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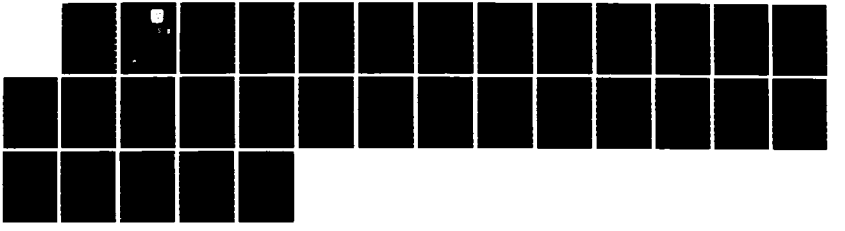

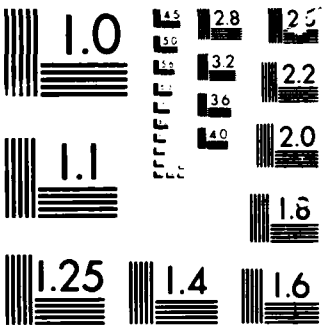

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STUDENT ESSAY

WATER: A STRATEGIC RESOURCE?

BY

COLONEL ROBERT E. THORNTON

15 APRIL 1986

US ARMY WAR COLLEGE, CARLISLE BARRACKS, PENNSYLVANIA

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USAWC MILITARY STUDIES PROGRAM PAPER

WATER: A STRATEGIC RESOURCE?

INDIVIDUAL ESSAY

by

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Carlisle Barracks, Pennsylvania 17013
15 April 1986

ABSTRACT

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Availability of fresh water has been taken for granted throughout our history. In fact, the United States has been blessed with what was once thought to be a limitless natural resource, fresh water. The sources for this fresh water are precipitation, surface water and ground water. Today these sources are under relentless pressure from chronic pollution and ove usage. The federal government has begun the process of studying and documenting the problems associated with our water supply but to date its efforts are far too little, too late. Budget constraints and funding projections only add to the already bleak picture. We are learning that wate problems can't be contained and that they cross state, local and private boundaries. This problem of area pollution has drawn considerable concern within the Department of Defense (DOD) as more and more of our installatio are finding their water environment jeopardized. Solutions for the preser tion, cleansing and protection of our fresh water systems are going to be expensive and technically complicated to accomplish and administer. Actic is needed now.

WATER A STRATEGIC RESOURCE

Water, water everywhere,
And all the boards did shrink;
Water, water everywhere
Nor any drop to drink.[1]

As the United States rushes into the 21st Century are we creating a situation parallel to the lament of the ancient mariner? Water, water everywhere and yet none is drinkable. From the day prehistoric man first settled on what is now the continental United States, he was blessed with a seemingly limitless natural resource, fresh water. The perception continued intact until the late 1960s when ecologists and naturalists sounded first warnings. National concern grew sufficiently that Congress, on a scale never before attempted, took action to try to evaluate our water situation. The Water Resources Planning Act of 1965 was the first step in a continuing evaluation process which was constructed to give Congress and the public a comprehensive overview of the status of our water resources. Congress published an initial study in 1968 and a decade later completed the Second National Water Assessment. These studies plus current publications and authoritative articles paint a fairly dismal picture of the future and the lack of success in our programs to date.

There are terms and basic systems which must be defined prior to addressing the crux of our national situation, the demise of a natural resource. First, we should clarify how much fresh water is available. Water continually passes over the continental United States in the form of water vapor. It has been estimated that 40,000 bgd (billion gallons per day) is suspended in the atmosphere. In actuality only 10%, 4,200 bgd, reaches the US. This

represents the equivalent of an average rainfall of 30 inches falling uniformly on the entire surface area of the US. The good news is the supply from the sky is plentiful, but the bad news is that only a small percentage of the total precipitation may be put to effective use. If we look at the water supply broken down by category use, the magnitude of the natural resource management becomes clear.

(All figures in billions of gallons per day)[2]

RESOURCE		USES	
Precipitation 4,200	=	Evaporation	2,787
		Runoff to streams & oceans	1,328
		Input into ground water	61
		Withdrawn from ground water	82*
		Consumption	106
		Domestic (7.3)	
		Power generation (1.4)	
		Manufacturing & minerals (8.2)	
		Public lands (1.4)	
		Agriculture (87.7)	

*Because of this nation's inability to use all the precipitation available, there is a 21 bgd deficit in our ground water.

