WORKING PAPER

No. 70
Mar. 1970

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

SALINITY, RUNOFF AND WIND MEASUREMENTS
YAQUINA ESTUARY, OREGON

CLEAN WATER

FEDERAL WATER
POLLUTION CONTROL
ADMINISTRATION
NORTHWEST REGION

PACIFIC NORTHWEST
WATER LABORATORY

CORVALLIS, OREGON

SALINITY, RUNOFF AND WIND MEASUREMENTS
YAQUINA ESTUARY, OREGON

April 1967 - October 1968

by

R. J. Callaway
G. R. Ditsworth
D. L. Cutchin

Working Paper No. 70

United States Department of the Interior
Federal Water Pollution Control Administration, Northwest Region
Pacific Northwest Water Laboratory
200 Southwest Thirty-fifth Street
Corvallis, Oregon 97330

March 1970

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

NORTHWEST REGION, PORTLAND, OREGON

James L. Agee, Regional Director

PACIFIC NORTHWEST WATER LABORATORY
CORVALLIS, OREGON
A. F. Bartsch, Director

NATIONAL THERMAL POLLUTION RESEARCH
Frank H. Rainwater

NATIONAL COASTAL POLLUTION RESEARCH
D. J. Baumgartner

BIOLOGICAL EFFECTS
Gerald R. Bouck

MANPOWER AND TRAINING
Lyman J. Nielson

NATIONAL EUTROPHICATION RESEARCH
A. F. Bartsch

WASTE TREATMENT RESEARCH AND TECHNOLOGY: Pulp & Paper; Food Processing; Wood Products & Logging; Special Studies
James R. Boydston

CONSOLIDATED LABORATORY SERVICES
Daniel F. Krawczyk

NATIONAL COASTAL POLLUTION RESEARCH PROGRAM
D. J. Baumgartner, Chief
R. J. Callaway
M. H. Feldman
B. D. Clark
G. R. Ditsworth
W. A. DeBen
L. C. Bentsen
D. S. Trent
D. L. Cutchin
E. M. Gruchalla
L. G. Hermes

DEPARTMENT OF THE INTERIOR

In its assigned function as the Nation's principal natural resource agency, the Department of the Interior bears a special obligation to assure that our expendable resources are conserved, that renewable resources are managed to produce optimum yields, and that all resources contribute their full measure to the progress, prosperity, and security of America, now and in the future.

A Working Paper presents results of investigations which are to some extent limited or incomplete. Therefore, conclusions or recommendations--expressed or implied--are tentative.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The National Coastal Pollution Research Program (NCPRP) of the FWPCA has as one of its functions in-house and extramural development of mathematical models of estuaries. The purpose of such models is in the management and prediction of water quality in estuaries.

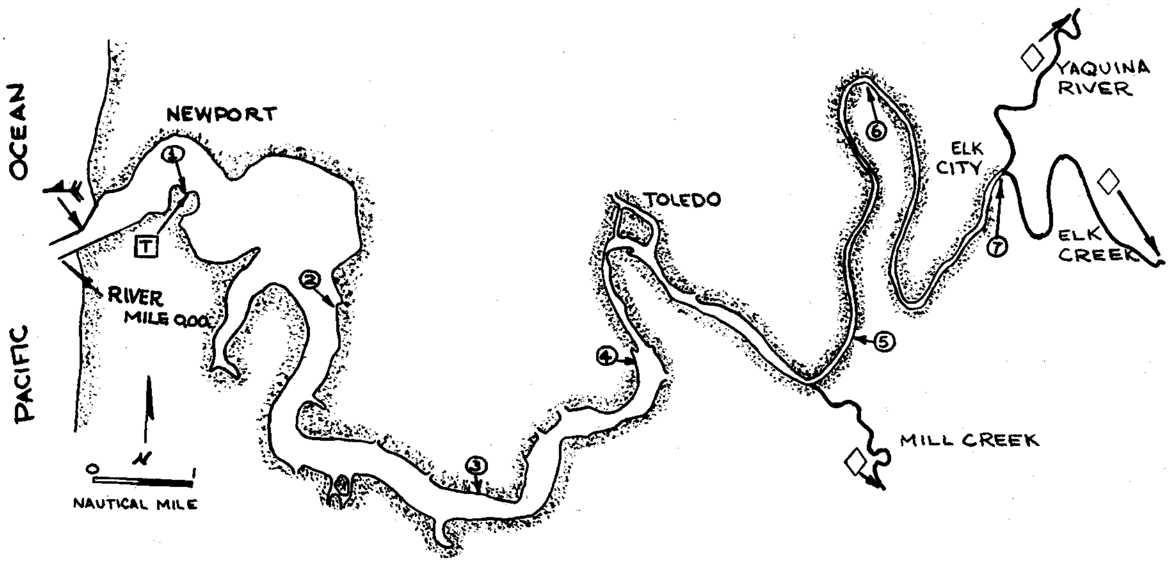
If a given model is properly verified and used with an eye to its limitations, it can be an indispensable tool. If it is not properly verified, it is an ornament; if it is used incautiously, it can create more problems and waste more time than no model at all.

Verification data is difficult to obtain in most cases and more difficult for some (e.g., bacteria distribution) than others (e.g., temperature). Salinity, as conductivity, is one of the easier properties to measure continuously and reliably and is of prime importance in determining the density structure of a water body.

The data collection program discussed in this report was intended for two purposes: 1) to provide data for verification of a solution of the advection-diffusion equation, and 2) to provide long, continuous records on which to test certain hypotheses related to time-series analysis.

During the course of the field collection and since then we have had several requests for the data and for descriptions of what was collected, where and when. This report is an informal summary of data processing techniques and lists the data available and its present condition.

As time permits, we will use the data ourselves to verify a model of the Yaquina River Estuary. In the meantime, we hope this report will indicate to those interested what is available; if still interested, we'll be happy to help you dig it out.



Legend

- O Conductivity Meter Location
- ⟵« Wind Recorder Location
- [T] Tide Gauge Location
- ◇ Stream Gauge Location

	Station	River Mile* (Nautical)
(1)	OSU Dock	∿ 1.5
(2)	Sawyer's Dock	∿ 3.5
(3)	Fowler's Dock	∿ 7.0
(4)	Criteser's Dock	∿ 9.5
(5)	Burpee	∿14.0
(6)	Charlie's Dock (Fritz)	∿16.0
(7)	Elk City	∿19.5

* River Mile 0.00 is the seaward end of the south jetty.

FIGURE 1. FWPCA Stations, Estuary Diffusion Project, Yaquina Estuary

FIELD DATA COLLECTION

Salinity Measurements

Conductivity data from which salinity values were computed were collected at 10 locations in Yaquina Bay and estuary during the period April 1967 - October 1968.

Locations and Depths of Data Collection

Data collection sites are shown in Figure 1 and are identified as OSU Surface, OSU Bottom, Sawyer, Fowler, Criteser Surface, Criteser Bottom, Burpee Surface, Burpee Bottom, Fritz* and Elk City. Each site is a private or public floating dock located nearshore and easily serviced by land routes (automobile).

Data were collected at the water surface (about 1.5 feet beneath the surface) at OSU Surface, Sawyer, Fowler, Criteser Surface, Burpee Surface, Fritz and Elk City. Bottom data (about 1.5 feet off the bottom) were collected at OSU Bottom, Criteser Bottom and Burpee Bottom at depths of about 16 feet, 7 feet and 7 feet, respectively, below Mean Lower Low Water (Figure 2).

Conductivity probes were attached to floating docks to obtain surface data and to pilings to obtain bottom data (Figure 3).

---

*We have, unfortunately, also called this Charlie, thus Fritz and Charlie refer to the same station.

