

DEVELOPMENT OF AN AUTOMATED HOPPER DREDGE MECHANICAL ULLAGE SENSOR MEASUREMENT SYSTEM AS A CONTRACT PAYMENT BASIS

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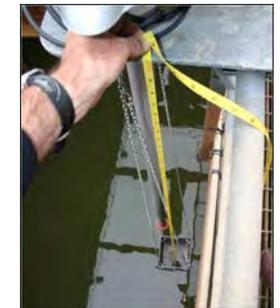
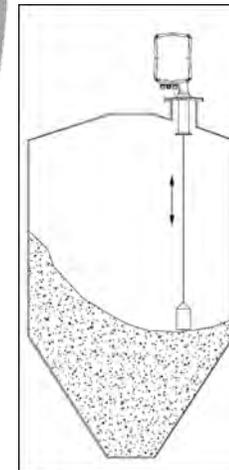
Portland District, USACE

Vern Gwin

USACE National Dredging Quality Management Program

WEDA Dredging Summit & Expo '19

Chicago IL 7 June 2019



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West Coast Entrance Bar Dredging

(Mouth of the Columbia River)

View to the Northwest

Benson Beach

NORTH JETTY

Mouth of the Columbia River (MCR) Channel

ebb
flood

SOUTH JETTY

Distance from tip of south jetty to tip of north jetty is two miles.



Center

Coastal Entrance Bar Dredging

- 3-4.6 million cubic meters dredged annually at the Mouth of Columbia River (MCR).
- Material is typically sand which is placed in ocean disposal sites
- Rough sea conditions shorter season.
- Two hopper dredges typically work simultaneously in the same four mile stretch.



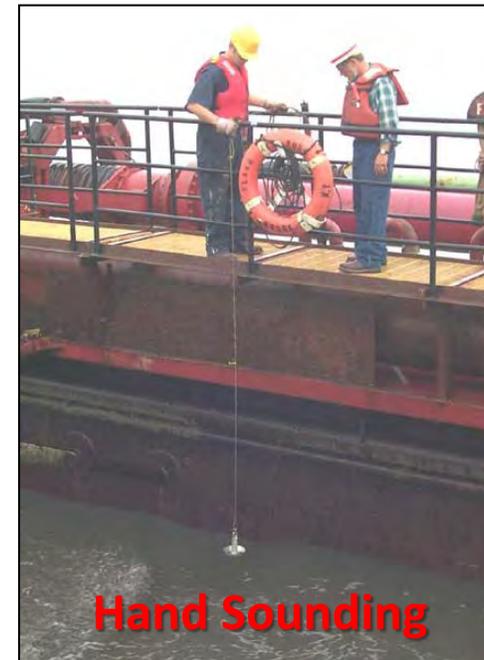
Background

- Payment for hopper dredging has traditionally been by one of two methods:

Pre/post Dredge Survey

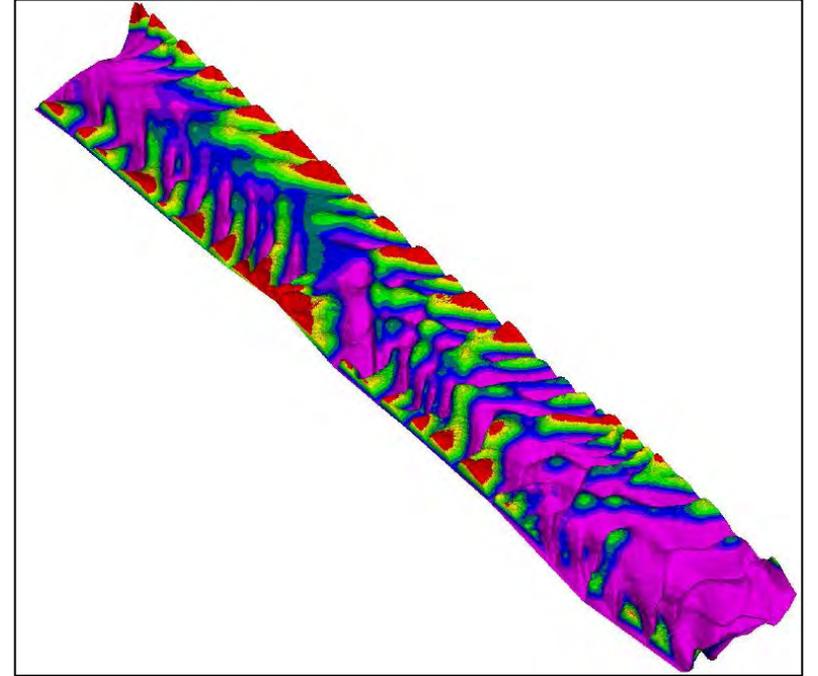


Bin Measure



Background

- Pre/post dredge survey:
 - Typically used in less dynamic areas such as the Columbia River and inland ports where quantity can be measured accurately by hydrosurvey
- Bin Measure:
 - ▶ Utilizes hand-soundings of the material in the hopper to determine dredged volume
 - ▶ Appropriate for coarse grained material (sand)
 - ▶ Typically used in areas that are too dynamic for accurate hydrosurveys (coastal bars) and where surveys are not practical (small or short duration work areas)

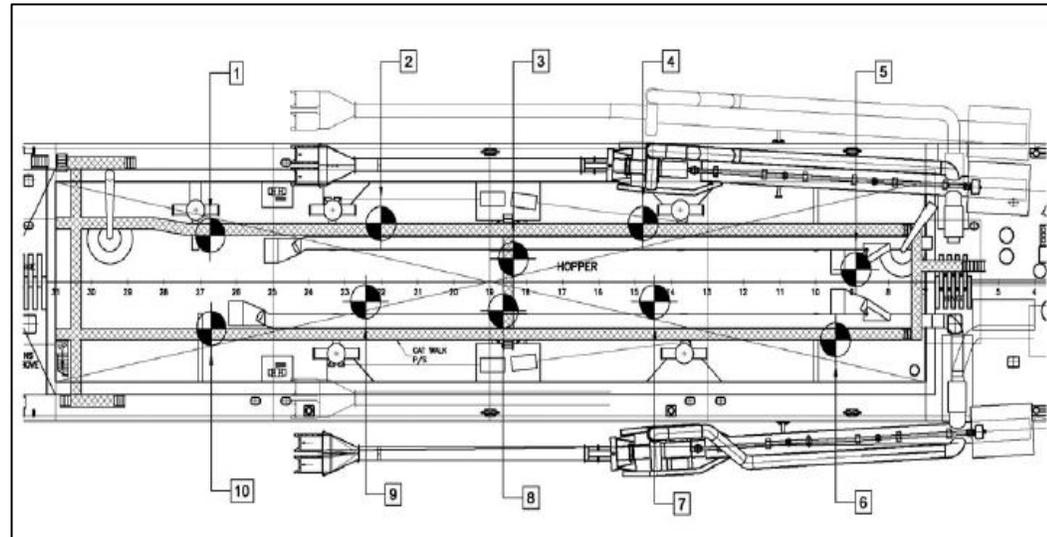


Measurement of Dredged Material (Payment By Bin Measure)

- An average is found from the ten soundings that are taken from around the outside of the hopper
- This average corresponds to a specific volume of material in the hopper matched using a vessel specific ullage table