The gross figures would indicate there is plenty of water available only the geographical distribution is wrong. We have our highest annual rainfall, for instance, in the Pacific northwest, several hundred miles from our prime agricultural areas in the south and north central United States. While there are systems in existence and futuristic designs to redistribute water resources from the "have" areas to the "have nots," that is still a very long and expensive way to any solution. There are, however, successful precedents of water management to study.

Israel has set the water management example for the world to follow. As a hydrological area it was an inhospitable region with chronic drought or rainfall at the wrong time and in the wrong place. Since 1950, though, Israel has increased its water utilization from 17 percent to almost 95 percent. In other words, Israel now captures and productively uses 95 percent of the precipitation which falls on its lands. This success story can be attributed to excellent planning and, more fundamentally, to the nationalization of its water resources. While the US has not taken such drastic measures, the Israeli experience does offer valuable lessons to be learned. Heretofore Americans have abused their fresh water resource to its limit, so some master plan must be devised and enforced.

The first step to that plan is to determine resources available at present. You must evaluate your situation against current problems, existing conditions and projected usage then decide how to proceed. On a national level we only started with the Water Resource Planning Act and the Water Resources Council in the mid-1960s.

Their initial task was to develop a method or system to examine water as a resource. The Council divided the continental US into 18 Water Resource Regions for purposes of compiling and analyzing water resources data. These regions are hydrologic areas covering either the drainage area of a major river or the combined drainage areas of a series of smaller rivers. The major regions are further divided into 106 sub-divisions which are smaller drainage areas or watersheds. The smaller areas were focal points used to collect basic and specific data in order to portray regional and national conditions. These regions and sub-regions have no ties to any artificial

administrative boundary created by federal, state, county or private property lines. By establishing these hydrological regions, researchers can focus on water conditions much more clearly.[3]

This fairly straightforward approach for surface water becomes confusing when discussed together with ground water problems. The surface and ground areas do not conform to the same boundary criteria explained above. Both of these special cases will be explained and discussed later.

We have discussed the abundance of fresh water and a logical method of evaluating relatively small geographic sections by hydrological areas. If this were the sum of this complex problem, solution would be simple. Man, however, has taken his ecological toll as he has progressed in the 20th Century. As this nation has grown in wealth and technology, we have paid a dear price exacted in the pollution of our environment and depletion of our natural resources. We attain fresh water for our usage from three sources: precipitation, surface water and ground water. Each of the three sources has been damaged by unchecked pollution and depletion. We will look at each of these area's unique problems and discuss what can be done to correct our mistakes.

Precipitation is water contained in the atmosphere in the form of water vapor. On earth this moisture is in the form of rainfall, snow, sleet or hail. Despite the vast quantities of water vapor available, the distribution system of precipitation is far from equitable or even predictable. The great system which fills the nation's reservoirs and streams has been known to go awry with devastating results.

Meteorologists have studied the earth's upper atmosphere for decades trying to understand what causes the formation of weather patterns. In particular, the fast moving band of air called the jet stream has tremendous impact on availability of precipitation and temperature norms. Another natural phenomenon affecting our rainfall has been volcanic eruptions, which change weather patterns thousands of miles away. A high altitude dust/ash cloud will change temperatures over continents, thus altering its climatic conditions and patterns.

Weather modification as a science and a fact is still in the age of black magic. For three decades researchers have intensely studied cloud seeding with silver iodide, frozen carbon monoxide and other nuclei. Winter cloud seeding in the northwest, in fact, has increased the total precipitation over small areas by as much as 10 to 20 percent per year. Yet in Florida results were very uneven and ranged from a plus 18 percent to minus 6 percent. As mentioned, the most successful large operation belongs to Israel. Through regular cloud seeding by planes and special chemical burning generators on the ground the Israelis have increased their average annual rainfall by about 15 percent.

