National Report of Canada
Eleventh Session of the GLOSS Group of Experts
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Introduction:

Canada's tide and water level programs support commercial and recreational navigation, marine transportation, coastal zone management, coastal hazards mitigation (storm surge and tsunami warning systems) and climate research. At present the Permanent Water Level Network (PWLN) portion of this program consists of 92 tide and water level (TWL) gauges, many of which provide near real-time water level observations.

Canada's PWLN is divided into 4 sub-networks, Pacific Region: 16 gauges; Atlantic Region: 16; Central & Arctic Region: 40; and Quebec Region: 23. The gauges of each sub-network are maintained by the corresponding 4 regional offices of the Canadian Hydrographic Service (CHS), which fall under the Department of Fisheries and Oceans. The exception is the gauges on the Great Lakes and the St. Lawrence River which are a shared responsibility between the CHS and the Water Surveys Branch of the Department of Environment.

An Overview of Canada's PWLN:

The coastal components of the Canadian PWLN sub-networks are illustrated in Figures 1 to 3. Information about individual coastal gauges in each sub-network (GLOSS id *if applicable*, station name and location, gauge type, co-located GPS and further information) is provided in Table 1. Generally, each region uses stilling wells with multiple sensors for redundancy. The usual combination of sensors is: a tape drop for sensor offset control, one or more float and pulley optical encoder sensors combined with either, or both, an atmospheric pressure compensated secondary bubbler or pressure sensor. New sensor developments are under way and include radar and laser-float sensors, see Figure 4. The high arctic stations are an exception because in arctic environments stilling wells can be difficult to maintain. Thus, the majority of arctic stations employ bottom mounted, atmospheric pressure compensated bubbler sensors.