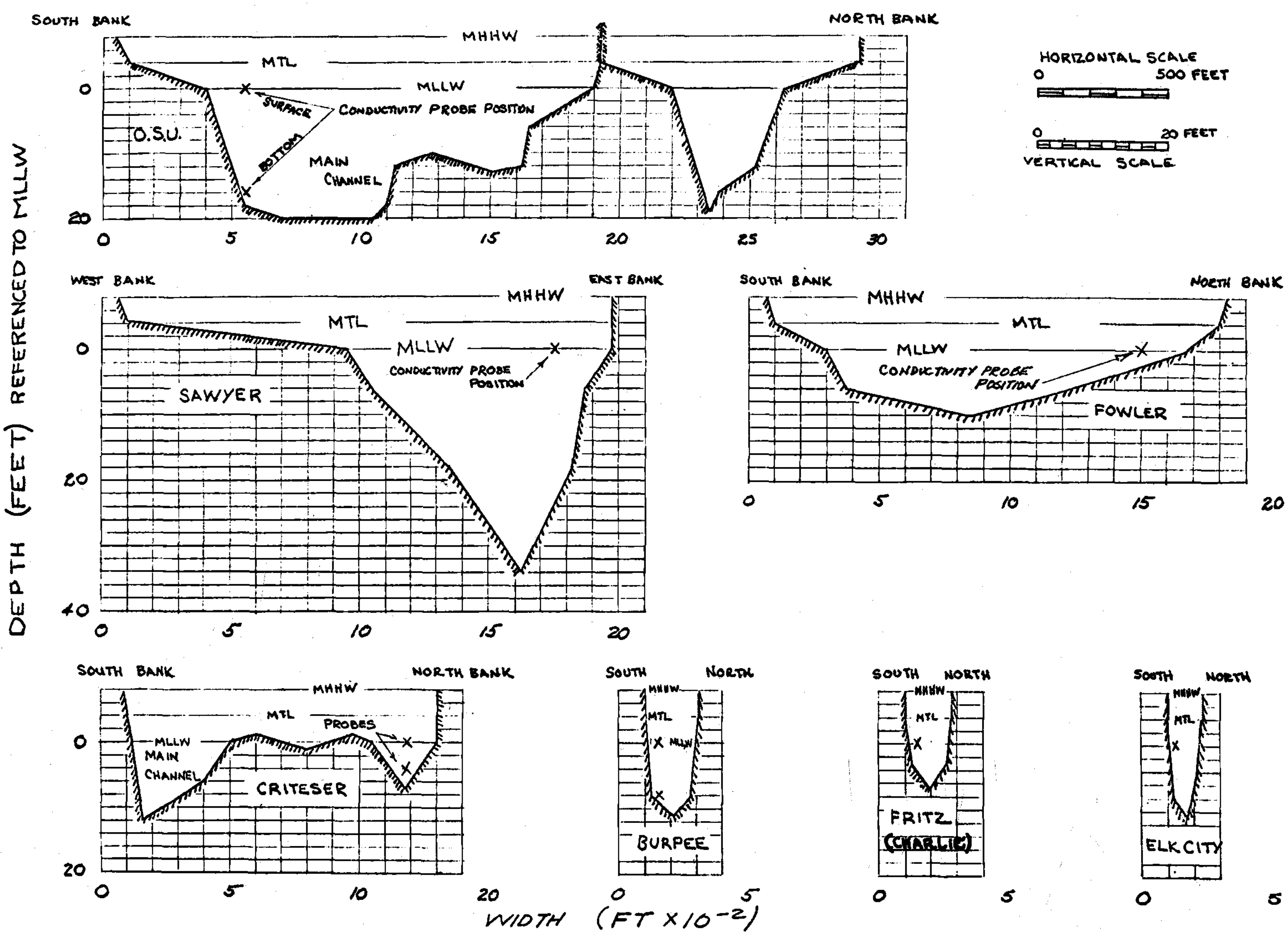


FIGURE 2

CROSS SECTIONS OF ESTUARY AT CONDUCTIVITY MONITORING SITES
YAQUINA BAY, OREGON

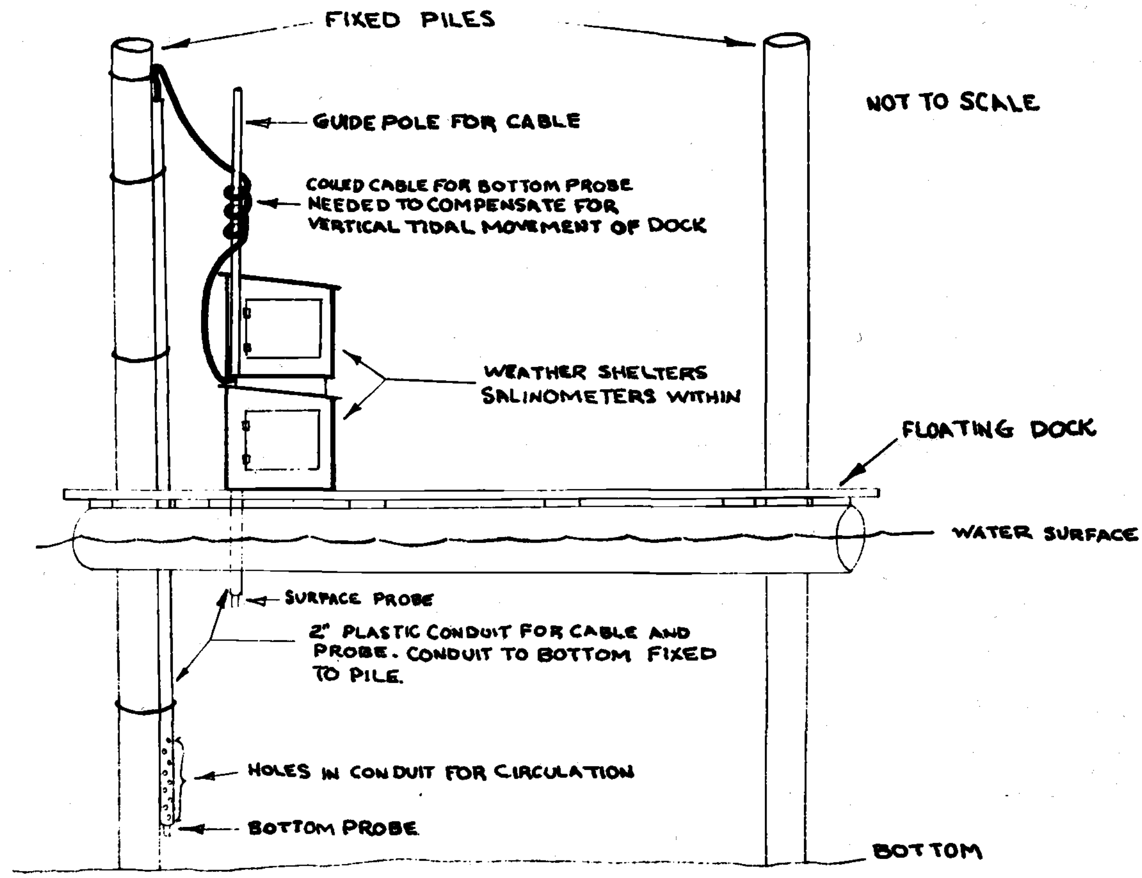


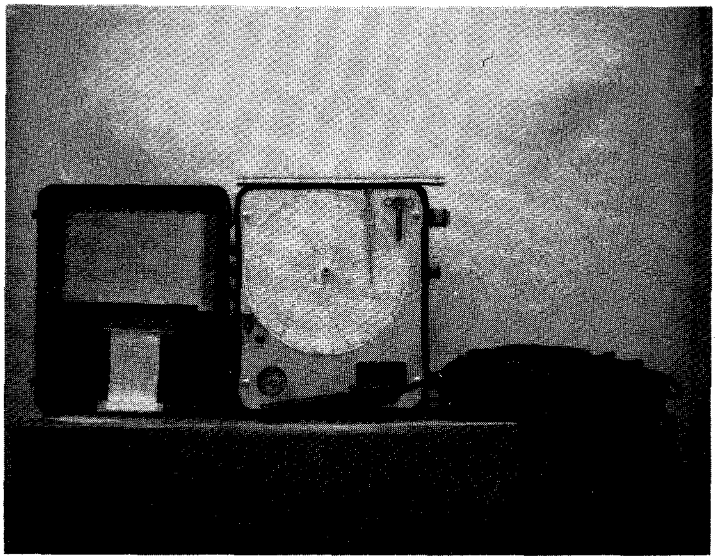
FIGURE 3 TYPICAL INSTALLATION FOR MONITORING SURFACE AND BOTTOM SALINITY.

Instrumentation

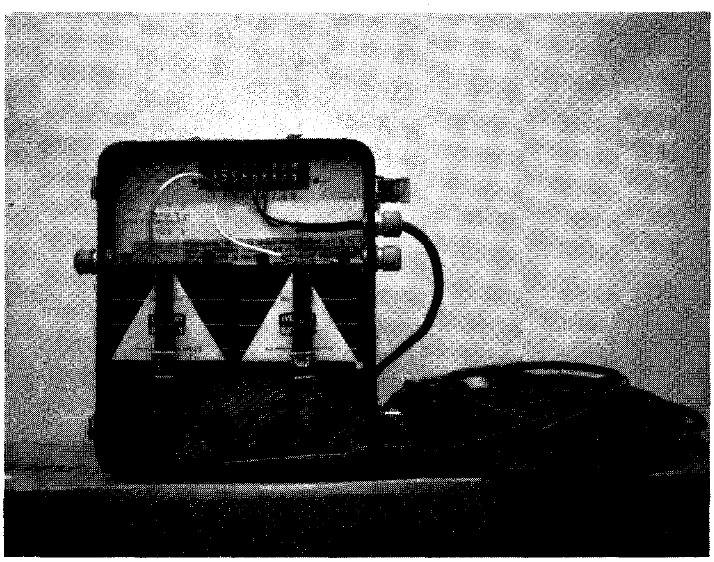
Conductivity data were collected with battery-powered Beckman** model RQ1-7CH2C-R9K recording conductivity meters (Figure 4). The system consists of a recording unit, power source, and associated electronics enclosed in a weather-resistant metal housing and a 100 foot long electrical cable with attached conductivity probe. An analog record of the conductivity is recorded by an ink pen on a polar chart (Figure 5), which is driven by a mechanically wound clockworks. The clockworks are geared such that the chart makes one revolution per week.

The instrument works on the principle that saltwater conducts electricity at a rate proportional to the salt content and temperature of the water. Alternating current, converted from battery-direct current by an oscillator, and transmitted to an exposed terminal in the water, passes through the water and is received by a second exposed terminal. This current is transmitted back to the recording unit. The ambient water temperature (which is not recorded) is measured by a thermistor and transmitted to the recording unit. A temperature compensator in the recording unit electronically cancels effects of temperature and causes the conductivity to be recorded at a constant reference temperature (25°C).

**Use of product and company names is for identification only and does not constitute endorsement by the U. S. Department of the Interior or the Federal Water Pollution Control Administration.



Front view of salinometer: shows chart, inking pen and cable with probe;foot long rule on top gives scale.



Rear view: door removed; shows power source, rear electronic panel and cable with probe.

