SFUND RECORDS CTR
156825

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AERONAUTICAL SYSTEMS DIVISION (AFSC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6503

REPLY TO ATTN OF: PMDA

3 APR 1986

SUBJECT: Final Air Force Plant 44 Remedial Action Plan, Responsiveness Summary and Record of Decision

TO: To Whom It May Concern

1. On October 4, 1985, the United States Air Force made available for public review and comment the Final Draft Remedial Action Plan, United States Air Force Plant 44, Tucson, Arizona (Draft RAP). The Draft RAP summarized the results of previous environmental investigations and ongoing monitoring programs at and in the vicinity of Air Force Plant 44, and analyzed remedial alternatives that might be suitable for responding to the conditions discovered through those efforts. Based on this analysis, the Air Force recommended the implementation of a groundwater extraction, treatment and recharge system to remedial groundwater contamination south of Los Reales Road.

2. Public comments on the Draft RAP were solicited during the period of October 4, 1985 through October 25, 1985. Additional comments from a number of public agencies were received both before and after the formal public comment period. In some instances, our review of these comments resulted in further refinement of the remedial alternative recommended by the Draft RAP. In other cases, these comments resulted in revisions to the Draft RAP to provide greater clarity to parts of its analyses. In all cases, the public comments received serious evaluation and were of tremendous benefit to the Air Force's selection of a final remedial alternative for Air Force Plant 44.

3. Enclosed for attachments to the Draft RAP is a Responsiveness Summary to the public comments. The Responsiveness Summary identifies the major issues identified by the public concerning the Draft RAP and the Air Force response to those issues. The Draft RAP and its supporting data, reports, studies and analyses, together with the Responsiveness Summary, constitute the Final Remedial Action Plant for Air Force Plant 44.

4. Under the Comprehensive Environmental Response, Compensation and Liability Act of 1980, and Executive Order 12316, the Air Force has both the responsibility and authority for responding to releases of hazardous substances at Department of Defense installations under Air Force control. Based on the prior investigations, the remedial alternatives analysis, its supporting documentation and the public comments received, the Air Force has decided to implement a remedial alternative for Air Force Plant 44 consisting of a groundwater extraction, treatment and recharge system. A copy of the Air Force's Record of Decision for the selection of this remedial action is enclosed and should also be attached to the Draft RAP.

Peter J. Ruppert

PETER J. RUPPERT, Lt Col, USAF
Chief, Facilities Mgt Div
Directorate of Manufacturing/QA

2

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE SYSTEMS COMMAND
ANDREWS AIR FORCE BASE DC 20334-5000

10 JAN 1986

REPLY TO ATTN OF: DEMV

SUBJECT: Environmental Assessment for AF Plant 44 Remedial Action Plan

TO: ASD/PMD

The subject assessment has been reviewed by the AFSC Environmental Protection Committee and is approved. Your Environmental Protection Certificate is attached.

FOR THE COMMANDER

FRANK P. GALLAGHER III, Lt Col, USAF, BSC
Chairman, AFSC Environmental Protection Committee

1 Atch
AF Form 815

PMAS F3257.81.F.2005 (AFD 40)

UNSCANNABLE MEDIA

See Document # 156869
for scanned image(s) of the media document(s) label(s).

To use the unscannable media document(s),
contact the Superfund Records Center.

Media - parent

FINDING OF NO SIGNIFICANT IMPACT

REMEDIAL ACTION PLAN

AIR FORCE PLANT 44

TUCSON, ARIZONA

The Air Force Plant 44 Environmental Assessment documents the analysis of four alternatives to mitigate the groundwater contamination problems caused by that facility in the general vicinity of the Tucson International Airport, Tucson, Arizona. The environmental assessment is enclosed.

Based upon the analysis documented in the environmental assessment and the Draft Final Remedial Action Plan attached to it, it is my decision to adopt Alternative 4, to remove the contaminated groundwater from the aquifer, treat the water, and use the treated water for groundwater recharge. Alternative 4 is selected for the following reasons:

1. The initial capital investment, regardless of the various ways in which the treated water could be used, is based upon available, reliable data which makes it cost-effective compared to Alternatives 2 and 3.

2. The technical feasibility, regardless of how the treated water could be used, generally exceeds that of any of the other alternatives.

3. It removes contaminants from the groundwater.

4. It treats the removed groundwater before using it for any further purpose.

PMAS F33657-81-F-0

5. It provides an added source of acceptable quality water.

6. It reduces the hazard of further groundwater contamination migration.

Alternatives considered were:

Alternative 1. No action, making no effort to remove groundwater contamination in regional aquifier.

Alternative 2. Contain contaminated groundwater plume by placing impermeable barriers around its perimeter, preventing further migration.

Alternative 3. Withdraw contaminated groundwater, disposing of it without treatment.

Alternative 1 was not selected because other alternatives would not cause greater environmental or health dangers. Alternative 2, as proposed in the environmental assessment, was not selected because existing hydrogeological data is inadequate to determine the extent of the effort involved and whether, if undertaken, it would prevent further contaminated groundwater migration. Additionally, available cost data strongly suggests that potential costs far outweigh benefits to be derived. Alternative 3 was not selected because of the limited uses available for the untreated water and the potential for further groundwater contamination.

Under Alternative 4 there are 12 alternative means of disposing of the treated groundwaters. In determining the preferred means of disposition, three additional criteria were applied:

1. The facility or facilities accepting the treated water must have the capacity to accept 5,000 gallons per minute because extraction at a lesser rate would not efficiently reclaim contaminated groundwater.

2. The accepting facility or facilities must have an operational life of 20 years; the projected period of continuous pumping to restore the contaminated aquifer is estimated at eight to ten years.

3. The process cannot reduce the existing water levels in the aquifer or otherwise degrade present water quality, in violation of state and the local land use management plan. The only means of distribution which satisfies these three criteria is that process which will recharge the aquifer directly with the treated water. This process has the added advantages of being cost effective relative to all viable alternatives considered and more effective in its initial stages of operation in reducing contamination levels. For the reasons stated above, I have selected the Direct Recharge Water Use Alternative under Alternative 4 as the most appropriate remedy to the present contaminated groundwater condition underlying AF Plant 44 and the area adjacent to it.