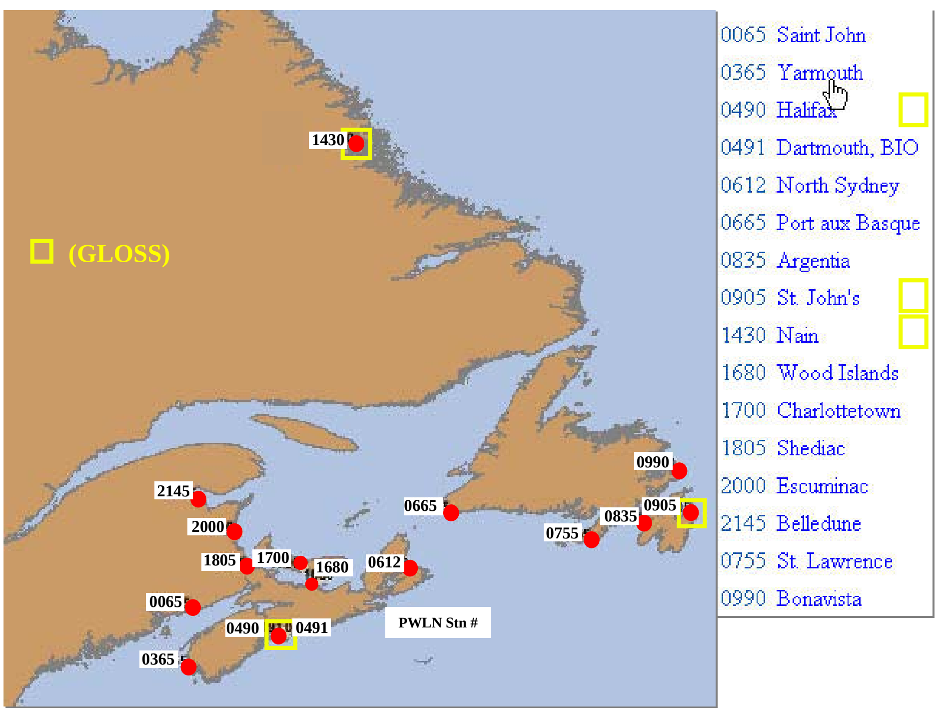

Figure 1: Atlantic PWLN gauges

Figure 2: Arctic PWLN gauges

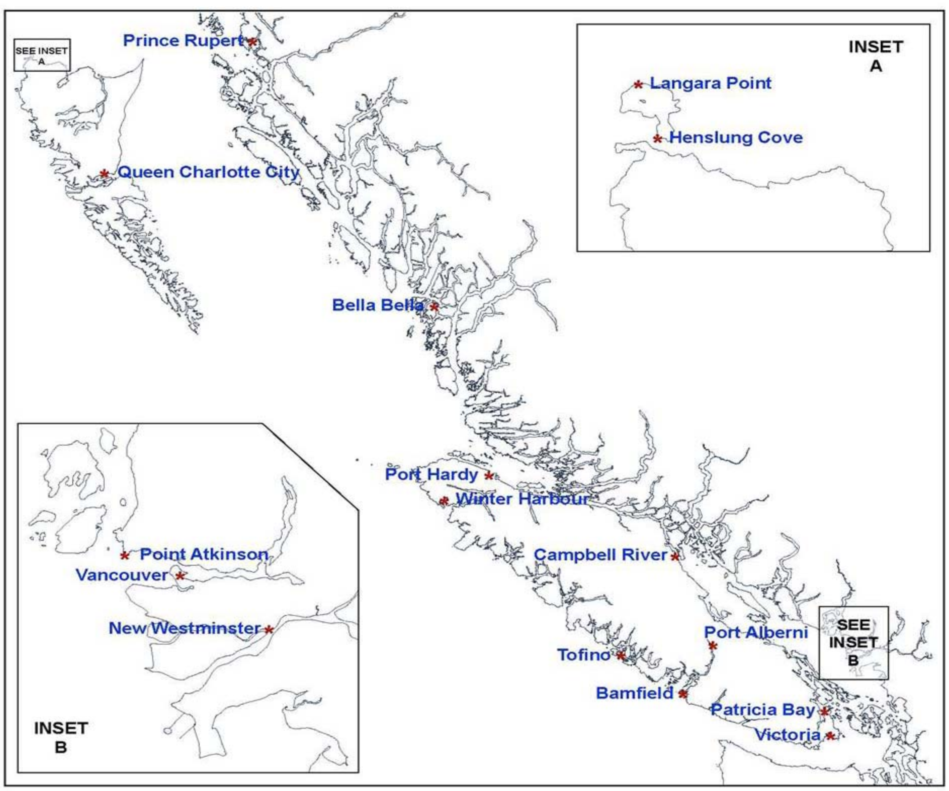

Figure 3: Pacific PWLN gauges

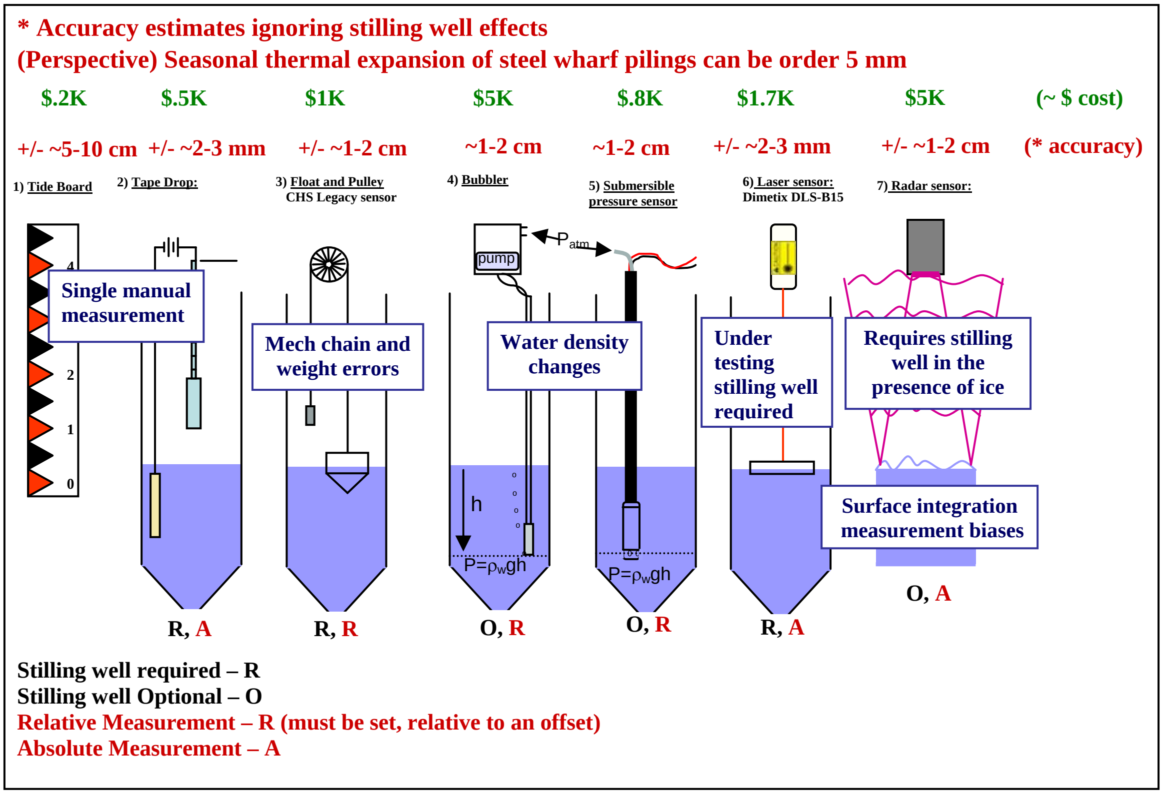

Figure 4: Deployed PWLN sensors

Water level data collection protocols differ somewhat from region to region. The Atlantic region employs a real-time data collection system, downloading one minute averaged data from most Atlantic gauges once every 10 minutes by telephone. The Halifax and Belledune gauges are the exception as they still collect data at 15 minute interval. Atlantic data is made available in real-time via a password protected emergency measures web page to Environment Canada's Atlantic Storm Prediction Center (ASPC), which is responsible for dissemination of both Storm Surge and Tsunami Warnings in Atlantic Canada, and to the Alaska Tsunami Warning Center (ATWC) in Palmer Alaska. Once per day Integrated Science Data Management (ISDM) polls Atlantic region's database and archives Atlantic data.