Far more serious than natural problems and our inability to modify our weather is the growing pollution of water resources. Industrialization and

its attendant contamination have created a situation which could destroy all progress. As one illustration, there is a hidden story underlying the quaint old movie thrillers filmed in the famous London fog. Millions of Britons burning low grade coal for warmth and power created that fog. Today we, too, create a "fog" by moving beyond just coal to include petro-chemicals for fuel and energy creating a new and more deadly killer--"ACID RAIN." Scientists have provided overwhelming evidence that acid rain is caused by sulfur dioxide, hydrogen sulfide and nitrogen oxide emissions released into the air by utility power plants, industry, and automobiles and that the emissions often travel for great distances before they fall back to earth. These pollutants then return to earth in the form of acid rain, acid snow, and acid dust.

Vast sections of Canada and the northern to southern US are victims of the damage caused by this pollution. Forests are dying and new growth stunted by the acid conditions. Pollution erodes stone and concrete used in construction. The worst effect, and possibly the most permanent of all, is the damage to our water system. The acid compounds are killing all the aquatic life in the lakes and small streams.

To combat this national tragedy both Canada and the United States have pledged support to take immediate legal action against the air pollution violators. Federal legislation putting more effective laws on the books and strict government enforcement seems the only acceptable approach. There will also be some sort of cost sharing program to relieve industrial pressure created by the burden of meeting new, more stringent, clean air controls. The awareness of the problem exists; the next step is action.

Surface water occurs in rivers, streams, lakes, swamps, marshes, and man-made reservoirs. Competing off-stream uses of water for energy, agriculture, domestic and industrial needs of the environment and in-stream flow have created numerous problems throughout the United States. The projection for the year 2000 is that 17 sub-regions in the midwest and southwest will have severe shortages of surface water. During times of low precipitation this number will more than triple. As demands increase for usable water the competition for surface water will grow. Trade-offs across legally established boundaries will have to be made, often creating restrictions which will be unpopular and commercially limiting.

The lower Colorado region is a good example of an overtaxed water system. The river now has an average flow of only 1,550 mgd, which is only a fraction of what the natural flow should be (6,500-7,000 mgd). The Colorado region has become a legal nightmare with the major population centers demanding more and more of this vanishing water resource. Such metropolitan areas as Los Angeles, Phoenix and Tucson are after the Colorado's waters. Seven states also drain the river for irrigation and it has become little more than a trickle by the time it reaches the Mexican border. Even this trickle is so laden with salts and agricultural wastes that it is virtually unusable. The US government was recently forced, through an international agreement, to install a $400 million demineralization facility in Arizona in order to deliver potable water to Mexico. The plant processes nearly 100 million gallons of water a day, removing most of the minerals and then depositing the potable water back into the riverbed. A separate canal for waste parallels the natural river and drains into the Gulf of California. Because of the tangle of interstate contracts and lower court decisions, Mexico and the seven states bordering

the Colorado River actually have the legal right to more water than exists in the river.

There are other watersheds being eyed for exploitation. A battle for the Little Bighorn has started over a proposal to divert water that flows through the Crow Indian reservation for a coal-slurry pipeline. San Antonio, Texas, is developing proposals to take water from the Red River on the Oklahoma border. Los Angeles, California, has turned the once lush Owens Valley into a semiarid region by taking its river water. The Owen Valley water war is not over yet. In 1970 Los Angeles built a second aqueduct to the Valley, this time to take the ground water. The issue is not the legal right to the water which was secured at the turn of the century, but residents and state officials question the moral right to create a desert wasteland. Southern California is also considering studies to take water from northern California. The Snake River in Idaho, the Yellowstone in Montana and the Columbia River are all being eyed by their thirsty neighbors.

While the distribution of fresh water is of great concern, the poisoning of this water is probably a far greater threat. Consumption includes agriculture, manufacturing and minerals, power generation and domestic use. All pollute the water. The poisoning of America has come of age. During the last 25 years man's intervention into the natural order of things has been at such a rate and depth that our ecological system may never recover from the true damage. The most alarming incursions are the creation of chemical compounds. Almost 1,000 new concoctions a year are added to the 60,000 plus already in existence. The Environmental Protection Agency (EPA) has classified over 35,000 of the chemicals as being either definitely or potentially hazardous to human health. Are you sure your water is safe to drink? To date more

than 700 synthetic chemicals have been identified in our drinking water. Over 77 billion pounds of hazardous chemical wastes are produced a year and the EPA estimates only 10 percent are being handled in a safe manner.

