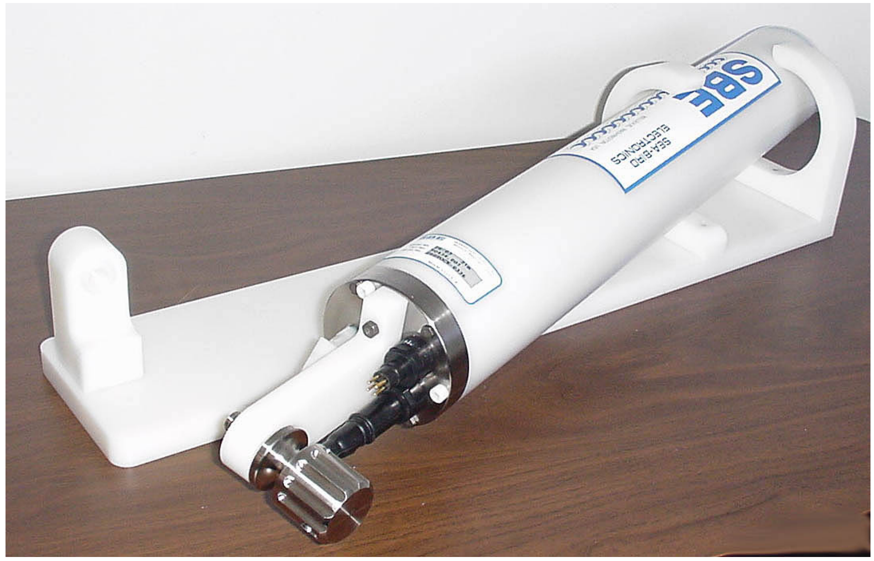
SBE 26 SEAGAUGE

Wave and Tide Recorder



Shown in optional mounting fixture

User's Manual

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Manual Version #017, 09/08/11
Firmware Version 4.1i and later
Seasoft for Waves Software Version 2.0 and later

Limited Liability Statement

Extreme care should be exercised when using or servicing this equipment. It should be used or serviced only by personnel with knowledge of and training in the use and maintenance of oceanographic electronic equipment.

SEA-BIRD ELECTRONICS, INC. disclaims all product liability risks arising from the use or servicing of this system. SEA-BIRD ELECTRONICS, INC. has no way of controlling the use of this equipment or of choosing the personnel to operate it, and therefore cannot take steps to comply with laws pertaining to product liability, including laws which impose a duty to warn the user of any dangers involved in operating this equipment. Therefore, acceptance of this system by the customer shall be conclusively deemed to include a covenant by the customer to defend, indemnify, and hold SEA-BIRD ELECTRONICS, INC. harmless from all product liability claims arising from the use or servicing of this system.

Table of Contents

Section 1: Introduction

This section includes contact information, Quick Start procedure, photos of a standard SBE 26 SEAGAUGE Wave and Tide Recorder, and shipping precautions for lithium batteries.

About this Manual

This manual is for use with the SBE 26 SEAGAUGE Wave and Tide Recorder. It is organized to guide the user from installation through operation, and data collection and processing. We've included detailed specifications, command descriptions, maintenance and calibration information, and helpful notes throughout the manual.

Sea-Bird welcomes suggestions for new features and enhancements of our products and/or documentation. Please contact us with any comments or suggestions (seabird@seabird.com or 425-643-9866). Our business hours are Monday through Friday, 0800 to 1700 Pacific Standard Time (1600 to 0100 Universal Time) in winter and 0800 to 1700 Pacific Daylight Time (1500 to 0000 Universal Time) the rest of the year.

Quick Start

Follow these steps to get a Quick Start using the SBE 26. The manual provides step-by-step details for performing each task.

Deployment:

1. Run Plan Deployment and Battery and Memory Endurance to determine sampling parameters (*Section 4*).
2. Install new batteries.
3. Connect SBE 26 to computer and run SeatermW (*Section 5*):
   A. Ensure all data has been uploaded, and then send **IR** to make entire memory available for recording if desired.
   B. Set date and time (**ST**) and wave and tide sampling parameters (**SI**); enable conductivity if SBE 4M conductivity sensor is installed (**CY**).
   C. Check status (**DS**) and calibration coefficients (**DC**).
   D. Start logging (**GL**).

Recovery and Data Processing:

1. Connect SBE 26 to computer and run SeatermW. Quit logging (**QL**), and upload data from SBE 26 memory (*Section 5*).
2. Run Convert Hex to convert raw data into separate wave and tide files (*Section 6*).
3. Run Merge Barometric Pressure to remove barometric pressure from tide file (*Section 7*).
4. Run Process Wave Burst Data and Create Reports to calculate and summarize wave statistics (*Section 8*).
5. Run Plot Data to display the data (*Section 9*).

Unpacking SBE 26

Shown below is a typical SBE 26 shipment.

SBE 26 in plastic housing

I/O Cable

9-pin adapter

Pressure Sensor
Oil refill kit

Spare parts kits (2)

Jackscrew Kit

Software, and Electronic Copies of
Software Manuals and User Manual

Shipping Precautions – Electrochem Lithium Batteries

The SBE 26 **may** be powered with Electrochem Lithium Batteries. Sea-Bird supplied these batteries as an option for the SBE 26 until February 2004, but does not supply these batteries anymore because of changes in regulations governing shipment of lithium batteries. Sea-Bird does sell a lithium battery pack kit, for building a battery pack using lithium batteries purchased elsewhere. The following applies only to Lithium batteries, not to the standard alkaline batteries.

The Law

U. S. domestic transportation of Electrochem lithium batteries is regulated by the Department of Transportation (DOT) through Title 49 Code of Regulation (49 CFR), HM-181 part 173.185. Internationally, air transportation is regulated by the International Air Transport Association (IATA). Pursuant to 49 CFR 173.185, all shipments of hazardous materials must comply with packaging regulations based on recommendations made by the United Nations.

The shipper is responsible for compliance with the law. Sea-Bird cannot advise you on this matter; consult the proper authorities.

Shipping

Note that the batteries must not be shipped inside the instrument.

If you will re-ship the SBE 26 by commercial aircraft:

1. Remove the batteries from the SBE 26.
2. Properly package and label the batteries, and fill out the required Dangerous Goods documentation.

Note:
Remaining battery capacity for used Electrochem lithium batteries is not known and cannot be determined without consumptive testing. **We do not recommend reusing** them unless you can positively determine how many samples were recorded with the batteries since their purchase.

If you will be shipping your SBE 26 to Sea-Bird for servicing or calibration, **DO NOT RETURN THE ELECTROCHEM LITHIUM BATTERIES TO SEA-BIRD**. Remove and store the batteries for future use, or dispose of properly. If you send the batteries to Sea-Bird, we will not ship them back to you. We will dispose of the batteries unless you are able to arrange to pick them up at Sea-Bird.

Section 2: Description of SBE 26

This section describes the functions and features of the SBE 26, including specifications, dimensions, power supply, and data I/O protocols.

System Description

The SBE 26 SEAGAUGE Wave and Tide Recorder combines Sea-Bird's reliable semiconductor-memory electronics with a stable time base, quartz pressure sensor, precision thermometer, and an optional SBE 4M conductivity sensor to provide wave and tide recording of unprecedented resolution and accuracy.

For tide and water level monitoring, the pressure sensor output is continuously integrated to average out wave action. The user-programmable tide integration time can be set from 1 minute to 500 hours, on 1-minute intervals. High-accuracy temperature information is recorded with each tide measurement. As an option, an SBE 4M conductivity sensor can be installed for recording conductivity data with each tide measurement. Waves are characterized by burst sampling, with the number of samples per burst, burst interval, and burst integration time programmed by the user.

The SBE 26 is self-contained in a rugged non-corroding plastic housing (600-meter depth rating); optional titanium housing for depths to 7000 meters is available. After recovery (and without opening the housing), the recorded data is transferred to a computer via an RS-232C data link for analysis, plotting, and permanent archiving. The battery compartment contains nine standard alkaline D-cells and is sealed separately to minimize risk to the electronics.

The standard pressure sensor is a 20 meter (45 psia) Quartzonix, with a temperature-compensated quartz element. An optional Paroscientific Digiquartz pressure sensor with a temperature-compensated quartz element is available in 13 ranges, from 1 to 6800 meters (15 to 10,000 psia). Temperature is measured with an aged, super-stable thermistor embedded in the SBE 26 end cap.

Tide measurements are obtained by continuously counting the pressure frequency with a 40-bit ripple counter. Each time the SBE 26 wakes up, the ripple counters are latched into registers and then reset. The wake-up times are set by a continuously powered, real-time clock with an accuracy of 5 ppm and a resolution of 2 milliseconds.

Wave burst measurements are made with a period counter, with its time base generated from a temperature-compensated, precision quartz crystal oscillator.

SBE 26 options include:
- SBE 4M conductivity sensor
- Titanium housing for use to 7000 meters (22,960 feet)
- Digiquartz pressure sensor
- Wet-pluggable bulkhead connectors in place of Impulse glass-reinforced epoxy bulkhead connectors
- Battery pack kit for lithium batteries for longer deployments (lithium batteries **not** supplied by Sea-Bird)
- Mounting fixture

Notes:
- Sea-Bird supplies the current version of our software when you purchase an instrument. As software revisions occur, we post the revised software on our FTP site. See our website (www.seabird.com) for the latest software version number, a description of the software changes, and instructions for downloading the software from the FTP site.
- Help files provide detailed information on Seasoft for Waves.

The SBE 26 is supplied with a with a modular Windows 95/98/NT/2000/XP software package, Seasoft for Waves. The software provides pre-deployment planning, communication with the SBE 26 for setup and uploading of data, separation of the raw data into separate wave and tide files, removal of barometric pressure from tide data, statistical analysis, and data plotting.

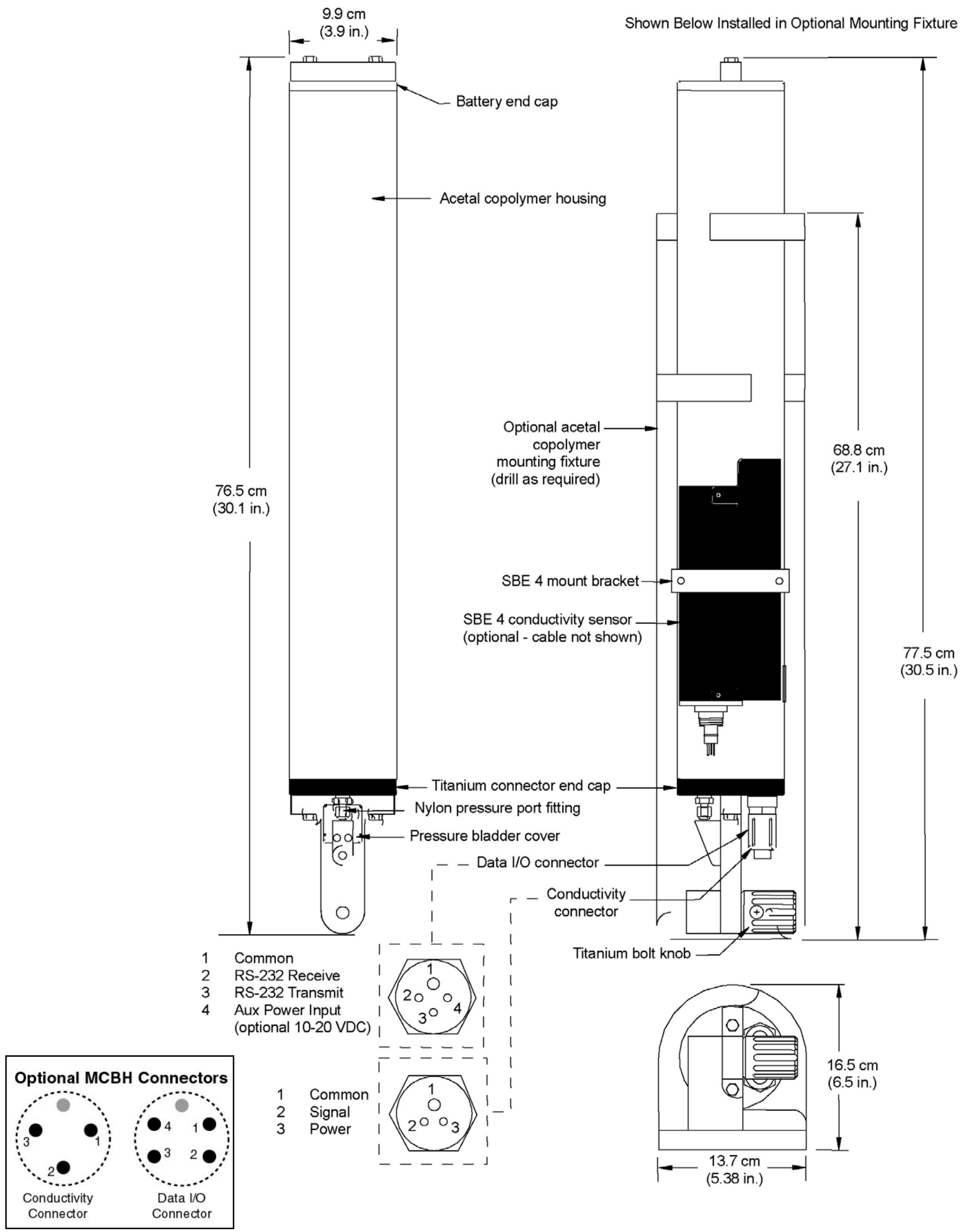
Specifications

Note:
The pressure sensor is mounted on the titanium connector end cap, with the pressure conveyed from the pressure port to the sensor via an oil-filled tube. The pressure reading is position sensitive as a result of the oil pressure head.

Pressure	
Range	0 to 1/ 5/ 10/ 20/ 60/ 130/ 200/ 270/ 680/ 1300/ 2000/ 4000/ 6800 meters (15/ 23/ 30/ 45/ 100/ 200/ 300/ 400/ 1000/ 2000/ 3000/ 6000/ 10000 psia)
Accuracy*	0.01% of full scale (3 mm for 45 psia range)
Repeatability *	0.005% of full scale (1.5 mm for 45 psia range)
Hysteresis *	0.005% of full scale (1.5 mm for 45 psia range)
Calibration	0 psia to full scale pressure
Tide Resolution *	0.2 mm for 1-minute integration; 0.01 mm for 15-minute integration
Wave Resolution *	0.4 mm for 0.25-second integration; 0.1 mm for 1-second integration
* Stated values in mm for accuracy, repeatability, hysteresis, and resolution are for 45 psia (20 m) pressure sensor. Scale for other ranges, multiplying by (actual sensor range in psia / 45 psia).	
Temperature	
Range	-5 to +35 °C
Accuracy	0.02 °C
Resolution	0.01 °C
Calibration	+1 to +32 °C (measurements outside this range may be at slightly reduced accuracy due to extrapolation errors)
Conductivity (optional SBE 4M conductivity sensor)	
Range	0.0 to 7 S/m
Accuracy	±0.0003 S/m/month (typical); ±0.001 S/m/month (guaranteed; not applicable in areas of high bio-fouling or contamination or if Application Note 2D procedures are not followed)
Resolution	0.00002 S/m
Calibration	2.6 to 6 S/m plus zero conductivity (air)

Other Specifications	
Counter Time Base	Quartz TCXO ± 2 ppm per year aging; ± 2 ppm per year versus temperature (-5 to 30 °C)
Memory	8M byte CMOS static RAM, battery-backed for minimum of 2-years data retention
Data Storage	**Recorded Parameter** — **Bytes/Sample** Tide with temperature — 4 Tide with temperature & optional conductivity — 8 Wave burst — 3
Real-Time Clock	Watch-crystal type 32,768 Hz; battery-backed for minimum of 1-year operation, regardless of condition of main battery. Corrected for drift and aging by comparison to counter time base. Accuracy 5 ppm, resolution 2 milliseconds.
Current Requirements	***Quiescent current when not logging***: 90 microamps ***Quiescent current when logging***: 1.2 ma (while integrating pressure in-between tide samples, only counter, real-time clock, and pressure sensor are on; microprocessor and digital electronics are off except for a 4.4-second period during each tide measurement, and duration of each wave burst) ***Operating current*** (for 4.4-second period during each tide measurement, and duration of each wave burst) *Without conductivity sensor:* 65 ma *With conductivity sensor:* 75 ma
Power Supply	***9 alkaline D-cell batteries***: Typical capacity 5 (cold water) to 10 amp-hours (warm water) ***Optional lithium batteries*** (batteries not supplied by Sea-Bird): Typical capacity of 9 D-cells 42 amp-hours; 3 DD-cells 30 amp-hours ***Optional External power source***: 10 - 20 VDC
Weight	***In air, standard housing****:* 6 kg (13 lbs)
Housing Materials	***Standard****:* 600-meter acetal copolymer (plastic) pressure case with titanium end cap ***Optional****:* 7000-meter titanium pressure case and end cap

Dimensions and End Cap Connectors



Power Supply

Notes:
- For battery endurance calculations, see *Section 4: Pre-deployment Planning – Plan Deployment and Battery and Memory Endurance*.
- The cut-off voltage is 7.0 volts. If the voltage falls below that, the SBE 26 provides a warning message, and will not take measurements.

The main batteries for a standard SBE 26 are nine D-cell alkaline batteries (Duracell MN 1300, LR20). The SBE 26 can also be powered by lithium batteries; Sea-Bird can supply a lithium battery pack kit (lithium batteries **not** supplied by Sea-Bird). For lithium batteries, see *Shipping Precautions – Electrochem Lithium Batteries* in *Section 1: Introduction*.

The SBE 26 can also be powered from an external 10-20 VDC source. The internal batteries are diode-OR'd with the external source, so power is drawn from whichever voltage source is higher.

On-board lithium batteries (non-hazardous units which are unrestricted for shipping purposes) are provided to back-up the buffer and the real-time clock in the event of main battery failure, exhaustion, or removal. The main batteries can be replaced without affecting either the real-time clock or the memory.

Data I/O

The SBE 26 receives setup instructions and outputs diagnostic information or previously recorded data via a three-wire RS-232 link. The SBE 26 is factory-configured for 9600 baud, 7 data bits, 1 stop bit, and even parity.

- The baud rate for general communication (setup and diagnostics) cannot be changed by the user.
- The baud rate for uploading data from memory can be user-programmed to 9600, 19200, or 38400 baud.

Section 3: Software Installation and Use

Notes:
- Help files provide detailed information on Seasoft for Waves.
- Sea-Bird supplies the current version of our software when you purchase an instrument. As software revisions occur, we post the revised software on our FTP site. See our website (www.seabird.com) for the latest software version number, a description of the software changes, and instructions for downloading the software from the FTP site.

This section describes the installation and use of Seasoft for Waves.

The SBE 26 is supplied with a modular Windows 95/98/NT/2000/XP software package software package, **Seasoft for Waves**. The software provides pre-deployment planning, communication with the SBE 26 for setup and uploading of data from the SBE 26, separation of the raw data into separate wave and tide files, removal of barometric pressure from tide data, statistical analysis, and data plotting.

Software Installation

Sea-Bird recommends the following minimum system requirements for installing the software: Windows 2000 or later, 500 MHz processor, 256 MB RAM, and 90 MB free disk space for installation. Although Seasoft for Waves was designed to work with a PC running Win 2000/XP, extensive testing has not shown any compatibility problems when using the software with a PC running Vista or Windows 7 (32-bit).

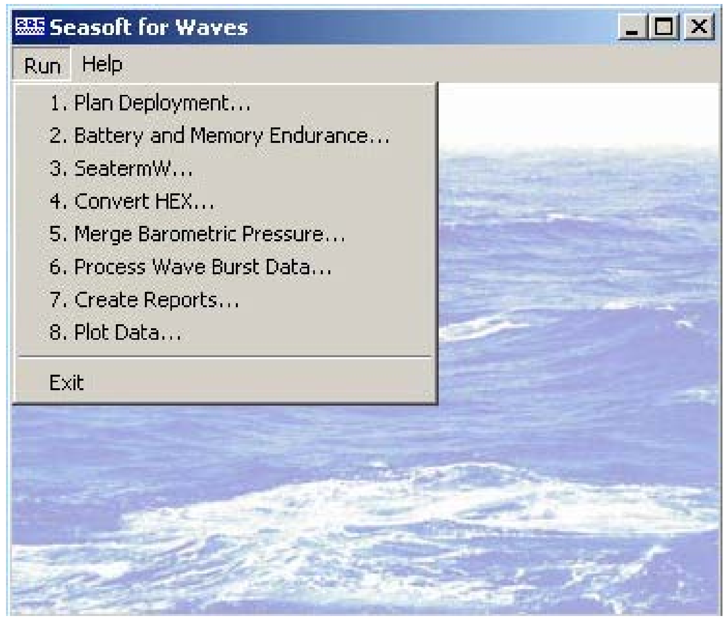
If not already installed, install Seasoft for Waves on your computer using the supplied software CD-ROM:

1. Insert the CD in your CD drive.

2. Install the software:
   A. In the CD-ROM drive, double click on **SeasoftWaves_V*_**.exe** (*_** = software version).
   B. Follow the dialog box directions to install the software.
   The default location for the software is
   c:/Program Files/Sea-Bird/SeasoftWaves.

Seasoft for Waves Use

Start Seasoft for Waves by double clicking on **SeasoftWavesLaunch.exe**. The main screen looks like this:



The Run menu lists each program module:

Type	Module Name	Module Description
Pre-deployment planning See *Section 4*	**Plan Deployment**	Calculate ratio of pressure amplitude measured by instrument to pressure amplitude at surface. Predict number of frequency bands calculated, width of each band, and frequency span.
	Battery and Memory Endurance	Calculate nominal battery and memory endurance for user-specified sampling scheme.
Terminal program See *Section 5*	**SeatermW**	Send commands for status, data acquisition setup, diagnostics, and data upload.
Data conversion See *Section 6*	**Convert Hex**	Convert uploaded raw data file into separate wave and tide files, with output data in engineering units.
Tide data processing See *Section 7*	**Merge Barometric Pressure**	Remove barometric pressure from tide data.
Wave data processing See *Section 8*	**Process Wave Burst Data**	Compute wave statistics.
	Create Reports	Output one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst.
Data plotting See *Section 9*	**Plot Data**	Plot data from a .tid, .wb, .was, .wts, and/or .wt file; plots can be printed. Plot Data can plot data at any point after raw hex data is converted into separate wave and tide files in Convert Hex.

File Types

File extensions are used by Seasoft for Waves to indicate the file type:

Extension	Description
.bmp	Bitmap graphics file created by Plot Data.
.bp	Barometric pressure data, used by Merge Barometric Pressure to remove barometric pressure from the tide data (.tid) file. This file, **not** supplied by Sea-Bird, is created by user, based on local barometric pressure data (such as that from a local weather station). See *Section 7: Tide Data Processing – Merge Barometric Pressure*.
.cap	Data and/or diagnostics captured using SeatermW.
.hex	Raw Hex data uploaded from SBE 26 memory using SeatermW.
.ini	There are two .ini files used in Seasoft for Waves: • SeasoftWaves.ini contains the location and file name of the last saved Program Setup (.psa) file and options settings for each module with a .psa file (Convert Hex, Merge Barometric Pressure, Process Wave Bursts, Create Reports, and Plot Data). • SeatermW.ini contains the last instrument type (SBE 26, 26*plus*, or 53), COM port, and baud rate used in SeatermW for communicating with the instrument. The .ini files are saved to %USERPROFILE%\Local Settings\Apps\Sea-Bird (*Example* C:\Documents and Settings\dbresko\ Local Settings\Apps\Sea-Bird)
.jpg	JPEG graphics file created by Plot Data.
.psa	Program Setup file, used by Convert Hex, Merge Barometric Pressure, Process Wave Bursts, Create Reports, and Plot Data to store setup information (such as input and output file names and locations, and processing instructions). The user can save the .psa files to the desired locations. As a default, the .psa files are saved to %USERPROFILE%\Application Data\SeasoftWaves (*Example* C:\Documents and Settings\dbresko\ Application Data\Sea-Bird\SeasoftWaves).
.r26	File containing one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst, created by Create Reports.
.rpt	Summary report, created by Process Wave Burst Data.
.tid	Tide measurements in engineering units, created from raw .hex file by Convert Hex. Also, file format for tide data that has had barometric pressure removed by Merge Barometric Pressure.
.was	Statistics and results from auto-spectrum analysis, created by Process Wave Burst Data.
.wb	Wave measurements in engineering units, created from raw .hex file by Convert Hex.
.wmf	Windows metafile graphics file created by Plot Data.
.wss	Fast Fourier Transform coefficients, created by Process Wave Burst Data if selected.
.wt	Surface wave time series, created by Process Wave Burst Data if selected.
.wts	Statistics from surface wave zero crossing analysis, created by Process Wave Burst Data.

See *Appendix III: Data Formats* for details on the format of each file.

Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance

This section covers:

- Planning the required wave burst parameters and placement of the SBE 26, using the Plan Deployment module in Seasoft for Waves.
- Calculating battery and memory endurance for the desired sampling scheme, using the Battery and Memory Endurance module in Seasoft for Waves.

Plan Deployment

Note:
See *Appendix VI: Wave Theory and Statistics* for a detailed discussion of the theory and equations for wave calculations.

Plan Deployment solves the wave dispersion relation to calculate and plot the pressure attenuation ratio:

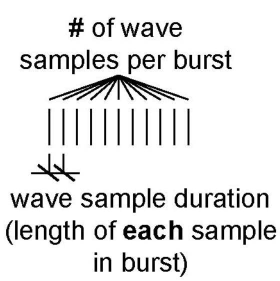
$$\text{Pressure attenuation ratio} = \frac{\text{pressure amplitude measured by SBE 26}}{\text{pressure amplitude at surface}}$$

given:

water depth (meters)
height of pressure sensor above bottom (meters)
wave period (seconds)

Pressure attenuation with depth is a strong function of the wave period; short period waves are attenuated much faster with depth than longer period waves. This implies that for a pressure sensor deployed at a fixed depth z, there is a high frequency cut-off *fmax* for which waves with f > fmax are not measurable. Above the high frequency cut-off, any noise in the subsurface pressure record is mapped by the transfer function into unrealistic surface wave height values.

The default high-frequency cutoff (fmax) for processing wave data in Process Wave Burst Data is the frequency where the ratio of pressure measured by the SBE 26 to pressure at the surface is less than (0.0025 / wave sample interval). Frequencies greater than fmax are typically not processed by Process Wave Burst Data.



Plan Deployment also predicts these surface wave analysis parameters:

- number of frequency bands calculated
- width of each frequency band (Hz)
- frequency span (Hz)

given:

water depth (meters)
height of pressure sensor above bottom (meters)
wave sample interval (time between successive wave pressure measurements)
points per wave burst (multiple of 4; for example, 4, 8, 16, etc.)
number of spectral estimates for each frequency band

Note:
If planning to calculate wave statistics, Sea-Bird recommends the following for meaningful, valid results:

- Samples per burst $\geq$ 512, and
- Samples per burst = power of 2 (for example, 512, 1024, etc.)

The maximum frequency in the frequency span is the lesser of:

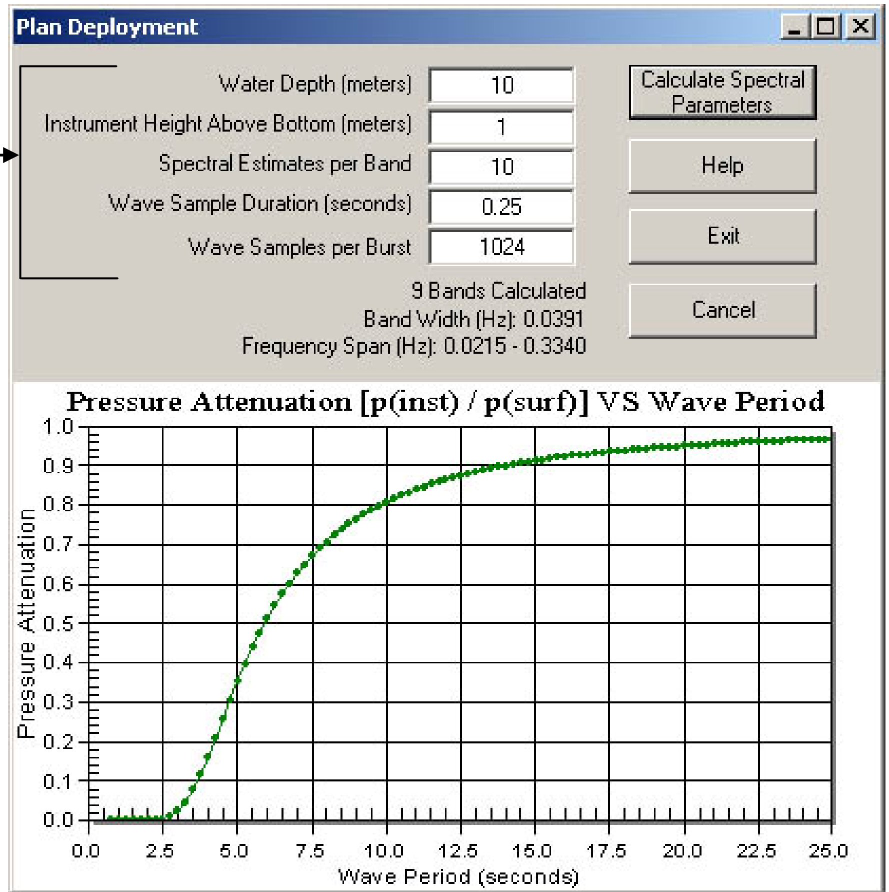
- 0.5 / sample interval (called the Nyquist frequency), or
- frequency (fmax described above) where ratio of pressure measured by SBE 26 to pressure at surface is less than (0.0025 / sample interval)

Appendix VI: Wave Theory and Statistics provides detailed discussion on band averaging.

