POWER AND WATER AUTHORITY

ELECTRONIC DATA COLLECTION
AND
ANALYSIS SYSTEM

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SYNOPSIS

The use of groundwater analysis software has always been associated with the laborious task of converting manually retrieved data to computer compatible format. This requirement has precipitated the development of prototype data acquisition systems to produce digital data in its most elementary form. That is, the variation of water levels with time.

The two main types of groundwater data acquired include long term water levels obtained from remote monitoring sites and short term test pumping data from test production bores. The use of digital acquisition and recording instrumentation promises greater accuracy and efficiency with a subsequent improvement in cost effectiveness of both operations. Prototype solid state electronic systems suitable for each application were therefore conceived, assembled and tested.

The equipment trialled included a MINDATA "Series 3500" and a SYSTEMS DESIGN SERVICES (S.D.S.) "Torrens" data logger, MINDATA pressure transducers for water level and barometric monitoring, WESDATA data loggers and pressure sensors and a KENT pressure transducer for the flow monitoring system. Trialling of this equipment has enabled knowledge and experience to be gained in the operation of a groundwater data acquisition system and the requirements to enable its successful implementation and on-going development have been identified.

A minimum specification requirement for future equipment has been formulated. However, as an interim to any upgrading, the test pumping data logging system is proposed to be based on the current equipment comprising the Mindata 3500 series logger, vented transducers and the 'flowmeter'. The equipment to meet the requirements of a remote site logging system should be resourced alternative to Wesdata and evaluated. In the interim, Cherryville single channel loggers and Mindata transducers are recommended to be used.
Facility required for the implementation phase has been outlined in this document. Introduction of staff to the technology will initially involve a "familiarisation of equipment" and training programme. Documentation of specific procedures required for the installation and operation of the equipment has been commenced. The initial validation and calibration procedures are contained within, however a field guide is proposed. In addition, a schedule of maintenance and checking, and procedures encompassing the aspects of data handling, downloading, truthing and cataloguing requires further development.

A software package to enable efficient processing of the logged data has been developed to produce a universally usable data form. This will service a number of computerised groundwater interpretation and analysis aids and ultimately an optimised parameter groundwater modelling package to be used as a predictive tool.
1. INTRODUCTION

The advantages of digitally recorded data have always been recognised. Its ultimate application in the realms of computer analysis requires data in this form. A wide range of technologies have thus been developed to fulfil this requirement.

In the water resources industry, the measurement of water levels provides the foundation from which both surface water and groundwater flows may be predicted and utilised in design. State-of-the-art technologies are based on solid state equipment developed solely for surface water applications. It is currently in common use throughout the country and was adopted for trial by Water Resources in the hydrographic field in the early 1980's. However, the evolution process has only commenced for the groundwater application in Australia for which specific needs still require recognition and appropriate design. Although the Australian market is limited, there are several specific instruments available in the United States at the current time. These are not in wide use due to cost limitations.

It was decided in 1989 that the development of a system utilising the available technology should be undertaken to service the groundwater application in the organisation. The advantages foreseen included improvements in accuracy of measurement, comprehensive recording and transcription of data and also a reduction in field labour intensity. Improvements in data accessibility would subsequently streamline the use of state-of-the-art computer interpretation and modelling techniques.

A project was thus initiated in 1990 to develop a system of digital data acquisition, retention and analysis. The three stages identified were:

(i) Data Acquisition - This was to be digitally recorded data using electronic componentry selected following a review
of all available equipment. An operational specification was to be validated under trials for system accuracy and reliability and ultimately its suitability for both short term test pumping and long term groundwater monitoring.

(ii) Data Processing, Retention and Retrieval Systems - The logged data is required for processing to produce a time series data in a form which is readily available for end user application. This was to be enabled through custom designed software. An architected system was to be developed to accommodate archival and easy access to the data base.

(iii) Interpretative and Analytical Software Suite - This phase aimed to develop a library of software appropriate to field and office levels of analysis. Effective on-site management of tests in progress may be facilitated by detection of trends and a primary analysis of data. Complete analysis of data is requisite of the desktop assessment and software analysis packages providing a greater scope will be utilised.

A chart diagram of the proposed system of data acquisition and management is shown on Figure 1.
2. EQUIPMENT TRIALLED

2.1 General

The basic suite of equipment required to establish a system of logging test pumping and remote site water level data was identified as a part of a commission involving the Australian Centre for Tropical Freshwater Research. The hardware options are presented in "Hardware Options for Pump Test Data Acquisition" (Reference 3).

The test pumping suite is based on a central logging system (unvented) which is required to service logging functions in proximity to the test bore. This includes pumped bore drawdown, discharge rate, barometric pressure and drawdown in a single "close" observation bore. The vented system was not preferred due to the potential for damage (both downhole and above ground) and handling factors, its performance under variable thermal conditions, the variability in venting characteristics (ie. efficiency) of available equipment and the potential for water ingestion in humid conditions.

The remote site logging requirement was proposed to be met by a single channel vented system.

Below is a general description of the equipment trialled during this project. Figure 2. indicates the relative positioning of the componentry within the data acquisition system. Their specifications are included in Appendix B.

2.2 Loggers

Mindata Logger

The unit trialled is a series 3500 Logger (see Plate 1). It will accept periodic signals from up to four analogue and two digital inputs, convert the data to user specified units, and record this data with corresponding time and date to a minimum resolution claimed to be one second. The 1:20000
Fig. 2

HARDWARE FLOW DIAGRAM

VARYING PRESSURE, TEMP, pH...

PROBE

VARYING ELECTRICAL SIGNAL

LOGGER

CALIBRATED DATA

LOGGER MEMORY

'DOWNLOAD'

DIRECT OR MODEM

PERSONAL COMPUTER

DISC

EDIT, ANALYSE

LONG TERM STORAGE

EACH LOGGER INPUT IS CALIBRATED FOR A PARTICULAR TRANSDUCER
SOME LOGGERS CAN USE "LOOK UP TABLES"
(14.5 bit) resolution of analogue data is adequate to meet any foreseeable requirement of the data acquisition system.

The logger is featured by a non-volatile (removable) memory module. Communication with the logger is via an IBM compatible computer and menu driven software is used to establish set up parameters and conduct interrogation procedures.

The hardware consists of a sealed ABS enclosure, housing two rechargeable 6V batteries, a memory module and solid state componentry. The input/output connections are submersible and located at the opposite end of the box to the communications port.

**Torrens Logger**

The Torrens data logger (see Plate 2) is described as a modular and reconfigurable data logger. As standard, it consists of 5 Euro card sized cards mounted in a 9 card rack and enclosed in a sealed polyester box and configured to service the digital inputs of a rain gauge and shaft encoder. It is reconfigurable to accept analogue inputs with the addition of the appropriate cards. It has 16 bit resolution of data and is considered adequate for the purposes of the data acquisition system.

The standard power supply is from three 6V 10AH batteries inside the box. Facility exists for solar charging with the connection of a solar panel. Connections are via Cannon Military Specified connectors on the side of the box.

Communication with the logger is via menu driven software and a computer connected to a 9 pin RS232 socket located on the communications card.

The logger trialled was equipped with facility for four analogue inputs. It is capable of logging a number of channels per input at variable logging interval. Data is stored on an EPROM module.
PLATE 1 MINDATA LOGGER AND BAROMETRIC TRANSDUCER

PLATE 2 TORRENS LOGGER (EEPROM MODULE REMOVED)
Cherryville Logger

This logger was developed by S.D.S. as a single channel logger for pluviometers and digital shaft encoders in particular. A 0-20mA analogue input may be fitted as an option at the time of manufacture. This will allow 1 channel to be used with 16 bit resolution.

The unit is an ABS enclosure housing a standard EPROM, a battery and solid state hardware. The EPROM holds 32K or optionally 64K RAM, and will facilitate 1 second recording resolution. Battery life is claimed to be in excess of six years of normal usage. Communication is via a 9-pin serial connector under the lid, and input via Cannon military specification connectors externally. The unit may be sealed to IP67 (waterproof) if required.

Wesdata Data Recorders and Pressure Sensors

The Wesdata recorders used were a 390 series and the pressure sensors, 983 and 984 series. The logging unit comprises a single channel data recorder directly coupled to a pressure sensor (see Plates 3 and 4). Both components reside downhole when in operation. The recorder is housed in a 300mm long polyurethane tube of 30mm diameter. At the couplings, the outer diameter is increased to 40mm. This section of the unit also houses 4xAA size batteries (extra heavy duty recommended) as well as the solid state componentry. A lithium battery retains the non-volatile software and is claimed to have a 5 year life span. This may be severely reduced if the main batteries have been fully expended and it is required to maintain logging procedure. The data recorder has 32k of available memory.

The pressure sensor is housed in a 30mm polyurethane tube. A screwed coupling and 2.5mm audio plug connects this component to the recorder. The mode of operation is based on a strain gauge diaphragm whose resistive element is a monolithic silicon piezoresistor. Venting of the system allows for atmospheric pressure compensation. A temperature sensor is also installed to facilitate thermal compensation.
PLATE 3 WESDATA LOGGER AND TRANSDUCER (ASSEMBLED)

PLATE 4 WESDATA LOGGER (MAIN) AND TRANSDUCER (LEFT) EXPLODED VIEW
and may provide temperature data if required. Three depth ranges are available for the sensors - 5, 10 and 20 metres.

2.3 Pressure Transducers

**Mindata Pressure Transmitters**

The pressure transmitters (see Plate 5) are a 1200 series and consist of piezoresistive strain gauges forming a wheatstone bridge whose output is proportional to the pressure applied to it. Voltage is monitored through the bridge. The element is mounted on a header and forms part of a stainless steel encapsulating tube of 21mm outer diameter. The cable joins at a moulded gland at the opposite end of the probe. A cable is supplied at the specified length and terminated at a plug which facilitates connection to the data logger. The unvented cable is specified as 2 wire polythene sheathed cable with an earth shield and PVC jacket and a Kevlar inner strain relief cable. The depths for which these transmitters are available range from 1 to 500 metres.

2.4 Flow Measurement

**Kent Absolute Pressure Transmitter**

This unit (see Plate 6) is a Deltapi K series transmitter. It comprises a main body, which houses the pressure sensor, and a gauge module situated above it, which houses the solid state componentry. A diaphragm type sensor provides gauge pressure through a 21 to 126 mbar span limit. The electronics module responds to inductance produced by the sensor and outputs a standard signal. The unit employed to monitor orifice pressure, is attached to the orifice offtake via tubing to a diaphragm inlet on the main body.

2.5 Barometric Measurement

**Mindata Barometric Transmitter**

This barometric transmitter (see Plate 1) is available from Mindata. It is similar in appearance and operation as the pressure transducers purchased except it is not of waterproof construction. The transmitter has a range of 0 - 30kPa.
PLATE 5 MINDATA PRESSURE TRANSDUCER AND CABLE SPOOL

PLATE 6 KENT PRESSURE TRANSDUCER (MOUNTED ON TRIPOD)
3. EQUIPMENT TESTING AND VALIDATION

3.1 GENERAL

Justification for commitment of this organisation to the proposed system will be based primarily on the successful demonstration of a working prototype. The prerequisite for the development of the prototype system was to gain a measure of the performance and behavior of individual componentry and then of the system in its assembled form. A process for testing was devised which also served to gain experience and confidence in application, development of new skills and procedures and to assimilate the new system into the existing structure.

Componentry sourced for the construction of the water level monitoring systems for trial, apart from the Wesdata system, were designed for surface water application. That is, relatively more docile environments in terms of magnitude and rate of water level movement, and not necessarily the requirement for portability. A major exercise was therefore to subject the components to conditions experienced during test pumping to test performance. The suite of tests described below were designed with these conditions under consideration and comprise two standard test forms and field testing to obtain an indication of accuracy and repeatability. Reliability and suitability assessment has been enabled from this testing.

3.2 STANDARD TESTS

3.2.1 Purposes

The criteria under which the testing procedures were developed are as below -

(i) To establish a procedure which may be readily applied and where system and component performance may be gauged under controlled, repeatable conditions;
(ii) To establish a standard for comparison of systems and components;
(iii) To provide an objective record of the performance of various componentry in terms of accuracy, repeatability, calibration factors and responsiveness.

3.2.2 Description

The tests were carried out in a facility which allowed full range access of the transducers in question, "accurate" manual measurement as a benchmark, and controllable conditions (see Plates 7 and 8). The claimed accuracy of manual readings is to at least 10mm under static conditions and 20mm for dynamic. In the subsequent text, these readings will be termed "manuals".

Two test scenarios termed "Static" and "Drawdown" were conducted. A comprehensive description of the test procedures is provided in Appendix C.

The Static test is designed to check the system calibration, response time and accuracy under static (ie. non-moving water level) conditions. The transducer is moved through the water by an attached measuring tape giving direct manual measurement of its depth which is then compared to the logged data.

The Drawdown test is designed to gauge system accuracy in a pump test observation bore (OB) or remote site monitoring bore situation in which the water level is dynamic. The transducer is placed in a well from which water is pumped at a reasonably steady rate using a submersible pump.

3.2.3 Results

3.2.3.1 Calibration

There are a variety of calibration methods available (Methods I,II,III in Appendix C "Standard Calibration Procedure"). It should be noted that although inaccurate calibration can later be corrected using a recalibration
PLATE 7 TEST WELL WITH FLOAT, WESDATA AND MINDATA TRANSUCERS INSTALLED (NOTE SEPARATE PUMP HOUSING WELL)

PLATE 8 GENERAL LAYOUT AT TESTING FACILITY
procedure described in Appendix D (Section IV), it is important that accurate manual readings can be monitored by the operator, while logging since the recalibration is based on these readings.

Different methods of calibration were investigated. The most successful was the Downhole Method I type (a) (i.e. the transducer connected to the logger, and moved through the water by an attached measuring tape). Problems were experienced in Method I type (b) using a Druck Pressure control instrument, mainly because the instrument was connected to the transducers via a length of tube, which allowed some temperature and hence pressure fluctuation.

The Method II type calibration, (with the probe replaced by a current generator, and using the manufacturers’ specifications of probe output at various depths) requires an (expensive) stable signal generator, and includes no check on the transducer.

The Method III type (where the depth to probe output relationship can be directly entered to the logger) is very convenient (where available), but depends on both the transducer and logger performing exactly to specification.

Overall, the Method I downhole calibration has the advantages that it is the most direct method, it involves the particular transducer for which the logger is being calibrated and it lends itself to immediate post calibration checking as described in the "Static Well Test". The manual measurement inaccuracy should be less than 10mm, and the method is easy to physically control.

Systems which use the 2 point calibration system make "perfect" calibration impossible since hysterisis and non-repeatability cannot be allowed for. Thus an alternative is to perform a primary calibration, then apply the Standard test (refer Appendix C). The correct calibration parameters (i.e. slope and offset for linear transducers) may then be
determined by an error analysis of the test results. See also comments in Section 3.2.3.3.

'DATMAN', a custom data manipulation package (see Section 5.2), can be used to calculate the calibration adjustments and the logged data can be linearly recalibrated to the "True" readings by applying the new slope (s) and offset (o) where:

\[
\text{Recalibrated data} = s \times \text{Logged data} + o
\]

Once "s" and "o" are known, the corrected logger calibration parameters can be calculated (refer Appendix D), and in both the Wesdata and Torrens systems, entered directly to the logger. The Mindata system does not allow calibration data to be entered, so a record of the calibration correction for each individual system must be kept, and applied at the data editing stage.

3.2.3.2 Static Water Level Test

The data collected from these tests are filed in working data files and diskettes (Reference 18). Typical test results are available on the "Symphony" spreadsheet files.

It must be noted that the "errors" in logged data hereafter referred to are differences compared to manual readings (ie. "error" = logged reading - manual reading for given time). System inaccuracy is described in terms of the difference of logged data compared to the true depth. It can be expressed as either a "total" inaccuracy (due to all causes) or can be separated into components including hysteresis, non-repeatability, non-linearity and temperature instability. It is also usually separated into transducer and logger components.

Manufacturers usually specify transducer error as a "percentage of Full Scale" (%FS). That is, a percentage of the transducer's specified operating range (e.g. a 20mm error from a 10m transducer would be expressed as 0.2 %FS).
The validity of the following results depends on the
accuracy and timing of the manual readings ("manuals"). All
tests described in this section were performed at the
Hydrographic Well situated at the WRD 2.5 mile Depot, and
set-up as described in the Appendix C. The work was
undertaken by personnel experienced in the manual collection
of water level information and hence the accuracy of the
"manuals" should be to within 10mm. Expressed as a %FS, and
assuming a 10m range transducer, this equates to approximately
0.1%FS. Given that the level of specification for transducers
is generally 0.1%FS, (logger resolution in all cases is better
than 0.1% and therefore not considered a major source of
error) it must be agreed that instrumentation failing to
perform at better than 0.2%FS in clearly not performing to
specification. In the following table, it should be noted
that the %FS calculation is dependent of transducer range and
is separately calculated in each case.

3.2.3.3 Comments

(i) There were errors at the calibration points, which
were usually 1m inside the transducer’s range (e.g. 1m and 19m
for a 20m transducer). This indicates that non-repeatability
and/or hysteresis forms part of the errors, as well as
non-linearity. However, it was considered that identification
of the exact sources of the inaccuracy was outside the scope
of this project.

In the first series of standard tests carried out, it was
considered adequate to find only the maximum error. Error
examination is somewhat predicted by the mode of errors seen.
That is, in the static testing (slow movement), some errors
were due to slow response to change. This is indicated on
Figure 3.1 for the Mindata and Wesdata 10m systems where
convergence is dependent on time.

(ii) The out-of-range performance of a transducer is also
of interest. This is possible when transducers are accidently
immersed too deeply, or during quick initial recovery
following testing.
### TABLE 3.1 Summary of STATIC WATER LEVEL TEST RESULTS

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>Logger/ Sample</th>
<th>Transducer Size</th>
<th>%FS Av.</th>
<th>%FS Max.</th>
<th>RESPONSE SPEC. TIME LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(mm)</td>
<td>(mm)</td>
<td>%FS</td>
</tr>
<tr>
<td>Wesdata 5m³</td>
<td>17</td>
<td>+32 0.6</td>
<td>+46 0.9</td>
<td>good</td>
<td>0.15</td>
</tr>
<tr>
<td>Wesdata 5m³</td>
<td>85</td>
<td>-26 0.5</td>
<td>-40 0.8</td>
<td>good#</td>
<td>0.15</td>
</tr>
<tr>
<td>Wesdata 10m³</td>
<td>19</td>
<td>+71 0.7</td>
<td>+119 1.2</td>
<td>varied</td>
<td>0.15</td>
</tr>
<tr>
<td>Wesdata 10m³</td>
<td>34</td>
<td>+5 0.05</td>
<td>+38 0.4</td>
<td>good</td>
<td>0.15</td>
</tr>
<tr>
<td>Mindata 10m³uv*</td>
<td></td>
<td>+130 1.3</td>
<td>G.T.</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Mindata 20m³v*</td>
<td>34</td>
<td>-7 0.04</td>
<td>-21 0.1</td>
<td>good</td>
<td>0.01</td>
</tr>
<tr>
<td>Mindata 20m³v</td>
<td>42</td>
<td>+6 0.04</td>
<td>+16 0.08</td>
<td>good</td>
<td>0.01</td>
</tr>
<tr>
<td>Torrens/ Mindata 20m³</td>
<td>17</td>
<td>+10 0.05</td>
<td>+17 0.08</td>
<td>good</td>
<td>0.01</td>
</tr>
</tbody>
</table>

**Notes**
1. Problem with calibration instrument stability
2. Static test at end of ranges.
3. Response time of transducer in excess of 10 minutes.

%FS Percentage of full range of transducer

* Transducer has been replaced by manufacturer
v Vented transducer
uv Unvented transducer
Figure 3.2: Dynamic Test Wesdata 5 m
0 - 5000 mm

Tape Reading (mm)
Results so far indicate the Wesdata 10m system to be accurate to within 1.2 %FS at a depth of 140 %FS and the Hindata 20m vented system to be accurate to within 0.14 %FS at a depth of 150 %FS. These figures were obtained from preliminary testing of the above mentioned systems and as yet have not been validated. It should also be noted that out-of-ranging is generally not desired and some loggers may activate self protection measures to avoid potential damage due to this practice.

3.2.3.4 Drawdown Test

These tests were performed in the same well as the static tests, with the water level varied by pumping and recharging. The main well is evacuated by pumping from an adjacent well connected to it at the bottom. The manual readings were taken using a "Tape and Float system". Two people were needed to take the manual readings - one monitoring time and the other reading the float tape (the float tape was held while the reading was taken). The timing of the readings could reasonably be taken to be accurate to within one second and with readings from the tape and float system accurate to approximately 10mm. An accuracy of approximately 20mm should therefore be attained from the manual readings if the drawdown rate is 10mm per second.

Repeat tests were carried out for each system to validate the results. The float measuring system was checked using a transducer tape. The systems were recalibrated between tests.

The errors quoted in Table 3.2 are differences between logged and manual readings. The sources of error may be identified mainly from non-linearity of response and hysteresis effects. This is indicated in Figures 3.2 to 3.5 where loop type responses are apparent. Such curves may be used for recalibration of data if the magnitude of the deviation is considered significant. Deviation from the "theoretical" response is generally greatest between the
calibration points (usually midway from the range limits). It should be noted that these characteristic responses are unique to each transducer. As such, this information would need to be applied to data for particular transducers to enable accurate recalibration.

The data collected during these tests is contained in working files and diskettes (Reference 18).

TABLE 3.2  TYPICAL RESULTS OF DRAWDOWN TESTS

<table>
<thead>
<tr>
<th>SYSTEM Logger/Transducer</th>
<th>ERROR</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average (mm) %FS</td>
<td>Maximum (mm) %FS</td>
<td></td>
</tr>
<tr>
<td>Wesdata 10m</td>
<td>30 0.6</td>
<td>80 1.6</td>
<td></td>
</tr>
<tr>
<td>Wesdata 10m*</td>
<td>50 0.5</td>
<td>100 1.0</td>
<td></td>
</tr>
<tr>
<td>Mindata 10m*</td>
<td>50 0.5</td>
<td>200 2.0</td>
<td></td>
</tr>
<tr>
<td>Mindata 20m&quot;</td>
<td>30 0.15</td>
<td>80 1.6</td>
<td></td>
</tr>
<tr>
<td>Mindata 20m'</td>
<td>20 0.1</td>
<td>50 0.25</td>
<td></td>
</tr>
</tbody>
</table>

Notes

* The response to changing pressure of both these transducers was slow. Both were returned to the manufacturers.

3.2.3.5 Comments

The maximum errors from observation bores are expected to be less than those in the above table since most would experience a slower decline in water level and response time would not be as critical. See also Section 3.3.4.2.
3.3 FIELD TESTING

3.3.1 Purposes

Field testing of the equipment served a multi-purpose function with two major thrusts involved.

(i) To develop a streamlined field procedure focussing on

(a) Physical set-up (transducer placement, conduit requirements, equipment layout etc.)
(b) Transducer movement during logging
(c) Data retention system (including file naming).

(ii) To test field performance and functionality of the system as assembled. The main aspects critically examined were

(a) Accuracy
(b) Durability (including battery performance)
(c) Reliability
(d) Effects of set-up configuration.

3.3.2 Description

Field testing included tests on the

(i) Pumped Bore
(ii) Remote Site / Observation Bore
(iii) Pumped bore discharge
(iv) Barometric pressure

Pumped bore testing was conducted at a number of localities. These included bores RN 26893 (2 1/2 mile Depot, Darwin) and RN 20544 (McMillans Rd., Darwin). Observation bore and long term testing was conducted at bores RN 8992 (Middle Point), and RN 22172 (McMinns borefield, Darwin) respectively.

During the period of this testing, equipment currently
trialled by the Western Australia Water Authority (WAWA) was made available for comparison purposes. This equipment included two data loggers namely Data Taker 2000 and Unidata Star Logger, and two pressure transducers. These included a Platypus 5m and a Druck 20m unit.

3.3.3 Results

3.3.3.1 Pumped Bore Results (Helical Rotor pumps)

Interference from both the pump motor and this particular pump type were found to contribute significantly to the pressures (and hence to recorded water levels) sensed by all strain gauge type transducers. The precise nature of the interference was not ascertained, however, it is likely to be related to shock emanating from pump or column instability, or stator/rotor contact reverberations resulting in microphonic responses.

A simple experiment to replicate shock effects was performed whereby a transducer at constant depth was subject to external shock using a hammer impacting a drum. The instantaneously recorded pressure was indicated to vary significantly from the constant hydrostatic pressure.

In the pumped bore, variations in pressure equivalent to +/-1.5m water were recorded at one second intervals using the Mindata logger/transducer combination, resulting in the graph shown on Figure 3.6 of Logged Head with Time. The graph was produced as a "screen dump" from the 'DATMAN' processor. This particular test was performed firstly at a number of different pumped rates while maintaining constant pump motor speed (by engaging each gear). The motor speed was then increased to obtain another range of pumping rates. The exercise demonstrated the correlation of these parameters to the magnitude of "scatter".
LOGGED RESPONSES USING
HELICAL ROTOR PUMP
(Varied pump and motor speeds)
The magnitude of the variations (i.e. the "scatter") due to physical vibrations which may be detected also depends on the logging system. The scatter was large for systems which take instantaneous readings (including Mindata, Torrens, Unidata), but much less apparent for the Wesdata system. This is a virtue of the Wesdata logging system which effectively averages a reading over a full second. Figure 3.7 is a comparison of the logged data types monitoring pumped bore drawdown.