I have determined through the environmental assessment that this is not a major Federal action which would significantly affect the quality of the human environment; therefore, an environmental impact statement is not necessary. This determination is based on the following factors:

1. There are minimal irreversible resource commitments and irretrievable losses of any natural resource.

2. There are no significant negative cumulative effects.

3. The physical and biological effects are restricted to the areas of planned activity.

4. No known threatened or endangered wildlife are affected.

Charles H. Alford

Charles H. Alford
Chairman,
Industrial Facilities Subcommittee
ASD Environmental Protection Committee

18 Nov 1985

DATE

Air Force Plant 44 (AFP 44) is a government-owned, contractor-operated defense manufacturing plant currently operated by the Hughes Aircraft Corporation. Located on approximately 2106 acres of land, it is adjacent to and southwest of the Tucson International Airport. Its manufacturing complex comprises 1,088,340 square feet of floor space.

The plant has been in operation since 1951 and presently manufactures the Army TOW missile, the Air Force Maverick missile, the Navy Phoenix missile, and the Marine Corps Angle Rate Bombing System. It employs approximately 8,000 employees having an annual pay roll exceeding $200 million.

The various manufacturing processes have produced industrial wastes. Initially, wastewater was discharged on the plant property, and then in 1954 treated effluent was discharged into lined and unlined surface impoundments. Each wastewater treatment process was approved by the predecessor to the present Arizona Department of Health Services (ADHS) and was believed to be an appropriate means of disposal at the time.

In 1977 a new zero discharge hazardous waste treatment facility began operations. This operation treats and recycles about 80% of the wastewater, the remaining 20% being placed in lined evaporation ponds. The present system does not discharge contaminants into the environment.

Beginning in 1979 EPA financed studies conducted by ADHS and those conducted by the Air Force concluded that the historic disposal practices had resulted in the presence of trichloroethylene (TCE) and other contaminants in the groundwater under AFP 44.

Air Force investigations were conducted pursuant to its four-phased Installation Restoration Program (IRP) to identify and remedy environmental problems resulting from past Air Force industrial waste disposal practices. Phase I consists of a records search. Phase II is the verification and qualification stage. Phase III is the analysis stage, and in Phase IV various cleanup options are considered and a remedial plan implemented. The IRP has disclosed that there is a zone of perched groundwater (saturated soil) beneath a portion of the plant covering about 100 acres, and ranging in thickness from one to 24 feet. Beneath this zone and separated by a relative impermeable material is a regional aquifer. The aquifer consists of an upper and lower zone separated by a clay aquitard or divider. In the perched zone, chromium at levels exceeding drinking water levels have been found, as has concentration of TCE, 1,1,1 - trichloroethane (TCA), and 1,1 - dichloroethylene (DCE). TCE, TCA, DCE, and Chromium have also been found to exist in the upper zone of the regional aquifer; and these wastes appear to have migrated in varying degrees to locations off AFP 44; chromium to just beyond the north boundary; TCE to the vicinity of Los Reales Road; and TCA and TCE have migrated to a lesser extent. The lower zone of the regional aquifer does not appear to have been directly contaminated by the upper aquifer, due to the impermeable barrier. However, two wells, which were drilled through the upper aquifer may have contaminated the lower. These wells were sealed when the problem was discovered. The problem is mitigated because migration in the lower zone is slower than in the upper. Contaminants in the perched groundwater should be removed because they provide the potential for further contamination in the regional aquifer.

As part of the IRP Phase IV, the Air Force has developed a Remedial Action Plan (RAP). The purpose of the RAP is to assess the extent of the groundwater contamination, consider various alternative measures to remedy the situation, and to propose the most appropriate remedy. Remedial action is appropriate because continued migration of the contaminated groundwater in its historic northwesterly path will contaminate both public and private residential wells in its path.

The selection standards for those alternatives which were considered are as follows:

a. limit to maximum possible extent continued migration of contaminated groundwater;

b. render contaminated groundwater suitable for beneficial use;

c. meet all applicable local, state, and federal regulatory requirements;

d. be cost effective;

e. create the least possible environmental affect on the regional aquifer and other action plans and land use programs in the Tucson area.

There were four basic alternative remedial measures considered: (a) no action, more particularly described on pages 46 through 48 of the attached final draft RAP; (b) containment by impermeable barriers, pages 49 through 51; (c) withdrawal of the contaminated groundwater and disposition of the untreated water by various means, pages 51 through 61; and (d) withdrawal, treatment, and disposition of the treated water by various means. Under the third basic alternative, there were four means of disposition considered and under the fourth basic alternative there were twelve means of disposition considered.

The "no action" alternative is adequately discussed at the referenced pages in the RAP and is hereby incorporated in this assessment. The environmental consequences of the "no action" alternative are unacceptable. The contaminated groundwater will continue to migrate and in some locations concentrations of contaminants would actually increase as high contaminant areas in the area of the physical structures of AFP 44 migrate. Over a 30-year period, the contaminant plume can be expected to migrate an additional three miles north-northeast. The "no action" alternative is also unacceptable because the other alternatives considered would result in improving existing contamination levels and ameliorating the present migration.

The alternative in which an impermeable barrier is constructed around the present plume of contaminated groundwater is adequately discussed at the referenced pages of the RAP and is likewise incorporated in this assessment. The technology to construct such a barrier exists. However, the magnitude of such a project is unknown because available data does not provide sufficient information as to the precise extent or depth of the plume. In other words, we have no present assurance that constructing this barrier would contain all the migrating contaminants. Nor in the absence of such data can there be any accurate estimate of the cost of such a project. There has been no known impermeable barrier constructed of the same or similar magnitude as that contemplated here. One distinctly negative effect of such an alternative would be to withdraw effectively from public and private use all that groundwater contained by the barrier. This raises the question of alternative sources of water, for those parties affected, in a developing area in which existing water resources are relatively scarce.