In Seasoft for Waves' Run menu, select Plan Deployment. The dialog box looks like this:

Enter values and then click *Calculate Spectral Parameters* to calculate bands, band width, and frequency span, and calculate and plot pressure attenuation. Note that wave sample duration and wave samples per burst are programmed into SBE 26 with **SI**.

Pressure attenuation is wave pressure amplitude measured by instrument divided by wave pressure amplitude at surface.



Example:
Water depth is 10 meters. You are interested in measuring waves with frequencies up to 0.36 Hz (period = 1 / 0.36 = 2.8 seconds). You plan to sample waves 4 times per second (wave sample interval = 0.25 seconds) with 1024 samples/wave burst, and to process data with 10 spectral estimates/band. Can you place the SBE 26 at 1 meter above the bottom and accomplish your goals?

Running Plan Deployment with the above parameters (see dialog box above), the Frequency Span is 0.0215 to 0.3340 Hz. Since 0.3340 < 0.36, you cannot accomplish your goals.

Iterating on a solution by changing the instrument height in Plan Deployment, you find that placing the SBE 26 at 2.5 meters above bottom will allow you to measure the desired frequencies. Alternatively, you could consider modifying other sampling parameters while maintaining the instrument height.

Battery and Memory Endurance

Note:
See *Specifications* in *Section 2: Description of SBE 26* for power and memory specifications.

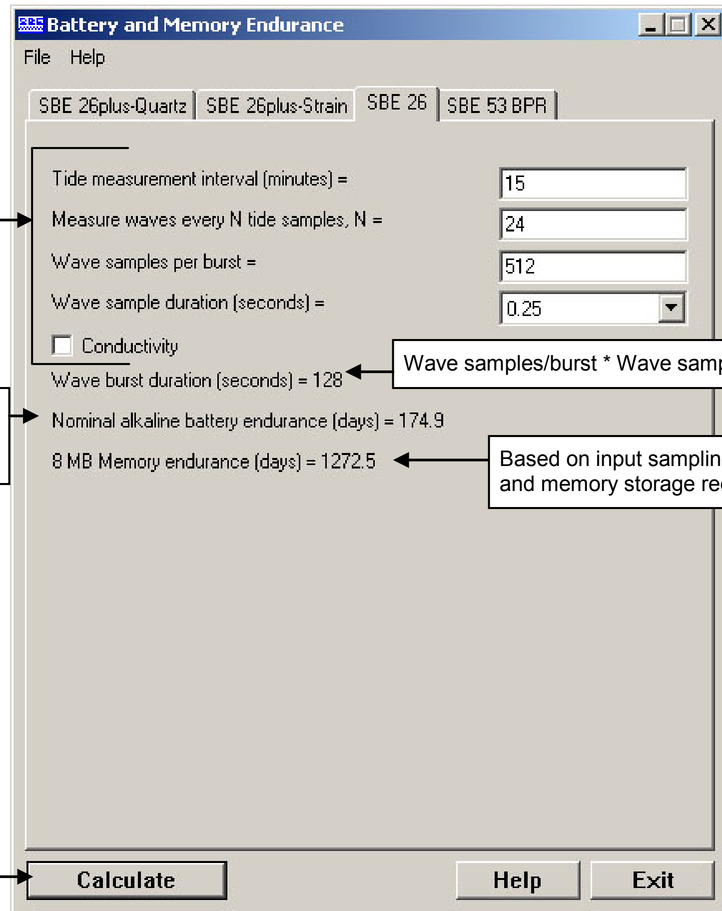
Power and memory endurance calculations for the SBE 26 are complex, and are dependent on the sampling scheme. Use Battery and Memory Endurance to calculate the endurance for a user-specified sampling scheme.

In Seasoft for Waves' Run menu, select Battery and Memory Endurance. Click on the SBE 26 tab in the dialog box. The dialog box looks like this:

Enter tide measurement interval, number of tide measurements between each wave burst, wave samples/burst, wave sample duration, and whether conductivity is also measured. Sampling setup is programmed into SBE 26 with **SI**; conductivity sampling is programmed into SBE 26 with **CY**or **CN**.

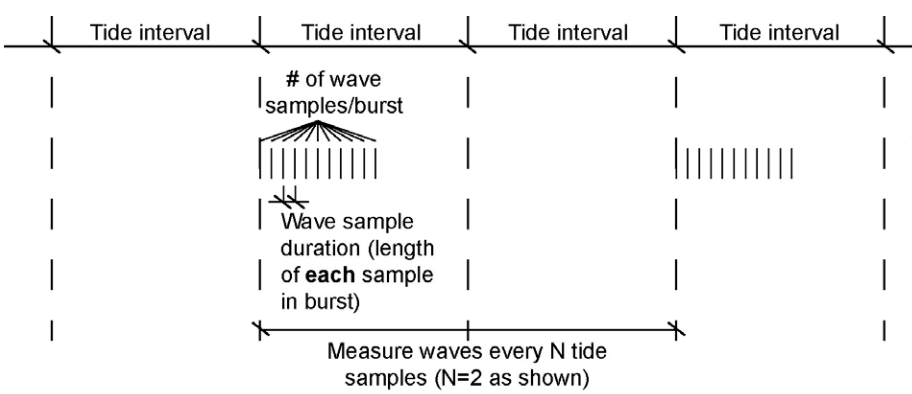
(Battery capacity / daily power consumption)
- Based on input sampling scheme and nominal 8 amp-hour capacity

Click *Calculate* to calculate battery and memory endurance.



Wave samples/burst * Wave sample duration

Based on input sampling scheme and memory storage requirements.



Notes:
- This drawing is schematic only, intended to define the sampling scheme terminology. See *Appendix II: Sample Timing* for timing details.
- See *Command Descriptions* in *Section 5: SBE 26 Setup, Installation, and Data Upload – SeatermW* for programming desired sampling scheme in SBE 26.

Note:
See *Specifications* in *Section 2: Description of SBE 26* for power requirements and battery ratings.

Discussions follow of the data and equations used in Battery and Memory Endurance; use this information to perform your own calculations if desired.

Battery Endurance

- **Quiescent power consumption when logging** (amp-hours per day)
  Only counter, real-time clock, and pressure sensor are on continuously while logging.
  1.2 mA * 86400 seconds/day * 1 hr/3600 second * 1 amp /1000 ma
  = 0.0288 amp-hours/day

- **Tide measurement**
  On time for microprocessor and digital electronics during each tide measurement = 4.4 seconds.

  Power consumption (amp-hours) during tide measurement *on* time:

  Without conductivity sensor (65 ma operating current)
  4.4 seconds * 65 ma * 1 hr/3600 second * 1 amp/1000 ma
  = 8.0×10^{-5} amp-hours

  With conductivity sensor (75 ma operating current)
  4.4 seconds * 75 ma * 1 hr/3600 second * 1 amp/1000 ma
  = 9.2×10^{-5} amp-hours

- **Wave measurement**

  Wave burst duration =
  [number of wave measurements * wave integration time (seconds)] + 1

  Power consumption (amp-hours) during each wave burst =
  65 ma * 1 hr/3600 second * 1 amp/1000 ma
  = 1.8×10^{-5} amp-hours / second of wave burst

- **Total power consumption (amp-hours)**

  Without conductivity sensor
  (total number of days * 0.0288) +
  (total number of tide measurements * 8.0×10^{-5}) +
  (total number of wave burst measurements * burst duration * 1.8×10^{-5})

  With conductivity sensor
  (total number of days * 0.0288) +
  (total number of tide measurements * 9.2×10^{-5}) +
  (total number of wave burst measurements * burst duration * 1.8×10^{-5})

Example: SBE 26 without conductivity sensor; with standard alkaline batteries.
Measure tides every 15 minutes (4/hour * 24 hours = 96 measurements/day).
Measure waves after every 24 tide samples (96 / 24 = 4 wave bursts/day).
Take 512 wave measurements per burst, at 0.25-second integration time per measurement.
Wave burst duration / day = 4 [(512 * 0.25) + 1] = 516 seconds.
Assume 8 amp-hours of battery capacity.
(Note: This is same sampling scheme as shown in Battery and Memory Endurance dialog box above.)

Power consumption = [(0.0288) + (96 * 8.0×10^{-5}) + (516 * 1.8×10^{-5})] * Number of Days
Power consumption = 0.045768 * Number of Days
Number of days of battery capacity = 8 amp-hours / 0.045768 = 174.8 days
As a check, compare with the output of Battery and Memory Endurance on the SBE 26 tab; the program shows approximately the same results.

Memory Endurance

Note:
In response to the status (**DS**) or sample interval (**SI**) command, the SBE 26 calculates memory endurance for the given sampling scheme, *taking into account the number of samples already in memory*. Battery and Memory Endurance calculates the *total* memory endurance for a sampling scheme.

The SBE 26 comes standard with an 8 MB memory. Memory used for storing logged data is:

$$\text{Bytes/day} = 4 * (N + C + W [(0.75 * M) + 4])$$

where
N = number of tide samples/day
C = N = number of conductivity samples/day (if conductivity enabled)
W = number of wave bursts/day
M = number of wave measurements/burst

Example: SBE 26 without conductivity sensor.
Measure tides every 15 minutes (4/hour * 24 hours = 96 measurements/day).
Measure waves after every 24 tide samples (96 / 24 = 4 wave bursts/day).
Take 512 wave measurements per burst.
(Note: This is same sampling scheme as shown in Battery and Memory Endurance dialog box above, and in power endurance calculation examples.)

N = 96, C = 0 (no conductivity sensor), W = 4, M = 512
Bytes/day = 4 * (96 + 0 + 4 [(0.75 * 512) + 4]) = 6592 bytes/day
Memory capacity ≈ 8 MB * 1024 * 1024 = 8,388,608 bytes
Memory endurance ≈ 8,388,608 / 6592 = 1272.5 days

As a check, compare with the output of Battery and Memory Endurance; the programs shows approximately the same results. Note that for this example, the SBE 26 memory capacity far exceeds the power capacity.

Section 5: SBE 26 Setup, Installation, and Data Upload - SeatermW

This section covers:

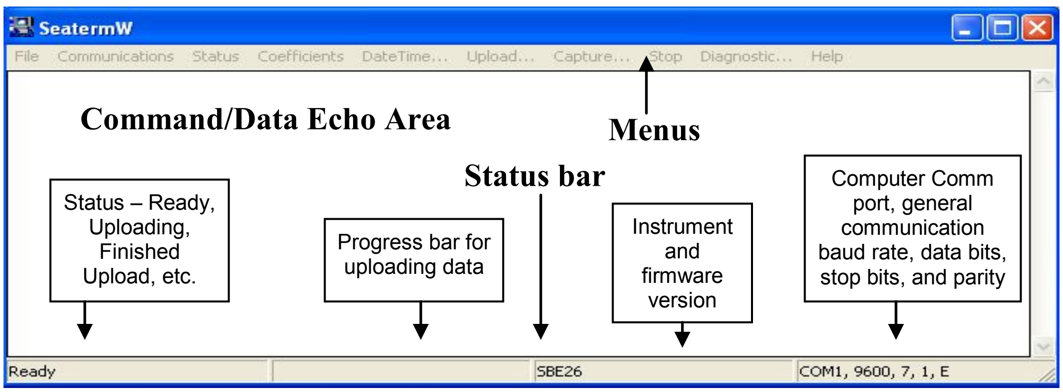
- Programming the SBE 26 for deployment using SeatermW
- Command descriptions
- Installing and deploying the SBE 26
- Recovery and uploading data from memory using SeatermW

Programming for Deployment - SeatermW

Note:
Once the system is configured and connected (Steps 3 and 4 below), to update the Status bar, click Status. SeatermW sends the status command (**DS**), which displays in the Command/Data Echo Area, and updates the Status bar.

1. Connect the SBE 26 to the computer using the 4-pin data I/O cable:
   A. By hand, unscrew the locking sleeve from the SBE 26's I/O connector. If you must use a wrench or pliers, be careful not to loosen the I/O connector instead of the locking sleeve.
   B. Remove the dummy plug from the SBE 26's I/O connector by pulling the plug firmly away from the connector.
   C. **Standard Connector** - Install the Sea-Bird I/O cable connector, aligning the raised bump on the side of the connector with the large pin (pin 1 - ground) on the SBE 26. **OR**
   MCBH Connector – Install the cable, aligning the pins.
   D. Connect the I/O cable connector to your computer's serial port.

2. In Seasoft for Waves Run menu, select SeatermW.
   The main screen looks like this:



- Menus – Contains tasks and frequently executed instrument commands.
- Command/Data Echo Area – Echoes a command executed using a Menu, as well as the SBE 26's response. Additionally, a command can be manually typed in this area, from the available commands for the SBE 26. The SBE 26 must be *awake* for it to respond to a command (use Connect to wake up the SBE 26).
- Status bar – Provides status information.

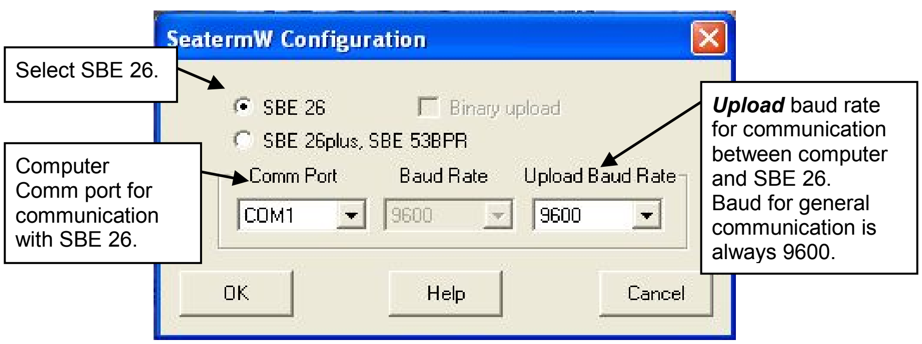
Note:
You must be *connected* to the instrument (Connect in Communications menu) when using Status, Coefficients, Upload, Stop, or Diagnostic.

Following is a description of the menus:

Menu	Description	Equivalent Command*
File	Exit SeatermW.	-
Communications	Connect / Disconnect - Re-establish communications with SBE 26. Computer responds with `S>` prompt. 26 *goes to sleep* after 2 minutes without communication from computer have elapsed. Configure - Establish communication parameters (instrument, Comm port, *upload* baud rate).	(press Enter key)
Status	Display SBE 26 setup and status (logging, samples in memory, etc.).	**DS**
Coefficients	Display pressure sensor and temperature sensor calibration coefficients that are hard coded in SBE 26 EPROM.	**DC**
Upload	Upload data stored in memory, in format our data processing modules can use. Uploaded data has .hex extension. Before using Upload, send **QL** to **stop logging**.	Upload with **DDb,e**, **DEb,e**, or **DAb,e** (use Upload if you will be processing data with Seasoft for Waves)
Capture	Capture SBE 26 responses on screen to file; may be useful for diagnostics. File has .cap extension. Click Capture again to turn off capture. Capture status displays in Status bar.	-
Stop	Interrupt and end current activity, such as uploading data or running a diagnostic test (such as **FR** or **VR**). Note: This does not stop logging – use **QL** to stop logging.	(press Esc key several times)
Diagnostic	Perform diagnostic tests on SBE 26. Diagnostic tests accessed in this manner are non-destructive – they do not write over any existing settings.	**DS**; **DC**; **DD0,10**; **FR**

*See *Command Descriptions* below.

3. In the Communications menu, select Configure. The dialog box looks like this:



Verify/modify the parameters in the Configuration dialog box. Click OK.

4. In the Communications menu, select Connect. The display looks like this:

```
SEAGAUGE POWER ON
S>
```

This shows that correct communications between the computer and SBE 26 has been established. If the system does not respond with the `S>` prompt:

- Select Connect again.
- Verify the instrument and Comm port were entered correctly in the Configure dialog box.
- Check cabling between the computer and SBE 26.

Note:
The SBE 26 communicates at 9600 baud, 7 data bits, 1 stop bit, and even parity, as documented on the instrument Configuration Sheet.

Note:
The SBE 26 automatically enters quiescent (sleep) state after 2 minutes without receiving a command. This timeout algorithm conserves battery energy if the user does not send **QS** to put the SBE 26 to sleep. If the system does not appear to respond, select Connect in the Communications menu to reestablish communications.

5. Display SBE 26 status information by clicking Status; SeatermW sends **DS**. The display looks like this:

```
SBE 26 SEAGAUGE V4.1d SN335, 06/06/02 08:37:54.328
pressure sensor: serial number 36285, range = 45 psi
clk = 32767.843  iop = 63  vmain = 13.1  vlith = 5.9
last sample: p = 14.6734  t = 2.227

tide measurement interval = 15 min
measure waves every 24 tide samples
128 wave samples/burst at 4.00 scans/second

tide samples/day = 96.000
wave bursts/day = 4.000
memory endurance = 4227.482 days
recorded tide measurements = 0
recorded wave bursts = 0

conductivity = NO
logdata = NO
```

6. Send the desired commands to set up the SBE 26 (see *Command Descriptions* below). Verify the setup by clicking Status again.

7. Test the setup by typing **GL** and pressing the Enter key to begin logging.

   The SBE 26 responds:
   `Start logging Y/N?`
   Type *y* and press the Enter key.

   The SBE 26 responds:
   `Are you sure ^Y/N?` (^ indicates the Ctrl key)
   Hold down the Ctrl key and type *y*, and press the Enter key.

   The SBE 26 displays the sample interval setup, and then asks:
   `Set up ok Y/N?`
   Type *y* and press the Enter key.

   The SBE 26 responds:
   `Start data logging`

Note:
See *Appendix II: Sample Timing* for a detailed description of when tide and wave measurements are made and stored in memory.

   The first two times the SBE 26 begins a tide measurement, the display shows:
   `SEAGAUGE POWER ON`

   For the third and subsequent tide measurements, the display looks like this:

```
SEAGAUGE POWER ON
Tides: 06/07/02  09:27:02.370
Psia=14.7705, ptemp=20.92, tvolt=1.268, cfreq=2699.342
```

   where:
   - time = end of tide interval measurement
   - psia = calculated and stored pressure
   - ptemp = calculated pressure temperature (not stored)
   - tvolt = stored temperature voltage
   - cfreq = conductivity sensor frequency (shown only if conductivity was enabled with **CY**)

   When a wave burst measurement is made, the display looks like this:
   `aadadadadad`
   where:
   - One *a* always displays at the start.
   - Number of *d*'s = (wave samples/burst + 1). For this example, the number of wave samples/burst is 4, so 5 *d*'s display.
   - Each *d* is preceded by (n – 1) *a*'s, where n = number of 0.25-second periods to integrate waves. For this example, n = 2 (two 0.25-second periods, corresponding to a wave sampling rate of 1 scan/0.5 seconds, or 2 scans/second).

8. End the test by typing **QL** and pressing the Enter key to stop logging.

   The SBE 26 responds:
   `Quit logging Y/N?`
   Type *y* and press the Enter key.

   The SBE 26 responds:
   `Are you sure ^Y/N?` (^ indicates the Ctrl key)
   Hold down the Ctrl key and type *y*, and press the Enter key. The SBE 26 stops logging.

9. (if ready for deployment) Type **GL** and press the Enter key to begin logging again, overwriting any data in memory.

   OR

   (if not ready for deployment) Type **QS** and press the Enter key to command the SBE 26 to go to sleep (quiescent state).

Command Descriptions

This section describes commands and provides sample outputs.
See *Appendix I: Command Summary* for a summarized command list.

When entering commands:

- Input commands in upper or lower case letters and register commands by pressing the Enter key.
- The SBE 26 sends **#** if an invalid command is entered.
- If the system does not return an `S>` prompt after executing a command, press the Enter key to get the `S>` prompt.
- If a new command is not received within 2 minutes after completion of a command, the SBE 26 returns to the quiescent (sleep) state and the display indicates `time out`.
- If in quiescent state, re-establish communications by clicking Connect or pressing the Enter key to get an `S>` prompt.
- Commands followed by * alter SBE 26 memory and prompt the user twice before executing (* is not part of the command). To execute the command, type *y* and press the Enter key in response to *`message`* `Y/N`. Then hold down the Ctrl key and type *y*, and press the Enter key in response to `are you sure ^Y/N`. Any other responses abort the command.
- The SBE 26 responds only to **DS**, **QS**, and **QL** while logging, and does not respond at all while making a wave burst measurement. If you wake up the SBE 26 while it is logging (for example, to send **DS** to check on logging progress), it does not interrupt logging. However, the integrated pressure frequency is incorrect for the interval when the SBE 26 woke up.
- Use Upload to upload data that will be processed by Seasoft for Waves. Manually entering a data upload command does not produce data with the required header information for processing by Seasoft for Waves.
- If the SBE 26 is uploading data and you want to stop it, press the Esc key or click Stop. Press the Enter key to get the `S>` prompt.

Entries made with the commands are permanently stored in the SBE 26 and remain in effect until you change them.

- The only exceptions occur if the electronics are removed from the housing and disconnected from the battery Molex connector (see *Appendix IV: Electronics Disassembly/Reassembly*), or the SBE 26's reset switch is used (see *Section 11: Troubleshooting*). Upon reassembly or resetting, initialize RAM (**IR**), reset the date and time (**ST**), and re-enter all the setup parameters.

Status Commands

Note:
You can wake up the SBE 26 and display status (press Enter key to get `S>`, then click Status) without interrupting logging. However, the integrated pressure frequency is incorrect for the interval when the SBE 26 woke up.

DS

Display operating status and setup parameters.

Equivalent to Status menu.

List below includes, where applicable, command used to modify parameter.

- Firmware version, serial number, date and time [**ST**]
- Pressure sensor serial number and full scale range
- Real-time clock frequency, voltages and currents (main operating current, main and back-up lithium battery voltages)
- Wait interval after each line of data [**LWx**] – line only appears if not 0
- Last measured pressure (psia) and temperature (ºC)
- Interval between tide samples [**SI**]
- Interval between wave bursts [**SI**]
- Number of wave measurements/burst [**SI**]
- Calculated number of tide samples/day [based on **SI**]
- Calculated number of wave bursts/day [based on **SI**]
- Calculated memory endurance for sampling scheme [based on **SI** and number of measurements in memory]
- Number of tide measurements in memory
- Number of wave bursts in memory
- Enabling of conductivity sensor [**Cx**]
- Logging status (logdata=no or yes)

Note:
Memory endurance in the **DS** response is based on *remaining* space in memory, taking into account the number of tide measurements and wave bursts in memory and the setup (tide measurement interval, wave samples, etc).
To determine *total* memory endurance for a sampling scheme:
- Run Battery and Memory Endurance, **or**
- Verify all logged data has been uploaded from memory; delete all logged data in memory with **IR**; and send **DS** again.

For information on **battery** endurance, see *Battery and Memory Endurance* in *Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance* for calculating power consumption for your intended sampling scheme.

Example: (user input in bold).

```
S>DS
SBE 26 SEAGAUGE V4.1d SN335, 06/06/02 08:37:54.328
pressure sensor: serial number 36285, range = 45 psi
clk = 32767.843  iop = 63  vmain = 13.1  vlith = 5.9
lwait = 1000 msec
last sample: p = 14.6734  t = 2.227

tide measurement interval = 15 min
measure waves every 24 tide samples
128 wave samples/burst at 4.00 scans/second

tide samples/day = 96.000
wave bursts/day = 4.000
memory endurance = 4227.482 days
recorded tide measurements = 0
recorded wave bursts = 0

conductivity = NO
logdata = NO
```

Notes:
- These calibration coefficients should match the Calibration Sheets supplied with the SBE 26.
- Some temperature sensor Calibration Sheets list g and x instead of AI and XI. Verify that g = AI and x = XI.
- These calibration coefficients are hard coded into the SBE 26 EPROM, and cannot be changed by command. **Other calibration parameters are entered in Convert Hex's Coefficient Configuration dialog box when converting the raw uploaded data to engineering units**; see *Section 6: Conversion into Tide and Wave Files – Convert Hex*.
- For discussion of how calibration coefficients are generated, see *Sensor Calibration* in *Section 10: Routine Maintenance and Calibration*.

Status Commands (*continued*)

DC — Display pressure sensor and temperature sensor coefficients that are hard coded into SBE 26 EPROM.

Example: SBE 26 with Paroscientific Digiquartz sensor (user input in bold).

```
S>DC
Paroscientific Digiquartz calibration coefficients:
U0 = 5.842227
Y1 = -3.932.789
Y2 = -11618.080
Y3 = 0.000
C1 = 157.03740
C2 = 20.163780
C3 = -148.10980
D1 = 0.0507923
D2 = 0.000
T1 = 25.08749
T2 = 0.4489404
T3 = 17.33406
T4 = 0.000
T5 = 0.000
M = 9532.5
B = 4766.3
Temperature coefficients:
Z = -49043.5
RH = 47000.0
AI = 271800.0
XI = -8.745
```

Setup Commands

IR * — Initialize memory, **which destroys all logged data in SBE 26 memory**. SBE 26 requires verification before it proceeds. All data bits are set to 0; sample number and data pointers are set to 0. Allow several minutes to initialize memory.

Send **IR** after uploading all data. Use of **IR** is optional, as SBE 26 writes over previously recorded information when **GL** is sent to begin logging. However, knowledge of initial memory contents (i.e., all zeroes) can be a useful cross-check when data is retrieved.

Example (user input in bold):

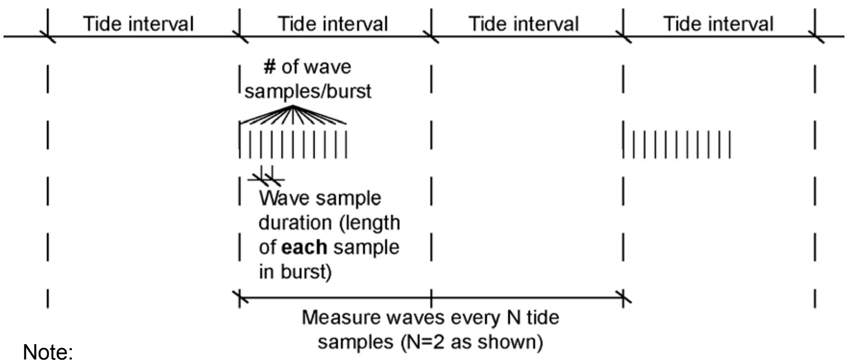
```
S>IR
Initialize ram Y/N? y
Are you sure ^Y/N? ^y
```
(Note: ^ indicates Ctrl key. Hold down Ctrl key and type *y*, and press Enter key.)
```
Writing ram 0
. .
Writing ram 255
```

ST — Set real-time clock date and time.

Example (user input in bold): Set current date and time to 05 October 2002 12:00:00.

```
S>ST
date (MMDDYY)=100502
time (HHMMSS)=120000
```

Setup Commands (*continued*)



Note:
This drawing is schematic only, intended to define the sampling scheme terminology. See *Appendix II: Sample Timing* for detailed description of when tide and wave measurements are made and stored in memory.

Note:
Time required for each wave burst must be less than (tide interval - 30 seconds). If the user setup does not meet this requirement, the SBE 26 reduces the number of measurements in the wave burst to meet the requirement.

Note:
Memory endurance is based on *remaining* space in memory, taking into account the number of tide measurements and wave bursts in memory and the setup (tide measurement interval, wave samples, etc). To determine *total* memory endurance for a sampling scheme:

1. Verify all logged data has been uploaded from memory.
2. Delete all logged data in memory with **IR**.
3. Send **SI** or **DS**.

For **battery** endurance, see *Battery and Memory Endurance* in *Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance*.

SI Set sampling intervals and parameters. SBE 26 displays present value and asks for new value for each parameter. Type in desired value and press Enter key. To accept present value without change, press Enter key. Program prompts as follows:

tide interval (integer minutes) = 15 minutes, new value =
Time for each tide measurement. SBE 26 integrates data over this entire period, counting frequency signal continuously and computing an average pressure for the interval.

wave burst after every N tide measurements: N = 4, new value =
Wave burst is sampled every (N * tide interval minutes). Maximum is 32767.

wave samples/burst (integer multiple of 4) =128, new value =
Number of wave measurements/burst. If entered number is not multiple of 4, SBE 26 rounds down to make it multiple of 4. **To calculate wave statistics on uploaded data, Sea-Bird recommends following for meaningful, valid results:**
-- waves samples/burst ≥ 512, and
-- wave samples/burst = power of 2 (512, 1024, etc.).

number of 0.25 second periods to integrate waves (1-128) = 1, new value =
SBE 26 samples at maximum rate of 4 Hz (0.25 seconds / wave burst measurement). This parameter reduces wave burst sampling rate and increases integration time per measurement (for example, one 0.25-second period to integrate corresponds to wave sample duration of 0.25 seconds; ten 0.25-second periods to integrate corresponds to wave sample duration of 2.5 seconds).

SBE 26 then displays a summary of sampling parameters as well as the calculated number of samples per day and ***memory*** endurance for the input sampling scheme (shown in example below). Note that this information is also included in **DS** response. After displaying summary, SBE 26 asks:

Wave and tide intervals ok Y/N ? =
y to save parameters and return to S> prompt, or *n* to start over at first prompt.

Setup Commands (*continued*)

Example (user input in bold)***:***

Set up SBE 26 to take a tide measurement every 15 minutes (tide interval = 15), measure waves after every 24 tide samples (wave burst after every N tide measurements = 24), and take 512 wave samples per wave burst (wave samples/burst = 512) at 1 Hz (number of 0.25 second periods to integrate waves = 4).