Historically, our surface water has washed away our problems. NO MORE! There are three million miles of interconnected surface water streams vulnerable to indiscriminant pollution. A Vermont survey of 50 water systems found that more than half were contaminated with chloroform. The EPA surveyed drinking water in 80 major US cities. In all of them, the water contained at least one of the six potentially harmful chemicals investigated. One such chemical, tri-chloro-ethylene (TCE), a cancer causing compound, is so potent that a mere five gallons carelessly poured into a water supply would render unsafe all the water that 50,000 households use in a full year.

Ground water occurs in the zone of saturation such as an aquifer or reservoir located within 2,500 feet of the land surface. The term aquifer describes a body of unconsolidated material such as sand, gravel, clay, rock or soil that is semipermeable enough to yield water in useful quantities.

An aquifer is said to be overdrawn when water is withdrawn from it at a rate greater than the long-term rate of re-charge or re-fill. Analysis of most current ground water draft data indicates that of the approximately 100 sub-regions eight hydrostatic sub-regions have critical problems, 30 have moderate problems and 22 minor difficulties. In other words, approximately 60 percent of all watershed regions are in trouble through overdraft.

This is the last area we will look at as a supply for fresh water. The ground water reservoirs were formed under the US as early as the Plerstorene times and have been slowly filled for thousands of years from rainfall. Experts estimated that the underground reserves of fresh water are equal in size to the amount of water contained in the Gulf of Mexico. The numbers are gigantic and it is hard to imagine that there would ever be a shortage, but during the last 25 years the total ground water withdrawals have increased at a 3.8 percent rate each year. Ground water provides over 40 percent of the fresh water used by the United States during a year, with California consuming one-quarter of that amount. Our central and western states are almost totally dependent on ground water to support their agriculture, industry and population centers.

Fifty percent of Americans depend on ground water, including residents of such cities as Miami, Tucson, Houston, Charleston and Atlantic City. Every aquifer in this nation is under man's relentless attack. In the San Joaquin Valley telephone poles bear marks to show the great subsidence or sinking of the surface land as man extracts water from the aquifer. In the last 50 years,

parts of the Valley have sunk more than 25 feet. The desert floor between Tucson and Phoenix is crossed with cracks up to 30 feet wide. Houston, Texas, is slowly sinking as water is sucked from beneath it. Subsidence has occurred over a 3,000 square mile area with a 12-foot depth at the maximum point. They also have an average sink rate of six inches per year from their demand for ground water. In Georgia and along the Texas coast salt water has begun encroaching on what once were fresh water aquifers. As man removed the water these underground reservoirs compacted, losing their ability to hold water; so even if pumping was stopped, these areas could never fully re-charge to previous capacity.

The Ogallala aquifer may not be a household phrase, but its importance to America and our agricultural economy is critical. While this water supply is unique, its problems are common. The Ogallala is an aquifer about the size of California with the equivalent water supply of Lake Huron. It stretches from South Dakota to Texas and supports agriculture, industry and civilization in eight states, America's bread basket. Since World War II the Ogallala has provided ever-increasing amounts of water. Today, the annual overdraft, i.e., the amount of water not returned to the aquifer, is nearly equal to the yearly flow of a natural Colorado River. The problem is no longer "if" the water will run out but "when." Estimates range from the year 2000 to 2020, frighteningly close. Then the nation stands to lose the crops on 5.1 million acres of irrigated land, or an area the size of Massachusetts. Yet solving the problem of overusage may prove to be the simpler of the two immediate problems facing our ground water supply today.

Chemical contamination of underground reservoirs has been likened to a time bomb. No one knows if this metaphorical bomb will explode, but there

are signs that it certainly is ticking away. The EPA estimates that three-fourths of the 175,000 known waste disposal sites may be leaking poisonous chemicals into underground water supplies. Experts believe that only one to two percent of our total ground supply is contaminated. While that sounds like a minor problem, it represents water supplies for a known five million people already affected and potential millions more who are in jeopardy just by being exposed to such chemicals. It is also suspected that as high as 20 percent of all cancers treated in the US are attributable to water contamination.

