

THE WATER RESOURCES DIVISION WATER LEVEL RECORDER
RENTAL PROGRAM - HISTORY AND OPERATION

By Sharon R. Jeffers and C. Russell Wagner

Open-File Report 84-735

NSTL, Mississippi

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

Chief, Hydrologic Instrumentation Facility
U.S. Geological Survey, Building 2101
NSTL, MS 39529

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ABSTRACT

The U.S. Geological Survey introduced a new water level recorder in the early 1960's to automate computation of streamflow records. At the same time it also developed a rental program as a means of providing the recorders to field offices. This report documents the experience gained over the past 20 years and offers suggestions for operation of a rental program in the future, as preparations are made to introduce a third generation of water level recorders.

INTRODUCTION

This report documents the history and present status of the 20 year old Analog to Digital Recorder (ADR) rental program. It can serve as a basis for improving the present management of the program, and facilitate a transition into the next generation of field recorders, the Adaptable Hydrologic Data Acquisition System (AHDAS) program. Several alternatives have been considered by the Hydrologic Instrumentation Facility (HIF) management for an orderly transition between old and new instrument packages.

1. Cutting back on maintenance of existing ADRs in view of program closeout.
2. Reviewing present rental rate structure, and providing sound basis for rate adjustment.
3. Exploring ways of using ADR rental rate income as a method of partially funding AHDAS development and acquisition costs.

Information and advice has been obtained from a wide range of sources within the Water Resources Division (WRD) and the Administrative Division (AD) of the U.S. Geological Survey. Personnel of the Systems Analysis Group in Reston have assisted in analyzing economic aspects of the study. Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

ANALOG TO DIGITAL WATER LEVEL RECORDER PROGRAM

History and Background

The ADR is a water level sensor and data recorder that uses a battery operated, slow-speed, paper tape punch which records a four digit number on a 16-channel paper tape at preselected time intervals. The recorder is basically a device for coding and recording the angular position of a rotating input shaft, but it can be adapted to accept a voltage input, to record several variables in sequence, and to interface with wire or radio telemetry systems.

The U.S. Geological Survey adoption of the ADR as the primary instrument to record river stage at gaging stations was the result of a 10 year study, begun in 1952, to develop a method for automation of streamflow records.

In 1963 the Survey and its cooperating agencies operated approximately 7,200 streamflow stations. Initially 268 stations were equipped with ADRs as part of a pilot study to determine the feasibility of an automation program. A work group established in 1962 recommended that conversion to the automated streamflow records system begin in FY64 at the rate of 1,000 ADRs per year. (Geological Survey Circular 474).

It was recommended that WRD initially equip the Boston District, which covered the states of Massachusetts, New Hampshire, and which Vermont completely with ADRs, and distribute other recorders in blocks of about 50 each to selected districts. As more ADRs became available coverage was completed within these districts before attempting partial coverage nation-wide. Within a ten-year period, essentially all full-time gaging stations were equipped with ADRs. Approximately 13,500 ADRs are currently in use by WRD to support its basic mission, to provide the hydrologic information needed for managing the Nation's water resources.

In 1980 the Survey contracted with the MITRE Corporation to conduct a study on program planning for an improved automated data acquisition system. This study was undertaken, because it was well recognized that the ADR technology was rapidly becoming obsolete. Based in part on this study, as well as the stated needs and suggestions of WRD staff, a major instrument development project was initiated by the HIF's Instrument Development Laboratory (IDL).

The Adaptable Hydrologic Data Acquisition System (AHDAS) Project has as its principal goal the development of a recording system to replace the present ADR system with a system using state-of-the-art technology. AHDAS will use a microprocessor technology and solid-state data memory design. A system-level design activity, including a comprehensive study of WRD requirements and an assessment of available technologies was conducted.

An AHDAS prototype development contract was awarded to TeledyneGeotech in January 1984. In June of 1985 a 15 month field test program will begin, and depending upon availability of funds, conversion from the ADR-based automated streamflow record system to the AHDAS system will begin in 1986-87.

RENTAL PROGRAM CONCEPT

The initial plan for procurement and financing the ADR program was developed jointly by WRD and AD, when the conversion from strip chart to ADRs was implemented.

A three year procurement begun, in FY64 and funded by advanced commitment of funds, provided for the delivery of 1,000 ADRs per year in FY64, FY65, and FY66. Highlights of this acquisition program featured a rental program with prepayment options. ADRs were rented to district and project offices. A \$40 per year rental rate was based on an estimated 10 year payback period. Field offices were initially allowed to pre-pay annual rental charges. The rental system was effective July 1, 1963. Instrument maintenance costs were the responsibility of the renting office.