The third alternative, withdrawing the contaminated groundwater and disposing of it in one or a combination of four enumerated means, is adequately discussed at the referenced pages and incorporated here. The four means of disposing of the untreated water are as follows: (a) direct discharge to the public sewer system, (b) injection of the untreated water into an as yet undiscovered deep geological containment strata; (c) solar evaporation; (d) disposal at a permitted hazardous waste treatment facility. The RAP discusses various cost, logistical, and technological problems which render each of these means unfeasible. In addition, the continued existence of the untreated contaminants or any form carries with it continuing Air Force liability for any future violations of the Resources Conservation and Recovery Act. These means also suffer from the same drawback confronting the second alternative, i.e., withdrawing this source of water from public and private use. Finally, withdrawing the contaminated water without recharging the aquifer would reduce the aquifer water level, thereby threatening existing public and private wells and violating state and local water management plans. Construction of a water treatment facility would be avoided, but there would be other construction and land acquisition costs associated with each of these means which would result in short-term environmental degradation and long-term removal of certain real estate from beneficial use.

The fourth alternative, withdrawing and treating the contaminated groundwater, and disposing of it in one or a combination of twelve enumerated means, is adequately discussed on the referenced pages of the RAP. Three additional criteria are deemed appropriate for this alternative to be feasible: (a) extraction at less than 5,000 gallons per minute (gpm) will not effectively reclaim contaminated groundwater; (b) continuous pumping for a minimum of eight to ten years is considered necessary to restore the aquifer; and (c) distribution must be consistent with the state statutory requirements and the local groundwater management plan. The prime consideration here is that drawdown of existing groundwater must be minimized and further degradation of groundwater quality be prevented. This alternative would require constructing a groundwater treatment facility at AFP 44 and then a distribution system or systems consistent with any of the twelve alternative means or combinations. Construction and operating costs would vary with the distribution system as depicted in Table 2, following page 79 of the RAP. Environmental impacts would vary depending upon the amount of construction each alternative means required.

The only alternative means or combination which satisfies the criteria of continuous use, adequate demand, and statutory and regulatory compliance, which is the preferred and the proposed alternative, is the recharging of the aquifer with the treated water. Even assuming a 10-year operating life for the required equipment, as opposed to a 20-year life for other systems, this means is cost effective. It reduces the contamination in two ways: by extraction and by subsequent dilution of the contaminated groundwater by treated water. This makes the system initially the most effecient in terms of reducing contamination levels. The required distribution system, costing an estimated $27 million, is relatively inexpensive and would be confined

to AFP 44, meaning that the ecological affects of constructing the distribution system would be considerably less than virtually every other alternative means and alternative considered. The preferred alternative complies with all relevant substantive legal standards, as more particularly discussed at pages 114 through 128 of the attached RAP.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AERONAUTICAL SYSTEMS DIVISION (AFSC)
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6503

18 FEB 1986

REPLY TO ATTN OF: PMDA

SUBJECT: Remedial Action Plan Responsiveness Summary, AF Plant 44, Tucson AZ

TO: Mr. Phil Briggs
Arizona Dept of Water Resources
99 E. Virginia Avenue
Phoenix AZ 85004

1. Attached you will find the Responsiveness Summary of comments received on the Air Force Final Draft Remedial Action Plan for Air Force Plant 44 in Tucson, Arizona (Atch 1). The summary reviews comments from the public received during the open public comment period in October 1985 as well as comments from the memebers of the Technical Review Committee (TRC) received both during and after that public comment period. These comments, the Air Force Responsiveness Summary, and the individual responses provided earlier to the major and most significant of the TRC member comments have been appended to the Final Remedial Action Plan and incorporated therein.

2. The Air Force evaluation of these comments, assisted by its contractors and technical consultants, has been of immeasureable benefit to the analysis of the groundwater contamination problem at AF Plant 44 and to the development of its Remedial Action Plan. In all cases your comments prompted serious reflection over the matters identified, resulting in either the reassessment of particular fundamentals of the proposal and, perhaps, a more persuasive presentation of the Air Force position, or the refinement of that particular matter in the Remedial Action Plan. You will find that reassessment or refinement documented in the Responsiveness Summary.

3. Having carefully considered the public and TRC member comments, the Air Force elected the preferred remedial action alternative identified in the Remedial Action Plan and indorsed in principle and in most particulars by the TRC. The Air Force will continue to monitor the progress of that alternative after its implementation to measure our success in meeting the goals of the Remedial Action Plan. Through the continued participation of the TRC and its Hydrogeologic Subcommittee the Air Force would expect to address those issues deferred for later review, together with any new concerns identified during the remedial action.

4. If further information is required, point of contact is Mr. Charles Alford, ASD/PMDA, Area Code (513) 255-4466.

Peter J. Ruppert

PETER J. RUPPERT, Lt Col, USAF
Chief, Facilities Mgt Div
Directorate of Manufacturing/QA

1 Atch
Responsiveness Summary

REMEDIAL ACTION PLAN

UNITED STATES AIR FORCE PLANT NO. 44
Tucson, Arizona

April 1986

Published by:
U.S.A.F. Plant No. 44
Box 11337
Tucson, Arizona 85734

cc: Mr. Phil King
Arizona Dept of Health Services
1740 W. Adams
Phoenix AZ 85007

Mr. F. Thomas Jefferson
City of Tucson
Tucson Water
P.O. Box 27210
Tucson AZ 85726-7210

Mr. Harry Seraydarian
U.S. EPA Region IX
215 Fremont Street
San Francisco CA 94105

[redacted]
Environmental & Energy Programs
Attn: Mr. R. E. Morrison
P.O. Box 11337, M/S J-1
Tucson AZ 85734-1337

AFPRO, Hughes Missile System Gp.
Attn: TM/Mr. R. Kilby
P.O. Box 11337, M/S D-4
Tucson AZ 85734-1337

RESPONSIVENESS SUMMARY TO PUBLIC COMMENTS ON FINAL DRAFT REMEDIAL ACTION PLAN UNITED STATES AIR FORCE PLANT NO. 44, TUCSON, ARIZONA

On October 4, 1985, the United States Air Force made available for pubic review and comment the Final Draft Remedial Action Plan, United States Air Force Plant No. 44, Tucson, Arizona (the "RAP"). The RAP summarized the results of prior environmental investigations conducted by the USAF at and in the vicinity of U.S. Air Force Plant No. 44 ("AFP 44") and presented an analysis of remedial alternatives that might be implemented in responding to groundwater contamination found to have emanated from the facility.

