Load and Draft Measurement Program

By Mircea Neacsu

The Load and Draft Measurement (LDM) program has been part of DREGEPACK for a long time. Recently it went through a major revamping as we had to do some new hopper installations and the users had additional requirements.

The purpose of LDM is to provide load reports to help you better manage and document the dredging process on a hopper dredge. If you don’t have a hopper dredge and you don’t plan to acquire one you can stop reading right now.

Still here? Good! Let us first see what you need to get the LDM program to work.

HOPPER DREDGE SYSTEM

First you need one or two draft measurements. Most hopper dredgers have forward and aft draft sensors installed and if your dredge is instrumented with the Entek bubbler system you have two such sensors.

The draft sensors are the absolute minimum required to make the LDM program work. If you have only those sensors, some of the quantities calculated by LDM aren’t going to be available but you will still have a basic draft and displacement graph.

To get the remaining values, related to the amount of material in the hopper you need one or two (typically 2) hopper level sensors. These sensors (sometimes called ullage sensors) are ultrasonic or radar transducers that measure the distance between the transducer and the surface of the material in hopper. In the typical case, you will have 2 such sensors, one forward and one aft.

So here is the recommended configuration:

- two draft sensors
- two ultrasonic hopper level sensors

The rest of this article will assume that you have this standard configuration.

DATA ACQUISITION

The Entek bubbler system can acquire data directly from the draft sensors and from the hopper level sensors. If you don’t have an Entek bubbler, we can provide a data acquisition box that can read those four analog signals and send them over a network connection to the computer running the LDM program. If your transducers are integrated with DREDGEPACK®, data will be sent automatically from the DREDGEPACK® computer to the LDM computer. In principle, you could run the LDM program on the same computer as the DREDGEPACK® program, but managing the screens can become too complicated: you would need one screen for the skipper, one for the dredge operator and one for the LDM information. It is probably simpler to just use a second computer on the same network as the main DREDGEPACK® computer.

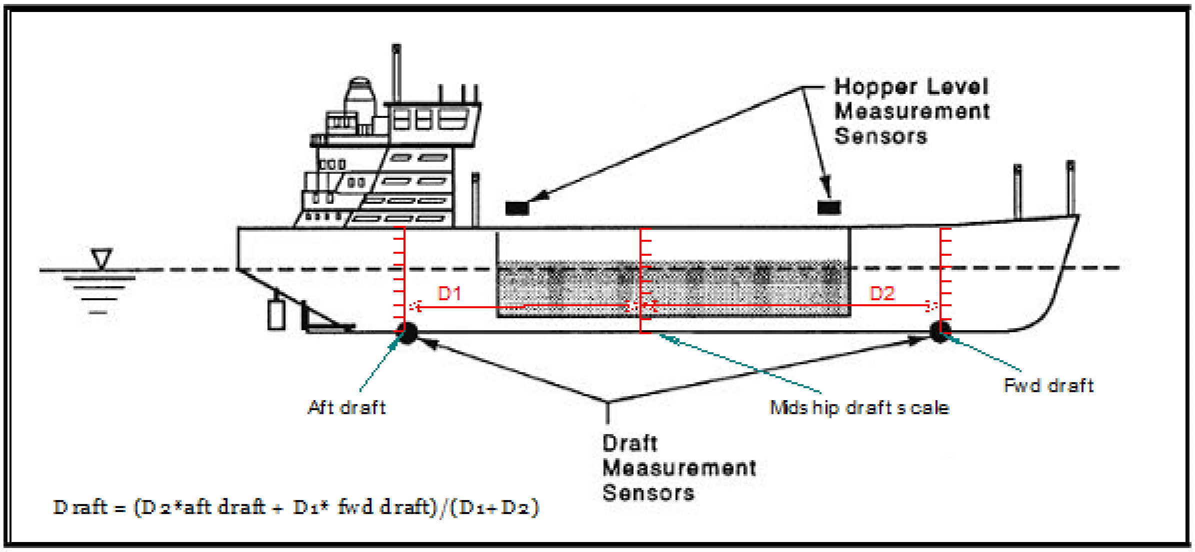
The voltage values are scaled to real units (meters or feet) by the Entek bubbler or our data acquisition box or DREDGEPACK®. In any case, LDM does not concern itself with this calibration and assumes the data coming in contains the real measurements.