FIGURE 4. Conductivity Recorder (Salinometer)

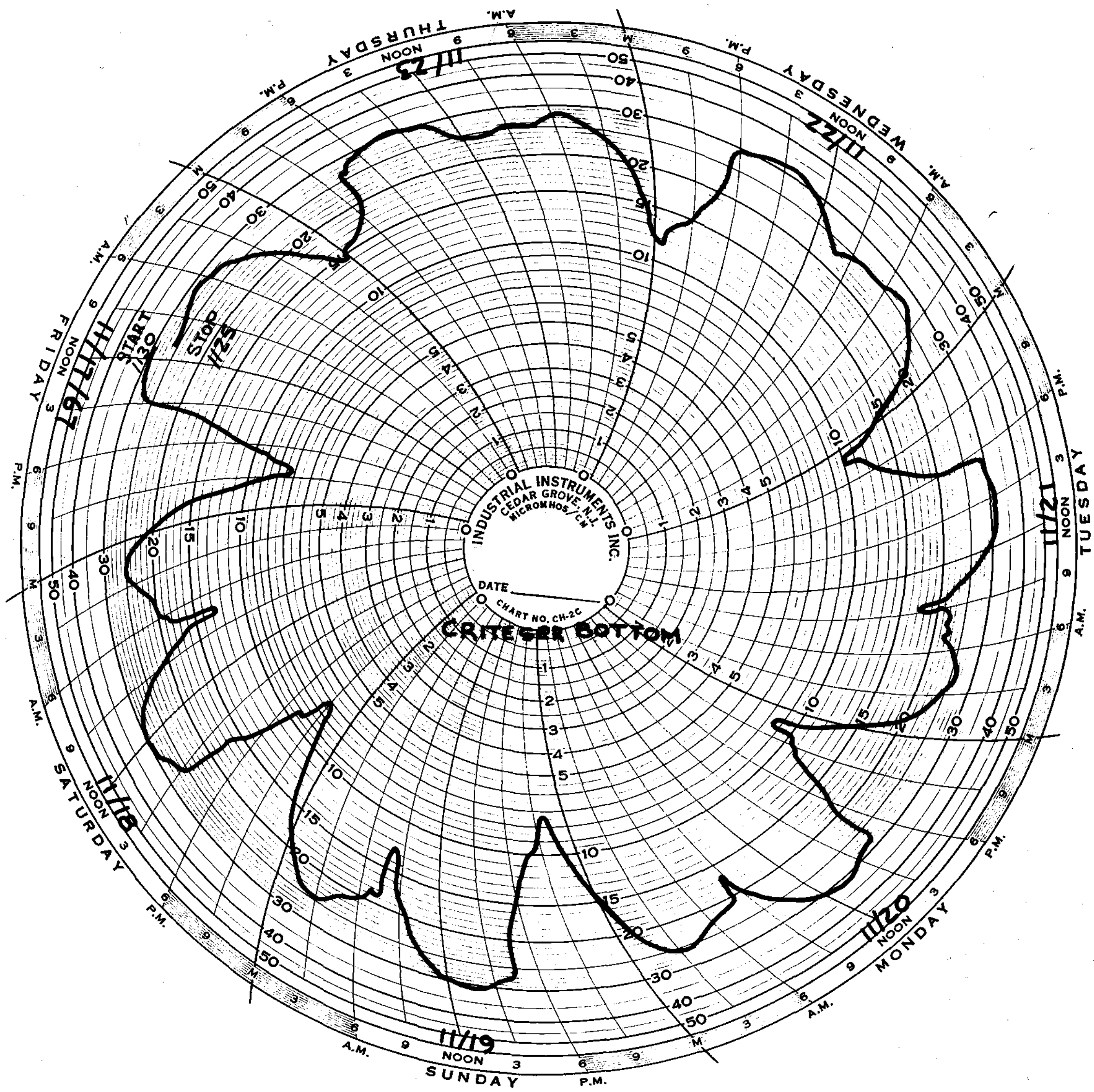


FIGURE 5. Chart Showing Typical Conductivity Trace

Flow Chart of Data Acquisition and Reduction

Steps involved in collecting salinity and wind data and reducing it are shown in the flow diagram (Figure 6).

Calibration

Instruments in service were calibrated weekly beginning in December 1967. Prior to that time, they were calibrated once a month. Tertiary saltwater standards (seawater dilutions) of approximately 6, 12, 18, 24, and 30 parts per thousand (PPT), respectively, were used for calibration. The conductivity probe of each instrument was immersed in each solution and the corresponding chart reading was recorded. The data were used to derive coefficients by which salinity data were calculated from the conductivity chart records. The tertiary standards were tested weekly against secondary standards to insure their reliability.

Maintenance and Service

Servicing of meters was done at least once a week and consisted of changing charts, cleaning the conductivity probes of mud and marine growth, checking pen operation and ink supply, checking, adjusting, if necessary, and winding clockworks, and checking batteries for proper voltage. Batteries were replaced as required.

Batteries maintained a serviceable voltage (9.5 volts minimum) for a period of 10 to 14 days. They maintained this voltage

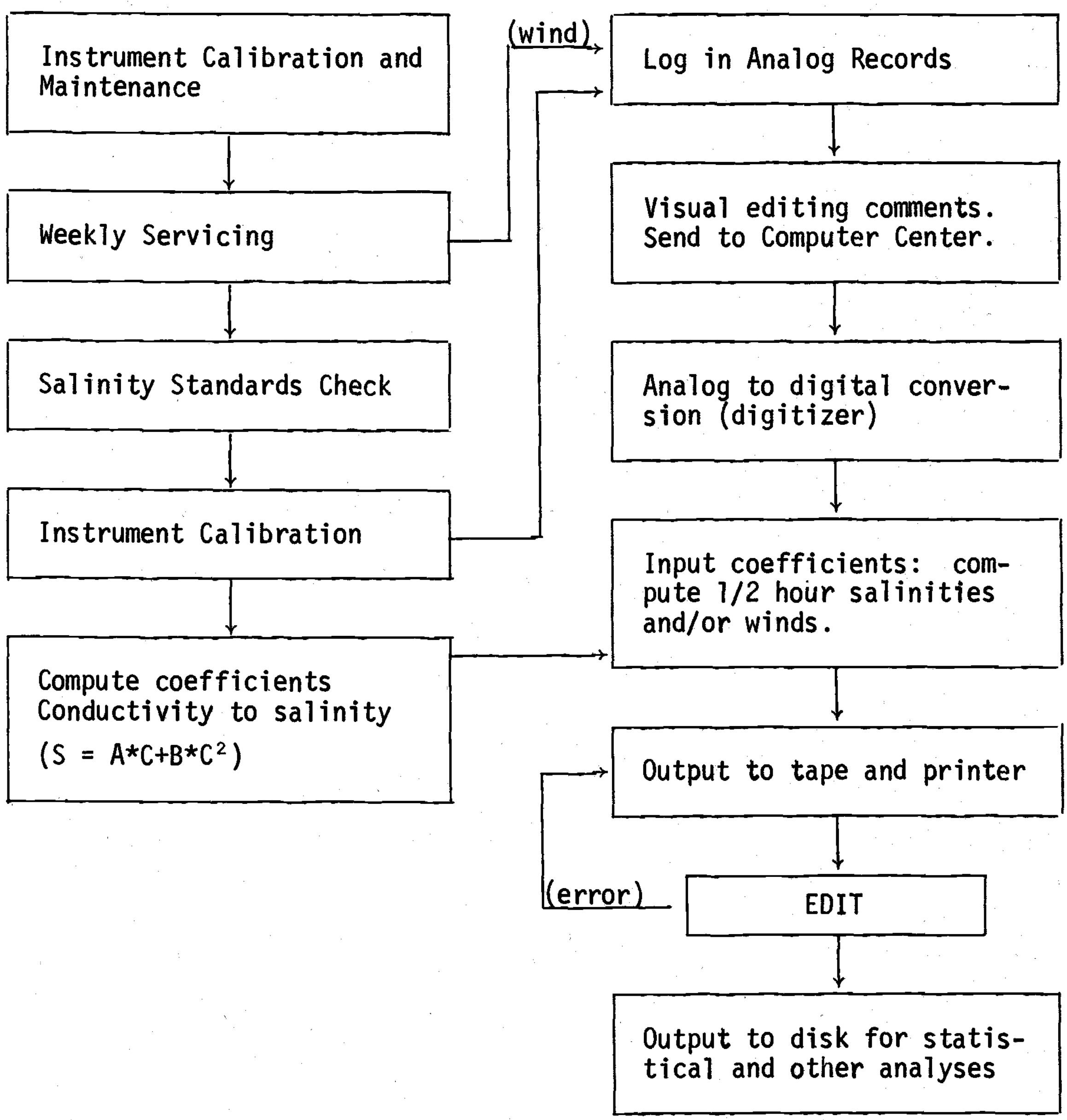


FIGURE 6. Salinity and Wind Data Processing

for the minimum period during cold weather. Battery life was more dependent on air temperature than the current draw due to large salinity fluctuations.

Problems Associated with Instrument Operation

Occasionally, an instrument would stop functioning for a period of hours or days. This seemed to occur most frequently during periods of cold weather.

Conductivity probes failed on occasion for no known reason. In such cases, generally, another cable was installed and the instrument operated satisfactorily.

Length of Record

The length of record at each station is shown in Figure 7.

Stream Flow Measurements

Streamflow data of the Yaquina River and Elk Creek, the two major tributaries to the Yaquina Estuary, were collected from April 1967 to November 1968 by the Pacific Northwest Water Laboratory. Together, these two streams drain about 68 percent of the Yaquina Bay watershed. Flow data for Mill Creek, a smaller tributary to the estuary, were obtained from the Geological Survey. Mr. Alden Christianson supervised the installation of the gauges and obtained the stage versus flow data.