The procurement history of the ADR reflects the growth of the streamflow record automation program:

<u>Year acquired</u>	<u>Number acquired</u>	<u>Percent of total stock</u>
63 or before	489	3.4
64-66	3111	21.4
67-71	4552	31.3
72-74	1800	12.4
74-76	1615	11.1
77-78	2094	14.4
79-80	724	5.0
81	150	1.0- last procurement of ADRs

Some ADRs in service with the Survey were originally purchased by cooperators for the Survey's use and later included in the rental program. No complete data can be found for the total number of ADRs acquired, but it is estimated that approximately 16,000 ADRs have supported the streamflow record automation program.

In the late '60s, to counter the problems associated with repair and maintenance of ADRs, the AD's Property Maintenance Section assumed responsibility for repair of ADRs and the rental fees were used to pay for repair expenses as well as purchase of new ADRs, timers and other peripheral equipment. At that time approximately 7500 ADRs had been purchased.

Administration of the rental program was handled jointly by the AD and the WRD. Because the ADR was personally accountable property, the tracking of the accountable employee, procurement and distribution of ADRs, and assessment of rental fees were handled by the AD, while decisions regarding the technical operation of the program rested with the WRD.

With the establishment of the HIF in 1979, sole management of the ADR rental program was passed to the HIF.

The rental program concept has worked well, and HIF recommends strongly that it be used for the future generations of field recorders.

Timers

The timer was considered a part of the ADR, and was not treated as a separate rental or sold item. A major deficiency of the program was that timers were included in the rental rate, but were not accountable personal property. Tracking of the semi-expendable item was nearly impossible, and historical data is of poor quality.

From the inception of the ADR program, one major problem of its technical success was the timing device used to trigger the paper tape punch at preset intervals. After testing five different types of timers, the spring-driven Chelsea-brand timer was selected as the most reliable and the majority of ADRs were equipped with this device.

The IDL-developed solid state timer began to replace the electro-mechanical timer in 1977. This timer has proven to be far superior to all previous models. Contracts have been awarded to provide complete conversion to this type timing device by the end of FY84. The table below summarizes the quantities of solid-state timers that have been procured. Not included are a few hundred which were produced in-house during development of the timers, as well as some commercially available units purchased in 1979.

<u>Model of Timer</u>	<u>Contract No.</u>	<u>Date</u>	<u>Contract</u>	<u>Quantity</u>
I	-----	1977	R. L. Jaegly	100
I	-----	1978	R. L. Jaegly	70
II	16362	5/79	R .L. Jaegly	1,150
III	18926	3/80	Mid America	1,500
III	19017	2/81	Abrams Instr.	3,800
III	19029	5/81	Aleph, Inc.	1,500
III	20759	9/82	Aleph, Inc.	6,500
III	20795	6/83	Aleph, Inc.	<u>2,000</u>
			TOTAL	16,620

In FY83, 14 percent of the ADR program funds were allocated for solid-state timer purchases and 3 percent of the budget supported repair of these devices.

By the close of FY84 conversion to solid state timers will be nearly complete and expenditures for additional new units will not be necessary.

Historical records of the earlier Chelsea electro-mechanical timing devices show a Mean Time Between Failure (MTBF) of 5.8 years, while a limited sample of Model III timers outside of the infant period demonstrated a MTBF of about 40 years. The older Model II timer had a MTBF of 2.1 years. Timer acquisition and maintenance costs should be a relatively low percentage of program expenses after FY84.

Rental Rates

An annual rental rate of \$40 was used from 1963 to 1973. However, except for the last few years of this period, the rental charges did not include recorder repair costs. From 1979 to 1980, when HIF was being formed, the rate had increased to \$54 per year. The following table indicates rental rates since the establishment

of HIF. We have also shown a computation of the original \$40 per year adjusted for inflation, based on the 1972 dollar value.

<u>Year</u>	<u>Actual Rental Rate</u>	<u>Adjusted for inflation</u>
1979	\$54	\$65
1980	\$54	\$71
1981	\$66	\$78
1982	\$72	\$83
1983	\$84	\$86
1984	\$84	--

It is clear that rental rates did not keep pace with inflation during the late 1960's and early 1970's, which accounts for the program decline in this period. These data are not completely accurate as WRD, on several occasions, committed large blocks of funds to the AD to sustain the program.

PROGRAM MANAGEMENT

One of the first activities assumed by HIF was the establishment and management of a contract with the NSTL on-site technical contractor, Computer Science Corporation, to provide for the repair of ADRs. This repair activity had been the responsibility of the Property Maintenance Section of the AD in Reston, Virginia. At the same time, the distribution of ADRs was transferred from the Shipping Receiving Section, AD in Reston to the HIF's Field Service and Supply Section. The HIF's activity was supported by the computerized ordering and inventory system. (HIF/CSS). Responsibility for personal accountability of ADRs remained with the Property Control Section, AD, until these items were deleted from controlled personal property lists in 1981.