DRAFT

Draft is measured by two bubbler ports situated near the forward and aft scales. To calculate the midship draft used in the load calculations the program uses the following formula:

$$draft_{mid} = \frac{D2 * draft_{aft} + D1 * draft_{fwd}}{D1 + D2}$$

FIGURE 1. Draft Diagram



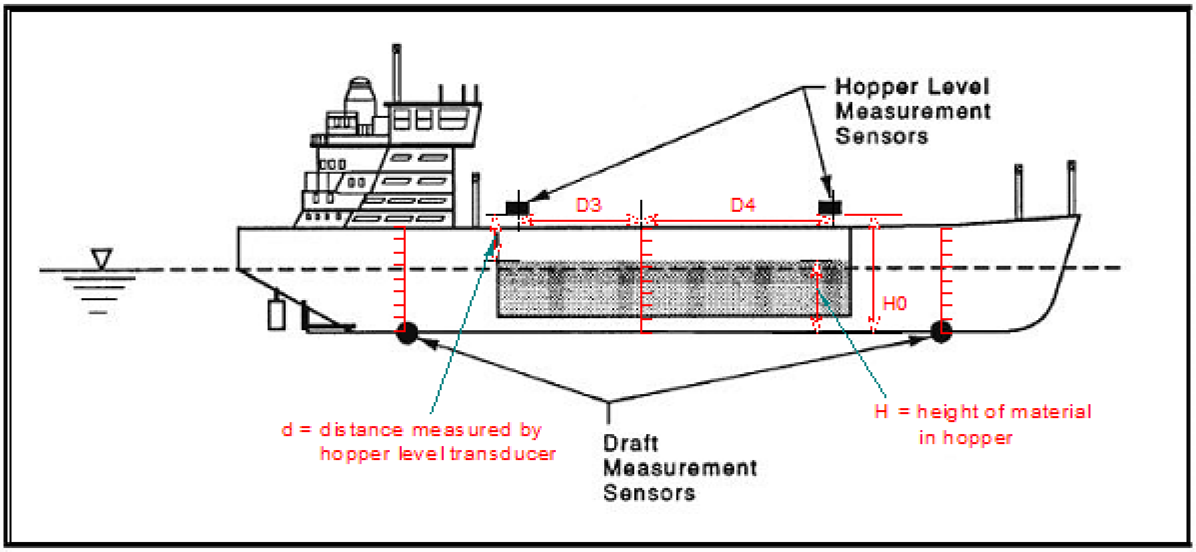
HOPPER LEVEL

The two ultrasonic or radar sensors measure the distances d_fwd and d_aft to the mixture surface. These are converted to height of material in hopper (measured from keel) using the formula:

(EQ 1)

$$H = H_0 - d$$

FIGURE 2. *Measuring the Hopper Level*



Where H0 is the height of ultrasonic sensors measured from vessel keel. The above formula is applied both for the forward and the aft hopper level sensor. The two values and are than combined to calculate the height of material in hopper at midship:

(EQ 2)

$$H_{mid} = \frac{D3 * H_{fwd} + D4 * H_{aft}}{D3 + D4}$$

LDM Calculations

After receiving the draft and hopper level from DREDGEPACK®, the LDM program does the following calculations:

1. **Determine the ship displacement (D).** Displacement is interpolated from a load table based on the current draft value.
2. **Determine the volume of material in hopper (V).** Hopper volume is interpolated from the load table based on hopper level.
3. **Subtract the lightship value (l) from displacement to obtain the load**: See "Lightship Calculation" for details regarding lightship calculation.
4. **Calculate the density of mixture in hopper** by dividing the load to the volume of material in hopper:

(EQ 3)

$$\rho_{mix} = \frac{L}{V}$$

5. **Calculate the tons dry solids** (TDS) using the following formula:

(EQ 4)

$$TDS = \rho_{insitu} * \frac{L - V * \rho_{water}}{\rho_{insitu} - \rho_{water}}$$

Where ρ_{insitu} is in-situ density and ρ_{water} is the water density.

