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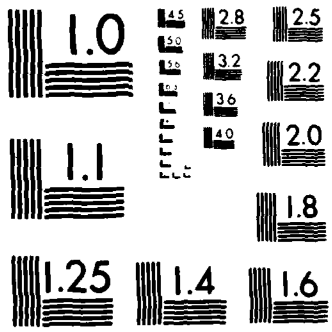

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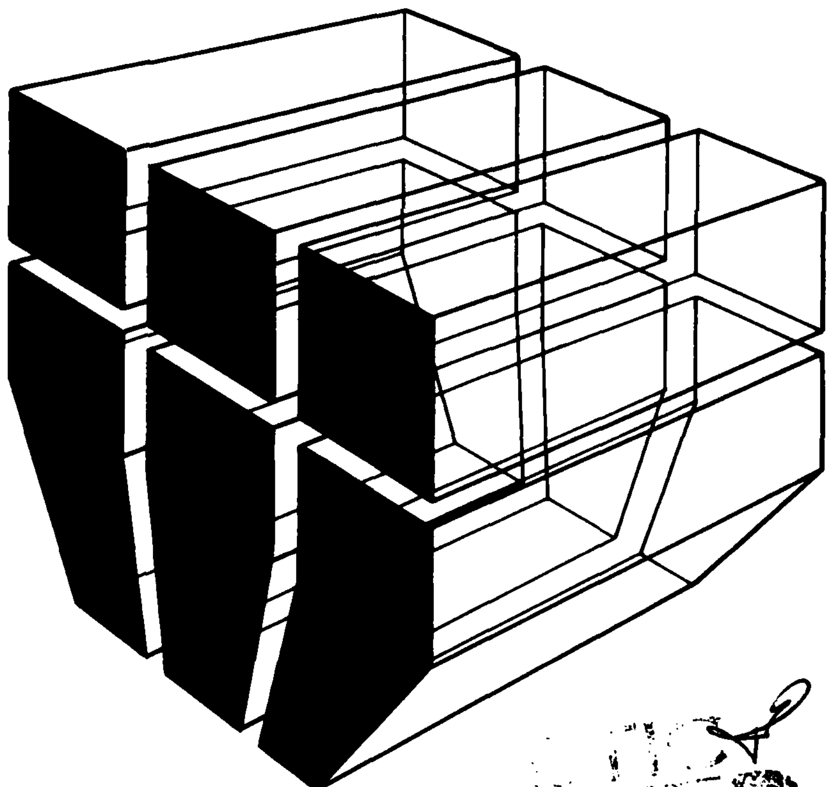
TECHNICAL REPORT N-85/01
November 1984
Closed-Loop Water Conservation/Supply Augmentation Techniques

CLOSED-LOOP CONCEPTS FOR THE ARMY: WATER CONSERVATION, RECYCLE, AND REUSE



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Potential commitment of U.S. Army troops in the Middle East and Southwest Asia has raised the issue of water supply in the success of combat operations. Moreover, increased demands for water in the face of growing ground- and surface water pollution, changes in global weather patterns, and expanding agriculture may affect the Army's mission in the future both at home and abroad. Coupled with increasing costs for potable water and outside wastewater treatement, this outlook suggests a clear need for conservative water use at Army installations. (Continued)

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To update existing regulations for Department of Defense facilities, a "closed-loop" approach is proposed. Water conservation, recycling, and reuse in various combinations can be initiated to reduce the need for fresh water and simultaneously cut the cost of heating wasted water. The closed-loop measures applying to a given installation must be determined individually. Factors such as geography, climate, population numbers, and mission are assessed and then the feasibility of each conservation, recycle, and reuse measure is judged. Possibilities for using closed-loop technology are explored for several types of Army installations.

Although it may be found impractical to use certain recycle or reuse techniques at some installations, conservation can probably be improved to some extent at all DOD facilities. Thus, education should help increase conservation awareness by U.S. troops, many of whom are accustomed to plentiful water supplies. DOD installations worldwide can benefit from a holistic approach to water use.

FOREWORD

This study was conducted for the Directorate of Engineering and Construction, Office of the Chief of Engineers (OCE), under Project 4A762720A896, "Environmental Quality Technology"; Task A, "Installation Environmental Management Strategy"; Work Unit 031, "Closed-Loop Water Conservation/Supply Augmentation Techniques." The work was performed by V. J. Ciccone Associates, Inc., for the Environmental (EN) Division of the U.S. Army Construction Engineering Research Laboratory (USA-CERL) under Contract No. DACA88-82-C-0016. The applicable STO is 6.27.20A. The OCE Technical Monitor was Mr. R. Newsome, DAEN-ZCF-U.

OCE, the Troop Support Agency at Fort Lee, VA, and the Construction Management Office of the Chief of Army Reserve provided information on water use patterns Army-wide.

Dr. R. K. Jain is Chief of EN. COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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1 INTRODUCTION

Background

Shortages of fresh, clean water are being experienced throughout the world, with prospects of becoming more severe unless better management is given to this vital resource. Even in areas of the United States, what were once thought to be limitless supplies of good water are either severely polluted or are being rapidly overtaxed.

There is no evidence that the Army's mission currently is impaired by water shortages. However, it should not be assumed that water will remain plentiful in the future. Recent focus on water as a factor in the success or failure of combat operations has been motivated by the potential for commitment of U.S. troops in the Middle East and Southwest Asia. In addition, the expansion ability of some existing U.S. installations probably is already limited by available water sources or water supply systems. It is also possible that some installations could be handicapped by a shortage of water in the future as water demands increase due to regional population growth or industrial expansion.

By instituting measures to reduce the demand for water now, the Army can save water and lower the cost of both water supply and wastewater treatment from the current level of $120 million per year. Also, there is a good potential for lowering energy costs if hot water usage can be reduced.

The Army should take a holistic approach toward the use of water. Such an approach is called a "closed-loop" concept in this study. It encompasses water conservation, recycling, and reuse. The opportunities to use one or a combination of these water-saving measures depend somewhat on the type of installation. In general, conservation could be practiced by all installations, recycling could be adopted for large water using activities, and water reuse could be considered for landscape and golf course irrigation at larger installations that still operate on-post sewage treatment plants.

Objective

The objectives of this study were to (1) examine the feasibility of implementing a closed-loop water reuse concept at various types of Army installations in the United States and overseas during peactime, mobilization, and wartime; and (2) provide a priority listing of installation activities for which water consumption and related water supply and wastewater treatment costs could be significantly reduced by water reuse.

Approach

Army data, technical information files, and general literature were searched to obtain information on Army water consumption levels, previous water reuse studies, and current water reuse technology. Several Army officials were interviewed for their views about water recycle and reuse opportunities at U.S. military installations worldwide. Information on commercial water treatment processes and product literature on selected items was requested from manufacturers. Selected technical and sales representatives were interviewed. Researchers from the U.S. Army Construction Engineering Research Laboratory (USA-CERL) attended the Bright Star 83 Exercises in the Mideast to learn which field water consumption activities offer the best opportunities for water savings through use of the closed-loop concept.

Mode of Technology Transfer

It is recommended that the information from this study be incorporated into a new technical manual on Army water conservation.

2 THE CLOSED-LOOP CONCEPT

Definitions

A "closed-loop water use" concept is the controlled use of available water supplies at an Army installation or separate activity. It includes water conservation and wastewater use by recycling alone or recycling and reuse, which may involve some degree of treatment. "Conservation" is a reduction in the demand for water by improved efficiency of use, or by reduced losses and water waste.[1] "Recycling" is the internal use of water by the original user before discharge. The term "reuse" applies to wastewaters discharged and then withdrawn by a user other than the discharger.

Assumptions

With today's technology, most wastewater can be treated to almost any level of quality. However, the greater the pollutant load and the higher the level of purity desired, the higher the cost.

There are no known instances in which potable water has been produced directly from domestic sewage or industrial wastewater. The Army developed a treatment system for nonsanitary wastewater from a field hospital, but decided not to use it because of its complexity and high cost.[2] Also, a demonstration project has been initiated by the city of Denver, Colorado, to process domestic wastewater using equipment produced by the Pure Cycle Corporation. These cases and a few research projects indicate the feasibility of producing potable water; but the economics, equipment reliability, and most important, public acceptance for the direct use of domestic wastewater as a source of drinking water have not been established.

Conditions do not exist currently, nor can it be predicted, where or when the Army might have to rely on potable water produced from wastewater. Even in water-short desert areas, the Army has elected to use seawater as a raw water source, because it can be treated with minimal concern for the presence of pathogenic organisms.

The production of nonpotable water from wastewater generally requires less sophisticated and less expensive treatment procedures than that for potable water. Also, the concern for health-related problems, although present, is much less if wastewaters are reclaimed for nonpotable use.

The reuse and recycling of wastewater by industry and agriculture has only recently become accepted as good business practice. The impetus behind this has been the enactment of Federal and State pollution abatement laws and regulations and the development of new technology to control pollutant discharges. With nearly 10 years of experience, commercial enterprises have

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[1] K. R. Sheets, "Water--Will We Have Enough to Go Around?", U.S. News & World Report (29 June 1981).

[2] M. K. Lee, et al., Water Purification Unit Development for Field Army Medical Facilities (Life Systems, Inc., Cleveland, OH, April 1978).

become aware that wastewater recycle and reuse can also produce significant cost savings through reductions in potable water consumption.

Recycle or reuse of domestic or industrial wastewater generally requires some form of pretreatment; industry has developed a wide variety of pretreatment processes and equipment. In most instances, however, each treatment process has to be tailored to meet the specific conditions, such as the quantity and quality of wastewater, acceptable quality of the end product, climatic conditions, and local pollution control requirements. Therefore, it is usually easier to pretreat an individual wastewater stream than a mixture of many discharges.

Need for the Closed-Loop Concept

Serious water shortages affected U.S. troops in some World War II operations. Through the end of this century, battle doctrine will most likely require even more water than would have been needed to offset World War II shortages because of the following considerations:

- Contamination by chemical and biological agents
- A force consumption rate by troops engaged
- Extensive, rapid site preparations
- Overburdening of fixed installation capacities during rapid mobilization
- Health and welfare of extensive refugee and displaced person populations
- Yields of water supply systems in rear areas suddenly forced to accommodate population orders of magnitude greater than their natural carrying capacities
- Prioritized water distribution
- Competition of water supply with ammunition and POL logistics.

The United States' commitments worldwide include contingency plans for rapid deployment of ground combat troops in strengths up to a reinforced corps. Troop placement in combat or noncombat zones demands an adequate water supply. This need is especially critical when commitments require troop placement in a desert, where the limited water supply poses a need for maximized conservation and recycling.

In particular, closed-loop concepts should be incorporated into U.S. Central Command's Near-Term Scenario Desert Base development activities. This experience would be valuable in developing practical, expedient mechanisms to reduce the logistics burden of water supply in the Mideast Theater of Operations. In fact, significant water, energy, and cost savings could be realized Army-wide by instituting a water management program and by using state-of-the-art technology to conserve water and recycle or reuse wastewater. The following types of Army installations could benefit from this closed-loop concept:

- U.S. troop
- Commercial and industrial type
- Army Reserve training
- Mobilization emergency
- Overseas semipermanent

- Theater of Operations
- Remote single-purpose
- Overseas special-purpose.

Development of a Closed-Loop Plan

The choice of techniques and equipment must be limited to realistic, low-cost measures that will not overburden the military logistics system and that will be consistent with the training and skill levels of troops using them under tactical conditions. Simplicity of operation and maintenance is the overriding consideration.