DREDGE Mc FARLAND
HOPPER ULLAGE TABLE
TOTAL HOPPER

ULLAGE	CU. YDS	ULLAGE	CU. YDS	ULLAGE	CU. YDS
6'-0"	3138	13'-0"	2269	20'-0"	1395
-3"	3107	-3"	2238	-3"	1363
-6"	3076	-6"	2207	-6"	1331
-9"	3045	-9"	2176	-9"	1299
7'-0"	3014	14'-0"	2146	21'-0"	1267
-3"	2983	-3"	2114	-3"	1235
-6"	2952	-6"	2083	-6"	1203
-9"	2921	-9"	2052	-9"	1171
8'-0"	2890	15'-0"	2021	22'-0"	1139
-3"	2859	-3"	1990	-3"	1107
-6"	2829	-6"	1959	-6"	1076
-9"	2798	-9"	1928	-9"	1045
9'-0"	2767	16'-0"	1897	23'-0"	1014
-3"	2736	-3"	1866	-3"	983
-6"	2706	-6"	1834	-6"	952
-9"	2674	-9"	1803	-9"	921
10'-0"	2643	17'-0"	1772	24'-0"	890
-3"	2612	-3"	1741	-3"	861
-6"	2580	-6"	1710	-6"	832
-9"	2549	-9"	1679	-9"	803
11'-0"	2517	18'-0"	1648	25'-0"	774
-3"	2486	-3"	1616	-3"	745
-6"	2455	-6"	1584	-6"	716
-9"	2423	-9"	1553	-9"	687
12'-0"	2391	19'-0"	1522	26'-0"	658
-3"	2360	-3"	1491	-3"	631
-6"	2331	-6"	1458	-6"	605
-9"	2300	-9"	1426	-9"	579
TOTAL HOPPER FULL			ULLAGE	CU. YDS	
			5'-11"	3148	
TOTAL HOPPER EMPTY			39'-6 5/8"	0	



Definition of Ullage



“Most commonly encountered as a technical word of the *beverage technologist*, the wine merchant or publican, meaning the unfilled space in a barrel or wine bottle”

Has also “been transferred into the vocabulary of rocket scientists to mean much the same: the unfilled space at the top of liquid fuel tanks, left to permit the fuel to expand with changes in temperature”

(<http://www.worldwidewords.org/weirdwords/ww-ull1.htm>).

In the dredging world (with its own adaptation of ullage), a linear measurement is taken between the dredged material surface and top of the hopper.

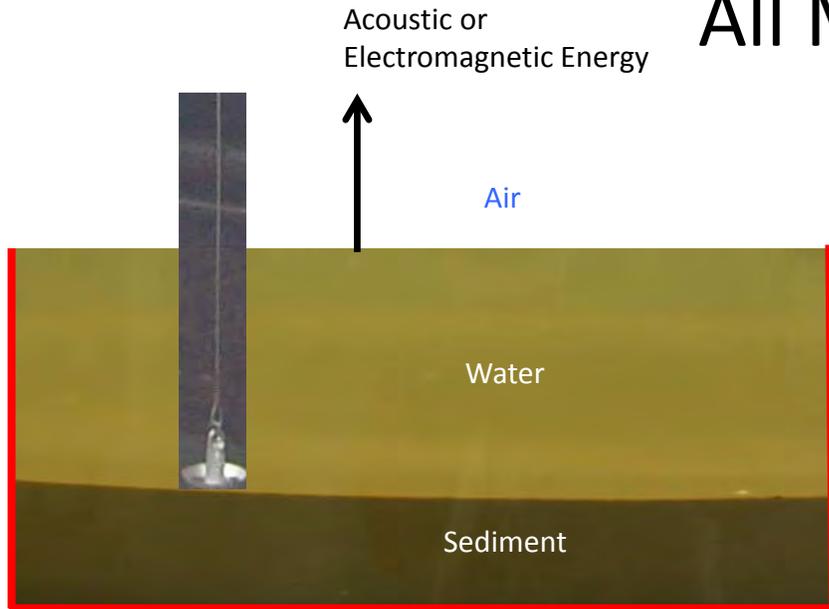
Measurement of Dredged Material

(Payment By Bin Measure)



- Measuring hopper volume necessitates that 2 Government QA staff live aboard (port and starboard) the contractor's dredge to witness soundings and compute volumes for payment 24/7
- Significant management effort is expended in recruiting, training, scheduling, and managing 24/7 QA inspection staff
- Inspectors and contractors work in harsh conditions and are exposed to safety risks

All Measurement Has Error



Sources of Error

Instrumental Errors: Imperfection in construction, adjustment, etc., of instruments

Personal Error: Limitations of the human senses of sight, touch, and hearing

Natural Errors: Variation of temperature, wave conditions, etc.

