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VOLUME 5
ORIGINAL

Property Inventory and Condition Survey
for the
Group IV Utility Systems Property
and
Group II Chemical Plant Property
within the
Shell Oil Company Leasehold Area
at
US Army Rocky Mountain Arsenal
Commerce City, CO

VOLUME FIVE

GROUP IV UTILITY SYSTEMS PROPERTY

Water Distribution System

prepared by
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St. Louis, MO

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US ARMY ROCKY MOUNTAIN ARSENAL
Commerce City, CO

SHELL OIL COMPANY LEASEHOLD AREA

POTABLE AND PROCESS WATER DISTRIBUTION SYSTEMS OPERATION AND MAINTENANCE REPORT

Prepared by
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Under the direction of
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I. INTRODUCTION

In the past, Shell Oil Company has been responsible for the operation and maintenance of the US Army Rocky Mountain Arsenal potable and process water systems. They are anticipated to step down from this role by the end of 1982 and cease all activity at Rocky Mountain Arsenal.

The purpose of this report is to determine the operation and maintenance requirements necessary to keep these water systems in operation. An account of operation and maintenance activities undertaken in the past will be obtained by reviewing past maintenance records and interviewing present maintenance personnel. This information will be the basis for estimating future operation and maintenance activities that will be required.

After operation and maintenance requirements are established, the annual maintenance and repair expenditures will be estimated. Future trends for water demands, labor man-hours and salary rates, maintenance requirements, and utility rates will be projected over a five-year period in order to estimate as accurately as possible the future potable and process water system budget.

II. DESCRIPTION OF WATER DISTRIBTUION SYSTEMS

Rocky Mountain Arsenal Water Distribution Systems

Two water distribution systems are present within the Rocky Mountain Arsenal. Potable and process waters are distributed throughout the Arsenal by separate distribution systems. These water distribution systems were installed during the early 1940s in order to serve the specific water demands within Rocky Mountain Arsenal.

In 1949 the water distribution systems were leased to Julius Hyman and Company. Under the terms of the lease agreement, Julius Hyman and Company became responsible for the operation and maintenance of the potable and process water systems. The water system was defined to include canals and lakes, storage reservoir, water treatment plants, chlorination stations, pumping station facilities, water distribution lines and associated equipment.

Potable Water Distribution System

Potable water is supplied to Rocky Mountain Arsenal by the city of Denver. A 33-inch city main entering the Arsenal from the south provides water at a pressure of approximately 90 p.s.i. Potable water is used throughout the Arsenal for domestic needs, a portion of the fire hydrants, and for various plant processes. The city of Denver bills Rocky Mountain Arsenal for all potable water delivered to the Arsenal. They in turn bill Shell Oil Company, who is the succeeding company to Julius Hyman and Company, for their share of the water usage.

The city of Denver water main is connected to the Rocky Mountain Arsenal potable water distribution system. Water can also be diverted into a one-million gallon underground storage reservoir located west of Ladora Lake. In order to increase the pressure in the distribution system or to provide an emergency water supply, water is pumped from the reservoir by pumps located in the pump house (Building 371) adjacent to Ladora Lake. Three, one million gallon per day pumps are located in this pump station.

The potable water distribution system consists primarily of approximately 22.5 miles of 3/4 inch to 16 inch diameter steel pipe. There are also a few short reaches of plastic and asbestos cement pipe in the system. Forty-nine fire hydrants are connected to the potable water distribution system. A majority of the fire hydrants, however, are connected to the process water system. The potable water distribution system has adequate metering and valving facilities that allow for proper maintenance of the system. There are two chlorination buildings that are being used to maintain an adequate residual chlorine content within the distribution system.

Process Water Distribution System

Process water for Rocky Mountain Arsenal is obtained from the South Platte River through a 70 mile Highline Canal which connects to a five mile intake canal located on the Arsenal property. Water from the Highline Canal is obtained under irrigation water rights owned by the government. The Highline Canal, along with surface runoff from a portion of the Arsenal property, provides water for a two-lake process water storage system. Uncontaminated water from the process water return system is also returned to the storage lakes for reuse.

Originally, the main process water return system and a separate return system serving the Power Plant both returned water to Lower Derby Lake. In 1964 the main process water system was converted into a closed system by Shell Oil Company. The outfall from this system discharges into a lift station (Facility 550) instead of the storage lake system. Two, 4,000 gallon per minute vertical turbine pumps mounted above the lift station pump water to the wet well for the cooling tower pump house (Facility 548). Three, 3,500 gallon per minute pumps located in the pump house lift process water into a cooling tower (Facility 549). The cooling tower consists of a two-cell tower with a 7,000 gallon per minute capacity. A 500,000 gallon reinforced concrete reservoir is located beneath the cooling tower. Three additional 3,500 gallon per minute pumps located in the cooling tower pump house return process water from the concrete reservoir back into the process water distribution system. These pumps can also be used to lift process water into a 500 million gallon elevated storage tank (Facility 551). Process water returned through this main system consists mainly of water utilized for mechanical equipment cooling purposes in buildings operated by Shell Oil Company.

Water from the process water return system serving the Power Plant is still returned to Lower Derby Lake. The outfall from this system discharges into a catch basin located to the west of Lift Station Facility 550 and empties into an open channel leading to Lower Derby Lake. Process water returned through this system consists of cooling water from the power plants and condensate from part of the condensate return system.

condensate should be re-used

Surface runoff from the Highline Canal and Uvalda Canal is also discharged into Lower Derby Lake. An outlet structure from Lower Derby Lake (Facility 369) discharges water from the lake into the Sand Creek Lateral. A diversion box (Facility 374) located on the Sand

Creek Lateral diverts water into an open channel which flows in Ladora Lake.

Surface runoff from the Highline Canal and Uvalda Canal originally discharged into Upper Derby Lake. In 1981 a diversion box installed along the Highline Canal was used to bypass Upper Derby Lake. Uvalda Canal was also blocked by an earthen dike. Both canals are diverted to an open channel which leads to Lower Derby Lake.

Process water is pumped into the distribution system by three, 10 million gallon per day pumps located in the pump house (Building 371) which also houses the potable water pumps. Three water well stations (Buildings 385, 386 and 387) have been used in the past to augment the process water supply. These water wells are connected to a 14-inch diameter water main leading to Ladora Lake. The wells have not been used in recent years; however, they can be put into operation if necessary. Process water is used throughout the Arsenal for building fire sprinkler systems, lawn irrigation systems, mechanical equipment cooling, and process make-up water. The primary daily use of process water is for process dilution requirements and mechanical equipment cooling purposes.

The process water distribution system consists of approximately 16.7 miles of four inch to 36 inch steel and asbestos cement pipe. There are approximately 108 fire hydrants that have been connected to the process water system. In the mid-1960s, the fire protection sprinkler systems were installed in several buildings. There are approximately 38 post indicator valves that were connected to the process water system in order to provide for fire protection. The process water distribution system has adequate metering and valving facilities that allow for proper maintenance of the system.

III. PHYSICAL CONDITIONS OF WATER DISTRIBUTION SYSTEMS

Typical Condition of Water Distribution Systems

Most water distribution systems in the United States consist of cast iron and ductile iron pipe. The 1981 American City and County Water Main Pipe Survey found that 75.3 percent of water pipes today consist of iron material. Table III-1 indicates the final results of the 1981 Water Pipe Survey. While only 4.6 percent of the water pipes consist of steel pipe, there is a significant amount of steel pipe used in the western states. Steel pipe comprises 11.8 percent of the water pipe in this area.