The prior investigations and remedial alternatives analyses were performed according to the requirements of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, the National Contingency Plan, 40 C.F.R. Part 300, the Department of Defense Installation Restoration Program and other relevant laws, regulations and guidelines. Based on the evidence developed and the conclusions reached as a result of these endeavors, the RAP recommended the implementation of a groundwater reclamation program consisting of a groundwater extraction and recharge wellfield and various systems to treat contaminated

groundwater in the area north of AFP 44's southern boundary and south of Los Reales Road. Public comments on the RAP's analyses and recommendations were solicited during the period of October 4-25, 1985.

Eight comments from the general public were received during the comment period, the substantive provisions of which are summarized and responded to below. Additionally, comments on the RAP were received from the Arizona Department of Health Services ("ADHS"), the Arizona Department of Water Resources ("ADWR"), the City of Tuscon (Tucson Water) ("COT") and the Environmental Protection Agency, Region IX ("EPA") after the public comment period had ended. ADHS, ADWR, COT and EPA, had had earlier opportunities to comment on the RAP during the period of its development. We have also responded to the most recent comments received from these entities.

A. Responses to Comments Received During the Public Comment Period

1. Comment: Two commentors asked why treated water should not be used for domestic consumption instead of being recharged back into the aquifer from which it was withdrawn.

Response: Although the proposed reclamation and treatment systems will purify contaminated groundwater to drinking water quality, the RAP recommends that treated water be

recharged back into the aquifer from which it is withdrawn. There are several reasons for recharging treated water instead of using it for domestic or other purposes now.

Recharging the aquifer increases the rate at which contaminated groundwater can be extracted. As is explained in the RAP, the groundwater extraction rate without aquifer recharge is approximately 2,000 gallons-per-minute ("gpm") while the extraction rate with recharge is more than doubled, i.e. approximately 4,200 gpm. The higher groundwater extraction rate which can be achieved by recharging the aquifer with treated water has important environmental and economic benefits.

Recharging treated groundwater will minimize aquifer drawdown impacts which would otherwise occur. Minimizing aquifer drawdown impacts will keep the reclamation project from interfering with downgradient water uses or from limiting the nature of response actions that could be implemented north of Los Reales Road. Since recharging water significantly increases groundwater extraction rates, recharging treated water will also greatly lessen the time required to restore water in the treatment area to a quality suitable for beneficial use.

Recharging treated water also eliminates treatment or storage complications that could arise during periods of

reduced domestic water demand assuming treated water were dedicated to domestic or other beneficial use. In the absence of a continuously available use for treated water, extraction rates would have to be reduced periodically, resulting in at least a temporary loss of the environmental and economic benefits discussed above. If extraction rates are not reduced in the face of reduced domestic demands, then storage capacity or alternate use distribution systems would have to be developed, either of which would create additional logistical and economic burdens.

In light of the preceding considerations, recharge of treated water is considered the preferred method for handling water subsequent to treatment. However, it should be remembered that the goal of the proposed remedial alternative is to restore water to a quality suitable for future beneficial consumption. Therefore, the recommended remedial action does not reject domestic use at all. In fact, recharging treated water is intended to restore the water as a potential source for beneficial use in the most environmentally sound and cost-effective manner.

2. Comment: One commentor suggested that the U.S. Air Force should take charge of cleaning the entire groundwater contamination problem which exists in the Tucson International Airport ("TIA") area, not just the area of

contamination south of Los Reales Road. This commentor assumed that AFP 44 is responsible for 85% - 95% of the contamination north of Los Reales Road. This commentor also felt that only addressing a part of the TIA groundwater contamination problem now was unwise.

Response: The USAF has conducted extensive investigations into the nature and extent of groundwater contamination that resulted from past waste disposal practices at AFP 44. During the last four years, this effort has included the construction and routine sampling of 104 monitoring wells and hundreds of soil samples.

Based on the data obtained from these efforts, it is apparent that wastes disposed of at some locations on AFP 44 prior to 1977 entered into and migrated over time in the upper zone of the regional aquifer system. The data obtained from these and other efforts persuasively demonstrate that the extent of this migration terminates in the vicinity of Los Reales Road.

While groundwater contamination also exists in the area north of Los Reales Road, the history of past disposal practices at AFP 44 and the data obtained from the many investigative efforts conducted in the TIA area do not support a conclusion that any significant levels of contaminants found in groundwater north of Los Reales Road are the result of

pre-1977 waste handling practices at AFP 44. The area north of Los Reales Road has been investigated by the Remedial Investigation Team ("RIT"), consisting of ADHS, ADWR, COT, EPA and a private consultant. An analysis of remedial alternatives for responding to conditions north of Los Reales Road found by the RIT during its investigations has not been completed; when such analysis will be completed is unknown.

In light of the above, there are significant reasons why the USAF cannot and should not attempt to remedy the entire TIA groundwater contamination problem. First, the USAF has neither the responsibility nor the legal authority for responding to releases of hazardous substances which do not result from Department of Defense facilities. Since the evidence persuasively demonstrates that the large area of contaminated groundwater north of Los Reales Road did not emanate from AFP 44, the USAF does not have the legal authority to respond to the conditions there based on the results of past waste handling practices at AFP 44. Instead, such legal authority is vested in the EPA and others by the Comprehensive Environmental Response Compensation and Liability Act and Executive Order 12316.

Second, the RIT has not yet completed its analysis of the appropriate response to the groundwater conditions dis-

covered during its investigations. Indeed, the RIT team's investigation of groundwater conditions north of Los Reales Road, including an analysis of the nature, extent and source of the contamination, is not yet completed, and what effort has been attempted needs to be significantly supplemented. Therefore, it is not presently known what type of response measure should be implemented in the area north of Los Reales Road, if any. It is possible that a groundwater reclamation system such as that proposed in the RAP may be an inappropriate response to the groundwater conditions there. Since the remedial alternatives analysis for the area north of Los Reales Road has not been completed, it would; (1) be unwise for scientific reasons to implement a groundwater reclamation program in that area now; and (2) be impermissible to do so since the National Contingency Plan requires that such an analysis be completed prior to the initiation of remedial actions in that area.

Finally, there is no benefit to be gained from delaying implementation of the proposed AFP 44 remedial action to await the outcome of the RIT feasibility study. In fact, delaying the implementation of the AFP 44 remedial action program would only increase the risk of greater environmental harm. Perhaps in recognition of this concern, ADHS, ADWR, COT and EPA have all endorsed the proposed USAF

groundwater reclamation program and encouraged its expeditious implementation.