As late as the mid-1970s, it was a popular belief that ground water was protected from pollution by the soil where microbes and the soil itself scoured out traditional pollutants. The truth is microbes are totally impotent against most of the 60,000 synthetic organic chemicals made today. To add to our chemical problem, fertilizers, salts spread on icy roads, bacteria from septic tanks, and salt water are all seeping into our water tables at an alarming rate.

For years farmers sprayed crops in the San Joaquin Valley with the pesticide DBCP which was later found to cause sterility and cancer in humans. They have stopped spraying, but the poison is infiltrating the soil and water and still spreading years later. One-third of the Valley's wells now test positive for DBCP and Fresno County with 250,000 people now faces the risk of contamination.

The EPA announced in 1974 that New Orleans' drinking water contained 66 man-made chemicals, including six suspected carcinogens. Then the Environmental Defense Fund found that white males who drank the city's water were almost twice as likely to die of cancer as the average American male. There is irrefutable evidence that there is a link between contamination and our nation's health.

Federal government involvement to this stage has primarily been to document our water problems on a national scale and little else.

Water as a natural resource is in danger of being or has been damaged beyond repair. There is no doubt it is less expensive and far easier to maintain and prevent pollution and overusage than it is to clean up or provide fresh water. Given our current unacceptable situation, what does the future hold? Israel through its nationalization of water resources may be showing us the way. Historically, water issues have been left to state and local authorities to control. It is becoming apparent that the only sensible method of managing water is through the hydrological regions established by the Water Resource Board in the mid-1960s. Atmospheric and ground water controls should also be subject to a regional or aquifer authority under a national policy agency. These agencies will be responsible for both water usage and enforcement of pollution standards.

There is an endless list of water problems which cross state and local county lines of jurisdiction and that are impossible to resolve under our current arrangement. El Paso, Texas, has crossed a state line to extract New Mexico ground water from 300 new wells it dug to support its growing population. The case has grown into litigation but a verdict is probably years away. San Antonio, Texas, has drawn down the Edwards Plateau aquifer to the point that natural springs in New Braunfelds, San Marcos and Austin, Texas, are now running at a small percentage of their natural flow of 15 years ago. What rights does a consumer have to strip the resources of a neighboring watershed or a common aquifer?

Increasingly it is becoming apparent that an agency above the state level must become responsible if we are to preserve our fresh water. Where

are the federal programs and guidance needed to put solutions to work? One could argue the 1960s were the beginning, the age of enlightenment, of our first truly national study and foundation for policies. The 1970s saw attempts to legislate controls which actively pushed for environmental improvements while trying to balance the need for economic growth. It appears the early 1980s will be remembered mainly for its conflicts and stalemate.

Nine major environmental laws, including the Clean Air and Clean Water Acts, have expired. Congress appears to be in a legislative paralysis over amendments and additional controls. It is regrettable it takes a scandal at the Environmental Protection Agency over the toxic waste clean-up program and the resignation of key appointees to see minimal action. The continuation of the "super fund" is the only bright spot for environmentalists. A "SUPER FUND" bill passed by the House in December 1985 mandates that the EPA clean up 600 hazardous waste dumps by 1991 out of the 850 currently on the national priority list. Sadly, Congressional inertia has nearly brought the existing program for cleaning up the nation's worst chemical contaminated dumps to a virtual standstill. While toxic waste clean-up will continue on a reduced scale, such problems as acid rain, ground water pollution and toxic and radioactive substance disposal are waiting lethally in the wings for their turn. A tragic event halfway around the world in Bhopal, India, may prove to be the catalyst to get the environmental legislation moving. Public awareness and support of an environmental bill will be hard for Congress to ignore.

Department of Defense (DOD) awareness for water conservation and protection grew out of the 1968 study completed under the Water Resources Planning Act of 1965. The Second National Water Assessment a decade later became a basis for a companion DOD study pertaining to water assessment for military installations. All military installations were geographically located to determine which water source aggregated sub-region they belonged in for the purposes of evaluation of specific hydrological problems. Earlier in this paper numerous water problems from availability to quality were briefly discussed, all of these problems affect the day-to-day operation of military installations. We share the water resource problems with our neighbors.