6. **Calculate the volume of dry solids in hopper** (CUM) by dividing the tons dry solids by the in-situ density:

LIGHTSHIP CALCULATION

The generally accepted definition of lightship or lightweight is the actual weight of the ship with no fuel, passengers, cargo, water, etc. on board. However, from our point of view lightship represents the weight of everything that is not in the hopper. Because our definition includes the water and fuel on board, the lightship value has to be determined quite often (usually on a daily basis).

The procedure to determine lightship is simple:

1. With only water in hopper, open the hopper door to sea to make the level inside the hopper equal to the water level.
2. Press the [OK] in the LDM dialog box.

Internally, the program performs the following calculations:

1. Determine the displacement as shown before.
2. Knowing that the hopper is opened to sea, use the draft value to determine the hopper volume. This differs from the normal measurement procedure where we use the hopper level to determine the hopper volume.
3. Calculate the weight of water in hopper:

(EQ 5)

$$L_w = V * \rho_{water}$$

4. Subtract the weight of water in hopper from displacement to obtain the lightship value:

(EQ 6)

$$l = D - L_w$$

HOPPER LEVEL ADJUSTMENT

When performing the lightship calibration, the program calculates the difference between the height of water in hopper, as indicated by the hopper sensors, and the draft value. Given that the water should be at the same level inside and outside the hopper, LDM calculates an adjustment factor for the hopper sensors and displays it.

TRIM-TRIM TEST

When the vessel is not perfectly trimmed, the two sets of sensors give two independent measurements of the trim angle. The trim, as measured by the draft sensors, is given by:

(EQ 7)

$$\theta = \tan^{-1}\frac{Draft_{fwd} - Draft_{aft}}{D1 + D2}$$

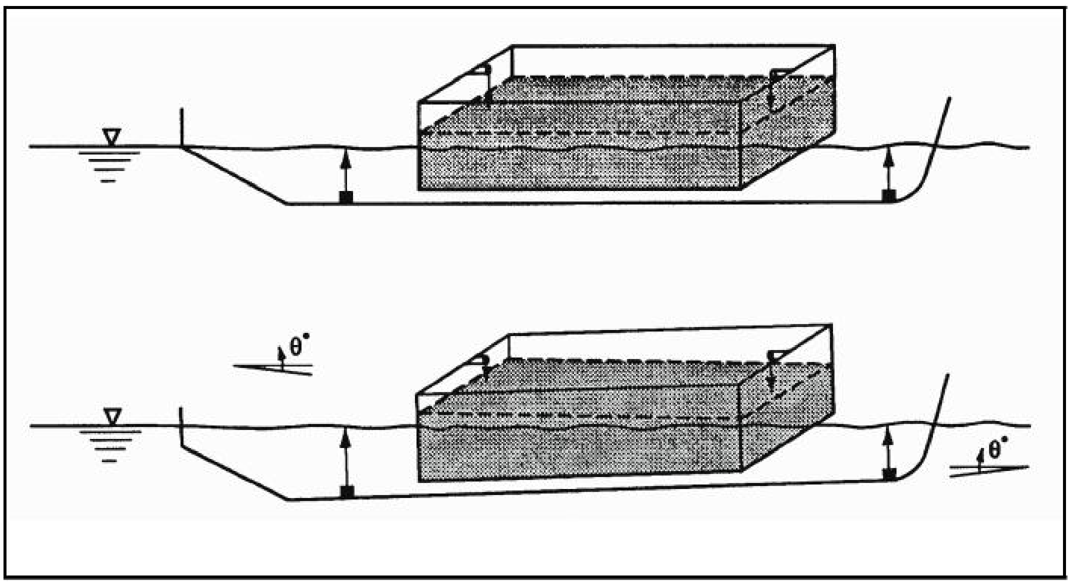
Similarly, the two hopper sensors are going to measure another trim angle:

However the trim angle measured by the two sets of sensors must be the same (see image below) hence we have:

(EQ 8)

$$\theta = \tan^{-1}\frac{H_{aft} - H_{fwd}}{D3 + D4}$$

FIGURE 3.



