutters but also as compared to other hydrodynamic dredging techniques such as agitation or plough dredging. In those methods vertical transport takes place and the sediment is in suspension, usually over the whole height of the water column. With Water Injection Dredging the density current remains just above the bed and the overlying water layers are not affected.
- When the sediment, bathymetric and hydrodynamic conditions are suitable, a WID vessel is capable of high production rates at low costs.
- Water Injection Dredging has a considerably lower CO<sub>2</sub>-footprint per m<sup>3</sup> of dredged sediment compared to conventional dredging techniques.

## WHAT ARE OTHER APPLICATIONS FOR WATER INJECTION DREDGING?

Because a WID vessel does not dig into or excavate sediment as do traditional dredgers, but rather applies water through its jets to dilute the sediment layer, it can operate in places where other types of equipment cannot, for instance, underneath jetties and moored vessels. This means the risk of damaging underwater infrastructure, such as cables and pipelines, quay walls, lock aprons and dry-docks is lower.

Under appropriate conditions, a WID vessel can also be used for levelling the water bed for pipelines, tunnel sections, and so on or for increasing the depth of pipelines and cables. Using the density current transport system, a moving current may not be necessary if sediment and bathymetry conditions are suitable.

## WHAT ARE THE LIMITATIONS FOR USING WATER INJECTION DREDGING?

Under certain circumstances Water Injection Dredging is not appropriate. For instance, in the first place, injection dredging can only be used where in-water dredged material placement is allowed. In general, the applicability of injection dredging is more restricted by site-specific conditions than when using more traditional types of dredgers. Also, the water injection technique cannot be used if the generated density current will create negative environmental impacts, for instance, if the density current causes resuspension of contaminants or an unacceptable level of suspended solids. Measuring production

by pre- and post-dredge hydrographic surveys can be complicated because surveying in fluid mud is not easy.

In addition, determining the destination of fluidised dredged material is difficult to predict. Therefore, from an environmental point of view, special attention should be spent to areas nearby the dredging location to determine if there are sensitive habitats, such as shellfish beds, spawning habitats, sandy gravelly habitats, clear water estuaries, coral reefs and so on. In addition, in most cases, if the soil is contaminated, Water Injection Dredging is probably not a suitable method.

## WHEN TO CHOOSE FOR WATER INJECTION DREDGING?

As a relatively new technique for dredging, Water Injection Dredging is not necessarily the first dredging technique that springs to mind when looking for a solution to increasing water depths at ports and in access channels. Yet it can be a very reasonable, economically viable and environmentally sound method. Especially for maintenance dredging or in areas that are difficult to reach, the smaller size of a Water Injection Dredger can offer mobility, flexibility and economy.

In circumstances in which sediments are not contaminated, and where placement of dredged material back into its own natural environment is permitted, the method can offer environmental advantages and provide cost savings as fewer crew are needed, no auxiliary plant is necessary and less energy is used as the sediment is moved by natural forces.

## FOR FURTHER READING AND INFORMATION

Athmer, J. (2004). "Water injection dredging: unbeatable economics for maintenance dredging," Port Technology International, pp. 203-207.

Smits, Jos *et al.* *Water Injection Dredging*. PIANC MarCom Working Group 51. In press, 2013.

Sullivan, Nicola (2000). "The Use of Agitation Dredging, Water Injection Dredging and Sidecasting: Results of a Survey of Ports in England and Wales". *Terra et Aqua*, nr 78, March.

Tavallali, Abbas and De Wit, Kathleen (2012). Effect of dredging sequence on the efficiency of water injection dredger and trailing suction hopper dredger, a case study of the port of Calais. Paper presented at DREDGING 2012, San Diego, CA. October 22-25.

Van Craenebroeck, K., Duthoo, J., Vandecasteele, M., Eygenraam, J.A. and Van Oostveen, J. (1998). "Application of Modern Survey Techniques in Today's Dredging Practice *Terra et Aqua*, nr 72, September.

Welp, Tim (2012) "Report of PIANC MarCom Working Group 51 Report "Guidelines for Water Injection Dredging (WID)". Presentation , PIANC DREDGING 2012, San Diego, CA. October 23.



This brochure is presented by the International Association of Dredging Companies whose members offer the highest quality and professionalism in dredging and maritime construction. The information presented here is part of an on-going effort to support clients and others in understanding the fundamental principles of dredging and maritime construction.