This is explained since most transducers convert varying pressure to resistance, which is then converted to a signal. In the case of 4-20mA transducers, the current is sampled almost instantaneously (about 300 microseconds) by the logger. However the Wesdata transducer converts the resistance to a frequency signal which is "counted" by the logger over one second.

A number of set-up configurations were separately investigated to reduce the effects of the pump vibrations including:

(i) Placing the transducer at different depths relative to the pump (from 2m below the inlet to 4m above it),

(ii) Perforating the transducer conduit,

(iii) Centralising the pump column,

(iv) Electric Filtering which involved adding a capacitor and coil to the transducer/logger circuit and

(v) Physical filtering which involved the installation of a fine mesh on the transducer as a buffer.

The configurations above were trialled and did not indicate that any particular technique significantly reduce the scatter of logged water level data from the pumped bore.
Fig. 3.7 Pumped Bore Drawdown

Mindata and Wesdata Logged Data; Manual readings

(4 minutes of Mindata data omitted for clarity)
For example, the scatter of logged head from a test where the transducer was outside its conduit, at the pump inlet and with a free hanging pump column was not significantly different to that from another test where the transducer was set inside a perforated conduit, 4m above the pump inlet, and where the pump column was centralised.

The effectiveness of various configurations used need to be re-affirmed under conditions other than those available during this series of tests. The worst scatter encountered varied from the order of 300mm at the original test site compared to the 3m scatter found at the McMillans Road test site (RN 20544) where pump setting, rate and bore construction differed.

The only controllable factor found to influence the vibrations using a helical rotor type pump was the pump speed. This was examined in detail through a separate series of tests on bore RN 20544 (see Reference 18). The Mindata and Unidata (borrowed from W.A.W.A.) systems were used for these tests. The Wesdata system (which at that time required a 50mm conduit) could not be fitted downhole.

A Mono 620 pump with 50mm column, set at 40m below ground was used for these tests. The tests were designed initially to determine whether the pump motor or shaft speed were variables associated with the "scatter" of data. If so, then a working range of speeds should be determined so that these could be specified to produce a scatter of data to within acceptable limits. In one test the pump shaft speed was kept constant at 3 different engine speeds (using the gearbox). In the test "MMTEST1" the engine was run at three different speeds in each of four gears (Refer Figure 3.6).

3.3.3.2 Pumped Bore Results (Electric Submersible Pumps)

Two systems, a Mindata and a Wesdata were trialled in a bore pumped by a "Multi-Motor" submersible pump. The logged
drawdown was compared to manual readings taken at intervals during the test. At this stage, the type of pump used may be considered to represent turbine pumps in general, notwithstanding the possibility of any electrical interference effects from the pump motor downhole.

A 7 minute section of both logged data sets is shown in Figure 3.8 as a "screen dump" from the "datman" screen. The overall accuracies of both systems were comparable, with both having approximately 95% of readings within 50mm of the manual readings.

In Figure 3.8, the Mindata output shows some variation of the type encountered in bores pumped with a Helical Rotor pump, but to a much smaller extent. The maximum amplitude of the vibrations found was 35mm and the period shown is around 16 seconds.

3.3.3 Comments

Examination of the graphs produced from the above tests led to the following conclusions:

(i) A helical rotor pump (eg. MONO) driven by a diesel motor is unsuitable for use in a bore where water level is to be logged using a system which takes instantaneous readings unless the output is conditioned.

(ii) With helical rotor pumps, the size of the data scatter in logged head is dependent on the pump shaft speed (worst at pump speeds below the specified efficiency range) and, to a lesser extent, on the pump motor speed (worst at very low engine speeds).

(iii) The Wesdata logging method (measuring the probe’s frequency output over 1 second) largely overcomes the problem at least in situations where the instantaneously logged readings are showing a variation of up to 300mm. The Wesdata system however is currently limited by size
TYPICAL LOGGED RESPONSE USING ELECTRICAL SUBMERSIBLE
and may be considered for trialling in a variety of pumping situations when the smaller (27mm OD) sensors become available.

(iv) The instantaneous measurement type system (eg. Mindata) indicated more suitability to electrical submersible pumps (and possibly turbine pumps in general) since pressure pulses or spikes do not appear to be generated to the same degree as the helical rotor pumps.

(v) Conditioning of instantaneous data is required if pumped bore drawdown is to be logged.

The most effective method of conditioning is by "mathematical" averaging of data rather than by physical filtering. This would involve post-processing of the data. However, adequacy of sample size (ie. number of data points), and given that the water level is constantly changing, is a major limitation. The Mindata logger/transducer combination is restricted by the loggers' current specification to log at a minimum of one reading per second, and the transducer response time of 300us. The Torrens logger's current option of allowing a number of readings taken one second apart did not appear to give an adequate solution. The Wesdata method of averaging many instantaneous readings over one second is "inbuilt" and overcomes this problem.

Design of circuitry is required if electrical conditioning is to be further contemplated. This is to afford adequate protection of the logging device and correct sizing of the capacitance required.

3.3.4 Remote Site Testing

3.3.4.1 Long Term Monitoring Sites

Two systems, a Wesdata and Cherryville (from S.D.S.) were trialled over a period of 3 months at a monitoring bore in the
McMinn’s borefield (RN 22172).

Both systems used 5m range transducers, placed at the same depth. The loggers were calibrated to read standing water level (SWL) and were set to log every 3 hours.

The data recorded is contained in a working file and diskette (Reference 18).

Figure 3.9 is a plot of the two sets of logged water levels. The calculated differences between the two sets vary between -66 to +20mm, and even after recalibration of both sets to the manual readings, this difference still varied (-38 to +20mm). This indicates that initial calibration is not the only source of inaccuracy.

The most significant occurrences during the test were failures of both loggers. Only twice in 8 visits were both in simultaneous operation and manual readings could be compared. Therefore, at this stage no definitive comment can be made regarding the relative accuracy and long term calibration drift of the systems. This testing also aimed to assess battery life, humidity effects and general hardware performance. Further testing is therefore required.

3.3.4.2 Test Pumping Observation Bore Sites

Both Mindata and Wesdata systems were trialled in an observation bore which was 10m from the pumped bore during a multi-rate pump test. Manual readings were taken at various intervals during the test.

Figure 3.10 is a plot of Drawdown against Time for the first 9 hours of the test. The errors of the logged data compared to the manual readings are also shown, and are summarised below. Note that the Mindata data had to be recalibrated because the probe was connected to the wrong logger input. The procedure for this correction is demonstrated in the example given in Appendix D.
Fig. 3.9 Remote Site Loggers - McMinns RN 22172
19/8/91 to 30/8/91

Water Level (m. bg)

Time (days from 19/8/1991)
Fig. 3.10  Logged Drawdown in Observation Bore

Drawdown (m)

Time (mins after 9:00:00, 21/8/1991)

- - - - - Mindata (re-calibrated)
- - - - Manual readings
- - - - - Wesdata
The errors of the Logged data compared to the Manual readings for the above test are summarised in Table 3.3 (see Reference 18 for data).

3.3.4.3 Comments

The results from both remote site and pump test observation bores have generally not been within specification of the instruments. Although this performance level has not met initial expectations, the magnitude of these discrepancies may be viewed as acceptable when it is considered that they are generally in the order of 50mm or less. However, the overall reliability of all systems has been unacceptably low.

The accuracy results are consistent with a 1989 U.S. report on a brand of pressure transducer/electronic logger (Reference 9), which found system errors similar to those quoted above, and recommended that frequent check measurements were necessary where accuracy was important. The tests were carried out over a 17 month period in 50mm observation bores. Two of the eight pressure transducers installed failed over that period. That report also found that "Potentiometer-Float" transducers (which have a variable resistor attached to a float) using the same brand of logger were considerably more accurate than the pressure transducers.

Problems with both the hardware and software were experienced in many trials. The software problems were most commonly in communication between the laptop computer and the systems. However, the logger programming errors were also detected. Trialling of the nominated systems indicated that considerable familiarity is required of field operators of equipment to achieve successful continuous operation, and accurate results.
Table 3.3 Comparison of Logged Data to Manual Readings for Observation Bore Testing

<table>
<thead>
<tr>
<th></th>
<th>Mindata</th>
<th>Wesdata</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(mm)</td>
<td>%FS</td>
</tr>
<tr>
<td>First 500 mins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>19</td>
<td>0.19</td>
</tr>
<tr>
<td>Maximum</td>
<td>55</td>
<td>0.55</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Average (incl. Recovery)</td>
<td>24</td>
<td>0.24</td>
</tr>
<tr>
<td>Maximum</td>
<td>162</td>
<td>1.62</td>
</tr>
</tbody>
</table>

Note

The "average" and "maximum" are calculated from the absolute values of the errors.

3.3.5 Flow Monitoring

3.3.5.1 Results

The Kent "Flowmeter" (a pressure transducer mounted on a tripod, with a hose connected to the piezometer in the discharge pipe) was used in two pump tests. The first test used a Mono 620 helical rotor pump, and the second a "Multi-Motor" electrical submersible pump. Manual readings were taken from a piezometric tube connected to the discharge tube.

The results from both tests indicated that performance was adequate. The maximum difference between the logged and manually read data in each case was less than 20mm, which would lead to an error of between 1 and 10% in flow.
measurement, depending on the flow rate. The mean error was less than 10mm.

The "Datman" screen on Figure 3.11 shows the logged and manual readings over a 14 minute period when the flow rate was varied from 1 to 1.5 l/s. Variations in logged data of up to 20mm were recorded during periods when the pump rate was nominally constant. These variations are visible in the piezometer tube and are caused primarily by pump/motor vibration of the discharge tube. However, entrapment of air at the sensor will also cause fluctuation and precautions should be taken to bleed the system of air.

3.3.5.2 Comments

At this stage, the flow monitoring system is useful as a check on unattended pump performance. However the system's response to daily temperature changes has not been ascertained. Some users report up to a 5% change in calibration for similar units in use in the Darwin water supply system. After a housing has been constructed for the unit, its' performance over long periods of pumping should be re-tested. Additional power supply is required to operate this unit when used in conjunction with a 12v logging system.

3.3.6 Barometric Monitoring

3.3.6.1 Results

Where unvented transducers are used the barometric pressure over the full course of logging period must be recorded. Unvented transducers measure total pressure rather than relative pressure to reference (atmosphere). Hence variation in the reference pressure must be ascertained. Barometric data thereby enables determination of water level variation given the changes in pressure head over the period of the pump test. The procedure for this is outlined in Appendix D.
Set: P
Cursor time: Tue Aug 13 12:02:00 1991  Value: 0.695
Flowmeter and Piezometer readings - Screen height approx. 300mm

Fig. 3.11

MANUAL AND LOGGED FLOWMETER RESPONSE
A test was conducted over a 2 month period using the Mindata barometric probe (Serial No. 120222) and the 3500 Series logger. The probe was set up in an air-conditioned office, and logged at least every hour. The Bureau of Meteorology advised that Barometric pressure changes inside the office would be very close to those recorded in their (also air-conditioned) recording site, which is within 10 km of this office.

Figure 3.12 is a plot of Barometric pressure with Time, showing the recalibrated logged data, and the Bureau of Meteorology data for the period 17/9 to 21/9/91. This is typical of the data recorded over the two month period.

The logger was originally calibrated for this probe using a Druck Pressure Instrument (see section 3.2.3). This calibration was performed using the "metres of water" scale (which assumes water density of 1000 kg/m3) and required recalibration using 'DATMAN' (as per example in Appendix D), probably for the reasons outlined in Section 3.2.3 above (pressure fluctuations through the tube used to connect to the transducer).

After recalibration, the maximum inaccuracy found in the 37 readings compared was equivalent to 4mm (0.13%FS) of water.

3.3.6.2 Comments

The system performed accurately and reliably over the 2 month period. The necessity to take two measurements (water and atmospheric pressure) to find one parameter (water level) will likely produce some additional error to the data.

The Bureau of Meteorology has reported some problems with electronically logged barometric pressure data. For example, instantaneous readings can be affected by wind gusting. A container for the probe must include vents to avoid pressurisation, while providing reasonable temperature stability.
The maximum variation of atmospheric pressure during a day without storms is likely to be less than 60mm equivalent water pressure, over more than 5 hours (i.e. 12 mm/hr). It is advisable to have graphic records of atmospheric pressure over all seasons to which logged data can be compared, and to manually record unusual events (e.g. storms) where possible.

There is a possibility that the atmospheric pressure change during a given period over large regions may be quite similar except for those times when local disturbances occur. The Bureau of Meteorology has data from 68 stations across the Northern Territory, so this possibility could be investigated, as it might mean that atmospheric pressure would only have to be logged at a small number of stations (or that Bureau of Meteorology data could be used) and applied to remote sites.

In addition to this, the magnitude of diurnal effects is generally in the same order or exceeded by the errors associated with the data that is currently obtainable. The meaning of such corrections should therefore be considered in the light of this. The processing required in order that these effects be incorporated is also substantial.
4. DATA ACQUISITION SYSTEMS

This section presents an appraisal of the equipment tested and its applicability to the perceived role within this organisation. The results presented within this section were obtained from the tests described in Section 3.

4.1 Test Pumping Prototype

Two prototype systems were trialled for the logging of test pumping data. These were based on the MINDATA 3500 and the TORRENS loggers. Each were coupled to the suite of transducers described in Section 3.

4.1.1 Field Test Appraisal

(i) MINDATA 3500 Data Logger (6 channel, 4 analogue input). This logger performed reliably in regards to uninterrupted operation and was considered to be "user friendly" for most applications. Specific tests were not performed to determine recording accuracy, nor the effect of variable and extreme temperature. It is recommended however, that at least the latter be examined under controlled conditions as it is possible that exposure to temperatures approaching its specified upper limit of 60°C will occur. The accuracy of the logger is stated to be 1:20000 and cannot be checked with available equipment. Thus it has been assumed that the accuracy of results is dependent on the transducers available.

A number of anomalies were detected in the logger software which should be addressed. These include:

- The logger is not capable of operating at the highest specified recording frequency (ie. 1 second) if there are four channels activated. This is presumed to be due to the minimum "power up" time of 300 micro seconds required for each transducer. The "power up" operation is performed in succession for each transducer. A 4 second period was found to be adequate.
- A date and time anomaly was detected at midnight. This caused a misreading of data when the 'LOGIN' processor was utilised. This has since been rectified.
- The software available is not guaranteed to provide a faithful record of downloaded data. Anomalies could possibly occur (at random) due to the logger/laptop data transfer process. Provision of an echo checking routine would eliminate this possibility. It is common that data is "missed" or misread in any data transfer process (including modems) and echo checking should be a matter of course. The software required for this is known to be available in other non-standard versions and is called 'checksum'. This may be made available by negotiation at extra cost.
- Channel 3 or 4 could not be activated unless Channels 1 and 2 were also activated. This was expected to be a problem since logger input channels are dedicated to specific transducers. This has since been rectified.
- The choice of logging interval is limited to either fixed interval or significant event. A desirable addition would be a logarithmic time scale for recording.

The system of venting through the logger is questioned. Termination of the vent is at the plug and provision has been made to vent internally. However, the box is claimed to be at least watertight (ie. IP67)

(ii) Torrens Data Logger. (4 analogue input, 12 channels per input) This logger is currently the foundation of the electronic data acquisition system for hydrographic data. The system has been implemented since 1988 and some comment on the reliability needs to be obtained from the Hydrographic Section.

Accuracy tests were not conducted since it was assumed that its resolution was within the available tolerance of the transducers to be attached. Similarly to the Mindata logger, it is recommended that temperature effects be checked under controlled conditions.
The operational problems encountered with this logger were few and only associated with software anomalies. For example, recording at the highest available frequency (ie. 1 second) with the four inputs active caused a channel and time disorientation. Apart from this, the loggers' main disadvantages are associated with its size and useability.

(iii) Minda Pressure Transducers. Two unvented pressure transducers, a 10m and a 20m, were initially purchased for testing. During the course of the tests, both developed problems and required servicing. The latter became inoperable and was replaced with a 20m vented transducer. The specific nature of the problems are discussed in Section 4.1.2.

Regardless that the number of transducers trialled is only a small statistical sample, their performance during this project have been unsatisfactory in terms of both reliability and accuracy of measurement. In contrast, these problems have not so far been reported in similar transducers used for hydrographic recording to date.

The tests performed in both static and dynamic water level situations generally produced data outside specification (refer Tables 3.1, 3.2 and 3.3). For a number of repeated trials, a variability in recorded data was observed. This variability also occurred between data generated by raising the transducer up and lowering down to the same position. The differences are presumably caused by hysteresis effects. In addition to this, each transducer is prone to produce at random, a single anomalous point of any magnitude. This data point needs to be detected in the data set and eliminated during processing.

The 10m unvented transducer (10mm accuracy) produced maximum errors of in excess of 100mm (1%FS) in static water level tests and was ineffective during dynamic water level tests. This transducer however is considered to be disadvantaged by a response lag characteristic. The problem was subsequently disclaimed by the manufacturer.
Tests performed on the 20m unvented transducer before its failure indicated maximum errors of 21mm (0.1%FS) and 80mm (1.6%FS) for static and dynamic water level tests respectively.

A 20m vented transducer was then offered as a replacement due to the unserviceability of the initial 20m unvented transducer. Its performance was indicated to be within specification (20mm accuracy) from static water level tests resulting in maximum errors of 16mm. The dynamic tests indicated results at 150% above specification (ie. max error 50mm). Although not proposed as suitable for use in the test pumping situation (refer Appendix C), the venting efficiency of the 20m vented transducer would need to be checked before further use.

(iv) Barometric Transducer. The initial transducer purchased failed due to water ingression and was replaced. The performance of the replacement item has been determined as acceptable (refer Section 3.3.6). Note that the transducer will measure changes in barometric pressure and must be calibrated to a datum initially (usually m.s.l. if provided by the Bureau of Meteorology).

(v) Flowmeter. Static tests were not performed with this transducer. The field trials were conducted with the transducer set in its intended position. That is, dynamic tests only were performed. The data available has not established the accuracy of the instrument, however a comparison with manual readings indicates there are discrepancies of up to 6%. This range in readings is expected due to the fluctuating nature of the flow from the orifice pipe.

Other tests showed there was generally a drift of 15mm in measurement during variable rate tests. This is possibly due to air entrapment in the offtake line and caused by either cavitation or turbulent flow in the orifice pipe, the loss of full pipe flow during the change of orifice plates or if the instrument was insufficiently bled of air. Generally, this
magnitude in variation translates to a difference in flow of less than 5% and therefore may be considered adequate. In practical terms, instantaneous flows from the orifice tube will vary by at least this amount depending on other factors such as the condition of wear of the pump, the pump discharge/head relationship, suitability of the pump, the nature of the discharge (eg. sandy etc.) and the conditions affecting the engine operating parameters.

The variability of temperature effects on the instrument needs to be quantified.

(vi) Other Loggers. The Wesdata logger has also been utilised on occasion to log water levels during test pumping. However, it is disadvantaged by the inability to cater for the measurement of flow, its size is prohibitive in most cases (although the new version is 27mm in diameter) and the use of vented cable is not considered desirable in the test pumping situation. It does provide "better" data or more consistent than either the Mindata or Torrens loggers due to the different sampling method. Of the other loggers borrowed (ie. Unidata and DataTaker 2000), only the Unidata produced analysable data. Coupled with the Platypus transducer, the data produced from a pumped bore was similar to that from the Mindata system in its scatter of data points.

4.1.2 Suitability and Application

(i) Mindata 3500 Data Logger. The logger is considered suitable in terms of its size and portability, relative ease of use and its robust and waterproof construction. The logger communicates with a computer through the serial port. The software as previously referred is menu driven and will require less familiarisation time (as compared to the Torrens logger) by the intending user. The logging status (eg. time, battery, memory, current reading, logger on/off) is provided by the a single command.

The logger as purchased requires a computer, the
communications cable (an option) and perhaps a battery recharger to be operable given an existing suite of transducers. Facility exists for modem attachment and solar battery recharge. The non-volatile memory module may be removed from the logger without loss of data.

Improvements in the two point calibration scheme and logging interval are desired. User input slope and offset factors are preferred since there is versatility offered by this calibrating method. Firstly, logger inputs do not need to be specified for particular transducers beforehand. For instance, if a suite of transducers (with known slope and offset factors previously determined) were available for a single logger, an appropriate transducer could then be selected for each specific task. In addition to this, it is considered that calibration using a number of points (i.e. depths of water) would increase the accuracy of the factors determined. Recalibration of the retrieved data could be possible if the appropriate factors were recorded.

Complete power-down of the unit will result in the loss of the operational parameters and also the calibrated settings of the transducer inputs. In the field situation, this will mean that re-calibration will need to be conducted. This is best achieved in the test bore at depths near to the range limits of each transducer. Direct input of calibration factors would eliminate this particular concern. Only the logged data is retained on the Eprom.

The logging interval desired is not usually linearly scaled for test pumping purposes. A logarithmic scale is preferred, however since there is more than adequate memory available for test pumping requirements, this is not a priority issue.

The inputs and output on the logger are a screwed bayonet type and make a positive connection. However, attempts to acquire spare connectors have indicated these are uncommon at the present time. When in stock, only two agents distribute
this item. It is expected that damage to these connectors will readily occur in the field, particularly to the "male" ends attached to the transducers.

(ii) Torrens Data Logger. The standard package consists of inputs for a shaft encoder, rain gauge and trickle charge from a solar panel. The logger is based on a modular concept whereby various options may be attached readily by the inclusion of the appropriate "card". This concept is extended to the data storage "card" on a non-volatile EEPROM which can be removed for office interrogation when serviced. The four analogue inputs required for the pressure transducers for this project were therefore optioned by the appropriate card (at additional cost). There is facility for modem attachment and relay activation.

The software is menu driven and communication is facilitated via the serial port of a computer. The versatility offered by this logger however, also creates complications in its use and set up procedures. A high degree of familiarity is required with the logger in selecting appropriate paths and options. The menu was developed for communication with small hand held computers and needs to be upgraded to advantage the full screen offered by laptop computers.

The connection with the transducers is via 10 pin military specification "cannon" plugs. These plugs are expensive but can be obtained from a number of sources. They should be adequate for all intended purposes.

This logger meets test pumping requirements in terms of features and logging capabilities. However, the unit is large compared to the Mindata logger and intended for permanent installation. There is a potential for problems to develop with the "card rack" if transported frequently.

Unlike the Mindata logger, there are no problems associated with complete power-down of the unit in terms of
loss of input settings (eg. time, logging interval, etc.) and operational parameters (eg. slope and offset data). In fact, it is advised that the battery be disconnected during transit. All necessary data is retained on the EEPROM in addition to the logged data.

(iii) Minda Pressure Transducers. Notwithstanding the level of accuracy provided by some transducers, results of testing in pumped bores has indicated that the data obtained using the available logging systems is generally unsuitable without "smoothing". This data reflects not only water levels, but also the superimposed effects of extraneous oscillatory forces. Tests conducted using helical rotor and submersible pumps have indicated that these effects may be detected under both scenarios.

The above results are primarily attributed to microphonic responses which are detected by these transducers in addition to water pressure. In conjunction with the instantaneous sampling method of the trialled loggers, the data output will appear as a "noisy" drawdown trace. If development using this type of transducer is to be pursued, then further understanding as to the origin of the "noise" must be gained in order to eliminate or reduce it. Alternatively, transducers which will detect water pressure only should be investigated (for example, capacitance probes). The particular methods of physical filtering already discussed in Section 3 have not generally been successful. However, mathematical or electrical smoothing should be further examined.

The stated over ranging capacity of three times is considered to provide an adequate safety margin for the transducers. Tests have not been conducted to fully investigate this, however, the accuracy at 150% over range has been indicated to be within 0.14% of full scale.

The suitability of the cabling should be assessed in terms of its durability, unsupported length capacity and workability. Testing for load and fatigue strength has not been conducted at this stage. An indication of the tensile
strength of the cable needs to be determined to establish its maximum unsubmerged capacity. This will be applicable in bores where deep water levels exist.

Only subjective comment can be offered in relation to the cables’ workability at this stage. The standard unvented cable supplied is able to be coiled on a normal garden hose reel. 100m of cable is recommended as a maximum length to service most situations. Vented cable is relatively less flexible and heavier. No particular disadvantage was perceived from this although permanent damage due to bending could be considered a potential problem. The venting efficiency and heat shielding requirements would need to be established if this type of transducer were to be used.

Sydney Water Board reports of corrosion problems (verb. comm. R. Masters and D. Evangelista) in these transducers needs to be clarified but appears to relate to electrolytic degradation.

The effect of the "bubble" at the pressure diaphragm orifice of the transducer in perceived as a potential source of measurement instability or possible error. It has been reported that the air entrapped will "dissolve" after two to three days. In the test pumping context, this time frame is critical. Therefore further clarification as to the effects of this bubble on accuracy is required.