S>**SI**

SBE 26 responds with prompts (described above) for you to enter sampling parameters. Press Enter key to accept current value, or type in new value and press Enter key.

When finished, a summary of parameters displays. For this example:

```
tide measurement interval = 15.0 min
measure waves every 24 tide samples
512 wave samples/burst at 1.00 scans/second

tide samples/day = 96.000
wave bursts/day = 4.000
memory endurance = 1272.544 days
recorded tide measurements = 0
recorded wave bursts = 0
```

Then, SBE 26 prompts:

Wave and tide intervals ok Y/N ? = **Y**

Cx

x=Y: Enable conductivity logging (if SBE 26 includes optional SBE 4M conductivity sensor).

x=N: Disable conductivity logging.

LWx

x= wait interval (milliseconds) after each line of data. Normally set to 0; increase for very old (slow) computers. Range 0 - 65535.

QS

Quit session and place SBE 26 in quiescent (sleep) state. Main power is turned off. Memory retention is not affected.

Logging Commands

> **Note:**
> You can wake up the SBE 26 and display status (press the Enter key to get the `S>`, then click Status) without interrupting logging. However, the integrated pressure frequency is incorrect for the interval when the SBE 26 woke up.

GL * Start logging, **which overwrites all logged data in SBE 26 memory**. Therefore, SBE 26 requires verification before it proceeds. SBE 26 displays sample intervals and then requires verification again that setup is OK before proceeding. When logging starts, first sample number is set to 0, so any previously recorded data is written over, regardless of whether memory has been initialized (**IR**).

QL * Quit logging. SBE 26 requires verification before it proceeds.

Example: Start and stop logging (user input in bold).
`S>`**`GL`**
`Start logging Y/N?` **y**
`Are you sure ^Y/N?` **^y** (Note: ^ indicates Ctrl key. Hold down Ctrl key and type *y*, and press Enter key.)
(SBE 26 displays sample interval setup, and then asks:)
`set up ok Y/N?` **y**
`start data logging`

(See *Programming for Deployment - SeatermW* for a description of screen displays while logging.)

(to stop logging, press Enter key several times to get `S>` prompt)
`S>`**`QL`**
`Quit logging Y/N?` **y**
`Are you sure ^Y/N?` **^y** (Note: ^ indicates Ctrl key. Hold down Ctrl key and type *y*, and press Enter key)

Data Upload Commands

> **Notes:**
> - **Use Upload to upload data to a .hex file that will be processed by Seasoft for Waves.** Manually entering **DD**, **DE**, or **DA** does not produce data with the required header information for processing by Seasoft for Waves. These commands are included here for reference for users who are writing their own software.
> - To save data to a file, click Capture before entering **DD**, **DE**, or **DA**.
> - The SBE 26 pauses for 1 second after receipt of **DE** or **DA** to allow the receiving software to change the baud rate. The baud automatically changes back to 9600 (baud rate for general communication) after data uploads.

Stop logging before uploading data.

DDb,e Upload raw data from memory in Hexadecimal from sample **b** to **e** at 9600 baud. If only **b** is entered, data for sample **b** is displayed. If **b** and **e** are omitted, all data displays.

DEb,e Upload raw data from memory in Hexadecimal from sample **b** to **e** at 19200 baud. If only **b** is entered, data for sample **b** is displayed. If **b** and **e** are omitted, all data displays.

DAb,e Upload raw data from memory in Hexadecimal from sample **b** to **e** at 38400 baud. If only **b** is entered, data for sample **b** is displayed. If **b** and **e** are omitted, all data displays.

Diagnostic Commands

TM * Memory test, **which destroys all data in SBE 26 memory**. Therefore, SBE 26 requires verification before proceeding. A pattern is written into all locations of each RAM. Data in RAM is then compared to pattern.

TE * Extended memory test, **which destroys all data in SBE 26 memory**. Therefore, SBE 26 requires verification before proceeding. Same as **TM** test, but 10 passes are performed, with pattern incremented by 1 for each pass.

Example: Perform extended memory test (user input in bold).

```
S>te
Extended memory test Y/N? y
Are you sure ^Y/N? ^y
```

(Note: ^ indicates Ctrl key. Hold down Ctrl key and type *y*, and press Enter key.)

```
Pass 1
Ram 0, OK
. .
Ram 255, OK
```

(repeats entire sequence for passes 2 through 10)

At conclusion of test or when Esc is received, SBE 26 displays:

```
Ram test passed with no errors
```

FR Measure and display frequencies:

Column	Output
1	**pf** = pressure frequency
2	**tf** = pressure temperature compensation frequency
3	**cf** = conductivity sensor frequency (displays only if conductivity enabled with **CY**)

SBE 26 runs continuously during test, drawing current. Press Esc key or Stop to stop test.

VR Measure and display voltages read by A/D converter:

Column	Output
1	Main battery voltage / 5.0161
2	Lithium battery voltage / 3.873
3	Raw thermistor voltage
4	Raw voltage from large reference resistor
5	Raw voltage from small reference resistor

SBE 26 runs continuously during test, drawing current. Press Esc key or Stop to stop test.

Installing and Deploying SBE 26

CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.

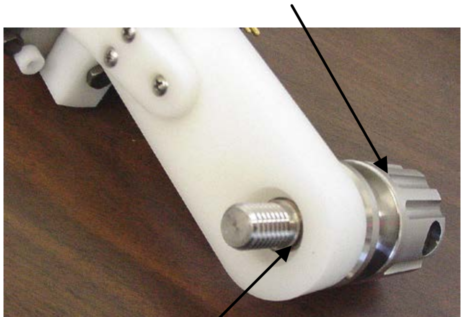
1. Install a dummy plug on the data I/O connector on the SBE 26 end cap:
   A. Lightly lubricate the inside of the dummy plug with silicone grease (DC-4 or equivalent).
   B. **Standard Connector** - Install the plug, aligning the raised bump on the side of the plug with the large pin (pin 1 – ground) on the SBE 26. Remove any trapped air by *burping* or gently squeezing the plug near the top and moving your fingers toward the end cap. **OR**
   MCBH Connector – Install the plug, aligning the pins.
   C. Place the locking sleeve over the plug. Tighten the locking sleeve finger tight only. **Do not overtighten the locking sleeve and do not use a wrench or pliers**.

2. If not using the SBE 4M conductivity sensor, install a dummy plug and locking sleeve on the SBE 26 3-pin bulkhead connector.
   Use the technique described in Step 1 for lubricating and burping a standard connector.

Note:
Acquisition of conductivity data must be enabled by sending **CY** in SeatermW when programming the SBE 26 for deployment.

3. (Optional) Install the SBE 4M conductivity sensor:
   A. Mount the SBE 4M to the SBE 26 with the supplied mounting bracket, positioning the SBE 4M connector towards the conductivity connector on the SBE 26.
   B. Connect the SBE 4M to the SBE 26 with the supplied cable, using the technique described in Step 1 for lubricating and burping, and then installing the locking sleeve.
   C. Remove the Tygon tubing that was looped end-to-end around the SBE 4M conductivity cell to keep the cell clean while stored.
   D. See *Application Note 70: Installing Anti-Foulant Device Mounting Kit on SBE 4, 16, 19, and 21 Conductivity Cells*, and *Appendix V: AF24173 Anti-Foulant Device*

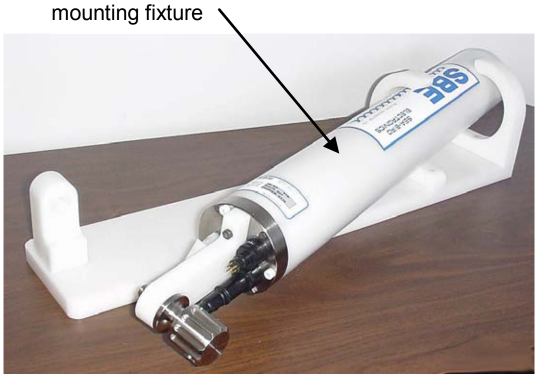
Mooring pin

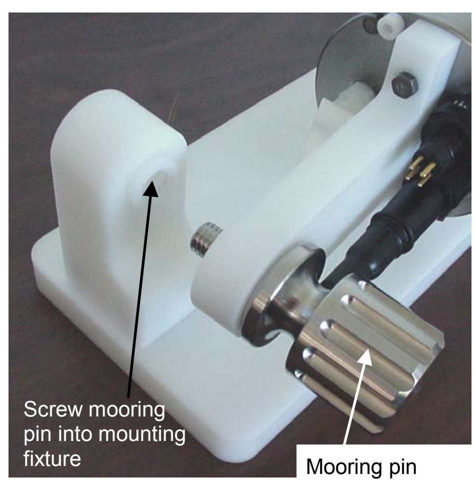


Install retaining ring in recess after inserting mooring pin

4. (Optional) Mount the SBE 26 in the Sea-Bird mounting fixture:
   A. Slide the mooring pin through the SBE 26 lift eye hole in the direction shown.
   B. Install the retaining ring in the lift eye hole recess, to hold the mooring pin to the SBE 26. Push part of the retaining ring into the recess, and hold it in place with a small tool (such as tweezers or small screwdriver). Using another pair of tweezers, work your way around the retaining ring, pushing it into the recess.
   C. Rotate the SBE 26 into the mounting fixture as shown.
   D. Screw the mooring pin into the mounting fixture.

Rotate SBE 26 into mounting fixture





Mooring pin

Recovering SBE 26

WARNING!
If the SBE 26 stops working while underwater, or shows other signs of flooding or damage, carefully secure it away from people until you have determined that abnormal internal pressure does not exist or has been relieved. Pressure housings may flood under pressure due to dirty or damaged o-rings, or other failed seals. When a sealed pressure housing floods at great depths and is subsequently raised to the surface, water may be trapped at the pressure at which it entered the housing, presenting a danger if the housing is opened before relieving the internal pressure. Instances of such flooding are rare. However, a housing that floods at 5000 meters depth holds an internal pressure of more than 7000 psia, and has the potential to eject the end cap with lethal force. A housing that floods at 50 meters holds an internal pressure of more then 85 psia; this force could still cause injury.
If you suspect the SBE 26 is flooded, point the SBE 26 in a safe direction away from people, and loosen the 3 screws on the connector end cap about ½ turn. If there is internal pressure, the end cap will *follow* the screws out, and the screws will not become easier to turn. In this event, loosen 1 bulkhead connector very slowly, at least 1 turn. This opens an o-ring seal under the connector. Look for signs of internal pressure (hissing or water leak). If internal pressure is detected, let it bleed off slowly past the connector o-ring. Then, you can safely remove the end cap.

Rinse the SBE 26 with fresh water. See *Section 10: Routine Maintenance and Calibration* for (optional) conductivity cell cleaning and storage.

Uploading Data from Memory

Note:
The SBE 26 communicates at 7 data bits, 1 stop bit, and even parity, as documented on the instrument Configuration Sheet. The baud rate for general communication is always 9600.

1. In Seasoft for Waves' Run menu, select SeatermW.
   SeatermW appears.

2. Select Configure in the Communications menu. The Configuration dialog box appears. Verify/modify the instrument, Comm port, and upload baud rate (9600, 19200, or 38400). Click OK.

3. Select Connect in the Communications menu. The `S>` displays. This shows that correct communications between the computer and SBE 26 has been established.
   If the system does not respond with the `S>` prompt:
   - Select Connect again.
   - Verify the correct instrument and Comm port were selected.
   - Check cabling between the computer and SBE 26.

4. If the SBE 26 is still logging, command the SBE 26 to stop logging by typing **QL** and pressing the Enter key.

   The SBE 26 responds:
   Stop logging (Y/N)?.
   Type *y* and press the Enter key.

   The SBE 26 responds:
   Are you sure (^Y/N).
   Hold down the Ctrl key and type *y*, and press the Enter key

5. Display SBE 26 status information by clicking Status. The status response should indicate `logdata = no`.

6. Click Upload to upload stored data in a form that Seasoft for Waves' data processing modules can use. SeatermW responds as follows:
   A. SeatermW sends the status (**DS**) command, displays the response, and writes the command and response to the upload file, with each line preceded by *. **DS** provides information regarding the number of samples in memory, sample intervals, etc.
   B. SeatermW sends the calibration coefficients (**DC**) command, displays the response, and writes the command and response to the upload file, with each line preceded by *. **DC** provides information regarding the sensor calibration coefficients.
   C. In the Save As dialog box, enter the desired upload file name and click OK. The upload file has a .hex extension.
   D. SeatermW sends the data upload command (**DD**, **DE**, or **DA**, depending on the upload baud rate you selected in the Configure dialog box in Step 2), and writes the Hex data to the upload file. The Status bar displays the progress of the upload, indicating the number of uploaded lines of data.

7. Type **QS** and press the Enter key to put the SBE 26 in quiescent (sleep) state until ready to redeploy.

8. Ensure all data has been uploaded by processing the data. See *Section 6: Conversion into Tide and Wave Files – Convert Hex*.

Section 6: Conversion into Tide and Wave Files – Convert Hex

Convert Hex converts uploaded raw hex (.hex) data into separate wave data (.wb) and tide data (.tid) files, with data in ASCII engineering units. Convert Hex must be run before further processing by Seasoft for Waves.

Note:
The first time you run Convert Hex, the Coefficients dialog box (Step 2 below) appears first.

Proceed as follows:

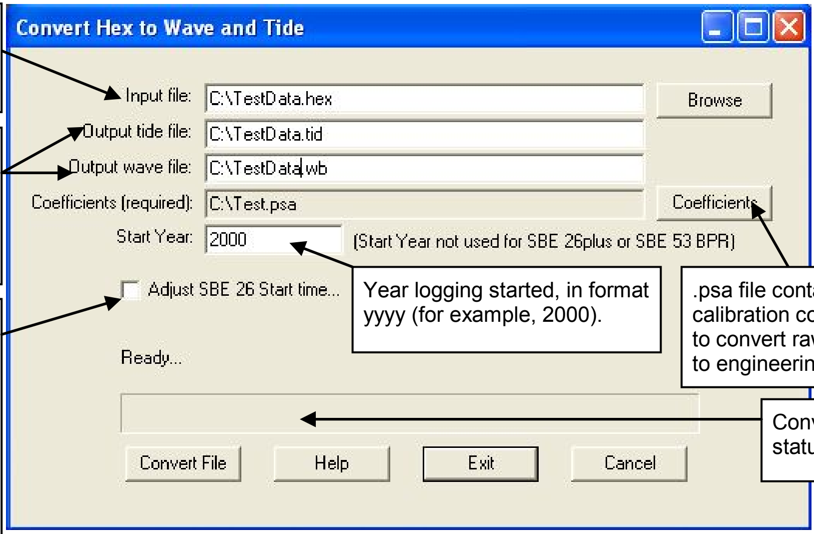
1. In Seasoft for Waves' Run menu, select Convert Hex. The dialog box looks like this:

.hex file uploaded from SBE 26 memory. Click Browse to search for file, or type in path and file name.

Desired path and file names for output tide (.tid) and wave (.wb) file. Default paths and file names are same as input .hex file. If desired, type in path and file name to change it from default.

Correct start date and time in input data file, if required. Because of a leap year firmware bug in SBE 26, you may need to adjust SBE 26 Start time if either of following is true:

- SBE 26 was deployed on February 29, or
- Date and time were set before February 29 and SBE 26 was deployed after February 29.



Year logging started, in format yyyy (for example, 2000).

.psa file contains calibration coefficients to convert raw hex data to engineering units.

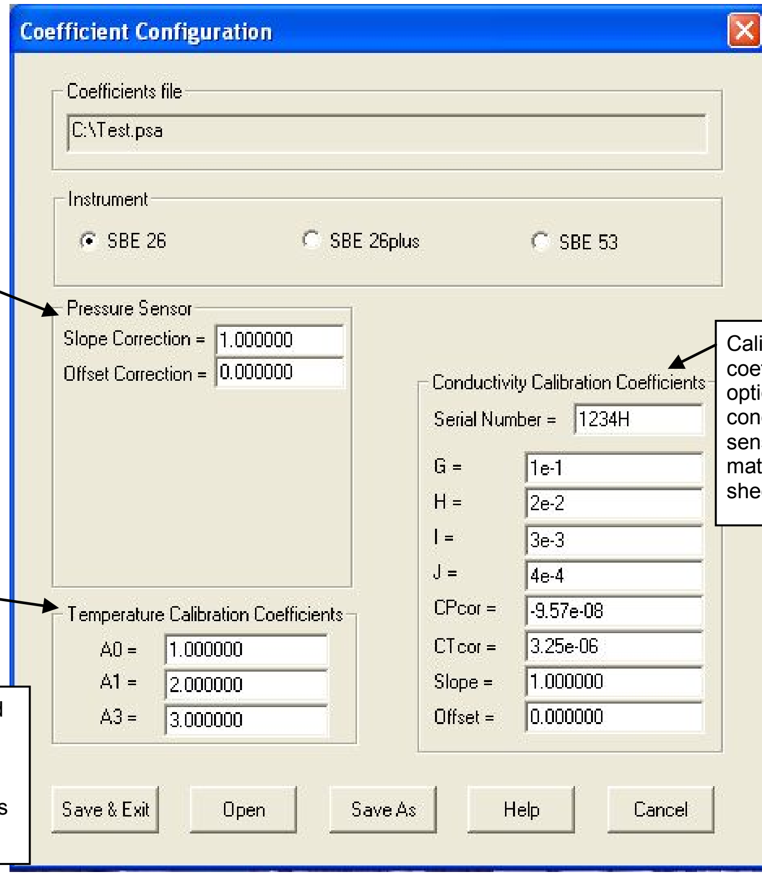
Conversion status bar.

Note:
SeasoftWaves.ini contains the location and file name of the last saved .psa file for each module. SeasoftWaves.ini is stored in %USERPROFILE%\Local Settings\Apps\Sea-Bird
(*Example* C:\Documents and Settings\dbresko\Local Settings\Apps\Sea-Bird)

Enter information in the dialog box. Click Coefficients to enter / verify calibration coefficients for converting raw hex data to engineering units.

Note:
Older versions of Seasoft for Waves used a .ini file or a .cfg file for calibration coefficients. These files are not compatible with the current version of Seasoft for Waves. Re-enter the calibration coefficients in the .psa file.

2. The Coefficients dialog box looks like this:



Slope and offset used to make small corrections for presure sensor drift between calibrations. Other pressure sensor calibration coefficients are hard coded into SBE 26 EPROM, and cannot be changed; view those coefficients with **DC** in SeatermW.

Calibration coefficients for optional conductivity sensor; must match calibration sheet.

Temperature sensor calibration coefficients; must match calibration sheet. Other temperature sensor calibration coefficients are hard coded into SBE 26 EPROM, and cannot be changed; view those coefficients with **DC** in SeatermW.

Save & Exit to save updated .psa file and return to Convert Hex to Wave and Tide dialog box.
Open to select a different .psa file.
Save As to save updated .psa file settings to a different .psa file.

Make desired changes. Click OK to return to Convert Hex to Wave and Tide dialog box.

3. Click *Convert File* to process the data. The Status bar at the bottom of the dialog box shows the progress of the calculations; when completed, the Status bar shows *Finished conversion*.

Section 7: Tide Data Processing – Merge Barometric Pressure

Note:
The barometric pressure (.bp) file is **not** supplied by Sea-Bird. It is created by the user, based on local barometric pressure data (such as that from a local weather station). See *Input Barometric Pressure File Format* below for the required data format.

Note:
SeasoftWaves.ini contains the location and file name of the last saved .psa file for each module. SeasoftWaves.ini is stored in %USERPROFILE%\Local Settings\Apps\Sea-Bird (*Example* C:\Documents and Settings\dbresko\Local Settings\Apps\Sea-Bird)

Merge Barometric Pressure reads in a tide (.tid) file (created with Convert Hex) and a barometric pressure (.bp) file, and subtracts barometric pressure from the tide data. The time in the files does not need to be aligned – Merge Barometric Pressure uses linear interpolation to align the data in time before subtracting barometric pressure. Merge Barometric Pressure can also convert tide pressure to water depth in meters, using average density and gravity.

Both the input tide data and output adjusted file have a .tid extension. However, Merge Barometric Pressure will not process a .tid file that it has already processed, preventing a user from erroneously removing barometric pressure multiple times from the tide data.

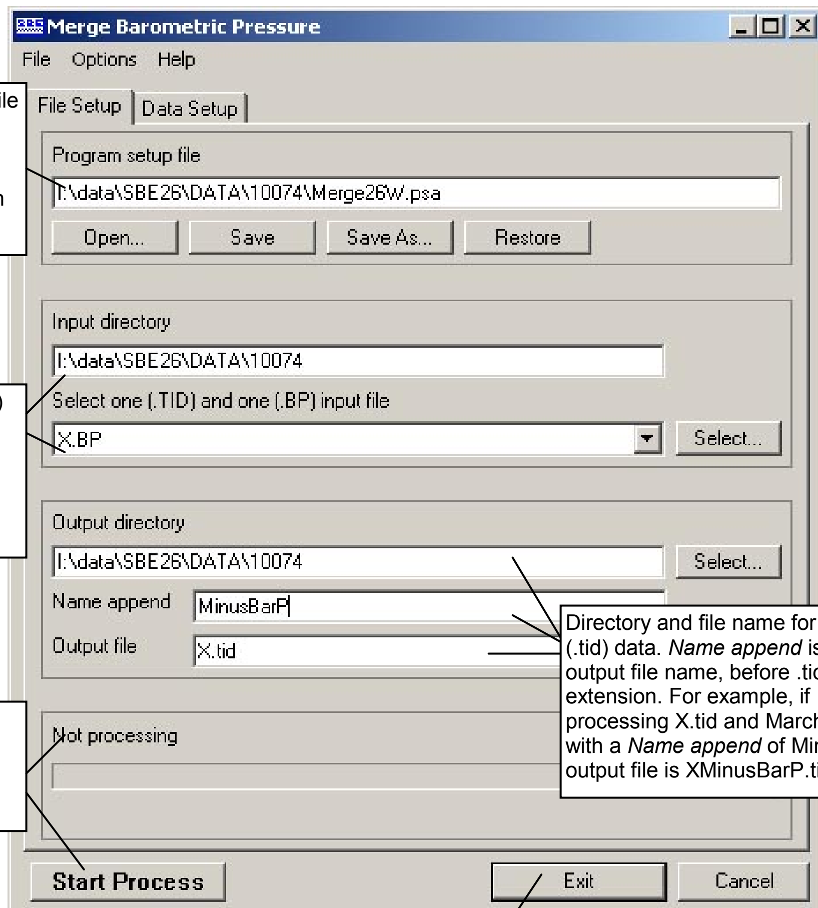
Remove barometric pressure as follows:

1. In Seasoft for Waves' Run menu, select Merge Barometric Pressure. The File Setup tab looks like this:

File to store all information input in File Setup and Data Setup tabs. **Open** to select a different .psa file, **Save** or **Save As** to save current settings, or **Restore** to reset all settings to match last saved version.

Directory and file names for tide (.tid) data and barometric pressure (.bp) data. Note that both .tid and .bp files must be in same directory, but they can have different names. **Select** to pick different files.

Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

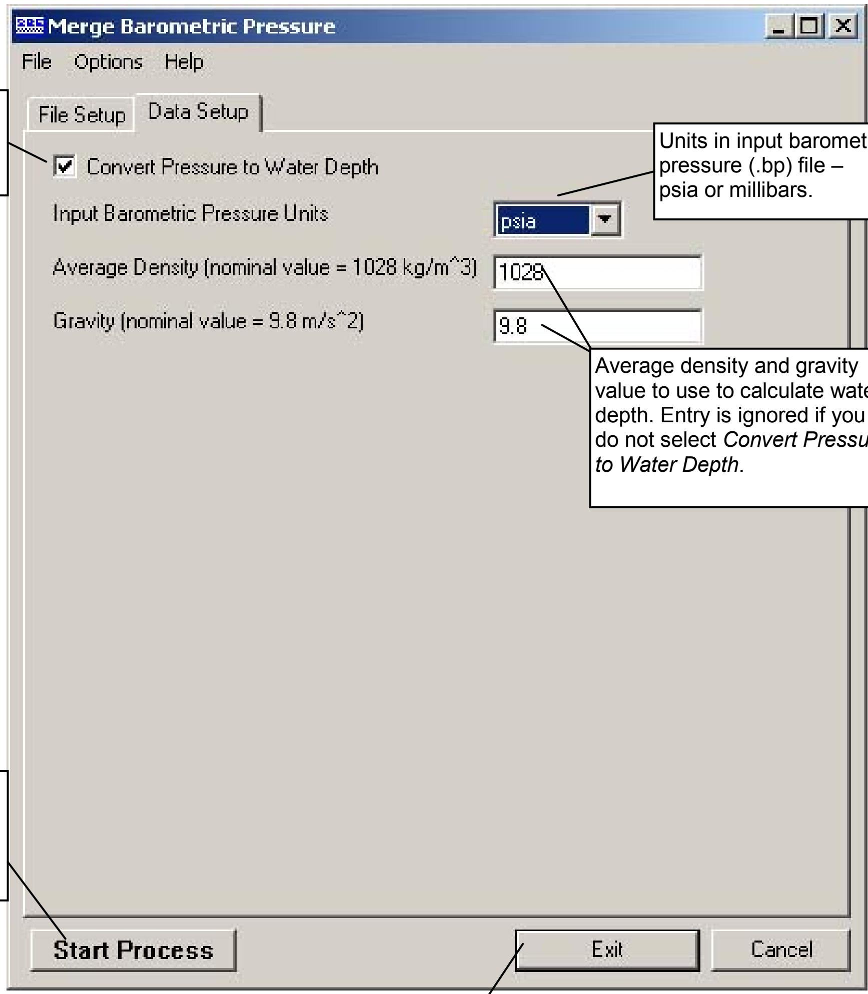


Directory and file name for output (.tid) data. *Name append* is added to output file name, before .tid extension. For example, if processing X.tid and March03.bp with a *Name append* of MinusBarP, output file is XMinusBarP.tid.

Return to Seasoft for Waves window.
- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Make the desired selections.

2. Click on the Data Setup tab. The Data Setup tab looks like this:



If selected, output .tid file contains water depth *in place of* pressure.

Units in input barometric pressure (.bp) file – psia or millibars.

Average density and gravity value to use to calculate water depth. Entry is ignored if you do not select *Convert Pressure to Water Depth*.

Click **Start Process** to begin processing data. Status field on File Setup tab shows *Processing complete* when done.

Return to Seasoft for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Make the desired selections and click *Start Process* to process the data.

Note:
Merge Barometric Pressure adds descriptive headings to the pressure (or depth), temperature, and optional conductivity and salinity columns. The presence of headings in the .tid file indicates that it has been processed by Merge Barometric Pressure. See *Appendix III: Data Formats*.

Input Barometric Pressure File Format

Note:
The barometric pressure (.bp) file is **not** supplied by Sea-Bird. It is created by the user, based on local barometric pressure data (such as that from a local weather station).

The required format for the input barometric pressure (.bp) file is:

MM/DD/YY HH:MM:SS P
MM/DD/YY HH:MM:SS P

where

MM = month	DD = day	YY = year
HH = hour	MM = minute	SS = second

P = barometric pressure in psia or millibars
(1 standard atmosphere = 14.7 psia or 1013.5 millibars)

Example .bp File:

```
07/01/94  00:00:00  1015.5
07/01/94  01:00:00  1016.4
07/01/94  02:00:00  1017.3
```

Merge Barometric Pressure Algorithm

The linear interpolation algorithm is:

$$p_{bp} = p0 + [(t - t0) * (p1 - p0) / (t1 - t0)]$$

$$\text{corrected pressure} = p - p_{bp}$$

where

t = time of tide sample in .tid file
p = pressure in .tid file at time t
t0 = latest time in .bp file that is less than or equal to t
p0 = barometric pressure at time t0
t1 = earliest time in .bp file that is greater than or equal to t
p1 = barometric pressure at time t1
p_{bp} = interpolated barometric pressure

Depth is calculated as:

depth = corrected pressure / (average density * gravity)

See Appendix *VII: Pressure-to-Depth Conversion*.

Section 8: Wave Data Processing – Process Wave Burst Data and Create Reports

Seasoft for Waves includes two wave data processing modules, which are covered in this section:

Note:
See *Appendix VI: Wave Theory and Statistics* for details on the calculations made by Seasoft for Waves.

- Process Wave Burst Data – Compute wave statistics from an input .wb wave burst file. Output .was statistics and results from auto-spectrum analysis, .rpt summary report, .wts statistics from surface wave zero crossing analysis, .wt surface wave time series, and .wss Fast Fourier Transform coefficients.
- Create Reports - Create .r26 file with one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst, from input .was and .wts files.