Central and Arctic region gauges collect data at 3 minute interval and are downloaded once per day by telephone. Data is made available each day to ISDM, and the previous days data is made available to interested parties via webpage http://www.marees.gc.ca/C&A/tidal_e.html. Pacific region gauges collect one minute averaged data and are downloaded hourly. A quality assured (QA) version of water level data is pushed to ISDM once per month. Notably, as part of Pacific region's QA procedures they correct their float and pulley data for both chain weight as it shifts from the float to the weight side of the pulley during rising and falling water levels (see Figure 2), and for changes in chain tension if and when the weight enters or leaves the water. Several of Pacific region's gauges are also part of the Pacific Tsunami Warning System (PTWS) and employ MSAT and GOES satellite transmission systems to provide their data to PTWS systems in real-time.

Although not shown in this document, Quebec region has an extensive real-time water level observation and forecasting system called SINECO (http://slgo.ca/en/context-obs/14-contexte/17-sineco.html). The SINECO network is an operational system covering the whole of the St. Lawrence Seaway from Montréal to Sept-Îles. SINECO is made up of 23 stations placed at strategic locations along the seaway, coupled with a numerical river stage model incorporating atmospheric forcing. This combination permits water levels to be forecast with a high degree of accuracy up to several days into the future. Stations are also equipped with sensors for measuring atmospheric pressure, water temperature and water salinity (salinity is only monitored at stations downstream of Île d'Orléans). SINECO uses submersible pressure sensors and thus the measurements of temperature and salinity are used to improve the accuracy of the water level measurements.

Table 1: PWLN Gauge Information

Arctic PWLN gauges				
GLOSS ID	Location	Gauge Type	GPS	Status
Proposed as replacement for GLOSS 153	Alert, Ellesmere Island, Eastern Canadian Arctic 82.49 N, 62.32 W	Bubbler system Telephone modem 3 minute data, download daily	yes	Gauge re-established Dec. 2002 Previous period of record, 1961-1979 Sampling at 3 minute intervals Daily transmission of data to ISDM
N/A	Holman, Victoria Island, Western Canadian Arctic 70.74 N, 117.76 W	Bubbler system Telephone modem 3 minute data, download daily	yes	Gauge established Dec. 2002 Sampling at 3 minute intervals Daily transmission of data to ISDM
N/A	Qikiqtarjuaq, Baffin Island, Eastern Canadian Arctic 67.52 N, 64.07 W	Bubbler system Telephone modem 3 minute data, download daily	yes	Gauge re-established July 2004 Sampling at 3 minute intervals Daily transmission of data to ISDM
N/A	Churchill, Hudson Bay, Central Canada 58.77 N, 94.18 W	Stilling well system with 2 separate float and pulley gauges with pressure backup Telephone modem 3 minute data, download daily	yes	Gauge established Jan 1940 Float and counterweight with encoder and a pressure sensor for backup Sampling at 3 minute intervals Daily transformation of data to ISDM
N/A	Tuktoyaktuk, Western Canadian Arctic 69.44 N, 132.99 W	Bubbler system Telephone modem 3 minute data, download daily	yes	Gauge re-established Aug 2003 Previous period of record 1961-1982 Sampling at 3 minute intervals Daily transmission of data to ISDM
Atlantic PWLN gauges				
GLOSS ID	Location	Gauge Type	GPS	Status
N/A	Saint John NB 45.25 N, 66.06W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone modem		Digital records span 1896 to May 2009 Database mined daily by ISDM
N/A	Yarmouth NS 43.83 N, 66.13 W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone modem		Digital records span 1956 to May 2009 Database mined daily by ISDM
N/A	Bedford Institute	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone Modem	yes	Digital records span 1972 to May 2009 Database mined daily by ISDM
222	Halifax, NS 44.67 N, 63.58 W	Stilling well system Float gauge 15 minute averaged data, download every 20 min., Telephone modem	yes	Digital records span 1895 to May 2009 Database mined daily by ISDM
N/A	North Sydney NS 46.21 N, 60.24 W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone Modem		Digital records span 1970 to May 2009 Database mined daily by ISDM
N/A	Wood Islands PEI 45.95 N, 62.75 W	Stilling well system Float gauge with secondary bubbler and pressure backup Telephone modem		Station severely damaged, gauge may be moved to alternative PEI location pending system requirements
N/A	Charlottetown PEI 46.23 N, 63.13 W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone modem		Digital records span 1911 to May 2009 Database mined daily by ISDM