It is important to recognize that the AFP 44 program has been designed to minimize any impact on any future remedial program implemented north of Los Reales Road, and that whatever response is implemented there would not alter the necessity for the actions proposed in the RAP. Therefore, not only is there no benefit to be gained from delaying the AFP 44 program, but substantial environmental, practical and economic considerations mandate its implementation as quickly as possible.

3. Comment: One commentor asked whether removing the "tainted water" would also remove contaminants from the aquifer medium so as to prevent any future contamination of clean water passing through the contaminated portion of the regional aquifer system.

Response: The proposed reclamation program is intended to prevent that possibility. To varying degrees, the contaminants found in the aquifer system can adhere to solids in the aquifer system. Through the extraction and recharge of several aquifer pore volumes, the proposed reclamation project is expected to "flush" the aquifer and remove contaminants that may be bound to aquifer sediments. The suc-

cess of this effort will be determined through continued monitoring of groundwater quality.

4. Comment: One commentor suggested that the remedial action program be implemented as soon as possible.

Response: This, of course, is one of the objectives stated in the RAP which the USAF will make every effort to achieve.

5. Comment: One commentor stated that treated water must be "re-injected at a faster rate than it is removed to prevent speeding the discharge rate due to an increasing of hydraulic gradient."

Response: The proposed reclamation wellfield has been designed to contain and capture contaminated groundwater emanating from AFP 44. The proposed locations of the extraction and recharge wells, and the proposed and extraction and recharge rates will provide a means of enhancing hydraulic gradients toward extraction wells, will allow extraction rates from the upper zone to be sustained, will minimize regional water level drawdown impacts, and will contain the contaminant plume. Water level and water quality monitoring data collected during wellfield operation will provide a basis for evaluating the response of the aquifer to wellfield pumpage, and will confirm containment and capture of the contaminant plume.

6. Comment: One commentor suggested that treated water from the reclamation project be used by industry since industry created it.

Response: A variety of industrial use alternatives were analyzed in the RAP, none of which were recommended because of the considerations stated there. The logic of this comment is not so compelling as to demand its adoption.

In any event, future industrial use of the aquifer when restored is certainly a possibility, provided that such use were consistent with the Arizona Groundwater Management Act and the Tucson Active Management Area Management Plan.

7. Comment: One commentor suggested that no efforts be made to cleanup the aquifer and that a proprietary tap water filtration unit be installed in 5000 homes at an estimated cost of $980,000. Filters for the units, reported to be capable of removing contaminants found in the TIA groundwater, would be disposed of free of charge.

Response: For a variety of reasons, we do not believe that a program such as the one proposed by this commentator should be implemented, including the following:

a. The analytic results which indicate that the Water Dome home filtration unit is capable of removing a variety of contaminants do not demonstrate that the units

would be capable of removing contaminant concentrations at the levels found in the aquifer south of Los Reales Road;

b. The mere use of filtration units could allow for continued contaminant transport in the aquifer that might result in an undesireable, further degradation of groundwater quality across a much larger area than presently exists;

c. The comment assumes that domestic use is the only use to be made of groundwater. There is no indication that the filter would be suitable for assuring the safety of other types of water uses - i.e. agricultural, industrial or recreational;

d. The economic assumption of a one-time fixed cost does not recognize the possibility that many more than 5000 of such units might be required. One unit per house would probably be insufficient, and more houses could require units if the groundwater contamination were to continue to migrate.

B. Recent Comments From ADHS

Comments on the RAP were received from ADHS subsequent to the close of the public comment period. These comments are reproduced in full and responded to below. The page references in the ADHS comments are to pages in the RAP.

Comment:

1. Page 2-

Although pre-1977 industrial wastewater disposal practices at AF Plant #44 may have been regarded as the "best accepted practices of their day", the treatment/disposal practices employed were inappropriate and unsuited for the quantities of industrial wastewater actually disposed.

Response: Industrial wastewater treatment and disposal practices at AFP 44 have historically been reviewed by ADHS (or its predecessor agency) as well as other public agencies prior to implementation. The systems used at the plant were modified periodically to ensure modernization or to resolve problems encountered during actual operations. It is simply a matter of fact that historic wastewater treatment and disposal methods at AFP 44 were those generally regarded at the time they were reviewed (by the State among others) not only as the best available in their day but as being appropriate for the types and quantities of wastes to be handled as well. This is not to say that they were perfect.

The best accepted industrial wastewater treatment and discharge practices of the 1950's, 1960's and early 1970's were eventually recognized as providing insufficient environmental protection. That recognition was one of the principal reasons for the enactment of the Clean Water Act in 1977, an Act which required more stringent national limita-

tions on industrial wastewater discharges. Even in 1977, however, the limitations were to be achieved through "technology-forcing" regulations which EPA was required to develop, i.e., legislation which established environmental protection goals for industrial wastewater discharges in the recognized absence of generally-available technology capable of achieving the ambitious goals of that Act.

To suggest today that the industrial wastewater systems used at AFP 44 twenty or thirty years ago were "inappropriate and unsuitable" at the time for the types and quantities of waste generated, especially where the State had been consulted in the design of those systems, overlooks historical reality.

Comment:

2. Page 2-

It should be stated that it is believed by the U.S. Air Force that the plume emanating from Plant No. 44 terminates near Los Reales Road.

Response: The fact that this determination is that of the USAF is made clear on page 5 of the RAP.

Comment:

3. Page 3 (bottom) - page 4 (top) -

It should be noted that the decision to demarcate Los Reales Road as the dividing line between EPA and Air Force investigations was made on rather limited evidence. Included as part of the referenced agreement was the contingency that, should further study indicate

> that contamination from Plant No. 44 extends significantly beyond Los Reales Road, the United States Air Force would be responsible for management of that contamination.

Response: First, we do not entirely agree that the evidence upon which this decision was made in 1983 was "rather limited." While we know more today than we did in 1983, an extensive body of evidence had already been gathered by the date of the decision. Indeed, enough evidence had been gathered for a panel of state, federal and private experts to conclude that the extent of contaminant transport from AFP 44 terminated south of Los Reales Road. If sufficient evidence had not been gathered, this decision would not have been made, with or without the caveat. The more important point, however, is that even today the facts do not indicate that the contamination from AFP 44 extends "significantly beyond Los Reales Road," including the data presented in the Results of the Tucson Airport Area Remedial Investigation, Phase I, Vols. I and III.