Process Wave Burst Data

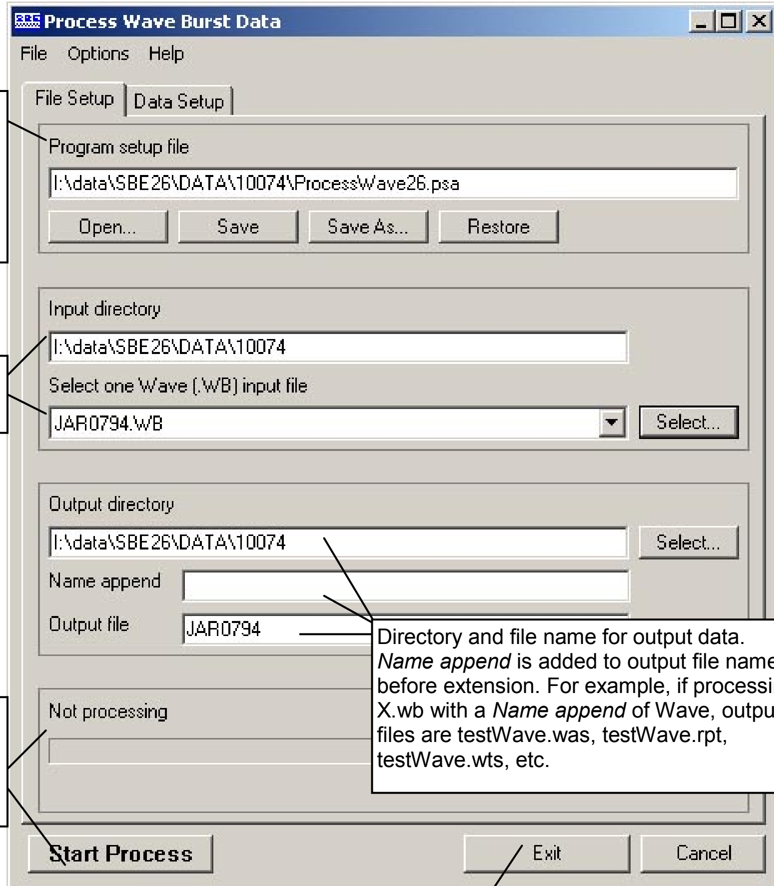
Process Wave Burst Data computes wave statistics from an input .wb wave burst file (created in Convert Hex). Process Wave Burst Data outputs three (or optionally four or five) files:

- Statistics and results from auto-spectrum analysis to a .was file.
- Summary report from auto-spectrum analysis to a .rpt file.
- Statistics from surface wave zero crossing analysis to a .wts file.
- (optional) Surface wave time series to a .wt file
- (optional) Fast Fourier Transform coefficients to a .wss file

Note:
SeasoftWaves.ini contains the location and file name of the last saved .psa file for each module. SeasoftWaves.ini is stored in %USERPROFILE%\ Local Settings\Apps\Sea-Bird (*Example* C:\Documents and Settings\ dbresko\Local Settings\Apps\Sea-Bird)

Process wave data as follows:

1. In Seasoft for Waves' Run menu, select Process Wave Burst Data. The File Setup tab looks like this:



File to store all information input in File Setup and Data Setup tabs. **Open** to select a different .psa file, **Save** or **Save As** to save current settings, or **Restore** to reset all settings to match last saved version.

Directory and file name for wave (.wb) data. **Select** to pick different file.

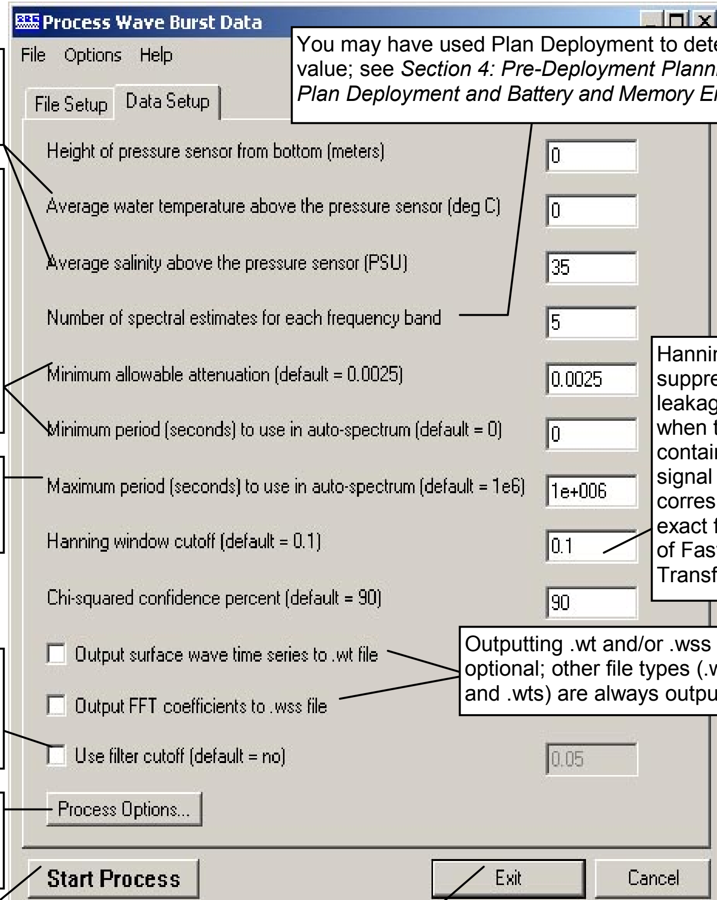
Directory and file name for output data. *Name append* is added to output file name, before extension. For example, if processing X.wb with a *Name append* of Wave, output files are testWave.was, testWave.rpt, testWave.wts, etc.

Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to Seasoft for Waves window.
- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Make the desired selections.

2. Click on the Data Setup tab. The Data Setup tab looks like this:



You may have used Plan Deployment to determine desired value; see *Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance*.

Average temperature and salinity used to calculate density, required for wave statistics algorithm.

High frequency cutoff for processing wave data, fmax, is smaller of:
- frequency where (measured pressure / pressure at surface) < (minimum allowable attenuation / wave sample duration).
- 1 / minimum period

If getting high frequency noise in output, adjust minimum allowable attenuation and/or minimum period. Frequencies > fmax are not processed unless *Use filter cutoff* is selected.

Hanning window suppresses spectral leakage that occurs when time series contains periodic signal that does not correspond to one of exact frequencies of Fast Fourier Transform.

Low frequency cutoff fmin = (1 / maximum period). Frequencies < fmin are not processed unless *Use filter cutoff* is selected.

Outputting .wt and/or .wss files is optional; other file types (.was, .rpt, and .wts) are always output.

If **not** selected, all Fourier coefficients for frequencies > fmax and < fmin are set to 0. If selected, filter ramps Fourier coefficients down to 0 for frequencies > fmax and < fmin.

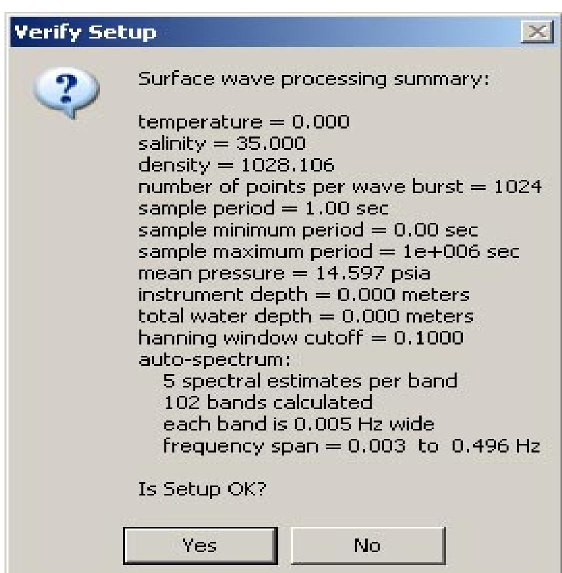
Select number of wave bursts to process and number of wave bursts to skip at start of data file. Default - process all bursts.

Begin processing. Status field on File Setup tab shows *Processing complete* when done.

Return to Seasoft for Waves window.
- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Make the desired selections and click *Start Process* to process the data.

3. The Verify Setup dialog box appears:



The dialog box summarizes data from the input .wb file and user inputs from the Data Setup tab, and shows calculated values for density, number of bands, band width, and frequency span. Review the summary; click *Yes* to process data.

Process Wave Burst Data Algorithm

For each wave burst, Process Wave Burst Data performs an auto spectrum analysis:

- Reads burst into an array.
- Removes mean, saves mean value.
- Uses mean value, and average water temperature and average salinity (input by user) to compute density.
- Removes trend.
- Makes array a power of two.
- Applies Hanning window to suppress side-lobe leakage.
- Adjusts scale factor to account for tapering by Hanning window.
- Fast Fourier Transforms to create raw spectral estimates of subsurface pressure.
- Computes maximum frequency to process.
- Sets Fourier coefficients greater than maximum frequency or less than minimum frequency to 0; **or**
  (if Use filter cutoff is selected) applies a filter that ramps the Fourier coefficients down to 0 for frequencies greater than maximum frequency or less than minimum frequency
- Saves Fourier coefficients.
- Band averages raw spectral estimates to create auto-spectrum.
- Applies dispersion transfer function to band center frequencies.
- Calculates wave statistics from auto-spectrum: variance, energy, significant wave height, and significant period.

Using the saved (non-band-averaged) Fourier coefficients, Process Wave Burst Data performs a surface wave zero crossing analysis:

- Applies dispersion transfer function to each frequency.
- Inverse Fast Fourier Transforms to create surface wave time series.
- Applies inverse Hanning window and adjusts scale factor.
- Zeroes all elements where inverse Hanning factor is greater than 10.
- Performs zero crossing analysis of surface wave time series to create an array of individual waves and their corresponding periods.
- Sorts wave array in ascending order.
- Calculates wave statistics from surface wave time series:
  average wave height, average period, maximum wave height, significant period, significant wave height $H_{1/3}$, $H_{1/10}$, $H_{1/100}$.

Create Reports: Summarize Wave Data

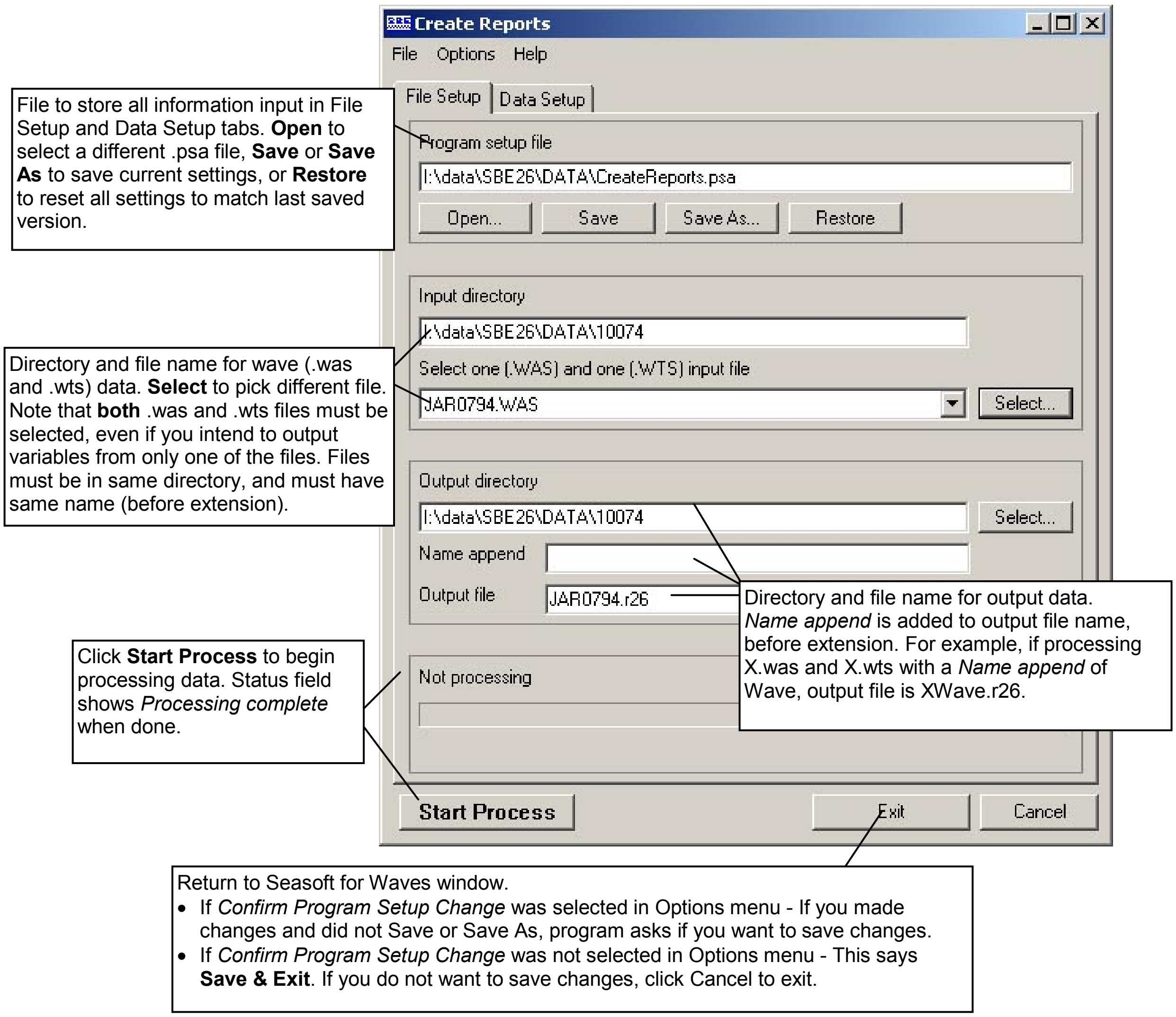
Create Reports creates a file containing one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst. The input .wts file contains surface wave time series statistics and the input .was file contains wave burst auto spectrum statistics (these files are created in Process Wave Burst Data). The output .r26 file format is user-defined and can contain one or more of the following variables:

	Variable	**Column Label**
From Surface Wave Time Series Statistics (.wts) File	Time	Time
	burst number	burst
	pressure sensor depth	depth
	number of waves	nwaves
	variance	var-wts
	Energy	energy-wts
	average wave height	avgheight
	average wave period	avgper
	maximum wave height	maxheight
	significant wave height	swh-wts
	significant wave period	swp-wts
	$H_{1/10}$	H1/10
	$H_{1/100}$	H1/100
From Wave Burst Auto-Spectrum Statistics (.was) File	variance	var-was
	energy	energy-was
	significant wave height	swh-was
	significant wave period	swp-was

Note:
SeasoftWaves.ini contains the location and file name of the last saved .psa file for each module. SeasoftWaves.ini is stored in %USERPROFILE%\Local Settings\Apps\Sea-Bird
(*Example* C:\Documents and Settings\dbresko\Local Settings\Apps\Sea-Bird)

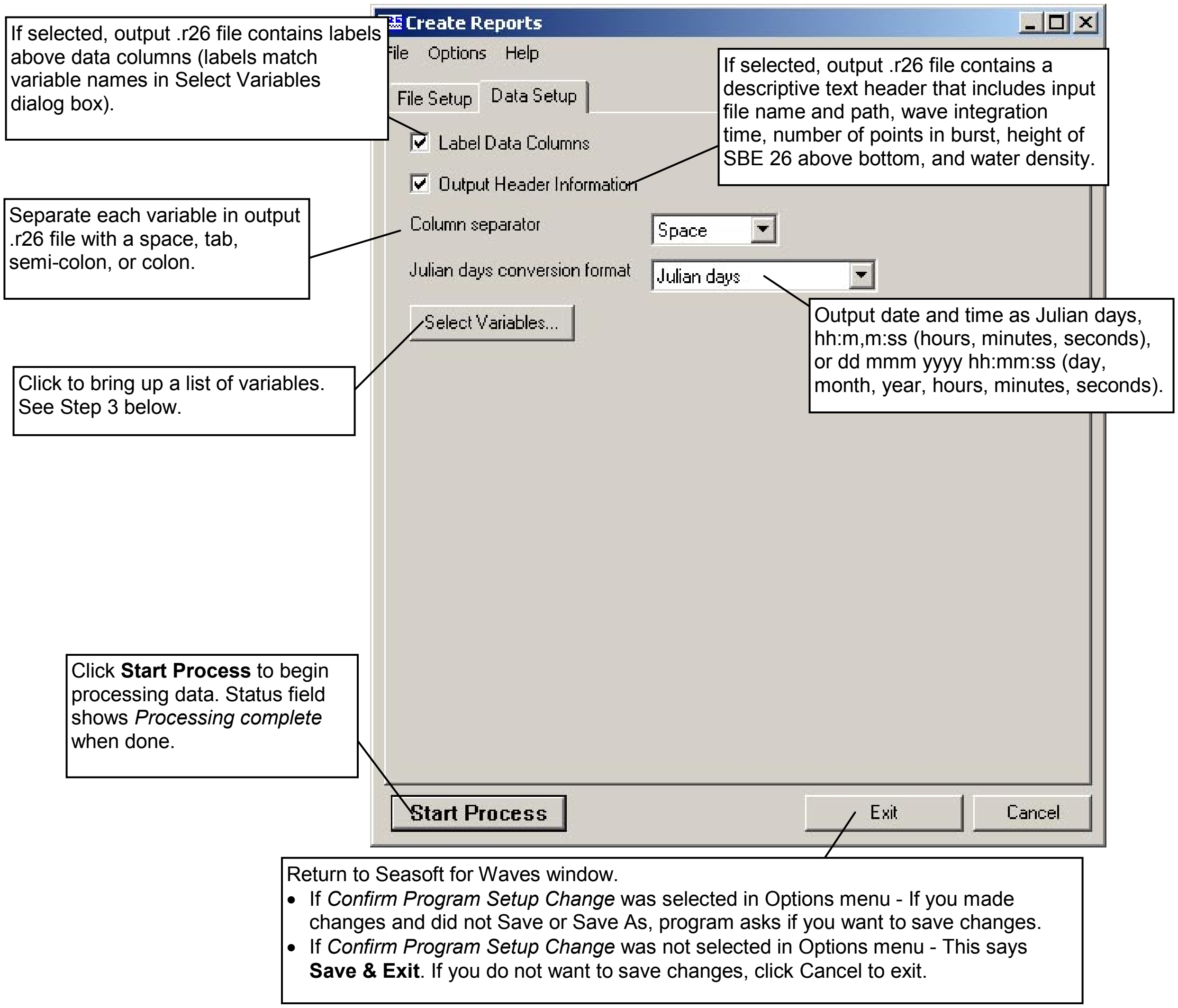
Proceed as follows:

1. In Seasoft for Waves' Run menu, select Create Reports. The File Setup tab looks like this:



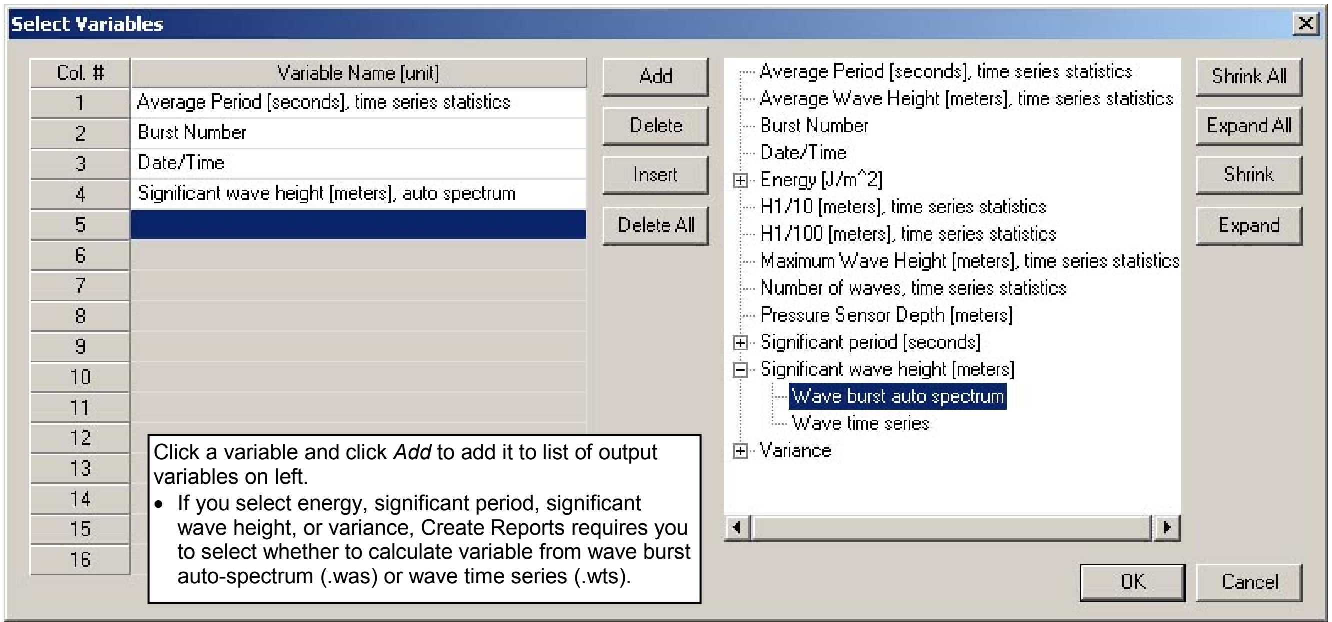
Make the desired selections.

2. Click on the Data Setup tab. The Data Setup tab looks like this:



Make the desired selections.

3. Click *Select Variables*. The Select Variables dialog box looks like this:



Make the desired selections and click *OK* to return to the Create Reports data setup tab.

4. Click *Start Process* to process the data.

Section 9: Data Plotting – Plot Data

Note:
SeasoftWaves.ini contains the location and file name of the last saved .psa file for each module. SeasoftWaves.ini is stored in %USERPROFILE%\ Local Settings\Apps\Sea-Bird (*Example* C:\Documents and Settings\ dbresko\Local Settings\Apps\Sea-Bird)

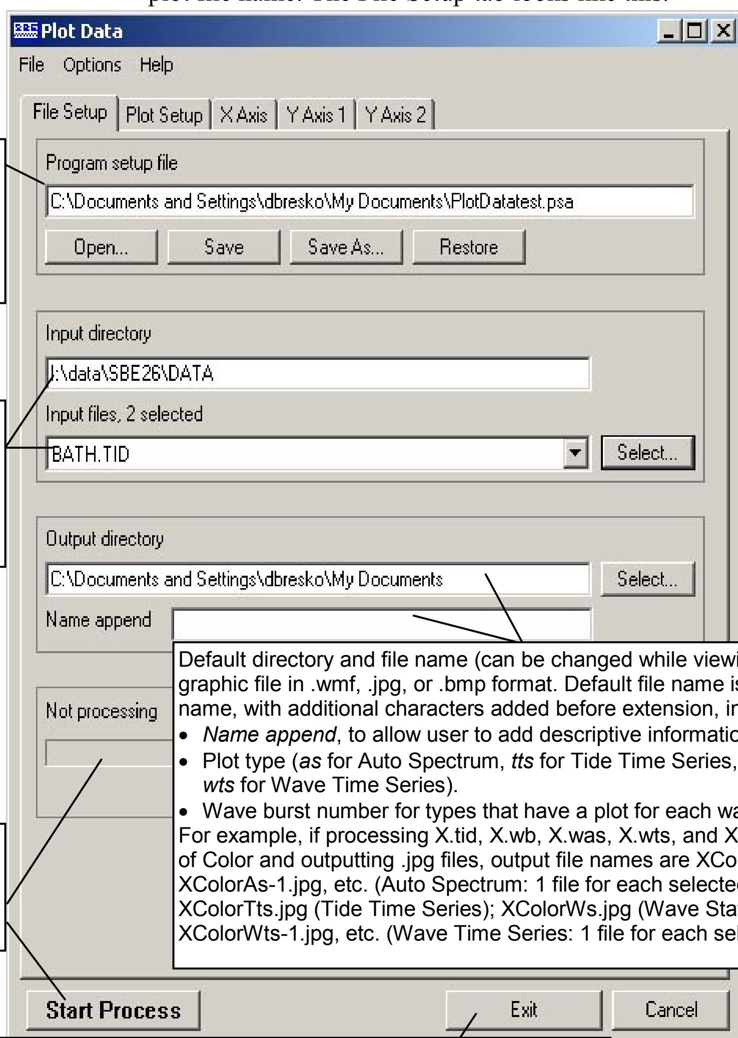
Plot Data displays and plots data from files with a .tid, .wb, .was, .wts, or .wt file extension. Plot Data:

- Plots up to five variables on one plot, with one X axis and up to four Y axes.
- Zooms in on plot features.
- Sends plots to a printer, saves plots to the clipboard for insertion in another program (such as Microsoft Word), or saves plots as graphic files in bitmap, metafile, or JPEG format.

In Seasoft for Waves' Run menu, select Plot Data. Each tab of the dialog box is described below, as well as options for viewing, printing, and saving plots.

File Setup Tab

The File Setup tab defines the Program Setup file, input data file(s), and output plot file name. The File Setup tab looks like this:



File to store all information input in File, Plot, and Axis tabs. **Open** to select a different .psa file, **Save** or **Save As** to save current settings, or **Restore** to reset all settings to match last saved version.

Directory and file names for input data files (.tid, .wb, .was, .wts, and / or .wt files). All files must be in same directory and have same name before extension. **Select** to pick different files.

Default directory and file name (can be changed while viewing plot) for outputting graphic file in .wmf, .jpg, or .bmp format. Default file name is set to match input file name, with additional characters added before extension, in order listed below:

- *Name append*, to allow user to add descriptive information to file name.
- Plot type (*as* for Auto Spectrum, *tts* for Tide Time Series, *ws* for Wave Statistics, or *wts* for Wave Time Series).
- Wave burst number for types that have a plot for each wave burst

For example, if processing X.tid, X.wb, X.was, X.wts, and X.wt with a Name Append of Color and outputting .jpg files, output file names are XColorAs-0.jpg, XColorAs-1.jpg, etc. (Auto Spectrum: 1 file for each selected wave burst); XColorTts.jpg (Tide Time Series); XColorWs.jpg (Wave Statistics); XColorWts-0.jpg, XColorWts-1.jpg, etc. (Wave Time Series: 1 file for each selected wave burst).

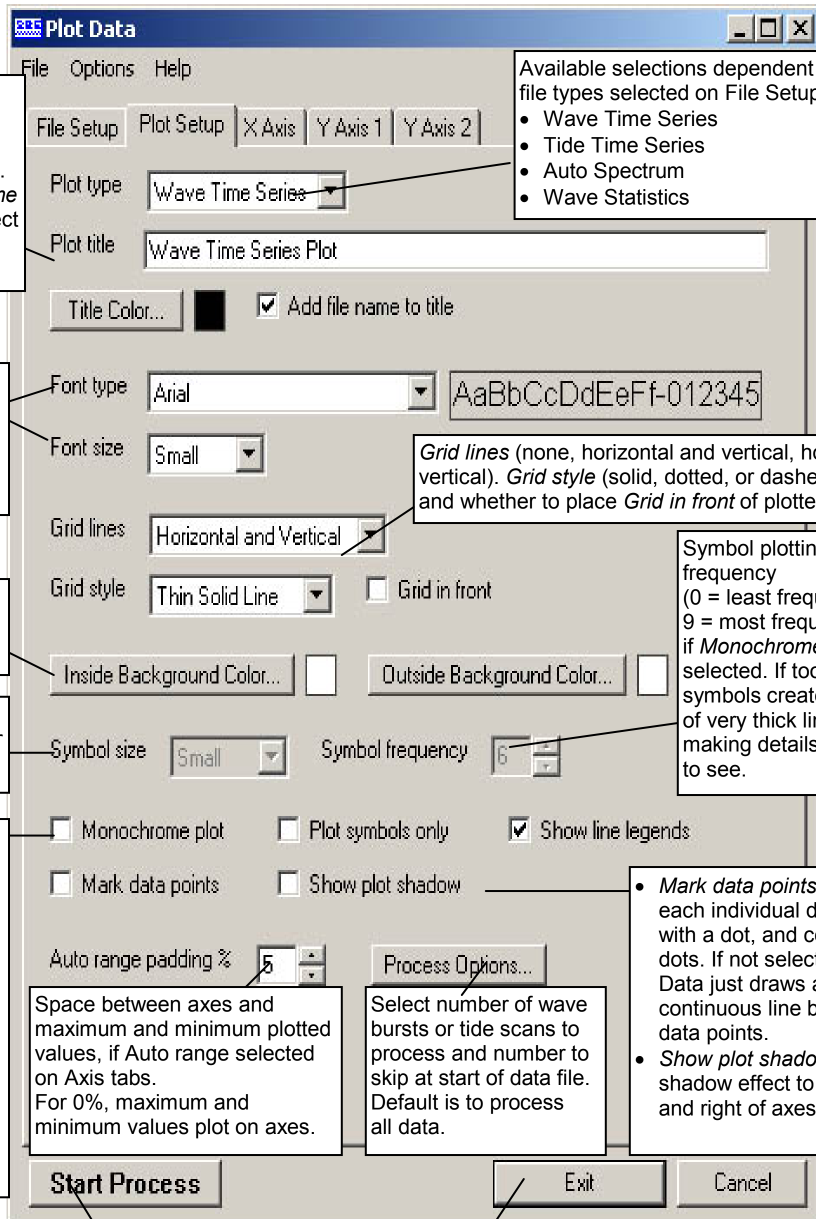
Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to Seasoft for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Plot Setup Tab

The Plot Setup tab defines the plot type, data to be included, and plot layout (title, color, font, grid lines, etc.). The Plot Setup tab looks like this:



- User input *Plot title*.
- User selected *Title color*.
- Select *Add file name to title* to add input data file name to user input title. For example, for a plot title *Wave Time Series* with input file *X.wb*, if you select *Add file name to title*, title is *Wave Time Series, X.wb*.

Available selections dependent on input file types selected on File Setup tab:

- Wave Time Series
- Tide Time Series
- Auto Spectrum
- Wave Statistics

Plot *Font type* and *Font size* (small, medium, or large). Plot Data displays example of font type to right of selection. List of fonts depends on what fonts are installed on your computer.

Grid lines (none, horizontal and vertical, horizontal, vertical). *Grid style* (solid, dotted, or dashed line), and whether to place *Grid in front* of plotted data.

Inside Background Color defines color within axes. *Outside Background Color* defines color outside axes.