Well calibrated sensors should give trim angles that agree within 0.5 degrees. LDM calculates the difference between the two trim values and displays it at the end of the lightship calibration. However, it doesn't do any additional adjustment; you can use this value as a quality control check.

DATA LOGGING

Every 30 seconds LDM records the current load and draft values together with additional data coming from DREDGEPACK® like boat position, heading, speed, arm depth(s), tide, production values (density and flow speed) in a database. This information can then be retrieved to produce dredging reports. There is one such report for each dredge cycle.

DREDGING CYCLE

LDM assumes that you are dividing your work in cycles (sometimes called trips) and each trip starts at the end of the dumping or pumping phase. The phases of a dredge cycle are:

- sailing empty
- dredging
- sailing full
- dumping or
- pumping

In addition to those there are two more states or phases:

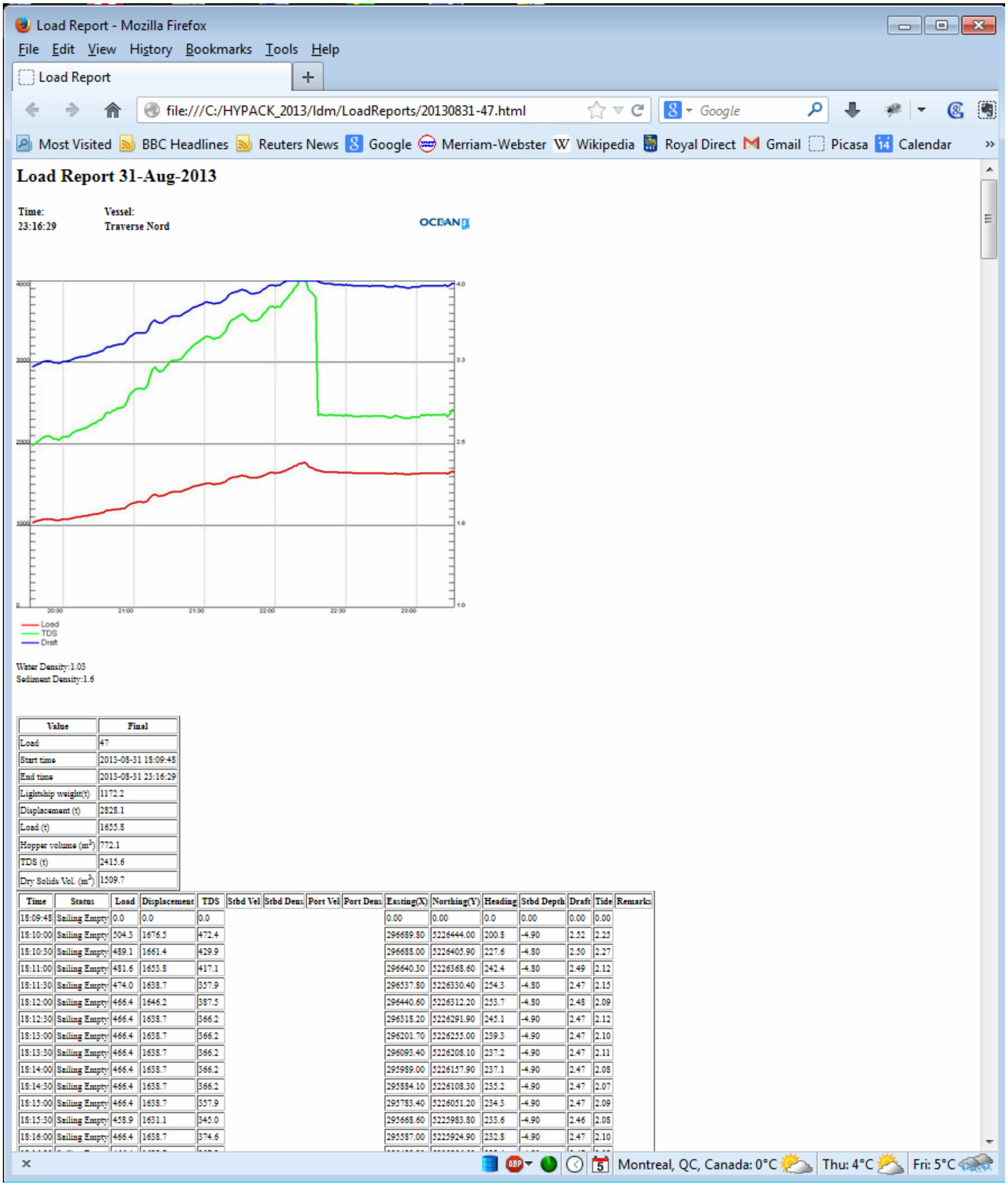
- Operational delay
- Technical delay

Each phase is assigned a function key (F1 to F7) so you just have to push one key to switch from one phase to the next. In addition, every time you switch to operational delay or technical delay status, the program allows you to enter a short comment about the reason for the delay.

WEB INTERFACE

Hidden inside the program, there is a small web server that allows you to access the dredging reports from a remote computer:

FIGURE 4. Sample LDM Report



Load Report 31-Aug-2013

Time: 23:16:29

Vessel: Traverse Nord

Water Density:1.03
Sediment Density:1.6

Value	Final
Load	47
Start time	2013-08-31 18:09:48