For the first time since the program's inception, management of the entire ADR program was located at one facility. Within the HIF, responsibility for the ADR program was divided as follows:

Distribution	-	Field Service and Supply Section
Repair (in-house and repair contract management)	-	Repair and Calibration Section
Financial Administration	-	Administrative Services Section
Acquisition	-	Technical Services Section

Total oversight of the program is the responsibility of the Chief, HIF, who chairs a committee with representatives of each of the involved sections. In FY84, a mid level engineering technician was assigned to manage the day-to-day details of operating this program.

In FY82, a commitment to develop a new generation of field recorders, coupled with major WRD budget cuts resulted in a turnaround in ADR program growth and caused a change in project management emphasis.

HIF management decisions shifted to maintenance of a program that was nearing the end of its useful life and for which there was a decreasing need because of reductions in the Survey's Data Collection Program. Program re-orientation included:

- o maintenance of an adequate contract repair staff with decreasing demand and income from rentals,
- o addressing long range planning for the program which had both an immediate demand reduction of unknown duration and a potential long-term program termination because of technological obsolescence, or
- o potential program increases occurring with insufficient lead-time to acquire new equipment of any configuration.

Attempts to forecast demand have been made; however, the inaccuracy of any forecast is evident based upon the conditions of field program instability and limited amount of accurate historical data.

The following tables reflect ADR usage expressed as change in demand determined from orders and termination for the period May 1982 to February 1984. This data may be biased by seasonal demand and by overlapping caused by startup and close down of gaging stations.

A modified plan for ADR maintenance and stocking was developed in 1983 in anticipation of the implementation of AHDAS. The program was aimed at minimizing the cost of maintaining ADRs so that money could be diverted to support the startup of AHDAS.

In the past, defective and worn out ADRs were rebuilt from the bottom up with new parts. In the modified plan, only defective parts were replaced, and badly damaged recorders were scrapped. Planned stock level of reconditioned ADRs was set at 500 units. An inventory of 500-1000 unserviced recorders will be maintained in bulk storage to meet unexpected program needs. All other recorders will be cannibalized for spare parts and disposed of in accordance with Federal Procurement Management Regulations.

The following table shows repair data for FY83:

Model	Average units or rental	Units returned to HIF	Per unit cost of repair
F-P basic	8,750	1,166	\$175
L&S basic	2,500	207	150
F-P telekit	1,000	249	245
L&S Mod. A	600	45	185
L&S I/O	400	161*	220