N/A	Shediac Bay, NB 46.23 N, 64.55 W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone modem	yes	Digital records span 1971 to May 2009 Operated at the Point Du Chene Marina 1971 until 1989. On 25 July 2003 a temp gauge was installed at the Shediac Bay Marina, ~1km from original site. New wharf structure at Point Du Chene will permit relocation to original site in 2009 Database mined daily by ISDM
N/A	Escuminac NB 47.08 N, 64.87 W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone modem		Digital records span 1963 to May 2009 Database mined daily by ISDM
N/A	Belledune NB 47.91 N, 65.84 W	Stilling well system Float gauge with secondary bubbler 15 minute averaged data, download every 20 min., Telephone modem		Digital records span 1999 to May 2009 Database mined daily by ISDM
N/A	Port aux Basque NFLD 47.57 N, 59.13 W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone modem		Digital records span 1935 to May 2009 Database mined daily by ISDM
N/A	St. Lawrence NFLD 46.92 N, 55.39 W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone modem		Digital records span 2005 to May 2009 Database mined daily by ISDM
N/A	Argentia NFLD 47.3 N, 53.98 W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone modem		Digital records span 1971 to May 2009 Database mined daily by ISDM
223	St. John's, NFLD 47.57 N, 52.72 W	Insulated, heated multi-well stilling well system, 3 sensors: laser, bubbler and pressure 1 minute averaged data, download every 10 min., Telephone modem	yes	Data records span 1935 to May 2009 New stilling well and sensor system installed in early fall of 2009. Database mined daily by ISDM
N/A	Bonavista NFLD 48.65 N, 53.12 W	Stilling well system Float gauge with secondary bubbler and pressure backup 1 minute averaged data, download every 10 min., Telephone modem		Digital records span 1953 to May 2009 Database mined daily by ISDM
224	Nain, Labrador 56.55 N, 61.68 W	Insulated, heated multi-well stilling well system, 3 sensors: laser, bubbler and pressure 1 minute averaged data, download every 10 min., Telephone modem	Yes	Digital records span 1963 to Oct. 1988 and start again in April 2001 Database mined daily by ISDM Existing stilling well system destroyed by ice in winter 2008. Lower quality bubbler data only from mid winter to Fall of 2009. New stilling well system installed Nov 2009
Pacific PWLN gauges				
GLOSS ID	Location	Gauge Type	GPS	Status
155	Prince Rupert, BC 54.32 N, 130.32 W	2 separate float gauges with BEI optical encoders (in separate wells) 1 minute averaged data, download every hour, Telephone modem	Prov . stn	Digital records span 1906 to May 2007 Data sent to ISDM monthly
N/A	Queen Charlotte City 53.25 N, 132.07 W	2 separate float gauges with BEI optical encoders (in separate wells) 1 minute averaged data, download every hour, Telephone modem	Prov . stn	Digital records span 1957 to May 2009 Data sent to ISDM monthly
N/A	Bella Bella 52.16 N, 128.14 W	2 separate float gauges with BEI optical encoders (in separate wells) 1 minute averaged data, download every hour, Telephone modem	Prov . stn	Digital records span 1962 to May 2009 Data sent to ISDM monthly

N/A	Port Hardy 50.72 N, 127.49 W	2 separate float gauges with BEI optical encoders (in separate wells) 1 minute averaged data, download every hour, Telephone modem	Prov. stn	Digital records span 1944 to May 2009 Data sent to ISDM monthly
N/A	Winter Harbour 50.51 N, 128.03 W	2 separate float gauges with BEI optical encoders (in separate wells) pressure sensor backup 1 minute averaged data, download every hour, Telephone modem, MSAT link GOES communications	Yes	Digital records span 1989 to May 2009 Data sent to ISDM monthly Pacific Tsunami warning
N/A	Campbell River 50.04 N, 125.25 W	2 separate float gauges with BEI optical encoders (in separate wells) 1 minute averaged data, download every hour, Telephone modem	Yes	Digital records span 1958 to May 2009 Data sent to ISDM monthly
156	Tofino, BC 49.15 N, 125.91 W	2 separate float gauges (in separate wells) with bubbler pressure sensor backup 1 minute averaged data, download every hour, Telephone modem, MSAT link GOES communication	Yes	Digital records span 1909 to May 2009 Data sent to ISDM monthly Pacific Tsunami warning
N/A	Bamfield 48.84 N, 125.14 W	2 separate float gauges with BEI optical encoders (in separate wells) 1 minute averaged data, download every hour, Telephone modem	Yes	Digital records span 1969 to May 2009 Data sent to ISDM monthly
N/A	Port Alberni 49.23 N, 124.81 W	2 separate float gauges with BEI optical encoders (in separate wells) pressure sensor backup 1 minute averaged data, download every hour, Telephone modem GOES communication	Yes	Digital records span 1970 to May 2009 Data sent to ISDM monthly Pacific Tsunami warning
N/A	Patricia Bay 48.65 N, 123.45 W	2 separate float gauges with BEI optical encoders (in separate wells) pressure sensor backup 1 minute averaged data, download every hour, Telephone modem GOES communication	Yes	Digital records span 1962 to May 2009 Data sent to ISDM monthly
N/A	Victoria 48.42 N, 123.37 W	2 separate float gauges with BEI optical encoders (in separate wells) 1 minute averaged data, download every hour, Telephone modem	Yes	Digital records span 1909 to May 2009 Data sent to ISDM monthly
N/A	Vancouver	2 separate float gauges with BEI optical encoders (in separate wells) 1 minute averaged data, download every hour, Telephone modem	Prov. stn	Digital records span 1909 to May 2009
N/A	New Westminister	2 separate float gauges with BEI optical encoders (in separate wells) 1 minute averaged data, download every hour, Telephone modem	Prov. stn	Digital records span 1959 to May 2009 Data sent to ISDM monthly
N/A	Point Atkinson	2 separate float gauges with BEI optical encoders (in separate wells) Telephone modem		Digital records span 1914 to May 2009 Data sent to ISDM monthly
N/A	Langara Point	Bubbler system 1 minute averaged data, download every hour, Telephone modem MSAT link		Digital records span 1962 to May 2009 Data sent to ISDM monthly Pacific Tsunami warning
N/A	Henslung Cove	Bubbler system and pressure sensor Internet connection GOES		Pacific Tsunami warning Data sent to ISDM monthly