The suitability of the transducers in the pumped bore needs to be examined in terms of accommodation downhole. It is recommended that conduit is used to house transducers downhole for a number of reasons. In particular, it is recommended for physical protection and cable control. The minimum internal diameter required is 27mm and options therefore include 25mm NB pvc conduit, 32mm galvanised water pipe (or similar) or 32mm continuous polybutylene hose. It is expected that in a number of instances, the size of bore and the diameter of pump column installed will limit these options and contingent measures need to be determined.
(iv) Flowneter. In terms of suitability, the instrument is considered adequate although bulky and heavy. It requires a constant and stable platform on which to be established for the duration of the test. The set up procedure needs care to ensure the offtake tube from the piezometer is completely bled of air and that the appropriate relative height measurements are recorded.

When used with either of the trialled loggers, an external power supply is required to boost supply to within the recommended operational voltage range of 12-42V. Shading of the instrument is also recommended.

(v) Barometric Transducer. The only operational problems foreseen involve the calibrating process if the transducer is used in conjunction with the Mindata logger. Power loss or resetting of this logger will result in complete loss of the contents of the ROM. Therefore, correct and accurate calibration may not be adequately achieved in the field due to the small pressures which need to be applied to effect the recalibration procedure. However, changes in barometric pressure should still be monitored and recalibrated using Bureau of Meteorology data at a later date.

The transducer is not waterproof and therefore will require care to ensure it is isolated from all potential sources of moisture. A temperature and wind shield is also recommended for use.

4.1.3 Other Factors

(i) Mindata 3500 Logger. The available memory in this logger is 131071 bytes. At a logging interval of 30 seconds, it will use approximately 85000 bytes per day if all channels are active. It will therefore accommodate approximately 1.5 days of logging before downloading is necessitated. When downloaded to ASCII form, the total storage requirement is about 422050 bytes. The logger provides an option to query the memory usage of at any instance.
In reference to the test pumping role, the logging interval, duration of testing, downloading procedure and memory and data storage requirements need to be addressed. The logger will permit downloading of data at any time, facilitating any requirement to process data during a test. Although logging is required to be stopped in order to do this, the downloading process is not likely to be in excess of 2 minutes. On recommencement of logging, subsequent data is added to the existing data set so that a complete record of the test remains intact. All data is retained in the memory module until its erasure is specifically requested. Resetting of the logger through the menu will clear all input parameters including the calibration, time, logging interval and all memory stored.

No power consumption figures are available at this stage, however, abnormal consumption of power has not been detected during any test. An indication of power consumption at the maximum rate (ie. 4 channels active) needs to be obtained to ensure uninterrupted logging. Although battery status is automatically logged once at midnight, it is important that personnel constantly be aware of it since the functionality of the logger and communication with it is dependent on a threshold of 11.9 volts.

Manufacturer support has been considered to be good.

(ii) Torrens Logger. This logger was not trialled as extensively as desired due to the limitation on the available (single set) ancillary equipment and in the majority of cases, tests were performed using the Mindata logger. However, experience in its general performance can be drawn from the "hydrographic" section. The transducers used for the Mindata logger were adapted for use with this logger via a "crossover" plug.

Only minor software "bugs" were detected during testing. These were eliminated after contact with the manufacturer. Further field testing is required to assess its performance.
under "mobile" conditions and reports of high power usage need to be affirmed. As observed, its modular construction and relative bulk are expected to disadvantage its field application. The communication package also requires upgrading as this will pose some difficulty with users who are unfamiliar with the menu system.

(iii) Mindata Pressure Transducers. Service requirements for this equipment have involved complete rebuild and replacement of parts and retesting under laboratory conditions. While Mindata are capable of performing a large part of this function, there is a major dependability on parts imported from the United States. In some cases, the delay period of orders or redundant period of equipment has been up to 6 months. The initial unvented transducers purchased are no longer supplied nor serviced, and only the replacement with a vented item can be offered.

(iv) Flowmeter. The transducer is common amongst devices for monitoring water levels and storage in local reticulation systems. A local agent for Kent Instruments exists.

A "lookup" table for the current combination of orifice plates and discharge tubes should be developed. At this stage, these figures are best presented in tabular form since calibration corrections may be effected easily. In the long term, mathematical relationships describing the "rating curves" for each configuration should be developed.

(v) Barometric Transducer. Comments as per Mindata Pressure transducer.

Three hourly barometric data is available from the Bureau of Meteorology for specific sites. Depending on the accuracy requirements of barometric correction in water levels, an interpolated data set based on this data could be utilised in the long term.
4.2 Remote Site Monitoring Systems

The Wesdata logging system was selected as the preferred system to be trialled. A Cherryville logger was used for comparison purposes and as a possible alternative system to be considered. This choice was due to its availability and current utilisation in the field as a single channel logger.

4.2.1 Field Test Appraisal

(i) Wesdata Logging System. Transducers of 5m and 10m ranges were initially purchased with dedicated loggers. Neither performed satisfactorily in terms of reliability. Both units have been returned for repair on more than two occasions. Service reports were not provided and hence a record of failure modes is unavailable. The history of hardware and software changes since the initial purchase is considered to be inappropriate for equipment available for general retail.

Tests to determine logging accuracy and temperature effects were not conducted due to the unavailability of suitable testing equipment. A long term downhole test was attempted and aborted as a result of failure of the logger. The possibility of deterioration of logger performance and battery life, particularly in Top End groundwaters which are typically of 32°C temperature, is of concern and needs to be affirmed. Other issues including long term drift in calibration, and the performance, efficiency and resistance to moisture ingress of the vented cable need to be addressed.

The standard tests were performed to obtain a measure of accuracy of the transducers (See also Section 3). The static water level test on the 5m transducer indicated the maximum error was up to 46mm. A 10m transducer initially used, was afflicted with an intermittent lagged response problem which was reflected in its performance level. Its replacement produced a maximum error of 38mm in the static test and in
dynamic water level tests, up to 80mm.

In-field testing of the 10m unit indicated there to be a maximum difference of 100mm compared to the manually observed water levels during the 6 week trial period. The internal clock maintained accurate timing.

There is no facility for monitoring battery status nor direct interrogation of water level unless the logging function is discontinued (ie. the loggers current reading cannot be checked unless logging is ceased). This facility is required since confirmation of the loggers operation (including battery status) and the need for calibration correction should be checked during each site visit.

(ii) Cherryville Logger. The only trial conducted on this logger was concurrent to the Wesdata field trial. A 10m vented Mindata transducer was attached to the logger for this test.

The logger failed due to battery problems after 37 days. Compared to manually observed data, the maximum error in water levels was 150mm.

4.2.2 Suitability and Application

(i) Wesdata Logging System. The system is purpose built for 50mm boreholes and external housing is not necessarily required for security of installation if adequate fixture is made at the borehead. However, a major design fault is the buoyancy of the unit (which should be designed to sink). A lead weight of approximately 1 kg was attached to the end of the unit.

Specific cable lengths for each bore need to be determined beforehand and made to order since cutting and joining of the cable is not feasible. That is termination of the cable is only permitted at either end. The type of cable used is not preferred since it does not tolerate axial torsion. An unwarranted amount of care is therefore needed to
spool and unwind the cable. Failure of the cable attachment at one end has already been experienced.

The communication software is more complicated than would be desired. Some ambiguity does exist in the menu options and is only supported by vague explanation in the handbook. An alternative to the 2.5mm audio plug and socket would be desirable as communications problems have been encountered apparently due to poor contact of the connection.

(ii) Cherryville Logger. The communications software and hardware is similar to the Torrens Logger. Comments as per Torrens Logger.

The size of the logger does not permit it to be secured within a borehead of less than 250mm diameter. An external housing would therefore be required in the majority of cases.

4.2.3 Other Considerations

(i) Wesdata Logger. The logger has a memory capacity of 64000 bytes. This will enable storage of approximately 20000 data pairs, or 12 readings daily for 4.5 years. The logger logs at a minimum of 12 hourly (i.e. twice daily) regardless of specified logging interval.

Continuous operation for over one month was not generally achieved and accuracy testing indicated variability and limited success in faithful data retrieval. The type of connector is considered inadequate to achieve complete record transfer in the majority of cases and the current interrogation procedure does not provide sufficient information to the user.

The battery consumption was not gauged and some confidence in this aspect will need to be gained before any permanent field installations are commissioned. This will have a major control on the timing of field checks. Testing has not been adequate to determine battery consumption characteristics, venting efficiency, resistance to moisture
ingression, long term field performance and durability and robustness under the perceived operational conditions. These factors should be examined if perserverence with this system is maintained. An attempt to standardise this equipment should also be made since various componentry has undergone a degree of evolutionary change.

(ii) Cherryville Logger. The memory capacity is 64000 bytes. This represents the storage of 20000 data pairs.

This logger has been used in hydrographic logging and claims to have battery capacity of 6 years on tipping bucket pluviometers.

4.4 Implementation

4.4.1 Infrastructure

A number of aspects need to be considered in establishing the infrastructure for this system. These are

(i) Equipment Requirements

Section 9 has identified the minimum specification for further equipment purchases, however the nomination of particular suitable products is yet to be made. All loggers and transducers trialled do not meet the specification requirement although it may be considered that a workable system could be developed if this equipment were adopted. Therefore, until such time that the required equipment is identified, the existing suite should be utilised to facilitate establishment of general procedures and for staff to develop familiarity with this technology. The format of any future system is not perceived to be widely different and trained staff should be able to adapt when this particular system is superseeded.

In the test pumping context, with consideration to the above stated purpose, the Mindata 3500 series logger servicing a 20m vented transducer, and the Kent flowmeter should be utilised for pumped bore monitoring. The second transducer
(10m unvented) initially available with this unit for a single 'close' observation bore is not deemed suitable for further use. However, this is not critical since observation bore drawdown is recommended to be monitored using remote site loggers. Barometric monitoring will not be required.

The current prototype for remote site water level monitoring should be abandoned and alternative equipment sought for evaluation. The Wesdata system presented problems with reliability, accuracy and manufacturer support. Generally, it was inadequate in terms of the standard of quality desired. Four units are currently available and if operable, should only be utilised if these limitations are understood. Such applications are only recommended in situations where manual monitoring of water levels may be used as an adjunct to logged data (for example, test pumping observation bores in long term tests with frequent manual readings).

On the basis of its availability and the support infrastructure already existing within the organisation, the Cherryville logger should be considered for reassessment and trial in the immediate future. At least 5 units should be installed for trial once appropriate sites are identified. These should be at locations within daily access in order that periodic checking can take place. The Cherryville loggers currently used for hydrographic recording utilise Mindata vented transducers. This combination should be maintained, however, the transducers acquired will need to encompass 10 and 20 metre ranges with cable lengths to specification.

This strategy should not be deemed to represent commitment to this system, but rather as an interim to the establishment of suitable instrumentation for remote site monitoring. The current range of single channel loggers suitable for this purpose is limited. Therefore, an ongoing process of 'market review' to ascertain a logging system within specification should be maintained. New products, such as the single channel logging system from Mindata whose
specification appears to suit the requirement, will be available by the end of 1992. Its claimed accuracy is increased by 100% as compared to the transducers currently available and is constructed of plastic and ceramics. It is favourable from a security aspect as it can be housed within 50mm casing.

Logging of observation bore drawdown during test pumping should also be met by remote site loggers. Two Cherryville loggers and a 20m vented transducer system compatible with the central logging system is recommended.

In general, any other major purchases should not be made until a definitive policy stating the recommended equipment has been made. Contingent and spare parts equipment may be obtained as appropriate.

(ii) Securing a testing and workshop facility
A basic testing facility requires a bore of at least 25m in depth to enable the prescribed 'Standard Tests' and equipment verification procedures to be performed. Instrumentation to effect minor electronic repairs and checks is required. For example, workshop servicing needs may include repair to cables and ends, part replacement and recalibration. Battery replacement and internal clock resetting may be accomplished on-site. For remote site water level monitoring, similar needs are envisaged and servicing on an 'as required' basis need only be performed.

(iii) Stipulation of procedure for the installation and operation of the equipment on-site and preparation a field operations manual.
Documentation specifically stating the installation and operation of the equipment on site will need to be compiled. This will incorporate directions for setting up, movement of the transducer (when necessary), field calibration procedure, logger status monitoring, security, downloading of data and perhaps a "trouble shooting" guide.
(iv) Staffing.
A staffing need in addition to the current levels in the groundwater monitoring and test pumping areas is identified in the workshop/testing area. However, this need is considered only to be on an intermittent basis and may be met by integrating existing instrument workshop staff or deployment of other staff within the organisation. The need will also depend on the network size (for remote site logging) and ultimately the performance of the equipment.

(v) Cost
In terms of hardware, the equipment required in the short term includes seven Cherryville loggers with Mindata transducers. Five loggers are recommended for remote site system evaluation and two for test pumping observation bores. An approximate cost of purchasing seven Cherryville loggers with transducers is $18,000, and the additional cost of installing five in the field is $3,000.

Costs associated with workshop establishment and documentation of procedures will involve an estimated 400 man hours equivalent to a cost of $16,000. The cost of maintenance of this equipment is estimated to be in the order of 10% of its capital value on an annual basis. In terms of the recommended (interim) suite of equipment, this represents approximately $2300 annually.

4.4.2 Training
The following aspects should be considered in establishing a programme of staff training.

(i) Subject Matter
Experience with personnel involved in this and other computer orientated data collection projects has indicated that computing knowledge is essential in order to facilitate accurate and reliable data retrieval. An understanding of computing protocol (eg. DOS) will enhance the development of confidence to utilise the available equipment and enable in-
field "trouble shooting". Therefore training is initially identified in the areas of basic computer operation. Instruction on logger communications, data handling and processing should follow.

(ii) Personnel Involvement
The personnel requiring training should initially involve test pumping and monitoring section supervisors and field leaders. This level of training is envisaged to involve a staged process and on-the-job learning for field crew. Basic computer skills should still be obtained through formal training.

(iii) Training Body
Computer training should be organised by the Staff Development Unit of PAWA. The current contract agency 'Computype' will deliver the subject matter 'as and when' required (depending on numbers). Training of logger operation and communication, data handling and processing aspects may be accomplished 'in-house'. Formal training should be supported by adequate 'on-the-job' and 'phase in' time.

(iv) Cost
A cost estimate for this exercise, assuming initially six personnel to undertake the computing training phase, consisting of two courses - 'Introduction to Computers' and 'Introduction to DOS' is $5500. This represents approximately 100 man hours and includes $2000 in course fees. Allocation of 150 man hours for in-house instruction on logger communications, data handling and processing is represented by a cost of $5300 including instructor time.
5. DATA PROCESSING SYSTEMS

5.1 General

The data processing stage of the project was necessary to accommodate the conversion of a variety of logger output formats to a standard compatible data form used by computer analysis packages. As well, existing data needs to be converted to a similar format to reside on the data base.

A number of systems exist which cater for the processing of logged data. These include 'DATMAN and LOGIN', 'HYDSYS' processor and 'System Design Services' (SDS) editing systems. Although the latter two packages have not been used extensively, they each have known limitations which disadvantage their selection to fulfil the capacity required. The SDS editor exclusively operates to process data from that company's loggers and the 'HYDSYS' processor was developed subsequent to both other packages. The requirement to develop a custom software package was therefore an integral part of the project. 'DATMAN and LOGIN' was developed under a consultancy to specification and is described below.

The backlog of existing data may be processed using spreadsheet routines which are readily available, however experience with 'LOGIN' has shown this program has advantages which will facilitate easy data input since it designed to specifically accommodate time series data.

5.2 DATMAN and LOGIN

A standardised data logger output format does not currently exist although proposals have been made to unify this aspect on a national basis. Consequently, raw data output formats are unique to individual logging systems and need to be converted to a general time series form commonly required by computer analysis software. A custom processing package was therefore devised to treat the logger outputs generated by the trialled systems. That is, the "Mindata",...
"Torrens" (and Cherryville) and "Wesdata" systems. The package was developed and encoded by Dr. John Doherty and Lindsay Brebber in the computer language 'TURBO C++' and specifically written with the processing of test pumping and water level monitoring data in mind although it is adaptable to any time series data (Reference 5). As an evolution model its modular design was desired to enable further additions and modifications to be made without major program changes. This flexibility will allow adaptation to different logging systems and the manipulation of data to produce any desired output format.

'DATMAN and LOGIN' is a two stage processor. 'LOGIN' enables conversion of the logger output to a general time series form. 'DATMAN' is utilised to perform data manipulation and smoothing routines. The resulting data is a continuous time series describing water level movements for the period of interest.

Many manipulations may need to be applied to the generated raw data to produce a meaningful and useful data set. These routines are described in the 'DATMAN and LOGIN' manual.

The resulting manipulated data is then suitable for archiving or for immediate use to aid in field interpretation of data to hand. More specifically, graphical and formatted data may be produced as a visual aid or can be directly applied by a variety of computer analysis packages.

Appendix D contains an example of data manipulation using 'DATMAN'.

5.3 Data Processing

Existing information to be installed on the data base is confined to historical test pumping data. In this case, the raw data form is in time series format and ready for direct
The program 'LOGIN' was designed as a pre-processor to create a general data input for 'DATMAN' and contains facilities for editing of raw data. It currently reads downloaded raw data from the three logging systems on trial. With minor modification to accept direct keyboard input, it is considered the most efficient and user friendly method of data input. The advantages it provides include date prompting, time series generation and time based ordering of data.

A number of spreadsheet programs exist which could also be used to facilitate input of this data. For example, Lotus1-2-3, Symphony, DbaseIV, and Rbase are some of the programmes currently available.

The exercise of clearing the current backlog should be allocated a staff resource and a specific time frame in which to complete this work, otherwise tendered to contract. Input of this data via 'LOGIN' or either of the above spreadsheet programmes will facilitate easy transfer to 'HYDSYS/GW' or some other groundwater database when available. General data including SWL, pump type and setting, available drawdown etc. should accompany this data on a text file or similar. This programme of data input should be attached to a separate project to computerise groundwater data.

All subsequent manual and logged data from test pumping should be stored directly on a standardised or accepted storage medium and input by test pumping personnel as available. Guidelines stipulating convention for data presentation, processing and storage will need to be formulated in the short term. In particular, the methodology for re-calibration and correction of logged data should be affirmed for both test pumping and monitoring data.

Manual monitoring information already exists on a computerised database and the status of data input will remain unchanged in the short term.
5.4 Implementation

5.4.1 Infrastructure

The following aspects should be considered in establishing the infrastructure for the processing of generated data.

(i) Equipment.

The processing requirements above can be met using in-house desktop or laptop computers. In the short term, the small scale data generating capacity (one test pumping unit, five remote site units intermittently) could conceivably be handled by a single additional computer (assuming that all current machines are fully committed). In the longer term, consideration to the processing time and number of stations to be processed will dictate the need for upgrading of this capacity.

The required software has already been obtained. This includes spreadsheet programmes, 'DATMAN and LOGIN', and a number of groundwater analysis packages to facilitate on site or desktop analysis. Installation of the 'HYDSYS/GW' database system is expected in the longer term and the need for a revision of processing procedures should be assessed at that time.

(ii) Processing Procedure Guidelines.

Guidelines need to be formulated with regards to conventional retrieved data format (ie. for incoming and stored data), a methodology for data processing, and a storage medium to which data may be finally downloaded.

(iii) Staffing.

Primary processing of data generated from the test pumping area should be conducted by the field personnel. The capability for on-site processing of data (ie. manipulation for the re-calibration and correction of data) is a requisite to field assessment and evaluation of parameters using
available groundwater software. Office desktop processing should only involve a further stage of processing. This may include reworking or overlaying of data to establish its integrity and should therefore be routinely performed by testing personnel. Similarly, processing of logged monitoring data should be performed by monitoring personnel.

(iv) Cost.
The cost of this exercise will mainly be identified in training time of the relevant personnel. The main hardware purchase will be a desktop or laptop computer to process data.

5.4.2 Training
Assuming the computing training initiative is undertaken (refer section 4.2), the relevant staff will require instruction in the use of the available processing package ('DATMAN and LOGIN') and the particular groundwater analysis package selected for field use, recommended to be either "WHIP" or "GWAP".
6. DATA STORAGE SYSTEMS

6.1 General

All data, both generated (raw) and processed needs to be catalogued and stored in a manner which will facilitate its efficient retrieval when required.

Data generated in-field during a testing programme may represent a substantial number of files. This raw data will require a system of cataloguing, storage and backup even before any processing is considered.

Mainframe management of corporate data is currently established in the organisation for hydrographic data and has facilitated initial groundwater data base requirements. The imminent installation of the "HYDSYS" data base system incorporating a current development for groundwater data management will enable all data to reside on the mainframe. The system of magnetic tape archiving currently being employed would be substantially increased in capacity as a consequence to service groundwater requirements.

The avenue provided by micro computers and diskette storage is considerable. The advantages lie in the user domain whereby ease of retrieval and portability of processed data and access to an array of groundwater analysis and presentation packages developed specifically for the micro computer is readily available. Thus the primary purpose of acquiring and collating data, to provide a basis for analysis and design, may be served in the most efficient manner if this data were to be available on diskette, or through networking of the in-house computing facilities.

However, caution in protecting and ensuring uniqueness of original data sets is recognised as being of major importance. Therefore, any modification, including post processing and interpretation in parameter calculation should be confined to the user's own work space and labelled as such. Procedural
issues such as security, access or updating will need to be addressed in the longer term.

6.2 Data Forms

Logger output form is unique to the logging system. Although there are current initiatives to standardise this in Australia, the trialled logging systems have individually developed formats.

6.2.1 Generated Data

Examples of data output are shown in Figures 6.1, 6.2, and 6.3 with features of each annotated.

6.2.2 Existing Data

Existing data is tabulated in time series form. Test pumping data generally consists of water level and flow rate measurements taken simultaneously on a time scale suited to logarithmic plotting. Water conductivity, pH and temperature are measured intermittently.

6.3 Data Cataloguing

All processed data needs to be catalogued to enable systematic data storage and to enable easy and effective retrieval. It is expected that the 'HYDSYS' system will require the data to be formatted specifically to enable data retrieval using this system. However, a general system of cataloguing is still required for data housed in a separate library.

6.3.1 Generated Data

The data loggers trialled each have provision for labelling and identification of the data set contained within it. However, the format of this is dependent on the logging system. The proposed system described in Appendix B attempts
### FIGURE 6.1  MINDATA LOGGER OUTPUT

<table>
<thead>
<tr>
<th>(1)</th>
<th>L I.V403</th>
<th>MINDATA 3500</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2)</td>
<td>probe 4m inside conduit 2m below</td>
<td></td>
</tr>
<tr>
<td>(3)</td>
<td># 19910710134229 19910710151401 000001 000100</td>
<td></td>
</tr>
<tr>
<td>(4)</td>
<td>T19910710134229</td>
<td></td>
</tr>
<tr>
<td>(5)</td>
<td>D1 000.145</td>
<td></td>
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<tr>
<td>(6)</td>
<td>D2 004.985</td>
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<td></td>
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<td></td>
<td>D2 004.151</td>
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<td>D2 004.189</td>
<td></td>
</tr>
<tr>
<td>(7)</td>
<td>FFFFT</td>
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</tr>
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</table>

**Notes:**

1. Software Version Number, Logger Model
2. Comments, Maximum 30 Alphanumeric Characters
3. Logging Start Time, Logging Finish Time
   
   
   \[ (: Y : M : D : H : M : S : ) \]
   
   Logging Interval
4. "T" Time Data Logged
5. "D1" First Channel, Data value
6. "D2" Second Channel, Data value
7. "FFFT" End of Log Marker, Will appear at end of
   
   Downloaded File only. (ie. will not appear if
   
   Logging is continued)
FIGURE 6.2    TORRENS OR CHERRYVILLE LOGGER OUTPUT

<p>| | | | |</p>
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<tbody>
<tr>
<td>1</td>
<td>RN22172</td>
<td>TRANS</td>
<td>MM 23091991 102840 19111991 124500</td>
</tr>
<tr>
<td>2</td>
<td>RESET LEVEL DVF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>-0.3155</td>
<td>REGRESS'N</td>
<td>9.7805MM 15min</td>
</tr>
<tr>
<td>4</td>
<td>23091991 103004</td>
<td>10072.9</td>
<td></td>
</tr>
<tr>
<td></td>
<td>23091991 123004</td>
<td>10110.1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>23091991 141504</td>
<td>10148.0</td>
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<td>10188.0</td>
<td></td>
</tr>
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<td></td>
<td>23091991 174504</td>
<td>10226.2</td>
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<td>23091991 211504</td>
<td>10301.6</td>
<td></td>
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<td>10250.2</td>
<td></td>
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<td>05101991 221504</td>
<td>10287.1</td>
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<td></td>
<td>06101991 001504</td>
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<tr>
<td></td>
<td>08101991 041504</td>
<td>10443.0</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

(1) Station Number, Input information (eg. transducer),
units of measure, Date of logger start (:D : M : Y:)
Time of logger start (:H : M : S:), Date of logger
finish, Time of logger finish.

(2) "Hello" message - required when logger is accessed.
(maximum of 30 characters)

(3) Scale Factor (slope), Logging format current,
Set level, Default reading check time.