There are over 1,000 military installations in the primary base structure within the continental United States and these installations are located in 90 of the 104 hydrological sub-regions developed for the national water study. Over 90 percent of our facilities are located in sub-regions which have water resource problems. Based on hydrologic principles, if an installation is located within a hydrologic area, it is virtually impossible for that installation to be isolated from the water source problems of the area.

Demographic trends show three-quarters of the US population is living in urban areas and the urban sprawl has effectively surrounded better than 66 percent of our military installations. As base operations have grown, so has the civilian support infrastructure turning most installations and their immediate areas into sizable urban centers. The Army has 280 installations in the DOD primary base structure with 260 located in areas with specifically identified water problems. The Air Force has 539 installations and 481 are in locations which have problems. The Navy and Marine services are the worst

case with 295 installations and 281 have specifically identified water related problems.[4]

As water regions or hydrostatic areas develop problems with quantity or quality, one may be assured that proposed and executed solutions will be translated into higher costs. These greater expenses will require more scarce money for water treatment, waste treatment or inter- or intra-basin transfers to insure adequate supplies. These increased costs will reflect directly in the expenditure of the installation's Operations and Maintenance (O&M) budget. In recent years utility costs have increased dramatically taking more and more of the O&M budget. DOD is facing major cutbacks in its funding support during the next five years yet still must come to grips with the problem.

With such a bleak picture, where can we go for relief? It is evident that without some major technological breakthrough we are going to have to help ourselves. Creative and innovative methods of water management must be developed to keep our military installation integrity as sound as possible. Several early areas for study are:

1. Examination of our energy consumption to minimize waste.

2. Use a metering system on installation facilities to include housing. Let housing occupants pay for consumption.

3. Recycle water for specific uses such as the base or public car wash.

4. Study the distribution system for losses and insure holding tanks, lines and valves are maintained properly. Our posts and bases are old and the distribution systems installed

years ago need attention. Not so long ago active pipes were unearthed at Chanute AFB, Illinois, that were thin metal linings surrounded by banded wooden sections. What else is buried under our installations?

5. Review areas requiring area watering for reduction or elimination. Develop a ZERO scaping plan. All of our installations maintain park areas which are water wasteful. Zero scaping is a new landscaping approach developed in the southwest to provide pleasant areas which require no watering and require very little maintenance or attention. A little creative planning can conserve both money and water.

Whatever approach is taken to improve our efficiency and water survivability, we must understand one singularly important fact. Sharing a hydrologic area means sharing the hydrologic problems. Installations must be the leaders in eliminating pollution, managing toxic wastes and accurate management of our water resource. In many respects DOD installations are controlled environments. We can capitalize on this to set the standard and provide the model.

CONCLUSION

After two comprehensive studies covering two decades, it is safe to say without comprehensive and rapid action to protect what remains of this nation's singularly most important natural resource, fresh water, our standard of living and society in general is in for drastic changes. The projections emerging from the data gathered paint a very discouraging picture for the future sufficiency of water resources for the United States. If our assessments are correct, the potential exists to cause basic changes in our national economic, industrial and commercial systems, as well as a major deterioration in the quality of life of the average American citizen. To describe WATER as a strategic resource is a gross understatement. Without adequate quantities of fresh water our entire civilized structure would collapse into chaos. How do we begin to manage and correct the situation we are responsible for?

First, the United States must develop a national strategy to manage its fresh water and protect it from pollution. Once the Federal government establishes the strategy and policy develops it to guide proper legislation, we will be on the right track. As mentioned earlier, Israel nationalized their water resource to insure its protection; we might be wise to follow suit. Congress has made feeble stabs at clean air and clean water legislation, but it has generally failed to act unless there is disaster or some event creating tremendous public pressure. Industry as a whole has refused to take any initiative or responsible action to clean up their involvement in mass pollution. After decades of taking profits without accepting their environmental responsibilities, industry may end up being forced to pay a high bill that might destroy

it. The damage done may never be corrected in anyone's lifetime. The laws must be passed and enforced to the limit.