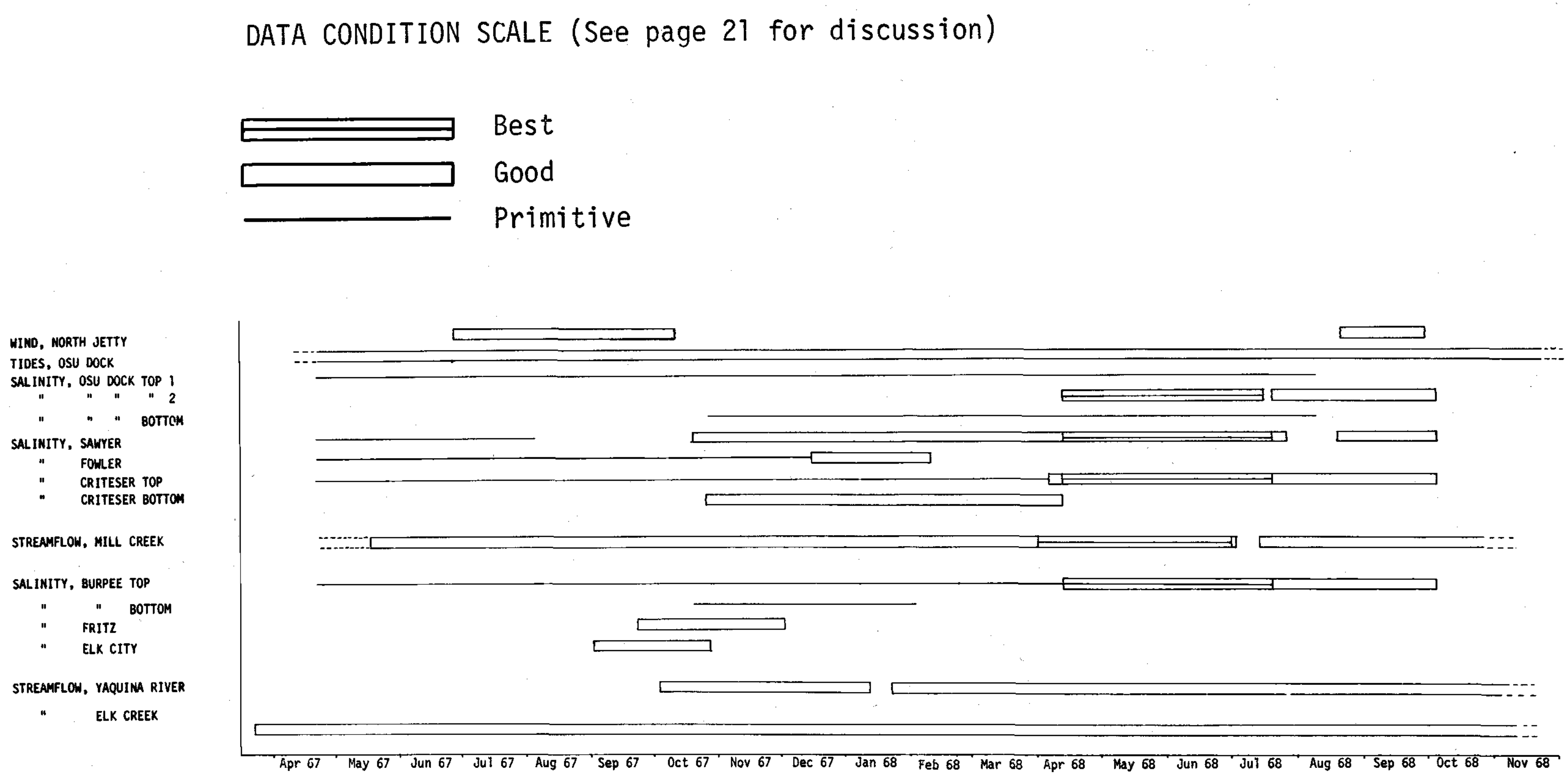


FIGURE 7. Data Extent and Present Condition.

Station Location, Instrumentation, and Techniques

Temporary gauging stations were installed immediately above the tidally-influenced reaches of each of the two major tributaries (Figure 1).

Water levels were continuously recorded in analog form (See Figure 8) with Leupold and Stevens Type F, Model 61, water level recorders. The water level, indicated on a visually-read staff gauge, installed at each site, was recorded on the analog record each time the instrument was serviced (weekly).

Using these data and data from periodic discharge measurements, the continuous flows in each stream were calculated. Stream flows versus stage for the Yaquina River and Elk Creek are shown in Figure 9. These streamflow data have been digitized and are on file as are the Geological Survey flow data from Mill Creek.

Wind Measurements

Wind speed and direction data were collected near the mouth of Yaquina Bay during the period June 1967 to January 1969.

From June 1967 to December 1967, data were collected from the north jetty (Figure 1) with a Climet Model 26 wind recording system. From April 1968 to October 1968, data were collected from the south jetty (Figure 1) with a Geodyne Wind Recorder (Figure 10). From July 1968 to January 1969, data were collected at the same site with the Climet recorder.