(4) Date, time, Logged Data value.
FIGURE 6.3  WESDATA LOGGER OUTPUT

(1) FILE NAME FOR DATA SOURCE  C:\WESDATA\DATA\318172A.dat
(2) "Standing water Level  5.23m"
(3) LOGGER START TIME  = 231:15:00:00
(4) LOG SCAN TIME  =  03:00:00
(5) LOG AVERAGE TIME  = 00:00:00
(6) LOGGER Sn. NUMBER  = 11282
(7) LOGGER PROG NUMBER  = 7
(8) NUMBER OF PROBES  = 2
(9) PROBE RESOLUTION  = 0
(10) logger Memory used  = 367  Bytes
(11)  
<table>
<thead>
<tr>
<th>Time</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>231:15:00:00</td>
<td>-8.238</td>
</tr>
<tr>
<td>231:18:00:00</td>
<td>-8.284</td>
</tr>
<tr>
<td>231:21:00:00</td>
<td>-8.331</td>
</tr>
<tr>
<td>232:15:00:00</td>
<td>-8.299</td>
</tr>
<tr>
<td>232:18:00:00</td>
<td>-8.342</td>
</tr>
<tr>
<td>232:21:00:00</td>
<td>-8.386</td>
</tr>
<tr>
<td>232:24:00:00</td>
<td>-8.409</td>
</tr>
<tr>
<td>233:03:00:00</td>
<td>-8.372</td>
</tr>
<tr>
<td>233:06:00:00</td>
<td>-8.315</td>
</tr>
<tr>
<td>242:03:00:00</td>
<td>-8.910</td>
</tr>
<tr>
<td>242:06:00:00</td>
<td>-8.856</td>
</tr>
<tr>
<td>242:09:00:00</td>
<td>-8.805</td>
</tr>
</tbody>
</table>

(12) Log ended at  242 :11:12:44

Notes:
(1) Destination file for download
(2) "Hello" message - Maximum 70 characters
(3) Logger Start Time in "Julian" days
   (ie. days after 1 January) (:D :H : M : S:)
(4) Logging Interval (minimum 1 sec.)
(5) Averages a number of readings if required
(6) Logger Serial Number
(7) Program Version Number
(8) Number of channels logged (1 or 2)
(9) Rounds logged value to required resolution
(10) Total memory used
(11) Data Log Time, Recorded Data
(12) Log End Time
to maintain consistency and uniqueness in file naming across the range of loggers available. This will identify individual data sets generated from each test.

The system will allocate only eight characters for alphanumeric labelling, imposed as a result of the limitations on the Mindata logger. Therefore only vital data can be used for labelling. That is, data pertaining specifically to the role of the data set only.

Each test, consisting of a number of data sets, requires identification to suitably locate it in the context of each project.

For example, a project consisting of a step drawdown test, constant discharge test with three observation bores and recovery will eventually produce nine data sets pertaining to water level movement and three to flow monitoring. Readings of water conductivity, temperature and pH with time will form at least separate three files. If unvented transducers are used, a further three data sets will be generated.

The system of data logger data set labelling is proposed in Appendix E, and is based on the "Tree" directory system. It pre-empt the introduction of the HYDSYS groundwater data base system, however, since a substantial accumulation of data is expected in the lead up period until its introduction, an interim system needs to be adopted. Systematic file naming is important when used in the data interpretation stage since uniqueness and ease of recognition of data files will facilitate efficient data handling.

6.3.2 Processed Data

Processed data encompasses the spectrum of data that is generated and processed using 'DATMAN' and existing data which has been input through the keyboard and is ready for archival.
Test pumping data exists for all production bores constructed as such in the Top End. For each test, usually consisting of a multi-rate (4 x 100 min steps) and a 24 hour constant discharge test with recovery, approximately 200 data pairs are generated. An extra 100 data pairs are recorded for each observation bore monitored. Additional data including the distance and direction to observation bores, pumping rate, water conductivity and temperature, discharge characteristics (eg. cloudy, sandy etc), bore water level and total depth should be included in some form as this is considered to constitute vital information.

Long term water level data has been regularly collected since 1985/86. The data for most areas is taken on a monthly basis and currently resides on the mainframe system. This data need only be organised to assimilate with any new data storage and cataloguing system to be introduced.

The proposed data cataloguing system for test pumping data is outlined in Appendix E. This should exist in parallel to the 'HYDSYS' data base.

6.4 Storage Medium

The main storage medium used by the mainframe system is magnetic tape. All hydrographic data is currently stored on tape and it is recommended that this system also be adopted for groundwater data storage. Diskette data should also be made available because of its portability to be used by micro computers which are not networked or appropriate for field use. For field use, 3 1/2" floppy diskettes formatted to 720kb are recommended for use.

6.5 Data Retrieval and Dissemination

Data will be required to be accessible from networked terminals or from individual diskettes. Modem access to data is envisaged in the long term to service remote site data requirements. "HYDSYS" installation on field laptop computers
and remote micro computers will be advantageous.
7. SOFTWARE SUITE DEVELOPMENT

7.1 General

The acquisition of suite of test pumping interpretation and analysis software is required to provide both on-site management of the testing programme in progress and to facilitate direct and complete analysis of data for desktop analysis. Two levels of analysis are required -

(i) A field analysis suite which should provide basic parameter (transmissivity and storativity) estimation and methods to enable assessment of bore developmental progress with support in terms of tabular and graphical output to screen and printer.

(ii) A desktop analysis suite which should provide type curve overlay analysis and comprehensive parameter analysis (leakage coefficient, unconfined aquifer analysis, partial penetration correction etc.) as well as all of the above.

The logger interrogation and downloading programmes are provided by the respective manufacturers. Development of the 'DATMAN and LOGIN' package (Reference 5; see section 5.2) was required to "link" the variable logger output formats and the "standard" input required by analysis software.

7.2 Available Software

The range of software currently available to the organisation include several public domain programme developed by IGWMC, and purchased software namely GWAP, SWIM, WHIP, and PTEST (References 1, 2, 7, 10, 12, 14, 15, 16, and 17). Research and documentation of the available software was conducted under a consultancy with The Australian Centre for Tropical Freshwater Research (Reference 4).

The software requirement for field evaluation of aquifer
parameters may be met by either GWAP or WHIP. The former is considered to be favourable in terms of "user friendliness" however appropriate training of staff will avail either package for this purpose.

7.3 Developed Software

In addition to the 'DATMAN and LOGIN' package developed as a result of this project, an inclusion to the suite of groundwater packages is a parameter optimisation routine (MODINV) which is based on the groundwater modelling package, MODFLOW (Reference 11). The forte of this package is its speed in achieving calibration of the particular model by computerised numerical inversion techniques. This phase of the project was undertaken as a consultancy jointly with the Australian Centre for Tropical Freshwater Research at the The James Cook University. The programme was developed by Dr. John Doherty and coded in the computer language FORTRAN.

7.4 Additional Requirements

An additional software requirement is the development of a "look-up" table or rating curve relationship to convert orifice piezometer readings to a corresponding flow rate. This exercise is required for a range of orifice plate and pipe combinations.
8. CONCLUSIONS

The long term goal for improvement and provision of more cost effective data is best achieved with the use and development of electronic technology. This will result in an improvement in accuracy and reliability of data measurement, elimination of transcription errors and a reduction in labour intensity while requiring little extra effort in catering for its acquisition. A system of electronic data acquisition, processing, retention and analysis is therefore under scrutiny in order to develop a streamlined approach. This system provides digital data forms which allow efficient storage for the increasing data base and ease of retrieval. The data may then be directly utilised as computer input with a minimum of manipulation.

A project was thus established to platform the construction of a data logging and analysis system which was compatible throughout. It necessitated a three stage process including the development of data acquisition, data processing and data retention systems. The work culminated in the following specification in terms of recommended format, integration and operational requirements and a hardware specification to tender for equipment supply.

The initial phase examined available electronic equipment to form an operational system facilitating the acquisition of data from test pumping situations and regional water level monitors. Three systems were recommended for a trialling process.

(i) Mindata System consisting of a Mindata 3600 six input logger (4 analogue, 2 digital), Mindata pressure transducers (1x10m and 1x30m range), Mindata barometric pressure transducer and a discharge monitor based on piezometric measurement translated to flow rate.

(ii) Torrens System based on a Torrens Logger with four analogue inputs with two pressure transducers, a
barometric transducer and a flow monitor as used in the Mindata System above.

(iii) Wesdata System consisting of a single channel logger and transducer. This system was required for remote site monitoring in test pumping and long term monitoring situations.

As most of the equipment was alien to the groundwater role, a significant proportion of time was required to be spent on proving and testing components and developing a workable system.

All systems trialled demonstrated poor reliability and the expected accuracy limit was not achieved. Faults were encountered in the Mindata and Torrens software and all hardware except the Kent Pressure transducer. The Wesdata equipment is not recommended for further use due to an assessment of its unsuitability.

A minimum specification desired for all future equipment purchases has been proposed in Section 9.3. However, in the interim, continuous trial of existing electronic logging equipment is recommended to facilitate the establishment of procedure and infrastructure. This measure will allow further examination of proposed equipment to the required specification. With careful selection to supercede the current system it will not be expected to pose a compromise with established procedures and infrastructure.

The interim system for the logging of test pumping data consists of a Mindata 3500 series logger, a 20m vented transducer, Kent pressure transducer to monitor flow and two Cherryville loggers with 20m vented transducers to be available for monitoring observation bores.

Cherryville single channel loggers with Mindata 10 and 20m vented transducers are recommended for further trial in remote water level monitoring situations.
The need to process logger output data to convert to a universally usable format and an abbreviated storage form was identified in the second stage of the project. A software package allowing flexibility in data manipulation and output resulted. This package, namely 'DATMAN and LOGIN' (Reference 5), is recommended for use in processing logger data and, with minor modification, used to process all existing data. As well, significant inroads were made in the provision of groundwater analysis and interpretation packages for data users. Facility will be available for the field analysis of aquifer parameters using the software packages "WHIP" or "GWAP".

A groundwater modelling package was also developed to enhance the speed of the modelling process by using mathematical inversion techniques. The package was released as "MODINV".

At this stage, a workable data retention system still needs to be examined in terms of location, facility and accessibility to data users. The "HYDSYS" data base system currently being installed will offer part requirement of the perceived system.
9. RECOMMENDATIONS

9.1 Test Pump Data Logging System

Recommendations are made with regard to the following in the short term.

(i) The Data Logging Configuration.
It is recommended that use of some of the existing equipment be continued to enable the test pumping data acquisition system to be established. This will consist of the Mindata 3500 series logger, 20m vented transducer and Kent 'flowmeter'. Observation bore drawdown should be monitored using Cherryville loggers (on trial) and Mindata 20m vented transducers. Two observation bore loggers should be made available for this purpose. A barometric transducer need not be utilised with this system.

The field software suite required includes a computer based selection of 'lookup' charts or flow/piezometer relationships enabling conversion of piezometric readings to flow rates, the 'DATMAN and LOGIN' data processing package and groundwater analysis package for preliminary determination of parameters. The method of processing pumped bore data, assuming a 'scatter' of data to be similar to those obtained from testing, should be addressed.

(ii) Training.
Training time should be allocated for computer familiarisation and operation before the introduction to the logger application software. Instruction should then be given to the use of the data processing programme 'DATMAN and LOGIN' and either "WHIP" or "GWAP" as the groundwater analysis package which will form the basis of parameter determination in the field.
(iii) Documentation of a Handbook describing field procedures should be undertaken.

Formulation of policy and a convention for equipment setup and operational procedure, and data processing and handling procedures should be addressed by relevant test pumping and professional personnel. Documentation of a this policy should then be undertaken.

The following recommendations address issues raised after trialling the first prototype system. This consists of a central logging system which monitors the pumped bore and a "close" observation bore, pump discharge, and barometric pressure.

(i) The use of vented or unvented transducers.
The "absolute" (or non-vented) transducers initially purchased are no longer available. Any further transducers supplied by the MINDATA company will be "gauge" transducers. The unvented transducer system recommended for this prototype was based on the perceived working conditions on site and the need to provide a relatively greater measure of protection for any vented system. Under the system recommended above, the potential for cable damage has been largely eliminated and therefore a vented system would be appropriate.

(ii) The measurement of pumped bore drawdown.
The "scatter" associated with pumped bore data may be significant and methods for filtering or eliminating this effect should be sought. Methods for isolating pump and motor vibrations should also be investigated. Alternatively, different types of water level sensors should be examined. As a final option, the retrieval of pumped bore data should be maintained at the current manual status.
In the interim, the operating speed limits for pump and motor in terms of efficiency should be quantified such that appropriate combinations may be used in practice. This will minimise the "scatter" of data. Where these limits are infringed by necessity (e.g. equipment availability and suitability downhole) pumped bore drawdown should be manually measured at the usual frequency.

(iii) The option for observation bore water level monitoring from a "central" logger.
Monitoring of water levels from any observation bore is considered to be best served by a dedicated remote logger. This strategy will reduce the amount of unspooled cable on site, reduce the possibility of data loss due to logger co-ordination and organisational problems, increase the "central" loggers' memory availability and eliminate the need to shield or protect cable from damage, or heating if vented cable is used.

(iv) The need for barometric monitoring and correction.
When compared to the errors associated with the logged data, the magnitude of the required correction may be considered to be insignificant. Barometric data is available from the Bureau of Meteorology in Darwin and general data corrections using this data could be applied if necessary. In addition, should dedicated remote loggers be utilised for observation bores, the use of vented apparatus will eliminate the need for this correction.

(v) The use of an alternative pressure transducer for the "flowmeter" should be examined.
The current unit is bulky, sensitive to elevation changes, and is attached to the orifice tube via a hose which is subject to air entrapment. Direct
coupling of an "absolute" transducer (which is similar to the water level transducer) to the piezometer will eliminate all problems mentioned above.

9.2 Remote Site Data Logging System

The following action should be undertaken in the short term.

(i) Data Logging Configuration

Further trial and evaluation of the CHERRYVILLE single channel data logger and MINDATA vented system, using 10 and 20m transducers should be conducted. This data logging system should be considered on the basis of the existing support within the organisation and the availability of equipment. Its only trial to date, which was of short duration, was not successful due to battery failure. However the Hydrographic Section’s reports of its performance level indicates that this is unusual and retrialling should be undertaken. The purchase of five units are recommended at this stage to be installed at locations within daily access.

(ii) Training

Similarly to test pumping staff, groundwater monitoring staff should undergo initial training in basic computer operation before accessing logger application programmes. Training should also encompass the data processing package, "DATMAN and LOGIN".

(iii) Documentation of a Handbook describing field procedures should be undertaken.

Formulation of policy and a convention for equipment setup, security and operational procedure and data
processing and handling procedures should be addressed by relevant monitoring and professional personnel. Documentation of this policy should then be undertaken.

The following recommendations are made with regards to the first prototype logging system and long term action in developing a remote site logging system.

(i) Further use of the Wesdata equipment is not recommended due to its unsatisfactory level of performance. Field tests using this equipment have demonstrated performance deficiencies as well as problems with communication and construction quality.

(ii) Future Logging Systems
The specification proposed in Section 9.3 should be considered in selecting appropriate equipment. Ongoing assessment of the Cherryville system should be made with regards to its suitability to remote site logging.

9.3 Minimum Specification of System Componentry

9.3.1 Loggers
Based on the assumption that the current system format will be maintained, the criteria below lists the essential and desirable features.

(i) Hardware
- minimum of four (4) analogue inputs (4-20 ma) for pump test system
- single 4-20 ma input for remote site logger
- compatible input plug types for remote site and test pumping
- robust construction with capability to perform at 80-100% humidity and -10 - 60°C temperature
conditions
- waterproof venting facility (if vented transducers)
- designed for portability (subjective assessment required)
- able to be housed and secured within bore (for remote monitoring bore)
- 12V battery (rechargeable) and desirable solar trickle charge facility
- electrical surge protection for transducer and recharge input
- battery low warning
- desirable non-volatile memory and lithium (or similar) battery retaining ROM
- desirable protection of reset buttons

(ii) Software
- communication via RS232C connector at 1200 to 9600 baud
- direct interface with laptop or desktop computer
- 64K minimum non-volatile memory
- minimum resolution of 1:20000
- logging interval logarithmic or linear
- field interrogation and download capability without interruption to logging
- interrogation of current status while logging to include at least logged data and time, battery voltage and memory usage
- direct input of calibration parameters for individual transducers (ie. slope and offset)
- user friendly communications menu (subjective assessment required)

9.3.2 Transducers
The minimum specifications listed below pertain to all transducers similar to those trialled.
(i) Water Level Transducers
- accuracy (linearity) to within 0.1% of full scale
- 4-20 ma output
- temperature compensation
- operating temperature range -10 - 60°C
- cable required to enable ease of handling and reasonably resistant to crushing, crimping, severance and chemical corrosion (some subjective assessment required)
- cable capable of at least 50m unsupported downhole
- adequate venting efficiency (if vented transducer)
- waterproof vent seal of vented cable
- durable and robust construction of transducer and sheath should be of inert material (some subjective assessment required)
- non-bouyant and adequately weighted to maintain straightness of assembly downhole
- waterproof connection with logger
- maximum outer diameter 40mm

(ii) Barometric Transducers
- accuracy (linearity) to within 0.1% of full scale
- 4-20 ma output
- temperature compensation
- operating temperature range -10 - 60°C
- desirable 80 - 100% humidity resistant
- transducer and sheath of inert construction
- durable and robust construction

(iii) Flow (Piezometric) Transducer
- accuracy (linearity) to within 0.1% of full scale
- 4-20 ma output
- temperature compensation
- operating temperature range -10 - 60°C
- desirable 80 - 100% humidity resistant
- transducer of inert construction
- durable and robust construction
- desirable lightweight and portable
10. ACKNOWLEDGEMENTS

The authors wish to acknowledge the input and guidance provided by the project Principal, D. Pidsley.

The technical advice and assistance provided by Dr. J. Doherty of the ACTFR and DPI (Qld) during the project was also greatly appreciated. His enthusiastic and immediate response to our enquiries during all phases of the project were well received.

Assistance and input was provided by technical officers R. Farrow and R. Setchell during the testing phase. The authors also wish to acknowledge the support provided by the officers of the Hydrographic Instrument Workshop.

The loan of equipment from the Western Australian Water Authority for trial and comparison through the co-operation of Bob Bowyer was appreciated.
11. REFERENCES


4. DOHERTY, J. "Software Options for Pump Test Data Acquisition, Processing and Interpretation", Report No. 89/12, Australian Centre for Tropical Freshwater Research, James Cook University, Townsville (1989).


18. WATER RESOURCES DIVISION. "Electronic Data Collection and Analysis Project", Internal File Number 480/02/0160, Water Resources Division, Darwin (1992)
APPENDIX A (i)

EXCERPT FROM THE CONSULTANT REVIEW

OF HARDWARE OPTIONS

(Reference 3)
**RECOMMENDATIONS**

There are many decisions to make in putting together a system for pump test data acquisition. These decisions must be made by PAWA personnel based on the information contained in this report and the accompanying product brochures. This section contains a description of my own leanings based on my present knowledge of field conditions to be expected by PAWA pump test staff. Obviously, those who have experienced these conditions, and who are aware of the many other constraints on these decisions, may wish to review these recommendations.

It should be pointed out that those around Australia with whom I have discussed pump test data acquisition and who have systems of their own, stress the experimental nature of setting up such a system. No system is perfect, and as they gain more experience and different pieces of equipment come onto the market, their perceptions of what constitutes the best system changes. As these perceptions differ from person to person, a large part of the choice of system components seems to be intuition, or previous experience with a particular piece of equipment. The decisions that PAWA staff must make on what to buy in order to automate their data acquisition must be considered in this light. Though decisions should be as well-informed as possible, a decision will only have been proved to be correct after the resulting system has been successfully operational for some time.

**Water Level Sensors**

The choke here is between pressure transducers and capacitance water level sensors. Obviously, as the longest of the latter items is only 6m, pressure transducers must be used in the pumped bore and close observation bores. Although capacitance sensors have, on paper, a better accuracy than pressure transducers, in practice the performance of the flexible ones which would be used downhole is degraded by dirt, deposits on the teflon tube and the possibility of touching the side of the hole; the latter phenomenon will become a greater problem in deeper holes. Also, their performance is affected by casing. Although Westdata (the makers of the flexible sensors) assure me that the calibration offset and not the scaling if affected, problems could arise if the water level falls through a casing collar or a reduction in casing diameter. Because of all these drawbacks, I prefer to use pressure transducers in all bores.

**Gauge or Absolute**

If the conditions encountered by PAWA staff were such that the water table was never more than 10m deep, and drawdowns would never exceed 20m, then I would recommend that
gauge transducers and vented cable be employed. Indeed this is the option chosen by most pump test practitioners and PAWA staff may consider that a system should be set up specifically for these conditions if they are common enough. However, with water depths as great as 110m, and, even for shallow water depths, with drawdowns over 30m not uncommon, I have been warned often enough about the problems associated with inefficient cable venting (either on its own or through heating of the cable or damage to it) to conclude that a gauge pressure transducer cannot be guaranteed to work in such conditions every time it is employed. Besides this, the cost of vented cable will become excessive unless a mechanism is set up to vent it down the hole and use unvented cable the rest of the way to the surface. However such a downhole vent cannot be guaranteed never to clog and, where large drawdowns are expected (for example 50m), vented cable length may still be unacceptably large. Hence I recommend that absolute pressure transducers be employed.

As was discussed earlier, the penalties in using absolute sensors are that a barometer must be purchased, software must be written to correct readings, and system accuracy will be cut by a factor of, at most, 2.

Centralized or Decentralized Logging

Here the choice is between a single logger with a large number of channels which collects water level information from all the bores as well as flow rate and water quality information, or a system comprising a number of loggers located at strategic sites such that transmission cable lengths are kept short. I prefer the latter system for a number of reasons. Firstly communications to distant observation bores are certain to be broken often by vehicles, animals and people. Secondly, although some multichannel loggers are cheaper than a number of single channel loggers (here, too, it depends on the make), signal transmission would need to be by current if multichannel loggers were used. As only the more expensive downhole transducers are able to transmit current, these would need to be employed, or an uphole transmitter would become necessary to convert a frequency or voltage signal provided by a cheaper transducer to current for transmission to the logging site. In either case the cost advantage of a centralized system would be diminished. A disadvantage of the decentralized system is that increased software complexity may be necessary to collate all the data, but this is, in principle, not difficult and does not, in my opinion, outweigh the advantages of decentralized logging.
**Signal Transmission**

There is no doubt that the pumped bore pressure transducer should not transmit its signal uphole using analogue or frequency modulated voltage because of the probability of electrical interference. The 4-20 mA current loop will probably work though it is suggested that the PAWA experiment with the ACTFR's Mindata system before accepting this conclusion as fact. If a 4-20 mA current loop is not immune to interference then some innovative thinking will be called for as there are no better alternatives on the market.

Frequency transmission would probably be satisfactory for monitoring pressure transducer output in observation bores, with some reservations if power lines are nearby. For the Westdata system, where logger and transducer are mounted together down the hole, it is considered unlikely that there will be electrical interference, for the frequency transmission is over a distance of about an inch.

If the flowmeter is sufficiently far from the pump and if the link between it and its logger is short, frequency transmission would probably be alright, though 4-20 mA transmission would be safer. The same holds for temperature and water quality monitors, though here there seems to be little choice. Even for those industrial type systems discussed in the previous section that have a 4-20 mA transmitter into which the sensor plugs, the link between the sensor and the transmitter will not be current loop with the sole exception of the Mindata temperature sensor. Hence all sensors except this latter one cannot be placed down the pumped bore, and the link between them and the logger, or possibly a current transmitter, should be kept short.

**Pressure Transducer Type**

I suggest Mindata pressure transducers for the pumped bore and the close observation bore. These units are accurate (though not quite as accurate as Drucks), and can be obtained as absolute transducers for ranges 0-20m (i.e. about 0-10m water depth), 0-50m (i.e. about 0-40m water depth), 0-100m (i.e. about 0-90m water depth) as well as other ranges. They are slightly cheaper than Druck units and, being Australian made, there should be help available should any problems be encountered. Also, I am informed that Drucks come with a metre of vented cable whether or not the element is gauge or absolute; hence a way would have to be found of joining this vented cable to unvented cable (if an absolute system were chosen) without permitting any electrical current or water leakage at the join.
For more distant observation bores I suggest that the much cheaper Westdata transducers together with their submersible loggers be used. The specifications are good, the cost is very low and electrical interference should not be a problem. The disadvantages of this alternative will be discussed below under "loggers".

It should be noted that with the use of Westdata systems down the observation holes the case against gauge sensors is not so strong. This is because Westdata vented cable is very cheap ($1.68 per metre) and better vented than most; also it is only slightly thicker than their unvented cable and hence only marginally more cumbersome. In this case cable cheapness does not cause problems with signal quality because the signal is digital and hence, while moisture ingress may affect its amplitude, it will not affect its "message" unless moisture ingress is excessive.

**Flowmeter**

It is probable that PAWA staff are in a better position to make this choice than I am because of their greater experience in flow measurement within the pump test context.