Data Availability:

Most water level data collected by the Canadian PWLN are transmitted to ISDM on a daily basis, followed by quality assured monthly submissions. Data are archived and available to the public for free. Exchanges with other government departments and international agencies occur on a daily basis. Monthly submissions of hourly and 15-minute tidal data are sent to the UHSLC. Monthly mean data are submitted to PSMSL on an annual basis.

Archived data and data products can be accessed through a request system in which clients fill out an online form and then receive the data after the request has been completed by a data technician. More recently the observed water level data, including daily and monthly means, has been made available for download from the ISDM website, along with the station information, station inventory and benchmark information. Data on the website is currently updated once a day.

Access to PWLN Data and Related Information:

National tidal predictions and information:
    http://www.waterlevels.gc.ca
Online data inventory and download of digital archive:
    http://www.meds-sdmm.dfo-mpo.gc.ca/meds/Databases/TWL/TWL_inventory_e.htm
Public Benchmark access:
    http://www.meds-sdmm.dfo-mpo.gc.ca/meds/prog_nat/benchmark/public/default_e.asp
Arctic gauge data:
    http://www.marees.gc.ca/C&A/tidal_e.html
Pacific gauge data:
    www.bctides.ca

PWLN Vertical Control and Existing Co-Location of Active GPS and Tide Gauges:

The CHS maintains at least 3 benchmarks associated with each of its PWLN stations and on a yearly basis re-levels and replaces them if necessary. CHS also attempts to meet the same standard, on an opportunity basis, at its temporary tide gauge sites. As highlighted in Table 1, the majority of the Arctic tide stations now have co-located active GPS vertical control to allow interpretation of tectonic motion and to better establish relative sea-level rise. A number of stations in both the Pacific and Atlantic regions can claim to have co-located active GPS (see Table 1), assuming that the definition of co-location is: ‘within several hundred meters to several kilometers’. In most cases the GPS data are collected and managed by the federal department of Natural Resources (NRCan). Several additional stations in the Pacific region may also claim to have co-located active GPS control if the Provincial active points are also considered, see Table 1. Finally, Canada’s Hydrographic offices are making more extensive use of GPS technology to better establish and manage their hydrographic datum holdings, and they now commonly use GPS, integrated with real-time reference shore station observations, to measure in-situ tidal heights while conducting operational sounding and dredging operations.

In addition to maintaining Canada’s PWLN the CHS also provides the predicted times and heights of high and low water for over 700 stations in Canada, including over 200 locations along the St. Lawrence shoreline. These predictions are available in print as part of the Canadian Tide and Current Tables, and are also available over the internet, http: //www.waterlevels.gc.ca.

Recent PWLN Developments:

Over the last 3 to 5 years significant improvements have been made to Canada's PWLN in terms of remediation of basic aging infra-structure and the acquisition and development of new data collection systems and water level sensors. Sensor redundancy and reliability have been improved, real-time data collection has been expanded and new sensor technologies including both radar and laser are under investigation, see Figure 2. CHS Atlantic is also presently re-examining the design of stilling-wells, particularly for use in ice-prone temperate and sub-arctic environments. Elements of an example system presently deployed at Nain employing a laser-float sensor are shown in Figures 5 to 7. An intra-sensor data comparison is shown in Figure 8. This overview of the Multi-well stilling well and the laser-float sensor are included as part of Canada's National report as a matter of potential interest to other tide gauge users. However, caution is suggested before considering adoption of these methods as they are somewhat new and with any new techniques their long-term robustness and stability remain to be determined.