Table III-1

1981 Water Pipe Survey Regional Results

	Percent of Pipe in Place by Region						
Water Pipe	North-east	South-east	North Central	Great Plains	South Central	West	National Average
Cast and ductile iron	93.0	73.6	94.7	66.9	80.4	59.0	75.3
Asbestos-cement	3.7	11.1	1.1	20.6	15.2	22.9	13.9
Steel	1.0	6.8	0.5	1.6	0.8	11.8	4.6
Reinforced concrete	2.0	1.1	2.5	4.1	1.6	2.5	2.5
Plastic	0.1	6.8	0.4	2.3	1.1	0.7	1.5
All other	0.1	0.6	0.8	4.4	0.0	3.1	2.0

Source: American City & County, "Cost, Not-Material, Shifting Pipe Choice," June 1981 Issue.

Pipe made from metal material is subject to corrosion. Corrosion is the main factor causing deterioration of the underground metal pipe systems. Continued corrosion of pipe results in pitting of the surface and eventual failure. The physical or chemical properties of the

soil surrounding pipe, not the composition of pipe material, determine the degree and rate of corrosion. In order to prevent corrosion, water pipes must either be coated to isolate the material from the corrosive environment or be provided with cathodic protection. The most common pipe coating in use today consists of coal tar enamel wrapped in asbestos. A need also exists to provide cathodic protection for coated pipes. Flaws in pipe coatings allow corrosion to occur due to galvanic effects between dissimilar environments.

Other pipe materials can be used in order to avoid corrosion problems. Asbestos-cement and plastic pipe are commonly used. Asbestos-cement pipe has been found to represent 22.9 percent of all water pipe installed in the western states.

Potable Water Distribution System Condition

An account of the physical condition of the potable water distribtuion system was obtained during interviews with representatives of Shell Oil Company who are responsible for maintenance of the system. Personnel with over ten years' experience at maintaining the system have indicated that although the pump station and chlorination facilities are in good condition, the potable water distribution system is generally in poor condition.

The predominantly steel pipe system is subject to corrosion throughout Rocky Mountain Arsenal. Open excavation of sections of the distribution system during repairs has revealed that the pipes are heavily pitted and are subject to internal and external corrosion. A ten-inch diameter water main entering the South Plants area from the west is in extremely poor condition. Recommendations have been made to the government to replace approximately 3,900 feet of this line. Continual inspection for and repair of corroded water mains is needed in order to allow for proper water distribution.

Process Water Distribution System Condition

The Shell Oil Company representatives previously mentioned were also contacted to obtain an account of the physical conditions of the process water system. The process water system is more complex than the potable water system and has several more components. In general, the process water supply and pumping facilities are in good condition while the process water distribution system is in poor condition.

The Highline Canal leading to Lower Derby Lake is subject to erosion during heavy runoff rates and clogging by vegetation and debris. Continuous maintenance and cleaning of the canal has kept it in good condition. Lower Derby and Landora Lakes are in fair condition. There has been excess vegetation growth along the sides of both lakes and algal growth in Ladora Lake. There have been no significant problems, however, caused by the presence of the vegetation.

The process water pumping facilities are considered to be in good condition. The only problem recently encountered at the pump house (Building 371) was a deterioration of the discharge pipe leading out of the pump house. This resulted in a four-foot submergence of the pump house floor and damage to the pump motors. The facilities associated with the process water return system are in excellent condition. The lift stations, cooling tower and elevated storage tank are well maintained.

The condition of the predominantly steel process water distribution system is similar to the condition of the potable water distribution system. Corrosion problems are prevalent throughout the system.

IV. PREVIOUS MAINTENANCE AND REPAIR REQUIREMENTS

General Water Distribution System Maintenance Requirements

Shell Oil Company is responsible for maintenance of the water distribution systems under the terms of the Shell Leasehold agreement. There is a permanent maintenance crew that maintains utilities for Shell Oil Company. This crew is also responsible for maintenance of the water distribution system within the Rocky Mountain Arsenal. In addition to carrying out routine maintenance tasks associated with the distribution systems, they are also responsible to see that special repairs are made to the systems. The maintenance and repair tasks which will be discussed do not include labor, utility and material costs associated with operation of the water distribution systems.

Maintenance practices undertaken within the water distribution systems were determined by interviewing maintenance representatives and reviewing expenditure records dealing with maintenance activities. In the following sections, a description of the maintenance activities that have been necessary in the past will be presented.

Maintenance of the Potable Water Distribution System

There are seven general categories of maintenance activities that were found to be followed within the potable water distribution system. Following is a description of the tasks involved in each of the categories:

Chlorination Facilities. The two chlorination facilities presently in operation are serviced on alternate days during the week. Mechanical parts of the chlorinators are serviced and

tests are made of the chlorine content present in the water after the chlorination facilities. The southern chlorinator uses dry chlorine. This requires maintenance personnel to manually mix a batch of dry chlorine with water.

Underground Leak Repair. Due to the high amount of corrosion in the water pipe, underground leaks are common in the distribution system. Leaks can be detected by water flowing up to the ground surface in the area of the leak. Maintenance personnel walk along the main water line in problem areas daily in order to detect leaks. Small leaks are normally repaired by plugging the opening. If this is not adequate to stop the leaks, the pipe is either welded with a patch or the leak is clamped closed. This category includes all construction activities necessary to excavate and repair the leak and replace the surface to its original condition.

Meters, Valves, and Water Mains. These items must be serviced regularly in order to operate properly. Meters are read monthly in order to determine water quantities that are used by Rocky Mountain Arsenal. Valves along water mains must be inspected for leaks regularly and replaced as necessary.

Cathodic Protection. A major program was initiated during the 1960s to provide cathodic protection for the potable water system. Although the initial protection program is complete, it is necessary to check the distribution system regularly. An electrician checks the cathodic characteristics of the system weekly with a meter to determine if it is adequately protected.

Pumps, Motors and Starters. The potable water pumps and appurtenances are inspected daily at the pump house. Parts are oiled

and inspected for defects. Occasionally parts need to be repaired or replaced.

Utility Buildings and Facilities. Buildings housing potable water pumps and valves must be maintained to avoid deterioration of the facilities. Tasks undertaken in the past under this category have included re-roofing of the main pump house. Maintenance involved in cleaning the intake screen for the pumps is also included in this category.

Miscellaneous. A few minor tasks which do not require continual attention have been grouped together. Valve guard posts are replaced, painted and numbered as necessary. Valve and air release boxes are protected from frost during winter months by placing straw around the boxes. A portion of clean-up activities around the pump house is included in the miscellaneous category.

Figure IV-1 indicates the magnitude of maintenance for each category as a percent of the total maintenance expenditure. Maintenance and operation of the chlorination facilities accounts for almost 50 percent of the potable water system maintenance. This category, along with underground leak repair and meter, valve and water main maintenance account for 92 percent of the potable water system maintenance.

The labor requirement for the above activities was estimated based on burden rates that Shell Oil Company developed for the ten-year period. Man-hour requirements were determined by dividing labor expenditure costs by the yearly labor burden rates. The labor requirements in man-hours for the period 1972 through 1981 is shown on Figure IV-2. The average annual man-hour requirement during the last decade was 2,040 hours.