USA-CERL has developed near-term operational concepts for managing water resources in an arid environment. These concepts are based on engineering judgment and military experience and can save water for typical water using activities. To develop these concepts, the water consuming activities of a representative military force that might be deployed to Southwest Asia (SWA) were examined (Table 1). Then, a detailed analysis was made of each activity to identify opportunities for use of closed-loop concepts by:

- Controlling excessive water usage
- Minimizing water loss through evaporation, spillage, and contamination
- Reusing water by internal recycling or some other measure
- Substituting water of lesser quality where it has been customary to use fresh water.

The concepts developed for the SWA force may apply to other Army installations as well. Each set of circumstances must be examined to decide which parts of a closed-loop plan are feasible for a given installation.

Table 1

Water Using Military Field Activities

Activity	Potable	Nonpotable
Major uses		
Drinking	X	
Hospital operations	X	
Decontamination		X
Construction		X
Dust control		X
Aircraft cleaning		X
Mess operations (Food preparation and utensil cleaning)	X	
Personal hygiene (Washing, shaving, teeth brushing)	X	
Showers		X*
Laundry		X*
Minor uses		
Bakery operations	X	
Photo developing	X	
Vehicle cooling makeup		X
Graves registration		X
Well drilling		X*
Pest control		X

*Nonpotable water can be used, but it must be clean and free of pathogenic organisms.

3 OVERVIEW OF WATER RESOURCES

World Water Situation

Changes in global weather patterns, agricultural expansion, and increased industrial wastewater discharges have increased the concern about future availability of fresh water. Frequent abnormal global weather patterns have resulted in too little rainfall to maintain water reservoirs at desired levels in many parts of the world. Expansions in agriculture needed to satisfy the increasing demand for food have caused farmers in many countries to use clean underground water for irrigating crops. In addition, pollutant levels in many rivers and other surface waters are now at such high levels that highly sophisticated treatment processes are needed to make water usable for domestic purposes.

These conditions have prompted many nations to search for ways to reuse water and thereby ease the demand on fresh water resources. In Israel, full reuse of urban and industrial wastewater has become a matter of national policy.[3] By 1981, about 30 percent of sewered domestic area wastewater was treated and reused, mostly for agricultural purposes. It is anticipated that by the year 2000, some 80 percent of that nation's wastewater flow will be reclaimed and reused.[4]

South Africa is taking the same action as Israel by imposing strict requirements on the treatment, disposal, and reuse of sewage effluent. Certain regions of that country are now rapidly approaching the point at which effluent from advanced wastewater treatment plants may have to be blended with conventional water supplies for potable use.[5]

Today, The Netherlands, a country rich in water, is confronted with a rising demand for rapidly decreasing fresh water supplies. The alternatives being examined are to treat either domestic sewage or the highly polluted water from the Rhine River.[6] Solutions to the same type of problems are being

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[3]R. Friedman, "Dan Region Project in Israel: From Laboratory Experiments to Full-Scale Wastewater Reuse," Proceedings--Water Reuse Symposium, Volume II (American Water Works Research Foundation, 1979), p 808.

[4]H. I. Shuval, "The Development of the Wastewater Reuse Program in Israel," Proceedings--Water Reuse Symposium II, Volume I (American Water Works Foundation, 1981), p 147.

[5]P. E. Odendaal, "Reuse of Wastewater in South Africa--Research and Application," Proceedings--Water Reuse Symposium, Volume II (American Water Works Research Foundation, 1979), p 886; A. F. Zunckel and M. P. Oliveira, "South African Water Reuse Policy and Its Practical Implications," Proceedings--Water Reuse Symposium II, Volume I (American Water Works Research Foundation, 1981), p 249.

[6]J. Hrubec, et al., "Studies on Water Reuse in the Netherlands," Proceedings--Water Reuse Symposium, Volume II (American Water Works Research Foundation, 1979), p 785.

sought in Hong Kong[7] and Mexico City,[8] and it is not unreasonable to expect that other densely populated areas will soon suffer the same plight.

U.S. Water Situation

Water supply problems in the United States have not reached quite the same proportions as in other countries; nevertheless, there are signs of an impending crisis. Legal battles over scarce water supplies are being waged, and rising sales of bottled water and home water purifiers reflect the public's fear of chemicals, bacteria, and toxic substances in drinking water.

The persistent water shortage problems in California and parts of the Southwest have long been publicized. Even the interbasin transfer of water from the Colorado River to southern California has not turned out to be the long-term solution needed. Although parts of the country have experienced sporadic water shortages in recent years, the most serious problem is developing on the High Plains, an area stretching from Texas to Nebraska. This entire region lies atop the Ogallala Aquifer, which is the source of drinking water for two million people and the lifeblood for a vast agricultural region. Water is being pumped at such a high rate from the aquifer that some researchers predict supplies could be seriously depleted by the year 2020.[9]

Warnings that the country is running out of clear, usable water have gone largely unheeded. There are, however, individual localities with continuing water problems, such as Denver, Colorado, that are attempting to find solutions before the situation becomes too serious. That city has completed a 10-year pilot study on producing potable water from domestic sewage and has initiated construction on a 1 mgd water reuse demonstration plant.[10] Preliminary indications are that the adopted technology can provide potable quality water, but the question remaining unanswered is--will the public accept the drinking water produced from their own sewage after the extensive testing program is completed and there is verification that the water is safe to drink?

The government has spent large sums of money over the past decade to clean up surface waters and make them "fishable and swimmable." Under the Clean Water Act, municipalities throughout the country are improving their sewage treatment. Also, industry in general is curtailing the discharge of pollutants and toxic substances in an effort to help restore river and stream quality.

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[7] W. R. Everest, "Reclamation of Wastewaters and Degraded River Waters by Advanced Waste Treatment in Hong Kong," Proceedings--Water Reuse Symposium II, Volume I (American Water Works Research Foundation, 1981), p 443.

[8] G. M. Gomez and F. F. Herrera, "Mexico City's Master Plan for Reuse," Proceedings--Water Reuse Symposium II, Volume I (American Water Works Research Foundation, 1981), p 308.

[9] K. R. Sheets.

[10] M. R. Rothberg, et al., "Demonstration of Potable Water Reuse Technology--The Denver Project," Proceedings--Water Reuse Symposium, Volume I (American Water Works Research Foundation, 1979), p 105.

The need is apparent for new, imaginative strategies to solve problems of water quality and quantity now confronting the United States and many other countries. What corrective measures should be taken have not yet been proposed, but it is quite certain that the future cost of water will be much higher than it is today.[11]

U.S. Army Water Situation

As one of the nation's largest water users, the Army also generates large quantities of wastewater. Figure 1 shows the history of both water usage and wastewater discharged during the 6-year period Fiscal Year (FY) 76 to FY81. While the amount of wastewater generated remained relatively constant, water usage decreased about 16 percent. This reduction is essentially all attributable to decreased water usage at ammunition plants.

While water usage has been declining, the cost of water has steadily risen. Over the 6-year period, the cost of providing water rose by 67 percent and the cost of wastewater treatment rose by 113 percent (Figure 2). As a result, the operation and maintenance (O&M) of these basic utilities now cost the Army nearly $120 million per year.*

Some Army installations located primarily in the west and southwest sections of the country have already experienced water problems. Forts Ord and Huachuca and White Sands Missile Range have had to periodically impose water use restrictions to avoid excessive draw-down in their well systems. Forts Bliss and Carson and their neighboring communities share raw water sources that today are being heavily taxed to support growing regional populations.

Except for the isolated instances above, there is no evidence that water conservation is a normal practice at Army installations in the United States. This same situation prevails at overseas installations, except that in West Germany, where the cost of water is high, considerable attention is devoted to maintenance and repair of water systems to minimize leakage.

To an extent, the Army's pollution abatement program has contributed to improved water management. For example, the number of vehicle washracks at many of the larger posts has been reduced to minimize the number of wastewater discharge permits that must be obtained. Also, as new centralized vehicle washing facilities are installed, water recycling features are being provided. The need for wastewater discharge permits has also increased water reuse. However, such instances have been limited to use of treated sewage effluent for golf course and landscape irrigation.

The opportunities to recycle or reuse water and the related cost-benefit features have been the subjects of several separate studies and research projects. An annotated bibliography of such reports is provided in Appendix A. Of those cited, only one (Reference 7) pertains to permanent installations. The rest focus on proposed wastewater treatment processes to permit water

[11] K. R. Sheets.

*Excludes the cost of O&M for water distribution and sewage collection systems, which amounts to an additional $30 million per year.

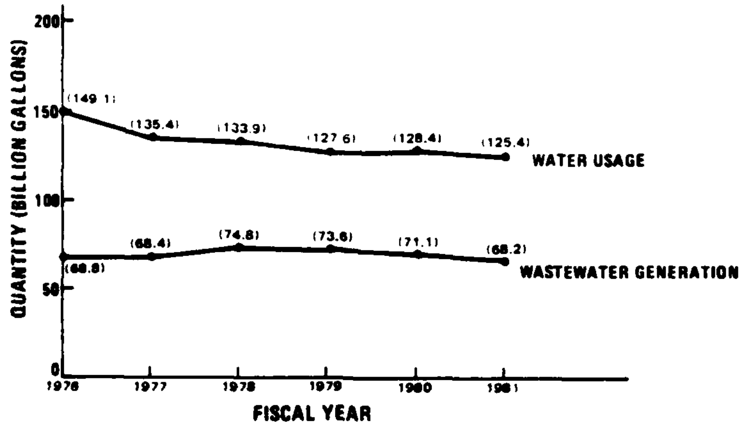

Figure 1. Water usage and wastewater generation Army-wide. (From Annual Summary of Operations [Facility Engineering, Office of the Chief of Engineers, U.S. Department of the Army, Fiscal Years (FY) 1976 to 1981].)

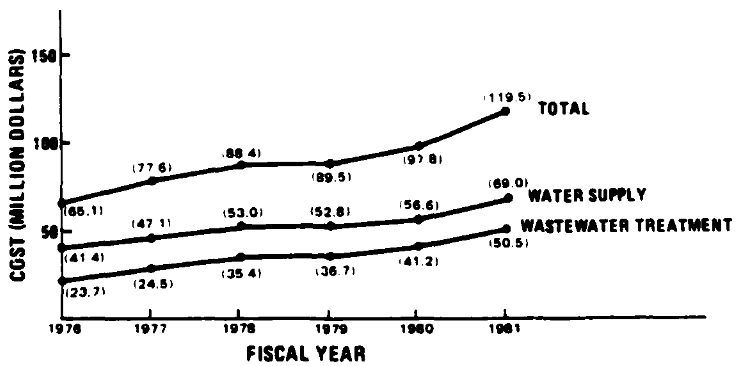

Figure 2. Cost of water supply and wastewater treatment Army-wide. (From Annual Summary of Operations [Facility Engineering, Office of the Chief of Engineers, U.S. Department of the Army, FY76 to FY81].)

recycling by field hospitals, showers, and laundries in a Theater of Operations.

An interest in controlling water usage has developed in the Army, but most attention is being focused on water conservation in hot desert regions. Little has been done to implement the recommendations from any of the prior studies, except to incorporate certain water-saving devices and techniques into the Army Facilities Component System. Meanwhile, some of the earlier concerns for water quality and quantity are resurfacing as even greater problems. They include the potential impact on the Army industrial base should there be inadequate water supplies, the constraint that installation water supply systems will have on Army mobilization ability, and the need for a more versatile way to produce and distribute potable water that will meet the needs of today's mobile Army forces.

4 ANALYSIS OF ARMY INSTALLATIONS

Troop Installations in the United States

Troop installations in the United States and its territories are identified as either active or semiactive. Active installations are those in continuous use and, as such, are authorized permanent facilities designed and constructed in accordance with DOD construction criteria.[12] Semiactive installations are primarily those built during World War II that are no longer in continuous use; instead, they are used by Reserve Components for annual training or by active Army units for field exercises. They are also maintained as installation resources in the event of mobilization. Facilities at semiactive installations, except those occupied by the active Army garrison, are emergency (mobilization)-type designed to criteria established by OCE. The garrison force, on the other hand, is usually provided permanent facilities in accordance with DOD construction criteria.