Symbol plotting frequency (0 = least frequent, 9 = most frequent), if *Monochrome plot* selected. If too frequent, symbols create illusion of very thick line, making details difficult to see.

Size (small, medium, large) of symbol for each variable, if *Monochrome plot* or *Plot symbols only* selected.

- *Monochrome plot*: Substitute black lines with symbols for colors (colors and symbols defined on Axis tabs). Allows you to set up axes with colors for viewing on screen, and then switch to black lines with symbols for black and white printing.
- *Plot symbols only*: Mark each individual data point with a symbol, and do not connect symbols with a line (symbols defined on Axis tabs).
- *Show line legends*: Show legends below plot title. Legend indicates line color or symbol, as applicable.

- *Mark data points*: Mark each individual data point with a dot, and connect dots. If not selected, Plot Data just draws a continuous line between data points.
- *Show plot shadow*: Create shadow effect to bottom and right of axes.

Space between axes and maximum and minimum plotted values, if Auto range selected on Axis tabs.
For 0%, maximum and minimum values plot on axes.

Select number of wave bursts or tide scans to process and number to skip at start of data file. Default is to process all data.

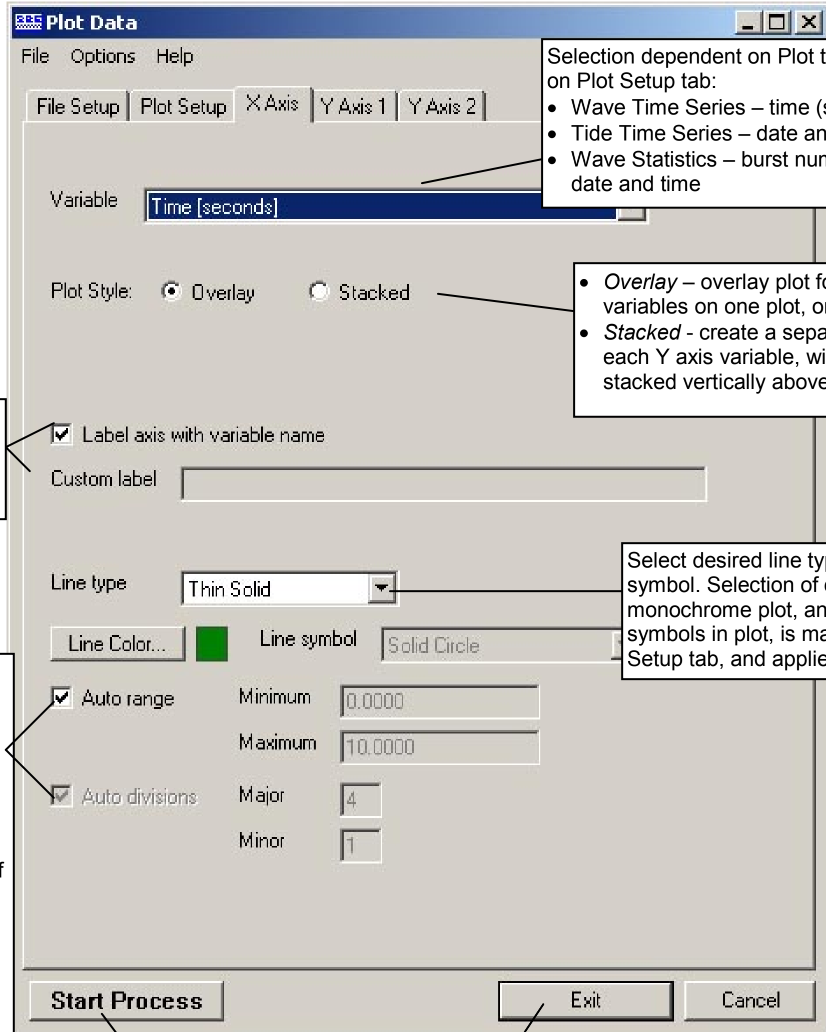
Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to Seasoft for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

X Axis Tab

Click on the X Axis tab. The X Axis tab defines the plot style as well as the X axis variable, scale, and line type.
The X Axis tab looks like this for **Wave Time Series**, **Tide Time Series**, or **Wave Statistics**:



Selection dependent on Plot type selected on Plot Setup tab:
- Wave Time Series – time (seconds)
- Tide Time Series – date and time
- Wave Statistics – burst number or date and time

- *Overlay* – overlay plot for all Y axis variables on one plot, or
- *Stacked* - create a separate plot for each Y axis variable, with plots stacked vertically above each other.

Select to label axis with variable name as listed in drop down Variable list, or enter Custom label for axis.

Select desired line type, color, and symbol. Selection of color or monochrome plot, and inclusion of symbols in plot, is made on Plot Setup tab, and applies to all axes.

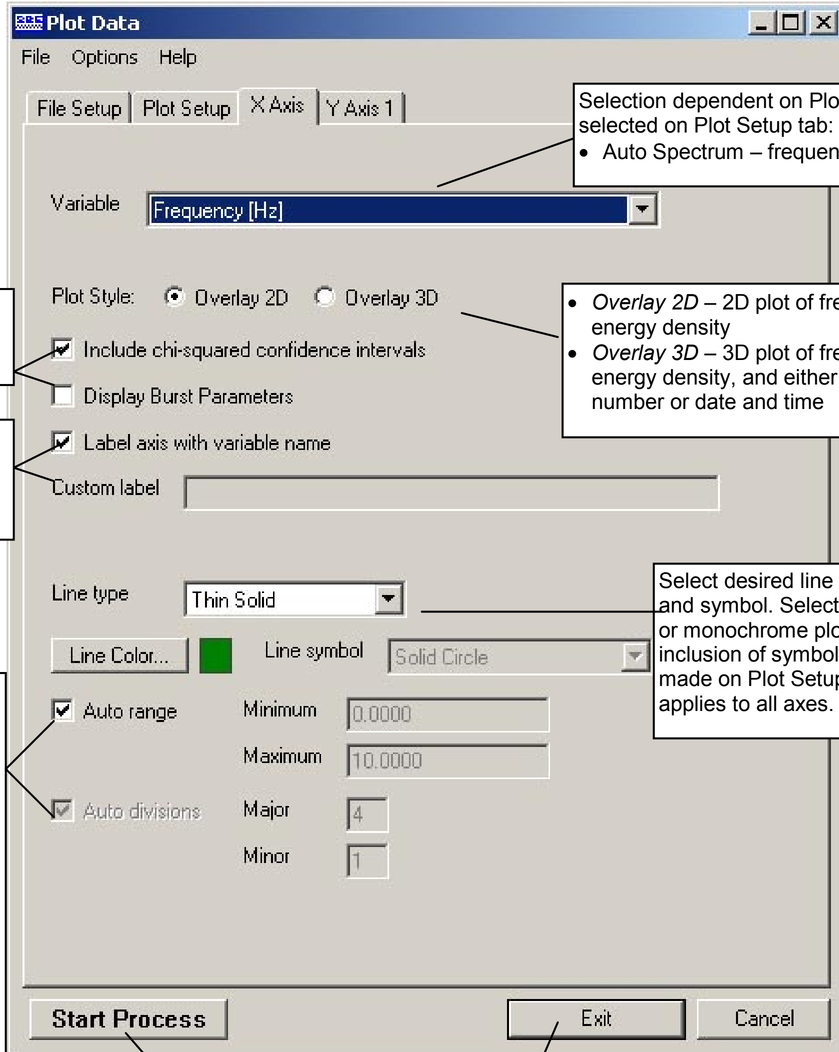
- *Auto range* - Plot Data selects axis Minimum and Maximum values, number of Major divisions on axis, and number of Minor divisions between Major divisions.
- *Auto divisions* - Plot Data selects number of major divisions on axis, and number of minor divisions between major divisions. User selects axis Minimum and Maximum values.

Any values that fall outside user-selected Minimum to Maximum range will plot at minimum or maximum, as applicable.

Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to Seasoft for Waves window.
- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

The X Axis tab looks like this for **Auto Spectrum**:



Selection dependent on Plot type selected on Plot Setup tab:

- Auto Spectrum – frequency (Hz)

If selected, confidence intervals and burst parameters display in text at right of a 2D plot.

- *Overlay 2D* – 2D plot of frequency and energy density
- *Overlay 3D* – 3D plot of frequency, energy density, and either burst number or date and time

Select to label axis with variable name as listed in drop down Variable list, or enter a Custom label for axis.

Select desired line type, color, and symbol. Selection of color or monochrome plot, and inclusion of symbols in plot, is made on Plot Setup tab, and applies to all axes.

- *Auto range* - Plot Data selects axis Minimum and Maximum values, number of Major divisions on axis, and number of Minor divisions between Major divisions.
- *Auto divisions*: - Plot Data selects number of major divisions on axis, and number of minor divisions between major divisions. User selects axis Minimum and Maximum values.

Any values that fall outside user-selected Minimum to Maximum range will plot at minimum or maximum, as applicable.

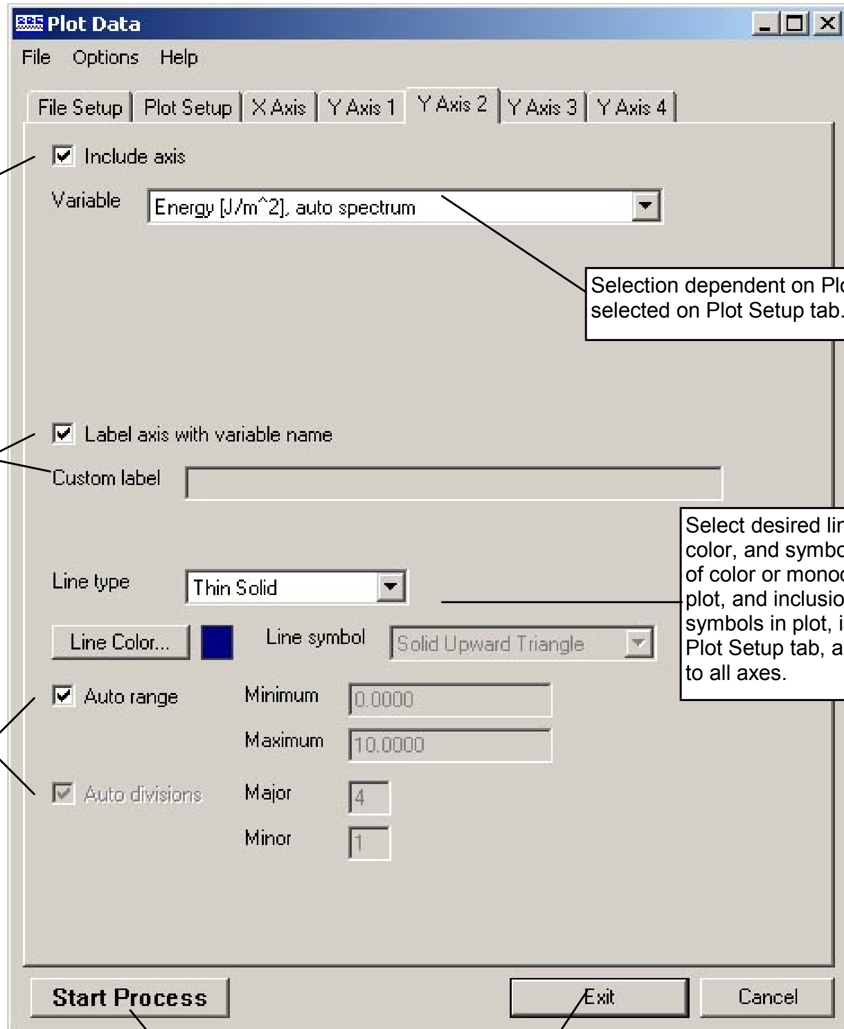
Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to Seasoft for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Y Axis Tab

The Y Axis tabs define the Y axis variables, scales, and line types.



Include this axis in plot. Plot Data can plot 1 X and up to 4 Y axes. At least 1X and 1 Y variable is required, so this selection is available only on Y Axis 2, 3, and 4.
Note: If you deselect an axis, all axes numbered above that axis are automatically deselected.

Selection dependent on Plot type selected on Plot Setup tab.

Select to label axis with variable name as listed in drop down Variable list, or enter a Custom label for axis.

Select desired line type, color, and symbol. Selection of color or monochrome plot, and inclusion of symbols in plot, is made on Plot Setup tab, and applies to all axes.

- *Auto range* - Plot Data selects axis Minimum and Maximum values, number of Major divisions on axis, and number of Minor divisions between Major divisions.
- *Auto divisions* - Plot Data selects number of major divisions on axis, and number of minor divisions between major divisions. User selects axis Minimum and Maximum values.

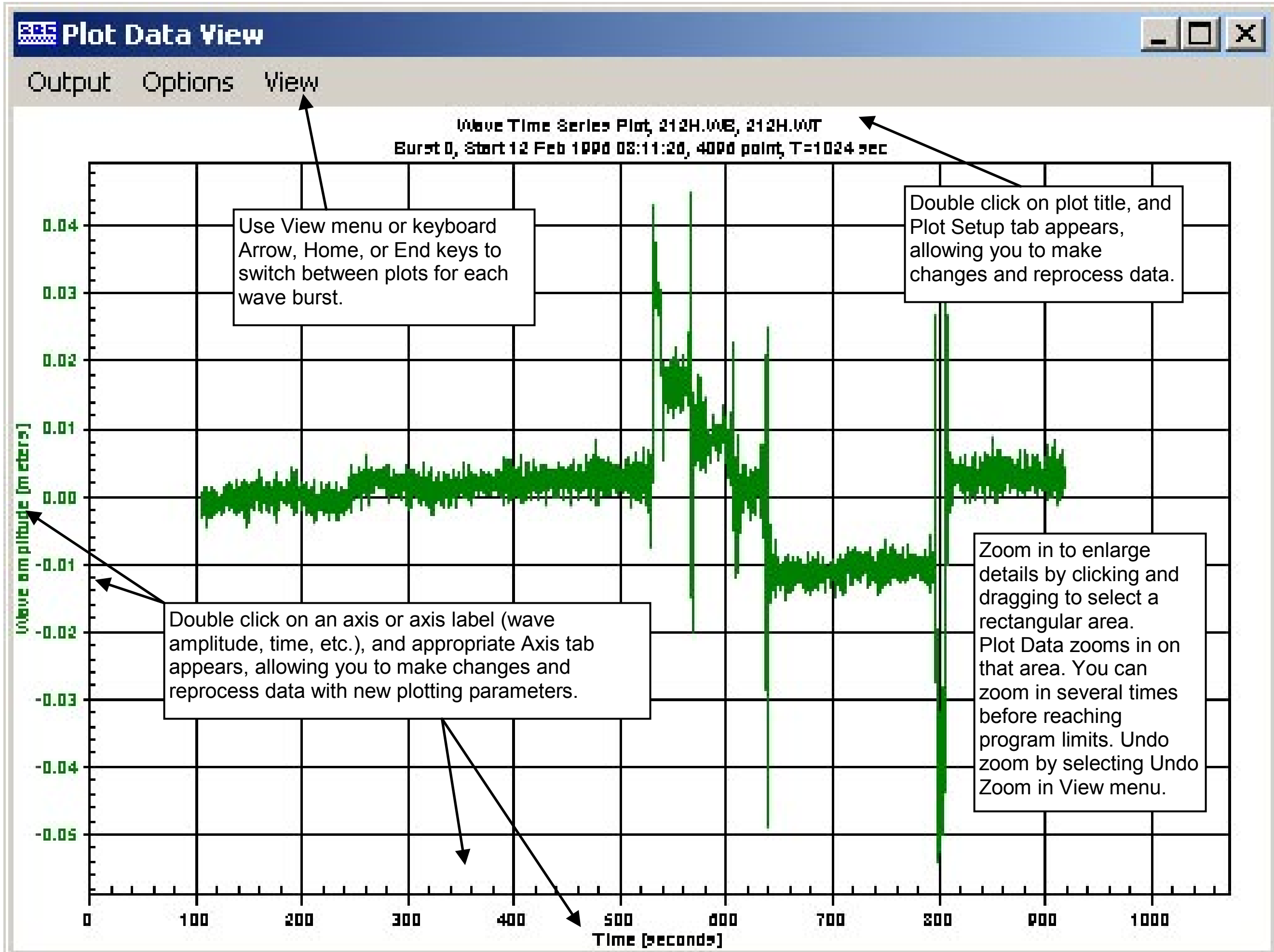
Any values that fall outside user-selected Minimum to Maximum range will plot at minimum or maximum, as applicable.

Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to Seasoft for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Viewing and Outputting Plots



The Plot Data View window's menus are described below:

Output – Output the plot to printer, clipboard, or a file.

- *Print* – Print the single plot that is displayed on screen. In the dialog box, select printer, orientation, color, etc.; these selections override selections you made in Plot Data and in the Plot Data View **Options** menu.
- *File* – Output to file the single plot that is displayed on screen, in the selected format (.wmf, .jpg, or .bmp). In the dialog box, select the desired directory and output file name; these selections override selections you made in Plot Data and in the Plot Data View **Options** menu.
- *Clipboard* – Output to the clipboard the single plot that is displayed on screen, in the selected format (.wmf, .jpg, or .bmp). The selected format overrides the selection you made in the Plot Data View **Options** menu.
- *Print Range* (for wave time series and auto spectrum plots) – Print plots for several wave bursts for the series that is displayed on screen. In the dialog box, select the wave burst print range. Orientation and size are as selected in the Plot Data View **Options** menu. Plots output to your system's default printer; to output to a different printer you must select a new default printer before you select *Print Range*.
- *File Range* (for wave time series and auto spectrum plots) – Output to file the plots for several wave bursts for the series that is displayed on screen, in the selected format (.wmf, .jpg, or .bmp). In the dialog boxes, select the wave burst file output range, and the desired directory and output file name. Directory and file name selections override selections you made in Plot Data and in the Plot Data View **Options** menu.

Notes:

- The first wave burst is labeled 0.
- To change the default printer in Windows XP: Click Start / Printers and Faxes. A list of printers installed on your system appears, with a check mark next to the default printer. Right click on the desired printer, and select Set as Default Printer.

Options – Sets up defaults for *how* the plot is output to the printer, file, or clipboard.

- *Print* –
  - Orientation – landscape, portrait, or (printer) driver default. If driver default is selected, orientation is determined by the default for the printer you select in Output / Print (if printing a single plot) or the system default printer (if printing multiple plots using Output / Print Range).
  - Print full page – If selected, scale plot to fit 8 ½ x 11 inch page. If not selected, Size determined by -
    Plot Data View Dimensions – plot dimensions as shown on screen.
    Values Entered Below – Units, Width, and Height entered here.

- *File* –
  - Data format – Metafile (.wmf), Jpeg (.jpg), or Bitmap (.bmp).
  - Size determined by -
    Plot Data View Dimensions – plot dimensions as shown on screen.
    Values Entered Below – Units, Width, and Height entered here.

- *Clipboard* –
  - Data format – Metafile (.wmf), Jpeg (.jpg), or Bitmap (.bmp).
  - Size determined by -
    Plot Data View Dimensions – plot dimensions as shown on screen.
    Values Entered Below – Units, Width, and Height entered here.

View – Sets up viewing options.

- *First Burst*, *Last Burst*, *Next Burst*, *Prior Burst*, *Go to Burst* (applicable to wave time series and auto spectrum plots) – Switch the plot on screen to a different wave burst.

- *Undo Zoom* –Return the plot to the original ranges specified on the Axis tabs. *Undo Zoom* is grayed out unless you have zoomed in (by clicking and dragging to select a rectangular area) to enlarge details.

- *Set Zoomed Ranges* – Substitute the current zoomed ranges of the plot for the Minimum and Maximum plot ranges on the Axis tabs. This allows you to save the ranges of the zoomed view, so you can go to exactly the same view the next time you run Plot Data. *Set Zoomed Ranges* is grayed out unless you have zoomed in (by clicking and dragging to select a rectangular area) to enlarge details.

Section 10: Routine Maintenance and Calibration

This section reviews corrosion precautions, connector mating and maintenance, battery replacement, pressure sensor maintenance, optional conductivity cell storage and cleaning, and sensor calibration. The accuracy of the SBE 26 is sustained by the care and calibration of the sensors and by establishing proper handling practices.

Corrosion Precautions

Rinse the SBE 26 with fresh water after use and prior to storage.

For both the plastic and titanium housing, all exposed metal is titanium (the plastic housing has a titanium end cap). No corrosion precautions are required, but avoid direct electrical connection of the titanium to dissimilar metal hardware.

The optional SBE 4M conductivity cell has an aluminum or titanium housing. The aluminum housing has a ring-shaped zinc anode. Check the anode periodically to verify that it is securely fastened and has not been dissolved.

Connector Mating and Maintenance

Note:
See *Application Note 57: Connector Care and Cable Installation*.

CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.

Clean and inspect connectors, cables, and dummy plugs before every deployment and as part of your yearly equipment maintenance. Inspect connectors that are unmated for signs of corrosion product around the pins, and for cuts, nicks or other flaws that may compromise the seal.

When remating:

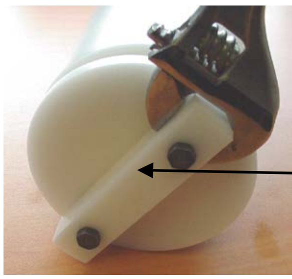
1. Lightly lubricate the inside of the dummy plug/cable connector with silicone grease (DC-4 or equivalent).

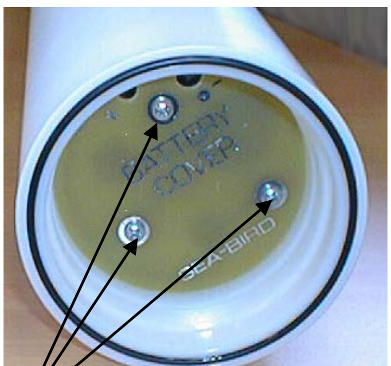
2. **Standard Connector** - Install the plug/cable connector, aligning the raised bump on the side of the plug/cable connector with the large pin (pin 1 - ground) on the SBE 26. Remove any trapped air by *burping* or gently squeezing the plug/connector near the top and moving your fingers toward the end cap. **OR**
   MCBH Connector – Install the plug/cable connector, aligning the pins.

3. Place the locking sleeve over the plug/cable connector. Tighten the locking sleeve finger tight only. **Do not overtighten the locking sleeve and do not use a wrench or pliers.**

Verify that a cable or dummy plug is installed for each connector on the system before deployment.

Battery Replacement





The SBE 26 uses 9 alkaline D-cells (Duracell MN1300, LR20), dropped into the battery compartment.

Leave the batteries in place when storing the SBE 26 to prevent depletion of the back-up lithium batteries by the real-time clock. Even *exhausted* main batteries power the clock (90 microamperes) almost indefinitely. If the SBE 26 is to be stored for long periods, **replace the batteries yearly to prevent battery leakage** (which could damage the SBE 26).

1. Remove the battery end cap (end cap without connectors):
   A. Wipe the outside of the end cap and housing dry, being careful to remove any water at the seam between them.
   B. Remove the end cap by rotating counter-clockwise (use a wrench on the white plastic bar if necessary).
   C. Remove any water from the O-ring mating surfaces inside the housing with a lint-free cloth or tissue.
   D. Put the end cap aside, being careful to protect the O-ring from damage or contamination.

2. Remove the battery cover plate from the housing:
   A. Remove the three Phillips-head screws and washers from the battery cover plate inside the housing.
   B. The battery cover plate will pop out. Put it aside.

3. Turn the SBE 26 over and remove the batteries.

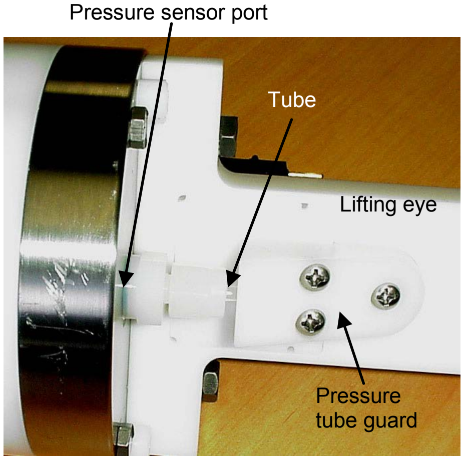
4. Install the new batteries, with the + terminals against the flat battery contacts and the - terminals against the spring contacts.

5. Reinstall the battery cover plate in the housing:
   A. Align the battery cover plate with the housing. The posts inside the housing are not placed symmetrically, so the cover plate fits into the housing only one way. Looking at the cover plate, note that one screw hole is closer to the edge than the others, corresponding to the post that is closest to the housing.
   B. Reinstall the three Phillips-head screws and washers, while pushing hard on the battery cover plate to depress the spring contacts at the bottom of the battery compartment. **The screws must be fully tightened, or battery power to the circuitry will be intermittent**.

6. Check the battery voltage at BAT + and BAT - on the battery cover plate. It should be approximately 13.5 volts.

7. Reinstall the battery end cap:
   A. Remove any water from the O-rings and mating surfaces with a lint-free cloth or tissue. Inspect the O-rings and mating surfaces for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of o-ring lubricant (Parker Super O Lube) to O-rings and mating surfaces.
   B. Carefully fit the end cap into the housing and screw the end cap into place. Use a wrench on the white plastic bar to ensure the end cap is tightly secured.

Pressure Sensor Maintenance



Connector End Cap

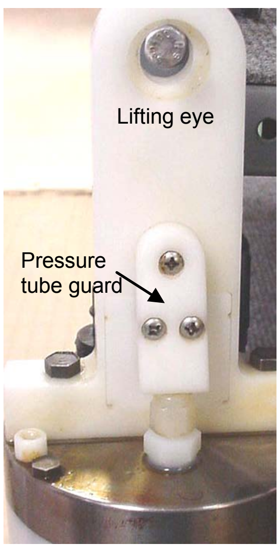
The pressure fitting – which includes a pressure port fitting, external tube, and polyurethane bladder bag – is filled with silicone oil at the factory. The oil transmits hydrostatic pressure via internal, capillary tubing to the pressure sensor inside the instrument, and prevents corrosion that might occur if the sensor diaphragm was exposed to water. The bladder bag is vacuum back-filled.

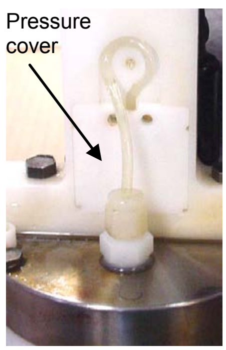
The bladder bag can develop tears and leaks over time. If the fitting has been damaged, or investigation due to poor data shows that the bag has torn, replace the fitting and bag and refill the oil. **Sea-Bird highly recommends that you send the SBE 26 back to the factory for this repair, as it is difficult to completely remove all air from the system in the field, resulting in potential pressure errors.** However, if you must do the repair to meet a deployment schedule, contact Sea-Bird to purchase the needed parts.

Parts required:

Part Number	Description	Quantity
30551	Pressure port bladder bag	2 *
50025	Pressure sensor oil refill kit **	1
50029	Nylon capillary assembly	2 *
30002	Swagelock, nylon, NY-200-1-OR	2 *
30521	Syringe, 60 cc, DURR #899069, MFG #309663 (18 gage needle ground)	1

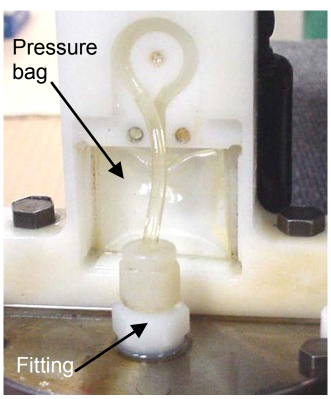
* Only 1 is required, but we recommend that you purchase a spare in case you have difficulty with the procedure.
** If you have a bell jar, use it to de-gas the oil in the oil refill kit.





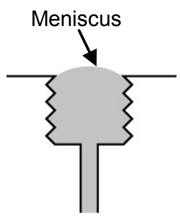
1. Securely mount the SBE 26 vertically (connector end cap up).

2. Remove the 3 Phillips-head screws attaching the pressure tube guard to the lifting eye. Remove the pressure tube guard and the pressure cover that is under it.



3. Remove the fitting from the end cap with a 9/16 inch wrench. Discard the fitting, tubing, and pressure bag.

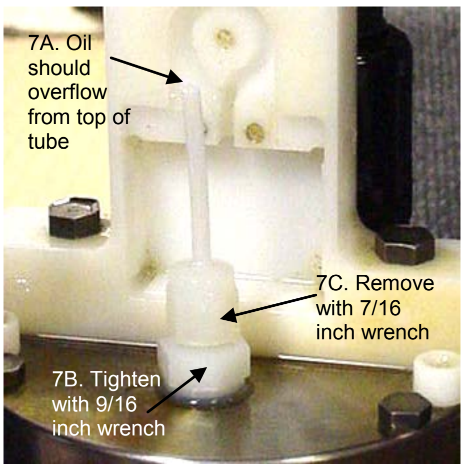
CAUTION:
Do not put a brush or any object in the pressure port. Doing so may damage or break the pressure sensor.



4. Clean the pressure bag cavity in the lift eye and the removed pressure tube guard and pressure cover, removing all residue/grit. Ensure that the holes in each corner of the pressure bag cavity in the lift eye are free of obstructions.

5. Clean the sensor end cap, being careful to remove any residue/grit near the pressure port.

6. From the 50025 pressure sensor oil refill kit, fill the small syringe with the supplied oil. Fill the pressure port, forming a meniscus on the surface of the end cap. Keep the SBE 26 in the vertical position for at least 30 minutes before proceeding, to allow any bubbles in the internal plumbing to rise to the surface. Add oil from the small syringe as necessary to maintain the meniscus.