**ADR DEMAND TRENDS
FISCHER-PORTER ADR
MAY, 1982 TO FEB., 1984**

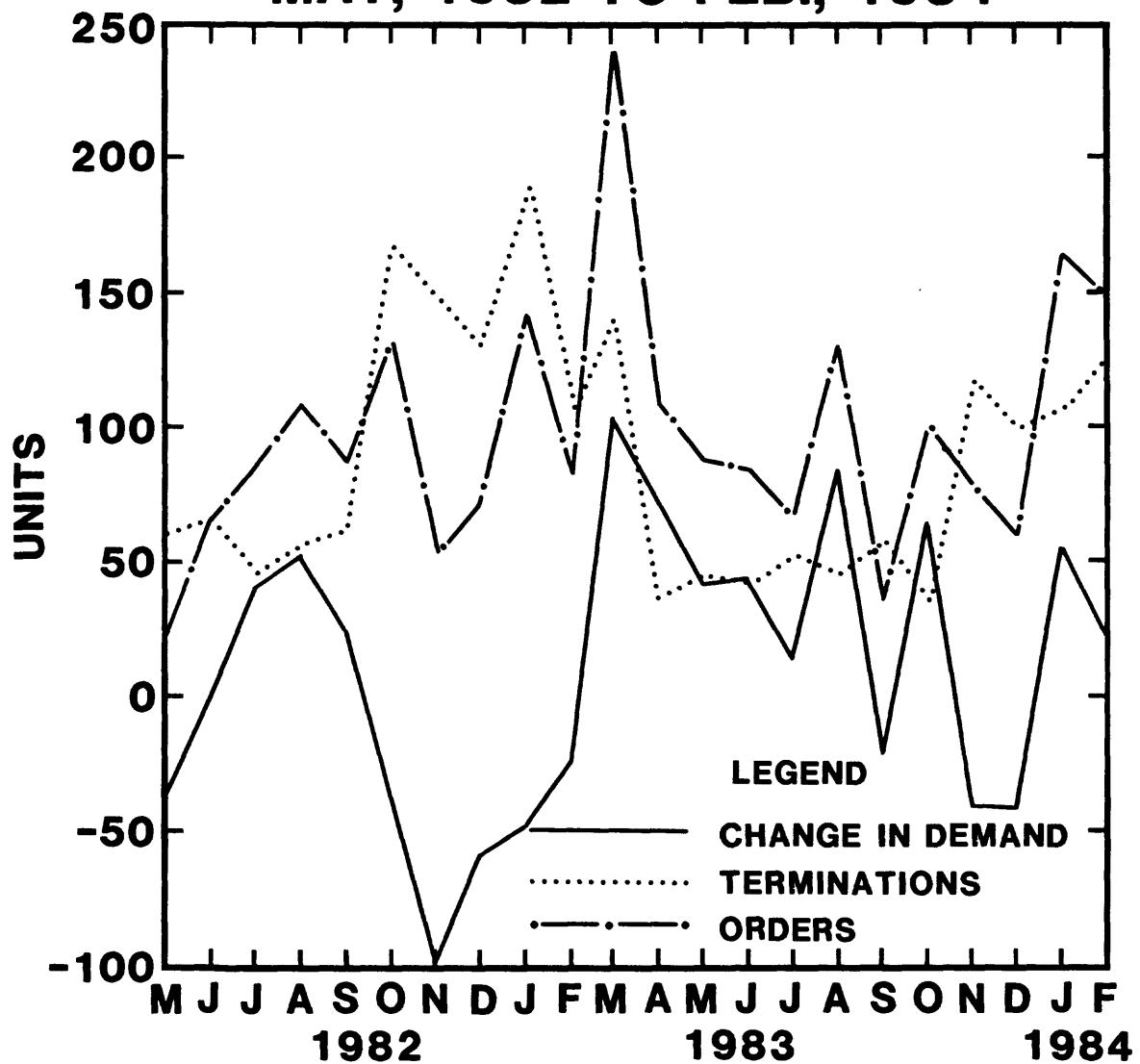


Figure 1.--ADR Demand trends Fisher-Porter May, 1982 to Feb., 1984.