Second, it is incorrect to state that the USAF was ever to have been responsible for the management of groundwater contamination north of Los Reales Road. That area has always been considered to be the managerial responsibility of federal and state regulatory agencies. In fact, the USAF has consistently been told that it will not even be a full participant in the analysis of remedial alternatives for

that area. While the USAF does not object to its limited participation in that effort given the USAF's conclusion that AFP 44 was not the cause of significant contamination beyond Los Reales Road, it is incorrect to say that the USAF was ever informed by any agency involved in this matter that the USAF would be responsible for managing response efforts in that area. In fact, the contamination problem north of Los Reales Road is being managed pursuant to a cooperative agreement between the State and EPA.

Comment:

4. Page 10 (top) -

> The Air Force has at this time been provided with all hydrogeologic and water quality data gathered by the Remedial Investigation Team through 1984. Efforts are additionally underway to coordinate ongoing groundwater quality sampling in the area between the Arizona Department of Water Resources and hydrogeologic consultants to the Hughes Aircraft Company. These should be noted.

Response: The 1984 RIT data were received by the USAF on October 18, 1985. (The USAF had, of course, been previously provided the RIT data through 1983.) Page 10 of the RAP was amended to read as it does at the request of several TRC members in June 1985 who pointed out then that the 1984 RIT data had not been given to the USAF. Although we do not understand why the 1984 data was not given to us before then, the USAF has completely reviewed this data and deter-

mined that it does not alter the conclusions or recommendations contained in the RAP.

Efforts to coordinate on-going sampling efforts between ADWR and the USAF's hydrogeologic consultant are acknowledged.

Comment:

5. Page 10 (middle) -

> The analysis of potential sources north of Los Reales Road, relying as it does on FIT documents and prior conclusions of unnamed TRC members, appears somewhat dated. A 1983 ADHS report prepared by Eberhardt concluded that Plant No. 44 was likely the most significant pollution source in the vicinity of the Tucson International Airport, although the report acknowledged the presence of other potentially significant sources in the area.

Response: The names of the "unnamed TRC members" are those contained in the references cited on pages 10-11 of the RAP. No reports or conclusions were published by the RIT during 1984 or prior to the publication of the RAP.

We have reviewed our files and cannot locate a 1983 ADHS report by Sandra Eberhardt, nor do we recall ever having been told of its existence. We do have a copy of the March, 1982 version of the Eberhardt report, however, in which ADHS concluded that the plume of groundwater contamination emanating from AFP 44 "has been documented by groundwater sampling and modeling to be limited to the area south of Los Reales Road." Thus, the comment incorrectly

implies that AFP 44 is the most significant source of contamination in the vicinity of the TIA. Instead, the comment should state at most that AFP 44 was regarded by Eberhardt as the most significant source of groundwater contamination south of Los Reales Road.

Comment:

6. Page 13 - ADHS and other TRC members have at this writing not yet received pilot plant performance data with which to independently confirm this assessment of pilot plant effectiveness in removing groundwater contaminants.

Response: The pilot plant performance data does confirm the fact. A report analyzing data from this system's first months of operations (which did not begin until April 1985) will be provided to ADHS and others when completed.

Comment:

7. Page 16 (middle)-

"Concentrations of chromium" mentioned in this discussion should refer to concentrations of chromium in excess of the 50 ppb drinking water standard.

Response: Please read page 17, and review Figure 2D, Total Chromium Concentrations, Regional Aquifer - Upper Zone, which is included in the RAP and referred to on page 17.

Comment:

8. Page 21 (bottom)-

It might be noted in this discussion that commercial grade TCE contains a number of other compounds as stabilizers or impurities. Some of these, such as epichlorhydrin, are known or suspected carcinogens.

Response: The discussion of TCE appearing on page 21 of the RAP is a quotation of EPA materials published during 1984 in the Federal Register.

Comment:

9. Page 30 -

This section is incomplete without reference to the ADHS action level for TCE of 5 ppb, and more recently established action levels for 1,1-DCE and 1,1,1-TCA (1 ppb and 200 ppb respectively). While these levels are voluntary as they apply to public drinking water suppliers, they can form the basis for groundwater discharge permit requirements. In such case they effectively serve to define the treatment limits of any groundwater reclamation facility that may be installed at Plant No. 44.

Response: On November 13, 1985, EPA published its final Recommended Maximum Contaminant Levels ("RMCL's") for TCE, DCE and TCA in drinking water. 50 Fed. Reg. 46880 (1985). RMCL is defined by new regulations to mean

> the maximum contaminant level of a contaminant in drinking water at which no known or anticipated adverse affect on health or persons would occur, and which includes an adequate margin of safety. Recommended maximum contaminant levels are non-enforceable health goals.

The final RMCL's for TCE, DCE and TCA are 0, 7 ppb and 200 ppb respectively. 50 Fed. Reg. 46901 (1985). These RMCL's became effective on December 13, 1985. Id. at 46880.

Also on November 13, 1985, EPA published proposed Maximum Contaminant Levels ("MCL's") for TCE, DCE and TCA. MCL's, when finally adopted, are enforceable standards applicable to water quality in public water supply systems. MCL's are to be set as close to RMCL's "as is feasible" taking into account the best technology, treatment techniques and other means which are found to be generally available considering cost. The proposed MCLs for TCE, DCE and TCA are 5 ppb, 7 ppb and 200 ppb respectively. 50 Fed. Reg. 46902, 46904 (1985). Based upon your comment, the state action levels for TCE, DCE and TCA are 5 ppb, 1 ppb and 200 ppb respectively.