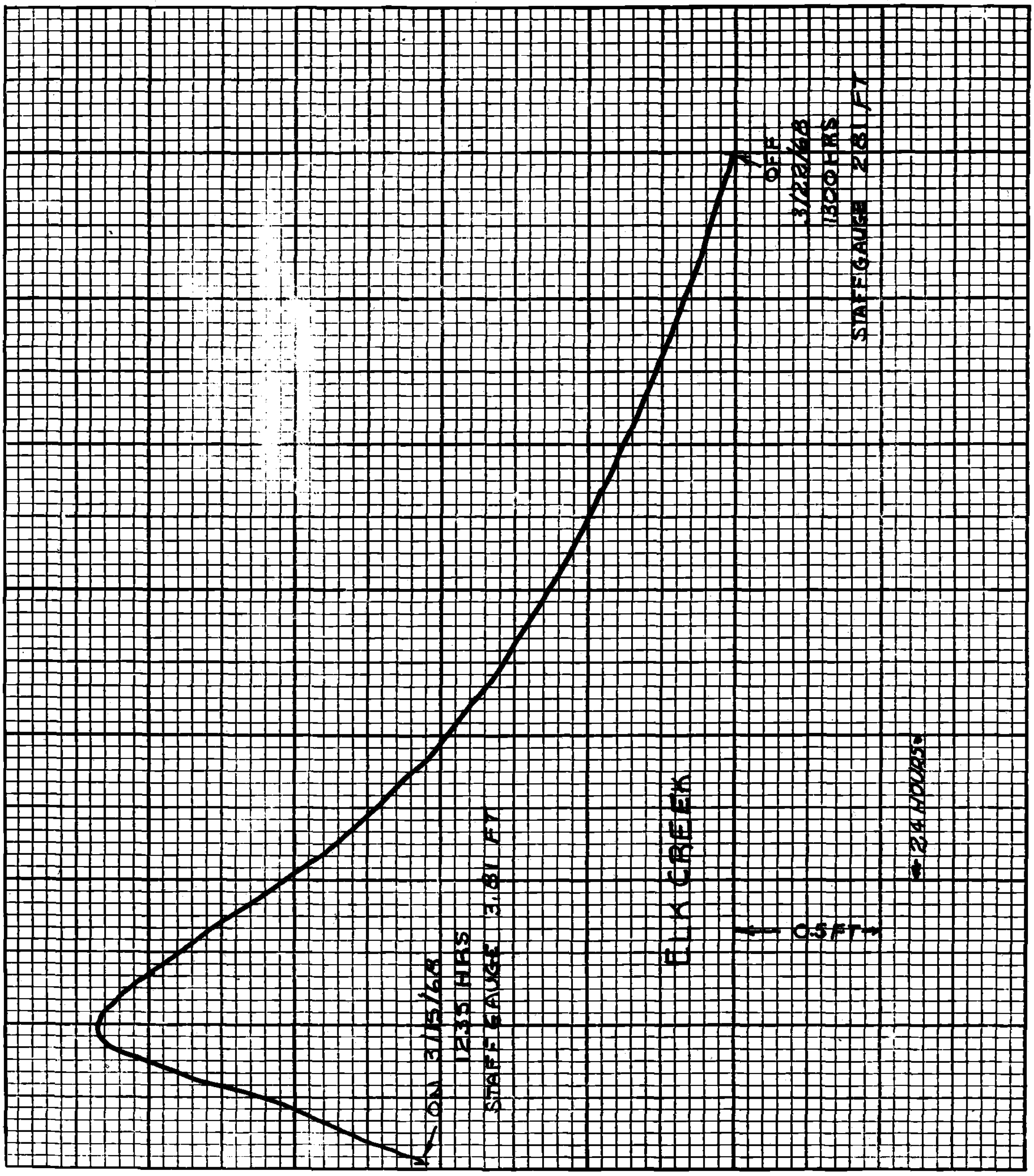
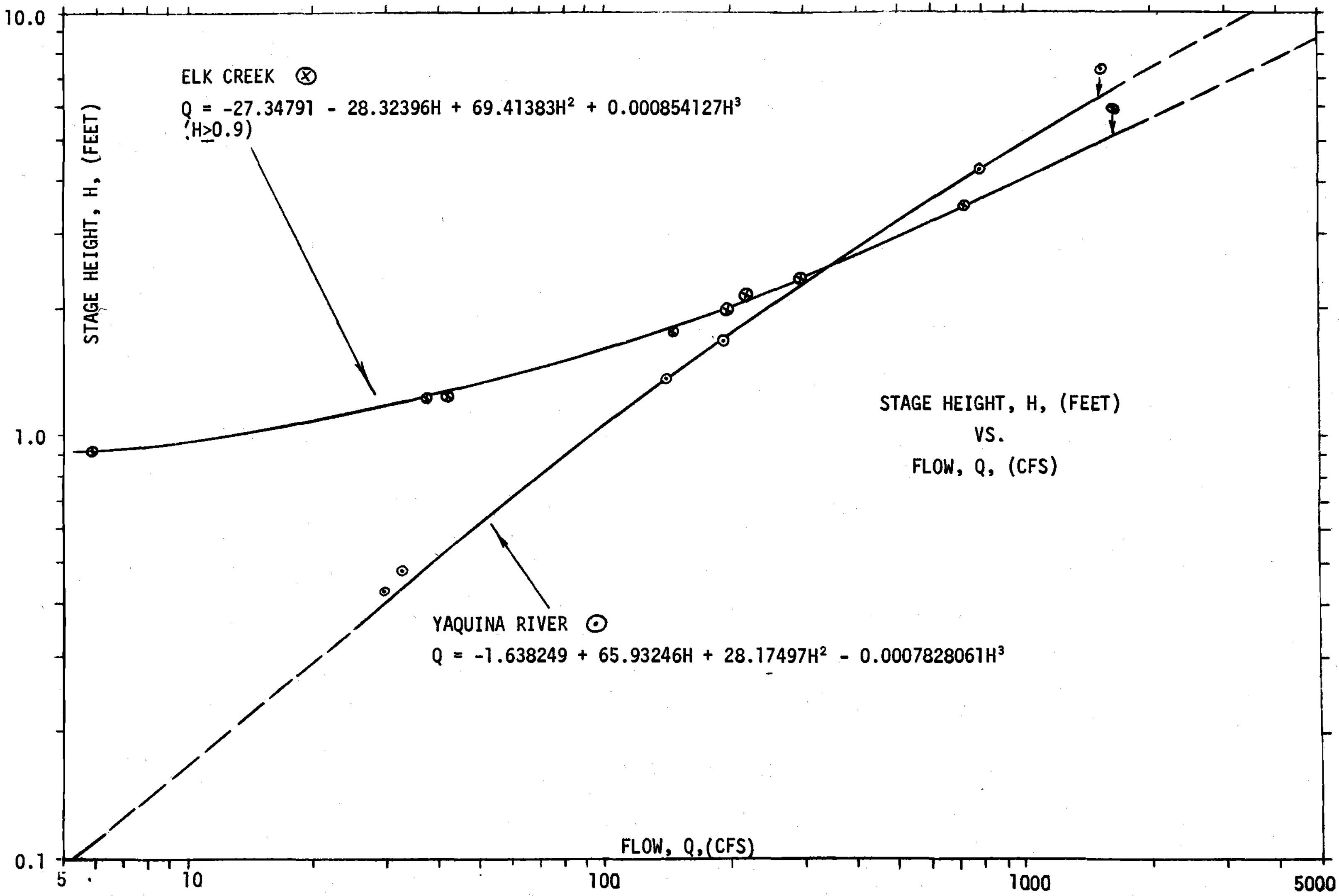
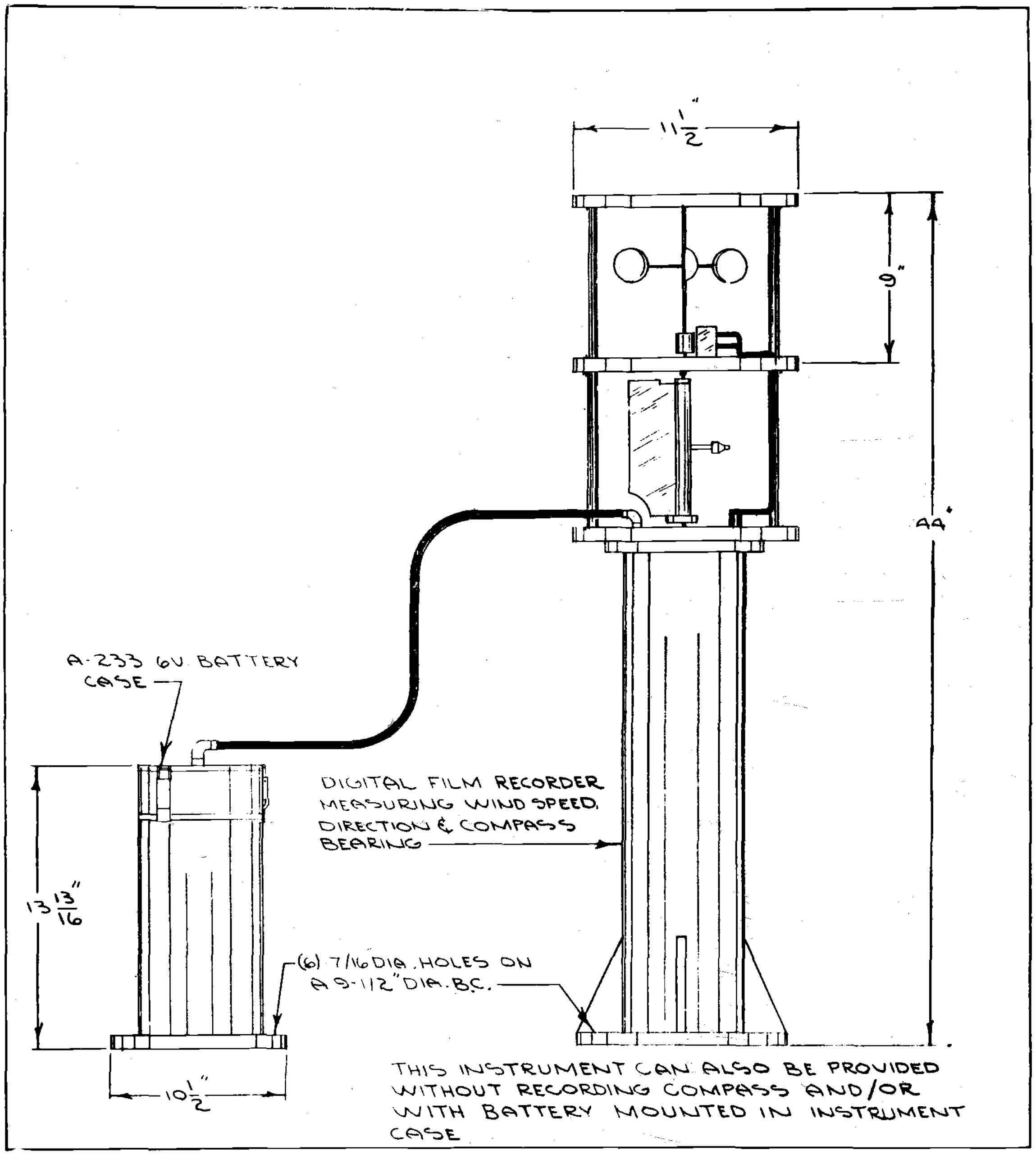


FIGURE 8. Example of Stream Flow Record



10.0
1.0
0.1
STAGE HEIGHT, H, (FEET)
ELK CREEK ⊗
Q = -27.34791 - 28.32396H + 69.41383H² + 0.000854127H³
(H≥0.9)
STAGE HEIGHT, H, (FEET)
VS.
FLOW, Q, (CFS)
YAQUINA RIVER ⊙
Q = -1.638249 + 65.93246H + 28.17497H² - 0.0007828061H³
FLOW, Q, (CFS)
5
10
100
1000
5000

FIGURE 9



Drawing from Geodyne Corporation General Catalogue

FIGURE 10. Geodyne Wind Recorder

The Geodyne system digitally recorded wind speed and direction in binary code on photographic film at half-hour intervals. The data records were reduced by the Geodyne Corporation and converted to digital printouts, histograms and analog records. Figure 11 shows a polar histogram of wind directions recorded during the period August 21 to September 30, 1968.

The Climet system continuously recorded wind speed and direction in analog form. An example, given in Figure 12, is from the October 2, 1967 record. Note the intense gusty period with a maximum gust of more than 100 knots. Data from these records have been digitized and integrated over half-hour intervals and daily averages computed. Figure 13 shows the printout for October 2, 1967.