**ADR DEMAND TRENDS
L&S ADR
MAY, 1982 TO FEB., 1984**

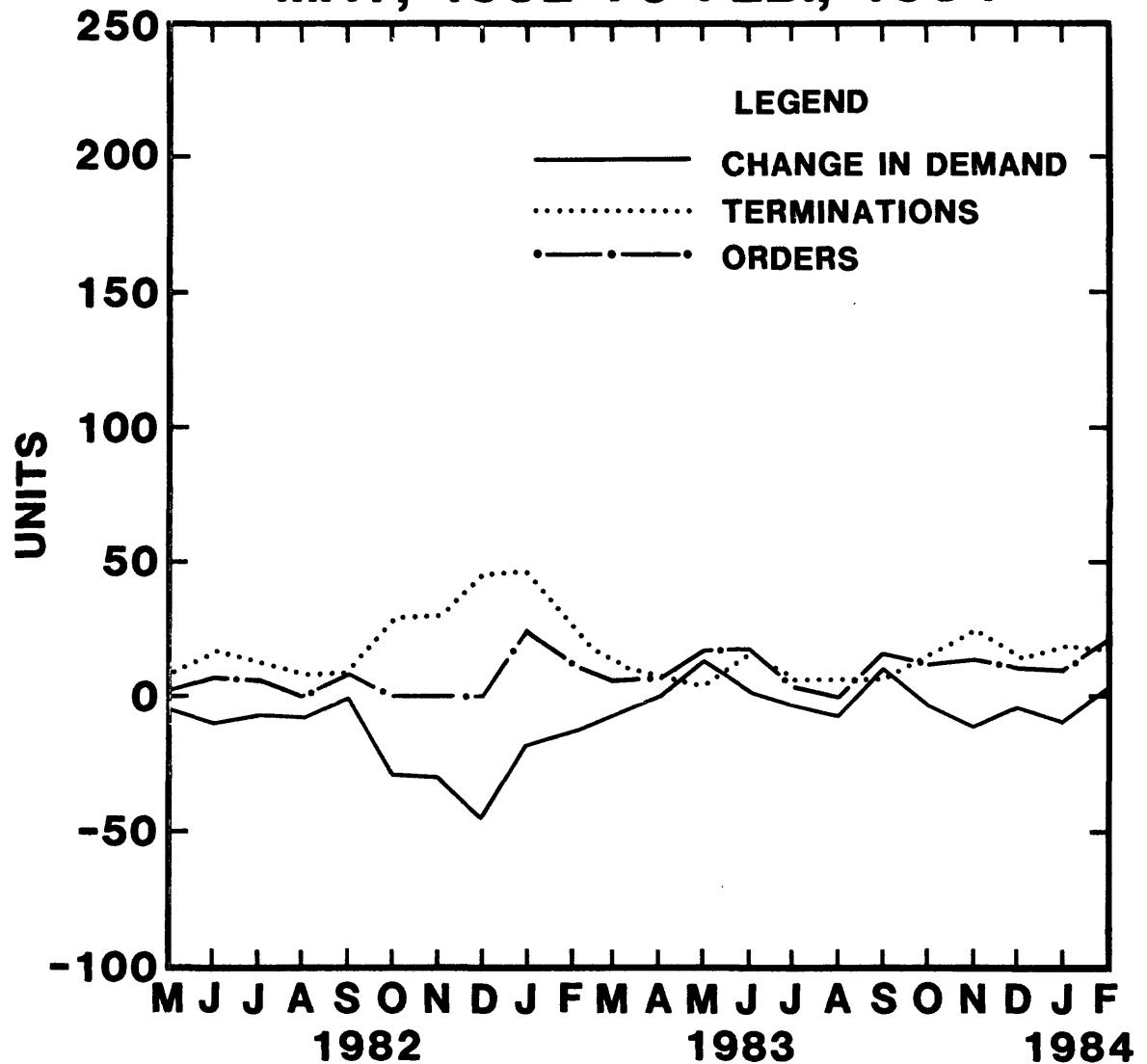


Figure 2.--ADR Demand trends, Leupold and Stevens,
May, 1982 to Feb., 1984.

**ADR DEMAND TRENDS
FISCHER-PORTER TELEKIT
MAY, 1982 TO FEB., 1984**

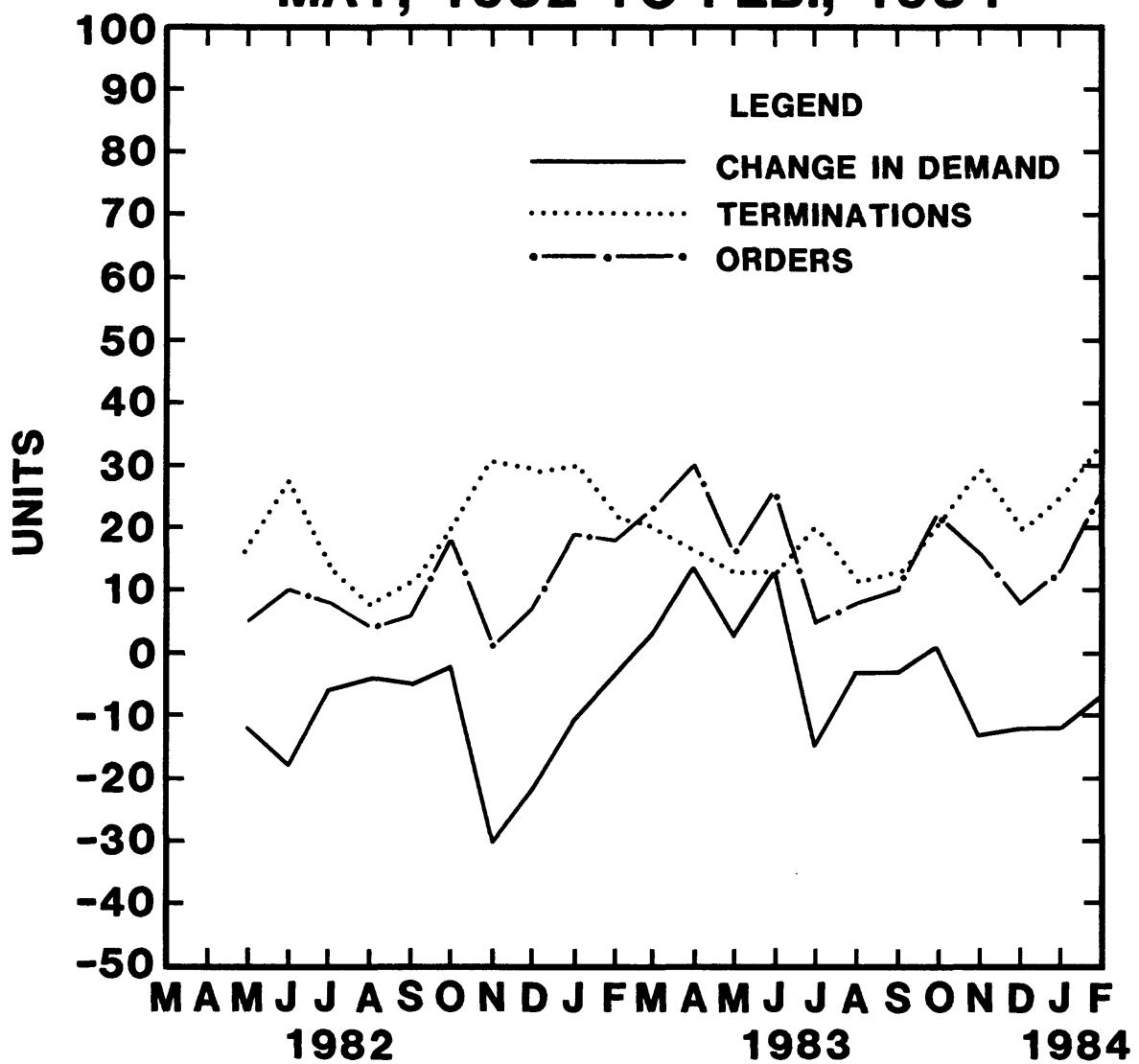


Figure 3.--ADR Demand trends, Fisher-Porter telekit,
May, 1982 to Feb, 1984.