With some reservations I suggest using the Signet 8500 paddlewheel flowmeter. The main advantages of this unit are that it is cheap, appears to be quite robust, is battery powered and transmits 4-20 mA current. Also, a particular sensor can be used on a variety of pipe sizes though, unfortunately, no one sensor can be used across the entire range of pipe sizes employed by the PAWA (ranges are 1/2 - 4 inches, 5-8 inches and 10-up inches). The disadvantages of this instrument are the possibility of abrasion of the paddlewheel, the possibility of bearing deterioration, and the fact that the measuring range is only 20:1 in a particular flow setting. If this instrument were used, it would be important that discharge orifice plate manometer readings be intermittently recorded for both in-test calibration of the flowmeter, and to monitor any change in the latter’s characteristics, over time.

If this alternative is not chosen then I would consider further the Great Lakes Instruments insertion paddlewheel sensor marketed by Combined Instruments, the Kent 3000R helical vane flowmeter (with or without the rate-of-flow indicator), the Signet "Mighty Mag" magnetic flowmeter or the Kent VBC magnetic flowmeter. Again, whatever instrument is chosen, the discharge orifice plate should be retained in case of flowmeter malfunction and as a check on flowmeter calibration. Also, depending on the type of flowmeter chosen, it may be desirable to adjust the span and zero of the electrical output as soon as the pump is switched on so that the logger is able to record flow rate variations with a high resolution. If this is the case, the manometer may be needed to set flow rate correctly upon the pump being switched on.
Water Quality and Temperature

The cheapest alternative here is to place a Westdata temperature and conductivity sensor in the drum or some other containment into which the water discharges prior to flowing away through a channel or irrigation fluming. As the electrical output of the Westdata temperature sensor is frequency, the logger to which it is connected would need to be close by; also, the water container should be well removed from the pump and its power cables. For the conductivity sensor, a Westdata four electrode or toroidal sensor (if in production) should be considered; if these are not optimized to groundwater conductivities. I am sure that Westdata would be happy to make the necessary adjustments.

In a situation where greater temperature accuracy is desired, or where it may be desirable to monitor flow from different aquifers into a pumped bore (requiring perhaps multiple temperature probes) then a Mindata downhole temperature sensor is suggested, this being the only unit available that will transmit current.

Loggers

It is suggested that a 4 channel Mindata logger be employed to receive signals from pressure transducers in the pumped bore and the closest observation bore. The other two channels could be used for different purposes at different times. For example one channel could be used for monitoring water level in another close observation bore. One may be used for monitoring temperature through a Mindata downhole probe, or it may be used for monitoring flow rate by receiving the flowmeter signal. The Mindata logger is well priced, can supply power to 4-20 mA transducers from its own power supply (which can be supplemented by an external supply), its logging status and the current transducer readings can be inspected using a laptop at any time, and the logger can be downloaded without affecting logging operations so that results up until a certain time can be plotted and inspected whenever desired. For a simple pump test set-up involving the monitoring and recording of water levels in up to three bores, together with the recording of flowrate, only this one logger would be required, as long as barometric correction was not required or was done under software control through manual reading of a barometer. Alternatively, a Mindata barometer could be purchased and plugged into one logger channel; see below.

As mentioned, the Mindata logger can provide power to downhole pressure (and temperature) transducers. Where a 4-20 mA device is supplying its own power (as will probably be the case with the flowmeter), there will need to be correct interfacing between the two. This matter will have to be discussed with Mindata if this option is chosen; it
should be possible, with many of the flowmeters described, for the logger to switch them on prior to sampling thus conserving flowmeter power. Another matter which needs to be discussed with Mindata is software flexibility for allowing different types of transducer (e.g., pressure, temperature, flow and possibly barometric) to plug into the logger at different times.

In more complex pump test situations where there are observation bores further afield it is suggested that Westdata submersible loggers be used. These have the advantage that they are cheap; this is a big advantage if there are many observation bores. They have the disadvantage that logging must be halted before downloading can take place, but, in the course of a pump test, it may be more important that the response of the pumped and close observation bores be closely monitored and intermittently plotted than that of the observation bores; it should be noted however that it is not difficult to halt, download, and then restart Westdata loggers. Another disadvantage is that, with the present state of Westdata equipment, the 891 field terminal cannot be used to start and stop logging and gather data. I suggest that, as it has been promised that this is about to be changed, Westdata be asked to include this change in any equipment they supply us. It would also be worthwhile encouraging them to speed up development of the promised hand-held unit for monitoring status and latest transducer reading of the downhole loggers. While neither the 891 nor the status monitor are essential, communication being possible in the equipment's present state by using a laptop, depreciation of the latter could be minimized by the use of a field terminal.

For temperature and water quality monitoring it is suggested that a Westdata multichannel logger be employed, preferably the soon to be developed four channel logger. The reasons for this are (i) it would interface with the cheap Westdata temperature and conductivity probes, (ii) these loggers are inexpensive, and (iii) three brands of logger on the one site may present disadvantages in terms of user training, software construction and manufacturer back-up. Some suitable container for the logger incorporating connection plugs may have to be constructed.

Another possibility which is worth considering is to allow a Westdata logger to interface with a frequency output flowmeter; this could be either a dedicated single channel unit or the same one that is being used to record water temperature and conductivity. A significant cost reduction in many types of the flowmeter can be achieved if a current output is not required and a pulse output is provided instead. For example, the Signet Rotor-X flow sensing element could be used instead of the 8500, or a Kent 3000R would not require a rate-of-flow meter. In these cases the flowmeter output could be frequency divided to a level
where very accurate measurements of period (and hence flow) could be made with a Westdata 389 logger operating in the period mode.

**Barometer**

A Westdata barometric sensor connected either to a single channel Westdata logger or to the multichannel logger monitoring water properties would be cheaper than, and as accurate as, any other alternative for barometric recording. Alternatively, if PAWA staff foresee that pump tests involving a pumped bore and only a single observation bore will be a common occurrence they may wish to purchase a Mindata barometric sensor. While this alternative is more expensive, it will allow for the use of only one logger in this simplest of pump test setups (the 4th channel would monitor the 4-20 mA output of a flowmeter).

**Software**

The system suggested above is modular and hence can be as simple or complex as the occasion demands. It is designed to be as easy to install and use as possible while preserving accuracy, flexibility and cost.

A set of software will need to be written to allow for information from all parts of the system described above to be pooled into a coherent form suitable for plotting and mathematical analysis. It is not intended to discuss the software details in this report, though its capabilities will need to include some of the following features. Assuming that the system is as outlined above:

(i) both Mindata and Westdata logging outputs will need to be read;
(ii) if Westdata loggers are downloaded and restarted, subsequent logger records will need to be joined into a single record pertaining to one hole;
(iii) if a transducer is moved down during a test to accommodate greater-than-expected drawdown, this shift in logger readings (either Mindata or Westdata) will need to be corrected for;
(iv) data gathered up until a specific time should be able to be plotted for inspection, with the responses of a number of bores being plottable on the same graph;
(v) water levels taken manually or flowrates measured with the discharge orifice plate should be useable for transducer or flowmeter output calibration.
A Comment

The hardware recommendations made above are based on information supplied in manufacturers' brochures and by manufacturers themselves, or their agents, during telephone conservations. When it is decided to proceed with the purchase of the abovementioned, or any other, items more detailed inquiries will need to be made to confirm information and prices supplied herein and to solicit any other information required for complete system design prior to purchase. The above recommendations are thus made subject to a favourable outcome to these further inquiries.

OTHER CONSIDERATIONS

Transducer Calibration

For many loggers, the transducer current or frequency readings are converted to head or drawdown as the data stored in the logger is downloaded; the transducer calibration constants (which may vary slightly from transducer to transducer) are stored in a file on the downloading computer. In the case of the Mindata logger, I gather that the calibration slope is assumed invariant and the effect of offset variation from unit to unit is allowed for by enquiring of the user the water height (according to any datum) when the transducer is installed: all logger outputs are then appropriately adjusted. In the Westdata case, the transducer can be entirely re-calibrated each time it is installed, for both slope and offset.

Transducer calibration drift can be monitored by comparing logger output with manually measured water depths. In fact if this latter information is taken while a pump test is underway, then the transducer can be calibrated against drawdown in the course of each pump test. Hence an operator procedure that allows for the measurement of water levels in all bores before a pump test begins, then just before the pump is switched off and again just before the transducers are removed from the hole, will provide enough information to ensure that, provided transducer linearity is according to specifications, the logger-recorded water levels are correct in spite of any possible drift in the transducer calibration constants over time. Naturally, the facility for using manually-gathered water levels for such continuous transducer calibration will need to be built into the software.

It may be of interest to PAWA staff to know that the ACTFR has a transducer calibration facility for water depths of up to 10 metres. This has been found useful in monitoring transducer and logger performance as well as in checking linearity specifications.
Flowmeter Calibration

Many users of flowmeters treat their specifications with suspicion. Furthermore, especially with mechanical meters, wear of moving parts may effect accuracy. Hence, as mentioned above, it is strongly suggested that the orifice place and manometer be retained on any system PAWA use for discharge of pumped water. This will allow a continuous check to be made on flowmeter performance and to monitor any changes that it may undergo from pump test to pump test.

If PAWA do not have their own flowmeter calibration facilities it may be of interest to them to know that the ACTFR possess calibration facilities for flow rates of up to nearly 100 l/s.

Computers

A data logger needs to download its data into a computer. Most environmental loggers are battery powered and consume very little current so that they can stay operational for long periods. Many have the capacity to withhold the contents of their memory even after the batteries have failed either because data is stored in EPROM or in lithium battery backed RAM. Hence loggers can be brought back to the office for downloading after their deployment is complete.

PAWA personnel have indicated that they would like to process at least some of their pump test data in the field. Hence a field computer will be necessary both for logger (or field terminal) downloading and for data plotting and processing. For field downloading purposes it would be best if the computer were battery-powered. Some form of laptop is the obvious choice; these normally have internal batteries which will keep them going for about five hours. For processing, a computer of at least XT power with a hard disk would be advisable. If 240V power is available at the campsite whenever this computer is likely to be used, this machine does not need to be a laptop. It should be noted that power line conditioning may be required to filter out spikes on the line feeding the computer from the generator. A suitable unit is the Arlec CUS 80250 costing $457.25 (wholesale) though there are many other similar devices around.

A savings in cost could be achieved if the processing and downloading computer were one and the same: laptops are available with hard disks and XT (even AT) power. However as I have left the task of costing and assessing computer requirements to the PAWA, I do not know how great is the price advantage of a single XT laptop with hard disk over a PC single-floppy-disk laptop plus an XT or AT transportable computer with hard disk. If the price difference is not too great then I would lean toward having the two computers; if the laptop
broke down the central logger could still be downloaded into the other computer in an emergency, as there will normally be power at the pumpsite. Also, as the computer used for field downloading of loggers may be subject to some rough treatment and exposure to the possibility of accidental damage, it may be cost-effective in the long term if this machine were as inexpensive as possible.
APPENDIX A (ii)

EXCERPT FROM THE CONSULTANT REVIEW
OF SOFTWARE OPTIONS

(Reference 4)
this report. It seems to be a very powerful, versatile, user-friendly and inexpensive package which would be suitable for both office and field use.

RECOMMENDATIONS

It will be necessary that some data-handling programs be written as part of this project. The minimum capability of this software will be to reshape logger output data files into a form suitable for a spreadsheet package or a plotting package to read, perhaps with the aid of a screen editor. No doubt PAWA staff have their own preferred screen editor; it is suggested that its ability to handle a text file the size of a logger data download file be tested, for the buffer size of some screen editors is smaller than others.

It is for PAWA staff to decide whether data editing and manipulation should be by spreadsheet or should be carried out using a program that is specially written for the purpose. I suggest that the latter path be taken, at least to some extent, viz:

(i) to read any of the logger data files;

(ii) to join them, cull them, remove offsets and refer them to the same time base;

(iii) to perform some data calibration procedures; and

(iv) to output data in a form suitable for input to a spreadsheet program, plotting program or pump test interpretation program chosen by the user.

The extent to which this program could include interactive graphics and more sophisticated data manipulation will depend on the time allocated for writing it; the latter is a matter for PAWA staff to decide. It would be highly advantageous if it were menu driven with options offered that were specific to the PAWA's pump test system so that pump test crew could use it with the minimum of training.

If the PAWA decides to buy a spreadsheet package they will find a number on the market. LOTUS 1-2-3 is very powerful (especially the latest version) and would probably be most suitable. However, if the PAWA already possesses another package, it is possible that it could also do the job.
If a spreadsheet program is not used, GRAPHER, represents a flexible inexpensive means to generate screen and hardcopy plots. Again, if the PAWA already possesses a plotting package then that may prove just as useful.

I suggest that Clarke's software provides a powerful base for pump test interpretation; I will not detail its capabilities as PAWA staff are no doubt aware of them. It is enough to note that it handles a sufficient variety of aquifer types to be of general use for both field and office interpretation. It is user-friendly, documented in detail and is interactive. Screen plots are available (CGA) for many of the procedures, though hardcopy output is limited to a Roland plotter or small HP plotter; the latter is not a serious disadvantage as many other plotters are compatible with these devices. Also, with a small amount of screen editing, Clarke's output files are GRAPHER or LOTUS compatible. Furthermore for field hardcopy, the DOS GRAPHICS command can be used in conjunction with PRINT SCREEN to obtain a printer copy of any screen plots.

It should be noted that some of the analysis routines are written for a colour monitor, though they will still work on a monochrome monitor. User interaction may not be as easy in the latter case.

Clarke's software does have some inadequacies, some of which are:

(i) discharge must be constant if curve matching procedures are used;

(ii) simultaneous curve-matching of the response of a number of observation bores is not possible (only one at a time can be handled);

(iii) parameter co-variance matrices are not calculated;

(iv) data points cannot be weighted prior to curve matching;

(v) well bore storage and partial penetration are not covered;

(vi) Neuman's method is available for forward modelling but not curve fitting;

(vii) only three graphs can be plotted on the one set of axes.

In view of these inadequacies, or simply to increase their range of available pump test interpretation software, the PAWA may wish to consider purchasing Geraghty and Miller's AQUESOLV or one or more of the packages listed by the IGWMC. The
The capabilities of each of these latter packages is summarised in a booklet which is already in the possession of the PAWA; these capabilities will not be repeated here. However on examining this booklet, the following packages appealed to me as possibly presenting to the PAWA a complement to the interpretation and display capabilities that they will have if they use Clarke’s software as their interpretational base. Note that the capabilities of some of these packages overlap to a greater or lesser extent.

1. **Graphical Well Analysis Package**: this package is used for screen-based curve fitting, though it has a hardcopy output facility. Pumped and monitoring wells can simultaneously be fitted to the appropriate curve. Model options not available in Clarke’s software include pumped bore storage and slug test curves.

2. **HJ-MATCH**: Inversion package for fully penetrated, leaking, confined aquifers. Multiple observation bores can be handled and directional transmissivities can be calculated.

3. **TS-MATCH**: this appears to be the equivalent of HJ-MATCH for nonleaky confined aquifers.

4. **WHIP**: a very powerful automatic aquifer parameter estimation package, with screen graphics and hardcopy output facilities: pumped bore storage, partial penetration and multiple wells are all handled.

5. **AQUIX**: forward and inverse modelling for confined and unconfined, leaky aquifers; partial penetration and gravity drainage (Neuman’s model) are included: screen graphics and hardcopy output (not printers) are included.

6. **AQUA-VU**: parameter estimation through mathematical inversion for four aquifer model types. Screen graphics and hardcopy facilities are unknown.

It should be noted, however, that AQTESOLV appears to include most of the features found in the above programs. It is disappointing that provision is not made in it for variable discharge rate or pumped-bore storage, but its graphical curve-matching and weighted least squares capabilities are quite impressive.
Table 1: Aquifer types, program options, necessary aquifer parameters, and arrangement of the input data

<table>
<thead>
<tr>
<th>Aquifer type</th>
<th>Option</th>
<th>Time</th>
<th>Necessary parameters</th>
<th>Arrangement of input data</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 confined aquifer</td>
<td>no</td>
<td>var</td>
<td>T S</td>
<td>h t r</td>
</tr>
<tr>
<td>1 confined aquifer</td>
<td>yes</td>
<td>var</td>
<td>T S</td>
<td>h t x y</td>
</tr>
<tr>
<td>2 semiconfined aquifer</td>
<td>no</td>
<td>var</td>
<td>T C</td>
<td>h r</td>
</tr>
<tr>
<td>2 semiconfined aquifer</td>
<td>yes</td>
<td>var</td>
<td>T C</td>
<td>h x y</td>
</tr>
<tr>
<td>3 semiconfined aquifer</td>
<td>no</td>
<td>con</td>
<td>T C</td>
<td>h t x y</td>
</tr>
<tr>
<td>3 semiconfined aquifer</td>
<td>yes</td>
<td>con</td>
<td>T C</td>
<td>h t x y</td>
</tr>
<tr>
<td>4 partially penetrating wells</td>
<td>no</td>
<td>con</td>
<td>T C</td>
<td>h t x y</td>
</tr>
<tr>
<td>4 partially penetrating wells</td>
<td>yes</td>
<td>con</td>
<td>T C</td>
<td>h t x y</td>
</tr>
</tbody>
</table>

Remarks:
- a. Pumping tests with single well, Cartesian coordinates may be used.
- b. Input data: h - groundwater level in observation well
c. Parameter: T - transmissivity
- c. - storage coefficient
- r - hydraulic resistance (C-D'/k'); D' - thickness of the semiconfined layer

HYDROPAR Specifications
APPENDIX B

EQUIPMENT SPECIFICATIONS
ENVIRONMENTAL DATA SYSTEM
MODELS 3000/3500

APPLICATIONS:
- Stream flow / rainfall / water quality monitoring
- Sewerage / drainage depth and velocity logging
- Flood / pollution warning systems
- Pump performance monitoring
- Groundwater resource measurement
- Groundwater aquifer recharge pump testing
- Environmental Impact Studies
- Industrial monitoring
- Tidal studies

FEATURES:
- Compact, low powered system, submersible enclosure for long term, remote operation
- Accurate analogue interfacing - accuracy to 1:20000
- Flexible data retrieval concept
  - field computer download
  - removable memory module
  - remote interrogation
- Design based on long experience, latest electronic technology with large non-volatile memory
- Simple menu driven operation including field calibration

MINDATA PTY. LTD.

SENSORS AND DATA SYSTEMS FOR MONITORING THE ENVIRONMENT
ENVIRONMENTAL DATA SYSTEMS
SERIES 3000

SPECIFICATIONS

THE SYSTEM:

INPUT OPTIONS:

Model 3000 is fitted with:
- 2 X Analogue inputs
- 1 X Switch input

Model 3500 is fitted with:
- 4 X Analogue inputs
- 1 X Switch input
- 1 X encoder input (H.S AD375)

FIELD COMMUNICATION SOFTWARE:
The "DATREX" field communication software package is a basic system suitable for operators who require a flexible, easy to use data logging system. The "DATREX" field communication software package is an application specific terminal system with the facility to log user specified variables and messages into the data file on command. It is usually modified to meet the specific requirements of large volume clients.

SENSOR OPTIONS:

- Water Level: Pressure sensor, rotary encoder, capacitance sensor
- Water Quality: Electrical conductivity, turbidity, temperature, Dissolved Oxygen, Redox, pH, etc.
- Switch Inputs: Rainfall, pump on/off, intrusion alarm, limit alarm
- Water Velocity: Doppler flow sensor

DATA RETRIEVAL OPTIONS:

(i) - Removable Memory Module. The memory module is exchanged with a blank one at a field service visit, and the used module returned to a host computer system for downloading and processing.

(ii) - Field Download to Computer Disc. Data is retrieved in the field to your portable computer's disc for return to the host computer.

(iii) - Telemetry. Using the optional telephone modem, data is retrieved over the Telecom switched network direct to the host computer. (Realtime information is available using either synthesized voice or direct computer access.) Satellite or Radio links are optional.

ELECTRICAL:

- Processor: 8086
- Operating Temperature: -10°C to +60°C
- Clock: Crystal regulated, Real Time ± 1 sec / month
- Memory Type: Flash EPROM or EEPROM
- Memory Capacity: Non-Volatile 10 year data retention
- Log Interval: 2 second to 24 hours, software selectable
- Analogue Accuracy: 12,000 (approx. 14 bit)
- Digital: Switch closure, Incremental encoder
- Communication: RS232 1200 / 9600 baud 8 data bits, 1 stop bit, parity ignore

MINDATA PTY. LTD.
Unit 2, 10 - 12 Peninsula Boulevard
Seaford Victoria 3196
AUSTRALIA
Telephone: (03) 785 3777
International: +61 3 785 3777
Facsimile: +61 3 785 3774

Your Nearest Distributor

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Silicon Strain Gauge Pressure Transmitters

1200 Series

Description

The MDL 1200 consists of a high performance sensor and integrated signal conditioning circuit engineered to meet the performance requirements of water management projects.

- Dams & Reservoirs
- Rivers & Streams
- Weirs & Flumes
- Boreholes
- Bore Water pressures
- Pipe & Tank pressures

Features

- Fully encapsulated electronics and moulded cable gland
- Integrated data logger option
- Standard 4-20mA output
- Each sensor individually calibrated
- Local support
- Optional threaded adaptors
Signal Conditioning Unit

Description
The MDL 12DO sensing element consists of piezoresistive strain gauges electronically diffused onto a single homogenous silicon wafer.

The piezo-resistors form a full Wheatstone bridge whose output is proportional to the pressure applied to the diaphragm. The sensing element is mounted onto a header in which glass isolated feed through wires monitor the changes in voltage. Gold leads connect the piezo-resistors to the feed through wires.

Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>A minimum of 12V DC must be present at the transmitter.</td>
</tr>
<tr>
<td>Output Current</td>
<td>4-20mA independent of supply voltage variations or cable lengths.</td>
</tr>
<tr>
<td>Pressure Ranges</td>
<td></td>
</tr>
<tr>
<td>(Metres of Water)</td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>Over pressure without shearing calibration</td>
</tr>
<tr>
<td>1.0 metres</td>
<td>25 metres</td>
</tr>
<tr>
<td>2.0 metres</td>
<td>25 metres</td>
</tr>
<tr>
<td>3.0 metres</td>
<td>25 metres</td>
</tr>
<tr>
<td>10 metres</td>
<td>30 metres</td>
</tr>
<tr>
<td>20 metres</td>
<td>40 metres</td>
</tr>
<tr>
<td>50 metres</td>
<td>70 metres</td>
</tr>
<tr>
<td>100 metres</td>
<td>150 metres</td>
</tr>
<tr>
<td>200 metres</td>
<td>300 metres</td>
</tr>
<tr>
<td>500 metres</td>
<td>760 metres</td>
</tr>
<tr>
<td>Higher range</td>
<td>available to 10,000 KPa</td>
</tr>
<tr>
<td>Linearity</td>
<td>± 0.1% FS</td>
</tr>
<tr>
<td>Please nominate</td>
<td>±0.2% FS</td>
</tr>
<tr>
<td>Repeatability</td>
<td>Less than ± 0.1% FS for all ranges</td>
</tr>
<tr>
<td>Operating Temp Range</td>
<td>20°C to 80°C</td>
</tr>
<tr>
<td>Resolution</td>
<td>Infinite over full range</td>
</tr>
<tr>
<td>Resonant Frequency</td>
<td>&lt; 30KHz</td>
</tr>
<tr>
<td>Shock Resistance</td>
<td>1000g</td>
</tr>
<tr>
<td>Combined Thermal Shift and coefficient of sensitivity</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>Error °C</td>
</tr>
<tr>
<td>1.0 meter water</td>
<td>less than 0.003%</td>
</tr>
<tr>
<td>2.0 meter water</td>
<td>less than 0.003%</td>
</tr>
<tr>
<td>5.0 meter water</td>
<td>less than 0.015%</td>
</tr>
<tr>
<td>10 meter water</td>
<td>less than 0.005%</td>
</tr>
<tr>
<td>20 meter water</td>
<td>less than 0.003%</td>
</tr>
<tr>
<td>50 meter water</td>
<td>less than 0.006%</td>
</tr>
<tr>
<td>100 meter water</td>
<td>less than 0.005%</td>
</tr>
<tr>
<td>Weight</td>
<td>150 gms</td>
</tr>
<tr>
<td>Dimensions</td>
<td>170mm x 21mm OD</td>
</tr>
<tr>
<td>Cable Options</td>
<td>2 wire polyethylene sheathed with earth shield and PVC jacket</td>
</tr>
<tr>
<td></td>
<td>4 wire available for use with temperature probe</td>
</tr>
<tr>
<td></td>
<td>Optional louvered strain relief Integral-vented cable</td>
</tr>
<tr>
<td>Options</td>
<td>Semiconductor temperature sensor</td>
</tr>
</tbody>
</table>

Model 1220 option Single Channel Data Logger

The MDL 1220 is an integrated pressure transmitter and programmable data logger. The combination is ready to use and contains all resident software. Any laptop computer or PC can be used to set the logging rate and read the data. The non-volatile memory collects 20,000 values and all data is stored in engineering units e.g. "mm" or "KPa". The logger and transmitter can be supplied as a single (submersible) package or as separate units. Interrogation is via a waterproof RS232 cable with lengths up to 100m. Batteries can be either internal, with a life of 3 months or external. A network option allows multiple units to be connected via inexpensive 4 wire cable.