FIGURE IV-1

POTABLE WATER SYSTEM
PERCENT OF MAINTENANCE EXPENDITURES : 1972-1981

SHELL OIL COMPANY LEASEHOLD

US ARMY ROCKY MOUNTAIN ARSENAL

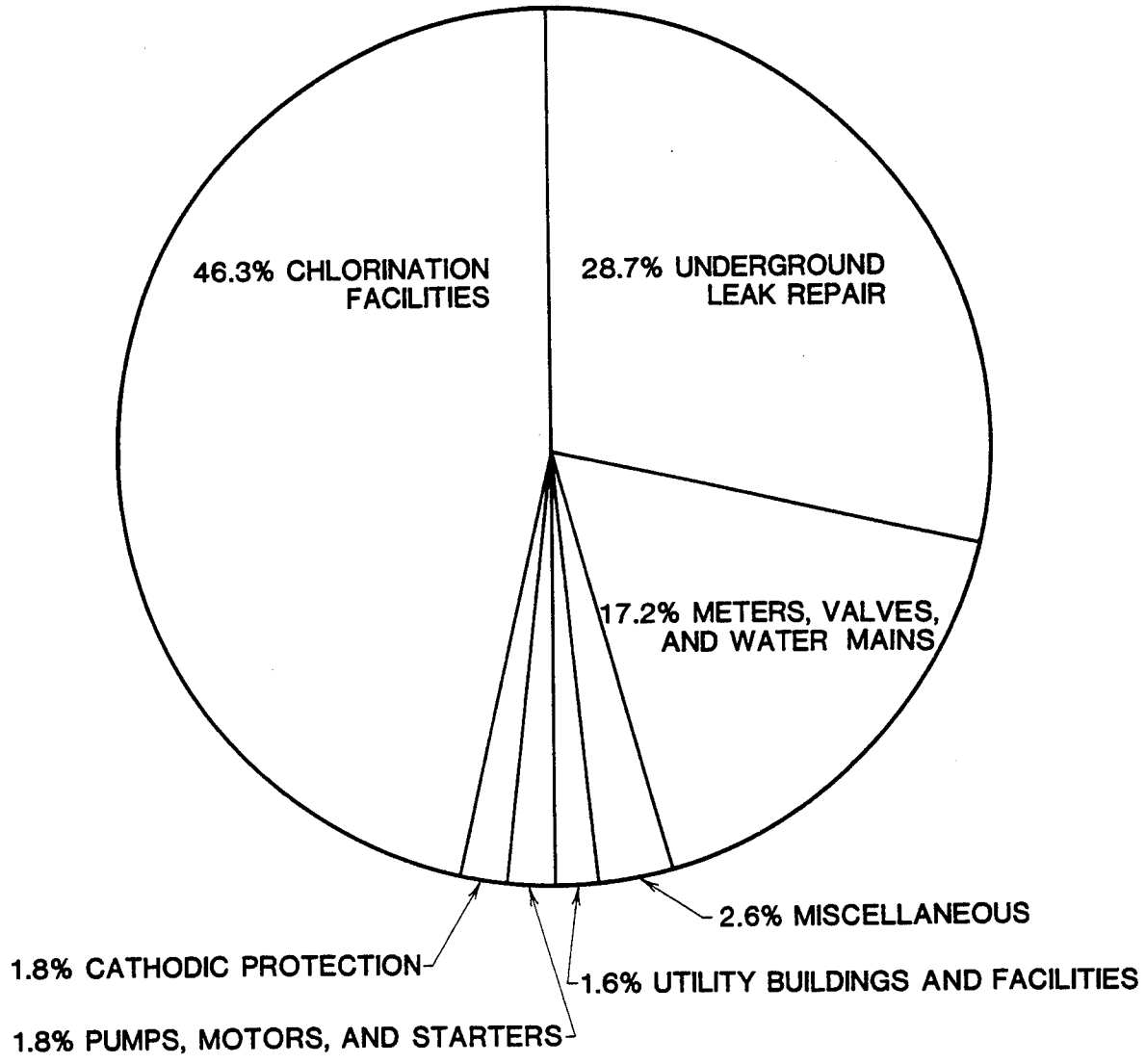


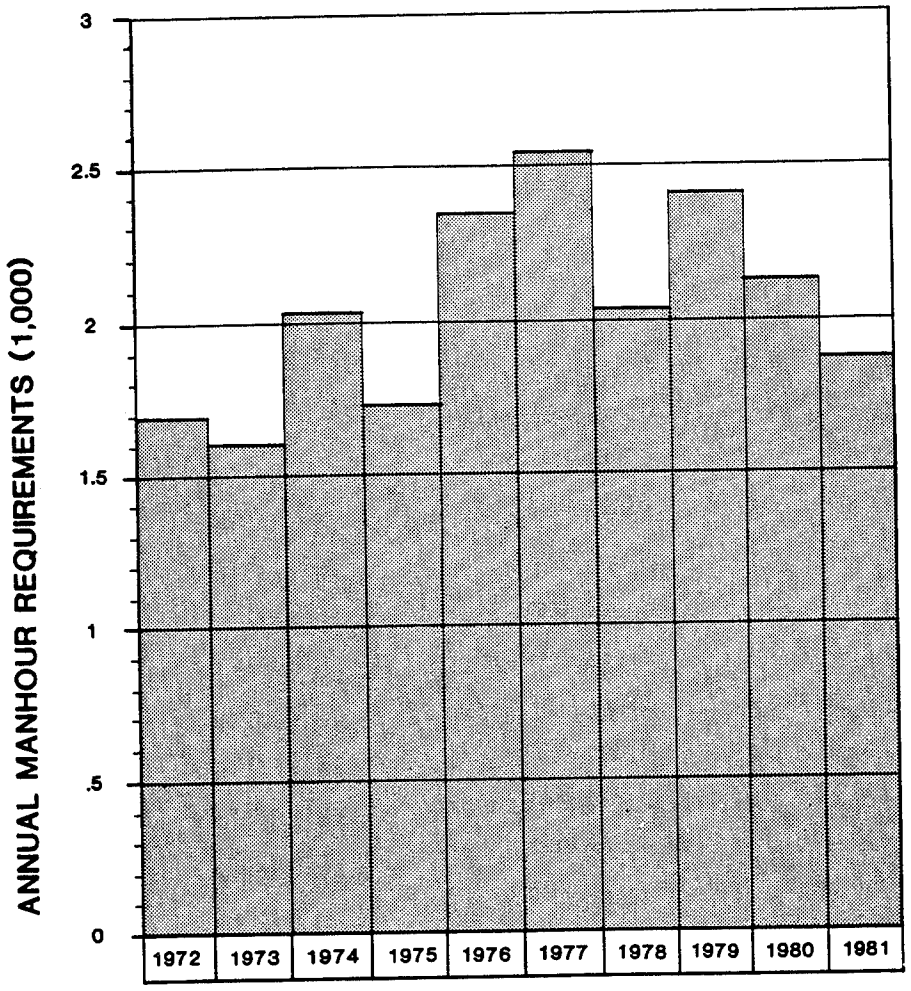
FIGURE IV-2

POTABLE WATER SYSTEM

ANNUAL MAINTENANCE MANHOUR REQUIREMENTS 1972-1981

SHELL OIL COMPANY LEASEHOLD

U.S. ARMY ROCKY MOUNTAIN ARSENAL



Maintenance of the Process Water Distribution System

There are six general categories of maintenance activities that were found to be followed within the process water distribution sytem. Following is a description of the tasks involved in each of the categories.

Utility Buildings and Facilities. Facilities associated with the process water system include the main pump house at Ladora Lake (Building 371) and the lift station, cooling tower, and elevated storage tank. All of these facilities are inspected daily. There are several pumps and mechanical equipment that must be serviced daily. A corrosion inhibitor is also added to the process water system at the cooling tower on a daily basis. The pumps located at the cooling tower are dismantled annually and repaired. Maintenance costs associated with repair of the structures housing the process return system mechanical equipment are also included in this category.

Underground Leak Repair. The tasks associated with this category have been described in the preceding potable water system section. Approximately ten to 20 major leaks per year occur in the potable and process water distribution systems.

Lakes and Canal. This category involves all maintenance required to keep the process water supply and storage facilities clean and in operation. The Highline Canal is cleared of all debris each spring. The canal is inspected weekly to assure that it does not become obstructed. Reaches of the canal that are subject to excessive erosion are covered with a lining material where needed. The flume and ditch between Lower Derby and Ladora Lake and the lake dikes are inspected regularly to check for deterioration.

Although lake weed eradication is no longer followed on a routine basis, general lake area cleanup is practiced periodically in order to avoid debris from entering into the lakes. Repair of the process water wells is included in this category. The maintenance required for these wells is minor since they have not been in recent use.

Pumps, Motors, and Starters. This category involves the repair and replacement of pumping equipment associated with the process water system. Maintenance required for the process water system is more demanding than the potable water systems due to the amount of mechanical equipment involved. Routine maintenance of this equipment has been covered in the utility facilities category.