**ADR DEMAND TRENDS
L&S ADR DIGITAL I-O
MAY, 1982 TO FEB., 1984**

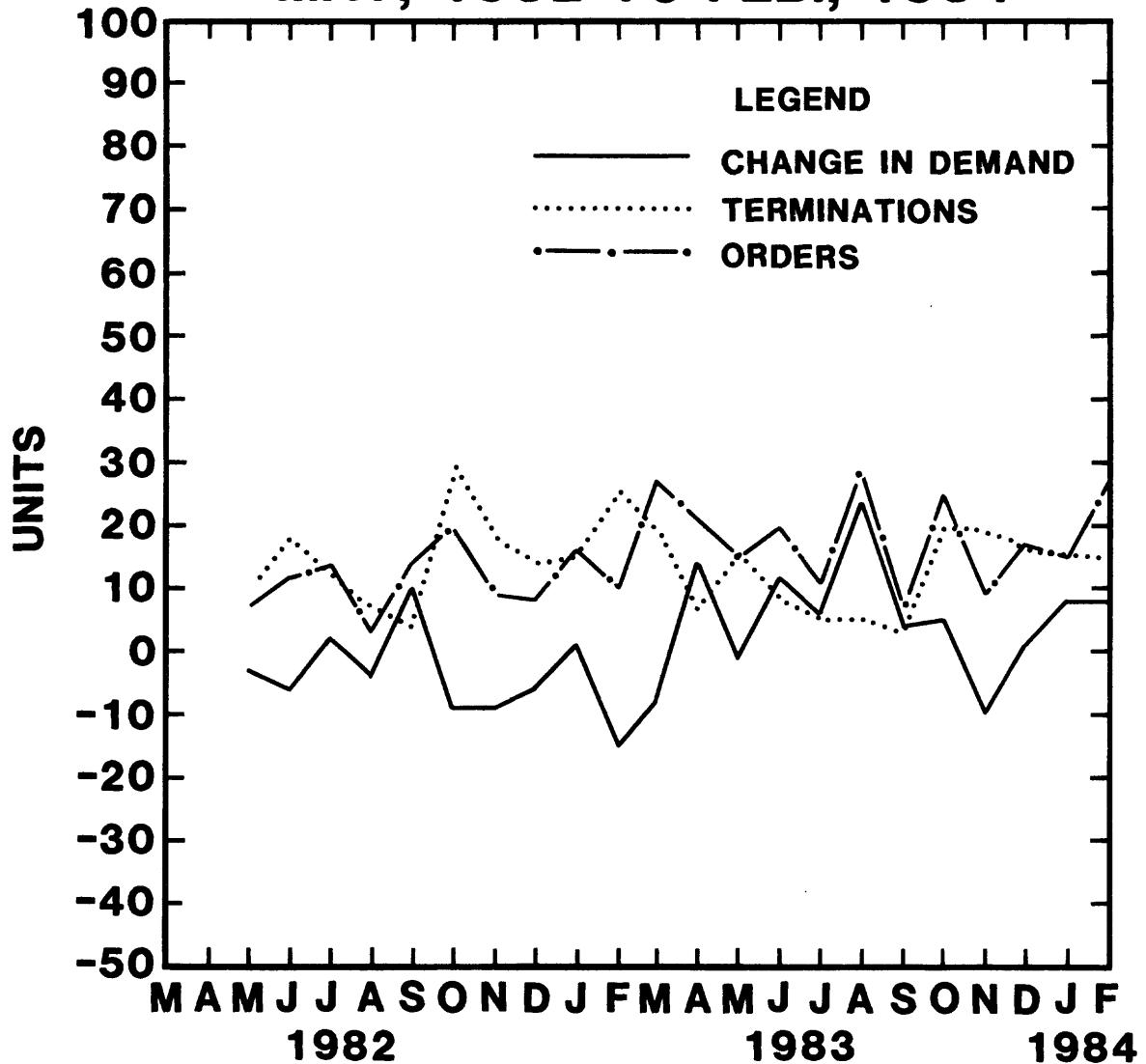


Figure 4.--ADR Demand trends, Leupold and Stevens ADR digital I-Ø,
May, 1982 to Feb, 1984.

Program savings in FY83 were used to procure parts for a conversion of ADRs from a 7 1/2-volt dry cell battery to a 12-volt gel-cell rechargeable battery power source. Savings in 1984 were committed to pay for nearly 50 percent of the AHDAS development contract with Teledyne Geotech.

The following breakdown identifies use of program income for a basic ADR in 1984. Similar data is available for other recorder types.