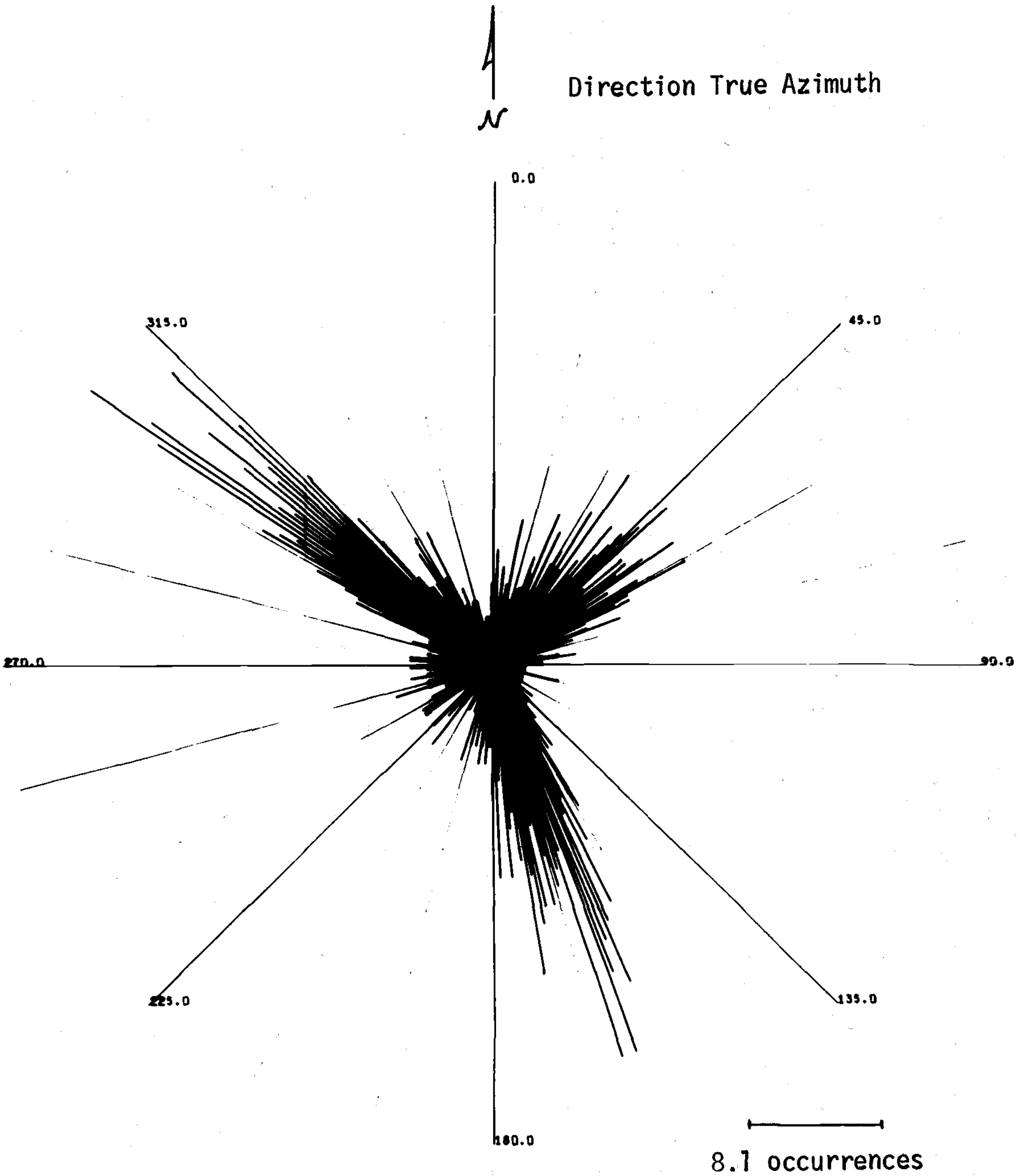


FIGURE 11. Polar Histogram of Wind Source Direction
August 21, 1968 - September 30, 1968

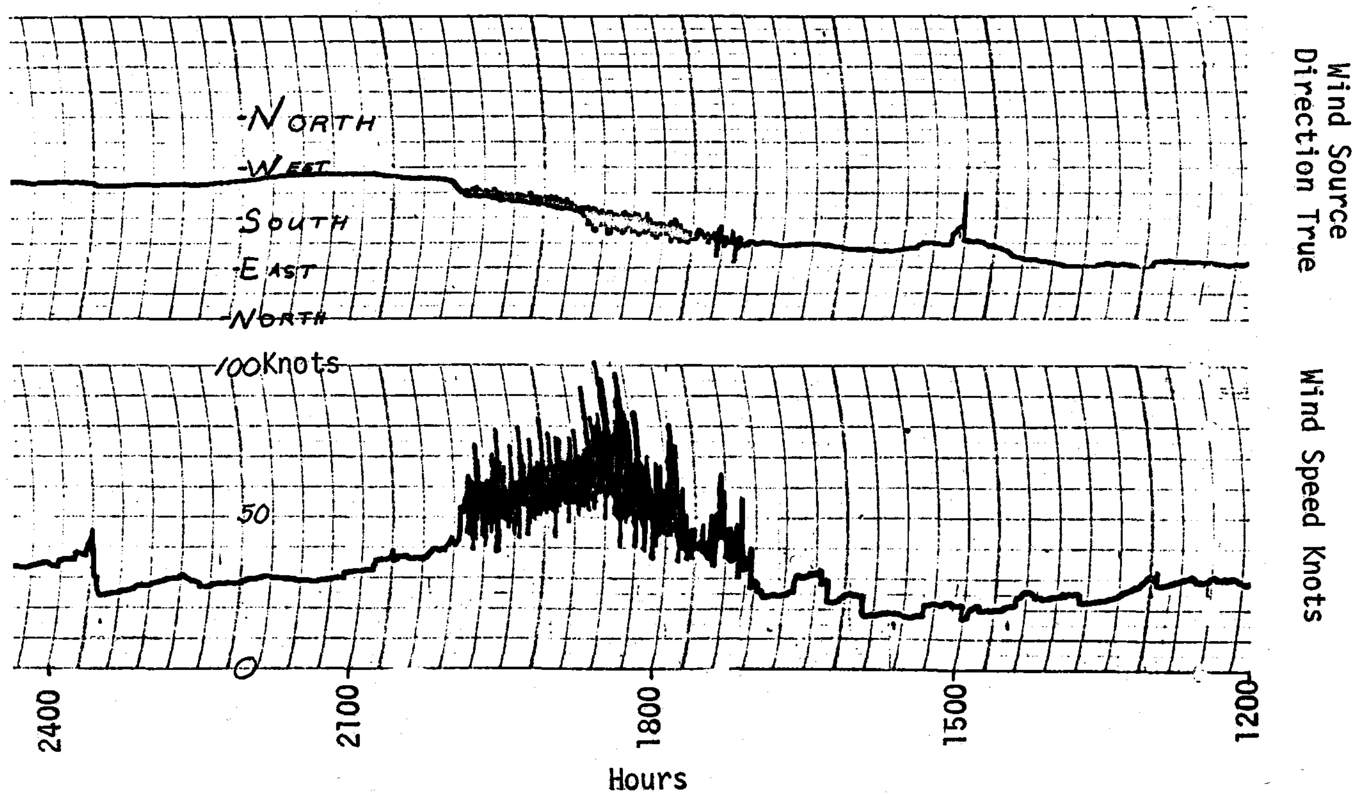


FIGURE 12. Example of Wind Record from Climet Recorder Record from October 2, 1967.

COMPUTER PRINTOUT - WIND DATA 10/02/67
(Retyped from actual computer printout)

HOUR	SPEED (KNOTS)	DIRECTION (°TRUE)	HOUR	SPEED (KNOTS)	DIRECTION (°TRUE)
0	12	151	12.0	30	93
.5	12	137	12.5	28	100
1.0	10	122	13.0	29	102
1.5	9	123	13.5	26	95
2.0	9	122	14.0	24	96
2.5	11	136	14.5	24	110
3.0	12	145	15.0	20	143
3.5	13	146	15.5	20	129
4.0	13	141	16.0	21	124
4.5	13	130	16.5	28	131
5.0	13	118	17.0	35	140
5.5	12	105	17.5	46	156
6.0	13	101	18.0	65	181
6.5	15	98	18.5	72	204
7.0	18	92	19.0	60	222
7.5	18	95	19.5	47	237
8.0	17	93	20.0	37	254
8.5	16	96	20.5	31	262
9.0	14	100	21.0	29	259
9.5	16	99	21.5	29	248
10.0	19	92	22.0	29	241
10.5	21	97	22.5	26	240
11.0	25	93	23.0	36	243
11.5	28	93	23.5	34	245
			AVERAGE	25	145

FIGURE 13. Printout of Half-hourly Wind Speed and Direction Values from Climet Record for October 2, 1967.

DATA QUALITY AND THE NOVEMBER 1969 STATE OF THE DATA RECORDS

To recapitulate, the salinity, streamflow, and some wind data were recorded in analog form on paper charts. These charts, up to about August 1, 1968, were digitized at half-hour intervals and stored on tape at the Oregon State University Computer Center. R. Jay Murray of the Computer Center handled the digitizing and storing operations and did many other magical and wondrous computer things in the way of data processing. Without his services and those of the Computer Center, we would not have been able to undertake this project.

Condition of the Data - November 1969

Figure 7 outlines the approximate extent of the data in "best" condition (triple line); data in "moderately good" condition (double line); and data in a "primitive" condition (single line). These classifications are meant to indicate the relative amount of data reduction that would be necessary to bring the records to an easily usable state. For example, there were many instrument failures and subsequent data gaps. The "best" data were interpolated by eye where short gaps appeared. Where interpolation was not practical due to the length of the gap or the complexity of the record, dummy data flags (See Table 1) were inserted to indicate a record gap. In automatic processing, these stretches of dummy data should cause only minor complications. The "moderately good" data have not been interpolated or patched with dummy data and have not been checked thoroughly. These data suffer only from a lack of attention. The "primitive" data suffer, in addition, from calibration difficulties.

Figure 14 shows daily averages at some selected stations over the time span indicated. Straight daily averages filter out much of the tides and higher frequency oscillations. Several of the plots show vertical bars which indicate the salinity extremes at that station over the day indicated. The extremes over a day are, of course, a function of tidal range, runoff conditions, wind, seiches, and local rainfall. The difference between extremes or the length of the bar may, therefore, change considerably over a few days. The high and low extremes in general do not extend equal amounts from the mean value. The length of the bars just give a rough indication of how much the curves were smoothed by the taking of daily averages.

Since the tides and higher frequencies have been filtered out, the curves in Figure 14 might reasonably be said to retain intermediate period (several days to weeks) variance plus long period (months to year) variance. The Yaquina River streamflow seems to be a fairly smooth function of time. The salinity records show, however, a considerable amount of roughness in the intermediate range. This may be due to some residual tidal energy sneaking through the daily average filter, to wind stirring of stratified water, or to some other mechanism.