Logger Specs - Model 1220

Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programming Commands</td>
<td></td>
</tr>
<tr>
<td>Set Time</td>
<td>Date Hr Min Sec</td>
</tr>
<tr>
<td>Set Logging Rate</td>
<td>Days Hr Min</td>
</tr>
<tr>
<td>Read Current Value</td>
<td>Displays reading in mm</td>
</tr>
<tr>
<td>Clear Memory</td>
<td>Digits stores values</td>
</tr>
<tr>
<td>Dump Data</td>
<td>Transfers memory contents to RS232 port</td>
</tr>
<tr>
<td>Hardware</td>
<td></td>
</tr>
<tr>
<td>Inputs</td>
<td>Strain gauge from pressure transducer. Optional 2 channel &amp; 4 channel logger</td>
</tr>
<tr>
<td>Output</td>
<td>1 channel for switch contacts at programmed setting</td>
</tr>
<tr>
<td>Resolution</td>
<td>10 BIT (0.1%) or 12 BIT (0.025%).</td>
</tr>
<tr>
<td>Microprocessor</td>
<td>HD 6031 CMOS</td>
</tr>
<tr>
<td>ROM</td>
<td>32K CMOS standard unit delivered with data acquisition software stored in ROM.</td>
</tr>
<tr>
<td>RAM</td>
<td>32K CMOS non volatile</td>
</tr>
<tr>
<td>RS232</td>
<td>Baud Rates 300 1200 4800 9600 Xon Xoff protocols supported.</td>
</tr>
<tr>
<td>Network</td>
<td>X 3.28 Protocol Supported,</td>
</tr>
<tr>
<td>Communications</td>
<td>RS232 - RS485 Supported.</td>
</tr>
<tr>
<td>Data Storage</td>
<td>20,000 values stored with date and time stamp.</td>
</tr>
<tr>
<td>Real Time Clock</td>
<td>Year Month Day Hr Min Sec. Also leap years are taken into account.</td>
</tr>
<tr>
<td></td>
<td>Accuracy ± 1 sec per month.</td>
</tr>
<tr>
<td>External Internal</td>
<td>9-12 Volt either Nicad or Alkaline. Uts approximately 6 months.</td>
</tr>
</tbody>
</table>

Mindata Pty. Ltd.
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Telephone 785 5777
Facsimile 61 3 785 5777
Telefax AA30333 COMMCOM MINDATA

Viewed at 15:07:17 on 29/07/2010
## Pressure Sensor Data Sheet

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>120204</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>28 in H2O</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>7-30 V</td>
</tr>
<tr>
<td>Zero Output</td>
<td>4.00 mA</td>
</tr>
<tr>
<td>Full Scale Output</td>
<td>20.00 mA</td>
</tr>
<tr>
<td>Linearity</td>
<td>0.1%</td>
</tr>
<tr>
<td>Overpressure</td>
<td>60 in H2O</td>
</tr>
<tr>
<td>Electrical Connections</td>
<td>RED +VE</td>
</tr>
<tr>
<td></td>
<td>GREEN -VE</td>
</tr>
<tr>
<td></td>
<td>SHIELD EARTH</td>
</tr>
<tr>
<td>Cable Length</td>
<td>40 m</td>
</tr>
<tr>
<td>Pressure Connection</td>
<td>1/4&quot; BSP</td>
</tr>
</tbody>
</table>

Date: 29/5/91        Checked By: [Signature]

---

**Mindata Pty. Ltd**

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Seaford 3198 AUSTRALIA.
Tel: +61 3 782 3777
Fax: +61 3 782 3774
TX AA30333 - COMCOM
# Pressure Sensor Data Sheet

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>1281</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0-200 kPa</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>7-30V</td>
</tr>
<tr>
<td>Zero Output</td>
<td>3.981 mA</td>
</tr>
<tr>
<td>Full Scale Output</td>
<td>20.02 mA</td>
</tr>
<tr>
<td>Linearity</td>
<td>0.1%</td>
</tr>
<tr>
<td>Overpressure</td>
<td>600 kPa</td>
</tr>
<tr>
<td>Electrical Connections</td>
<td>Pin A +ve red, Pin B -ve green</td>
</tr>
<tr>
<td>Cable Length</td>
<td>150 M</td>
</tr>
<tr>
<td>Pressure Connection</td>
<td>1/4&quot; BSP</td>
</tr>
</tbody>
</table>

Date: 6/8/90  Checked By: P64

---

Mindata Pty. Ltd

Unit 2, 10 - 12 Peninsula Blvd.,
Seaford 3198 AUSTRALIA.
Tel +61 3 785 3777
Fax +61 3 785 3774
TX AA30333 - COMCOM
| **Pressure Sensor**  
| **Data Sheet**  

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>1266</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>0-100 kPa</td>
</tr>
<tr>
<td>Supply Voltage</td>
<td>7-30 V</td>
</tr>
<tr>
<td>Zero Output</td>
<td>At 17°C 3.945 mA</td>
</tr>
<tr>
<td>Full Scale Output</td>
<td>19.96 mA</td>
</tr>
<tr>
<td>Linearity</td>
<td>0.1%</td>
</tr>
<tr>
<td>Overpressure</td>
<td>300 kPa</td>
</tr>
</tbody>
</table>
| Electrical Connections | PIN A +VE WHITE  
|                   | PIN B -VE BLUE      |
|                   | PIN C EA SHEILD     |
| Cable Length     | 170 M               |
| Pressure Connection | 1/4" 1/8 BSP     |

Date 19/6/90 Checked By P6ff

Mindata Pty. Ltd

Unit 2, 10 - 12 Peninsula Bvd.,  
Seaford 3198 AUSTRALIA.  
Tel +61 3 785 3777  
Fax +61 3 785 3774  
TX AA30333 - COMCOM
Pressure Sensor Data Sheet

Serial No. 268
Range 0-30 kPa
Supply Voltage 7-30 V
Zero Output 1000 mbar - 12 mA
Full Scale Output 3000 mbar - 20 mA
Linearity 0.1%
Overpressure 90 kPa
Electrical Connections
   +VE WHITE
   -VE BLUE
Cable Length 50 M
Pressure Connection 1/4" BSP

Date 20/6/90 Checked By PGH

Mindata Pty. Ltd
Unit 2, 10-12 Peninsula Blvd.,
Seaford 3198 AUSTRALIA.
Tel +61 3 785 3777
Fax +61 3 785 3774
TX AA33333 - COMCOM
## Pressure Sensor Data Sheet

<table>
<thead>
<tr>
<th><strong>Serial No.</strong></th>
<th>120822</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range</strong></td>
<td>750 mBar - 1250 mBar</td>
</tr>
<tr>
<td><strong>Supply Voltage</strong></td>
<td>8-30 V</td>
</tr>
<tr>
<td><strong>Zero Output</strong></td>
<td>1000 mBar = 12.04 mA</td>
</tr>
<tr>
<td><strong>Full Scale Output</strong></td>
<td>1250 mBar = 20.03 mA</td>
</tr>
<tr>
<td><strong>Linearity</strong></td>
<td>0.1%</td>
</tr>
<tr>
<td><strong>Overpressure</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Electrical Connections</strong></td>
<td>WHITE +ve, BLUE -ve</td>
</tr>
<tr>
<td><strong>Cable Length</strong></td>
<td>SUPPLIED</td>
</tr>
<tr>
<td><strong>Pressure Connection</strong></td>
<td>1/4&quot; PIPE</td>
</tr>
</tbody>
</table>

**Date:** 3/3/91  
**Checked By:** [Signature]

---

**Mindata Pty. Ltd**  
Unit 2, 10 - 12 Peninsula Blvd,  
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Tel +61 3 783 3777  
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TX AA30333 - COMCOM
Kent Deltapi K Series
Electronic Transmitters

Model K-DC Transmitter
for differential pressure
spans: from 21 mbar to 72 bar (8.4 in H₂O - 1044 psid)
static pressure: up to 160 bar (2320 psig)

Specification sheet

- High accuracy with wide choice of measuring ranges
- Self-compensating for static pressure changes
- Compact, rugged, lightweight, easy to install and service
- Modular construction - high commonality of parts
- Non-interacting external zero & span and external damping adjustments
- Unique inductive sensing (patents issued or pending) with advanced electronics guarantees high stability and reliability
- Compatible with all 2-wire systems
- Complies with relevant IEC, NEMA and SAMA requirements for test procedures and environmental protection
- Meets NACE specification MR-01-75, 1984 revision
- Flameproof and Intrinsic Safety CENELEC approvals

<table>
<thead>
<tr>
<th>Sensor code</th>
<th>Measuring range limits (mbar)</th>
<th>Span limits (mbar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2000</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>3000</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>4000</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>5000</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>6000</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>7000</td>
<td>0</td>
</tr>
</tbody>
</table>

Conversion factors: 1 mbar = 19.2 mm H₂O = 0.1 kPa = 0.4015 in H₂O = 0.0145 psig

**FEATURES**

Model K-DC, the medium range differential pressure variant of the Kent Deltapi K series of electronic transmitters, provides accurate differential pressure, level, low gauge pressure, vacuum and specific gravity measurements in spans of up to 72 bar (1044 psid) at line pressures of up to 160 bar (2320 psig).

It incorporates a unique inductive sensing and measuring system that provides consistently reliable and stable performance under all types of process conditions, coupled with simple test and calibration procedures and minimum maintenance requirements. The Deltapi K transmitter comprises two main elements: a sensor and an electronics module.

The sensor converts the differential pressure of the process fluid (liquid, gas or vapour) into proportionate changes of two inductance values from which the electronics module produces a standard output signal. Seven versions of sensors are available to suit the measuring ranges or spans to be used. The electronics module, including all coarse and fine adjustments, process terminations, etc., comprising the top works, is contained within a waterproof housing mounted on the bottom works containing the sensor, process flanges, drain/vent valves, etc.

*Protected by one or more of the following Patents
Italy n. 23219-A/81 and n. 21983-A/83
Europe n. 71581
U.S.A. n. 4536695 and 4659679
Swed. n. 513994 and 534062
Japan Patents applied for
Input spans: from 21 mbar to 72 bar.
Span adjustment
- Internal coarse step (switch selector).
- External fine continuous.
Zero adjustment
- External fine continuous.
Suppression-elevation adjustments
- Internal coarse step (switch selector).
- External fine continuous.
Maximum zero suppression
94% of URL (Upper Range Limit) or 50% of min span.
Zero supp. + span = URL.
Maximum zero elevation
100% of URL or 600% of min span.
Damping
- Standard: 0.5 sec time constant (63%).
- Optional: externally adjustable from 0.2 to 2.5 sec time constant (63%).

**FUNCTIONAL SPECIFICATIONS**

Normal operating pressure limits
operates within specifications between 15 mbar abs (atmospheric pressure with Fomblin Y04 oil fill) and 160 bar (*).

Overrange limits
Equal to max operating pressure or 0 bar absolute on either side without damage to the transmitter.

Volume of process chamber
10 cm³ approx.

Volumetric displacement
< 0.1 cm³ for max span.
< 0.2 cm³ overranged.

Power supply
Transmitter operates on 12 to 42 Vdc with no load.

Load limitation: see figure on right.

**PERFORMANCE SPECIFICATIONS**

Unless otherwise stated performance specifications are given at reference operating conditions, static pressure equal to atmospheric pressure and zero based range for transmitter with isolating diaphragm in AISI 316 L or Hastelloy C 276 and silicone oil fill. Test procedures and operating influences are in accordance with relevant IEC and SAMA standards.

Unless otherwise stated, all errors are quoted as percentages of output signal span. Total effect is the maximum effect (zero shift and span change) at any point in the calibrated range.

**Accuracy rating**
For all spans by sensor type:

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Accuracy Rating (%)</th>
<th>Independent Linearity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 ± 0.1%</td>
<td>±0.20%</td>
<td>±0.10%</td>
</tr>
<tr>
<td>10 ± 0.1%</td>
<td>±0.10%</td>
<td>±0.20%</td>
</tr>
</tbody>
</table>

(*) includes combined effects of terminal based linearity, hysteresis and repeatability

**Operating influences**

**Ambient temperature**
Zero shift and span change for a 10 K change over the range - 25 to + 65 °C:

<table>
<thead>
<tr>
<th>Input span</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 ± 0.1%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>10 ± 0.1%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

**Static pressure**
On zero, max shift for 160 bar change:

<table>
<thead>
<tr>
<th>Input span</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>21 ± 0.1%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>10 ± 0.1%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

**Output signal**: 4 to 20 mA, 2-wire.

**Internal resistance of the optional output meter**:
- 3.6 Ω for 90° type
- 5.7 Ω for 240° type

**Vibration**
Total effect at 1 to 500 Hz and acceleration up to 20 m/s² (2g) in any axis:

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Total Effect (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>±0.05%</td>
</tr>
<tr>
<td>8</td>
<td>±0.10%</td>
</tr>
<tr>
<td>5</td>
<td>±0.15%</td>
</tr>
</tbody>
</table>

**Mounting position**
Rotations in plane of diaphragm have no effect. A tilt to 90° from vertical causes the following zero shifts which can be corrected with the zero adjustment:
Environments 

- Less than 0.1% with up to 500 MHz at 5 V/m field strength with instrument properly installed.
- DC magnetic field effect at 0% and 100% input up to 50 Gauss (5 Tesla)
  - On zero: less than 0.1%
  - On span: less than 0.1%
- Effect on calibration after a long term exposure at more than 1300 Gauss (130 mTesla): negligible.

Humidity and barometric pressure

No influence.

Output meter

Indication accuracy:
- ±1.5% fsd, 240° scale
- ±2% fsd, 90° scale

Stability factor

± 0.15% of full scale for six months.

Start-up drift at 10% and 90% input after 5 min., 1 h and 4 h; no influence.

Physical specifications

Calibration

- Standard: at maximum span, zero based range, 20 °C and atmospheric pressure.
- Optional: at specified range and ambient conditions; at operating conditions (line pressure and temperature)

Optional extras

1/2 NPT flange adapters.

Output meter: plug-in type.

Mounting

- Flat type: either for vertical 60 mm (2in) stand pipe or surface mounting
- Universal type: for vertical and horizontal 60 mm (2in) stand pipes, at surface mounting. Can also support model KB-2 valve manifold.

External damping adjustment

Cleaning procedure for oxygen service

Preparation for Hydrogen service

Calibration at specified range and operating conditions

Environmental protection

- Wet and dust-laden atmospheres
- The transmitter is dust and sand tight and protected against immersion effects as defined by IEC 144 (1963) to IP 67 (certificate of conformity GSI n. AD-5478-B6) or by NEMA 6.
- Suitable for tropical climate operation as defined in DIN 50 015.

Hazardous atmospheres

- Suitable for use in Zone 2 Areas.

We recommend the use of Explosion Proof or Flameproof type.

- Suitable for use in Zone 1 Areas.

- Suitable for use in Zone 0 Areas.

Compliance

- IP 67
- EEx ia 11C T6, certificate n. 87-85243

- EEx ia IIC T6, certificate n. 87-85243

Mounting position

Any, with sensing diaphragm vertical.

Electronics housing may be rotated to any position. A positive stop prevents over travel.

Net weight

5.8 kg approx (12.8 lbs) without options.

Packing

Expanded polystyrene box.

Instrument code list

See publication C.15.103

(1) Steel forging is always prescribed.
(2) Monel is 310 nickel based.
(3) Hastelloy is a Nickel based alloy.
(4) Teflon is a Teflon based polytetrafluoroethylene.
(5) Teflon is a Teflon based polytetrafluoroethylene.
(6) Teflon is a Teflon based polytetrafluoroethylene.
(7) Monel is a Nickel based alloy.
(8) Hastelloy is a Nickel based alloy.
(9) Teflon is a Teflon based polytetrafluoroethylene.
(10) Teflon is a Teflon based polytetrafluoroethylene.
MOUNTING DIMENSIONS
(not for construction unless certified)

Electrical connections

TYPICAL MOUNTING CONFIGURATIONS

On vertical 60 mm (2 in) pipe with K-KB three-valve manifold block; adaptable to surface mounting with four M16 x 40 bolts.

ELECTRICAL CONNECTIONS

The Company's policy is one of continuous product improvement and the right is reserved to modify the specifications contained herein without notice.

ABB

Kent Tieghi spa
Via Statale 113 22076 Lenna (Como) Italy
Tel: (0344) 58 111  Telefax: 39 044 KENTIL & Faccsimile (0344) 96278
### SECTION 10. SERIES 3000/3500 DATA LOGGER SPECIFICATIONS

#### ELECTRICAL:
- **Processor:** 80C652
- **Operating Temperature:** -10°C to +60°C
- **Clock:** Type Crystal regulated, Real Time. Accuracy ± 10 seconds per month.
- **Memory:** Type EPROM or EEPROM. Capacity (Non-volatile 10 year data retention)
- **Log interval:** 1 second to 24 hours.
- **Inputs Configuration:**
  - Model 3000: 2 X Analogue, 1 X Switch Closure
  - Model 3500: 4 X Analogue, 1 X Switch Closure, 1 X Rotary Encoder (Model AD375)
- **Input Specification:** Analogue Accuracy & Resolution 1:20,000 (approx 14.5 bit) Nominal 12VDC switch power supplied to sensors switch on 1 second standard, total 500mA all inputs.
  - Switch closure Normally open.
  - Encoder 1mm increments, maximum rate 10 metres / minute
- **Communication:** RS232 1200 / 9600 Baud
  - 8 data bits, 1 stop bit, parity ignore.
- **Power:**
  - 2 X internal sealed lead acid batteries, 12V 2.2A, each.
  - Average recharge or exchange requirement - 4 months.

#### MECHANICAL:
- **Enclosure:** Material Tough impact resistant ABS Protection IP67, submersible.
- **Connectors:** Material Plated brass, gold plated contacts. Protection Submersible rated to 30 metres water.
- **Mounting:** Shelf or wall mount using screws through base outside of gasketed area.
- **Weight:**
  - 1250 gms excluding batteries
  - 2890 gms including batteries
- **Dimensions:** 230 X 140 X 95 mm
## SECTION 8 SAMPLE DATA FILE

<table>
<thead>
<tr>
<th>Data File</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SERIES 3500 Stream Site 123</td>
<td>Logger model &amp; Site name.</td>
</tr>
<tr>
<td>84/86/98 22:26:29</td>
<td>Start Date / Time</td>
</tr>
<tr>
<td>15/87/98 16:16:43</td>
<td>End of file or memory exchange Date / Time</td>
</tr>
<tr>
<td>00:15:00 L1 L2 R EN</td>
<td>Recording Period / Inputs 1, 2, &amp; 5 selected.</td>
</tr>
<tr>
<td>L 900604223000 05.006 10.234</td>
<td>level 1 / level 2</td>
</tr>
<tr>
<td>L 900604224500 05.006 10.234</td>
<td></td>
</tr>
<tr>
<td>L 900604230000 05.006 10.234</td>
<td></td>
</tr>
<tr>
<td>R 900604230733</td>
<td>Date and Time of Raingauge tip</td>
</tr>
<tr>
<td>L 900604231500 05.006 10.234</td>
<td></td>
</tr>
<tr>
<td>L 900604233000 05.006 10.234</td>
<td></td>
</tr>
<tr>
<td>L 900604234500 05.006 10.234</td>
<td></td>
</tr>
<tr>
<td>B 900605000000 12.45</td>
<td>Midnight battery voltage</td>
</tr>
<tr>
<td>L 900605000000 05.006 10.234</td>
<td></td>
</tr>
<tr>
<td>L 900605001500 05.006 10.234</td>
<td></td>
</tr>
<tr>
<td>L 900605003000 05.006 10.234</td>
<td></td>
</tr>
<tr>
<td>L 900605004500 05.006 10.234</td>
<td></td>
</tr>
<tr>
<td>FFFF</td>
<td>End of file</td>
</tr>
</tbody>
</table>
1. (Event Recorder)

The CHERRYVILLE Recorder operates with a standard tipping bucket rainfall transducer. It records the time of each tip and calculates the total rainfall.

To achieve the objectives of small size, low power consumption and low cost, Systems Design Services (S.A.) use a recently developed single chip CMOS Micro Computer. This microcomputer also means the recorder communicates in the same user friendly mode as the TORRENS Data Logger.

Features of the CHERRYVILLE Recorder include:

* 1 second recording resolution
* Battery operation for periods greater than six years.
* Long recording period - one year with 64k Data Storage Module with 10mm rain per day and 0.2mm bucket. 512KB EPROM modules are also available.
* Range of selectable scale factors e.g. 0.2, 0.5, 1.0 mm etc.
* Switch debounce to eliminate double counts
* Small size
* Low Cost (Single Channel Only)
* Sealed enclosure to IP55 or optionally to IP67
* Military Specified Environmental Connectors
* Uses same Field Test Unit as TORRENS Data Logger
* Data Storage Modules compatible with TORRENS Data Logger Reader and Data Edit Software
* Standard EPROM or Ram memory 32k or 64k (Removable Data Storage Module)
* Data Storage format directly supported by HYDSYS Hydrometric Archive Software System.
* A stand alone Solid State Recorder
The TORRENS Data Logger was developed to capture data intelligently for the detailed analysis of one of Australia's most valuable resources - Water. The Data Logger is also suitable for other field and laboratory measurements. The TORRENS Data Logger is Australian designed and manufactured. Features of this device include:

* Up to 24 Recording Channels.
* 4 Recording modes:
  - Event
  - Periodic
  - Significant Event
  - Regression Line.
* Up to 24 Input Transducers.
* Wide range of scale factors and offsets for transducer calibration - range +/- 99999.9999.
* 4 Programmable outputs for driving other equipment e.g. water samplers, pumps or control valves.
* Data Storage Modules may be EPROM or RAM.
* On board A/D converter enables data logger battery voltage to be accurately measured locally or remotely.
* Solar powered with battery back up.
* IP56 or Optional IP67 Environmental enclosure.
* Military Specified Environmental connectors as standard, other customer specified connectors available upon request.
* Menu driven prompts from data logger - no cryptic code to program and retrieve data.
* Data Storage format directly supported by HYDSYS software.
* The basic unit is an investment in productivity.
* Modem interface option permits:
  - Remote interrogation via Field Test Unit or computer
  - Voice synthesis reporting of rainfall, rainfall rate, water level, battery voltage and three user chosen transducers
  - Auto dial out on the following conditions:
    - (a) channel point logged to Data Storage Module
    - (b) channel data going outside a Hi-Lo range
  - 8 character password can be programmed for modem security access
  - Dial out times can be limited to certain hours
  - Control code commands for polling systems.
* 16 bit resolution four channel analog card option.
* Satellite interface option enables use of the ARGOS Satellite System.

Systems Design Services designed the TORRENS Data Logger to meet the current and future requirements of Water Resources measurement. We offer a complete system from Data Loggers, Transducers, Data Retrieval and Data Editing to final analysis stage.

The Data Logger already supports a wide range of transducers. If however your requirements demand a different transducer type, in most cases Systems Design Services can adapt their general interface to suit.
The logger setting up and interrogating software is designed to be used on a personal computer using MS-DOS, version 2.0 or later. This software is supplied on a 5.25 inch DSDD disk.

**SPECIFICATIONS.**

390 Housing, PVC tubular, 29.3mm diameter 300mm long. From serial number 11400 on the housing will be polyurethane. These units will use the Infra-Red coupled data port.

490 Housing, ABS instrument case with integral battery housing.

Batteries, 4 x AA size. *Extra heavy duty.*

Memory battery, LMn02. Life span is approximately 5 years. This will be severely reduced if the recorder is stored without the main batteries installed.

390 Memory size, 32k bytes ultra-low power.

490 Memory size, 64K bytes ultra low power.

Temperature, 0 to 50 degrees celsius.

Input Signal, 5 volt square wave. Period, Frequency and Event Counting measurements are supported by the loggers software.

Analog input, Analog input voltages are not applicable with this logger. All sensors that are manufactured by Wesdata are fitted with an in-built voltage to frequency converter, for use with the frequency measurement program.
SPECIFICATIONS.

PRESSURE SENSOR.

Pressure range: 982 0 to 20 Meters (0 to 200 kPa)
983 0 to 10 Meters (0 to 100 kPa)
984 0 to 5 Meters (0 to 50 kPa)
985 Absolute Sensor for Atmospheric Pressure.

Temperature range: -5 to 50 Degrees C. (Compensated to +/- 1% of full scale)

Linearity: 0.15% of full scale.

Resolution: +/- 0.05% of full scale

Atmospheric sensor resolution is +/- 0.05 milli Bars

TEMPERATURE SENSOR.

Temperature Range: 0 to 50 Degrees C.

Resolution: 0.02 Degrees C.

Accuracy: Dependent on calibration technique,
Generally better than 0.1 Degrees C.

Calibration of all Sensors Supplied by Wesdata is the responsibility of the end user. Sensors can be supplied with calibration data, for a nominal $10.00 charge. However, because all sensors are software calibrated to achieve the accuracy that the end user desires, it is recommended that regular routine calibration checks are carried out to ensure that the sensor is still performing correctly and that the gathered data is accurate.
C1  CALIBRATION

C1.1  Introduction
C1.2  Calibration methods
C1.3  Proposed calibration method

C2  STANDARD ACCURACY AND RESPONSE TEST

C2.1  Introduction
C2.2  Procedure
C2.3  Analysis
C2.3.1  Accuracy
C2.3.2  Over-range performance
C2.3.3  Responsiveness
C2.4  Logger recalibration
C2.5  Testing logger and transducer separately

C3  STANDARD DRAWDOWN TEST

C3.1  Aims
C3.2  Procedure
C3.3  Analysis
C3.4  Comments

C4  SHORT FIELD TEST

C4.1  Aims
C4.2  Procedure
C4.3  Analysis
C4.4  Comments
C1. CALIBRATION

C1.1 INTRODUCTION

Calibration is the process whereby the parameters necessary to convert the electric signals produced by the transducer to engineering units (appropriate to the physical quantity being measured) are calculated and entered to the logger.