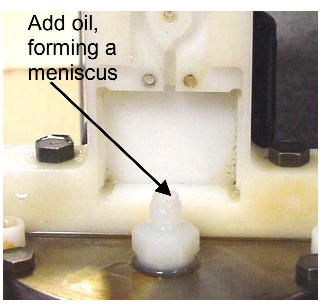


7. Install the supplied capillary fitting (50029) in the pressure port.

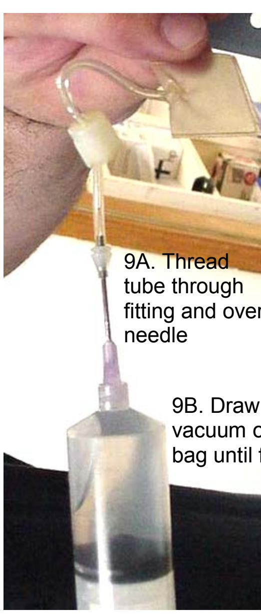
   A. As the fitting is installed, oil should rise the length of the tube and overflow. Wipe up the excess oil with a paper towel.

   B. Gently tighten the lower portion of the fitting with a 9/16 inch wrench - **DO NOT OVERTIGHTEN**.

   C. Remove the upper portion of the capillary fitting and tube using a 7/16 inch wrench. Store it for possible use another time.



8. Using the small syringe, add oil to the lower portion of the fitting, forming a meniscus.

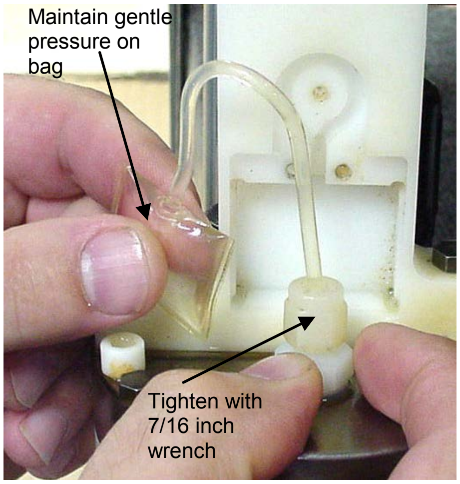


9. Fill the large syringe (30521) ¼ full with oil.

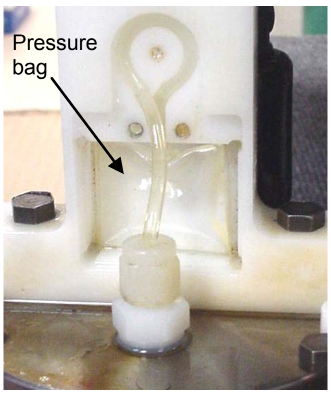
   A. Thread the tube from the pressure bag (30551) through the Swagelock fitting (30002), and install the pressure bag tube over the needle.

   B. Pull the plunger back on the syringe, drawing a vacuum on the pressure bag until it is completely flat. Maintain the vacuum on the bag.

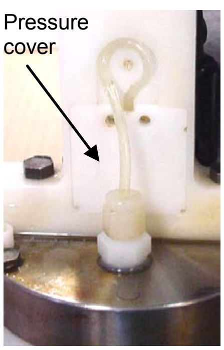
   C. Hold the syringe vertically with the bag down and slowly release the plunger, allowing the vacuum to be released. The bag should slowly fill with oil. There is enough oil in the bag when the bag looks like a *small pillow*. It is very important that there are no air bubbles in the pressure bag; you may have to perform this step several times to ensure that there are no bubbles.

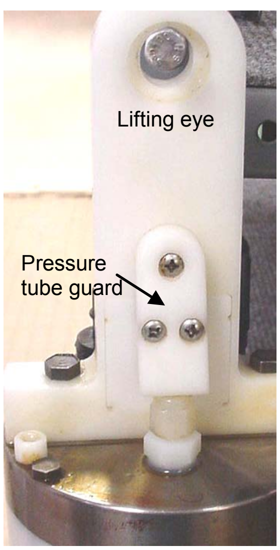


10. After the bag is filled, gently remove the tube from the needle, keeping the bag at or below the level of the end of the tube to prevent air from entering the bag. Maintaining gentle pressure on the bag to keep the oil at the end of the tube and prevent air from entering the bag, insert the end of the tube into the lower portion of the fitting on the end cap and screw the Swagelok fitting down, using a 7/16 inch wrench. Oil should overflow from the fitting, preventing air from entering the bag; the overflow should stop when the fitting is tightened. When completed, the bag should be approximately ½ full of oil and contain no air.



11. Install the pressure bag in the pressure bag cavity. Place the tubing in the indent, going counter-clockwise from the bag to the fitting.





12. Reinstall the pressure cover, pressure tube guard, and 3 Phillips-head screws, being careful not to pinch the tubing or the bag.

13. Log data on the SBE 26, and download the data. Compare the pressure readings to a local barometer. A pinched or overfilled bag will give pressure readings that are higher that the correct values.

Conductivity Cell Maintenance

CAUTIONS:
- **Do not put a brush or any object inside the conductivity cell to dry it or clean it.** Touching and bending the electrodes can change the calibration. Large bends and movement of the electrodes can damage the cell.
- **Do not store the SBE 4M with water in the conductivity cell.** Freezing temperatures (for example, in Arctic environments or during air shipment) can break the cell if it is full of water.

The SBE 26's optional conductivity cell (SBE 4M) is shipped dry to prevent freezing in shipping. Refer to *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells* for conductivity cell cleaning procedures and cleaning materials.

- The Active Use (after each cast) section of the application note is not applicable to the SBE 4M, which is intended for use as a moored instrument.

Sensor Calibration

Sea-Bird sensors are calibrated by subjecting them to known physical conditions and measuring the sensor responses. Coefficients are then computed, which may be used with appropriate algorithms to obtain engineering units. The pressure, temperature, and optional conductivity sensors on the SBE 26 are supplied fully calibrated, with coefficients printed on their respective Calibration Certificates (in manual).

We recommend that the SBE 26 be returned to Sea-Bird for calibration.

Quartz Pressure Sensor Calibration

The pressure sensor is capable of meeting the SBE 26's error specification with some allowance for aging and ambient-temperature induced drift. The pressure sensor is supplied with coefficients derived from a calibration performed over temperature (0 - 125 °C). When used in the quartz sensor *temperature model* (as incorporated in Sea-Bird software), these coefficients reflect the initial calibration of the sensor.

Note:
Although the pressure sensor manufacturer can re-calibrate the pressure sensor by duplicating the original procedures, the sensor must be removed from the SBE 26, the cost is relatively high, and lead times can be considerable.

The pressure sensor coefficients are hard coded into the SBE 26. These can be viewed using **DC** in SeatermW, but cannot be changed by command. However, values for slope (default = 1.0) and offset (default = 0.0) can be entered in Convert Hex's Coefficient Configuration dialog box to make small corrections for sensor drift. Techniques are provided below for making small corrections using the slope and offset terms by comparing SBE 26 pressure output to:

- Readings from a barometer
- Readings from a dead-weight pressure generator – provides more accurate results, but requires equipment that may not be readily available

Before using either of these procedures, allow the SBE 26 to equilibrate in a reasonably constant temperature environment for at least 5 hours before starting. Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature. Sea-Bird instruments are constructed to minimize this by thermally decoupling the sensor from the body of the instrument. However, there is still some residual effect; allowing the SBE 26 to equilibrate before starting will provide the most accurate calibration correction.

Calculating Offset using a Barometer

1. Place the SBE 26 in the orientation it will have when deployed.
2. In SeatermW, connect to the SBE 26.
3. Send **FR** to display the pressure and pressure sensor temperature compensation frequencies. Click Stop to end the test.
4. Compute pressure in psia from the frequency with the formula shown on the calibration sheet.
5. Compare the SBE 26 output to the reading from a good barometer. Calculate *Offset* = barometer reading – SBE 26 reading.
6. Enter the calculated offset (positive or negative) in Convert Hex's Coefficients Configuration dialog box.

Offset Correction Example
Pressure measured by barometer is 1010.50 mbar. Pressure calculated from SBE 26 pressure frequency is 14.06 psia.
Convert barometer reading to psia using relationship: mbar * 0.01 dbar/mbar * 1 psia / 0.689476 dbar = psia
Barometer reading = 1010.50 mbar * 0.01 / 0.689476 = 14.66 psia *Offset* = 14.66 – 14.06 = +0.60 psia
Enter offset in Convert Hex's Coefficient Configuration dialog box.

Calculating Slope and Offset using a Dead-Weight Pressure Generator

Tests show that room-temperature-derived *slope* and *offset* corrections to the initial quartz calibration can account for long-term drift to within less than 0.01% of the sensor's full scale range. To perform this correction:

1. Use a suitable dead-weight pressure generator to subject the sensor to increments of known pressures. The end cap's 5/16-24 straight thread permits mechanical connection to a pressure source. Use a fitting that has an o-ring face seal, such as Swagelok-200-1-OR. See *Application Note 12-1: Pressure Port Oil Refill Procedure & Nylon Capillary Fitting Replacement*.
2. In SeatermW, connect to the SBE 26.
3. Send **FR** to display the pressure and pressure sensor temperature compensation frequencies. Click stop to end the test.
4. Compute pressure from the frequencies with the formula shown on the calibration sheet.
5. Enter the calculated slope and offset (positive or negative) in Convert Hex's Coefficient Configuration dialog box.

Pressure Slope and Offset Correction Example
A 45 psia sensor has drifted and its responses are low, as shown below:

Actual Pressure (psia)	Indicated Pressure (psia)
0.000	-0.057
9.000	8.939
18.000	17.936
27.000	26.932
36.000	35.929
45.000	44.925

Linear regression (best straight-line fit) *pcorrected = (pindicated * slope) + offset*
yields *slope* = 1.00039381 and *offset* = 0.057. Enter these correction coefficients, originally set to 1.0 and 0.0 respectively, in Convert Hex's Coefficient Configuration dialog box.

Temperature Sensor Calibration

The primary source of temperature sensor calibration drift is the aging of the thermistor element. Sensor drift is usually a few thousandths of a degree during the first year, and less in subsequent intervals. Sensor drift is not substantially dependent upon the environmental conditions of use, and — unlike platinum or copper elements — the thermistor is insensitive to shock.

The temperature sensor calibration certificate shows the following coefficients:

- **AI** and **XI** are hard coded in the SBE 26 EPROM and are used to calculate the raw hex data (Note that some temperature sensor calibration sheets list g and x instead of AI and XI. Verify that g = AI and x = XI.). View these coefficients with **DC** in SeatermW.
- **Z** and **RH** are used internally only.
- **A0**, **A1**, and **A3** are used in Convert Hex to convert the raw temperature data to engineering units. View and/or modify these coefficients in Convert Hex's Coefficient Configuration dialog box.

Conductivity Sensor Calibration

The optional SBE 4M conductivity sensor incorporates a fixed precision resistor in parallel with the cell. When the cell is dry and in air, the sensor's electrical circuitry outputs a frequency representative of the fixed resistor. This frequency is recorded on the Calibration Certificate and should remain stable (within 1 Hz) over time.

The conductivity sensor calibration certificate shows the following coefficients: g, h, i, j, Cpcor, and Ctcor. View and/or modify these coefficients in Convert Hex's Coefficient Configuration dialog box.

- Cpcor makes a correction for the highly consistent change in dimensions of the conductivity cell under pressure. The default is the compressibility coefficient for borosilicate glass (-9.57e-08). Some sensors fabricated between 1992 and 1995 (serial numbers between 1100 and 1500) exhibit a compression that is slightly less than pure borosilicate glass. For these sensors, the (hermetic) epoxy jacket on the glass cell is unintentionally strong, creating a composite pressure effect of borosilicate and epoxy. For sensors tested to date, this composite pressure coefficient ranges from -9.57e-08 to -6.90e-08, with the latter value producing a correction to deep ocean salinity of 0.0057 PSU in 5000 dbars pressure (approximately 0.001 PSU per 1000 dbars). Before modifying Cpcor, confirm that the sensor behaves differently from pure borosilicate glass. Sea-Bird can test your cell and calculate Cpcor. Alternatively, test the cell by comparing computed salinity to the salinity of water samples from a range of depths, calculated using an AutoSal.

Note:
See Application Note 31 for computation of slope and offset correction coefficients from pre- and post-cruise calibrations supplied by Sea-Bird or from salinity bottle samples taken at sea during profiling.

Enter values for slope (default = 1.0) and offset (default = 0.0) in Convert Hex's Coefficient Configuration dialog box to make small corrections for conductivity sensor drift between calibrations:

Corrected conductivity = (slope * computed conductivity) + offset
where
slope = true conductivity span / instrument conductivity span
offset = (true conductivity – instrument reading) * slope; measured at 0 S/m

Conductivity Slope and Offset Correction Example
At true conductivity = 0.0 S/m, instrument reading = -0.00007 S/m
At true conductivity = 3.5 S/m, instrument reading = 3.49965 S/m
Calculating the slope and offset:
Slope = (3.5 – 0.0) / (3.49965 - [- 0.00007]) = + 1.000080006
Offset = (0.0 - [-0.00007]) * 1.000080006 = + 0.000070006

The primary mechanism for calibration drift in conductivity sensors is the fouling of the cell by chemical or biological deposits. Fouling changes the cell geometry, resulting in a shift in cell constant (slope of the calibration curve), typically resulting in lower conductivity readings over time. Offset error (error at 0 S/m) is usually due to electronics drift, and is typically less than ± 0.0001 S/m per year. Because offsets greater than ± 0.0002 S/m are a symptom of sensor malfunction, Sea-Bird recommends that drift corrections be made by assuming no offset error, unless there is strong evidence to the contrary or a special need.

The most important determinant of long-term sensor accuracy is the cleanliness of the cell. We recommend that the conductivity sensors be calibrated before and after deployment, but particularly when the cell has been exposed to contamination by oil slicks or biological material.

Section 11: Troubleshooting

This section reviews common problems in operating the SBE 26, and provides the most common causes and solutions.

Problem 1: Unable to Communicate with SBE 26

The S> prompt indicates that communications between the SBE 26 and computer have been established. Before proceeding with troubleshooting, attempt to establish communications again by clicking Connect in SeatermW or hitting the Enter key several times.

Cause/Solution 1: The I/O cable connection may be loose. Check the cabling between the SBE 26 and computer for a loose connection.

Cause/Solution 2: The instrument and/or Comm port may not have been entered correctly in SeatermW. Select Configure in the Communications menu, and verify the settings.

Cause/Solution 3: The I/O cable may not be the correct one. The I/O cable supplied with the SBE 26 permits connection to the DB-9P input connector on a standard RS-232 interface.

- SBE 26 Pin 1 (large pin) goes to DB-9 pin 5 (ground)
- SBE 26 pin 2 (counter-clockwise from large pin) goes to DB-9 pin 3
- SBE 26 pin 3 (opposite the large pin) goes to DB-9 pin 2

Cause/Solution 4: If attempting to communicate with the SBE 26 after you started logging, the SBE 26 may be collecting a wave burst (indicated by sequences of *a*'s and *d*'s on the display). You cannot communicate with the SBE 26 while it is collecting a wave burst. Try to establish communications again a few seconds after the characters stop.

Cause/Solution 5: In rare cases, the program that controls the SBE 26's microprocessor can be corrupted by a severe static shock or other problem. This program can be initialized by using the reset switch. Proceed as follows to initialize:

1. Open the battery end cap and remove the batteries (see *Battery Replacement* in *Section 10: Routine Maintenance and Calibration*).
2. There is a toggle reset switch on the battery compartment bulkhead, which is visible after the batteries are removed. The switch is used to disconnect the internal lithium batteries from the electronics. Set the switch to the reset position for at least 5 minutes.
3. Reinstall or replace the batteries, and close the battery end cap.
4. Establish communications with the SBE 26 (see *Section 5: SBE 26 Setup, Installation, and Data Upload - SeatermW* for details). Initialize RAM (**IR**), reset the date and time (**ST**), and re-enter all the setup parameters.

Note:
Using the reset switch erases the SBE 26 memory – all logged data in memory is lost and all user-programmable parameters (date and time, sampling scheme, etc.) are reset to default values.

Problem 2: Nonsense or Unreasonable Data

The symptom of this problem is an uploaded file that contains unreasonable values (for example, values that are outside the expected range of the data).

Cause/Solution 1: An uploaded data file with unreasonable values for pressure, temperature, or conductivity may be caused by incorrect calibration coefficients in the instrument .psa file. View the coefficients by clicking the Coefficients button in Convert Hex. Verify that the calibration coefficients in the instrument .psa file match the instrument Calibration Certificates.

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Glossary

Battery and Memory Endurance – Seasoft for Waves module for calculating power endurance and memory endurance for a user-specified sampling scheme.

Convert Hex – Seasoft for Waves module for converting uploaded .hex file into separate wave (.wb) and tide (.tid) files.

Create Reports – Seasoft for Waves module for outputting one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst.

Fouling – Biological growth in the conductivity cell during deployment.

Merge Barometric Pressure – Seasoft for Waves module for removing barometric pressure from tide data.

PCB – Printed Circuit Board.

Plan Deployment – Seasoft for Waves module for calculating the ratio of pressure amplitude measured by the instrument to pressure amplitude at the surface, and predicting number of frequency bands calculated, width of each band, and frequency span.

Plot Data – Seasoft for Waves module for plotting wave and tide data.

Process Wave Burst Data– Seasoft for Waves module for computing wave statistics.

SEAGAUGE – High-accuracy wave and tide recorder with a quartz pressure sensor, precision thermometer, and optional SBE 4M conductivity sensor.

Seasoft for Waves – Modular Win 95/98/NT/2000/XP program for pre-deployment planning, communication with the SBE 26 for setup, uploading of data from the SBE 26, separation of the raw data into separate wave and tide files, removal of barometric pressure from tide data, statistical analysis, and data plotting. Modules include Plan Deployment, Battery and Memory Endurance, SeatermW, Convert Hex, Merge Barometric Pressure, Process Wave Burst Data, Create Reports, and Plot Data.

SeatermW – Seasoft for Waves module for communication with the SBE 26 for setup and uploading of data from the SBE 26.

TCXO – Temperature Compensated Crystal Oscillator.

Triton X-100 – Reagent grade non-ionic surfactant (detergent), used for cleaning the conductivity cell. Triton can be ordered from Sea-Bird, but should also be available locally from chemical supply or laboratory products companies. Triton is manufactured by Avantor Performance Materials (www.avantormaterials.com/commerce/product.aspx?id=2147509608). .

Appendix I: Command Summary

Note:
Commands followed by ***** alter SBE 26 memory and prompt the user twice before executing (* is not part of the command). To execute the command, type Y and press Enter key in response to ***message Y/N***. Then hold down Ctrl key and type *y*, and press Enter key in response to ***are you sure ^Y/N***. Any other responses abort the command.

CATEGORY	COMMAND	DESCRIPTION
Status	**DS**	Display status and setup parameters.
	DC	Display pressure sensor and temperature sensor calibration coefficients that are hard coded into SBE 26 EPROM.
Setup	**IR ***	Initialize memory, which destroys all logged data in memory.
	ST	Set real-time clock date and time.
	SI	Set sampling intervals and parameters: • Tide interval • Wave burst after every N tide measurements • Wave samples/burst – for most accurate results, this number should be a power of 2 (2, 4, 8, 16, 32, 64, 128, etc.) • Number of 0.25-second periods to integrate waves
	Cx	**x=Y**: Enable conductivity logging (use if optional SBE 4M conductivity sensor included). **x=N**: Do not.
	LWx	**x=** wait interval (milliseconds) after each line of data. Normally set to 0; increase for very slow computers. Range 0 – 65535.
	QS	Enter quiescent (sleep) state. Main power turned off, but memory retention unaffected.
Logging	**GL ***	Start logging, overwriting any logged data in memory.
	QL *	Quit logging.
Data Upload	**DDb,e**	Display raw data from memory in Hex from sample **b** to **e** at 9600 baud.
	DEb,e	Display raw data from memory in Hex from sample **b** to **e** at 19200 baud.
	DAb,e	Display raw data from memory in Hex from sample **b** to **e** at 38400 baud.
Diagnostic	**TM ***	Memory test, which destroys all data in memory.
	TE *	Extended memory test, which destroys all data in memory.
	FR	Measure and display pressure frequency, pressure temperature compensation frequency, and conductivity sensor frequency. SBE 26 runs continuously during test, drawing current. Press Esc key or Stop to stop test.
	VR	Measure and display (main battery voltage/5.0161), (lithium battery voltage/3.873), raw thermistor voltage, raw large reference resistor voltage, and small reference resistor voltage. SBE 26 runs continuously during test, drawing current. Press Esc key or Stop to stop test.

Appendix II: Sample Timing

Note the following, as illustrated in the example below:

- When **GL** is sent to start logging, the SBE 26 sleeps for one tide interval before starting logging.
- The SBE 26 integrates the pressure sensor output over the entire tide interval, calculating and storing an average pressure for that time period.
- Actual calculation and storing of tide data is delayed by two tide intervals. For example, as the SBE 26 begins tide measurement #3, it is simultaneously calculating and storing the data from tide measurement #1.
- Wave burst sampling is done after the **calculation and storing** of the applicable measurement. For example, if the SBE 26 is set up to sample a wave burst after every four tide measurements, the first wave burst occurs after the calculation and storing of data from tide #4.
- Time required for each wave burst must be less than (tide interval - 30 seconds). If the user setup does not meet this requirement, the SBE 26 reduces the number of measurements in the wave burst to meet the requirement.

Example:
Tide interval = 60 minutes.
Wave burst of 128 measurements at 0.5 seconds/measurement (128 x 0.5 = 64 seconds) after ever 4 tide measurements.
User sends **GL** at 12 pm.

Time	**Begin Tide Measurement #**	**Begin to Calculate and Store Data from Tide Measurement #**	**Begin Wave Burst #**
12:00	(user sends **GL**)		
13:00	#1	-	-
14:00	#2	-	-
15:00	#3	#1	-
16:00	#4	#2	-
17:00	#5	#3	-
18:00	#6	#4	-
19:00	#7	#5	***#1***
20:00	#8	#6	-
21:00	#9	#7	-
22:00	#10	#8	-
23:00	#11	#9	***#2***
00:00	#12	#10	-
01:00	#13	#11	-
02:00	#14	#12	-
03:00	#15	#13	***#3***

Appendix III: Data Formats

This appendix provides detailed information on data format for each file type.

Extension	Description
.hex	Raw Hex data uploaded from SBE 26 memory using SeatermW.
.tid	Tide measurements only, created from .hex file by Convert Hex. Also, file output by Merge Barometric Pressure, which removes barometric pressure from an input .tid file.
.bp	Barometric pressure data, used by Merge Barometric Pressure to remove barometric pressure from the tide data (.tid) file. See *Section 7: Tide Data Processing – Merge Barometric Pressure* for .bp format.
.wb	Wave measurements only, created from .hex file by Convert Hex.
.was	Statistics and results from auto-spectrum analysis, created by Process Wave Burst Data.
.rpt	Summary report, created by Process Wave Burst Data.
.wss	Fast Fourier Transform coefficients, created by Process Wave Burst data if *Output FFT coefficients to .wss file* is selected. Details not provided.
.wts	Statistics from surface wave zero crossing analysis, created by Process Wave Burst Data.
.wt	Surface wave time series, created by Process Wave Burst Data if *Output surface wave time series to .wt file* is selected.
.r26	File containing one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst, created by Create Reports.

Hex Data Format (.hex extension)

A .hex file contains raw hexadecimal data uploaded from SBE 26 memory using SeatermW' Upload. The beginning of a sample .hex data file follows:

```
* Sea-Bird SBE 26 Data File:
* FileName = 23.HEX
* Software Version 4.0.b.20
*ds
*SBE 26 SEAGAUGE V4.1d  SN 335, 06/06/02  13:09:14.439
*pressure sensor: serial number = 36285,  range = 45 psi
*clk = 32767.843   iop = 63   vmain = 13.1   vlith = 5.9
*last sample:   p = 13.3193   t = 1.407
*
*tide measurement interval = 5 min
*measure waves after every 1 tide samples
*1024 wave samples/burst at 4.00 scans/second
*
*tide samples/day = 288.000
*wave bursts/day = 288.000
*memory endurance = 0.052 days
*recorded tide measurements = 27
*recorded wave bursts = 27
*
*conductivity = YES
*logdata = NO
*dc
*Paroscientific Digiquartz calibration coefficients:
*    U0 =  5.881116
*    Y1 =  -3971.433
*    Y2 =  -9778.307
*    Y3 =  0.000
*    C1 =  170.09370
*    C2 =  22.880490
```

```
*    C3 =  -230.10930
*    D1 =  0.0589810
*    D2 =  0.0000000
*    T1 =  24.31375
*    T2 =  0.5175830
*    T3 =  17.76489
*    T4 =  0.00000
*    T5 =  0.00000
*    M = 9532.5
*    B = 4766.3
*
*Temperature coefficients:
*    Z = -49405.0
*    RH = 46995.0
*    AI = 268135.0
*    XI = -8.879
*S>
FFFFFFFD        (flag beginning of tide parameters)
04C6B570        (time of beginning of first tide sample)
012C0001        (tide integration period, wave integration period)
FFFFFFFE        (flag end of tide parameters)
5ED8C726        (tide data – pressure and temperature)
000ACF6B        (conductivity data, only present if enabled)
00000000        (flag beginning of wave burst)
04C6B7C8        (wave burst time)
A7578200        (pressure temperature compensation frequency)
9A12CB9A        (wave burst pressure data)
12C89A12        ( " )
CB9A12CB        ( " )
9A12C89A        ( " )
12CB9A12        ( " )
CB9A12C8        ( " )
FFFFFFFF        (flag end of wave burst)
5ED8C726        (tide data)
000ACF6B        (conductivity data, only present if enabled)
```

- Beginning lines - ***** flags header. Header lines contain (in order):
  - Input file name
  - Software version used to upload the data
  - SBE 26 response to display status (**DS**) command
  - SBE 26 response to display calibration coefficients (**DC**) command

- Following lines - Data follows, with eight characters per line, followed by a carriage return and line feed. Data is described below.

Tide Parameters and Data

Data (lines after the `*S>`) is described below:

- First line - *FFFFFFFD*; flags the start of tide parameters.
- Second line - Start time (seconds since January 1, 1989) of integration of first tide sample.
- Third line - First four characters is tide sample interval (seconds); last four characters is number of 0.25-second periods to integrate wave samples.
- Fourth line - *FFFFFFFE*; flags the end of tide parameters.
- Fifth and following lines – Fifth line is a tide record (pressure and temperature). For tide record, first 19 bits are pressure number and last 13 bits are temperature voltage. If conductivity logging is enabled (**CY**), a tide record is followed by a conductivity record.
  All lines that are not flags, tide parameters, or wave burst data are tide (pressure and temperature) or conductivity records.

Convert Hex converts the raw hex data to pressure, temperature, and (optional) conductivity in engineering units when the data is separated into tide and wave burst files. The tide data conversions are described below:

Tide Record (pressure and temperature)

pressure = [slope correction * (pressure number - B) / M] + offset correction
where

- slope and offset corrections are read from the Convert Hex calibration coefficients (.psa) file.
- M and B are scaling parameters that depend on pressure sensor range, and are stored in EPROM:

Pressure Sensor Range (psia)	M	B
23	21845	0
30	15887.5	7943.8
45	9532.5	4766.3
100	4766.3	2383.2
200	2383.1	1191.6
300	1588.8	794.4
400	1191.6	595.8
1000	476.6	238.3
2000	238.3	119.2
3000	158.9	79.5
6000	79.4	39.7
10000	47.7	23.9

temperature voltage = (temperature number - 4095) / 819

Temperature is computed as follows:

LR = ln ([AI / (temperature voltage - XI)] - 15000.0)
temperature = [1.0 / (A0 + A1 * LR + A3 * LR^3)] - 273.15
where

- AI and XI are hard coded in the SBE 26 EPROM and are read from the .hex file header.
- A0, A1, and A3 are read from the Convert Hex calibration coefficients (.psa) file.

Note:
Some temperature sensor calibration sheets list g instead of AI and x instead of XI.

Example: tide record = 49E6A726 hex = 0100 1001 1110 0110 1010 0111 0010 0110 binary

The first 19 bits are 0100100111100110101 binary = decimal 151349.
For this example, assume 45 psia pressure sensor, slope correction = 1.0, and offset correction = 0.
pressure = [slope correction * (151349 – 4766.3) / 9532.5] + offset correction = 15.3772 psia

The last 13 bits are 0011100100110 binary = decimal 1830.
temperature voltage = (1830 - 4095) / 819 = -2.766 volts
For this example, assume A0 = 1.0e-3, A1 = 2.3e-4, A3 = 1.5e-7, XI = -8.745, and AI = 271800.
LR = ln ([271800 / (-2.766 - -8.745)] - 15000.0) = 10.32414
temperature = [1.0 / (1.0e-3 + 2.3e-4 * 10.32414 + 1.5e-7 * 10.32414^3)] - 273.15
= [1.0 / 3.5396e-3] - 273.15 = 9.366 °C

Conductivity Record

conductivity frequency (Hz) = conductivity number / 256

Conductivity frequency is converted to conductivity using the coefficients and equation found on the calibration certificate for the sensor. These coefficients are read from the Convert Hex calibration coefficients (.psa) file.

Example:
Conductivity number = 000ACF6B hex =708459 decimal
Conductivity frequency = 708459 / 256 = 2767.418 Hz

Wave Burst Data

- First wave burst line = `00000000`; flags the start of a wave burst.
- Second wave burst line = Start time (seconds since January 1, 1989) of wave burst.
- Third wave burst line = First 24 bits is pressure temperature compensation frequency; last 8 bits are 0.
- Fourth and following wave burst lines = Next n groups of 24 bits are pressure frequencies, where n is number of wave samples per burst.
- Last wave burst line = `FFFFFFFF`; flags the end of a wave burst.