End time	2013-08-31 23:16:29
Lightship weight(t)	1172.2
Displacement (t)	2828.1
Load (t)	1655.8
Hopper volume (m^3)	772.1
TDS (t)	2415.6
Dry Solids Vol. (m^3)	1509.7

Time	Status	Load	Displacement	TDS	Stbd Vel	Stbd Dens	Port Vel	Port Dens	Easting(X)	Northing(Y)	Heading	Stbd Depth	Draft	Tide	Remarks
18:09:48	Sailing Empty	0.0	0.0	0.0					0.00	0.00	0.0	0.00	0.00	0.00	
18:10:00	Sailing Empty	504.3	1676.5	472.4					296689.80	5226444.00	200.8	-4.90	2.52	2.25	
18:10:30	Sailing Empty	489.1	1661.4	429.9					296688.00	5226405.90	227.6	-4.80	2.50	2.27	
18:11:00	Sailing Empty	481.6	1653.8	417.1					296640.30	5226368.60	242.4	-4.80	2.49	2.12	
18:11:30	Sailing Empty	474.0	1638.7	357.9					296537.80	5226330.40	254.3	-4.80	2.47	2.15	
18:12:00	Sailing Empty	466.4	1646.2	387.5					296440.60	5226312.20	253.7	-4.80	2.48	2.09	
18:12:30	Sailing Empty	466.4	1638.7	366.2					296318.20	5226291.90	245.1	-4.90	2.47	2.12	
18:13:00	Sailing Empty	466.4	1638.7	366.2					296201.70	5226255.00	239.3	-4.90	2.47	2.10	
18:13:30	Sailing Empty	466.4	1638.7	366.2					296093.40	5226208.10	237.2	-4.90	2.47	2.11	
18:14:00	Sailing Empty	466.4	1638.7	366.2					295989.00	5226157.90	237.1	-4.90	2.47	2.08	
18:14:30	Sailing Empty	466.4	1638.7	366.2					295884.10	5226108.30	235.2	-4.90	2.47	2.07	
18:15:00	Sailing Empty	466.4	1638.7	357.9					295783.40	5226051.20	234.3	-4.90	2.47	2.09	
18:15:30	Sailing Empty	458.9	1631.1	345.0					295668.60	5225983.80	233.6	-4.90	2.46	2.08	
18:16:00	Sailing Empty	466.4	1638.7	374.6					295587.00	5225924.90	232.8	-4.90	2.47	2.10	

In addition, the program can export the cycle data in a CSV format that can be directly imported in Excel.