Water usage design criteria for Army installations in the United States have remained unchanged since World War II at 150 gal/person/day (see Appendix B). Actual water usage for FY77 for all U.S. installations averaged 194 gal/-person/day.* The highest, 442 gal/person/day, was reported for the Health Services Command (HSC) and the lowest, 46 gal/person/day, was by the Military District of Washington (MDW). The Training and Doctrine Command (TRADOC) and Forces Command (FORSCOM), with their large troop populations, used 172 and 148 gal/person/day, respectively, during the same period.[13]

The history of water usage and the associated O&M costs from FY76 through FY81 are shown in Figures 3 and 4, respectively. This record gives no definite trend in usage and the annual fluctuations of approximately 10 percent cannot be readily explained. The history of costs reflects an even more irregular pattern, in that annual costs do not coincide with changes in the volume of water used. It is possible to conclude, however, that although average annual water usage has not noticeably decreased, costs have definitely risen.

Several factors contribute to the cost increases--for example, higher energy prices, higher expenditures for plant maintenance and repair, and the continuously rising cost of purchased water. In regard to water prices, 36 of 97 Army installations in the United States purchase all or nearly all of their water, which amounts to about 26 percent of the total water usage by troop installations reported in FY81.[14]

In contrast to water usage, the volumes of wastewater generated fluctuated little over the 6-year period (Figure 3). However, the cost of treatment and disposal reflects the same rising trend experienced in supplying water (Figure 4). The one factor adding significantly to costs has been the change

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[12] DOD 4270.1-M, Construction Criteria (U.S. Department of Defense, June 1978).

*Last year for which published data on consumption per capita is available.

[13] Annual Summary of Operations (Facility Engineering, Office of the Chief of Engineers, U.S. Department of the Army, FY76 through FY81).

[14] Annual Summary of Operations, FY81.

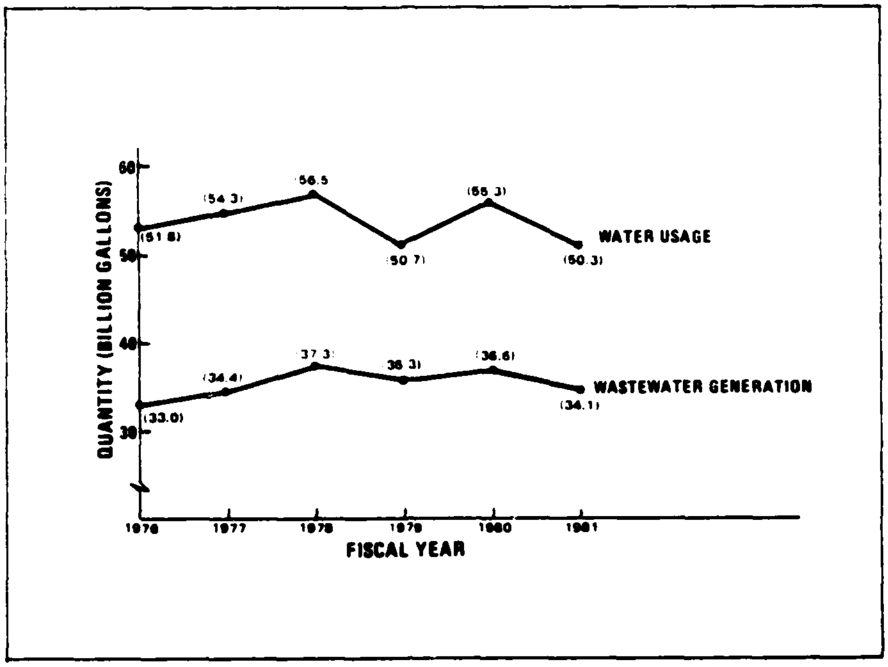

Figure 3. Water usage and wastewater generation for troop installations in the United States. (From Annual Summary of Operations [Facility Engineering, Office of the Chief of Engineers, U.S. Department of the Army, FY76 to FY81].)

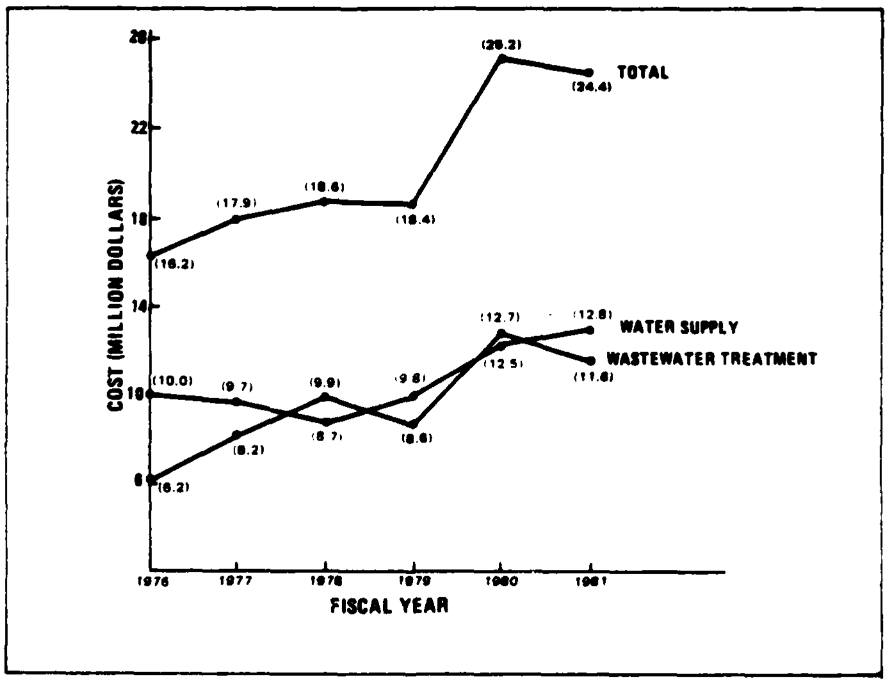

Figure 4. Cost of water supply and wastewater treatment for troop installations in the United States. (From Annual Summary of Operations [Facility Engineering, Office of the Chief of Engineers, U.S. Department of the Army, FY76 to FY81].)

from on-post sewage treatment to off-post treatment service at regional plants. Under the Army Pollution Abatement Program, 41 of 96 troop installations now purchase wastewater treatment service for 80 percent or more of their wastewater. Further, 13 others have been connected to plants that receive less than 80 percent of the installation's discharge.

On average, about 66 percent of the potable water used by U.S. troop installations reaches sewage treatment facilities. TRADOC and FORSCOM installations treat 69 percent and 67 percent, respectively, which closely approximates the generally accepted design factor of 67 percent for sizing sewage treatment facilities.

Overview of Water Using Activities

Water using activities at most troop installations closely parallel those in a civilian urban community of comparable size. They include functions commonly associated with residential housing (family and bachelor quarters), administration, retail sales, schools/training, and food service. In addition, there are commercial and industrial activities encompassing vehicle and aircraft washing, central heating and air-conditioning plant operations, and landscape irrigation. Details can be found elsewhere.[15]

Water use by activity or activity group is not currently measured because the Army has never required flow meters to be installed on distribution lines serving individual facilities. However, based on engineering estimates in a USA-CERL study of four of the Army's largest troop installations, it has been determined that troop and family housing-related functions and landscape irrigation are the largest water users.[16]

Water Conservation Opportunities

Except when individual installations have experienced an occasional water shortage, water conservation has not been practiced at Army installations. Because U.S. military personnel, like civilians, have become accustomed to using water freely, positive measures would be needed to reverse this pattern.

One effective way to change water using habits has been the use of water saving devices such as low-flow showers and low-flush toilets. Ten to fifteen percent reductions in water usage have been achieved by adding such mechanical devices to existing facilities.[17] At a typical Army post, water usage in family quarters alone could be reduced by almost 100,000 gal/day. Adding to this the potential savings in troop barracks and that realized by close regulation of lawn watering, the overall savings in water could be quite significant.

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[15] J. T. Bandy, M. Messenger, and E. D. Smith, A Procedure for Evaluating Subpotable Water Reuse Potential at Army Fixed Facilities, Technical Report N-109/ADA111191 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1981); J. Bandy and R. J. Scholze, Distribution of Water Use at Representative Fixed Army Installations, Technical Report N-157/A133232 (USA-CERL, 1983).

[16] J. Bandy and R. J. Scholze.

[17] Water Conservation Management (American Water Works Association, 1981).

A reduction in household water usage normally produces a major energy savings as well, since less water needs to be heated for bathing and other household functions. In addition, the overall quantities of water that must be processed through the water supply and sanitary waste disposal systems are reduced.

Although the use of water saving devices alone could conserve water, better results are achievable by integrating these measures into an installation, or even an Army-wide, program to promote water conservation. Other important aspects of such a program include educating installation residents and civilian employees, monitoring water usage, and making facility inspections.

Water Recycling Opportunities

The potential benefits from reusing water are probably greater at installations in the United States than elsewhere in the Army, because these facilities use the most water. However, the deterrents to recycling and reuse water must be understood. For example, about 33 percent of the troop installations today no longer operate sewage treatment plants, making it impractical to gain access to treated sewage effluent for further use. Further, because of the prevailing attitude in the Army toward water conservation and competing demands for funds, a closed-loop water use system probably would not be included in the installation's budget unless required to correct significant water shortage problems. Today, most Army posts have a large backlog of mission-related facilities yet to be funded, and these would probably be given priority over water reuse projects.

In an Army study on potential reuse of subpotable water at fixed facilities, the following activities and facilities are considered good candidates for using recycled water:[18]

- Cooling towers
- Industrial laundries
- Vehicle and aircraft washracks.

Of these, cooling towers are prime candidates for recycling because the necessary technology is simple and readily available. Newly constructed towers normally incorporate such recycling features. Older ones installed with once-through systems should now be candidates for retrofit with a recirculating system.[19]

The commercial laundry industry has not yet adopted total water recycling systems because of the high cost and the difficulties with renovating the wastewater. However, partial recycling, in which rinsewater is used for subsequent wash cycles, is considered practical and is being done on a limited scale. Because a typical post laundry consumes about 30,000 to 50,000 gal/day[20]

[18] J. T. Bandy, M. Messenger, and E. D. Smith.
[19] J. T. Bandy, M. Messenger, and E. D. Smith.
[20] J. T. Bandy, M. Messenger, and E. D. Smith.

this modified procedure has the potential of saving water as well as the energy needed to heat it.

Vehicle and aircraft washing facilities probably offer the best opportunity for recycling wastewater. USA-CERL is giving considerable effort to this matter, which has resulted in the recent installation of specially designed washracks for tracked vehicles at several installations, including Forts Lewis and Riley. Private industry has likewise focused much attention on cleaning automobiles, trucks, and aircraft with a minimum of water and with provisions for recycling. Many commercial systems do not require sophisticated, automated facilities and may have use in the military.

Water Reuse Opportunities

The most readily accessible source of wastewater is an on-post sewage treatment plant. In most instances, the quantity of water available is quite large, probably exceeding the amount that could be used conveniently. Of all possible uses, treated effluent is most suitable for landscape and golf course irrigation because usually no further treatment is needed to improve water quality beyond secondary standards.