The preceding does not alter the Target Treatment Levels identified in the RAP since the Target Treatment Levels meet or exceed even the non-enforceable health goals for public water supply systems. In light of these recent events, however, the Table appearing on page 36 of the RAP is amended to read as follows:

APPLICABLE, RELEVANT STANDARDS AND
TARGET TREATMENT LEVELS

	EPA FINAL RMCL	EPA PROPOSED MCL	EPA FINAL RMCL	STATE ACTION LEVEL	RAP TREATMENT TARGET
Trichloroethylene	--	5 ppb	0	5 ppb	5 ppb
1,1,1, Trichloroethane	--	200 ppb	200 ppb	200 ppb	16.8 ppb
1,1 Dichloroethylene	--	7 ppb	7 ppb	1 ppb	0.033 ppb
Chromium	.05 ppm	--	--	--	.05 ppm

Second, this comment states that the state action levels may serve as a basis for Arizona groundwater discharge permit requirements. Operations of the pilot reclamation project at AFP 44 have demonstrated that the treatment systems to be employed in the USAF's full-scale groundwater reclamation program will purify contaminated water to levels which meet or exceed the state action levels. Therefore, although the suggestion that the reclamation project must undergo a formal permitting process in which state action levels--may serve to define treatment limits raises a number of legal questions, such questions are as a practical matter mooted by the performance capabilities of the proposed treatment systems. Nevertheless, several brief responses to those legal issues are set forth below.

First, the USAF concurs with EPA's conclusion that on-site CERCLA response measures undertaken pursuant to CERCLA § 104 need not apply for nor receive permits. See Lee M. Thomas Memorandum re: CERCLA Compliance With Other Environmental Statutes. Nevertheless, the USAF, without waiver of any legal rights, will apply for relevant state permits, and has previously and repeatedly informed ADHS of this intention. Second, we seriously question whether state action levels, i.e. non-enforceable health goals, can serve as legal requirements in a permitting process.

In any event, the USAF will make applications for appropriate permits once the final design documents for the remedial action are completed, an event which should occur in the near future. Since the treatment operations will exceed the state action limits, it is anticipated, as ADHS has in the past assured the USAF, that there will be no substantive issues raised by state groundwater discharge permit program that would delay implementation of the proposed groundwater reclamation project. (Also see the response to ADHS comment 16 in paragraph B.16 below.)

Comment:

10. Page 34-36 -

While the proximal reason for establishing stated treatment targets for 1,1,1-TCA and 1,1-DCE is discussed in the text (i.e., "Previous correspondence among the EPA, ADHS, and the

USAF . . ."; p. 34), the ultimate reason for employing these levels is not. They are the 10^{-6} excess cancer risk level cited in the 1976 EPA publication, "Ambient Water Quality Criteria for Dichloroethylenes," and the human health criterion cited in the 1976 EPA publication "Ambient Water Quality Criteria for Chlorinated Ethanes." Both of these documents should be noted in these discussions.

Response: Both of the two documents referred to in this comment are by this reference so noted.

Comment:

11. Page 65-

TEPCO's belief that use of reclaimed water for the Irvington Station is "impractical and unwarranted" is not elaborated upon. What is the basis for this belief?

Response: In a September 1, 1982 to ADWR, TEPCO stated:

> Subsequent to initial discussions between TEP and DWR, we have reviewed the potential process of disposal of the TCE-contaminated water through evaporation in the cooling towers of our Irvington Station. Due to the large number of significant problems and unknown associated factors, TEP is of the opinion that further consideration of the use of the Irvington Road Station for elimination of the TCE would be impractical and unwarranted. We suggest that further efforts by DWR and all affected agencies and companies be directed toward other possible cleanup alternatives.

Comment:

12. Page 86 -

ADHS concurs with the conclusion that the reclamation/treatment/recharge alternative is the preferred one of those considered.

Response: We appreciate ADHS's concurrence in the selected remedial alternative and the valuable assistance which ADHS has provided to the USAF in its development of the RAP.

Comment:

13. Page 94 -

Although the methods that will be employed to treat contaminated groundwater are discussed in the Malcolm Pirnie report that is incorporated by reference, the public nature and more widespread distribution of the RAP would seem to warrant a more explicit discussion of treatment techniques than currently appears.

Response: Since the USAF shared this perception, both Malcolm Pirnie reports on treatment alternatives were physically attached to all copies of the RAP that were distributed for public comment. For this reason, we did not attempt to restate the treatment alternative analyses performed by Malcolm Pirnie on page 94 of the RAP.

Comment:

14. Page 97-

References in this and the ensuing discussion to "FIT" activities are incorrect. Field Investigation Team ("FIT") activities in the area, undertaken by EPA, ended in 1982-83. Since October, 1983, a Superfund Remedial Investigation conducted by ADHS as lead agency with EPA funding, has been completed. Members of the Remedial Investigation Team (RIT) included ADHS, ADWR, EPA, the City of Tucson, and Dr. Kenneth D. Schmidt, a private consultant. The RIT reports will be released to the public in the near future. A Superfund Feasi-

bility Study, funded by EPA and conducted by ADWR with assistance from ADHS, EPA, and the City of Tucson, is ongoing.

Response: Thank you for correcting our error.

Comment:

16. Page 115-116 -

The ADHS requirement for a Notice of Disposal for any treatment alternative utilizing groundwater recharge, and the possibility of the necessity of obtaining a groundwater discharge permit from the Department should be explicitly discussed. The Air Force's responsibility to ADHS in this regard extends beyond the supplying of information mentioned in this discussion.

Response: Filing of a Notice of Disposal ("NOD") and the possible relevance of a groundwater discharge permit are already explicitly discussed on page 38 of the RAP, with appropriate reference to relevant Arizona regulations. The USAF's legal responsibility in this regard is briefly discussed in the repsonse to ADHS comment number 9 above. The USAF's intention in this regard has been frequently explained to ADHS in the past, and has been evidenced by the fact that NOD's were filed with ADHS for AFP 44's pilot reclamation project recharge wells on April 4, 1985.

Comment:

17. Figure 2.A. (Appendix) -

The 10 ppb contour drawn for TCE is not at all consistent with the groundwater quality information portrayed on this map (note the 320 ppb concentration at monitor well M-36). If the contours are not representative of actual

groundwater conditions, they should be changed or an explanation given as to why they have been drawn as they are.