Meters, Hydrants, Valves and Mains. This category has also been described in the preceding potable water section. The maintenance of fire hydrants is added to the process water system. There are a large number of fire hydrants connected to this system which are subject to periodic leaks. Approximately 25 hydrants per year require replacement of parts.

Cathodic Protection. The same cathodic protection maintenance is required for the process water system as with the potable water system.

Figure IV-3 indicates the magnitude of maintenance for each category as a percent of the total maintenance expenditure. Utility buildings and facilities account for 68.5 percent of the process water system maintenance. This large percentage is due to the amount of major equipment involved with the process water system which must be

FIGURE IV-3

PROCESS WATER SYSTEM
PERCENT OF MAINTENANCE EXPENDITURES: 1972-1981

SHELL OIL COMPANY LEASEHOLD

US ARMY ROCKY MOUNTAIN ARSENAL

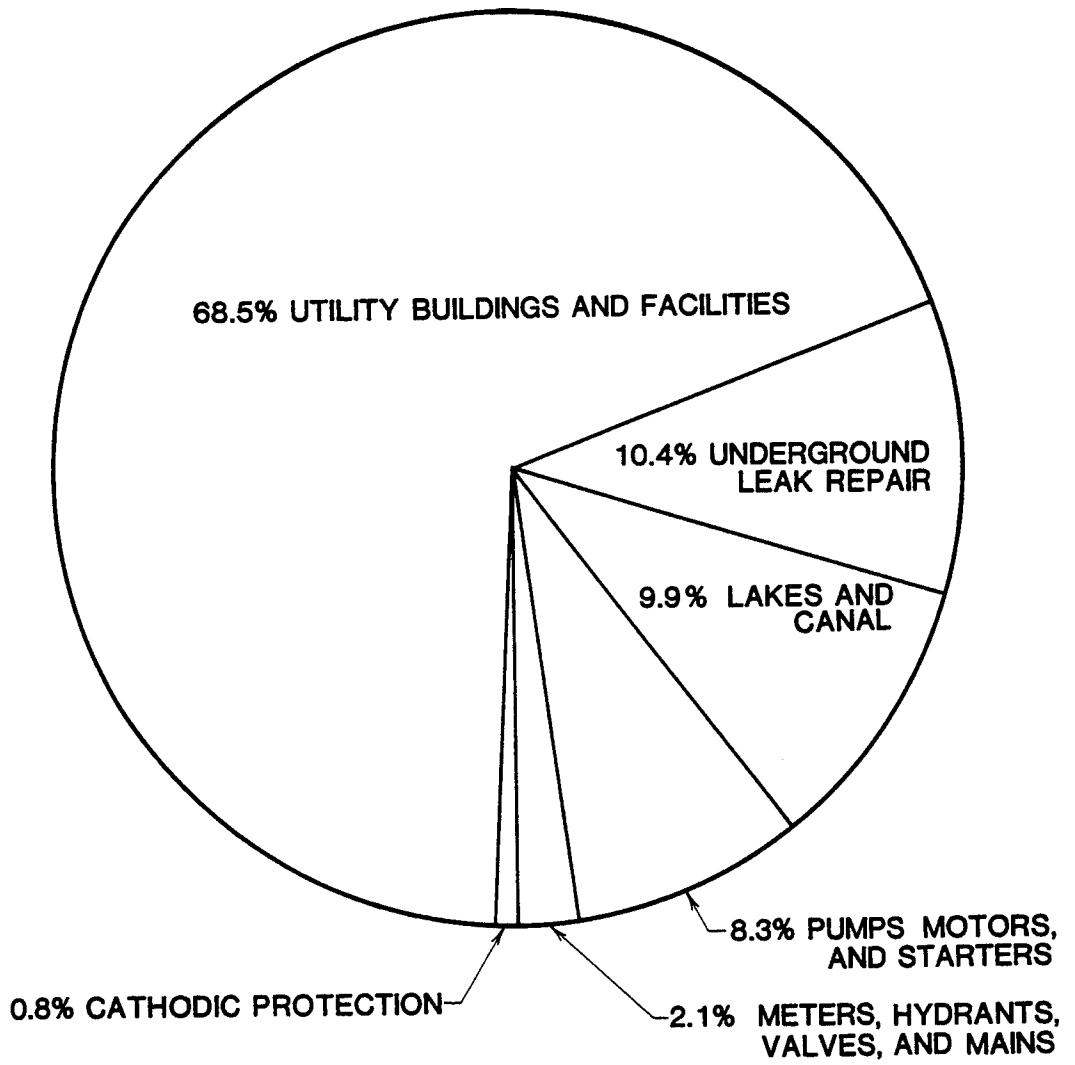


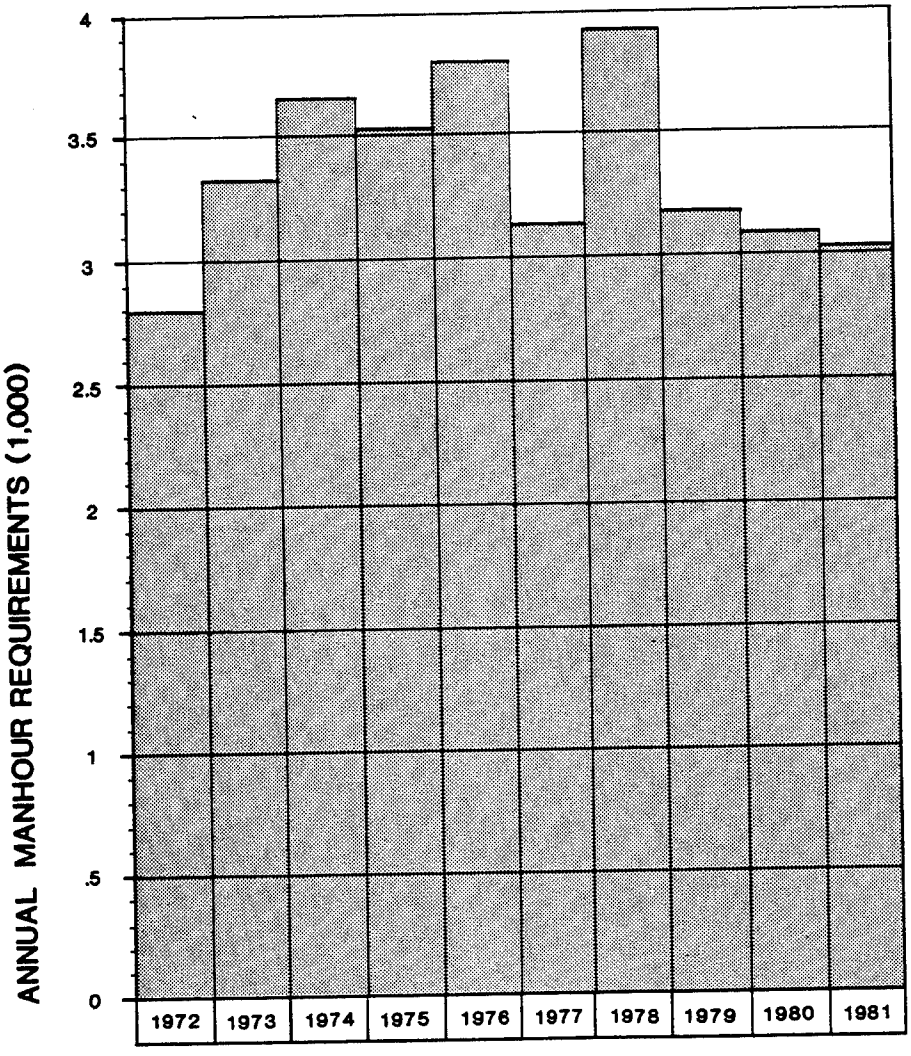
FIGURE IV-4

PROCESS WATER SYSTEM

ANNUAL MAINTENANCE MANHOUR REQUIREMENTS 1972-1981

SHELL OIL COMPANY LEASEHOLD

U.S. ARMY ROCKY MOUNTAIN ARSENAL



regularly maintained. Underground leak repair, lakes and canal maintenance, and pumps, motors and starter repairs each account for approximately 10 percent of the maintenance expenditure.