ADR Rental Rate Income and Expenditures -- FY 1984

INCOME

Rental Charges..... \$84.00

EXPENDITURES

Refurbishing cost (no capital outlay)

\$175/unit labor and material - 6 yr

MTBF)..... \$30.00

Timer repair cost - distributed

\$42/times x 1500 est. units - 13,500

ADRs)..... 4.50

Overhead - (Administrative overhead,
warehouse handling, computer charges).... 15.00

12-volt power conversion..... 1.00

AHDAS development - distributed

(\$450K - 13,500)..... 33.50

Total Program Expenditures..... 84.00

The following tables show overall distribution of income and expenses for 1984 and 1985. Table 1 shows actual costs for 1984. Table 2 shows projected 1985 distribution with no increase in rental rates and Table 3 shows 1985 distribution with a \$1 per month increase.

A synopsis of the previous tables shows several options available to program managers for the next several years. Funding the acquisition of AHDAS (Field Component) units to replace aging ADRs is considered a high priority.

FY84 \$450,000 from ADR Rental Account was used for AHDAS Development.

FY85 \$537,000 from ADR Rental Account could be available.
(No in- \$350,000 could be expended for ATE leaving 187,000 to
crease) carryover into FY86 to procure initial AHDAS units.

FY85 \$720,000 from ADR Rental Account would be available.
(With \$350,000 could be expended for ATE leaving \$370,000
increase) increase) to carryover into FY86 to procure initial AHDAS units.

	F-P 5101001	F-P 5101002	F-P ALL	L-S 5102001	L-S 5102002	L-S 5102003	L-S ALL	TOTAL
Units on Rental #	8,750	1,000	9,750	2,500	600	400	3,500	13,250
Timers on Stock #								12,000
Repaired Timers #								1,500
Cost of Timer:								
Repair Distributed \$	41,000	5,000	46,000	12,000	3,100	1,900	17,000	63,000
F-P Basics repaired #			2,000					2,000
Contract Repair of F-P:								
Distributed \$	235,800	26,700	262,500					262,500
L&S Basic repaired #							500	500
Contract Repair of L&S								
Distributed \$				19,900	4,800	3,300	28,000	28,000
Overhead Cost:								
Distributed \$	94,900	11,700	106,600	27,700	7,300	4,400	39,400	146,000
Parts & Supplies \$								
Distributed \$	73,700	9,100	82,800	21,500	5,700	3,400	30,600	113,400
Repair 5101002								
Distributed \$		26,300	26,300					26,300
Repair 5102002								
Distributed \$					15,700		15,700	15,700
Repair 5102003								
Distributed \$						10,500	10,500	10,500
Purchases of Accessories								
Distributed \$					22,100		22,100	22,100
Misc. Repair clocks, covers,								
Distributed \$	34,100	4,200	38,300	10,000	2,600	1,600	14,200	52,500
TOTAL OPERATING COSTS								
DISTRIBUTED \$	479,500	83,000	562,500	91,100	61,300	25,100	177,500	740,000
RENTAL INCOME								
DISTRIBUTED:								
5101001 @ \$7/mo.	-735,000							
5101002 @ \$10/mo.		120,000	-855,000					
5102001 @ \$7/mo.				-210,000				
5102002 @ \$10/mo.					-72,000			
5102003 @ \$10/mo.						-48,000	-330,000	-1,185,000
SURPLUS	-255,500	-37,000	-292,500	-118,900	-10,700	-22,900	-152,500	-445,000
Extraordinary Expenses and Credits								
Power Conversions								15,000
Carryover from FY 83								-20,000
Available for AHDAS & Expended								-450,000

Table 1.--ADR cost analysis FY-84

	F-P 5101001	F-P 5101002	F-P ALL	L-S 5102001	L-S 5102002	L-S 5102003	L-S ALL	TOTAL
Units on Rental #	8,750	1,000	9,750	2,500	600	400	3,500	13,250
Timers on Stock #								12,000
Repaired Timers #								1,000
Cost of Timer:								
Repair Distributed \$	42,900	5,300	48,200	12,500	3,300	2,000	17,800	66,000
F-P Basics repaired #			1,200					1,200
Contract Repair of F-P:								
Distributed \$	149,000	16,600	165,600					165,600
L&S Basic repaired #							300	300
Contract Repair of L&S								
Distributed \$				12,700	3,000	2,000	17,700	17,700
Overhead Cost:								
Distributed \$	100,000	12,300	112,300	29,300	7,800	4,600	41,700	154,000
Parts & Supplies \$								
Distributed \$	74,800	9,200	84,000	21,900	5,700	3,400	31,000	115,000
Repair 5101002								
Distributed \$		28,000	28,000					28,000
Repair 5102002							16,500	16,500
Distributed \$								
Repair 5102003							11,000	11,000
Distributed \$								
Purchases of Accessories								
Distributed \$					19,200		19,200	19,200
Misc. Repair clocks, covers,								
Distributed \$	35,800	4,400	40,200	10,500	2,700	1,600	14,800	55,000
 TOTAL OPERATING COSTS								
DISTRIBUTED \$	402,500	75,800	478,300	86,900	58,200	24,600	169,700	648,000
 RENTAL INCOME								
DISTRIBUTED:								
5101001 @ \$7/mo.	-735,000							
5101002 @ \$10/mo.		120,000	-855,000					
5102001 @ \$7/mo.				-210,000				
5102002 @ \$10/mo.					-72,000			
5102003 @ \$10/mo.						-48,000	-330,000	-1,185,000
 SURPLUS	-332,500	-44,200	-376,700	-123,100	-13,800	-23,400	-160,300	-537,000
Extraordinary Expenses and Credits								
ATE*								350,000
Carryover from FY 84								---
Available for AHDAS to Carryover into FY 86								187,000