Treated sewage effluent for golf course and landscape irrigation is currently used at White Sands Missile Range and at Forts Devens, Huachuca, and Carson. Other installations have evaluated irrigation as a way to dispose of sewage effluent, but none have found it to be as economical as conventional treatment systems, mainly because of the need to purchase additional land. Often the most suitable disposal sites on an installation are already used for other purposes or are not considered compatible with spray or overland flow disposal of wastewater. This deterrent to sewage effluent reuse could be greatly reduced if some form of drip irrigation could be established--particularly one that uses buried piping. Such systems are designed to deliver optimal amounts of water directly to the root zone of vegetation. Because water distribution for this type of system requires minimal pressure (generally gravity flow), water use is much more economical and O&M costs are lower than for either spray or overland flow systems.

Other direct uses requiring smaller quantities of well disinfected sewage effluent include steam cleaning and water screens for paint spray booths. However, if these facilities are not near the sewage treatment plant, piping treated effluent to them could be too costly compared to the benefits received.

Another possible source of low-cost water that can be used with no treatment is storm water. Modifications could be made to existing storm water collecting systems to collect rainfall runoff in ponds. This water could be used for recreational purposes or for irrigation, fire fighting, and other activities not requiring potable quality water.

Commercial and Industrial Installations

Commercial and industrial installations include storage and repair depots, arsenals, test ranges and facilities, and laboratories. Excluded from consideration are the Army plants that manufacture propellants, explosives, and pyrotechnics, and the operation of associated ammunition load-and-pack facilities.

Commercial and industrial installations consist of permanent facilities, usually designed and constructed to accommodate specific process operations. The workforce mainly consists of civilian employees who commute to and from the installation. Most are separate Army bases and are often located in or near large commercial and industrial centers from which the labor force and material support are usually obtained.

These types of facilities are operated by the Army Materiel Command (AMC), U.S. Army Health Services Command, and U.S. Army Engineer Command. Because most are the responsibility of AMC, this part of the analysis focuses only on these activities.

The quantities of water used and wastewater produced by AMC installations during FY76 through FY81 are shown in Figure 5. In general, the reported amounts reflect a relatively uniform pattern of water usage and wastewater generation.[21] This relationship also indicates that the quantity of wastewater produced averages about 60 percent of the water used.

The associated costs of water supply and wastewater treatment shown in Figure 6 reflect an increasing trend for these services. In both instances, the costs have increased nearly 100 percent over the 6 years for which records are available. Much of the increase can be attributed to the rise in personnel and energy costs associated with providing these utility services. It is notable that the unit cost of purchased water (about 2 billion gal/year) rose from $0.34 to $0.65 per 1000 gal over the 6 years. During the same period, the annual unit cost of purchased wastewater treatment services for about 1.2 billion gal increased from $0.29 to $0.70 per 1000 gal.[22]

Overview of Water Using Activities

Water using activities common to all commercial and industrial installations are basically person-related and include hygiene, comfort heating and cooling, housekeeping, and food preparation. Those directly related to mission operations naturally vary with the type of work performed. Depots performing maintenance and repair along with arsenals and equipment test activities customarily require water for employee showers and industrial operations such as steam cleaning, metal finishing and plating, paint spraying, and engine/transmission testing. These activities and the amounts of water involved are fully described elsewhere.[23]

The quantity of water required by laboratories depends on the type of research conducted. In general, relatively small quantities of water are used, and the demand commonly fluctuates throughout the year.

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[21] Annual Summary of Operations, FY76 through FY81.
[22] Annual Summary of Operations, FY76 through FY81.
[23] J. T. Bandy, M. Messenger, and E. D. Smith.

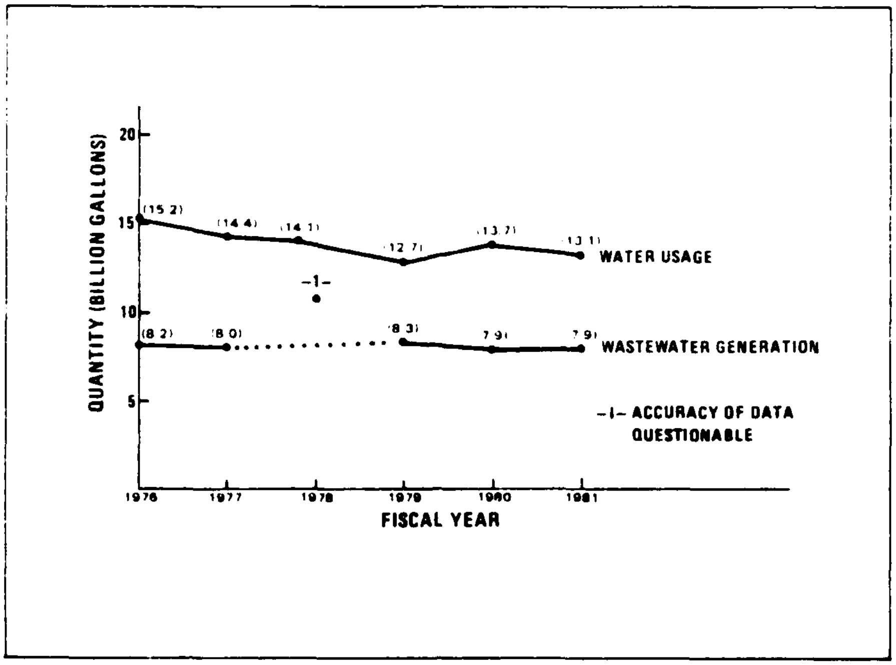

Figure 5. Water usage and wastewater generation for U.S. commercial and industrial installations. (From Annual Summary of Operations [Facility Engineering, Office of the Chief of Engineers, U.S. Department of the Army, FY76 to FY81].)

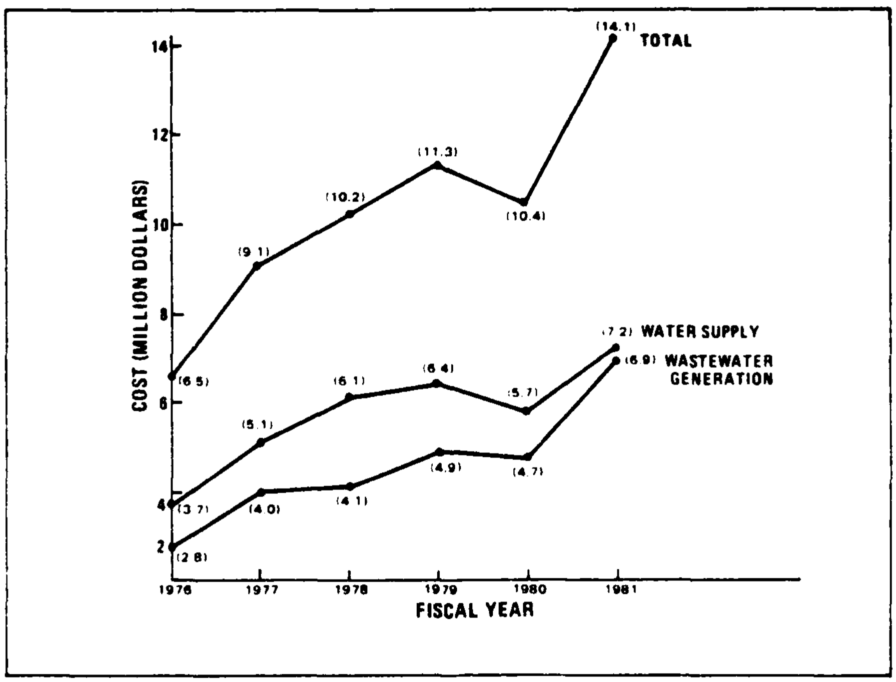

Figure 6. Cost of water supply and wastewater treatment for U.S. commercial and industrial installations. (From Annual Summary of Operations [Facility Engineering, Office of the Chief of Engineers, U.S. Department of the Army, FY76 to FY81].)

Water Conservation Opportunities

The demand for water can be reduced by instituting a command-supported conservation program that emphasizes employee education and the use of water saving devices. For example, self-closing valves, low-flush toilets, and low-flow shower heads are available and can be readily added to even the oldest plumbing system. Conserving water in some industrial operations also may be possible, but is a function of each type of activity and can be confirmed only by making detailed plant surveys for each case considered.

Water Recycling Opportunities

The best opportunities for water recycling are found in the industrial processes. In many instances, these are the same processes that produce contaminated wastewater subject to control by Federal and State environmental regulations. Thus, the optimal situation is one in which pollutant discharges are controlled while water usage is reduced.

At AMC installations, approximately 300 million gal of industrial wastewater annually are subjected to some form of treatment at the current (FY81) cost of $6.50 per 1000 gal.[24] This represents nearly a six-fold increase in unit treatment costs since 1976. This finding and the fact that the cost of water continues to rise appear to justify devoting more attention to both conservation and recycling. Among the activities that should be evaluated for recycling are:

- Steam cleaning
- Metal finishing and plating
- Cooling towers
- Paint spraying.

Water Reuse Opportunities

Opportunities for water reuse are generally limited to commercial and industrial installations that operate their own wastewater treatment plants. The effluent from such plants, if treated to a minimum of secondary water quality standards, can be used directly for purposes such as landscape irrigation and water walls for paint spray booths. Additional treatment to reduce suspended or dissolved solids would also permit effluent use for other industrial needs such as steam cleaners, cooling towers, and metal plating baths. However, the economy of water reuse is greatly affected by the level of intermediate treatment needed and the extent of the transmission piping required to distribute effluent to the activity.

Storm water also has reuse potential. It is currently collected in reservoirs or ponds at some industrial plants to provide water for fire fighting and landscape irrigation. Although not as reliable a source as wastewater effluent, storm water could also be treated and used for other purposes.

[24] Annual Summary of Operations, FY81.

Reserve Component Installations

Installations used by Army Reserve units include training centers, contract maintenance shops, weekend training areas, and semiactive posts. Training centers are permanent structures built by the Army where members of Reserve units meet to undergo training one weekend each month. The typical facility includes administrative offices, classrooms, assembly hall, arms and storage rooms, mess and dining room, latrines, and parking for privately owned vehicles. No accommodations are provided for sleeping. Depending on the units' types and sizes, a center may contain an equipment pool with maintenance shops and enough land to support outdoor training. In almost all instances, these facilities are located in urban areas where they are readily accessible to reservists. Utility services are generally purchased from the local municipality or utility corporation, or are provided by the Army if a military installation is nearby. These facilities are built according to DOD construction criteria, in which water consumption is based on the number and types of fixtures provided.[25]

Weekend training areas are generally small parcels of land used for outdoor instruction and field maneuvers. Normally, no permanent improvements are made to the property.

Contract maintenance shops are regional facilities, often colocated with a Reserve Center, where major repairs to vehicles and other equipment are made by civilian government employees or contractors. Water is provided at these shops for washrooms, showers, heating plants, and fire protection.

Semiactive posts are former active installations retained by the Army and operated by the Chief of Army Reserve for field training of Reserve Units. They are also maintained for mobilization in the event of an emergency. In general, these installations have been actively used in the past, but are now operated by a small garrison force that hosts Reserve units for their 2 weeks of summer training. The types of activities conducted are essentially those found on active installations, but on a much smaller scale.

Overview of Water Using Activities

The water consuming activities at Reserve Centers and contract maintenance shops are those related to personal hygiene, general cleaning, mess operations, and vehicle and aircraft cleaning. Activities at semiactive installations include those conducted at active posts, but the quantity of water used fluctuates with the population. In general, most of the activity is during the summer months when field training is normally scheduled.

The largest single use of water at semiactive installations is probably for vehicle and equipment cleaning. Before concluding the 2 weeks of training, each unit is required to clean the buildings assigned for their use and any vehicles and equipment they may have drawn from the central equipment pool to supplement their own organic equipment.

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[25] DOD 4270.1-M.