Non-linearity, non-repeatability and hysteresis in the system response make it desirable to calibrate the system over a number of points throughout the transducer range. Thus the calibration is best combined with the Standard accuracy test, described below (Section C2).

Alternatively, a two point calibration can be done, and any corrections necessary can be calculated from a standard test done at a later date, or from comparison with check readings taken during field use.

The corrected calibration parameters can be entered to the logger in the case of many systems (including Torrens and Wesdata). Those systems (including Mindata) which do not allow manual calibration entry must have the corrections applied at the data editing stage.

The calibration parameters or corrections must be recorded in the equipment history file, and must be related to both the probe and logger.

The short field test described below (Section C4) can be used as an ongoing calibration check, while taking into account the difficulty of making precise measurements of the transducer depth and standing water level in the field.
C1.2 CALIBRATION METHODS

Method I: The system is calibrated as a whole, with the transducer attached to the logger.

I(a) Downhole calibration:
The transducer is moved through the water to a series of known depths, as described in Section C2.2 and so is exposed to normal operating water temperature and pressure conditions. See also Section C1.3.

I(b) Probe connected to pressure control instrument:
As per I(a), except that the transducer is not immersed, and is at room temperature. This method was not found to be as accurate as Method I(a) because of some difficulties experienced with the stability of the particular instrument used, and possibly because of calibration drift with temperature.

Method II: Electric signal generator connected to the logger

The signals appropriate to particular depths are obtained from the transducer specifications, and applied to the logger input circuit. (The manufacturers must be consulted about any precautions necessary.)

This method suffers from the disadvantage that it depends on the probe performing to specification, but may be the only practical method in the case of calibrating for quantities which are difficult to control (e.g. Wind speed).

Method III "Software" calibration

In some cases (including Torrens) the probe output specifications can be entered directly in the logger (e.g. 4 mA at 0 depth and 20 mA at 10m depth) and the logger software
calculates the calibration parameters.

The success of this method is dependant on both the logger and transducer performing to specification.
C1.3 PROPOSED CALIBRATION METHOD

The method I(a) above was found to be most accurate and is certainly the most direct - with all system components involved in conditions which are similar to those encountered in the field.

To allow for the variety of errors inherent in any system the calibration should be done at the same points and with the same set-up as for the standard test described in Section Section C2.1.

The calibration and testing of a system can be combined as follows:

(i) Perform a two point calibration as per manufacturer's instructions;
(ii) Perform the standard test (as per Section C2.2);
(iii) Calculate any necessary corrections to the calibration parameters obtained in (i), and enter the corrected data in the logger, or (if this is not possible) apply them at the data editing stage. (c.f. Sections C2.3 and C2.4). (The initial two point calibration is necessary to obtain data in the correct units, which makes error analysis easier.)

Experience with individual systems, combined with well maintained equipment history files will be required.
C2 STANDARD ACCURACY AND RESPONSE TEST

C2.1 INTRODUCTION

A standard test has been devised to assess and compare the accuracy and responsiveness of water level measuring equipment in controlled conditions.

The test is carried out in a well, with the transducer being moved through the water, and is done in three stages to find:

I accuracy within transducer range;
II accuracy outside transducer range;
III responsiveness of system to change in water level.

The over-range accuracy is recorded because the transducer may be over-ranged for short periods from which data may be important (e.g. in first few minutes of recovery after a pump test). The transducer can only be immersed to a depth inside its’ specified "overpressure" range (i.e. the depth to which it can be immersed without affecting its’ calibration or response).

Since it is possible that the calibration may be affected by going outside the specified linear range (even while remaining within the specified allowable overpressure), stage I must be completed before the transducer is over-ranged.

Readings are taken:

With the transducer exposed to normal operating water temperature and pressure conditions;
At a number of depths throughout the transducer range, to allow for non-linearity;
At the same depths at different times, to allow for non-repeatability, and after approaching those depths from both above and below, to allow for hysteresis.

More than one probe of the same range can be tested
simultaneously, with all transducers attached to the same measuring tape.
C2.2 PROCEDURE

2.2.1. The facilities and conditions in which the test is conducted must be such as to allow accurate probe placement.

Thus the test must be done in well where the water level can easily be seen and controlled (to minimise errors in manual readings), and which is preferably free of other equipment (to minimise problems and time loss in moving probe).

The test must be carried out by at least two people, one responsible for accurate transducer placement, and the other responsible for taking accurate time records.

2.2.2. Examine the equipment, checking that

(i) the transducers are ready to be immersed (e.g. Wesdata sensors must have vacuum grease on the "O" rings);

(ii) the batteries are fully charged;

(iii) the system is communicating properly with the computer;

(iv) the transducer venting system is adequate;

(v) the transducers have been immersed for long enough to have stabilised

2.2.3. Have a receiving file for the test data and results, including records of:

(i) Type, range, Serial No. of both the probe and logger being tested;

(ii) Purpose, Date and Operators;

(iii) Timed manual readings of the probe depth (best recorded on a standard Data Collection Sheet)

2.2.4. Select the depths at which the probe is to be tested.

Data is to be collected from two depth ranges - both within and outside the probe’s normal operating range.
(i) Within Range:

The selection of depths must include 0.5m to full range, in steps of at most 25% F.S., e.g. a 20m probe should be tested at 0.5, 5, 10, 15, 20m;

(ii) Outside Range:

Check the probe specifications to find the allowable "overpressure" - the depth to which the probe can be placed without affecting it's calibration. (Note that the probe will be less accurate outside its' calibration range and that water pressure is approximately 10 kPa per metre depth.)

Since it is possible that the calibration may be affected by going outside the specified linear range (even while remaining within the specified allowable overpressure) this stage of the test must include some readings from within the normal operating range. The selection of depths must include 0.5m, 50% F.S., and at least 2 depths outside F.S., probably 25% and 50% above F.S. (e.g. for a 20m transducer, use 0.5, 10, 25 and 30m).

If the logging system allows, the overrange performance can monitored while logging, and the transducer's maximum depth set when the errors have become unacceptable. (Note that the acceptable error for over-range operation will be much greater than that for normal operation, because the transducer will presumably only be over-ranged accidently and for short periods from which data may be important (e.g. in first few minutes of recovery after a pump test).

2.2.5. The downhole equipment must be set up as follows:

The transducer is attached to a measuring tape with the zero mark at the bottom of the transducer (electric insulation tape is adequate). The probe is moved through the water, and held at a particular depth only by the measuring tape.

It is desirable that the measuring tape be attached only
to the probe to ensure that it is hanging vertically. However, if there are other cables or tapes downhole, the probe cable may have to be joined to the measuring tape, in a way which allows free movement of the tape relative to the cable. One way of doing this is to attach rings to the cable at approximately 3m intervals and run the tape through them. If a few probes are being tested simultaneously, then all their cables must be taped together, and kept separate from the measuring tape. When setting transducers at any depth, the weight of the probe must be on the tape.

2.2.6. Synchronise watch and logger, check synchronisation.

2.2.7. Procedure for performing stages I and II (i.e. accuracy testing):

(Note that stage I must be completed before II is begun)

(i) Start logger - using a small logging interval (e.g. 5 secs);

(ii) Place probe at selected depth intervals, leaving at each depth for at least 1 minute. Record times of probe movement (time probe moved from previous depth and time it arrived at new depth), so two times are recorded for each depth, between which the probe was at that depth.

(iii) Repeat at same depths, with transducer moving up and down through the full range at least twice. Readings for both increasing and decreasing probe depths must also be recorded for the greatest and least depths selected. Move probe beyond end readings and back to get 2 readings (1 up, 1 down) at same depth. E.g., after having taken the 0.5m
readings (with the probe having reached that depth from below), move the probe up to 0.2m and then back to 0.5m, and take the readings for 0.5m (approaching from above).

(iii) The manual records should therefore include two times for each selected depth, for at least 4 runs for stage I, and at least 2 runs for stage II.

2.2.8. Procedure for performing stage III (i.e. responsiveness testing):

(i) Set the logging interval as small as possible, and recheck the time synchronisation of the watch and logger.

(ii) Move the probe up and down by at least 3m as quickly as possible. Stop the movement suddenly at a predetermined time. (The person controlling the probe should stop it moving when told to do so by the person taking the time records - timing accuracy to a second should be achieved). Keep the probe at the same depth for at least 2 minutes.

(iii) The stop times chosen must be related to the logging interval, in the case of systems with minimum logging intervals over 5 seconds. The movement to a particular depth should be repeated 3 times stopping one, three and five seconds before the logger takes a reading. E.g., if the minimum interval available is 10 seconds, and the system is logging on even minutes, the stop times must be HH:MM:09, HH:MM:27, HH:MM:55 etc.

(iv) Note that in stages I and II, times are recorded as depths are reached, whereas in stage III, the probe placement is performed to a time schedule.
(v) The responsiveness of the probe should be tested at at least 4 depths within the transducer’s range, and with the probe moving both up and down to those depths.

2.2.9. Download data.
Depending on the analysis method chosen, the file can either be processed for viewing and manipulation by 'DATMAN' or printed and attached to manually taken records.

C2.3 ANALYSIS

To determine the system’s Accuracy, Response Time and Over-range performance.

Accuracy :

A highly accurate, consistent and reliable measurement system is ideally required to provide check data from which the accuracy of the system under test can be determined. Until such a system is acquired, the manual depth measurement procedure outlined above is the best available and can provide an accuracy of 10mm.

For the purpose of this test, the "error" of a logged reading is the difference between the logged reading and the manual reading for that time. This means that the validity of the test is dependent on the accuracy of the manual readings. This in turn depends on the care taken in setting up the test, in taking and timing individual readings and in keeping readable records of dates, serial no.s and readings.

Maximum error alone is inadequate as an accuracy parameter - any system which depends on transduction of a physical quantity to an electric signal is prone to a variety of causes of error, which may not show up in any one short
test period, and the manual reading giving the maximum error may be suspect. The statistical nature of measurement accuracy is well established, and future work should attempt to describe the particular characteristics associated with this work.

If the errors found could be adequately described by a Normal distribution, then the Mean (M) and Standard Deviation (SD) could be used to compare results and to gain a measure of the accuracy of a particular system. While there is always a possibility that the maximum error taken during subsequent system use may exceed that found in the test, approximately 95% of subsequent readings are expected to be within \( M \pm 2\times SD \). For example, the mean and SD found in a test are 10mm and 16mm respectively, then 95% of that system's future data would be expected to be within -26 and +46mm. In reality, the distribution is expected to be "skewed" by individual operators.

The Mean error over all readings (within range) should be zero, if the calibration is as good as possible. Therefore the analysis is best done in two stages - firstly finding the calibration parameters which give a zero mean error, and minimum SD and then using the recalibrated data to find the system accuracy. The recalibration must be applied to the systems for all subsequent use (as per C2.4).

Note that even with the best possible calibration some system error is inherent, and that any particular later use of the system may not have a zero mean error. This is because the check readings available may not cover the full transducer operating range. The calibration for zero mean error from the standard test is, however, the best available over the full range, with use when the water level is both increasing and decreasing.

The following methods are based on systems which have a linear response to changing pressure - in future systems with non-linear calibration parameters may be available. In that
case, the basic procedure will remain the same, with some additional processing required to find the parameters of a best curve fit (to a True Depth v. Logged Depth plot) through the data obtained as described above and these parameters used for the recalibration.

(i) Finding the recalibration parameters:

The recalibration parameters are the slope (s) and offset (o) which can be used to convert the logged data (L) to the manually acquired data (M) (which is taken to be the "true" data), by the relationship:

\[ M = sL + o \]

s and o are the slope and offset of the "best straight line through the data obtained on a plot of the Manually recorded data against the Logged data.

Once s and o are known they can be used to calculate corrected calibration parameters to be entered in the logger or as factors to be applied to data subsequently collected by the system as in C2.4.

Method 1 - using 'DATMAN':

See also an example in Appendix D

(i) Use 'LOGIN' to create a file of the manually recorded depths and read the logged and manual data into the programme.

(ii) Examine the data at a large enough scale to see any anomalies (e.g. caused by an incorrectly recorded time). If there is doubt about any data point (i.e. if it is significantly different to the general pattern) the manual reading for that time should be discarded so that point is not included in the calculation of s and o. Alternatively a third data set may be created as the difference of the two data
sets and it can be viewed to find any points which appear anomalous.

(iii) Recalibrate the logged data by the manually recorded depths. Examine the M.v.L plot shown on the screen. The slope and offset values (s,o as above) should be close to 1 and 0 respectively (depending on the accuracy of the original calibration) and the r^2 value over 0.999. If the r^2 value is below 0.999, or if the plot shows any points off the best straight line, recheck for anomalous data.

(iv) Record the s,o values on the system history sheet.

(v) Calculate the errors of the recalibrated and the original logged data by subtracting the manually recorded depths from them. The effect of the recalibration can then be assessed. Write this error data to a file which can be read into a spreadsheet. Use the spreadsheet to calculate the mean and standard deviation of the errors, and find the maximum and average errors from the absolute values of the errors.

Method 2 - using a Symphony Worksheet programme:

(i) Using either "DATMAN" or the printout of the logged test data, find the logged readings for each of the times that the transducer first reached a particular depth.

Enter these readings and other information requested in the Symphony Spreadsheet "CHK-PRB", (which includes notes on its' use). Use the first recorded reading at each depth.

This spreadsheet will calculate the mean logged reading for each depth, and the average and maximum errors for the probe's specified range (in metres and % of full scale. The
spreadsheet also calculates the mean and standard deviation of the errors both inside and outside the transducer operating range (after running the macro called "error"). Some examples and printouts from the worksheet are contained in the "Probe check spreadsheet" folder.

Check some of the "error" calculations, and view a graph of error v. depth.

Print the sheet or write the basic accuracy results on a sheet to be kept with the manually collected test data. Record the accuracy parameters on the system history sheet.

The recalibration parameters "s" and "o" must be calculated separately. Perform a regression analysis, using the column of the Means of readings at each depth as the "X-range" and the corresponding column of "Actual Depths" as the "Y-range". Symphony provides the slope (s) as the "X-coefficient" and the offset (o) as the "Constant".

Note that this method allows only one logged reading for each probe placement to be used for the accuracy and recalibration calculations, as opposed to Method I, which includes the logged data for the times of each manual reading included.

C2.3.2 Over-range Accuracy:

(i) Over-range;

In general the probes will be operational, but less accurate, to some degree beyond their specified ranges.

Examine the Stage II data through , and note at what depth (and by how much) the logged readings begin to deviate by over (the greater of) 100 mm or 0.5 %FS from the manual readings. Include this depth and the system error at the maximum depth used in the test in the system history file.
Check that the system accuracy at the depths within range used during stage II has not deteriorated from that found at the same depths in stage I. If the accuracy performance has changed, the possibility that over-ranging the transducer has affected the calibration must be investigated, by repeating stage I for at least 1 complete transducer movement through the range in each direction, taking readings at each stage I depth. If the calibration change is confirmed, the system has failed to meet its’ overpressure specification. Separate testing of the logger and transducer should then be done (c.f. Section C2.5) to find which should be replaced. (The transducer is most likely to have suffered physical change during overpressure).

C2.3.3 Probe Response Time:

Using either "DATMAN" or a printout of the downloaded logger data, examine the stage III data.

Note how long the system took to achieve steady readings after each of the "stop" times recorded as in 8. above. Take the system response time as the maximum length of time taken for logged data to come within the greater of 5mm or 0.1% FS. While this response time should be less than 1 second, up to 3 seconds should be allowed because of the difficulty of timing the stop times to less than a second. Note that the accuracy of the system’s timing depends on the number of transducer inputs being processed, and the length of time needed to take a reading.

In the case of systems with relatively large minimum logging periods (e.g. 10 seconds for Wesdata), the settling time must be inferred from the differences found between cases where the stop times were varied relative to the logging time as per 8(iii) above. (eg. compare responses from cases where the stop time was 2 seconds before the first logged reading to those which were 5 seconds before the logged reading - noting how close the first logged reading was to subsequent readings. If, e.g., in the 2 second cases the
difference between logged readings was 20mm and in the 5 second case, was only 5mm then the loggers response time (to within 5mm) would be between 2 and 5 seconds.)

If the results are unacceptable, the test should be repeated at a minimum of 5 different depths, with the probe held at each depth for 3 minutes, after being moved by at least 3m, to confirm the problem.

After the problem is confirmed, the logger and transducer must be tested individually, as set out below (Section C2.5) - although in this case the problem would be expected to be due to the transducer rather than the logger.
C2.4 LOGGER RECALIBRATION PROCEDURE

C2.4.1 Loggers which can have recalibration parameters entered directly

Once the recalibration parameters $s$ and $o$ as in C2.3.1 above are known, the corrections necessary to the logger’s calibration parameters can be calculated and entered to the logger. In most cases, the loggers calibration is linear, and the parameters are a slope and offset. The slope and offset are those of a straight line through a plot of either Logger Raw Data $v$. Actual Depth or Actual Depth $v$. Logger Raw Data. (The logger "raw" data is basically the numbers produced by the logger’s Analogue-to-Digital circuit in response to the electric signal input from the transducer.)

Let $NS$ and $NO$ be the new slope and offset (to be entered in the logger) calculated using the recalibration parameters $s$ and $o$ (with sign as found above in C2.3) from the original logger slope and offset, $OS$ and $OO$ respectively.

In the case where the recalibration is being applied to Raw logger data, $OS = 1$, and $OO = 0$.

(i) Where logger calibration is related to a Raw $v$. Actual Depth plot, i.e. with the actual depths as the "X" axis (e.g. Torrens):

$$NS = s \times OS$$

$$NO = s \times OO + o$$

(ii) Where logger calibration is related to an Actual Depth $v$. Raw plot, i.e. with the actual depths as the "Y" axis (e.g. Wesdata):

$$NS = OS/s$$

$$NO = OO - (OS/s \times o)$$
C2.4.2 Loggers which cannot have recalibration parameters entered directly (e.g. Mindata)

Since the original calibration can only be changed through the calibration routine (allowing only a 2 point calibration) the logger can't have fine adjustments made to its' calibration.

Thus the \( s \) and \( o \) values must be used at the data editing stage, by

\[
RC = LD \cdot s + o
\]

where \( RC \) is the recalibrated data, \( LD \) is the logged data (using the original 2 point calibration) and \( s \) and \( o \) are as calculated (including sign) in Section C2.3.1 above.

This recalibration should be done before any further data manipulation, e.g. barometric correction or comparison to manual readings are done.
C2.5 TESTING LOGGER AND TRANSDUCER SEPARATELY

Once a system problem is identified, its' source must be identified, at least to the extent of whether the transducer or logger is at fault, before either or both are returned to the manufacturer. Only the relevant item need then be dispatched.

The manufacturer must be consulted before any testing of this nature is done, to ensure that any necessary precautions are taken and to obtain any necessary circuit diagrams.

The logger can be tested alone using the signal provided by an accurate and stable electric signal generator as an input instead of the transducer.

The appropriate signal can be calculated from the transducer specifications e.g. a 12 mA input signal replicates that provided by a 20m range 4-20mA transducer placed at a depth of 10m. A range of signals can be input to the logger and its' linearity, repeatability, response etc. can be checked. The entire standard test can be replicated in this way, if desired.

The probe can be tested alone using a milli-ammeter to read its' output. Even a relatively cheap milli-ammeter which can read to 0.01 mA is adequate to check most problems. (0.01 mA is equivalent to approximately 6mm for a 10m range 4-20 mA transducer.)

To replicate any part of the standard test, do the relevant transducer movements as above, and take timed records of the milliammeter readings. The milli-ammeter readings can then be used directly (instead of metres head) to assess the transducer, or can be converted to the desired units by linear interpolation from the transducer's specifications.
C3 STANDARD DRAWDOWN TEST

C3.1 AIMS

There may be some concern that the standard accuracy test results may not be replicated in a situation where the transducer is at a fixed depth and the water level is moving much more slowly than the probe movement speeds used in the standard accuracy test.

The system may be tested in a set-up as described above (i.e. in a well whose standing water level (SWL) is clearly visible), but with the water level varied by pumping.

The pump should be outside the well if possible, and could cause as little vibration in the well as possible.

C3.2 PROCEDURE

An accurate independent water level measurement is essential - a freely moving and responsive "Float and tape" system, or other highly specified and proven device can be used. Another manual SWL measuring is desirable as a check, or a proven electronic system may be placed downhole and its' readings used for comparison.

The system to be tested is set logging at a small logging period, and manual SWL readings taken at regular intervals. The system error is calculated from the differences between logged and manual (or check system’s) readings.

C3.3 ANALYSIS

The analysis can be carried out as per C2.3 above – i.e., find the mean and standard of the errors calculated as the differences between logged data and manually collected data.

Note that any recalibration required (as per C2.3 from a standard accuracy test) or any necessary barometric correction
must be done before calculating the errors.

C3.4 COMMENTS

Since the accuracy of the manual readings is much less certain than in the standard accuracy test, the results of this test should not be used for system calibration.

Experience with the chosen systems (including error comparison of logged data to reliable check measurements) will show whether a separate drawdown test is in fact necessary - in the absence of any extraneous factors (e.g. pumping effects), the accuracy obtained in the standard test should be repeated in field use.
C4 SHORT FIELD TEST

C4.1 AIMS

The short field test is designed to provide logged readings over the transducer’s range which may be later compared to timed manual readings. It can be used as a verification of precedent or subsequent logged data or to confirm the use of the equipment for the particular application.

The test data will appear in the same downloaded file as the logged data, and can be examined when the logged data is processed.

The results of the short test should be briefly summarised on the equipment history files.

The test should be done at various times during a system’s use, particularly, e.g., before and after a series of pump tests are done, and before and after a system is placed at a remote site, and preferably at a time when the Standing Water Level (SWL) is steady.

C4.2 PROCEDURE

The transducer must have a measuring tape (with clearly identified marks at 1 metre intervals) attached to the transducer (with the tape’s zero mark preferably at the bottom of the transducer).

Record the time by which the transducer had reached each of at least 4 depths from 0.5m to its full depth, both while raising and lowering it. The transducer should be held in position by hand, so that the tape reading can be clearly seen. The point used for the measurement (e.g. "top of casing") must be accurately related to the point from which SWL is measured. Ensure that the transducer is steady at each of the times and depths recorded.

Take manual Standing water levels both before and after the test.
C4.3 ANALYSIS

Compare the logged head data to the set depths at the manually recorded times, by finding the differences between them at each of the common times. The most convenient way to do this is to use as outlined in C2.3 above.

Approximately 95% of the differences should be within that found from the previously applied standard test of the system’s accuracy (C2).

If the differences are significantly high, find their mean and standard deviation.

If the standard deviation is close to that found in the standard test, and if on recalibration (of logged by manual data over the test period) the "s" parameter (as in C2.3) is found to be between 0.999 and 1, then the most probable cause of the discrepancies is that the transducer depth was incorrectly set. Check the SWL measurements from before and after the test period.

The short test results found after the logging period should also be examined, before any recalibration of the logged data to be processed is considered.

If there is serious doubt about the accuracy of any data to be used, the system should be returned for a full standard test.

If the "s" and "o" values found from a subsequent standard test confirm those from both the short field tests, the logged data to be processed should be recalibrated at the editing stage, and where possible the corrected calibration parameters entered in the logger.
C4.4 COMMENTS

In comparing a system’s performance in a short field test to a standard test, consideration must be given to the difficulty of obtaining accuracy in the field, and to the numbers and ranges of readings included.

Properly recorded experience with individual systems, and consultation between those responsible for collection and use of logged data may lead to updating the test procedures outlined here.
APPENDIX D

'DATMAN' EXAMPLE PROCEDURES
D1. CONVERTING LOGGED HEAD TO DRAWDOWN

D2. MAKING BAROMETRIC CORRECTIONS TO WATER LEVELS LOGGED WITH AN UN-VENTED PROBE

D3. CALIBRATING LOGGED DRAWDOWNS BY MANUAL READINGS

D4. EXAMPLE OF DATA SET CORRECTION AND RE-CALIBRATION
D1. CONVERTING LOGGED HEAD TO DRAWDOWN

Water level data which was logged in terms of "head" (i.e. the depth of water above the transducer) may need to be converted to drawdown (i.e. change in water level compared to that at some particular time).

If the head at the time \( T_0 \) is \( H_0 \), then the drawdown at any time compared to \( H_0 \) is:

\[
DD = H_0 - H
\]

(1)

i.e. the drawdown at any time is found by subtracting the head at that time from the head at time \( T_0 \). A fall in water level is therefore calculated as a positive drawdown.

"DATMAN" provides a facility to subtract a constant from a complete data set, which can be used if (1) above is rewritten as:

\[
DD = -(H - H_0) = (H_0) * -1
\]

Therefore the procedure to perform the conversion is to subtract \( H_0 \) from the entire data set, and then multiply the set by \(-1\).