The labor requirement for the above activities was estimated based on burden rates that Shell Oil Company developed for the ten-year period. These are the same rates used in determining the potable water man-hour requirements. The labor requirement in man-hours for the period 1972 through 1981 is indicated on Figure IV-4. The average annual man-hour requirement for process water maintenance during the last decade was 3,350 hours.

V. PREVIOUS OPERATION AND MAINTENANCE EXPENDITURES

Operation and Maintenance Expenditure Records

Annual expenditure summaries for the potable and process water systems during the past decade were obtained from Shell Oil Company. Two separate reports are used to summarize expenditures. The Shell Oil Company Annual Report summarized the expenditures for which they are responsible. In accordance with the provisions contained in the lease agreement, this includes the first $25,000 of expenditures for maintenance and repair activities and also all non-reimbursable expenditures for operation and maintenance. A second report, Maintenance and Repair, summarizes in detail all maintenance and repair expenditures, both reimbursable and non-reimbursable by the government, that have been charged to the water systems accounts.

In order to arrive at the total expenditure required for operation and maintenance of the two water systems, it was necessary to compare both expenditure reports. Annual non-reimbursable expenses and an additional $25,000 were subtracted from the annual expenditures presented in the Maintenance and Repair Report. These results were then added to the annual expenditures in the Shell Oil Company Annual Report. The final expenditure summaries for the potable and process water system are shown in Tables V-1 and V-2 respectively.

It was not possible to determine an exact breakdown between labor and miscellaneous expenditures which together comprise the original $25,000 subtracted annually from the Maintenance and Repair Report. The breakdown of labor and miscellaneous expenditures was obtained by

Table V-1

Potable Water Expense Summary

1972 - 1981

Year	Labor Expense	Utility Expense	Miscellaneous Expense	Total
1972	11,431	66,589	65,905	143,925
1973	11,540	70,460	51,621	133,621
1974	15,450	57,135	73,789	146,374
1975	16,226	53,224	29,250	98,703
1976	24,328	62,228	13,463	100,019
1977	28,946	68,559	72,638	170,143
1978	24,980	43,369	26,367	94,716
1979	32,483	37,913	46,149	116,545
1980	31,868	44,338	28,897	105,103
1981	31,428	42,900	46,436	120,764

Table V-2

Process Water Expense Summary

1972 - 1981

Year	Labor Expense	Utility Expense	Miscellaneous Expense	Total
1972	18,832	139,436	65,751	224,019
1973	23,990	198,813	143,816	366,619
1974	27,868	122,198	88,432	238,498
1975	32,997	196,433	93,443	322,873
1976	39,409	132,822	97,178	269,409
1977	35,663	130,709	61,663	228,035
1978	48,041	135,309	140,380	323,730
1979	43,020	147,513	141,166	331,699
1980	51,973	178,184	94,085	324,242
1981	55,561	194,277	109,240	359,078

analyzing the past records and determining the ratio of labor to miscellaneous expenditures. Although the breakdown between labor and miscellaneous expenditures is approximate, it is considered accurate enough to represent actual conditions and show existing trends.

Potable Water System Expenditures

In Section IV, potable water system maintenance and repair activities were divided into seven categories. These activities are necessary in order to keep the system operable. Table V-3 indicates the expenditures associated with these activities. The average annual maintenance and repair expenditure was $50,402.

Table V-3

Potable Water Distribution System
Itemized Maintenance and Repair Expenditures

1972 - 1981

Type of Maintenance	Total Expenditure	Percent of Total Expenditure	Average Annual Expenditure
Utility Buildings and Facilities	$ 7,856	1.6	$ 786
Pumps, Motors & Starters	8,909	1.8	891
Cathodic Protection	9,290	1.8	929
Miscellaneous	13,305	2.6	1,331
Meters, Valves & Water Mains	86,934	17.2	8,693
Underground Leak Repair	144,403	28.7	14,440
Chlorination Facilities	233,323	46.3	23,332
Total	$504,020	100.0	$50,402

This value is well below the total annual potable water expenditure values presented in Table V-1. Activities and required purchases necessary to operate the water system are not included in Table V-3.

The cost for potable water which must be purchased from the city of Denver accounts for a major portion of the operation expenditure. Expenditures are also necessary for the manpower and material requirement for operating the potable water system.

The total potable water distribution expenditures required for operation and maintenance of the potable water system are shown on Figure V-1. The expenditures are itemized into labor, miscellaneous, and water purchase expenses. Labor and water requirements have been discussed previously. Miscellaneous expenses involve material, overhead items, and contract services required during the operation and maintenance of the system.

Process Water System Expenditures

In Section IV, process water system maintenance and repair activities were divided into six categories. These activities are necessary to keep the system operable. Table V-4 indicates the expenditures associated with these activities. The average annual maintenance and repair expenditures for the process water system were $103,462.

As was the case with the potable water system, this value is well below the total annual process water expenditure values shown on Table V-3. Electricity costs necessary for pump and equipment operation account for a major portion of the operating expenditure. Water is obtained from surface runoff with only a small expense required to amortize the water rights. Similar expenditures for manpower and material requirements for operating the potable water system are applicable to the process water system.