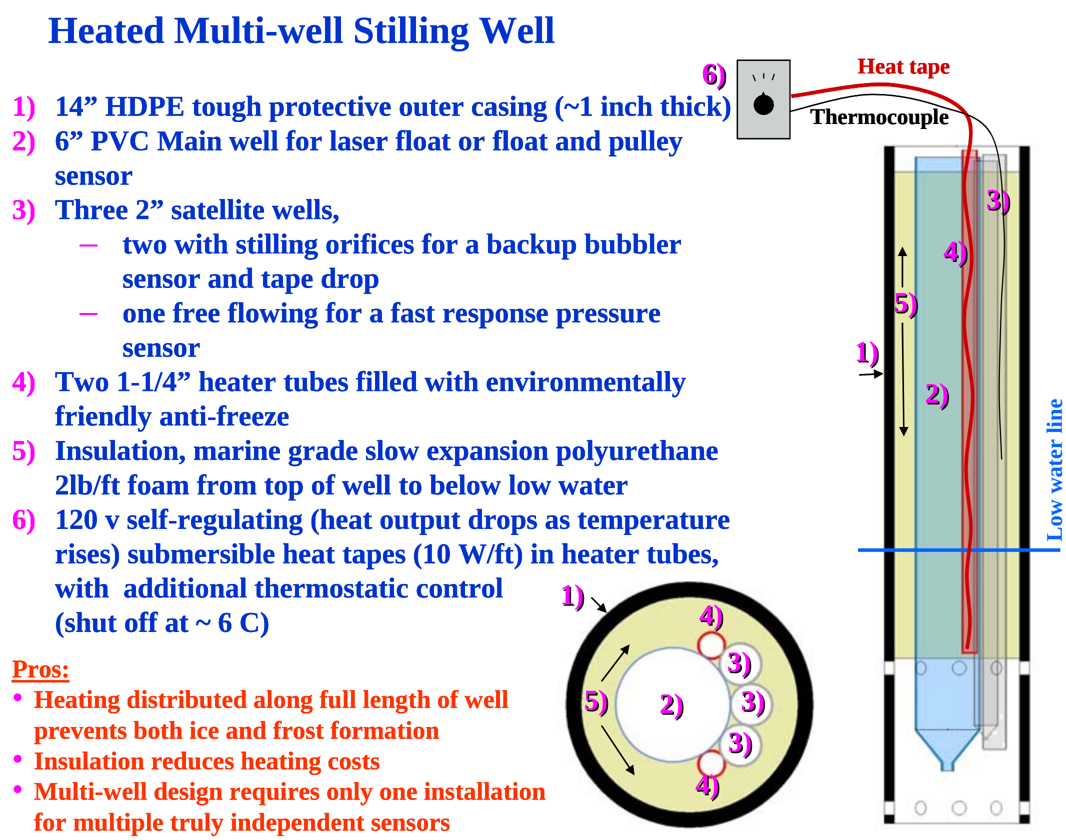

Figure 5: The Insulated, Heated Multi-well Stilling Well

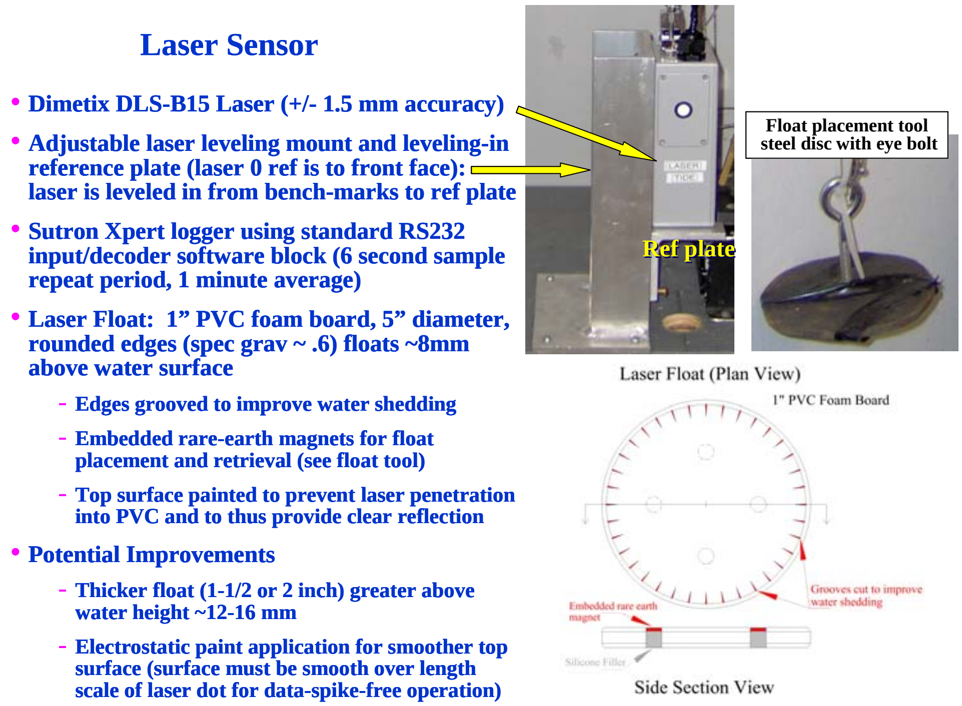

Figure 6: The Laser-Float Sensor

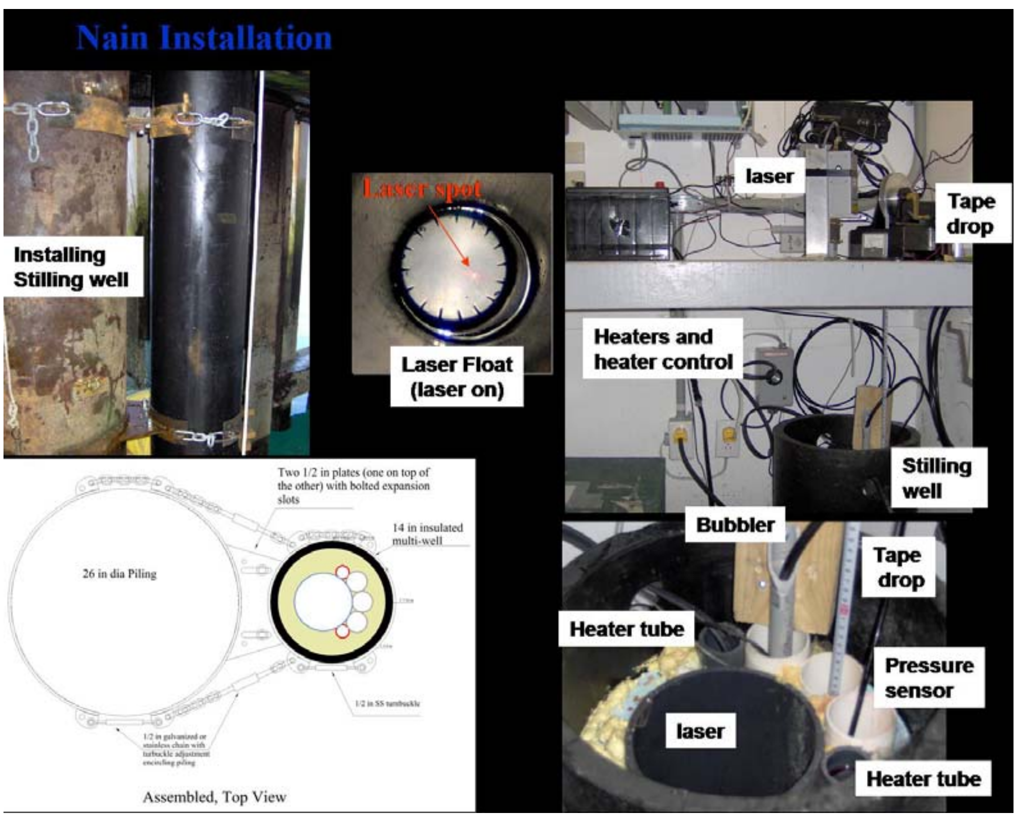

Figure 7: Nain, An Example Installation

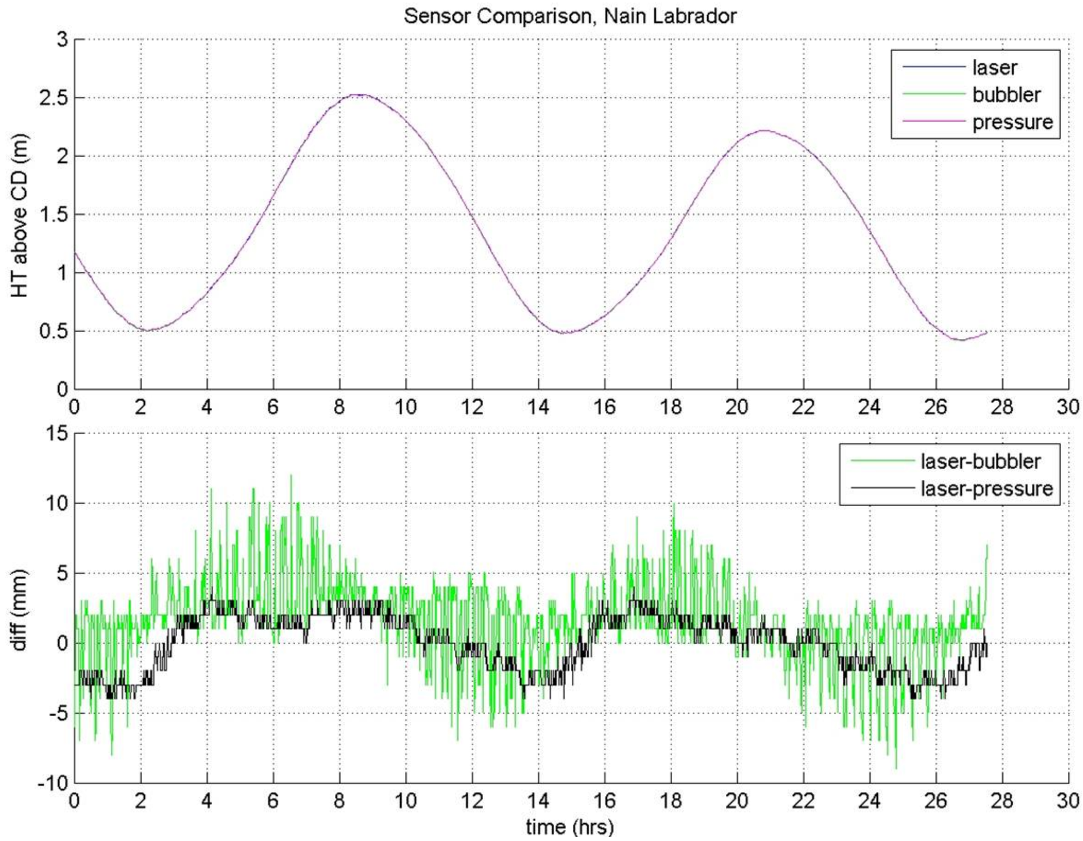

Figure 8: Sensor Comparison at Nain

The laser is calibrated at the factory to theoretically provide an absolute ranging measurement with nearly range independent +/- 1.5 mm accuracy. Thus, it should be possible to simply install and leveled-in the device relative to benchmarks as one would install a tape drop. In practice, after accounting for the height of the float above water in the well, this procedure appears to achieve an accuracy of a couple of mm's relative to a tape drop, assuming that identical measurement frequency and averaging procedures are employed when comparing both devices. Small differences, order mms, between the devices are in practice observed. However, this is to be expected in this case because both devices are in separate stilling wells, which are not identically stilled and thus will exhibit slightly different behavior, and because the use of a tape drop is somewhat subjective based on user and technique employed.

Both the bubbler and pressure sensor's measurements are dependent on fixed sensor depth and on water density and vertical water density profile, both of which are not exactly known and can change appreciably seasonally. Thus the comparison between sensors presented in Figure 8 is only one of relative behavior.

Once the laser has compared adequately to the tape drop for a range of measurements its level of accuracy should be similar to that of the tape drop. It is then assumed that the bubbler and pressure sensors can be more usefully calibrated for their slope and offset by least-squares analysis of their time series with respect to that of the laser over a number of days of simultaneous operation. Following this calibration procedure all three sensors display highly correlated behavior as shown in the top panel of Figure 8.