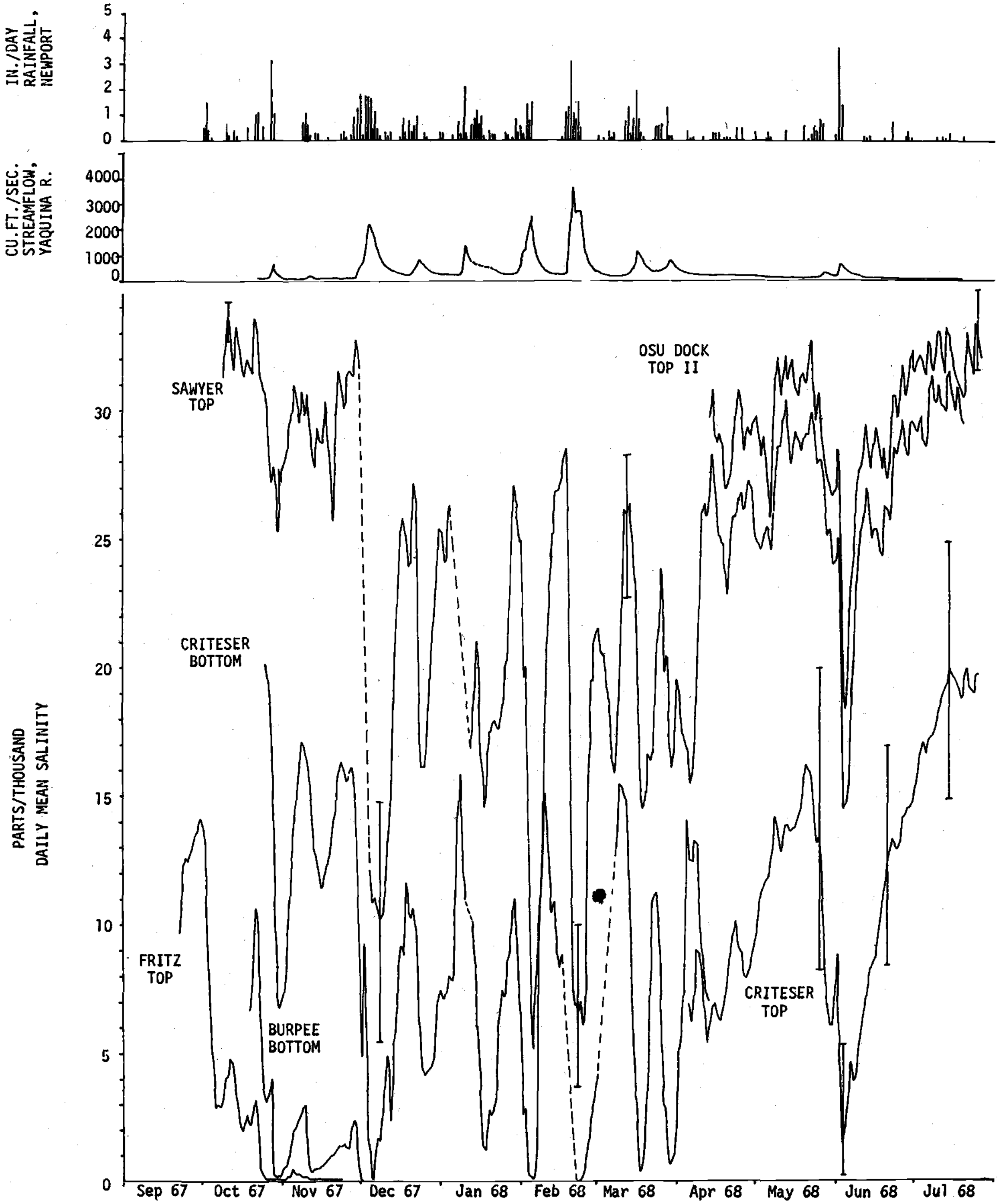


FIGURE 14. Daily Averages for Selected Parameters.

October of 1967 was the end of an extremely dry summer. The salinity reached 14 PPT at Charlie's Dock (River Mile 16.0). Soon after the beginning of the fall rains, the salinity at Charlie's Dock and Elk City dropped to zero. During the winter, the salinity fluctuated greatly with each major storm. After the beginning of the dry season in early April of 1968, the salinity began to increase slowly at all locations. The general trend of the salinity during this period is a striking feature in spite of the fact that the summer of 1968 was anomalously wet. When the data are completely reduced, it will be interesting to compare this with the dry summer of 1967.

Note that during the summer of 1968, salinity variations at intermediate frequencies seem to be relatively coherent between the stations, i.e., peaks and troughs in the salinity records seem to show up at the same times. This suggests that these variations may be caused by the tides.

The traces in Figure 14 begin and end at various times and some show gaps. Some of the gaps are interpolated with a straight dotted line. This dotted line is included as an aid to keeping track of the traces. The extent of the excursions makes it a bit difficult to follow the salinity traces.

Description of Data Block Available For Use Through OS-3 System

A block of data from 000 on April 13, 1968, until 2330 hours on July 5, 1968, has been cleaned up and put out on disk file at the

OSU Computer Center. The block consists of half hourly values of observed tide, streamflows, and surface salinities. The data are arranged according to the following format (I4,9F6.1):

I4 - Arbitrary index number, recycling at 12. Starts at 1 on 0000 hours on April 13, 1968. Is 12 on 0530 hours and 1 again at 0600 hours on the same date. Helps in scanning printouts by isolating 6 hour blocks.

F6.1 - Observed tide at OSU dock in feet above a reference point 29 feet below MLLW. Tides are actually measured to hundredths of a foot, but this number has been rounded.

F6.1 - Salinity in PPT measured about 6 inches beneath the surface at the OSU dock (Station "OSU Surface II").

F6.1 - Salinity at "Sawyer's Dock" surface.

F6.1 - Salinity at "Criteser's Dock" surface.

F6.1 - Salinity at "Burpee" surface.

F6.1 - Streamflow of Yaquina River in cubic feet/second.

F6.1 - Streamflow of Elk Creek.

F6.1 - Streamflow of Mill Creek.

F6.1 - Sum of Elk Creek and Yaquina River. These two water sources enter the estuary system and mix at a point above any of the salinity sensors. For simplicity, they may be considered as one input. For convenience, the sum was included in the data file.

The file contains 94 days of data. At 48 half-hourly points per day, that is a total of 4,512 points for each individual series, or about 41,000 total.

Over certain short time periods, missing data were supplied by eyeball interpolation. Over some larger stretches of highly variable data where eyeball interpolation was not practical, dummy flats, e.g. 40 PPT for salinity, were inserted as has been mentioned before.

TABLE I

INSERTED DUMMY VALUES

Dummy Data	Station	From, To, Times Inclusive	
40.0 PPT	Sawyer Salinity	0000 hrs on April 13 to & including 0930 on April 19	
40.0 PPT	Criteser Sal.	0630 on June 11	1000 June 12
40.0 PPT	Sawyer Sal.	0000 on June 12	0930 June 14
40.0 PPT	Criteser Sal.	1800 on June 16	1700 June 17
00.0 CFS	Mill Cr. Streamflow	0000 on July 1	2330 on July 15

Figure 15* is a plot of the salinity, streamflow, and tide data over a short section of the data. This section was selected because at the left it shows several days characteristics of a long dry spell; in the center it shows the system response to a large freshwater influx; and on the right it shows the recovery of the system. Due to

* Figure 15. Half-Hourly Values of Tide, Salinity, and Streamflow, May 17 Until June 19, 1968. (Due to reproduction expense and difficulties this figure will be available upon request only.)

drafting and reproduction difficulties, the plot is not extremely exact and should only be used for rough quantitative estimates. It is precise enough, however, to see the progress of the tidal wave up the estuary; i.e., the salinity maximums are shifted to later times as they are recorded at stations progressively further up the estuary. There are some breaks in the plot where data were not available. The OSU dock salinity and the Sawyer's dock salinity occasionally cross and reverse. The light trace is the OSU dock value. At the points where the OSU trace crossed the Sawyer trace, the Sawyer trace was omitted. Around June 10-12, some bumps are to be seen on the Yaquina plus Elk Creek streamflow trace. These were caused by the interference of extremely high tides with the stream gauge on the Yaquina River. Amplitude of these tides was at most six inches at the gauging stations.

Dr. H. Frolander of the OSU Department of Oceanography has maintained a midstream top and bottom salinity sampling program in Yaquina Bay for several years. Water samples are obtained and taken to shore for analysis by a laboratory salinometer. Some preliminary unpublished results of this program are listed in Table II. Times listed indicate the beginning of the cast. A cast takes about 12 minutes. These data were supplied us by Mr. D. J. Bergeron.

Table II gives some indication of the degree of stratification at various times. Note that the estuary is relatively unstratified at least during the major part of May. In late May, the storms

TABLE II

FROLANDER, BERGERON, McCORMICK, CRANDAL SALINITY DATA (PARTIAL)

Buoy Number	15			21			29			39		
Approximate River Mile	3.5			5.5			8			10		
Date	Time (PST)	Salinity PPT Top	Salinity PPT Bottom	Time (PST)	Salinity PPT Top	Salinity PPT Bottom	Time (PST)	Salinity PPT Top	Salinity PPT Bottom	Time (PST)	Salinity PPT Top	Salinity PPT Bottom
20 April 1968	1301	18.57	25.73	1223	15.87	23.01	1045	11.24	21.69	1000	6.75	19.75
1 May 1968	1232	27.10	29.23	1146	20.78	26.68	1045	11.18	15.91	1010	4.60	6.61
11 May 1968	1207	33.31	33.31	1132	31.63	32.86	1043	23.88	26.60	1005	15.68	17.43
23 May 1968	852	30.08	30.96	948	28.59	29.61	1045	24.22	25.93	--	--	--
29 May 1968	1047	19.76	25.95	1148	20.79	24.10	1300	16.37	19.93	1340	13.89	14.53
12 June 1968	1443	29.85	31.90	1340	29.08	30.98	1250	16.85	19.64	--	--	--
21 June 1968	927	?	?	1045	?	?	1231	19.60	24.65	1311	15.00	18.16
28 June 1968	1541	32.83	33.09	1400	29.18	30.87	1237	21.99	23.09	1151	13.80	14.95
11 July 1968	1300	33.35	33.38	1215	31.75	32.30	1130	24.03	24.37	1050	16.96	17.20

caused a considerable amount of stratification. This stratification was dissipated by late June.