FIGURE V-1

POTABLE WATER SYSTEM
ITEMIZED EXPENDITURES 1972-1981

SHELL OIL COMPANY LEASEHOLD
US ARMY ROCKY MOUNTAIN ARSENAL

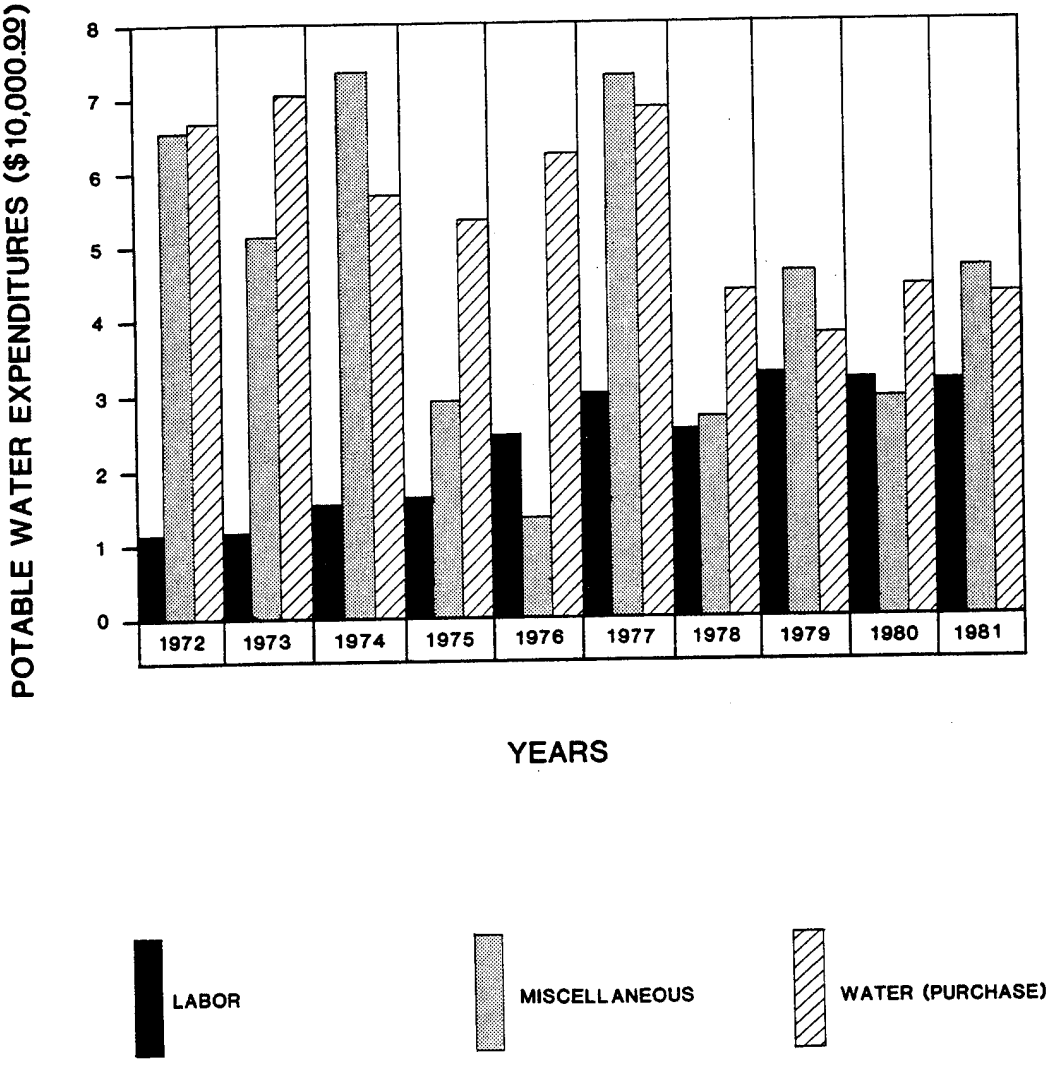


FIGURE V-2

PROCESS WATER SYSTEM
ITEMIZED EXPENDITURES 1972-1981

SHELL OIL COMPANY LEASEHOLD
US ARMY ROCKY MOUNTAIN ARSENAL

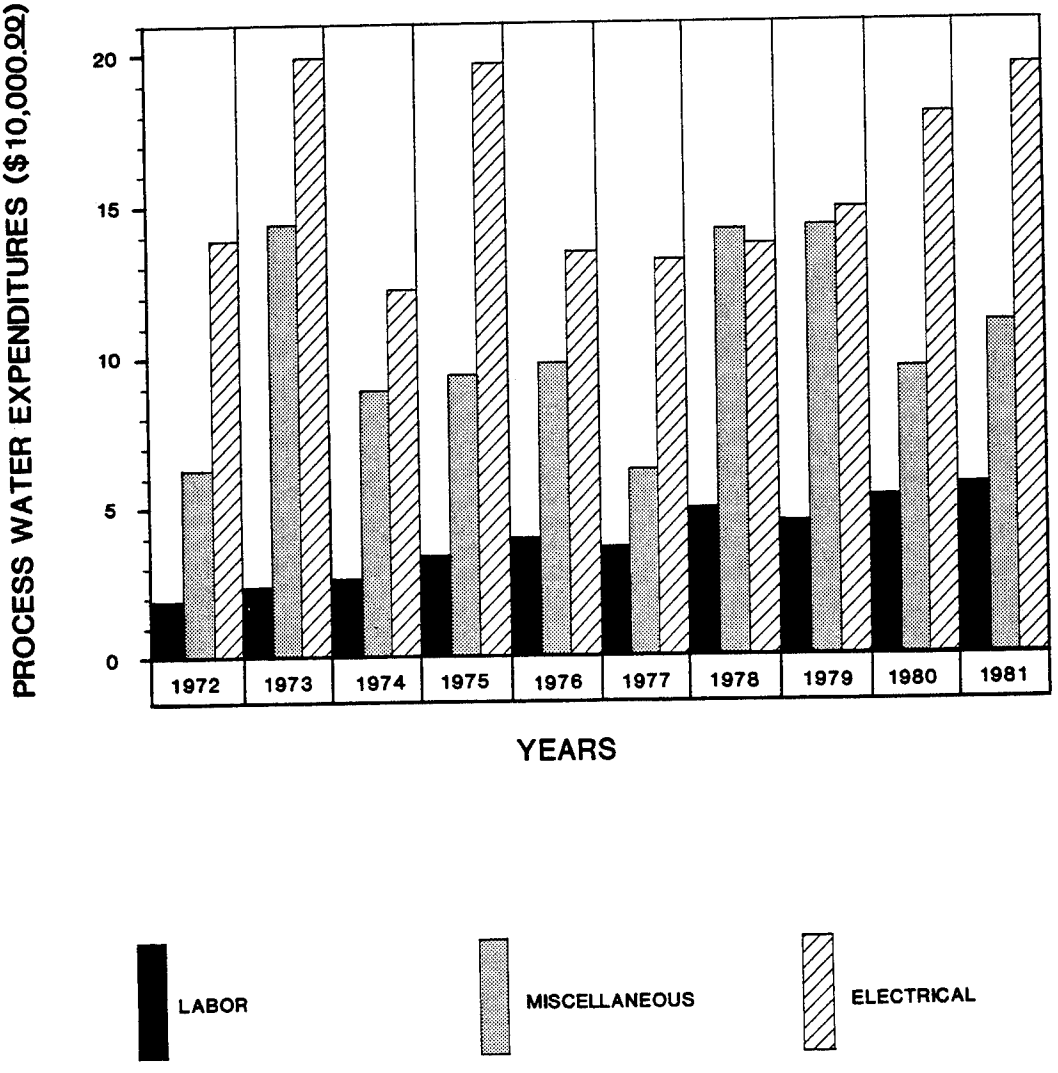


Table V-4

Process Water Distribution System
Itemized Maintenance and Repair Expenditures

1972 - 1981

Type of Maintenance	Total Expenditure	Percent of Total Expenditure	Average Annual Expenditure
Cathodic Protection	$ 8,713	0.8	$ 871
Meters, Hydrants, Valves & Mains	21,370	2.1	2,137
Pumps, Motors & Starters	85,322	8.3	8,532
Lake & Canal	102,231	9.9	10,223
Underground Leak Repair	108,073	10.4	10,807
Utility Buildings & Facilities	708,913	68.5	70,891
Total	$1,034,622	100.0	$103,462

The total process water distribution expenditures required for operation and maintenance of the process water system are indicated on Figure V-2. The expenditures are itemized into labor, miscellaneous, and electrical expenses.

VI. PROJECTED WATER SYSTEM OPERATION AND MAINTENANCE REQUIREMENTS

Operation and Maintenance Projections

Some basic assumptions were made before projecting operation and maintenance requirements. It was assumed that all facilities presently in operation in the water systems will continue to be utilized, except for the process water return facilities. Also, the present potable and process water systems were assumed to be adequate to handle the future demands. It is expected that the maintenance activities and programs presently practiced are adequate to keep the water systems operable and will be continued.

In order to project maintenance over a five-year period, past maintenance records and expenditures were analyzed to determine trends that may exist. Labor, utility, and maintenance components were studied separately in order to obtain an accurate projected expenditure evaluation. After evaluating the information indicated in Figures V-1 and V-2 showing itemized water distribution expenditures, it was determined that only information for the years after 1977 would be suitable for this analysis. There are noticeably larger water usage patterns prior to 1978 which indicate that there were major processes in operation at that time which no longer exist. It is believed that the additional water demand made necessary by these operations affected the operation and maintenance requirements only during the period of time that they were in operation and are no longer applicable.

Potable Water System Projections

Estimates were made concerning the trend for labor, utility and maintenance components of the potable water system through the year

1987. The method for determining the trends for each component is outlined as follows:

The trend for labor requirements was determined after analyzing the results of Figure IV-2. After 1977, the man-hour requirements have stabilized around a value of 2,000 hours. Allowing for a ten percent deviation, it is estimated that 2,200 man-hours will be required to maintain the system. However, the organization selected to operate and maintain the system in the future will probably not operate as efficiently as the existing maintenance personnel during the first few years. Labor rates in terms of dollars per man-hour were estimated by projecting burden rates of the existing maintenance personnel. The 1982 rate was inflated nine percent annually and an overhead factor varying from 46 to 48 percent was applied in order to develop the annual labor rates.