The behavior of the sensors can then be compared into the future, along with periodic station checks to the tape drop, and dissimilar behavior of one sensor relative to the other two can be used to identify developing sensor issues. In addition, when the behavior of both the bubbler and pressure sensor depart from that of the laser in ways that are clearly expected due to seasonally changing water density, which in temperate climates is inevitable (offsets accompanied by range contraction or expansion with changing water density) they may occasionally be cautiously recalibrated. Operationally, this appears to be necessary infrequently and as indicated it must be carefully assessed as there is always the danger of mistaking fresh water contamination of the stilling well, or other slowly developing sensor issues, with average water density change. Similar procedures can be applied to multiple-sensor systems employing float and pulley sensors combined with bubbler and pressure sensors.

The bottom panel of Figure 8 shows the residual difference behavior between the sensors. The ~1 cm noise at about 15 minute interval between the laser and the bubbler sensors is unfortunately due to a software bug in the auto-zero process of the bubbler (the manufacturer is presently working on a fix).
Considering and excluding this, the calibrated bubbler and the laser appear to agree at near mm level. It is significant that both the bubbler and laser sensors use stilling wells with approximately the same stilling. The pressure sensor on the other hand is intended to be capable of fast response (tsunami warning applications) and is thus in a well that is fairly lightly stilled as the well is mainly for sensor positioning and protection. Because of this difference in stilling well behavior, measurements made with the pressure sensor should slightly lead those of the laser in both an increasing and decreasing water level sense. Much of the difference behavior shown in the bottom panel of Figure 8 between the laser and the pressure sensor can be attributed to this source. One must also keep in mind that the errors displayed are only on the order of a couple of mm's and that neither bubbler nor pressure sensor behavior can be expected to be truly linear as water density can not be expected to be identically uniform in the vertical.