To the degree that the data in Table II can be compared with the time series data recorded on the shore, agreement is good. A characteristic figure for this agreement is about ±2 PPT. In the range 20-35 PPT salinity, it is difficult to read the pen traces on the analog chart records to much better than ±1 PPT. The remaining differences might be explained by cross-stream and long-stream gradients in the salinity.

Table III* is a partial list of unpublished salinity data collected by W. D. Clothier, G. R. Ditsworth, and W. A. DeBen of the PNWL in connection with a 1967-1968 nekton sampling program. The format of the table is similar to that of Table II. Salinities, however, were sampled at intervals of 1 meter from 1 meter beneath the surface to the bottom. The samples were taken generally during the period of the flood following the lowest low water associated with the spring tide. The stations were located to the side of the main channel at the river miles indicated. The Clothier study also included temperature, D.O., and Secchi disk measurements. The nekton samples were classified, counted, measured, and weighed; the data are on punch cards at the Pacific Northwest Water Laboratory. The salinity and temperatures were taken with a Beckman Instruments RS-5 portable inductive salinometer.

---

* Table III. Clothier, Ditsworth, DeBen: Salinity Data (Partial). (Due to reproduction expense this table will be available upon request only.)

Absolute accuracy greater than ±2 PPT salinity should not be of much importance to most researchers. The time stability of the calibration should be significantly more important. Weekly calibrations show a week-to-week variation of about 1 PPT salinity and a gradual drift of 1 or 2 PPT salinity over the three-month period. These weekly calibrations were used in the production of the final data file. The apparent change in the calibrations may be partly due to air-temperature variation on the different calibration days.

The time constant of the salinity recorder was less than a minute. The analog trace, in visual examination, did not show evidence of any significant variations with periods of less than one half hour. The salinity records are, therefore, uncontaminated by aliasing. The tides and streamflows were even more slowly varying.

In Figure 14, notice how in April of 1968 the rains stop, the streamflows taper off, and, most dramatically, the salinity begins to increase along a fairly steady trend. As mentioned before, the summer of 1968 was an anomalously wet summer. Most summers in this region are characterized by an almost total absence of rain. In view of this and other meteorological factors observed over several years, it seems reasonable to assume that the year is divided into two sharply-defined seasons: the wet season lasting from about October through April or May, and the dry season lasting the remainder of the year.

Since the data block on file starts in mid-April and continues through mid-July, it would almost entirely lie in the dry season. This says that the stochastic processes which generated this data block have a fighting chance of being stationary. If the time period of the record had spanned one of the common transition times, then the generating process could not have been assumed stationary. A process is "stationary" over a time period if the moments of the distribution of the data formed over the ensemble of all possible estuary performances at time t during that time period are constant, as t varies from the beginning of the time period to the end.

The data are largely non-random due to the presence of the tides. The phase of the tidal constituents is very stable over long periods. One of the most discouraging aspects of the problem is that the system seems to be highly non-linear. Notice how the excursion of salinity due to the tides is smashed down as the salinity nears the fresh water and ocean water limits; i.e., the estuary water cannot get any fresher than fresh water, nor any saltier than ocean water. The salinity values at a point are primarily due to large-scale convection and diffusion. The effects of convection and diffusion are modified by the change of the length-to-width ratio of a water parcel as it is shuffled up and down an estuary of irregular shape. It is interesting to note that the diffusion coefficients are probably time variable with fluctuations at twice the tidal frequencies, because of the increase in turbulence during the flood and ebb tide. Salinity values are also probably affected by the minor changes in open ocean salinity.

APPENDIX

EXAMPLE OF USE OF "BAY" FILE

"*DETREND" is a computer subroutine designed to detrend a time series either by (1) removing the mean, or (2) removing the linear trend. This subroutine is part of the ARAND system of time series analysis programs written by Lyle Ochs and Jeff Ballance of the Oregon State University Computer Center. Documentation is available from the center.

"*CDETREN" is the calling program for *DETREND. It is quite a versatile routine and should serve most parties without modification. (1) The input and output logical units (LUNS) are specified by the user. (2) The user may skip a number of records, call down the subroutine on a specified number of records, and skip the remaining records on the input data file. (3) The user may specify input and output formats. The output format must be specified for two numbers, the integer sequence number, and the floating point detrended data number.

The "dummy data" feature is included as an aid in passing over the placeholder dummy data inserted in various places in BAY. The user informs the program of the dummy data value. When dummy data is read the program stops reading data and acts on the real data already read.

The sample run included here demonstrates several of the aspects mentioned above. Characters typed in by the operator are underlined. The spacing between lines was artificially expanded to allow for explanatory notes.

The data on "BAY" is arranged in columns. The first column contains sequence numbers which repeat in cycles of 12. The second column, the first data column, contains tidal information. In the example run the operator has given instructions to skip completely the first 5 records on BAY and then to read the next 25 records according to the format (4x,F6.1). This will input tidal data points 6 through 30. The operator then has instructed the subroutine to find the mean of these 25 points and to compute a data series with the mean subtracted. The mean is listed by the computer on the operator's teletype and the mean detrended data series is outed to a file.

Note at this point that the computer came back with a "LUN 40 UNDEFINED". The subroutine *DETREND writes out, as do all the ARAND subroutines, certain messages and parameters on LUN 40. The particular messages and parameters output by *DETREND are to be found on the last page of the sample run. Many operators choose to set 40=NULL and therefore dump all the "helpful messages and parameters."

After the subroutine acts on the data and the main program writes the output, the operator can specify a switching code.

SWITCHING CODE:

=0: No more data for processing; program goes to end.

=1: More data for processing; program essentially begins again.

=10: Next data on LUNIN is dummy data; program "thumbs" through it until it finds some real data. It backspaces LUNIN and asks for another switching code.

Note that the switching code allows the user to skip records, process records, go back to the beginning of the program, and use the skip feature again, and process more records, etc.

In the sample run the operator has set the switching code = 1. The program then asks for input and output formats and logical units. The subsequent instructions given by the operator have caused the computer to read and act upon the first 27 values of salinity at "OSU surface." Note that in this second cycle the operator has asked for linear detrending.

The next page shows a short listing of the first part of BAY. The operations carried out in the sample run considered data only from the first part. The detrended output data are listed on the next page. The helpful messages stored on LUN 40 are shown on the next page.

```
 TIME
TIME 0.046 SECONDS    MFBLKS 0   CFBLKS 0
#EQUIP,1=BAY
#EQUIP,2=FILE
#EQUIP,3=FILE
#FORTRAN,I=*CDETREN,X=50


 NO  ERRORS  FOR  CDETREN

#FORTRAN,I=*DETREND,X=51


 NO  ERRORS  FOR  DETREND

#LOAD,50,51
RUN
RUN
```

```
INPUT FORMAT
 (4X,F6.1)   (CR) (LF)
```

↑Space over one, then type in format, including right and left parentheses.

```
(4X,F6.1)
OK? 1     (CR)
```

"1" means "Yes, format is OK".

```
OUTPUT FORMAT
 (I4,F6.1)
```

Note output format specified for two numbers, sequence number plus floating point detrended data number.

```
(I4,F6.1)
OK? 1
```

↙Reads data off of LUN 1.

```
INPUT LUN = 1
OUTPUT LUN =2
```

↖Puts sequence numbers plus detrended data numbers on LUN 2.

```
NUMBER OF RECORDS TOSKIPOVER =  5
MEAN OR LINEAR DETRENDING?  1
```

← Skips over 5 data points before considering any set of data points.

↗ Indicates to subroutine *DETREND that you wish "mean" detrending.

```
DUMMY DATA VALUE 50   <- If you are using dummy data as a "placeholder" enter
                         value here; if not, enter value above any possible data
                         value.
NUMBER OF POINTS TO ACT ON =25
```

After skipping over the number of points specified above (5 pts.) the program applies *DETREND to this number of points (25 pts.) following.

```
DETREND ENTERED WITH.. LENGTH OF SERIES =    25
REMOVED      1   (1)MEAN, (2)LINEAR TREND

LUN 40 UNDEFINED      ARAND subroutines are now set up to write "helpful"
#EQUIP,40=3           messages on LUN 40.
#GO
MEAN =  3.17560000E 01      Subroutine gives mean.
SWITCHING CODE =1
```

By typing "1" operator indicates that more data is to be processed.

```
INPUT FORMAT
 (10X,F6.1)           Input format for new data, i.e. reading second column
(10X,F6.1)            from BAY.
OK? 1

OUTPUT FORMAT
 (I4,F6.1)
(I4,F6.1)
OK? 1

INPUT LUN = (BREAK)
#
                            Broke here to rewind data file and to equip
 REWIND,1                   a new output file.
#EQUIP,4=FILE
#GO
1 <-- Operator indicates that program should again read off LUN 1.

OUTPUT LUN =4

NUMBER OF RECORDS TOSKIPOVER = 0
```

MEAN OR LINEAR DETRENDING 2

DUMMY DATA VALUE 50

NUMBER OF POINTS TO ACT ON =27

```
DETREND ENTERED WITH.. LENGTH OF SERIES =    27
REMOVED      2   (1)MEAN, (2)LINEAR TREND
MEAN =  2.91666667E 01
A COEFFICIENT = -8.06471306E-02, B COEFFICIENT=  3.02957265E 01
SWITCHING CODE =0
```

↖ Subroutine *DETREND gives mean plus linear coefficients.

Code set = "0" ends routine.

END OF FORTRAN EXECUTION

#