An infrastructure exists to manage our water resources using the two-tiered structure of regional and sub-regional hydrological areas outlined in the National Water Assessment study. Supporting management groups with area responsibility delineated by hydrological areas should be established to handle ground water issues for delineated aquifers. A typical group would be relatively small--7 to 9 members--allowing for representation by major factions such as: Chaired by federally appointed person with the equivalent authority similar to that of a Federal Judge, a State Representative, a local government representative, environmentalist, industrialist from the area. These groups would be the watchdogs responsible for identifying and correcting pollution problems and resolving water usage conflicts. They would be autonomous and able to cross state, county or city lines to resolve problems within their water region. This complex and large operation would have to come under a federal umbrella and a single national monitor to have any chance of working.

Military and federal installations and facilities are good starting points for implementation of both conservation and protection programs. Some programs have been started but we are a long way from being successful. Several problem areas needing management attention were identified earlier in this paper. Priority now must be given to environmental studies, toxic chemical control, water management both on and off post and general awareness of conservation. Too often these vital programs are nothing more than additional duties for NCOs or junior officers. They are generally discussed once a year as required by regulation and then filed away. Commanders must take active and continuing

interest in all aspects of this problem to include contingency plans if a major problem arises.

Second, the population of this country must become aware of our situation. A mass media effort must be made to insure America understands the seriousness and implications of the water resource issue. Minimize consumption and pollution prevention must become household words. Industry, agriculture and the individual must work at protecting our water. As a nation of mass consumers we are about to face monumental decisions. Most people take for granted the water related to every aspect of their daily lives. Consider that a car takes 100,000 gallons of water to produce, a ton of steel takes 60,000 gallons, a cotton dress 1,500 gallons, and a bushel of corn 37 gallons. The daily average water usage for a family of four is five gallons for drinking and cooking, dishes take 18 gallons, toilets nearly 100 gallons, bathing 80 gallons, laundry 35 gallons and lawns, etc., use 100 gallons.[5] Can we learn to change? Consider the comparison of two cities--Tucson and Phoenix, Arizona. Tucson has developed the hard way with limited water availability and is considered to have a desert mentality. They consume an average 160 gallons of water per person per day. Phoenix, on the other hand, has relied on the Salt River for its water needs and has developed an oasis mentality using over 260 gallons of water per day per person. Both cities are well below the 335 plus gallons used by the average American family. The price of education will be small compared to the potential savings. I also doubt the standard of living in Tucson has suffered because of the water conservation efforts.

Third, money must be made available to push our technological limits to find solutions for these man-made problems. In coastal areas the use of

advanced desalination techniques could provide an alternate source of fresh water instead of resorting to the overdrawn ground water sources. There is a large demand for industrial water which does not have to be potable. Slightly brackish water or highly mineralized water can be used in closed industrial systems thereby saving fresh water. But by far the worst problem facing US industries is the generation of an awesome 300 million tons of toxic waste a year. Incinerators and various bacteria are helping dispose of a portion of this waste. At Times Beach, Missouri, a mobile incinerator producing 4000° F. eliminated 99.9 percent of the dioxin in 1,750 gallons of liquid waste and 40 tons of soil in six weeks. Westinghouse Electric is testing a mobile plasma arc furnace capable of 20,000° F. Perhaps the most promising advance involves the use of bacteria. A Texas company is developing microbes that eat PCBs, creosote and pentachlorophenol. This "molecular breeding" process can produce bugs which will eat almost any toxic chemical. The bacteria becomes so dependent on the chemical that it dies when it has consumed what is available. Homestake Mining Company has developed a bacteria which picks up metals in the waste water and also eats the cyanide used for gold extraction. South Dakota's Whitewood Creek has now seen the return of trout because of this discovery.

As more and more of our underground water sources are polluted, we must develop more comprehensive and inexpensive methods of analyzing our water. Once we know the pollutants, we are confronted with developing a wellhead system for cleaning the water. Our ground pollution is so widespread and coming from so many sources it may never be corrected. We must stop pollution where we can and then purify the water as we get it through advanced technology.

ENDNOTES

[1]Louis Untermeyer, A Treasury of Great Poems, 1955, p. 896.

[2]US Water Resources Council, The Nation's Water Resources 1975-2000, December 1978, p. 12.

[3]Ibid., pp. 7-8.

[4]R. D. Schwartz, Current and Projected Water Resources Problems and Their Impact on DOD Installations, May 1979, pp. 35, 43 & 53.

[5]Fred Powledge, et. al., Water - Special Report 1984, March 1984, pp. 8 & 12.

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