Convert Hex automatically makes the conversion of the raw hex data to pressure when the data is separated into tide and wave burst files. The conversions are described below:

Pressure temperature compensation frequency = PTCF = 24 bits / 64

Pressure frequency = PF = 24 bits / 256
Pressure period = T = 1 / PF

Pressure is computed as follows:

U = [(1.0 / PTCF) * 1000000] - U0
(note that U0 may be listed as X0 on the calibration sheet)

$C = C1 + (C2 * U) + (C3 * U^2)$

D = D1 + D2 but D2 = 0, so D = D1

$T0 = (T1 + T2 * U + T3 * U^2 + T4 * U^3 + T5 * U^4) / 1000000$ But T5 = 0 , so
$T0 = (T1 + T2 * U + T3 * U^2 + T4 * U^3) / 1000000$

W = 1.0 - (T0 * T0 / T * T)

pressure = slope correction * [C * W * (1.0 - D * W)] + offset correction

where

- U0, C1, C2, C3, D1, T1, T2, T3, and T4 are hard coded in the SBE 26 EPROM and are read from the uploaded .hex file header.
- Slope and offset corrections are read from the Convert Hex calibration coefficients (.psa) file.

Tide Data Format (.tid extension)

A .tid file is created from the .hex file in Convert Hex. A sample tide data (.tid) file is shown below:

```
1   11/13/92 10:27:16   14.8125    22.102   3.55682    23.909
2   11/13/92 10:28:16   15.0086    14.818   3.48032    27.844
3   11/13/92 10:29:16   15.0836    11.242   3.07901    26.714
4   11/13/92 10:30:16   15.1536     8.951   3.07101    28.376
5   11/13/92 10:31:16   15.2267     7.225   3.06788    29.772
```

Note:
If conductivity logging is not enabled (conductivity = NO in the status display), the sixth and seventh columns are not included in the .tid file.

- Column 1 = Tide measurement number
- Columns 2 and 3 = Date and time of beginning of tide measurement
- Column 4 = Measured pressure in psia
- Column 5 = Measured water temperature in °C
- Column 6= Measured conductivity in S/m
- Column 7 = Calculated salinity in PSU

If Merge Barometric Pressure has been run on the .tid file to remove the effect of barometric pressure, the output .tid file contains descriptive column headings. The presence of headings in the .tid file indicates that it has been processed by Merge Barometric Pressure. Additionally, Merge Barometric Pressure has the ability to replace the pressure in the fourth column with calculated water depth. See *Section 7: Tide Data Processing – Merge Barometric Pressure* for details, and for the required data format for the barometric pressure (.bp) file to input in Merge Barometric Pressure.

Wave Burst Data Format (.wb extension)

A .wb file is created from the .hex file in Convert Hex. A sample wave burst data file is shown below:

```
SBE 26 SEAGAUGE
*    0   39714178    1.00  32
        21.344801     21.344801     21.250858     21.058917
        20.948967     20.986165     21.101858     21.188864
        21.204989     21.157996     21.094862     21.030808
        21.030145     21.133848     21.241456     21.250286
        21.139034     21.006829     20.983782     21.064104
        21.176656     21.267824     21.261526     21.168517
        21.102853     21.075775     21.035574     21.002877
        21.046280     21.145214     21.204416     21.199654
*    1   39724978    1.00  32
        22.135044     22.135044     22.203410     22.258581
        22.272837     22.277849     22.284841     22.250777
        22.173778     22.123603     22.151409     22.223522
        22.288892     22.341974     22.368526     22.333153
        22.246305     22.182725     22.175729     22.182845
        22.194884     22.236219     22.252728     22.185787
        22.119699     22.198516     22.385685     22.516203
        22.506578     22.397684     22.269475     22.156724
```

- First line - * flags beginning of data for a wave burst. Line contains (in order):
  - Wave burst number
  - Start of wave measurement (seconds since January 1, 1989)
  - Wave integration period (seconds)
  - Number of points in wave burst

- Second and following lines (until next line with *) - Measured pressures in psia, with four values per line

Wave Burst Auto-Spectrum Statistics (.was extension)

A .was file is created from the .wb file in Process Wave Burst Data. A sample wave burst Auto-Spectrum statistics file is shown below:

```
SBE 26 SEAGAUGE
*  0  39714178  1.00 1024  10   5.666  4.466  1024.211  90  0.637  1.843
    51 5.371094e-003 9.765625e-003 5.9946e-003 6.0210e+001 1.0732e+001 3.0970e-001
    3.091334e-003   3.298001e-003   2.160857e-003   7.776975e-004
    5.304750e-003   3.731420e-003   1.790720e-002   2.439886e-002
    8.326155e-002   1.082657e-001   5.056803e-002   5.299359e-002
    2.502890e-002   2.332787e-002   2.122386e-002   1.846813e-002
    3.559706e-002   3.633030e-002   2.943071e-002   8.796323e-003
    8.000838e-003   4.111465e-003   2.995502e-003   6.887020e-003
    2.995481e-003   4.263404e-003   1.317504e-003   3.054346e-003
    1.688730e-003   2.141096e-003   1.688405e-003   3.960159e-003
    1.314685e-003   1.714741e-003   1.393692e-003   1.332473e-003
    3.300501e-004   5.239898e-004   3.741254e-004   1.336304e-003
    5.561366e-004   6.184441e-004   8.887792e-004   4.510226e-004
    5.383913e-004   4.866397e-004   1.003825e-003   5.819744e-004
    7.742675e-004   1.622945e-003   9.336277e-004
*  1  39724978  1.00 1024  10  6.378  5.178  1024.211  90  0.637  1.843
    51 5.371094e-003 9.765625e-003 6.2661e-003 6.2937e+001 1.0732e+001 3.1663e-001
    2.399138e-003   4.958530e-003   5.970532e-003   5.397915e-003
    3.676770e-003   2.406614e-002   1.292470e-002   2.224974e-002
    4.823480e-002   1.086449e-001   7.481066e-002   8.684431e-002
    1.948858e-002   2.912741e-002   3.741619e-002   2.336472e-002
    2.254591e-002   1.218159e-002   1.780615e-002   4.395502e-003
    9.833613e-003   3.936535e-003   5.881464e-003   4.571996e-003
    5.443738e-003   4.163474e-003   3.601095e-003   3.585647e-003
    5.531514e-003   1.835893e-003   1.114426e-003   3.934834e-003
    2.174772e-003   1.469032e-003   1.335585e-003   9.147523e-004
    6.760068e-004   8.808380e-004   5.716856e-004   7.181183e-004
    6.005655e-004   4.775679e-004   1.299268e-003   3.855911e-004
    4.464863e-004   4.614029e-004   6.163178e-004   8.327592e-004
    1.575676e-003   1.628755e-003   4.645250e-003
```

- First line - ***** flags the beginning of the data for a wave burst. Line contains (in order):
  - Wave burst number
  - Start of wave burst (seconds since January 1, 1989)
  - Wave integration time (seconds)
  - Number of points in the wave burst
  - Number of spectral estimates for each frequency band
  - Water depth (meters)
  - Pressure sensor depth (meters)
  - Density (kg/m^3)
  - Chi-squared confidence interval (percent)
  - Multiplier for Chi-squared lower bound
  - Multiplier for Chi-squared upper bound

- Second line contains (in order):
  - Number of frequency bands calculated
  - Frequency of first frequency band (Hz)
  - Interval between frequency bands (delta f) (Hz)
  - Total variance (meters^2)
  - Total energy (Joules / meters^2)
  - Significant period (seconds) = frequency band with greatest variance
  - Significant wave height (meters) = 4 × sqrt (total variance)

- Third and following lines (until next line with *****) -
  Values (beginning with the first frequency) for the Auto-Spectral density function <Gaa>. Units are meters^2 / Hz. To obtain the variance (m^2) in a frequency interval δf (Hz), multiply the value of <Gaa> by δf.

Wave Burst Auto-Spectrum Report (.rpt extension)

A .rpt file is created from the .wb file in Process Wave Burst Data. A sample wave burst Auto-Spectrum report file is shown below:

```
surface wave processing summary:
file = apr12sp.wb
temperature = 15.000
salinity = 33.000
density = 1024.431
number of points per wave burst = 1028
sample period = 1.00 sec
burst # 1:
    mean pressure = 21.207 psia
    instrument depth = 4.466 meters
    total water depth = 5.666 meters
auto-spectrum:
    10 spectral estimates per band
    51 bands calculated
    each band is 0.010 Hz wide
    frequency span = 0.005  to  0.492 Hz

MM/DD HH:MM SIG.HT SIG.PER                  ENERGY (CM.SQ.)
             (CM)   (SEC)   22+  20   17 15  13  11  9   7   5   3
---------------------------------------------------------------------------
04/05 15:42   31    11       1   0    0   2   2  19  13  10  10   3
04/05 18:42   32    11       2   2    0   1   2  15  18  11   7   4
04/05 21:42   46     3       2   2    0   2   3   7  12  15   8  82
04/06 00:42   39     9       1   3    0   2   5  10  13  14   8  39
04/06 03:42   41    18       3  13    0   6   2   6  17  11   9  41
04/06 06:42   45    10       4   2    0   8   3  10  21  12  13  56
04/06 09:42   49     8       2   2    0  11   2  13  23  27  29  42
04/06 12:42   57    16       1   5    0  28   5   6  28  17  43  71
04/06 15:42   61    16       1   5    0  59   3   9  27  18  60  50
04/06 18:42   67    16       6   2    0  72  37   9  17  12  52  70
```

The energy (centimeters squared) is the sum of the variance over the indicated frequency band:

- The 9 second wave period column is the sum of the variances where the frequency is between 1/10 Hz and 1/8 Hz.
- The 20 second wave period column is the sum of the variances where the frequency is between 1/22 Hz and 1/18 Hz.
- The 22+ second wave period is the sum of the variances of all the frequencies less than 1/22 Hz.

Significant period = 1 / (band averaged frequency with the greatest variance)

Surface Wave Time Series Statistics (.wts extension)

A .wts file is created from the .wb file in Process Wave Burst Data. A sample surface wave time series statistics file is shown below:

```
SBE 26 SEAGAUGE
*  0  39714178  1.00  1024   109   5.666      4.466    1024.431
  6.860774e-003 6.892497e+001 1.972292e-001 7.431193e+000
  6.293907e-001 3.115848e-001 9.138889e+000 4.114119e-001 6.293907e-001
*  1  39724978  1.00  1024   112   6.377      5.177    1024.431
  6.632170e-003 6.662836e+001 1.914052e-001 7.223214e+000
  4.505061e-001 3.078597e-001 9.000000e+000 3.902955e-001 4.505061e-001
```

- First line - * flags the beginning of the data for a wave burst. Line contains (in order):
  - Wave burst number
  - Start of wave burst (seconds since January 1, 1989)
  - Wave integration time (seconds)
  - Number of points in the wave burst
  - Number of individual waves found
  - Water depth (meters)
  - Pressure sensor depth (meters)
  - Density (kg/m^3)

- Second line contains (in order):
  - Total variance of time series (meters^2)
  - Total energy of time series (Joules / meters^2)
  - Average wave height (meters)
  - Average wave period (seconds)

- Third line contains (in order):
  - Maximum wave height (meters)
  - Significant wave height (meters) [average height of largest 1/3 waves]
  - Significant period (seconds) [average period of largest 1/3 waves]
  - $H_{1/10}$ (meters) [average height of largest 1/10 waves] - If less than 10 waves, $H_{1/10}$ is set to 0
  - $H_{1/100}$ (meters) [average height of largest 1/100 waves] - If less than 100 waves, $H_{1/100}$ is set to 0

Surface Wave Time Series (.wt extension)

A .wt file is created from the .wb file in Process Wave Burst Data, if *Output surface wave time series to .wt file* is selected. Part of a sample surface wave time series file is shown below:

```
SBE 26 SEAGAUGE
*  0   39714178    1.00  32
        -0.1783     -0.2180     -0.1793     -0.0721
        0.0615       0.1677      0.2036      0.1582
        0.0521      -0.0754     -0.1829     -0.2384
```

- First line - * flags the beginning of the data for a wave burst. Line contains (in order):
  - Wave burst number
  - Start of wave measurement (seconds since January 1, 1989)
  - Wave integration period (seconds)
  - Number of points in wave burst

- Second and following lines (until the next line with *) - Measured wave amplitudes in meters, with four values per line.

Wave Burst Statistics Report (.r26 extension)

A .r26 file is created from the .was and .wts file in Create Reports. Part of a sample report file is shown below:

```
# filename = D:\SBE26\951002[.WAS, .WTS]
# wave integration time = 1.00
# number of points in the burst = 1024
# height of SBE 26 above the bottom = 0.300
# density = 1024.153
         Burst    Time-jdays    Time-hours         Depth        Nwaves     Avgheight        Avgper
Maxheight         H1/10        H1/100       Swp-wts       Swh-wts
             0     232.67205         0.000        17.759           211  4.600717e-01  3.838863e+00
3.384997e+00  1.441726e+00  3.134322e+00  4.200000e+00  8.141103e-01
             1     232.75538         2.000        17.679           185  2.278769e-01  4.383784e+00
8.741022e-01  7.083250e-01  8.741022e-01  6.344262e+00  5.092874e-01
```

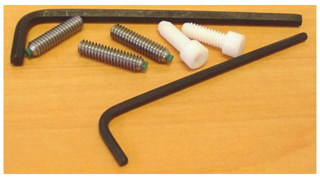
- Beginning lines - # flags header. Header lines contain (in order):
  - Input file name
  - Wave integration period (seconds)
  - Number of points in the wave burst
  - Height of pressure sensor above bottom
  - Water density

- Column heading line and data – Data varies, depending on user-selected variables to be output.

Appendix IV: Electronics Disassembly/Reassembly

Note:
Disassembling the electronics erases the SBE 26 memory – all logged data in memory is lost and all user-programmable parameters (date and time, sampling scheme, etc.) are reset to default values.

Jackscrew kit

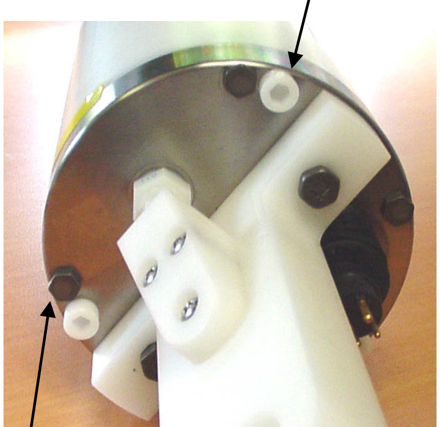


Sea-Bird provides a jackscrew kit with the SBE 26, to assist in removal of the connector end cap. The kit contains:

- 2 Allen wrenches
- 3 jackscrews
- 2 spare plastic socket hex-head screws

Disassembly

CAUTION:
Disconnect and dismount the optional SBE 4M conductivity cell from the SBE 26 before disassembly to avoid breaking the conductivity cell.



1. Establish communications with the SBE 26 (see *Section 5: SBE 26 Setup, Installation, and Data Upload - SeatermW* for details). **As a precaution, click Upload to upload any data in memory before beginning.**

2. Wipe the outside of the end cap and housing dry, being careful to remove any water at the seam between them.

3. Remove the four titanium hex-head screws securing the connector end cap to the housing.

4. Remove the three plastic hex-head screws from the end cap using the larger Allen wrench. Insert the three jackscrews in these three holes in the end cap. When you begin to feel resistance, use the smaller Allen wrench to continue turning the screws. Turn each screw 1/2 turn at a time. As you turn the jackscrews, the end cap will push away from the housing. When the end cap is loosened, pull it and the PCB assembly out of the housing.

5. Remove any water from the O-ring mating surfaces inside the housing with a lint-free cloth or tissue. Be careful to protect the O-rings from damage or contamination.

6. Disconnect the Molex connector connecting the PCB assembly to the battery compartment bulkhead.

7. Remove the jackscrews from the end cap.

Reassembly

> **Note:**
> Before delivery, a desiccant package is inserted in the housing and the electronics chamber is filled with dry Argon gas. These measures help prevent condensation. To ensure proper functioning:
> 1. Install a new desiccant bag each time you open the electronics chamber. If a new bag is not available, see *Application Note 71: Desiccant Use and Regeneration (drying)*.
> 2. If possible, dry gas backfill each time you open the housing. If you cannot, wait at least 24 hours before redeploying, to allow the desiccant to remove any moisture from the housing.
>
> Note that opening the battery compartment does not affect desiccation of the electronics.

1. Remove any water from the O-ring and mating surfaces with a lint-free cloth or tissue. Inspect the O-ring and mating surfaces for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of O-ring lubricant (Parker Super O Lube) to O-ring and mating surfaces.

2. Reconnect the Molex connector to the PCB assembly. Verify the connector holds and pins are properly aligned.

3. Carefully fit the PCB assembly into the housing, aligning the holes in the end cap and housing.

4. Reinstall the 4 hex-head screws to secure the end cap to the housing.

5. Reinstall the 3 plastic hex head screws in the end cap.

6. Establish communications with the SBE 26 (see *Section 5: SBE 26 Setup, Installation, and Data Upload - SeatermW* for details). Initialize RAM (**IR**), reset the date and time (**ST**), and re-enter all the setup parameters.

Appendix V: AF24173 Anti-Foulant Device

AF24173 Anti-Foulant Devices supplied for user replacement are supplied in polyethylene bags displaying the following label:

AF24173 ANTI-FOULANT DEVICE

FOR USE ONLY IN SEA-BIRD ELECTRONICS' CONDUCTIVITY SENSORS TO CONTROL THE GROWTH OF AQUATIC ORGANISMS WITHIN ELECTRONIC CONDUCTIVITY SENSORS.

ACTIVE INGREDIENT:
Bis(tributyltin) oxide…………..…………………………..... 53.0%
OTHER INGREDIENTS: ……………………………….... 47.0%
Total……………………………………………………….... 100.0%

DANGER

See the complete label within the Conductivity Instrument Manual for Additional Precautionary Statements and Information on the Handling, Storage, and Disposal of this Product.

Net Contents: Two anti-foulant devices
Sea-Bird Electronics, Inc.
13431 NE 20th Street
Bellevue, WA 98005

EPA Registration No. 74489-1
EPA Establishment No. 74489-WA-1

AF24173 Anti-Foulant Device

FOR USE ONLY IN SEA-BIRD ELECTRONICS' CONDUCTIVITY SENSORS TO CONTROL THE GROWTH OF AQUATIC ORGANISMS WITHIN ELECTRONIC CONDUCTIVITY SENSORS.

ACTIVE INGREDIENT:
Bis(tributyltin) oxide………..…………………………..... 53.0%
OTHER INGREDIENTS: ……………………………….... 47.0%
Total……………………………………………………..... 100.0%

DANGER
See Precautionary Statements for additional information.

FIRST AID	
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for15-20 minutes. • Call a poison control center or doctor for treatment advice.
If swallowed	• Call poison control center or doctor immediately for treatment advice. • Have person drink several glasses of water. • Do not induce vomiting. • Do not give anything by mouth to an unconscious person.
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice.
HOT LINE NUMBER	
Note to Physician	Probable mucosal damage may contraindicate the use of gastric lavage.
Have the product container or label with you when calling a poison control center or doctor, or going for treatment. For further information call National Pesticide Telecommunications Network (NPTN) at 1-800-858-7378.	

Net Contents: Two anti-foulant devices

Sea-Bird Electronics, Inc.
13431 NE 20th Street
Bellevue, WA 98005

EPA Registration No. 74489-1
EPA Establishment No. 74489-WA-1

PRECAUTIONARY STATEMENTS

HAZARD TO HUMANS AND DOMESTIC ANIMALS

DANGER

Corrosive - Causes irreversible eye damage and skin burns. Harmful if swallowed. Harmful if absorbed through the skin or inhaled. Prolonged or frequently repeated contact may cause allergic reactions in some individuals. Wash thoroughly with soap and water after handling.

PERSONAL PROTECTIVE EQUIPMENT

USER SAFETY RECOMMENDATIONS

Users should:

- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Wear protective gloves (rubber or latex), goggles or other eye protection, and clothing to minimize contact.
- Follow manufacturer's instructions for cleaning and maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.
  - Wash hands with soap and water before eating, drinking, chewing gum, using tobacco or using the toilet.

ENVIRONMENTAL HAZARDS

Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the local sewage treatment plant authority. For guidance contact your State Water Board or Regional Office of EPA. This material is toxic to fish. Do not contaminate water when cleaning equipment or disposing of equipment washwaters.

PHYSICAL OR CHEMICAL HAZARDS

Do not use or store near heat or open flame. Avoid contact with acids and oxidizers.

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling. For use only in Sea-Bird Electronics' conductivity sensors. Read installation instructions in the applicable Conductivity Instrument Manual.

STORAGE AND DISPOSAL

PESTICIDE STORAGE: Store in original container in a cool, dry place. Prevent exposure to heat or flame. Do not store near acids or oxidizers. Keep container tightly closed.

PESTICIDE SPILL PROCEDURE: In case of a spill, absorb spills with absorbent material. Put saturated absorbent material to a labeled container for treatment or disposal.

PESTICIDE DISPOSAL: Pesticide that cannot be used according to label instructions must be disposed of according to Federal or approved State procedures under Subtitle C of the Resource Conservation and Recovery Act.

CONTAINER DISPOSAL: Nonrefillable container. Do not reuse this container for any purpose. Offer for recycling, if available.

Sea-Bird Electronics/label revised 01-28-10

Appendix VI: Wave Theory and Statistics

Surface Gravity Waves - Description

Types of Waves and Restoring Forces

The most characteristic physical feature of any kind of wave is the restoring force. If a medium at rest (such as still water) is disturbed in some way (by the wind, for example, or by dropping a rock into a pond), the restoring force acts to return the medium to its initial still state.

Compressibility is the restoring force for sound waves. Surface tension acts as the restoring force at any surface of contact between any two different fluids (like air and water), and produces very high frequency capillary waves. Gravity waves arise through the restoring force of gravity on water particles displaced from equilibrium levels. If the equilibrium level is a free surface (the boundary between water and air), surface gravity waves are formed. If the equilibrium level is an internal surface in a stratified fluid, internal gravity waves are formed. These internal waves tend to have longer periods (minutes to hours) than surface gravity waves (seconds). Finally, planetary effects such as rotation introduce restoring effects such as the Coriolis force and potential vorticity, yielding very long period waves called inertial waves, Rossby, and planetary waves.

Spectrum of Surface Waves in the Ocean

Surface waves in the ocean occupy a broad range of wavelengths and periods.

- At extremely short periods, the spectrum is dominated by capillary waves, followed by a broad (1 - 20 second) band of surface gravity waves, mostly wind driven.
- Longer period (> 10 minutes) gravity waves may occur in association with earthquakes and large-scale meteorological systems (storm surges).
- Tides, which are another type of forced gravity wave, dominate the spectrum in the 12 - 36 hour band.
- At longer periods, *inertial* and *planetary* waves are prevalent; gravity does not play a dominant role any longer.

See Pond and Picard (Figure 12.1, Table 12.1) (*Appendix VIII: References*).

Definition of Terms

a = wave amplitude, [m]

D_w = density of water, [Kg/m^3]

E = $W_w H^2 / 8$, total wave energy per unit area, [J/m^2]

f = 1 / T, wave frequency, [Hz], [cycles/sec]

g = 9.80665, acceleration of gravity, [m/sec^2]

h = water depth, [m]

H = 2a, wave height, [m]

k = $2 \pi / L$, wave number, [rad/m]

L = wave length, [m]

φ = phase angle, [radians]

σ = $2 \pi / T$, radian frequency, [rad/sec]

t = time, [sec]

T = wave period, [sec]

T_b = total time of the wave burst series (total sample period), [sec]

W_w = D_w g, specific weight of water, [Kg/(m^{2}sec^2] = [Pa/m]

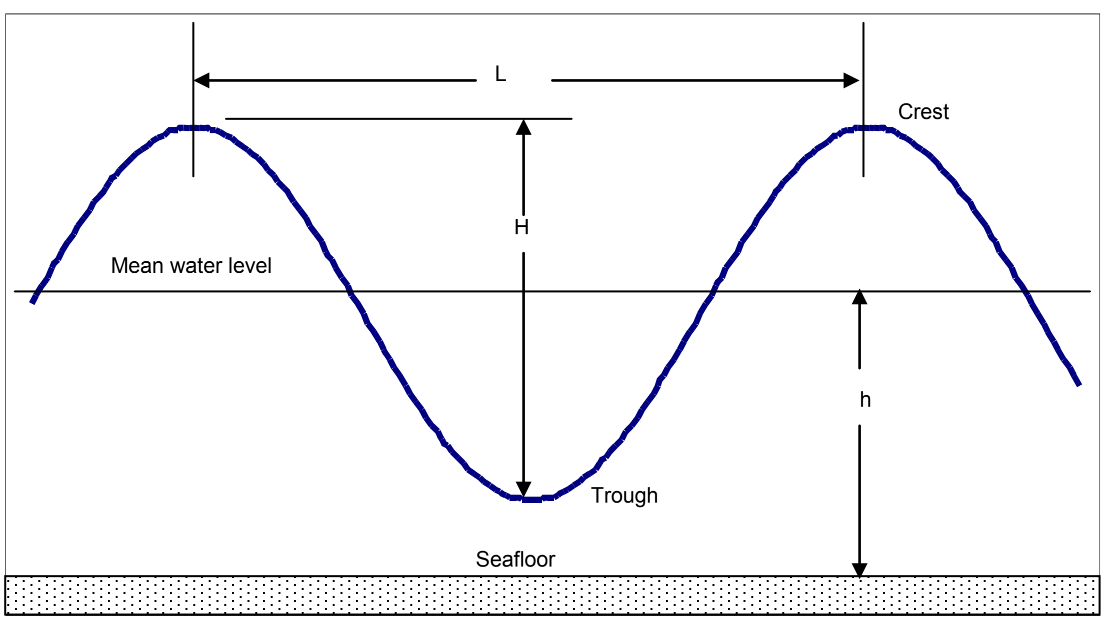
x = horizontal distance, [m]

z = instrument depth, [m]

Basic Linear Wave Description

A traveling disturbance of the sea surface is commonly represented as a linear simple harmonic wave traveling in the x horizontal direction:

$$A(x,t) = a \cos(kx - \sigma t + \varphi) \quad [1]$$



Simple-Harmonic Linear Wave Traveling on the Sea Surface

Phase Angle

The phase angle φ represents a shift of the wave relative to some reference time. This is useful for describing the relationships between a group of waves of different frequencies. When a time series is separated by spectral analysis methods into frequency components defined by [1], the two numbers that are computed for each frequency are:

amplitude	a(f)
phase	φ(f)

The physical time lag associated with a given phase depends on the wave period (T). For example, a phase of π radians implies a time lag of 5 seconds for a wave with a period of 10 seconds (T = 10 sec), while the same phase implies a lag of 2.5 sec for a wave with T = 5 sec.

Dispersion Equation

For surface gravity waves described by [1], there is a special relationship between wave period and wave length. This relationship, which depends on water depth, is called the dispersion relation and is given by:

$$\sigma^2 = gk \tanh(kh) \qquad [2]$$

Implications of Linear Theory

Equation [1] represents a single frequency-wavenumber component of a sea surface that usually contains a whole group of waves of different sizes, lengths, and propagation directions. One of the major assumptions of linear theory is that we can take this jumbled combination and treat each frequency component (or frequency band) separately by using [1].

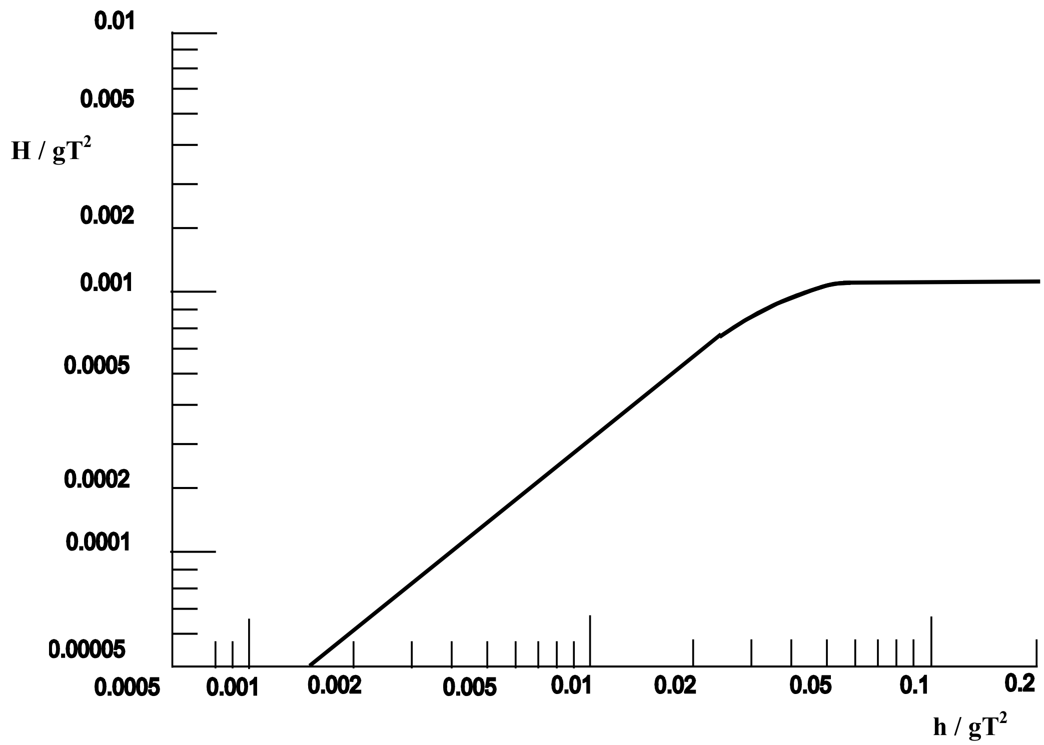
First order linear *small amplitude* theory is the simplest and most direct solution to a very complex general set of equations and boundary conditions for surface gravity waves. The simple results are based on a set of approximations that are strictly valid only over a restricted range of conditions. Small amplitude wave theory is not a good model of steep or breaking waves, or waves traveling in very shallow water. The theory is a good model of long ocean waves away from viscous boundary layers and horizontal boundaries.