*Planned Procurement of Automatic Test Equipment needed to test electronic components of AHDAS.

Table 2.--Projected ADR cost analysis FY-85 (no increase)

	F-P 5101001	F-P 5101002	F-P ALL	L-S 5102001	L-S 5102002	L-S 5102003	L-S ALL	TOTAL
Units on Rental #	8,750	1,000	9,750	2,500	600	400	3,500	13,250
Timers on Stock #								12,000
Repaired Timers #								1,000
Cost of Timer:								
Repair Distributed \$	42,900	5,300	48,200	12,500	3,300	2,000	17,800	66,000
F-P Basics repaired #			1,200					1,200
Contract Repair of F-P:								
Distributed \$	149,000	16,600	165,600					165,600
L&S Basic repaired #							300	300
Contract Repair of L&S								
Distributed \$				12,700	3,000	2,000	17,700	17,700
Overhead Cost:								
Distributed \$	100,000	12,300	112,300	29,300	7,800	4,600	41,700	154,000
Parts & Supplies \$								
Distributed \$	74,800	9,200	84,000	21,900	5,700	3,400	31,000	115,000
Repair 5101002			28,000	28,000				28,000
Distributed \$					16,500		16,500	16,500
Repair 5102002								
Distributed \$							11,000	11,000
Repair 5102003								11,000
Distributed \$								
Purchases of Acces-								
series								
Distributed \$					19,200		19,200	19,200
Misc. Repair clocks,								
covers,								
Distributed \$	35,800	4,400	40,200	10,500	2,700	1,600	14,800	55,000
TOTAL OPERATING COSTS								
DISTRIBUTED \$	402,500	75,800	478,300	86,900	58,200	24,600	169,700	648,000
RENTAL INCOME								
DISTRIBUTED:								
5101001 @ \$8/mo.	-840,000							
5101002 @ \$12/mo.		144,000	-984,000					
5102001 @ \$8/mo.				-240,000				
5102002 @ \$12/mo.					-86,400			
5102003 @ \$12/mo.						-57,600	-384,000	-1,368,000
SURPLUS	-437,500	-68,200	-505,700	-153,100	-28,200	-33,400	-214,300	-720,000
Extraordinary Expenses								
and Credits								
ATE*								350,000
Carryover from FY 84								---
Available for AHDAS to								
Carryover into FY 86								370,000

*Planned Procurement of Automatic Test Equipment needed to test electronic components of AHDAS.

Table 3.--Projected ADR cost analysis FY-85 (with increase)

FY86 (Based on increased rates in 1985)

\$720,000 available from 1986 income + 1985 carryover
\$370,000 = \$1,100,000 available.

Purchase of 1,000 units at \$2,500*	=	\$2,500,000
Available (1986)		<u>1,100,000</u>
Shortfall		\$1,400,000

*estimated unit cost

AHDAS Funding Possibilities

It is difficult to predict the WRD's financial situation two years down the road. Several options are available to fund the first AHDAS units.

1. Direct Federal funding from WRD
2. Substantial increases in ADR rental rates - possibly setting ADR rates equal to AHDAS which probably will be about 1 1/2 - 2 times present ADR rental - beginning FY 86.
3. Allowing Districts to prepay several years rental on AHDAS as was done in the early days of ADRs.
4. Special Division-wide assessment on CBR programs.
5. Other Federal Agency participation.
6. Blend of these, or others.

SUMMARY

HIF and WRD management must soon develop a strategy to finance the procurement of AHDAS units in such a manner as to make a conversion from ADRs in the shortest possible time and at the least possible cost. Several important aspects of this planning should include:

- o Serious breakdowns and missing records will result if replacement of ADRs is significantly delayed.
- o Data processing costs will be higher if field offices must maintain two separate data reduction, manipulation, and publishing formats for long periods.
- o HIF and field office costs will be high as long as two instrument systems must be maintained.

Creative financing schemes should be possible to maximize the implementation of AHDAS with a minimum amount of new outside capital.