Brinker and Wolf 1977

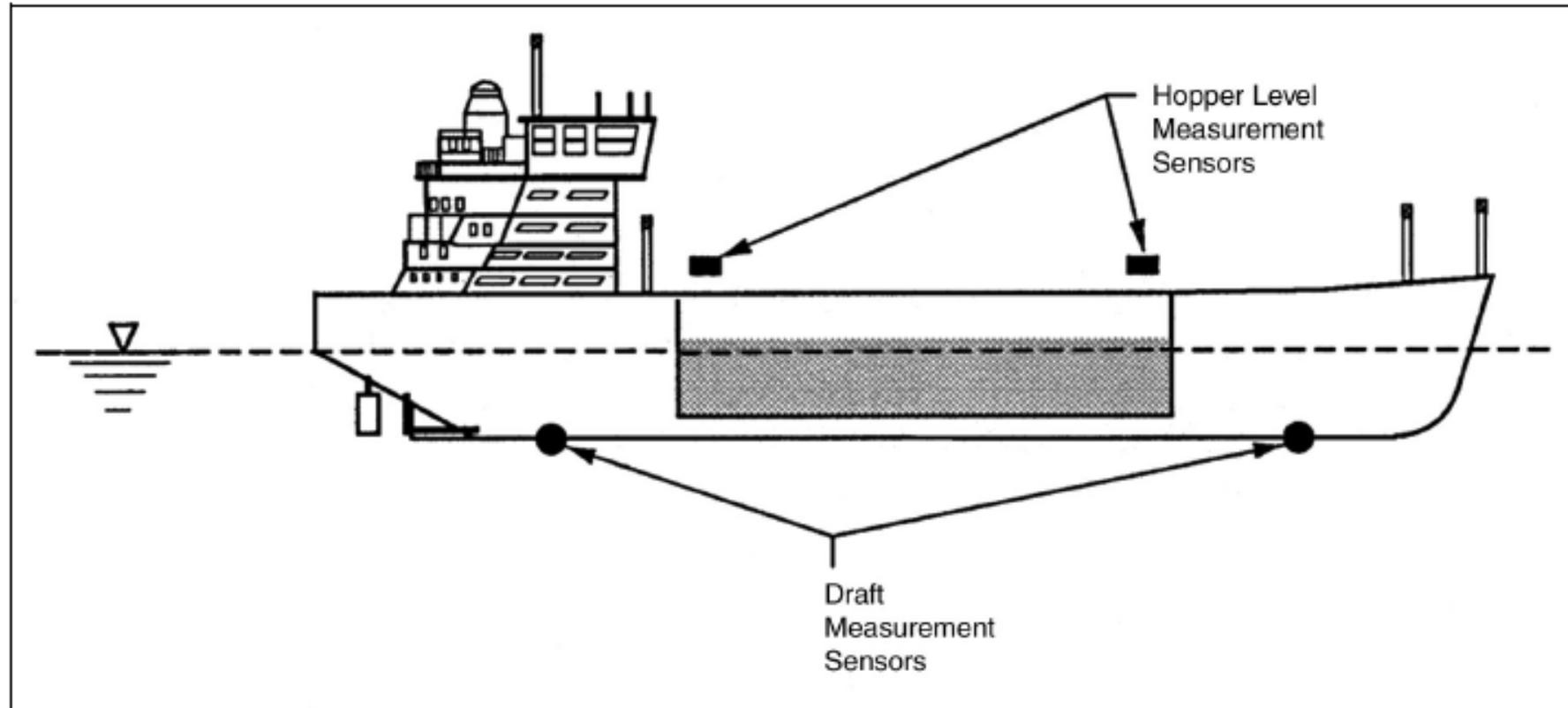


Columbia River Bar Pilot Boat

Additional Measurement Error Sand Waves in Hopper



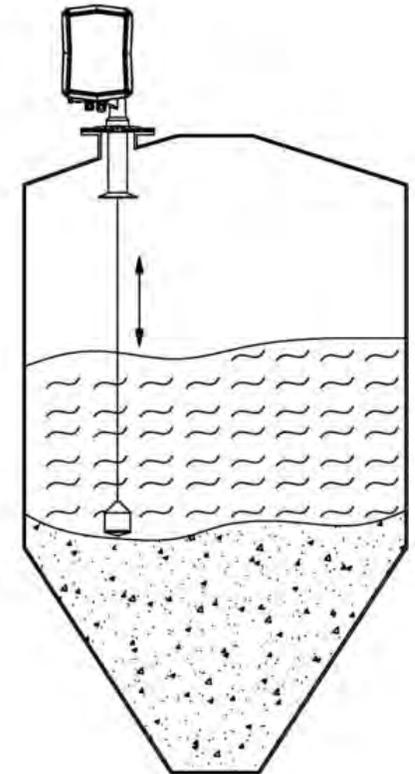
Evaluated Various Measurement Systems





Nivobob: A Mechanical Ullage Sensor

- Closely replicates hand soundings so that contractors can use historical data as a basis for bidding.
- Nivobob system originally developed in 1988 for use in bulk storage silos.
- Electromechanical plumb bob style (brushless electric motor) to continuously measure level of sludges and solids in liquids.
- Sounding lead driven down into hopper on rope wound on a 120 volt motor-driven roller, makes contact with bulk material then motor changes direction and lead driven back to the upper stop position.