Although the above comparison does not definitively demonstrate the manufacturers quoted +/-1.5 mm laser accuracy it does illustrate that errors appear to be of mm order. Further testing is still required, although previous tests have already confirmed that a laser-float system displays greater accuracy than a float-pulley-encoder system if the float and pulley remains uncorrected for chain weight transfer and weight submersion.

The pros of the laser are: it has no moving parts, it should potentially be capable of treatment as an absolute measurement device; its life-time is estimated to be 3 to 5 years at the present 10 samples per minute sampling schedule; it is fairly inexpensive; and if it fails a new tested unit may simply be mounted in place of the old, plumbed, and turned on, simplifying field replacement. The laser's cons are: it still requires a stilling-well and is thus susceptible to all the errors inherent with stilling-wells; float placement and recovery (which have not been discussed) are a bit finicky; and although example systems have been in operation now for up to 8 months and display few problems other than a few data spikes (it is still unclear whether these spikes are due to laser reflection inconsistencies off of the somewhat imperfect floats presently in use, or are due to data-logger grounding issues) the laser is nonetheless still a relatively untested water level field device.

Recommendations Forwarded from 2007 National Report of Canada:

The GLOSS station at Little Cornwallis Island (GLOSS ID 153) has not been in operation since September 1994, and it is extremely unlikely this station will ever be re-activated. Canada recommends this station be removed from the GLOSS list and replaced by the PWLN station located at Alert on Ellesmere Island, see Figure 2 and Table 1.

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