Water Conservation Opportunities

The intermittent use of Reserve Centers does not present opportunities for significant reductions in water consumption. Nevertheless, savings can accrue from the installation of water conservation devices such as low-flush toilets and urinals and self-closing faucets on lavatories. Further, attention could be given to minimizing the amount of water used for washing vehicles. Elaborate vehicle washing facilities would not be justified, however, because the number of vehicles at any one center is generally small and frequent washing normally is not required. Instead, consideration should be given to the use of high pressure/low water consumption/hand operated spray systems. Commercial systems of this type are relatively inexpensive and would require no modification to a facility before use.

Water saving devices similar to those just described can also be installed in regional maintenance shops to achieve modest, but contributing, reductions in water usage and utility costs.

Water Recycling and Reuse

Again, the relatively small size and limited activity at training centers and maintenance shops do not appear to present opportunities for water recycling or reuse. Reuse would not be justified for landscape irrigation, even if treated sewage effluent could be made available; the cultivated ground area at these facilities is generally too limited to justify the costs involved. Further, irrigation of weekend training areas is not required or even considered acceptable.

Recycling of vehicle washwater at semiactive posts, used for Reserve summer training has the most potential for savings. It would be particularly beneficial at installations where many tracked vehicles must be cleaned at the end of each 2-week training cycle. This condition existed at Fort Drum and prompted a research program to develop a more efficient, economical vehicle washing system. To date, several prototype washing facilities have been designed and built for U.S. and overseas installations, and are currently being evaluated.

Mobilization and Emergency Installations

Mobilization and emergency installations are those officially designated by the Army to be used for training individuals and units inducted into the service during a national emergency. Mobilization can be directed by the President in several stages, depending on the nature of the emergency. Increasing numbers of reservists can be called into service by issuing selective, partial, or full mobilization declarations; then, when all of the nation's resources are needed for an emergency, total mobilization is directed. The latter situation could involve expanding the Army by forming new units.

Facilities to be provided in an emergency depend on the number of personnel called into service and the mission assigned to any particular installation. Present guidance on how the Army plans to provide necessary facilities is as follows:

1. Existing Army installations are to be used to the extent that unused space is available or that space can be made available by internal adjustment of space already occupied

2. Semiactive installations are to be placed in an active status

3. State controlled installations (National Guard Camps) are to be put into national service

4. Additional facilities are to be constructed on active and semiactive installations to increase capacity whenever feasible

5. New installations are to be constructed if all other installations are fully programmed.[26]

Preplanning for the emergency expansion of existing installations by either realignment or the addition of new facilities is required by AR 210-23, and the specific procedures to be used in determining an installation's expansion ability are set forth in TB ENG 354.[27] A critical evaluation that must be made as part of the process is to determine what population can be supported by existing utilities. Of all the utilities that can limit the mobilization ability of an installation, water and sewage systems may be the most critical because their capacities cannot be rapidly or readily increased.

Present guidance on evaluating the total mobilization ability of an existing water supply system is to determine the average per capita consumption for the highest 3 months of the year and multiply that by a capacity factor to account for uncertainties in water demands or for unusual peak daily conditions.[28] This procedure does not take into consideration any reductions in water usage that could be achieved by conservation measured or by recycle or reuse. Hence, it could result in an unnecessarily low expansion capability determination for some existing installations and cause large expenditures of construction funds for additional water supply and sewage treatment facilities that may not be entirely necessary or justified.

New troop installations may be required in addition to expanding existing active installations and returning others to active service to support total mobilization. Construction under these circumstances is usually semipermanent, roughly equal to that built during the early days of World War II. Siting new military installations in this country could be much more difficult than in the past; one problem could be locating an adequate source of clean water.

Water use criteria for designing water systems at new installations are vague and confusing. As indicated in the water supply criteria extract provided in Appendix B, the design depends on what reference document is used.

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[26] Army Regulation (AR) 210-23, Master Planning for Army Installations Emergency Expansion Capability (U.S. Department of the Army, 23 January 1976).

[27] TB ENG 354, Installation Expansion Capability Guide (U.S. Department of the Army, January 1976).

[28] TB ENG 354.

If AR 415-50 is selected, it is "on the basis of actual need at each installation."[29] Other documents specify the amount of water in gal/person/day, depending on the type organization expected to occupy the installation. The differences in criteria cited in the documents listed in Appendix B should be reconciled and revised guidance should be published.

Overview of Water Using Activities

Activities requiring water during mobilization would be essentially the same as for active troop installations, except those pertaining to family housing. Under these conditions, dependents could be required to leave the installation to open up space for officer and enlisted quarters.[30]

Guidance on the management of water resources during mobilization does not exist. It appears that the Army expects the population at an installation to be commensurate with the water supply available and that there should be no need to conserve water.

Water Conservation Opportunities

In an emergency, it appears logical that mobilization facilities should be provided quickly with minimum possible demand on available resources. Therefore, economies need to be realized not only in the design and construction of water supply systems but in the subsequent use of water itself.

In the transition from peacetime to emergency operations at existing installations, water usage would decrease somewhat if dependents left the post. Other reductions could be achieved by placing restrictions on water used for vehicle washing and landscape irrigation. Water could be further saved by removing garbage disposal units and by installing low-flow showers and low-flush toilets. These measures could also help eliminate the need to enlarge water supply and sewage treatment systems to serve an increased population.

The per capita water usage factor of 150 gal/person/day used to design mobilization facilities for World War II probably would not be adequate today, and should be increased. A recent analysis performed by USA-CERL suggests that a rate of 170 gal/person/day would be enough if reported increases in water use since World War II are considered. Adopting an increase in the design factor automatically reduces the population size that can be supported by existing water supply systems. A more prudent approach would be to plan on restricting water usage and thereby reduce the per capita factor below the present design level.

Water Recycling Opportunities

Although the major reduction in water usage will be realized from conservation measures, additional savings can accrue from recycling water. Logical activities for recycling with relatively little cost are vehicle and aircraft

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[29] AR 415-50, Basic Facilities and Space Criteria for Construction at U.S. Installations in Event of Emergency (HQ Dept. of Army, 15 May 1978).
[30] AR 210-23.

washing. It is also possible for installations operating post laundries to make simple plumbing changes that enable rinsewater use as washwater in a subsequent laundry cycle. Although this latter technique appears to have no health implications, it should be verified with the Office of the Surgeon General.

Water Reuse Opportunities

During a national emergency, there would be no real benefit from installing a wastewater reuse system if its primary purpose is land irrigation. However, the use of treated sewage effluent for large-scale industrial processes at Army plants could be a viable alternative to expanding an existing water supply system. Such decisions can only be made on a case-by-case basis after careful analysis of plant water requirements.

Overseas Semipermanent Installations

U.S. forces stationed overseas on a long-term basis generally occupy installations under some type of agreement with the host nation. Throughout Europe and Japan, the Army occupies installations that were former host-nation military bases. In Korea, the installations used today were Army bases during the war. In general, overseas bases are much smaller than troop installations in the United States.

Construction funded by the Army overseas has been primarily limited to mission-essential projects. When possible, the Army has requested the host nation to renovate or replace existing facilities that have deteriorated or become inadequate. Because host nation support in Korea has been limited, the United States has built some semipermanent facilities to provide improved living conditions for U.S. soldiers. The criteria for this construction, generally determined on a case-by-case basis, closely follow those for permanent construction in the Continental United States (CONUS), minus many of the nicer amenities.

The Army purchases most water and sewage treatment services for overseas installations from nearby municipal authorities. Exceptions are the small, isolated installations, such as communications and special weapons sites, and most U.S. bases in Korea; in general, these installations operate their own water supply systems and rely largely on the treatment of surface water. Their wastewater treatment systems are very basic and include septic tanks, lagoons, and a limited number of small, packaged treatment plants.

Annual water consumption at all overseas areas has increased slightly during FY76 through FY81, from approximately 23 billion to 25 billion gal (Figure 7). This quantity, although about 25 percent of that consumed by U.S. installations, cost the Army $42.3 million in FY81, or nearly 60 percent more than for the water consumed in the United States. The largest of the overseas users is the U.S. Army in Europe, where the annual amount of water used has remained constant at about 16.5 billion gal. However, per capita consumption of 107 gal/day (FY77) is considerably less than in Japan (180 gal/day) and Korea (231 gal/day).

The cost of water in overseas areas (Figure 8) is generally much higher than in the United States because most of it is purchased. Over the past 6

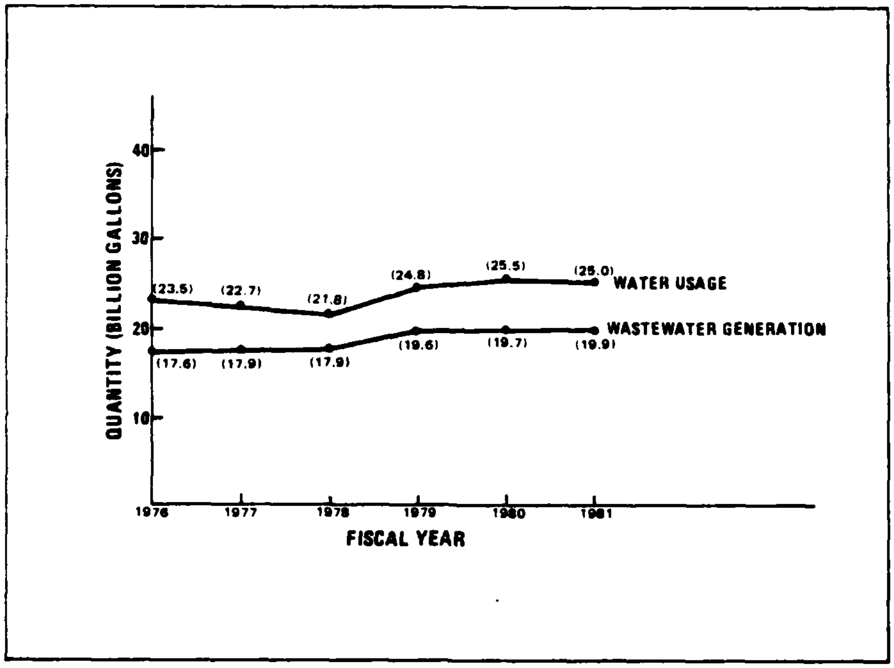

Figure 7. Water usage and wastewater generation for Army overseas installations. (From Annual Summary of Operations [Facility Engineering, Office of the Chief of Engineers, U.S. Department of the Army, FY76 to FY81].)

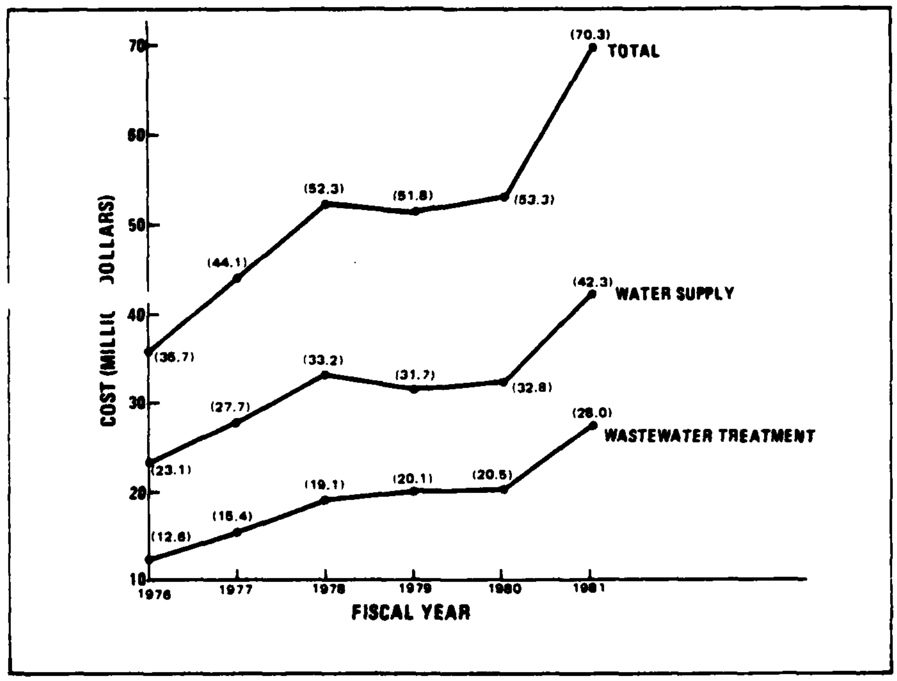

Figure 8. Cost of water supply and wastewater treatment for Army overseas installations. (From Annual Summary of Operations [Facility Engineering, Office of the Chief of Engineers, U.S. Department of the Army, FY76 to FY81].)

years, the price of purchased water has essentially doubled; it currently costs $2.94 per 1000 gal in Europe and $3.19 per 1000 gal in Japan (FY81). The highest price was $7.20 per 1000 gal paid by the Western Command.

