Suitability of Airborne Lidar Bathymetry for The Netherlands

Netherlands authorities (Rijkswaterstaat and the Hydrographic Office of the Royal Netherlands Navy) are considering alternatives to singlebeam echosounding and MBES in the shallow water areas of their responsibilities. Airborne Lidar Bathymetry (ALB) is such an alternative system: it measures bathymetry by laser ranging with a pulse frequency of 1000 Hz from an airborne platform. ALB relies on the penetration of the light waves through water to measure distance. The propagation of light in water is hindered by the absorption of light by the elements in the water. Light is attenuated at increasing depth because of diffraction and absorption. The maximum penetration depth with ALB is two or three times the Secchi-depth. Limited Secchi depth due to turbidity in the Netherlands waters is therefore expected to be a limiting factor.

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Principle
The ALB system consists of a transmitter (the laser), a scanner (rotating mirror) and a receiver (Figure 1). A laser pulse is sent down via the scanner. When the receiver detects the reflected signal, the time difference gives slant range. The laser generates a wavelength of 1,064nm (red) which is converted into a 532nm (green) laser signal by a frequency doubler. A red laser signal is fully reflected by a water surface, whereas a green laser can penetrate water and will be reflected by the bottom.
The receiver splits the signal into two green channels, one infrared and one 645nm channel (the Raman channel).
A Raman signal is generated where photons hit water molecules. The exact wavelength of a Raman signal depends on the original laser signal and the rotation speed of water molecules. Infrared and Raman signals are used to calculate the range to the water surface. The two green signals are used to calculate the range through the water. In the aircraft, all return-signals are recorded for post-processing.
The aircraft is equipped with dGPS and INS sensors to accurately determine the position and attitude of the aircraft for each pulse. A video recording is made during data acquisition, which can be used, for example, for interpreting spikes in the data. A typical ALB acquisition flight has a low altitude of approximately 250 metres. At airspeed of 90m/s an area of about 65km2 can be acquired in one hour.

Propagation
The green laser signal is directed forward under a 20Â° angle. Its travelling through the water at a 20Â° angle reduces some light propagation errors. Ten per cent of the green laser signal is reflected at the water surface; the rest will penetrate the water. Scattering of the signal is caused by two factors: reflection and refraction. Reflection and refraction occur when change in the medium of propagation results in a differing speed of light (Snelliusâ€™ Law).
Reflection will be in the same, but complementary, angle as the incoming angle. In conclusion, 10% of the signal is reflected under a 20Â° angle whilst 90% will be diffracted and propagated through the water under an angle of 15Â° (see Figure 2). In the water the signal will disperse and be absorbed by waterborne particles. By the time the pulse reaches the bottom, the footprint will be half the water depth, with an average dispersion of 28Â°. Only a fraction of the laser signal will reach and be reflected by the bottom.
The curve in Figure 3 shows the infrared return arriving first at the receiver. An instant later, the â€˜bottom returnâ€™ will arrive.
The amount of backscatter recorded at the receiver depends on various factors. Weather, such as mist and rain, are a major cause of backscatter. But also the sun can distort the signals, since it is also a light source. High waves are another factor. In the presence of materials and elements, the light may be completely absorbed, leaving no return signal.
The water depth is resolved by the formula below. As may be seen, this depends on the angle of attack. Since the unscattered depth patch is known (see Figure 3), the vertical depth can be calculated, as in this example:

Where:
c=light speed, 3 108 (m.s-1)
t=time (s), 15 ns
n=index (1,33)
q=Angle aircraft water surface,
15 degrees

Bottom Detection at Shallow Depth
Figure 4 shows that, in the case of shallow water, the surface return signal and bottom return signal overlap, since both reflections follow with very short interval. The tail of the signal is steep, as the dispersion of the signal is limited and the reflection relatively strong. The signal depends on the length of the pulse, so signals will mix more with increasing signal length. In deep water, the opposite is true. Regardless of water depth, the surface reflection is constant; it depends on flying height only. As the bottom reflection in deep water is limited, it will be increasingly difficult to distinguish the return signal from noise (Figure 5). The signal tail will be flat.

Survey Coverage
The coverage depends on aircraft speed. This may range from 40km/h to 350km/h, resulting in coverage ranging from 8 to 60km2. Aircraft

speed, flying height and nadir angle determine the point density of the survey area.

Where:
S, Aircraft speed= 97,2 m.s-1
H, Hight aircraft above water = 347 m
q, Nadir angle = 20 degrees
f, Frequency laser= 1000 Hz

Wreck Detection
Lidar has a low resolution and a high point density. The resolution, the distance between two points, depends on the swath and thus the water-depth. Since the pulse disperses up to half the water-depth, different pulses can overlap, depending on the water-depth. Standard spot densities are used. In Figure 7, 5 various parameters are shown of spot density and the resulting probability of detecting an object of 2X2 metre. In the graph one can see that this probability increases at higher spot densities. It may also be seen that the probability decreases at shallower depth and increases from a depth of 4 metres. This effect is caused by dispersion of the signal in the water. At depths greater than 20 metre the probability of detecting anything quickly converges to zero.

Measurement
Several variables are used to describe water turbidity. The transparency is measured with a so-called Secchi disc or light attenuation coefficient. Another, more reliable, variable is the extinction coefficient.

Research
The possibility of using ALB depends on the ability of light to penetrate the water. In the Netherlands, Secchi-disc measurements and extinction coefficients are measured both in salt and fresh water. These measurements, carried out by National Institute of Coast and Sea (RIKZ), are available through the DONAR system. This research into the application of ALB addresses assessment of the possibilities per area. As discussed before, the penetration of light depends, amongst other factors, on material in the water. Materials present in the water depend on the season. In this research, the period of lowest turbidity and algae was considered. Per location, a graph was presented showing the extinction coefficient over several years. It shows per area the period of lowest extinction coefficient. The black line gives the maximum extinction by a given depth, so that above the black line the bottom cannot be detected.

Conclusion
From the observations, it is concluded that the transparency is highest in the months May, June, and July, depending on the exact area. The continental shelf of the North Sea is not suitable for ALB. Only the Doggersbank, a large bank with an average depth of 25 metre in the Northsea, is suitable for ALB in the months May and June.
In the considered inlandwaters (rivers and estuaries) the transparency depends on the current and the growth of algeae. It seems that ALB cannot be used in the Westerschelde.

Note by the editor: The above feature is a summary of a thesis by a young surveyor. By publishing this feature we are encouraging also young people to submit articles.