Assumptions

For the linear theory to be valid, a major requirement is that the wave height H be small compared with both the wavelength L and the water depth h. These conditions are usually expressed as:

H / L	$<< 1$	(wave steepness)
$H L^2 / h^3$	$<< 1$	(Ursell parameter)

Another measure of the effect of wave steepness on the validity of the small amplitude theory, based on laboratory measurements, is shown below. For the theory to be valid, you must be below the curve indicated. For example, if the wave period of interest T is 10 sec and the water depth h is 100 meters, the parameter $h / gT^2 = 0.1$. This means that H / gT^2 must be less than 0.001 for the theory to be valid, which translates into a maximum wave height of 1 meter.



Range of Validity of Linear Wave Theory
(Theory Valid for Values Below Curve)

A final rule of thumb is that estimates of surface wave heights should be accurate within ± 5% provided:

$z / L < 0.3$ to 0.5,

where z is the depth of the instrument below the surface and L is the wavelength of the observed waves.

Subsurface Pressure Due to Surface Gravity Waves

As a surface wave passes over a subsurface position, the elevation and depression of the sea surface causes a differential subsurface pressure disturbance. This pressure disturbance decays with depth according to the relation:

$$p = W_W A(t) K(f,z) \quad [Pa] \qquad [3]$$

where the vertical pressure response function is:

$$K(f,z) = \cosh[k(h - z)] / \cosh(kh) \quad [dimensionless] \qquad [4]$$

where
A(t) (defined by [1]) = water surface displacement, which varies between +a and -a meters
W_w = specific weight of water near the surface
h = water depth
k = wave number [radians/m], calculated for a given wave period and depth with the dispersion relation [2]
z = vertical distance [m] from the measurement point to the mean (undisturbed) water surface

Equation [3] is the essential result required to relate subsurface pressure to surface wave height. For a given pressure frequency component P(f), the transfer function used to obtain surface wave amplitude a(f) from subsurface pressure is:

$$a(f) = P(f) / W_W K(f,z) \quad [m] \qquad [5]$$

For deep water waves (kh >> 1 and h/L > 0.5) equation [3] takes the form:

$$p \approx W_W A e^{-kz} \quad [Pa] \qquad [6]$$

which clearly represents an exponential decay with depth.

For shallow water waves (hk << 1 and h > L/2) equation [3] takes the form:

$$p \approx W_W A \quad [Pa] \qquad [7]$$

which is simply the hydrostatic equation.

The table below, developed with Plan Deployment, shows pressure attenuation [p(bottom) / p(surface)] vs. bottom depth for waves with T = 2, 5, 10, 20, and 25 seconds.

Water Depth [meters]	Sensor Height above Bottom [meters]	Wave Period [seconds]				
		25	20	10	5	2
2	**0**	0.99	0.99	0.96	0.84	0.25
4	**0**	0.99	0.98	0.92	0.70	0.04
8	**0**	0.97	0.96	0.84	0.45	-----
15	**0**	0.95	0.93	0.72	0.17	-----
20	**0**	0.94	0.90	0.63	0.08	-----
30	**0**	0.91	0.85	0.48	0.02	-----
40	**0**	0.87	0.81	0.35	-----	-----
50	**0**	0.84	0.76	0.25	-----	-----
75	**0**	0.77	0.65	0.1	-----	-----
100	**0**	0.70	0.55	0.04	-----	-----

Pressure attenuation [p(bottom) / p(surface)] for various bottom depths and wave periods (----- = less than 0.001).

High Frequency Cutoff

The table above shows that the pressure attenuation with depth is a strong function of the wave period; short period waves attenuate much faster with depth than longer period waves. This implies that for a pressure sensor deployed at a fixed depth z, there is a high frequency cutoff fmax for which waves with f > fmax are not measurable. Above the high frequency cutoff, any noise in the subsurface pressure record is mapped by the transfer function into unrealistic surface wave height values. The default high frequency cutoff for Process Wave Burst Data is the frequency where the ratio of pressure measured by the SBE 26 to pressure at the surface is less than (0.0025 / wave sample interval) [see equation 20]. Frequencies greater than fmax are not processed by Process Wave Burst Data for most applications.

Note:
Frequencies greater than fmax are processed if *Use filter cutoff* is selected in Process Wave Burst Data.

Example:
Water depth is 10 meters. You are interested in measuring waves with frequencies up to 0.36 Hz (period = 1 / 0.36 = 2.8 seconds). You plan to sample waves 4 times per second (wave sample interval = 0.25 seconds) with 1024 samples per wave burst, and to process data with 10 spectral estimates/band. Can you place the SBE 26 at 1 meter above the bottom and accomplish your goals?

Running Plan Deployment with the above parameters, the Frequency Span is 0.0215 to 0.3340 Hz. Since 0.334 < 0.37, you cannot accomplish your goals.

Iterating on a solution by changing the instrument height in Plan Deployment, you find that placing the SBE 26 at 2.5 meters above bottom will allow you to measure the desired frequencies. Alternatively, you could consider modifying other sampling parameters while maintaining the instrument height.

Wave Processing Steps

To compute surface wave energy spectra and statistics, the frequency dependent attenuation must first be removed from the subsurface pressure data. Fourier analysis techniques are used to decompose the subsurface time series into a group of linear wave components, each with a distinct frequency, amplitude, and phase.

Initial Processing of Pressure Data

First the wave burst data is read into an array. The mean is computed and then the mean and trend are removed from the array. A trend is expected in the wave data due to tides and other low frequency waves. If these trends are not removed, distortions can occur in the processing of spectral estimates; the *ramp* function in the time domain leaks all over the spectrum in the frequency domain.

Density (D_w) is computed from the user-supplied salinity and temperature.

Instrument depth (z) and water depth (h) are computed by:

$$z = 6894.757 \text{ (mean pressure - 14.7) } / D_W g \quad \text{[m]} \qquad [8]$$

$$h = z + \text{height of pressure sensor above bottom} \quad \text{[m]} \qquad [9]$$

where the factor 6894.757 is used to convert the pressure from psi to Pascals.

If the number of wave samples is not a power of two, the array length is made a power of two by filling it with the last de-meaned and de-trended pressure value.

Next, a Hanning window is applied to the time series to suppress the spectral leakage that occurs when the time series to be Fourier transformed contains a periodic signal that does not correspond to one of the exact frequencies of the FFT. Physically, this means that an integral number of waves does not fit in the time series. When this occurs, energy at one frequency leaks to other frequencies. This causes errors when applying the frequency dependent dispersion transfer function to the transformed data. The Hanning window has the form:

$$u(t) = 1 - \cos^2(\pi t / T_b) \quad 0 \le t \le T_b \qquad [10]$$

The windowing operation reduces the total energy in the time series so each element is multiplied by the scale factor SF, where

$$SF = (8 / 3)^{1/2} \qquad [11]$$

to obtain the correct magnitudes in later spectral estimates.

Finally, each element in the time series is multiplied by the factor 6894.757 to convert the measured pressure from psi to Pascals.

Surface Wave Auto-Spectrum

The Finite Fourier transform of a time series with N points contains N raw spectral estimates at frequencies given by:

$$F_j = j \mid T_b \quad j = 0, N\text{-}1 \quad [\text{Hz}] \qquad [12]$$

where T_b is the total time of the series (seconds). The first spectral estimate (j = 0) is the mean of the time series, and is 0 since the subsurface pressure time series has been de-meaned.

The interval between spectral estimates (resolution bandwidth) is:

$$\delta f = 1 / T_b = 1 / (N\delta t) \qquad [13]$$

where δt is the time interval between samples in the subsurface pressure time series.

While N raw spectral estimates are computed, only the first (N/2 + 1) are unique. For a real input time series the second (N/2 - 1) values are identical to the first N/2 values. The limiting frequency is the Nyquist frequency, given by:

$$\text{Nyquist} = 1 / (2\delta t) \quad [\text{Hz}] \qquad [14]$$

The forward Fourier transform of the time series is defined by:

$$Z_j = (1 / N) \sum_{n=0}^{N-1} x_n \exp(-i\, 2\, \pi\, n\, j / N) \qquad [15]$$

where
Z_j (the raw spectral estimates) are complex numbers.
$i = (-1)^{1/2}$

The raw spectral estimates are directly related to the single frequency wave described in [1]:

$$a_j = 2 \mid Z_j \mid , \qquad \varphi_j = \arg(Z_j) \qquad [16]$$

The variance at each frequency is:

$$\text{var}_j = \mid Z_j \mid^2 , \qquad j = 1, N\text{-}1 \qquad [17]$$

The total variance of the spectrum:

$$\text{var}_{total} = \sum_{j=1}^{N-1} \mid Z_j \mid^2 \quad [\text{Pa}^2] \qquad [18]$$

is equal to the variance calculated from the time series [28].

For each frequency up to the Nyquist, the relationship between the single pressure wave variance [1] and [17] is:

$$a_j^{\,2} / 2 = 2\, \text{var}_j \qquad [19]$$

Once the Fourier transform has been obtained, the Fourier coefficients for the frequencies greater than fmax and less than fmin are *typically* set to 0.0:

fmax = minimum of:
frequency where (subsurface / surface pressure = 0.0025 / δ t) [20]
or
1 / user input minimum period [21]

fmin = 1 / user input maximum period [22]

Maximum frequency limits prevent noise in the subsurface time series from being mapped by the dispersion transfer function into unrealistic wave heights.

If the user selected *Use filter cutoff*, a filter is applied that ramps the Fourier coefficients down to 0 for frequencies greater than fmax and less than fmin.

- For frequencies less than fmin:
  fourier coefficient = f * exp ([f – fmin]/ fc)
- For frequencies greater than fmax:
  fourier coefficient = f * exp ([fmax – f]/ fc)

where
f = frequency
fc = user input filter value

A copy of the Fourier transform is saved; it will be used to recover the surface wave time series.

Band Averaging

Each raw spectral estimate contains two degrees of freedom. Band averaging can be used to increase the number of degrees of freedom and reduce the error of the estimate. The number of degrees of freedom (n_d) associated with grouping n_f spectral estimates in a frequency band of width δf is twice the number of frequencies in the band. $\delta f = n_f / T_b$

Band averaging is performed by adding up the total variance in a frequency band and dividing the sum by the width (Hz) of the frequency band (δf). For positive frequencies less than the Nyquist, the estimate of the one-sided subsurface pressure auto-spectral density function for a frequency band centered at f_b is:

$$< G_{pp} (f_b) > = \frac{2 \sum_{k=1}^{n_f} | Z_k |^2}{\delta f} \qquad [Pa^2 \ sec] \qquad [23]$$

Confidence Intervals (Error Bars)

The properties of a *real-world* (random) time series cannot be precisely determined from sample data. Only estimates of the parameters of interest can be obtained. The method for setting error bars on the estimates of the auto-spectral density function $<G_{pp}>$ is related to the Chi-Square distribution function:X^2.

The confidence interval (1-α; α is the significance) for the *true* auto-spectral value G_{pp} based on an estimate $<G_{pp}>$ is given by:

$$\frac{n_d <G_{pp}>}{X^2 n_d ; \alpha / 2} \leq G_{pp}(f_b) \leq \frac{n_d <G_{pp}>}{X^2 n_d ; 1 - \alpha / 2} \qquad [24]$$

where

n_d = 2 * number of frequency bands averaged

$X^2 n_d;\alpha$ = percentage points, Chi-Square distribution with n_d degrees of freedom and significance α

The Chi-Square distribution is described completely in most statistics books (for example, J. E. Freund, Mathematical Statistics, 1962, Prentice Hall, Inc.). For example, if 10 frequencies are averaged per band and we wish to know the error bars corresponding to the 90% confidence interval:

$n_d = 20$ alpha = significance = 0.1

$X^2_{20;0.05} = 31.41$ $X^2_{20;0.95} = 10.85$

Therefore, the error bar is:

$$(0.637 <G_{pp}>) \leq G_{pp} \leq (1.843 <G_{pp}>)$$

This means that we can say with 90% certainty that the *true* value of G_{pp} lies somewhere between 0.637 and 1.843 times the estimated value of G_{pp}.

When band averaging, the value of the auto-spectral estimate lies somewhere in the band averaged frequency band; the error bars for the frequency are as wide as the band.

Band averaging is a trade-off between *vertical* and *horizontal* error bars. If you average a lot of bands, you get a good estimate of the magnitude of a peak in G_{pp}, but there is a lot of uncertainty as to its precise frequency value. If you band-average only a few bands, the frequency of a peak is precisely defined, but there is a lot of uncertainty as to the value of G_{pp}.

Sometimes a peak in the spectrum stands out from the background if there are few frequencies in the band, but vanishes into the background as the number of frequencies averaged increases. When this happens, an understanding of the physical problem being investigated can help in deciding whether the peak is real or not.

Surface Wave Auto-Spectral Density Function

The one-sided surface wave auto-spectral density function for a frequency band centered at f_b is:

$$G_{aa}(f_b) = |H(f_b)|^2 G_{pp}(f_b) \quad [m^2 \sec] \qquad [25]$$

The transfer function $H(f_b)$ is used to convert the subsurface pressure to surface waves and is computed with equations [2] and [4].

$$H(f_b) = 1 / [W_w K(f, z)] \quad [m / Pa] \qquad [26]$$

A plot of the surface wave auto-spectral density function G_{aa} with error bars is probably the most useful way of describing the sea surface shape due to a surface wave field. A glance at the spectrum shows where the wave variance is in frequency space.

The surface wave spectral density function G_{aa} has units of [m^2 sec]. To find the variance [m^2] in a frequency interval δf (Hz), multiply G_{aa} by δf.

Total Variance and Energy

The total variance Var_{tot} is the sum of all the band-averaged spectral estimates:

$$var_{tot} = \sum_{k=1}^{n_b} G_{aa}(f_k)\,\delta f \qquad [m^2] \qquad [27]$$

where
δf is the number of spectral estimates in the band divided by the total sample period,
n_b is the number of frequency bands computed,
$G_{aa}(f_k)$ is the spectral estimate for the frequency centered at f_k.

The total wave energy (J / m^2) is found by multiplying the total variance by the specific weight of water (W_w).

Significant Wave Height and Period

The significant wave height is the average height of the highest 1/3 of the waves and is estimated from the auto-spectrum as:

$$H_{1/3} = 4\ (Var_{tot})^{1/2} \qquad [m] \qquad [28]$$

The significant wave period estimated from the auto-spectrum is the period corresponding to the frequency with the highest variance.

Surface Wave Time Series

To reconstruct the surface wave time series from the subsurface pressure, the transfer function $H(f_i)$ [see equation 26] is applied frequency by frequency to the scaled raw spectral estimates:

$$A(f_i) = H(f_i)\,P(f_i) \qquad f_i \leq \text{Nyquist} \qquad [29]$$

where $A(f_i)$ are the raw spectral estimates of surface wave amplitude and $P(f_i)$ are the spectral estimates of subsurface pressure. The spectral estimates for f_i > Nyquist are given by $A(F_{n-i}) = A(f_i)$.

The Inverse Fast Fourier Transform (IFFT) is taken to construct the surface time series.

The influence of the Hanning window is removed with a deconvolution in the time domain; each point x_i is multiplied by the inverse of the Hanning window w_i corresponding to the same time point. This procedure is unstable near the end points where $w_i \approx 0$. Therefore, the time series is set to 0 at the beginning and end where the window reaches 1% of its maximum value.

Finally, each point in the time series is multiplied by 1 / sqrt (8/3) to compensate for the initial scaling of the time series.

Total Variance and Energy

The unbiased sample variance is a fundamental statistical measure of the time series. Variances from different bursts can be compared to see if the wave field is stationary or changing. The unbiased estimator for the variance is:

$$< \sigma_x{}^2 > = (1 / [N-1]) \sum_{j=0}^{N-1} | x_j - < \mu_x > |^2 \qquad [m^2] \qquad [30]$$

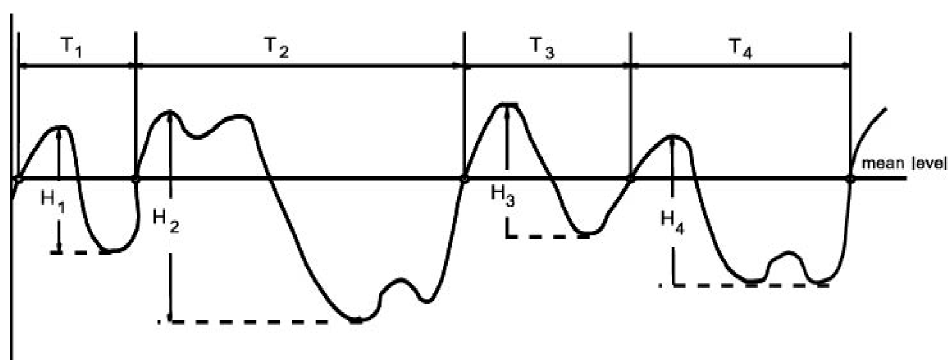
where μ_x is the sample mean. In this case, the mean is zero since the time series has been de-meaned. The variance obtained from the reconstructed time series can be compared with the total variance obtained from the auto-spectrum [25] as a check on the *goodness* of the time series reconstruction.

An estimate of the total wave energy contained in the record is:

$$E = W_w < \sigma_x{}^2 > \qquad [J / m^2] \qquad [31]$$

Average Wave Height and Period: H_{avg}, T_{avg}

Since the wave time series is typically very irregular due to the random nature of the sea surface, the calculation of wave heights and periods can only be approximate and statistical. A standard method for estimating wave heights and wave periods is summarized in the Handbook on Wave Analysis and Forecasting, from the World Meteorological Organization (WMO- No. 446, 1976, Geneva, Switzerland) and illustrated below:



Zero-Crossing Method for Estimating Wave Heights and Periods from a Wave Time Series

Individual *waves* are isolated by identifying the zero *upcrossings*; H and T for each captured wave is stored in an array. Averaging over all the captured waves yields the average wave height H_{avg} (meters) and the average period T_{avg} (seconds). H_{max} is the largest captured wave.

Sea State (Significant Wave Height)

The significant wave height ($H_{1/3}$) and average period (T_{avg}) define the sea state. $H_{1/3}$ is the average height of the highest 1/3 of the waves and has physical significance because it is the approximate wave height picked out visually and reported by trained observers at sea.

$T_{1/3}$ is obtained by picking out the highest 1/3 of the captured waves and averaging their periods.

The parameters $H_{1/10}$ and $H_{1/100}$ are similarly defined as the average height of the highest 10 and 1 percent of the captured waves, respectively.

Appendix VII: Pressure-to-Depth Conversion

Force is mass * acceleration, units are Newtons [N]:

$N = Kg\ m / sec^2$

Density (ρ) is mass / volume, units are [Kg/m^3]:

This is the *in situ* value, and is approximately 1025 Kg/m^3 at the surface.

Specific weight (W) is weight / volume, units are [N/m^3]:

$W = \rho * g$

where g = local gravity [m / sec^2]

Hydrostatic equation:

$p = p_{atm} + W * z$

p_{atm} = atmospheric pressure in Pascals [N / m^2]

p = total pressure in Pascals [N / m^2]

W is average density times gravity [N/m^3]

z = depth [m]

Conversions:

1 Pascal = 10^{-4} decibars

1 psi = 0.6894757 decibars

Example:

average density = 1025 kg / m^3

average gravity = 9.8 m / sec^2

pressure reading = 6000 decibars = 6×10^7 Pascals

atmospheric pressure = 14.7 psia = 1.013529×10^5 Pascals

$W = 1025 * 9.8 = 10045$ [N / m^3]

$6 \times 10^7 - 1.013529 \times 10^5 = 10045 * z$

$z = 5.989865 \times 10^7 / 10045 = 5963.031$ meters

Appendix VIII: References

Textbooks:

Bendat, J.S. and A.G. Piersol, 1986. *Random Data, Analysis and Measurement Procedures*, 2nd edition, Wiley, NewYork, ISBN 0-471-04000-2.

Bevington, P.R., 1969. *Data Reduction and Error Analysis for the Physical Sciences*, McGraw-Hill, New York.

Freund, J.E., 1962. *Mathematical Statistics*, Prentice Hall, EngleWood Cliffs, N.J.

LeBlond, P.H., and L.A. Mysak, 1978. *Waves in the Ocean*, Elsevier Amsterdam, ISBN 0-444-41602-1.

Neumann and Pierson, 1966. *Principles of Physical Oceanography*, Prentice Hall, EngleWood Cliffs, N.J.

Pond and Picard, 1983. *Introductory Dynamical Oceanography*, 2nd Ed., Pergamon Press, New York, ISBN 0-08-028728-X

Press, W. H., *et. al.*, 1986. *Numerical Recipes*, Cambridge University Press, New York.

Reports:

Earle, M.D. and J.M. Bishop. 1984. *A Practical Guide to Ocean Wave Measurement and Analysis*, Published by: ENDECO, Inc., Marion, MA.

Handbook on Wave Analysis and Forecasting, 1976. World Meteorological Organization, Geneva, ISBN 92-63-10446-8.

Knowles, C.E., 1981. Estimation of surface gravity waves from subsurface pressure records for estuarine basins. UNC Sea Grant College Publication UNC-SG-WP-81-6.

Morang, A, *1990. Quality Control and Management of Oceanographic Wave-Gauge Data*, Instruction Report CERC-90-1, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi.

Scientific Publications:

Bergan, A.O., A. Torum and A. Tratteberg, 1968. Wave measurements by pressure type wave gauge. Proc. 11th Coastal Eng Conf., ASCE, 1: 19-29.

Bishop, C.T. and M.A. Donelan, 1987. Measuring waves with pressure transducers. *Coastal Eng.*, 11: 309-328.

Forristall, G.Z., 1982. Subsurface Wave-Measuring Systems, *in: Measuring Ocean Waves*, National Academy Press, Washington D.C., pp. 194-209.

Grace, R.A., 1970. How to measure waves. *Ocean Ind.*, 5(2): 65-69.

Hom-ma, M., K. Horikawa and S. Komori, 1966. Response characteristics of underwater wave gauge. Proc. 10th Coastal Eng. Conf., ASCE, 1: 99-114.

Michel, W.H., 1968. Sea Spectra Simplified. *Marine Technology,* January 1968: 17-30.

Wang, H., D. Lee and A. Garcia, 1986. Time series surface wave recovery from pressure gage, *Coastal Engineering*, 10: 379-393.

Appendix IX: Replacement Parts

Part Number	Part	Application Description	Quantity in 26
22018	Battery, alkaline D-cell, Duracell MN1300 (LR20)	Power SBE 26	9
41124	Battery cover plate	Retains **alkaline** batteries	1
801483	9D (10.8 V/42 amp-hours) lithium battery pack kit	Note: **Batteries not included.**	-
30346	Screw, 10-24 x 1” hex-head, titanium	Secures connector end cap to optional titanium housing	4
50092	SBE 16/19 Jackscrew Kit	For removing connector end cap	1
60021	Spare battery end cap parts	Assorted o-rings and hardware: • 30090, Parker, 2-153N674-70 (housing face seal) • 30145, Mach Screw, 6-32 x ½ PH SS (secures battery retainer plate to bulkhead posts) • 30242, Washer, #6 Flat, SS (for 30145 screws) • 30816, Parker, 2-234E603-70 (battery end cap piston seal)	-
50056	Spare parts kit	Assorted spare parts: • 30090, Parker, 2-153N674-70 (face seal, battery end cap) • 30815, Parker, 2-233E603-70 (piston seal, connector end cap) • 30816, Parker, 2-234E603-70 (piston seal, battery end cap) • 30145, Mach screw, 6-32 x ½ PH SS (battery endplate) • 30242, Washer, #6, Flat SS (for 30145 screws) • 30447, Bolt, ¼-20 x 1-1/4 Hex (end cap lift eye hardware) • 30493, Mach screw, 10-24 x 1-1/4 (secures connector end cap to plastic housing) • 30552, Retaining ring (secures mounting fixture to its bolt)	1

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Part Number	Part	Application Description	Quantity in 26
17695	3-pin to 3-pin cable, RMG-3FS to RMG-3FS, 0.28 m (11 in.) long	From SBE 26 to optional conductivity sensor - standard connectors	1
171752	3-pin to 3-pin cable, MCIL-3FS to RMG-3FS, 0.28 m (11 in.) long	From SBE 26 to optional conductivity sensor - optional wet-pluggable connector on SBE 26	1
801225	4-pin RMG-4FS to DB-9S data I/O cable, 2.4 m (8 ft) long	From SBE 26 to computer - standard connector	1
801374	4-pin MCIL-4FS to DB-9S data I/O cable, 2.4 m (8 ft) long	From SBE 26 to computer - optional wet-pluggable connector	1
171888	25-pin DB-25S to 9-pin DB-9P cable adapter	For use with computer with DB-25 connector	1
17043	Locking sleeve	Locks I/O cable or dummy plug in place - standard connector	2
171192	Locking sleeve	Locks I/O cable or dummy plug in place - optional wet-pluggable connector	2
17045.1	3-pin RMG-3FS dummy plug with locking sleeve	For when optional conductivity sensor not used - standard connector	1
171500.1	3-pin MCDC-3-F dummy plug with locking sleeve	For when optional conductivity sensor not used - optional wet-pluggable connector on SBE 26	1
17046.1	4-pin RMG-4FS dummy plug with locking sleeve	For I/O connector during deployment – standard connector	1
171398.1	4-pin MCDC-4-F dummy plug with locking sleeve	For I/O connector during deployment - optional wet-pluggable connector	1
801347 / 801542	AF24173 Anti-Foulant Device	For use with optional conductivity sensor – Bis(tributyltin) oxide device inserted into anti-foulant device cup in mount kit	1 (set of 2)
50315	Anti-foulant device mount kit	Mounts on ends of conductivity cell to hold AF24173 Anti-Foulant Devices	1
30411	Triton X-100	Octyl Phenol Ethoxylate – Reagant grade non-ionic cleaning solution for conductivity cell (supplied in 100% strength; dilute as directed)	1
50102	Mounting fixture	Optional mounting fixture with mooring lock pin	1

Appendix X: Manual Revision History

Manual Version	Date	Description
006		• Add conductivity channel, and add cy/cn commands to enable and disable conductivity logging. • Update figure to show two-connector end cap.
008		• Change quiescent current to 1.2ma to reflect new Paroscientific circuit.
009		• Change installation instructions, refer to setup26.bat.
010		• Add support for Merge26, add ptoz appendix.
011		• Change wording of high frequency cut-off
012	10/94	• Change reference from PIZZAZ PLUS to PIZZAZ 5.
013	02/06	• Completely rewrote manual, added graphics, etc. • Added information on Windows software (SeatermW) which replaces WDisp, Plan26, and Term26.
014	12/02	• Add information on memory consumption – 3 bytes for wave burst sample, 4 bytes tide sample. Replace PN 24012 anti-foul assembly in appendix with PN 50315 assembly. • Appendix (data formats) – 47662.5 / 9532.5 in Tide Record equation and example are for 45 psia only, and these are now out of date as well. Values vary depending on pressure sensor; values are stored in EPROM. Change equation and change example. • Change B in DC command example to 4766.3 (new value for 45 psia sensor).
015	05/03	• Incorporated release of complete Windows version of Seasoft for Waves. • Added information on handling of optional lithium batteries. • Updated replacement parts list.
016	06/06	• Housings rated to 600 and 7000 meters, not 680 and 6800 meters • Update manual for software changes (Battery and Memory Endurance was added after stopped production of the 26). • Add diagrams to visually explain sampling parameters. • Lithium batteries not available from Sea-Bird, update shipping precautions, remove from replacement parts list, add battery pack kit. • Add pressure sensor maintenance information. • Add Appendix on AF24173 Anti-Foulant Devices • Add Recovery information, with warning about pressure in housing. • Correct information on PN 22018; 1 battery, not 9. • Update Triton website URL. • Update conductivity cell cleaning to correspond to revised application note 2D.
017	09/11	• Update for Seasoft for Waves 2.0 – Update Convert Hex dialog box to reflect changes. • Update for previous Seasoft for Waves changes – .ini file for calibration coefficients changed to .psa file, location of SeasoftWaves.ini changed (better compatibility with Vista), SeatermW menu changes (Connect and Configure menus replaced by Communications menu). • Update recommended minimum system requirements for installing software; add information about compatibility with Windows 7. • Remove all information on DOS software. • Correct .wb and .wt file description (said “start of tide measurement’, corrected to “start of wave measurement”). • Add information on battery storage – replace main batteries every year to prevent leaking. • Update information on connector maintenance – was inconsistent with application note 57. • Change front cover photo (previously showed orientation in mounting fixture inconsistent with SBE 26). • Update AF24173 Anti-Foulant Device appendix to current label. • Add notes to clarify that Sea-Bird does not provide barometric pressure (.bp) file, must be created by customer. • Update website information for Triton.

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