See example 4.2 below.
D2. MAKING BAROMETRIC CORRECTIONS TO WATER LEVELS LOGGED
WITH AN UNVENTED PROBE

Any water level data logged using unvented transducers must be corrected for the changes which have occurred in the atmospheric pressure either since the transducer was calibrated or the transducer was at a set depth.

In some situations (e.g. the analysis of a pump test), only the data subsequent to a particular time (T0) needs to be corrected. In any case, a time T0 at which the head (H0) or drawdown (DD0) is known must be selected, and the changes in barometric pressure compared to the value at that time (B0), must be applied to the data to be analysed.

If the change in barometric pressure (B) at any time compared to its' value at a reference time (B0) is BC, then

\[ BC = B - B0 \]  

(2)

i.e. the change in barometric pressure at any time is the barometric pressure minus the barometric pressure at the reference time.

Since an increase in barometric pressure increases the head read by the transducer, the heads logged by the system must be decreased by that amount. If the barometrically corrected head data is BCH then :

\[ BCH = H - BC \]  

(3)

Conversely, since an increase in head is associated with a decrease in drawdown :

\[ BCDD = DD + BC \]  

(4)

where BCDD is the barometrically corrected drawdown, and BC the change in barometric pressure from that at the reference time T0.

The procedure for applying barometric corrections to a set of logged head data is :
(i) select a reference time $T_0$, at which both the actual head and barometric pressure are known;

(ii) convert the set of barometric pressure readings to one of changes in barometric pressure from that at $T_0$, by subtracting the value at $T_0$ from the entire set (as (2) above);

(iii) find the barometrically corrected head by subtracting the set of barometric pressure changes from the set of logged head readings. (The "Process" option can automatically interpolate values of the barometric pressure changes for those times at which there are head values)

The procedure for applying barometric corrections to a set of logged drawdown data is the same as outlined above, except that the set of barometric pressure changes must be added to the set of logged head readings.

See also example 4.1 below.
D3. CALIBRATING LOGGED DRAWDOWNS BY MANUAL READINGS

"DATMAN"'s "Calibrate" facility allows one set of data to be calibrated by another. The calibration parameters are the slope (s) and offset (o) of the best fit straight line through a plot of the set by which the calibration is done (the "true" set \{T\}) against the set to be calibrated \{C\}). I.e., the original values of \{C\} are multiplied by s and have o added to them, where s and o are from the best straight line through a \{T\} .v. \{C\} plot.

Note that where there is no value of \{C\} at a time for which there is a value of \{T\}, a value is automatically interpolated for \{C\}. This can lead to a meaningless result as a linear interpolation with respect to time is usually only accurate where the interval between readings is short. Therefore, some points may have to be deleted from the calibrating set \{T\}.

Before the calibration is completed, the \{T\} .v. \{C\} plot, and the s, o and r² values are shown on screen. At this stage the plot can be inspected and any points which lie significantly off the best straight line can be noted.

If there are only a few points significantly off the best straight line, the calibration can be aborted, and both data sets examined with a view to deleting those \{T\} values causing the anomalies.

If there are many anomalous points or if the r² value is lower than, for example, 0.980, serious consideration must be given to the validity of the calibration.
D4. EXAMPLE OF DATA SET CORRECTION AND RE-CALIBRATION

The following example is based on sample data contained on the diskette labelled "DATMAN Example". The files referred to below can be read into and manipulated as described here.

The data entered in the file "H-UNCORR.pro" is uncorrected head data, which can be corrected for barometric effects using the barometric pressures recorded in the file "Baro-p.pro". The resulting data can then be converted to drawdm.m and recalibrated using the check data from the file "Chek-r.pro".

D4.1 Barometric correction

Read the files named H-uncorr.pro and Baro-p.pro into as sets \{U\} and \{B\} respectively.

(i) Select a reference time (T0) - use the first time of \{U\}. Note the value of the barometric pressure at this time (B0 = .......)

(ii) Convert \{B\} to change in barometric pressure compared to that at T0 as in (2) above. Mark both ends of the set and press "-", then type xxxxxx and [enter]. Now, B0 = 0;

(iii) Create a new set \{C\} of barometrically corrected head (as in (3) above) by using \{U\} as the non-interpolated set and subtracting \{B\} from it. Highlight "Process", [enter], U, B, highlight "U-B", [enter], C, type "Baro Corrected Head", [enter]. Compare the values of \{U\} and \{C\} at various times - note that C0 = U0, and that the difference between the two sets varies between -22 and +18mm ; <=CHECK

(iv) Save \{C\} to disk by highlighting "Write", "Ascii",
"H-bcorr.pro", [enter].

Set \{C\} is now the head data which has been barometrically corrected. View \{C\} at an expanded scale, and compare it to \{U\}, the original uncorrected data set.

See the example in 4.4 below.

D4.2 Converting head to drawdown

(i) Use the data set \{C\} as above;

(ii) Select the same time as used above as T0. The drawdown is found as in (1) above. Note the value of \{C\} at time T0 (.....) and subtract it as in 4.1 from \{C\}. Multiply it by -1 (",", -1, [enter]). \{C\} is now drawdown (compared to the water level at T0).

(iii) View \{C\} at an expanded scale, and compare it to the original data set. Note that the effect of barometric correction is large in this case because of the relatively small change in water level (0.14m) over a period of 5 days.

D4.3 Recalibrating logged drawdown by check readings.

(i) Correct the logged head for barometric effects and convert it to drawdown (using the same reference time T0), as outlined above. Call the set \{C\}. Copy it as set \{R\}. (The recalibration will be done on \{R\}, and it can be compared to \{C\}.)

(ii) Read the check readings in as \{T\}.

(iii) Start the recalibration process by entering "L". Set \{R\} is to be calibrated by set \{T\}. Notice the anomalous point - which corresponds to the \{T\} value at 00:00 on 06/091. Abort the process ( [ESC] )
and view set \{T\}.

(iv) For convenience, assume that the \{T\} value of 1 is found to be false - delete it from the set \{DEL\} ;

(v) Restart the calibration - note the change to the \{T\} \cdot \{C\} plot ;

(vi) For convenience, assume that a Short Field Test confirms the recalibration now on screen - accept it, view set \{R\} (which is now of recalibrated data, with \(R_0 = \ldots\)) and compare it to \{C\}, the uncalibrated data.
D5.1 NOTES ON CALIBRATING LOGGED DRAWDOWNS BY MANUAL READINGS

"DATMAN" can perform a Linear recalibration of a data set by another ("true") set. This converts an original data set \( O \), to ReCalibrated data \( R \), using a "true" set \( T \).

\[
R = s'O + o
\]

where \( s \) is the slope and \( o \) the offset of the Best Straight Line through a \( T \, v. \, O \) graph.

This type of Data manipulation is valid only where there is:

- a wide range of \( T \) values compared that of the complete \( O \) set;

- an (almost) unique value of \( T \) for given \( O \) values.

This "re-calibration" is useless if e.g. Manual readings are only available for 10 to 10.2m DD, when the logged DD ranges from 0 to 12m (because any introduced error in the slope will be magnified by 12/0.2 (=60) in this example), or if at different times different Manual readings are recorded at the same logger reading.

"DATMAN" shows a \( \{T\} \, v. \, \{O\} \) graph and shows the slope, offset and correlation co-efficient calculated from a Best Straight Line through the points.

In general the unsuitability of the data to recalibration as regards uniqueness will be visible as scatter on the graph and a low value of "r squared" (which is often above 0.99).

Note that if \( \{T\} \) and \( \{O\} \) do not share the same times, currently (Dec '91) automatically interpolates values of \( \{O\} \) for \( \{T\} \) times, which can lead to errors - particularly if \( \{T\} \) either pre- or post-dates \( \{O\} \). If this happens, the meaningless data must be deleted from \( \{T\} \).
D5.2 LINEAR RE-CALIBRATION OF LOGGED VALUES BY MANUAL READINGS USING "DATMAN"

- Read in the Barometrically corrected (as above) Logged Drawdown (BCDD) (data set \{L\}) and the manual readings (entered through 'LOGIN') \{Z\}, ("Remove" any other sets);
  - Both should be zero at some time, \(t_0\);
  - If both sets are not close, Recalibration can be considered, with consideration of (A) and (B) in 2.1 above;

- Select the Manual readings which will be included in the "True" set by which the calibration will be done.

Do NOT use manual readings from times for which:

(i) there is no Logged data ("DATMAN"'s linear time interpolation of the logged data may be inappropriate);
(ii) the logged data appears suspect, or is changing rapidly;

DO use manuals which are from times where the logged drawdown is relatively steady;

DO use manuals which cover a significant range of the overall Drawdown (as in (A) above).

It is probably desirable to use numbers of points at any given 'steady' level according to their assumed reliability - it may be desirable to add some earlier zero values to the manuals - which can be done through 'LOGIN';

- Copy \{Z\} as \{T\} ("set to recal. BY");
- Delete the unsuitable points from \{T\}, which is now the "True" set;
- press L for calibrate;
- Calibrate \( L \) using \( T \);
- Check the graph of \( T \) v. \( L \) for scatter and correlation as per (B) above;
- If calibration looks acceptable, then accept it, otherwise try to see which points are causing the scatter and amend \( T \);

- \( L \) is now recalibrated data, and should have its Information Line (I.L.) updated ("recalibrated by NN readings);
- Go through original Manuals \( Z \), at expanded scales, to see how close it looks;

- Calculate the "errors" of Logged recalibrated data compared to the manual readings by subtracting set \( Z \) from set \( L \) (at common times - interpolate \( L \) onto \( Z \) times, this time deleting only times which are not common, and leaving any suspect data);
- Call the resulting set \( E \);
- WRITE \( E \) in "other" format with some convenient units and start time (e.g. minutes after an even hour);
- Call file "CAL-ERR.DAT";

- This file can now be read into a spreadsheet programme, for calculation of the error statistics and the reliability of the data can be estimated.

Notes:

(i) It is desirable to have Barometric pressure readings at the same times as the LDD which is to be corrected. At least hourly readings should be taken.

(ii) Choose a "start" time, \( t_0 \), (usually the last even minute for which the DD was 0), where the Logger readings are steady; Some Logged data will usually precede this \( t_0 \); Make sure to include a Manual reading of 0 in Manual file.

(iii) The LDD at any time is the initial head at the
start time (t0) less the Logged Head at that time:

\[ \text{i.e. } LDD = LH0 - LH \quad (1) \]

or \[ \text{LDD} = (LH - LH0) \times -1 \text{ (easier for "DATMAN"). (2)} \]

(iv) The change in Barometric Pressure at any time (BC)
is the current Barometric Pressure minus the
initial Barometric pressure (at the "start time"
\[ \text{i.e. } \ BC = BL - BLO \]

(v) When the change in Barometric pressure (BC) at a
given time is positive, the Logged Head (LH) at that
time will be higher by BC than that due to WL alone,
which means that the LDD will be too LOW by that
amount.

\[ \Rightarrow \ BCDD = LDD + BC \text{ and } BCLH = LH - BC \]

\[ LDD = LH0 - LH \quad (1) \]

\[ \text{i.e. } BCDD = (LH0 - LH) + BC \]

D5.3 "DATMAN" PROCEDURE FOR BAROMETRIC CORRECTION:

(i) To convert LH to LDD:
- Read in the logged data (DATA SET, READ, ENTER, ENTER, "filename", ENTER)
- Call it set "L" (\{L\});
- Enter suitable "Information line" ("I", enter, "Logged Data...");
- Decide suitable "start time", t0;
- Set the cursor at this start time (move ...) and expand
the horizontal and vertical scales (Expand H,5,E,V,5), and
check on that t0 is suitable - i.e. that the logged readings
are fairly steady at that time. If not, choose another t0,
and make sure to include that time in the manual reading file
(through LOGIN) as an extra time when the DD was 0
  - Take the value of \{L\} at t0 as LH0;
- Convert \{L\} to DD as per (2) above by:
- Marking both ends of the set;
- Subtracting LHO from the set ( - , "LHO", ENTER );
- Multiplying set by -1 ( * , "-1", ENTER );
- Enter new info. line ( I, "Logged DrawDowns RNXXXXX,
  DD made =0 at hh:mm:ss dd:mm..... )
- Set {L} is now same as LDD above

(ii) To apply the Barometric conversion :

- Read in the Barometric pressure data;
- call it set {B};
- find its’ value at t0 (same to t0 as above) i.e. B0
- Mark both ends of {B};
- Subtract B0 from set ( - , "B0", enter);
- Enter new info line ( I, "change in barometric pressure
  from value at t0..");
- {B} is now BC as above;

- Convert {L} to BCDD as per (4) by adding {B} to {L}
  (PROCESS, ENTER, 2 SETS, ENTER, L, ent, B,ent, L+B,
  ent,C, and make the information line "Logged DD corrected for
  Barometric Pressure Changes, RNXXXXX" )

  Note that if {L} and {B} are not at same times, currently (Dec ‘91) automatically interpolates values of {B}
  for {L} times, which can lead to errors - particularly if {L}
  either pre- or post- dates {B}. If this happens, the
  meaningless data must be deleted from {L}.

  The best way of spotting this is to take a "TIME SERIES"
  from {L} and "INTERPOLATE" {B} onto the time series. Call the
  set "T" and enter the info line "Barometric changes compared
  to t0, at LDD times";
  Go through {T} (get the cursor to {T} by PgUp and expand
  the scales - any problems will usually be apparent.

  If all {T} is OK, then add it to {B};
  If all {T} is not OK then :
- delete the problem points;
- Take a new time series from the current \{T\}
- Interpolate \{L\} onto that time series - \{L\} is now Logged DD at Times common to both original logged Head and Barometric Pressure.
- Add \{L\} and \{T\}.
- Result ( \{C\} ) is BCDD as above.
- Give \{C\} suitable Info line
- Save \{C\} as (e.g.) "LogDD-BC.pro", using WRITE,ent,Ascii,"name",ent.
D5.4 EXAMPLE OF DATA SET CORRECTION AND RE-CALIBRATION:

Use files:

"SYOB-MHF.PRO"   "DATMAN" file of logged Head from a pump test observation bore;
"SY-MAN00.PRO"   "DATMAN" file of Manual readings from a pump test observation bore;
"BARO-TYP.PRO"   "DATMAN" file of Barometric Pressure.

These files are from the "Syrimi" sub-directory of the Pump Test OB diskette. The Barometric data is used to correct the Logged data, and the corrected data is then to be recalibrated by the Manual data.

A complication in this example is that the original calibration of the logged data is very poor - the logger input used was calibrated for a different probe. Before the data can be recalibrated it must be corrected for Barometric changes (B) - however, this data is presumably calibrated properly - so (B) must be recalibrated to the "poor" calibration, before it can be applied to the logged data, and the corrected data then recalibrated to the Manual readings.

Read the 3 files above as sets (L), (Z) and (B), and press S (to rescale plot).

(i) Convert Logged Head to DD (as per (2) of 1.1 above)

- Select the initial Head reading before DD started (LH0) say 10.02, and subtract it from {L} (Mark both ends of set, - , ent, "10.02", ent);
- Multiply (*) result by -1;
- {L} is now Logged (uncorrected) DD (LDD above);
- S to rescale;
- Notice the large differences between the Logged and Manual readings.
(ii) Make the Barometric correction to LDD:

- First {B} must be recalibrated to the incorrect {L} calibration, for which a slope and offset are required. Assume that the Barometric changes (max. approx. 70mm in 6 hours) are relatively small and that the recalibration slope and offset for the Barometrically corrected data will be very close to those for the uncorrected data.
- Using the calibrate routine the slope (m) and offset (C) needed to calibrate {L} to the manuals {Z} can be found (see 2.1, 2.2 above).
- Assume that this "m" and "C" are reasonably close to those which would recalibrate {B} to {L} (i.e. assume that the Barometric data {B} is as accurate as the manuals {Z}).

- As per 2 above, the recalibration must be done using a "True" set ( {T} ), which includes only manual readings at times for which credible Logged data is available, and includes manual readings for a large part of the total DD range.

- Choose elements of {T} - for this example choose only 4:
  - When selecting {T} values it is necessary to go through the set at an expanded scale, so that irregularities can be seen;
  - Start at time t0, the last recorded zero manual reading before the start of Drawdown (9:30:00 here) (move, ent, "09:30:00", ent) - the logged value at this time is 0.001m.

- Look for next flat part of curve - move to 10:30. Expand Horizontal scale (H) by 10, and vertical (V) by 4
APPENDIX E

FILE NAMING PROCEDURE
The file naming convention proposed is necessary for efficient field data retrieval and systematic cataloguing. The success of such a system depends largely on the understanding and consistent application by all users.

Two stages of data file transfer are necessitated. These are

(i) logger downloading and
(ii) database entry

1. LOGGER DOWNLOADING

During this phase, files downloaded must be immediately given unique names to avoid later confusion. It is inevitable that a number of files will be similar in appearance and structure. The following convention for establishing unique names for files as they are downloaded and the systematic approach required is described below.

(a) Create Separate Directories for Each Bore Tested

The convention is based on the grouping of test data pertaining to a particular bore (eg. step, constant discharge and recovery) to be stored on the same directory.

The files containing the relevant data should be located in a directory whose name is based on that bore’s registered number. Additional information pertaining to the date of testing within the directory name will make it unique if more than one test is performed on the bore. That is, the number of the test (an ‘alpha’ number) and the year should be denoted.

For example, the directory name 12345a91 denotes that data pertains to bore RN 12345, and the first test performed on it in 1992. A subsequent test in 1991 would thus require a directory to be named 12345b91. Test data for a number of different bores may then be placed on the same diskette (in separate directories).
(b) Data File Naming

Within each 'test bore' directory, individual data files should be named in accordance with the particular type of test performed. All drawdown data from the pumped bore and observation bores, and the pumped bore discharge history are included. Logging of water levels should be maintained following cessation of pumping and therefore residual drawdown readings will be attached to either the step test or constant rate test data.

Any data file pertaining to pumped or observation bores will be differentiated by the registered number of that bore. A file extension system will be used to designate the data type. Examples of this system are shown below.

Periodic or logged measurement of other parameters such as pH, conductivity, temperature etc. may also be included in this directory. Comments and observations relevent to the bores' performance and test conditions (eg. water condition, weather, SWL, test anomalies, pump set, pump rate adjustment, equipment used, field crew involved etc.) should be created as a text file using a word processor or proforma sheet and transferred to diskette.

<table>
<thead>
<tr>
<th>Extension</th>
<th>Data Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>.crd</td>
<td>Constant Rate Test, Drawdown</td>
</tr>
<tr>
<td>.crp</td>
<td>Constant Rate Test, Pumping History</td>
</tr>
<tr>
<td>.std</td>
<td>Step Drawdown Test, Drawdown</td>
</tr>
<tr>
<td>.stp</td>
<td>Step Drawdown Test, Pumping History</td>
</tr>
<tr>
<td>.sld</td>
<td>Slug Test, Drawdown Rate</td>
</tr>
<tr>
<td>.crc</td>
<td>Conductivity during Constant Rate Test</td>
</tr>
<tr>
<td>.stc</td>
<td>Conductivity during Step Drawdown Test</td>
</tr>
<tr>
<td>.crt</td>
<td>Temperature during Constant Rate Test</td>
</tr>
<tr>
<td>.crH</td>
<td>pH during Constant Rate Test</td>
</tr>
<tr>
<td>.stH</td>
<td>pH during Step Drawdown Test</td>
</tr>
<tr>
<td>.txt</td>
<td>Text File (comments)</td>
</tr>
</tbody>
</table>

* Additional codes will be introduced as required
Examples

Examples of data files contained in the directory 12345a91 (ie. pumped bore RN 12345) include:

- **12345.crp** - Pumping history of RN 12345 during constant rate test
- **12345.crd** - Drawdown in RN 12345 during constant rate test
- **23456.crd** - Drawdown in Observation bore RN 23456 during constant rate test
- **12345.con** - Conductivity readings in RN 12345
- **12345.txt** - Comments and observations made during testing

(c) Naming and Labelling of the Diskette

To facilitate data recovery from diskette storage, adequate information should appear on the diskette label. This should include the bore number, test type and the date the test was performed. The appropriate directory name may then be derived from this information if access to data is required. This diskette should then constitute the basis for the raw data library and all diskettes 'write' protected. This system somewhat parallels the existing Technical note book system whereby test groupings (eg. step, constant rate and recovery) on individual bores are assigned separate books. Where test data has been input from technical note books, the book number should be indicated as well.

An example diskette label is shown below.

```
ATOWN (book No. 756)
12345 Step Test 9/11/91
12345 Const. Rate 10/11/91

APLACE (book No. 893)
78910 Step Test 16/11/91
78910 Const. Rate 17/11/91
```
This data will then be required to be transferred to the database.
E2. DATABASE ENTRY

Data retrieved as indicated in Section E1 above must undergo processing to produce a universally applicable format before transfer to the database. The processing will be undertaken using software packages such as that discussed in Section 5.

The database will be configured as a multi level directory system. The root directory will comprise directories named as Registered bore numbers. Processed data from diskette will be transferred to sub-directories given names based on the year and the month of testing. That is, all data from the diskette directory 12345a91 (tested in November, 1991) will be placed in a sub-directory 91Nov. Should there be more than one test in the month, the date of commencement of the test should be attached. For example, 91Nov9 will contain results of the test on 9/11/91, while 91Nov20 will contain the subsequent test.

Additional information should be added at the processing stage to facilitate both screen and hardcopy checking after this data is utilised. Particular details of the test may be included in the 'first line descriptor' and should be formatted as below.

(a) First Line Descriptor

The universal data format allows for a descriptive first line to be included. The following basic data (separated by commas) to be included in strict order are -

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumped Bore</td>
<td>Registered number of pumped bore</td>
</tr>
<tr>
<td>Test type</td>
<td>Constant rate, step test, etc.</td>
</tr>
<tr>
<td>Obs. Bore</td>
<td>Registered number of obs. bore (the pumped bore is an obs. bore)</td>
</tr>
<tr>
<td>Pumping Rate</td>
<td>Pumping rate or rates in L/s</td>
</tr>
<tr>
<td>S.W.L.</td>
<td>Standing Water Level in metres</td>
</tr>
</tbody>
</table>
**Av. Drawdown**  
Available drawdown in metres  
(omit for obs bore)

**Distance**  
Distance from pumped bore in metres  
(omit if pumped bore)

**Date**  
The date the test commenced

**Book Number**  
Technical note book number

Examples of first line descriptors are below.

**Pumped bore, constant rate test, data file**

<table>
<thead>
<tr>
<th>Pumped Bore</th>
<th>Pumping Rate</th>
<th>Available Drawdown</th>
<th>Book Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD, 12345, C, Q=15, 12345, SWL=53.23, A.DD=25.1, 10/11/91, 756</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Observation bore, constant rate test, data file**

<table>
<thead>
<tr>
<th>Pumped Bore</th>
<th>Pumping Rate</th>
<th>Available Drawdown</th>
<th>Book Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD, 12345, C, Q=15, 23456, SWL=52.25, d=10, 10/11/91, 756</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Pumped bore, step test, data file**

<table>
<thead>
<tr>
<th>Pumped Bore</th>
<th>Pumping Rates</th>
<th>Available Drawdown</th>
<th>Book Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>DD, 12345, S, Q=15, 16, 17, 12345, SWL=53.23, A.DD=25.1, 9/11/91, 1756</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Pumping history file, step test

<table>
<thead>
<tr>
<th>Pumped</th>
<th>Pumping Rates</th>
<th>Book Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH,12345,S,Q=15,16,17,12345,SWL=53.23,A.DD=25.1, 9/11/91, 756</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Step Obs. SWL Available Date
Type Test Bore Drawdown Tested

(b) Data Cataloguing

The database is proposed to be established under a bore registered number system. That is, all test data pertaining to that bore, regardless of when conducted, will be stored in a directory denoted by the bore registered number. Subdirectories will be established for the particular tests performed as indicated in Section B1 above. The naming system should be retained as the files are processed and located on the database. This format will represent the data collection accessed by users on a 'read only' basis. The entire process is graphically represented in the flow chart on Figure E.1.

This data will be primarily utilised by a number of interpretation packages. Working and interpretation files (eg. .sav) will be derived as a result and correct protocol (ie. a path is set) should be established to ensure these are saved on the users' personal working areas. For example, 12345.SAV relates to analysis on the pumped bore 12345. Once interpretation has been completed, this file should be stored in the users' private library for future reference.
**DISKETTE CONTENTS**

(directory level directory system)

- Root Directory
  - 12345.std
  - 12345.stp
  - 12345.crd
  - 23456.crd
  - 12345.crc
  - 12345.crt
  - .. etc...

- (Directories for other bore tests performed)

**COMMENTS and MISCELLANEOUS DETAILS**

- 12345.txt
  (Input using word processor or proforma sheet)

**UNIVERSAL DATA FORMAT**

(add descriptors to individual files)

- Pumped bore constant rate data file
- Observation bore constant rate data file
- Pumped bore step test data file
- Observation bore step test data file

**PROCESSING**

Manipulation and Correction

**DATABASE**

(directory level directory system)

**FIGURE E.1**

FILE NAMING SYSTEM