Data published by OCE[31] indicate that, on the average, about 50 percent of the water consumed overseas is processed through sewage treatment plants. However, in Europe, the percentage is nearly 88 percent. Like purchased water, sewage treatment in overseas areas is becoming increasingly expensive. In FY81, expenditures amounted to $28 million or 140 percent more than that paid for equivalent services by troop installations in the United States ($11.6 million).

Overview of Water Using Activities

Certain activities at U.S. overseas bases use less water than bases in the CONUS. For example, the relatively small bases overseas have little improved land requiring irrigation. Industrial activities are less extensive because equipment that needs major rebuilding is normally shipped back to depots in the United States. Except for Western and Southern Command bases, the need for air conditioning at overseas installations is considerably less because of the cooler climates. Also, the typical base contains one or more small heating plants that rely either on tall stacks or dry particulate collection processes rather than wet scrubbers to control air pollutants. Bulk laundry service is commonly provided by contractor plants located off the installation.

A list of typical water consuming activities in overseas areas includes functions associated with the following facilities:

- Troop and family housing
- Mess/club facilities
- Medical clinics/hospitals
- Vehicle and aircraft washracks
- Laundries/laundromats
- Paint spray booths
- Boiler plants
- Steam cleaning facilities.

Water Conservation Opportunities

The high costs of water and sewage treatment incurred by the U.S. Army suggest that positive efforts should be made to reduce water consumption at all overseas installations. The relatively low European Theater per capita water consumption of 107 gal/day might indicate frugal use of water. Likewise, the very high per capita usage levels in Japan (180 gal/day) and Korea (231 gal/day) suggest members of these commands are using excessive amounts of water.

[31] Annual Summary of Operations, FY76 through FY81.

Indications are that Army units in Europe and the Far East currently have no water conservation programs. Consequently, variations in water usage overseas cannot be fully explained at this time. Several reasons for the lower rate in Europe have already been advanced, and water thievery is speculated as the cause for higher rates in the Far East. Nevertheless, much better answers must be obtained before a practical approach to water conservation can be developed.

Water Recycling and Reuse

Conditions overseas differ from those in the United States in ways that limit major opportunities for water reuse. In general, treated sewage effluent is not readily available or of suitable quality for other uses. Accessibility is a problem because almost all U.S. bases are serviced by municipal sewage treatment plants. At bases in the Orient, wastewater treatment seldom exceeds primary treatment standards, causing the effluent produced to be unacceptable for general reuse.

Opportunities for recycling water are likewise limited because of the size of the bases and the scope of their activities. Nevertheless, the continuing requirements to wash vehicles and aircraft do appear to have recycling potential. Other possibilities at selected locations might include steam cleaning and spray painting. As indicated above, the remaining functions are not major water users, which makes the cost effectiveness of recycling questionable.

Remote Installations

Remote installations house special activities that must be located in isolated or unique areas. Examples are communications, intelligence monitoring, and research stations; missile sites; and certain special military advisory group facilities located in foreign countries. These types of installations can have staffs numbering 5 to 75 and often operate 24 hr/day, 7 days/week.

Permanent or semipermanent facilities are usually provided at these types of installations. Because most house classified missions, access is normally controlled by security fencing, gates, and possibly sentry stations. Most remote stations are established for long-term use, which means they are designed based on DOD construction criteria.

Overview of Water Using Activities

Besides the mission activities, which probably are not large water consumers, water is required for personal hygiene, food preparation, general cleaning, and possibly laundry. The water supply systems range from field expedient to conventional pressurized types. Water sources include wells, municipal water, cistern, or even tanker truck. There are no known published criteria on the daily per capita requirements in these situations. It is probably determined on a case-by-case basis; however, per capita needs can be assumed to range from 50 to 75 gal/day.

The types of latrines likewise vary from field expedients to conventional waterborne sewage. In the Federal Republic of Germany (FRG), sites may rely on holding tanks because sewage effluent discharge is not permitted by the host nation.

Water Conservation Opportunities

Occupants of small, remote installations can be expected to practice water conservation, particularly if they are totally responsible for operating their own water supply systems. Nevertheless, self-discipline should be supplemented with water saving devices when practical.

Another way to limit water consumption is to avoid the use of flush toilets. In many situations, this procedure may be necessary because of the physical difficulties with sewage disposal. Several expedient disposal techniques could be used, such as incinerating toilets and pit latrines, composting toilets, and aerated vault latrines. In fact, where waste disposal is strictly controlled, as in the FRG, the composting toilet can be a low-cost method of disposing of garbage and human waste.

Water Recycling and Reuse

Recycling does not appear to be cost-effective for small, remote camps because the quantities of water used for individual activities and as a whole are relatively small. However, water reuse could be feasible. For example, shower water could be collected and treated with defoaming and disinfecting agents to enable it to be used for flushing toilets. Another useful technique is to collect and treat all wastewater, except for that containing human waste, to obtain a supply of nonpotable water. Several commercially packaged, self-contained reclamation units are available for use by small industrial plants, shopping centers, and housing developments. Because these systems are expensive and require continuous monitoring of the chemical-biological-physical treatment process, however, it may be prudent to limit their use to locations in the United States where factory repair and maintenance services can be readily obtained.

Theater of Operations Installations

Theater of Operations installations are overseas bases developed or constructed by the Army to support military operations. Maximum use is usually made of available infrastructure, but in locations where it is inadequate, essential facilities are constructed. The basic construction support program is the Army Facilities Component System (AFCS).

Facilities are provided primarily for combat support (Corps Area) and combat service support (COMZ) units whose performance is more efficient under good working conditions. However, during the first 6 months of an operation, nearly all units rely on tents for shelter and TO&E equipment to perform their mission. This period is characterized by austere living conditions in which the facilities themselves are identified as "initial standard." As the tactical situation permits, tents are gradually replaced by buildings, and other physical improvements are made to enhance mission performance. The upgrading of facilities to "temporary standard" provides the minimum essential resources needed for successful completion of the military mission, projected to be 24 months from initial entry into the Theater.

The Army may be required to conduct military operations in any area of the world. Therefore, provisions have been included in the Army's planning guidance and in the AFCS to permit the construction of facilities suited to the four basic climatic regions: temperate, tropic, desert, and frigid zones.

USA-CERL and the U.S. Army Engineer Waterways Experiment Station (WES) have completed a study on base development in the Middle East. The results have been published in a separate report that consolidates problems in base development and provides planners and engineers with a single-source handbook covering construction problems and practices unique to the Middle East.[32] Chapter 5 of that report discusses water management.

Overview of Water Using Activities

In a Theater of Operations, water is required for many of the same functions performed by military units during peacetime training. However, the overall amount is generally less, and can range from a low of 20 gal/person/day in hot, desert areas to about 50 gal/person/day in other climatic regions. In contrast to peacetime operations in which potable quality water is used almost exclusively, combat forces are frequently required to use water of both potable and nonpotable quality. The type used depends largely on the nature of the activity requiring water, as indicated in Table 1.

The quantity of water used by the various military activities under combat conditions is markedly different from that discussed earlier for a garrison. In the field, where somewhat lower standards of cleanliness may be accepted, much less water is used for personal hygiene, bathing, and cleaning vehicles. Likewise, smaller amounts of water are required in preparing meals since prepackaged rations are mainly used in a combat situation. For certain other activities specific to combat areas, more water than normal may be required. These include construction, which in undeveloped areas can be extensive, and decontamination of personnel and equipment following a nuclear, biological, or chemical attack. In these instances, however, the water does not have to be potable.

Water Conservation Opportunities

U.S. soldiers have become accustomed to always having abundant water. As a consequence, they generally have difficulty overcoming old habits in disciplining themselves to conserve water during field exercises and even in combat. The solution to this problem begins with educating soldiers on how to save water and ensuring that all observe prescribed conservation procedures through strong command supervision.

Conservation should be practiced conscientiously in a Theater of Operations, even when water is abundant; the payoff can be a reduced demand on the

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[32] A. Kao, Troop Construction in the Middle East, Technical Report M-323/BO76455 (USA-CERL and U.S. Army Engineer Waterways Experiment Station, 1982).

Theater logistics system. Reducing water usage to reasonable quantities can result in reduced mileage and fuel consumed by water transport vehicles, less fuel to heat water, and decreased operating hours for purification equipment needed to produce potable water. It is also possible to reduce the number and size of components in the field water supply system (purification equipment, storage and distribution facilities) by simply lowering the demand for potable water.

Although education and training are fundamental to the success of any conservation effort, compliance should be encouraged through water saving devices and techniques when practical. Many of the devices identified earlier for permanent Army installations apply equally to Theater of Operations installations.

In hot, desert regions where water resources are especially critical, particular attention must be given to conservation. Expedient, practical measures that military forces can use in water-short regions are presented elsewhere.[33]

Water Recycling Opportunities

Virtually all wastewater generated by a field activity must undergo some type of treatment before it can be recycled. Treatment ranges from simple filtration for removal of suspended particles to more sophisticated chemical processes to reduce the dissolved solids content. Commercial treatment equipment is available to renovate almost any type of wastewater. However, treatment systems are most often custom-designed for each situation because contaminants and contaminant levels vary among activities, water properties differ among sources, and water quality standards are susceptible to change for each location. It is possible to integrate a series of treatment steps that accommodate a wide variety of these input and output water parameters; however, equipment for renovating wastewater to produce high-quality water is often complicated to operate and maintain, usually expensive, and functions best in a protected, fixed environment. In other words, a simple, multipurpose, reliable commercial wastewater treatment process that can readily be deployed to a combat area is not available.

If water supplies are abundant, as in most temperate and tropical zones, there is little justification to recycle. To do so would only add to the logistics burden of a Theater because of the additional equipment and expendable supplies needed. On the other hand, if water supplies are expected to be scarce, as in desert areas, or not readily accessible, as in arctic or northern mountainous areas, recycle should be used when practical. However, it should be restricted to major water consuming activities. Decisions on where and when to recycle must be tempered with the realization that highly skilled wastewater treatment and reclamation personnel are not going to be available to operate this type of equipment. Also, it is doubtful that the Army would even permit recycling if many additional fulltime personnel were needed just to operate and maintain the equipment, or if extensive training were required.

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[33] Theater of Operations Construction in the Desert (Office of the Chief of Engineers, January 1981).

Activities for which water recycling might benefit a military force operating in a combat area are:

- Central showers
- Field laundries
- Aircraft washracks.