Water usage trends were estimated after reviewing billings to Rocky Mountain Arsenal for potable water used during the period from 1978 to 1981. The annual water usage averaged approximately 42,830 million gallons. A conservative value of 45,000 million gallons was used for the projected annual potable water usage. It is assumed that the water usage rate will not vary significantly during the next five years. The cost to purchase potable water was obtained from the city of Denver. The existing rate is 42.3 cents per 1,000 gallons for 45,000 gallons. Indications are that this rate may be increased during 1984. The existing rate was estimated to increase by ten percent per year beginning in 1984. (See Table VI-1.)

The trend for maintenance requirements was determined after analyzing Figure V-1. After 1977, the annual maintenance expenditures have not exceeded $46,500. A conservative value of $48,000 was assumed for the maintenance expenditure for 1982. This value was inflated annually by ten percent throughout the study period.

Table VI-1

Potable Water System
Future Operation and Maintenance Analysis

1982 - 1987

O & M Items	1983	1984	1985	1986	1987
Labor Man-hours	2,400	2,300	2,200	2,200	2,200
Labor Rate ($/Hr.)	20.06	21.88	24.02	26.18	28.73
Labor Cost ($)	48,144	50,324	52,844	57,596	63,206
Water Use (MG)	45,000	45,000	45,000	45,000	45,000
Water Rate ($/1000G)	0.423	0.465	0.465	0.465	0.465
Water Cost ($)	19,035	20,925	20,925	20,925	20,925
Maintenance Cost ($)	52,800 *	58,100	63,896	70,280	77,300
Total Cost ($)	119,979	129,349	137,659	148,801	161,431

*An additional $187,200 is recommended to replace a portion of the 10" water main leading to the South Plants Area.

The results of the future operation and maintenance analysis are presented in Table VI-1. This analysis was used to determine the projected operation and maintenance expenditures over a five-year period.

Process Water System Projections

Estimates were also made concerning the trend for labor, utility and maintenance components of the process water system through the year 1987. The method for determining the trends for each component is as follows:

The trend for labor requirements was determined after analyzing Figure IV-4. After 1978, the man-hour requirements have stabilized

near a value of 3,000 hours. Allowing for a ten percent deviation, it is estimated that 3,300 man-hours will be required to maintain the system in the future. However, the succeeding organization will not operate as efficiently as the existing maintenance personnel during the first few years. Labor rates used are the same that were used to determine the potable water system labor expenditures.

Water usage trends were estimated after reviewing billings to Rocky Mountain Arsenal for process water during the period from 1978 to 1981. The average annual process water usage averaged approximately 25,300 million gallons. Due to the fact that the water usage in 1978 was unusually low, a conservative value of 30,000 million gallons was used for the projected annual process water usage. It is assumed that the water usage rate will not vary significantly during the next five years. There is no direct cost associated with the purchase of water since it is obtained from surface runoff. The utility cost for obtaining process water involves the electrical requirements needed to pump process water into the distribution system. Past process water records indicated that the electrical requirements for pumping was approximately 1.4 KWH per million gallons. Additional pumping is required to maintain adequate water pressure in the system. This will result in a 660,000 KWH demand per year based on a water demand of 30,000 million gallons per year. The cost to purchase electricity was obtained from the Public Service Company of Colorado. The existing rate is 3.58 cents per KWH. This rate is anticipated to increase to 4.0 cents per KWH when the decreased operation is in effect. The electricity rate was increased by 12 percent in 1983 and ten percent annually for the remainder of the study period.

The trend for maintenance requirements was determined after analyzing Figure V-2. After 1977, the annual maintenance expenditures have averaged approximately $121,200. The value should decrease in

1983 when wash-downs from a current decontamination project are completed. It is estimated that the maintenance costs will also decrease by 25 percent when the process water return facilities are shut down. Maintenance expenditures for 1983 are estimated to be $90,800. This value was inflated annually by ten percent throughout the study period.

The results of the future operation and maintenance analysis are presented in Table VI-2. This analysis was used to determine the projected operation and maintenance expenditures over a five-year period.

Table VI-2

Process Water System
Future Operation and Maintenance Analysis

1982 - 1987

O & M Items	1983	1984	1985	1986	1987
Labor Man-hours	3,500	3,400	3,300	3,300	3,300
Labor Rate ($/Hr.)	20.06	21.88	24.02	26.18	28.73
Labor Cost ($)	70,210	72,204	74,462	81,158	89,063
Water Use (MG)	30,000	30,000	30,000	30,000	30,000
Pumpage (KWH)	660,000	660,000	660,000	660,000	660,000
Pump Rate ($/KWH)	0.045	0.050	0.055	0.061	0.067
Pump Cost ($)	29,700	33,000	36,300	40,260	44,200
Maintenance Cost ($)	90,800	99,880	109,868	120,855	132,940
Total Cost ($)	190,710	205,084	220,630	242,273	266,223

VII. SUMMARY AND CONCLUSIONS

In general, the potable and process water systems in Rocky Mountain Arsenal are in fair condition. The structures and mechanical equipment in the systems are serviced regularly and are in good condition. Water pipes in the systems, however, are considered to be in poor condition. Leaks that occur in the lines are repaired immediately but, due to the age of the system, the pipes are seriously deteriorated.

The water systems seem to have been maintained satisfactorily by Shell Oil Company. Maintenance associated with the potable water system mainly involved servicing the chlorination facilities and repairing water lines and their appurtenances. Maintenance associated with the process water system principally involved repair and servicing of the utility buildings and structures, repairing water lines, maintaining the lakes and canal in the supply system, and servicing the pumps within the system.

Future maintenance requirements of the water systems are not expected to change significantly in the future. The same maintenance activities will be required to keep the system in an adequate and serviceable condition. Pipe leaks may become more prevalent due to the age and existing condition of the pipes. This will increase the maintenance requirement in the future. Replacement of the main potable water line entering into the South Plants area would greatly decrease the amount of underground leak repair which would otherwise be necessary. Operation requirements for the water systems will be reduced due to the decrease in water demand. The facilities still must be serviced regularly and will not cause a significant decrease in the maintenance requirements, except for a reduction in maintenance of the process water return system.

A major result of future operation of the water system will be a significant decrease in the utility purchase requirement. The potable water requirement for Rocky Mountain Arsenal has amounted to only 35 to 40 percent of the present total water requirement in recent years. Although the decrease in potable water requirement will significantly affect the overall operation and maintenance expenditures, it will not affect Rocky Mountain Arsenal since presently they only pay for the water they actually use. The utility purchase requirement for the process water system will also decrease significantly due to a lower electrical demand for pumping water into the distribution system. Although the process water presently used by Rocky Mountain Arsenal is only one percent of the total process water pumped, it will be necessary to provide for adequate fire protection requirements. Presently the Arsenal pays for the process water they actually use and a demand charge to account for their portion of the fire protection provisions.

After evaluating the labor, utility, and maintenance components of the potable and process water systems, a five-year operation and maintenance expenditure projection was made. The result of this analysis is presented in Figures VII-1 and VII-2 for the potable and process water systems respectively. Previous and projected annual expenditures are presented for the period 1972 to 1987. A graph of the total water system previous and projected annual expenditures is shown on Figure VII-3. This represents the total expenditure required to operate and maintain both the potable and process water system. The projected annual expenditures are only an estimate based on present operation and maintenance activities. It is believed that these results accurately estimate the current trends and will be useful in determining future operation and maintenance requirements.