- Measurement control is done by comparing the moved distance between up and downward movement (rotations of rope roller) and checking for discrepancy.
- Measuring range of up to 30 meters.
- Design life up to 225,000 measurements - limited by two main factors, the rope used and the internal electric motor.



Nivobob Model 3300 Level Sensor

(Source: UWT Level Control)

Development History

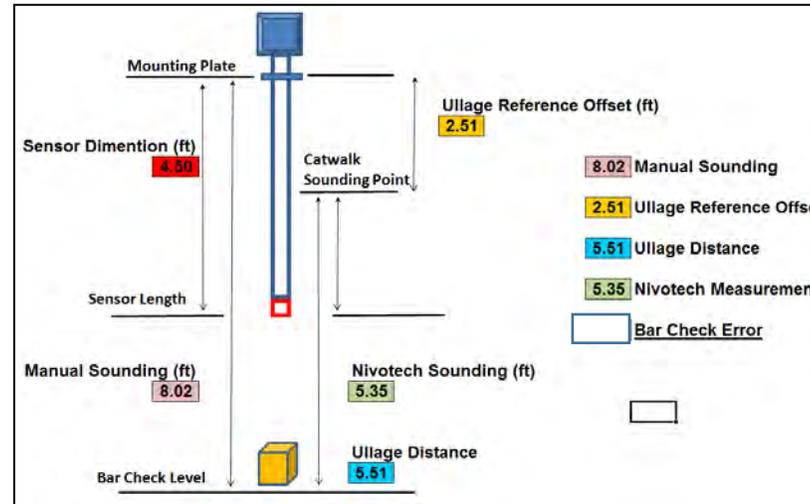
- First significant deployment onboard the Great Lakes Dredge & Dock Company's (GLDD) TERRAPIN ISLAND in 2009.
- Contracted under an annual NWP regional hopper dredge contract.
- Two sensors were installed over the hopper as close to manual sounding stations as possible