A practical field treatment system considered useful for all of the above activities is discussed in two previous studies on water conservation.[34] Water is renovated by a coagulation process that involves the addition of polymers and powdered, activated carbon, followed by diatomite filtration. The suggested batch process is simple to operate and appears to offer greater flexibility in field situations than predesigned continuous flow systems. For example, only the amounts of chemicals used in the coagulation step must be adjusted to accommodate local variations in basic water quality and contaminant levels. This suggested wastewater treatment process is a refinement of that used in the Army's field shower and laundry pollution abatement kit. (Note: further tests should be conducted to verify that water of acceptable quality can be produced for recycling and to develop detailed instructions for equipment operators.) Details of this treatment process are provided elsewhere.[35]

Water Reuse Opportunities

Water reuse is not recommended in a Theater of Operations where water is relatively abundant for the same reasons given for recycling. It may be feasible in water-short areas or when water is not readily accessible; however, water reuse may pose potential health and logistical problems. Unless clearly separated and marked, wastewater could be mistakenly used for the wrong purposes. Wastewater collection and transportation from one activity for use by another also incurs transportation and storage costs unless the generator and potential user are essentially colocated.

Treated wastewater not recycled for shower and laundry should be used for general cleaning, construction, or fire fighting. Also, untreated wastewater from nearly any source can be used for dust control and grounding electrical systems. Shower wastewater could be used for flushing toilets after adding defoaming and disinfection agents. This use is only appropriate when a shower and latrine are colocated and installation of waterborne sewage is authorized.

Special Purpose Installations

A special purpose installation is an overseas base specifically authorized by the U.S. Congress to protect national security. Its construction and operation is negotiated by the U.S. Government with a host nation and is usually based on a mutual security agreement. Examples of such installations are

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[34] J. M. Morgan, et al., Mathematical Modeling for Evaluation of Field Water Supply Alternatives (Arid and Semi-Arid Regions) (U.S. Army Medical R&D Command and U.S. Army Mobility Equipment R&D Command, January 1981); Troop Construction in the Middle East, Chapter 5.

[35] Theater of Operations Construction in the Desert.

the bases for the Sinai Peacekeeping Force built at Eitam and Sharm-ah-Sheykh, and the RDJTF bases planned for Ras Banas in Egypt and the island of Masira off the coast of Oman.

Functions requiring water at these installations depend on the resident organization's mission. There are apparently no published criteria for planning or basic design specifically for such bases. Instead, design is determined on a case-by-case basis. For the Sinai Peacekeeping Force camps, the water system designs were based on a daily water requirement of 130 gal/person, to be obtained from an existing water system;[36] at Ras Banas, the design criterion was 150 gal/person/day, with the water being produced by an on-site reverse osmosis desalination plant.[37]

Overview of Water Using Activities

Activities at special purpose installations are similar to those at any other overseas base in peacetime. Consequently, water should be needed for at least domestic functions and fire fighting. Other typical needs might include vehicle cleaning, recreation (swimming pool), and landscape irrigation. All of these activities are included in the Peacekeeping camps' design and could be considered representative of water using activities at similar special purpose installations.

Water Conservation Opportunities

Opportunities for reducing water consumption would be comparable to those discussed earlier for remote installations. Therefore, it would be appropriate to use the same water saving devices on showers and toilets.

In water-short areas such as the Middle East, the need for waterborne sewage systems should be critically evaluated to determine if some other means of human waste disposal can be used that is equally effective and less costly in terms of water facilities construction, construction effort, and materials. Alternatives include the composting, vault, and chemical toilet systems, which are currently under evaluation by USA-CERL.

Water Recycling Opportunities

The potential for recycling water at special purpose installations appears limited because the populations are relatively small and the usual caretaker activities do not require large amounts of water. On the other hand, if greater than normal vehicle and aircraft washing is required because of unusual climatic conditions, recycling washwater should be considered.

Water Reuse Opportunities

Water reuse is likewise impractical in small camps. However, when camps are in water-short regions like those mentioned above, wastewater can be used

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[36] Project Development Brochure for Design and Construction of Facilities for Sinai Peacekeeping Base Camps at Eitam and Sharm-ah-Sheykh (Huntsville Division, U.S. Army Corps of Engineers, 1 September 1981).

[37] RDJTF Facilities Ras Banas, Egypt, Design Analysis, Pre-Final Submittal (U.S. Army Corps of Engineers, undated).

to reduce the demand for fresh water. For example, shower wastewater could be used for toilet flushing and treated sewage effluent could be used for landscape irrigation, if required.

5 CONCLUSIONS AND RECOMMENDATIONS

A basis has been provided for Army exploitation of closed-loop concepts in conserving valuable water resources worldwide. In particular:

1. It is feasible to implement a closed-loop water reuse concept at various types of Army installations in the United States and overseas for peacetime, mobilization, and wartime.

2. A priority listing has been provided of activities at each type of installation for which water consumption and related water supply/wastewater treatment costs could be significantly reduced by water reuse.

Based on the literature search, interviews, and analyses conducted during this study, it is recommended that the Army initiate the following actions:

1. Develop and implement an Army-wide water resources management program to achieve more efficient use of available water supplies during peacetime, emergency, and mobilization.

2. Assess the adequacy of water supplies for key training and commercial/industrial installations through the year 2000 to enable more effective planning for the long-term use of these installations.

3. Develop a water conservation strategy in conjunction with the water resources management program to reduce nonessential usage of potable water at U.S. and overseas Army installations. In addition, consider using proven commercial water saving devices and plumbing fixtures.

4. Evaluate current water use criteria used in sizing installation water supply systems for peacetime, emergency, and mobilization to determine if they suit today's Army and to change them if necessary.

5. Analyze procedures the Army currently uses in determining what military population can be supported by existing installation water supply and sewage treatment systems under full mobilization. Assess the validity of this procedure in planning for future emergencies.

6. Make greater use of available technologies to reduce water usage and control pollutant discharges. Primary effort should be directed toward:

- Recycling water used by selected industrial operations at Army arsenals and repair depots
- Recycling water used by industrial laundries
- Recycling water used by field showers and laundries, and for cleaning aircraft when these activities are performed by a military force operating in water-short areas of the world
- Reusing shower wastewater to flush toilets at permanent or semipermanent, remote installations

- Using drip irrigation of treated sewage effluent for landscape care at Army installations.

REFERENCES

Annual Summary of Operations (Facility Engineering, Office of the Chief of Engineers, Department of the Army, FY76 through FY81).

Army Regulation (AR) 210-23, Master Planning for Army Installations Emergency Expansion Capability (U.S. Department of the Army, 23 January 1976).

AR 415-50, Basic Facilities and Space Criteria for Construction at U.S. Installations in Event of Emergency (HQ Dept. of Army, 15 May 1978).

Bandy, J. T., M. Messenger, and E. D. Smith, A Procedure for Evaluating Subpotable Water Reuse Potential at Army Fixed Facilities, Technical Report N-109/ADA111191 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1981).

Bandy, J., and R. J. Scholze, Distribution of Water Use at Representative Fixed Army Installations, Technical Report N-157/A133232 (USA-CERL, 1983).

DOD 4270.1-M, Construction Criteria (U.S. Department of Defense, June 1978).

Everest, W. R., "Reclamation of Wastewaters and Degraded River Waters by Advanced Waste Treatment in Hong Kong," Proceedings--Water Reuse Symposium II, Volume I (American Water Works Foundation, 1981), p 443.

Friedman, R., "Dan Region Project in Israel: From Laboratory Experiments to Full-Scale Wastewater Reuse," Proceedings--Water Reuse Symposium, Volume II (American Water Works Research Foundation, 1979), p 808.

Gomez, G. M., and F. F. Herrera, "Mexico City's Master Plan for Reuse," Proceedings--Water Reuse Symposium II, Volume I (American Water Works Research Foundation, 1981), p 308.

Hrubec, J., et al., "Studies on Water Reuse in the Netherlands," Proceedings--Water Reuse Symposium, Volume II (American Water Works Research Foundation, 1979), p 785.

Kao, A., Troop Construction in the Middle East, Technical Report M-323/B076455 (USA-CERL and U.S. Army Engineer Waterways Experiment Station, 1982).

Lee, M. K., et al., Water Purification Unit Development for Field Army Medical Facilities (Life Systems, Inc., Cleveland, OH, April 1978).

Morgan, J. M., et al., Mathematical Modeling for Evaluation of Field Water Supply Alternatives (Arid and Semi-Arid Regions) (U.S. Army Medical R&D Command and U.S. Army Mobility Equipment R&D Command, January 1981).

Odendaal, P. E., "Reuse of Wastewater in South Africa--Research and Application," Proceedings--Water Reuse Symposium, Volume II (American Water Works Research Foundation, 1979), p 886.

Project Development Brochure for Design and Construction of Facilities for Sinai Peacekeeping Base Camps at Eitam and Sharm-Ah-Sheykh (Huntsville Division, U.S. Army Corps of Engineers, 1 September 1981).

RDJTF Facilities Ras Banas, Egypt, Design Analysis, Pre-Final Submittal (U.S. Army Corps of Engineers, undated).

Rothberg, M. R., et al., "Demonstration of Potable Water Reuse Technology--The Denver Project," Proceedings--Water Reuse Symposium, Volume I (American Water Works Research Foundation, 1979), p 105.

Sheets, K. R., "Water--Will We Have Enough to Go Around?", U.S. News & World Report (29 June 1981).

Shuval, H. I., "The Development of the Wastewater Reuse Program in Israel," Proceedings--Water Reuse Symposium II, Volume I (American Water Works Foundation, 1981), p 147.

TB ENG 354, Installation Expansion Capability Guide (U.S. Department of the Army, January 1976).

Theater of Operations Construction in the Desert (Office of the Chief of Engineers, January 1981).

Water Conservation Management (American Water Works Association, 1981).

Zunckel, A. F., and M. P. Oliveira, "South African Water Reuse Policy and Its Practical Implications," Proceedings--Water Reuse Symposium II, Volume I (American Water Works Research Foundation, 1981), p 249.

APPENDIX A:

OVERVIEW OF PREVIOUS DOD STUDIES ON WASTEWATER RECYCLE/REUSE

Over the past 10 years, water reuse has been the subject of several DOD-sponsored studies. A brief overview of these published reports follows.

1. A Procedure for Evaluating Subpotable Water Reuse Potential at Army Fixed Facilities, Technical Report N-109/ADA111191 (U.S. Army CERL, November 1981).

The treatment and reuse of wastewater produced on fixed Army installations are discussed. An evaluation model is provided for: assessing the potential for water reuse; identifying installations with the best reuse potential; and evaluating conceptual reuse schemes at individual installations. From the full spectrum of Army water using activities, the most promising candidates for using reclaimed water are:

- Land irrigation
- Cooling towers
- Plating and metal finishing shops
- Industrial laundries
- Vehicle and aircraft washing
- Dynamometers and engine test cells
- Air pollution scrubbers

2. CALSPAN, Inc., Characterization Studies of Wastewater Generated from Military Installations, CALSPAN Report No. ND-5296-M-1 (U.S. Army Mobility Equipment R&D Command [USAMERADCOM], April 1973).

Characteristics of wastewaters produced at a military installation are identified. Sources include laundry, shower, kitchen, hospital, and vehicle washracks.

3. Culp/Wesner/Culp, Development Plan for Military Quality Criteria for Specific Wastewater Reuse Applications (U.S. Army Medical R&D Command and Naval Civil Engineering Laboratory, June 1979).

A plan is presented for development of detailed quality criteria for potable and nonpotable reuse of renovated wastewater. Use of conventional numerical standards or maximum contaminant limits is recommended. Suggested nonpotable reuse criteria to be developed include:

Field Use
Shower and washroom
Laundry
Vehicle and aircraft washing
Construction and dust control

Fixed Installations
Same as above, plus:
Swimming
Land irrigation
Industrial operations

4. A. D. Little, Inc., Development of Data Base Requirements for Human Health Based Water Quality Criteria for Military Recycle/Reuse Applications (U.S. Air Force Engineering & Services Center, U.S. Army Medical R&D Command, and Naval Civil Engineering Laboratory [NCEL], June 1980).