FIGURE VII-1

POTABLE WATER DISTRIBUTION SYSTEM
OPERATION AND MAINTENANCE EXPENDITURES 1972-1981

SHELL OIL COMPANY LEASEHOLD

US ARMY ROCKY MOUNTAIN ARSENAL

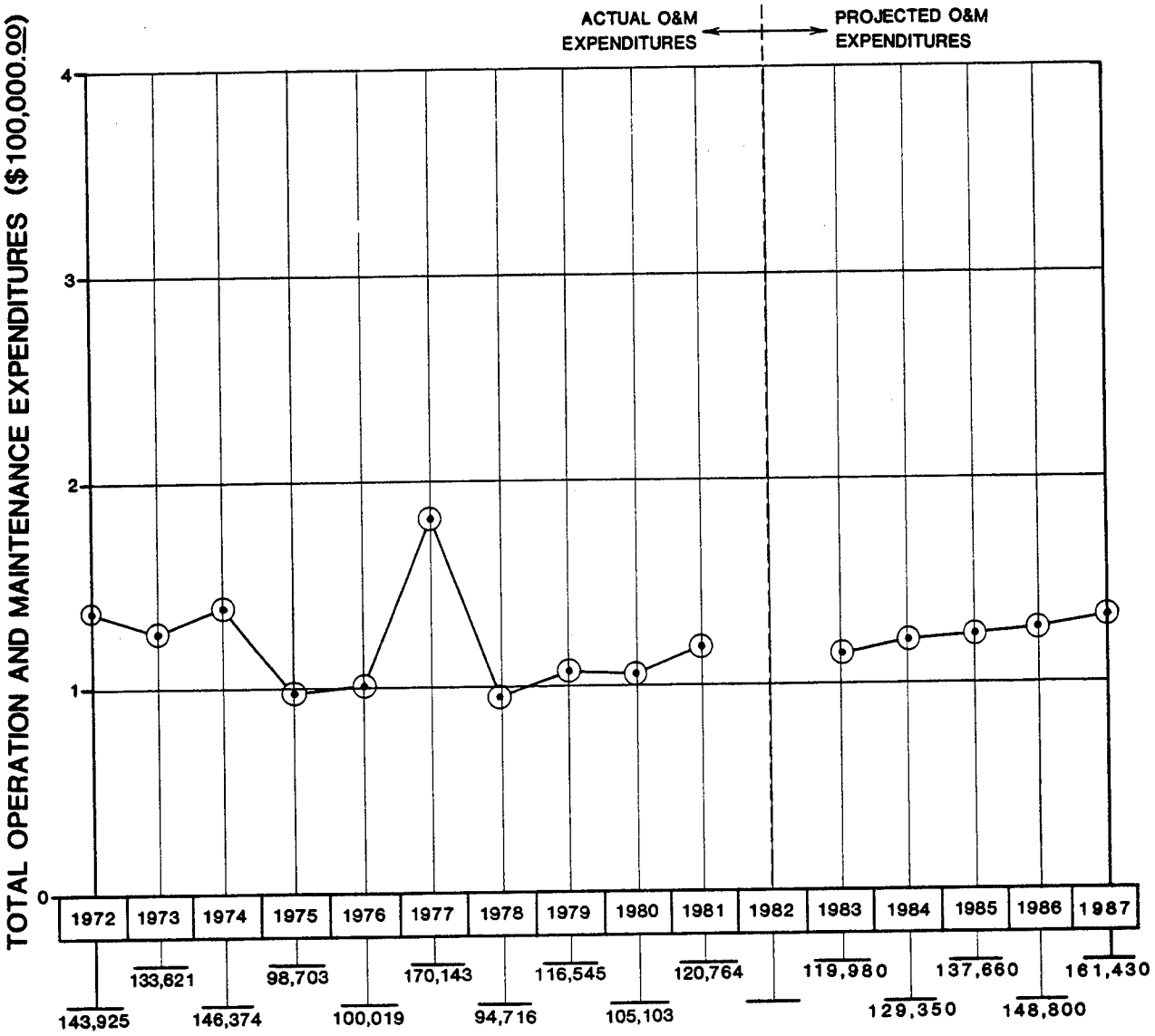


FIGURE VII-2

PROCESS WATER DISTRIBUTION SYSTEM
OPERATION AND MAINTENANCE EXPENDITURES 1972-1981

SHELL OIL COMPANY LEASEHOLD

US ARMY ROCKY MOUNTAIN ARSENAL

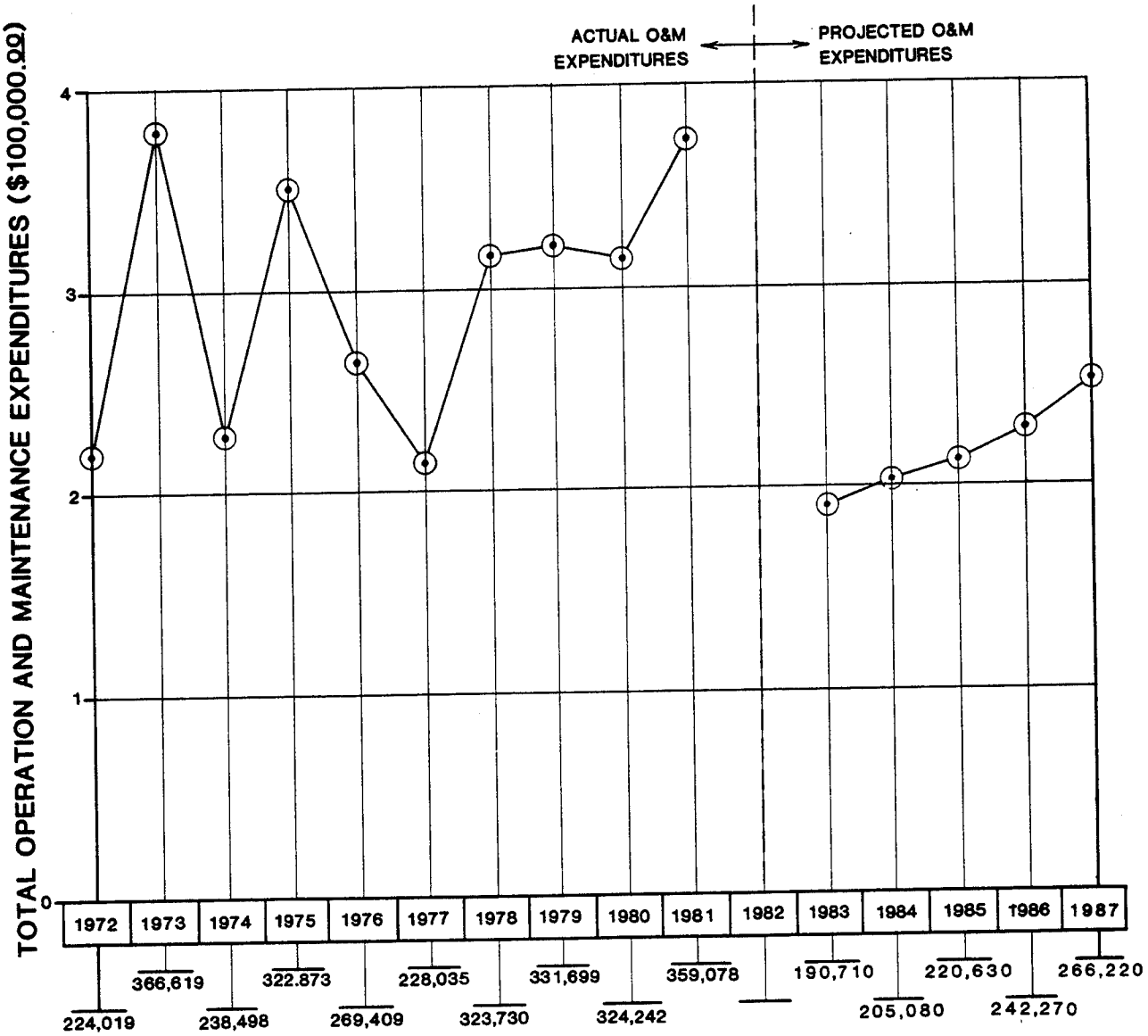


FIGURE VII-3

TOTAL WATER DISTRIBUTION SYSTEM
OPERATION AND MAINTENANCE EXPENDITURES 1972-1981

SHELL OIL COMPANY LEASEHOLD

US ARMY ROCKY MOUNTAIN ARSENAL