Nivobob in Action



Developed Daily Bar Check and "TERRAPIN Tube"



Stand Alone Sensor Accuracy Performance

Year - Dredge - Location	Number of Measurements	Sounding Station	Average of Manual Soundings (m)	Average of Mechanical Soundings (m)	Difference Between Averages (cm)
2009 - TERRAPIN - MCR	453	Aft-Port	4.303	4.115	18.80
	453	Fwd-Stbd	4.184	3.886	29.80
2009 - TERRAPIN - CR	219	Aft-Port	4.280	4.110	17.00
	219	Fwd-Stbd	4.040	3.720	32.00

No sensor failure!

Development History



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2010 - DODGE ISLAND - MCR	879	Aft-Port	2.790	2.830	-4.00
	879	Fwd-Stbd	3.160	3.190	-3.00
2010 - DODGE ISLAND - CR	453	Aft-Port	2.188	2.219	-3.10
	453	Fwd-Stbd	3.737	3.828	-9.10

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	453	Fwd-Stbd	3.737	3.828	-9.10
2011 - TERRAPIN - MCR	879	Aft-Port	3.789	3.795	-0.60
	879	Fwd-Stbd	3.161	3.194	-3.30

No sensor failure!

Automated Sensor System

- Given level of accuracy attained and the demonstrated operational robustness on the stand-alone operational basis.....
- NWP made the decision to require the contractor provide an automated mechanical ullage sensor system for the 2012 dredging contract.
- Volumes determined by manual soundings would remain as the contract payment basis and sensor system volumes would be compared to pay volumes, and operational metrics defined.
- Tech specs required five sensors be installed on each side of the hopper
- Located as close to the manual sounding stations as possible (jointly agreed)
- Sensors were required to be connected in series via a single communication line tied to a central communication and control system to allow for remote operation from the bridge.

Automated Sensor System Deployments



2012, 2013 & 2018



2014, 2015 & 2016



2017

Automated Sensor System Accuracy Performance

Year	2012	2013	2014	2015	2016	2017
Total Volume by Hand Soundings (m ³)	2,618,360	2,721,861	1,497,922	2,850,704	1,966,595	1,224,934
Total Volume by Sensor Soundings (m ³)	2,615,869	2,718,029	1,490,951	2,839,467	1,957,819	1,235,736
Volume Difference (m ³)	2,492	3,831	6,971	11,237	8,775	-10,802
Relative Percent Difference (%)	0.10	0.14	0.47	0.39	0.45	-0.88

Automated Sensor System History

- 2012 Soundings taken in MCR and CR
- 2013 Soundings taken in MCR, CR, and San Francisco Main Channel
- 2014 *First year system used as the contract payment basis in MCR and CR*
- 2014 NWP reduced onboard complement by half and started “daytime only” manual sounding to:
 1. verify ullage sensor measurements
 2. reduce costs while increasing personnel safety
- 2015 In addition to MCR and CR, used for pay in the San Francisco Main Channel and entrance channel at Humboldt Bay, California
- 2016 used for pay in all locations plus Grays Harbor
- 2017 used for pay in MCR and CR