Methodology is provided for the development of nonpotable reuse water criteria for human exposure to contaminants in wastewater.

5. Walden Division of ABCOR, Evaluation of Health Effects Data on the Reuse of Shower and Laundry Waters by Field Army Units (U.S. Army Medical R&D Command, April 1979).

This is an assessment of the health effects of short-term shower and laundry reuse. Based on an evaluation of existing data, water reuse would not result in toxic effects. A protocol is suggested for human clinical trials to verify that no toxic effects would be experienced. Five candidate wastewater treatment processes are identified and evaluated for their ability to remove problem contaminants.

6. Process Design for Treating Shower Wastewater by Ultrafiltration (USAMERADCOM, June 1977).

Mathematical models are used to describe permeate production from ultrafilters in the treatment of shower water.

7. Treatment of Wastewaters from Military Field Laundry, Shower and Kitchen Units (USAMERADCOM, May 1973).

The findings of a field test at Fort A.P. Hill are discussed to evaluate the treatment of laundry, shower, and kitchen wastewaters using powder carbon, a cationic polyelectrolyte, and a modified ERDLATOR purification unit. It is concluded that high-quality water can be produced using these chemicals and equipment.

8. VMI Research Laboratories, Mathematical Modeling for Evaluation of Field Water Supply Alternatives (Arid and Semi-Arid Regions) (U.S. Army Medical R&D Command and USAMERADCOM, January 1981).

A mathematical model is described for evaluating the least-cost alternatives of meeting projected potable and nonpotable water requirements for a Corps-sized operation in a desert region. It is concluded that there is no evidence to indicate possible adverse health effects from short-term use of treated, recycled shower and laundry wastewater. Recycling and reuse of shower and laundry water are most economical when potable water must be produced using reverse osmosis equipment and when fresh water must be transported long distances. A shower and laundry wastewater treatment process using powdered activated carbon is suggested for field use.

9. Pilot Plant Development of an Automated, Transportable Water Processing System for Field Army Medical Facilities, USAMBRDL-ER-314-7-1 (U.S. Army Medical Bioengineering Research and Development Command, June 1978).

This is the first of six reports that describe the development and operation of a pilot plant for processing water needed by a medical facility in the field. Water processing consists of a water treatment unit (WTU), water purification unit (WPU), UV/ozone oxidation unit and an automated instrumentation unit. The WTU removes suspended solids and turbidity from nonsanitary wastewaters (shower, lavatory, laundry, kitchen, operating room, laboratory, and X-ray) to permit discharge of effluent. The WPU removes dissolved contaminants using reverse osmosis to produce nonpotable water for reuse by the hospital. The WPU also purifies natural water for potable use.

10. Studies on MUST Field Hospital Wastewater Treatment, Report 2121 (USAMERADCOM, December 1974).

Results are presented of field experiments on the use of polyelectrolyte-aided carbon coagulation as a pretreatment for purifying hospital wastewater by reverse osmosis. The process was determined to be satisfactory and capable of producing nonpotable quality water for direct recycle and reuse.

11. Study on Power-Laundry Wastewater Treatment, Report 2118 (USAMERADCOM, November 1974).

A test was conducted at a commercial laundry to evaluate the effectiveness of powdered, activated carbon and a cationic polyelectrolyte in upflow-type solids-contact clarifier as a way to produce effluent suitable for discharge into navigable waters. The treatment process was found effective, but costly in terms of chemicals required and disposal of accumulated sludge.

12. The Remote Base Integrated Water/Wastewater System, NCEL Technical Memorandum M-54-76-19 (November 1976).

Requirements for and a technological approach to developing a water and wastewater system for troop camps of 100, 1000, and 5000 capacity are described. Water is to be produced using reverse osmosis (RO) treatment equipment and wastewater is to be collected with a vacuum system. Conservation and water reuse are considered to the extent of using low-flush toilets, low-flow showers, and RO brine for toilet flushing. To advance the water supply concept, additional research on reducing RO membrane fouling has been proposed.

13. D. J. Boumgartner, Water Supply and Waste Disposal Problems at Remote Air Force Sites in Alaska, Technical Report TN-62-1 (Air Force Systems Command, March 1963).

Investigations into water supply and human waste disposal at remote Air Force Stations in Alaska were performed by the Alaska Division, American Association for the Government of Science. Water supply sources during the summer were wells containing large amounts of iron and coliform organisms that were removed by carbon and diatomaceous earth filters. Snow melters were used during winter when wells freeze. Human waste was disposed of in septic tanks, which have to be heated in cold weather. Because of the water shortage, other methods of disposal are being sought--electric incinerators were tested and found unsatisfactory; bath water and oil types of recirculating toilets were tested, but neither proved entirely satisfactory.

14. M. Mellow, Utilities on Permanent Snowfields (U.S. Army Cold Regions Research & Engineering Laboratory, October 1969).

Methods of supplying water and disposing of human wastes in locations such as Greenland and Antarctica are discussed. Water is obtained primarily by melting snow or ice, and storage and distribution systems must be heated and insulated to remain operational. A reasonable water requirement for a temporary camp is 5 gal/person/day, whereas the minimum consumption for a permanent camp is 10 gal/person/day. Sewage is disposed of by hydraulic discharge to a sink melted into the snow. Surface dumping and burning are also used but are less desirable because of the problem of disposing of residual liquids.

16. N. L. Drobney, Polar Sanitation - Synthetic, Nonfreezing Waste--Carriage Media (NCEL, August 1967).

Twenty-seven synthetic fluids that could be used as media for human waste in cold regions such as Antarctica are examined to identify a nonfreezing liquid that would permit use of a recirculating sewage system. Experimental investigations are needed to verify the concept's practicality.

APPENDIX B:

ARMY WATER SUPPLY CRITERIA

Source Document	Scope of Guidance	Criteria--Water Planning	References/Comments
Emergency/Mobilization Construction			
1. TB ENG 354, Installation Expansion Capability Guide (Jan 1976)	Expansion of CONUS installation for mobilization	Use average of 3 highest months consumption in past year and multiply by capacity factor.	AR 210-23 and TB ENG 354
2. Corps of Engineers Mobilization & Operations Planning System (CEMOPS)(Feb 1982)	Planning for mobilization facilities	Emergency construction Airborne and infantry units - 100 gal/person/day Armored units - 150 gal/person/day Hospital - 150 gal/bed/day Permanent Construction Armored units - 150 gal/person/day Hospital - 150 gal/bed/day Field Training Camp Armored unit - 75 gal/person/day Hospital - 100 gal/bed/day	To be used instead of local usage and experience factors.
3. TM 5-884-2, Engineering and Design Water Supply--Emergency Construction (Aug 1965)	Emergency construction (mobilization facilities)	Armored division - 150 gal/person/day Air Force units - 150 gal/person/day Hospital units - 150 gal/bed/day Hospital res. staff - 100 gal/person/day Other military projects - 100 gal/person/day Civilian residents - 100 gal/person/day Civilian employees - 30 gal/person/shift	Includes water for laundries to serve resident personnel, washing vehicles, limited watering of planted and grassy areas, and similar uses.
4. AR 415-50, Basic Facilities and Space Criteria for Construction at U.S. Installations in Event of Emergency (15 May 1978)	Criteria for the development of the capability (mobilization) plans and document for installations called for by AR 210-23 (master planning for Army installations; emergency expansion capability)	"Water supply and sewage disposal will be provided on the basis of actual need at each installation. Utilities will be as simple as practicable, but of such permanency as to serve the installation without requiring abnormal maintenance during life of the building."	
5. TM 5-880-3, Installation Planning Emergency Construction (March 1971)	Planning criteria, requirements, and procedures for the expansion of troop-training installations for use in the event of a mobilization mission	No criteria on utilities for training installations, Army hospitals, and staging areas. Criteria for depots--"The design of utilities, including water supply, fire prevention, electricity, sanitary sewage, and drainage, should be the minimum required for the life of the depot."	

Source Document	Scope of Guidance	Criteria--Water Planning	References/Comments
Permanent/Semipermanent Construction			
1. TM 5-813-1, Water Supply, General Considerations (July 1965)	General construction criteria - U.S. installations for Army and Air Force	Permanent construction Armored division - 150 gal/person/day Camps and forts - 150 gal/person/day Hospital units - 150 gal/person/day Field Training camps Armored division - 75 gal/person/day Camps and forts - 50 gal/person/day POW and internment camps - 50 gal/person/day Hospital units - 100 gal/person/day	
2. DODM 4270.1-M	Criteria for design of permanent and semipermanent facilities	Criteria cover individual facilities based on the number and types of fixtures. No criteria provided on water supply or sewage collection systems.	
3. FM 5-35, Engineer Reference and Logistical Data (April 1971)	General planning factors	Temporary camp w/bathing facilities (includes allowance for waterborne sewage system) - 15 gal/person/day Semipermanent camp - 30-60 gal/person/day Permanent camp - 60-100 gal/person/day Hospital with waterborne sewage - 50 gal/bed/day	
4. TM 5-813-4, Water Supply--Water Storage App I (July 1965)	Design criteria on water supply	Permanent camp - 150 gal/person/day Permanent depot - 150 gal/person/day Permanent hospital - 150 gal/bed/day Emergency construction and POW camp - 70 gal/person/day	
Theater of Operations Construction			
1. HNDM 1110-1-4, AFCS Design Manual (March 1982)	AFCS--Primarily Theater of Operations facilities	Troop camps - 15 gal/person/day Hospital - 85 gal/bed/day POW camp - 5 gal/person/day	TM 5-700
2. TM 5-700, Field Water Supply (July 1967)	Field operations, combat zone Occupation areas Disaster areas	Temporary camp - 15 gal/person/day w/bathing facilities Semipermanent camp - 30-60 gal/person/day Permanent camp - 60-100 gal/person/day	
3. JCS-MJCS-42-79 (31 Jan 1979)	Construction in support of contingency operations	Water source - 50 gal/person/day Water treatment - 50 gal/person/day Water storage - 25 gal/person Water distribution - 11 LF/person Sewage treatment - none specified	Used in development of Civil Engineering Support Plans (CESP)

	Source Document	Scope of Guidance	Criteria--Water Planning	References/Comments
4.	FM 101-10-1, Staff Officers Field Manual--Organization, Technical and Logistic Data (July 1976)	Theater of Operations	Individuals - 3-6 gal/person/day Installations: Camp (initial) with bath - 25-50 gal/person/day Camp (intermediate) - 75-100 gal/person/day Camp (temporary) - 100-130 gal/person/day Hospital - 200 gal/bed/day	Applies to temperate, cold, desert, and jungle zones.
5.	TRADOC PAM 525-11, Near-Term Water Resources Management Plan (15 June 1981)	Theater of Operations - arid region	Basic planning factor - 20 gal/person/day Survival level - 7.2 gal/person/day Austere level - 11.7 gal/person/day Full requirement - 18.9 gal/person/day Hospital - 65 gal/bed/day	Applies to arid regions.

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Closed-loop concepts for the Army: water conservation, recycle, and reuse / by E. D. Smith, W. P. Gardiner, F. Huff, J. T. Bandy. - Champaign, Ill ; Construction Engineering Research Laboratory ; available from NTIS, 1984.
50 pp. (Technical report / Construction Engineering Research Laboratory ; N-85/01.

1. Water conservation. 2. Water reuse. I. Smith, Edgar D. II. Gardiner, W. P. III. Huff, F. IV. Bandy, John T. V. Series : Technical report (Construction Engineering Research Laboratory ; N-85/01.

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