Specification Section



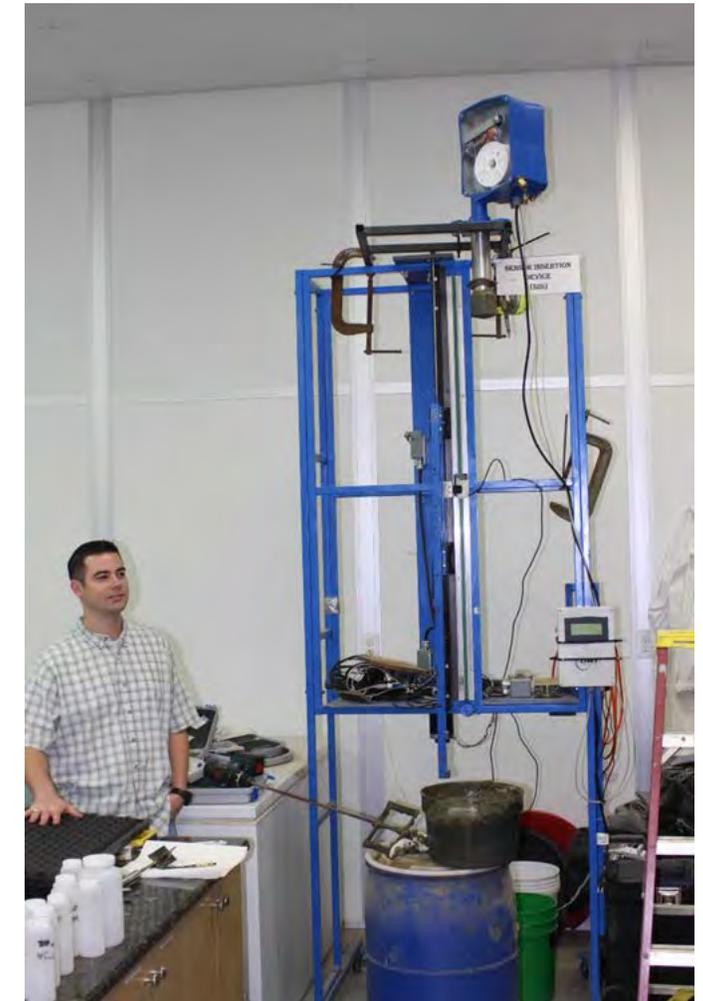
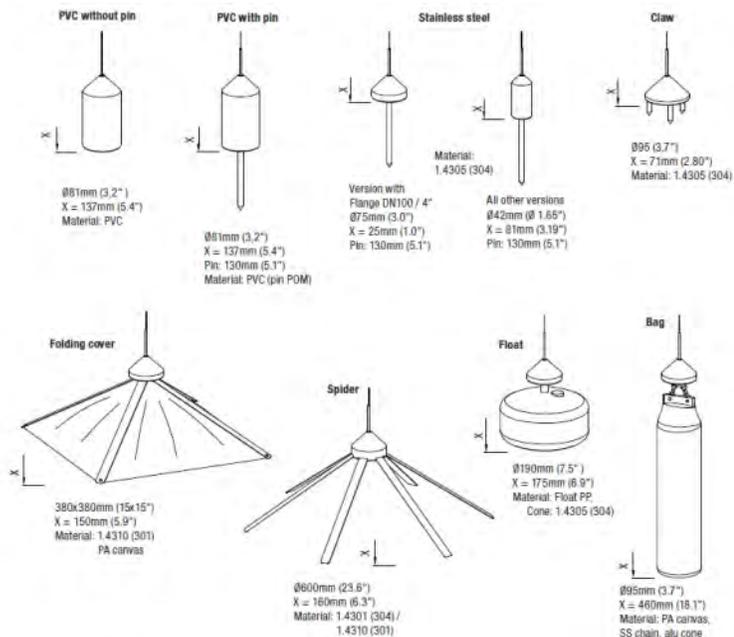
- Portland District uses DQM specs in hopper contracts
- 35 20 23.03 82 MECHANICAL ULLAGE SENSORS
 - Gives requirements for system
 - Provides requirements for payment
 - Provides guidance for ullage system failures

System Observations

- System-measured volumes more accurate in open seas than river
- Have not had a sensor fail (some 6+ years old)
- Won a Corps Innovation of the Year Award
- Started to see multiple volumes being reported.....
- No litigation - yet

Current R&D Activities

- Testing alternate weights to measure different types of loads (e.g., fine-grained).
- Different types of contracts?



(Source: UWT Level Control)

QUESTIONS?