Response: The TCE contour lines presented in Figure 2.A are the TCE contour lines based on past AFP 44 disposal areas as the source of groundwater contamination. Included within the area between the 10 ppb TCE contour and the 100 ppb TCE contour on Figure 2.A of the RAP are the following upper zone monitor wells and TCE concentrations:

Monitor Well Number	TCE Concentration
M-16	74 ppb
M-25	96 ppb
M-10	10 ppb
M-13	10 ppb
EPA-1	48 ppb
EPA-4	30 ppb
EPA-2	34 ppb
EPA-3	96 ppb
M-34	ND*
EPA-5	57 ppb
M-36	320 ppb

(*ND means none detected)

The monitor wells and TCE concentrations reported outside the 10 ppb contour on Figure 2A are as follows:

Monitor Well Number	TCE Concentration
M-21	ND*
M-19	3.2 ppb
M-15	ND
M-24A	7.0
M-14	2.7
M-22A	ND
M-39	ND
M-36	ND
M-37	ND
EPA-6	4.5 ppb
M-35	ND
M-32	ND
M-31	ND
M-33	ND
M-30	ND
M-1A	ND
M-28	ND

(*ND means none detected)

Of the 28 relevant wells on Figure 2.A, only 2 wells have readings that are at all inconsistent with the 10 ppb contour: M-34, in which no TCE was detected but which lies between the 10 and 100 ppb contours; and M-36, which had a TCE concentration of 320 ppb, which is located over a mile

north (and downgradient) of AFP 44's northern boundary, and which falls within the 10 and 100 ppb contour lines of the plume emanating from AFP 44. The statement that the 10 ppb contour is "not at all consistent with the groundwater quality information portrayed" on Figure 2.A is a statement that could only have been made without referring to the groundwater quality information portrayed on Figure 2.A.

Further discussions on the concentrations of TCE found in M-36 are included in the attached comments from Hargis & Associates on the RIT Phase I report and subsequent responses in this Responsiveness Summary.

C. Recent COT Comments

1. Comment: To clarify our previous comment, why didn't the USAF consider a combination of potable reuse, i.e., potable and/or industrial water could have been supplied to AF Plant No. 44 regardless of the alternative selected? A combination of potable uses to AF Plant No. 44, Davis-Monthan, and the City, coupled with reinjection if desired could beneficially use all water produced by an optimized pumping scheme and may have been cost effective despite the longer clean up period required.

The point of this comment is that potable uses could have been combined to use the optimum amount of water produced by a reclamation well field. An alternative which uses 310 gpm when you must dispose of 2000 gpm is not a realistic alternative.

The City fully endorses the remedial alternative selected. The above comment is intended only to point out what appears to staff to be a weakness in the evaluation of alternatives.

Response: The USAF appreciates COT's endorsement of the proposed remedial alternative. Since this comment acknowledges the appropriateness of the proposed groundwater reclamation system, we will not respond in detail to all possible combinations of the various response measures discussed in the RAP.

In essence, this comment suggests that other beneficial uses could have been made of treated water, and that the extraction rate of contaminated water could have been adjusted to accord with the demand for various water uses. As stated in the RAP, and noted in our response to similar comments on potable usage of treated water above, recharge is an important component of the reclamation program not only for cost-effectiveness considerations, but for significant environmental reasons as well. Without recharge, not only is the operating life of the reclamation project more than doubled, but the failure to recharge would result in significant aquifer drawdown impacts and related adverse effects. In balancing the potential benefits to be derived from immediate potable or industrial use of treated water against the increased operating costs of a longer term reclamation project and other environmental risks, the USAF decided that recharge was an essential component of the proposed remedial action.

The real issues then are whether some water from the treatment plant could be diverted for immediate beneficial use, and whether any near-term benefits gained from such a diversion justify the additional capital investment and operating costs associated with other distribution systems that would need to be constructed from the treatment plant to provide a water service during the approximate ten-year period during which the treatment plant is expected to operate.

Even if the answer to the first question were yes, the answer to the second question would be no. By way of example, consider the additional capital, operating and maintenance costs associated with the three proposed uses discussed in the comment: use of treated water at AFP 44, at Davis Monthan AFB and by the City. The estimated additional capital costs of the distribution systems for these three uses is $4,773,210 (see, Table 2 of the RAP), roughly a twenty percent increase above the capital costs associated with the treatment and recharge proposal alone. The approximate additional operating costs for these distribution systems for ten years is approximately $10,051,790 dollars (halving the combined 20-year operating cost estimates for these systems presented in Table 2 of the RAP). The approximate capital and operating expenditures for the three addi-

tional treatment plant distribution systems, from which approximately ten years of benefit would be derived, is $14,825,000. The cost of such alternate systems far outweigh any near term benefits associated with such uses during the anticipated period of the reclamation system.

D. Recent EPA Comments

1. Comment: The extent of contamination in the aquitard below the upper aquifer and in the lower aquifer has not been completely defined. The RAP should acknowledge this and indicate the Air Force plan and schedule for further investigation of the vertical extent of migration of AFP 44 contaminants.

Response: Eleven lower zone wells have been monitored during the USAF's investigations to define the nature and extent of groundwater contamination in the lower zone of the regional aquifer. Data representative of that gathered from these wells during the USAF investigations or monitoring programs are depicted on Figure 2.E of the RAP, which shows the following:

Monitoring Well	TCE	TCA	DCE	Chromium
M-27	ND*	ND	ND	ND
M-1B	ND	ND	ND	ND
M-26	77 ppb	ND	ND	ND
M-22B	ND	ND	ND	ND
M-24B	ND	ND	ND	ND
M-2C	ND	ND	ND	ND
M-12B	8.2 ppb	ND	ND	ND
HAC-1	340 ppb	ND	19 ppb	.01 ppm
M-1B	ND	ND	ND	ND
M-29	2.8 ppb	ND	ND	ND
EPA-2A	ND	ND	ND	.02 ppm

(*ND means none detected)

Of these eleven lower zone monitor wells, contaminants have been detected in five, and only three had concentrations exceeding the state action levels: HAC-1, M-12B and M-26. These three wells monitor lower zone water quality in the vicinity of former production wells which penetrate (or formerly penetrated) both zones of the regional aquifer system. Given the existence of a 50-100 foot thick aquitard separating the upper and lower zones (which is documented in the RAP and supporting documents), given the fact that contaminants were rarely found in the lower (which is documented in the RAP and supporting documents), and

given the fact that concentrations of contaminants exceeding state actions levels occur only in areas penetrated by former production wells, the USAF concluded that the lower zone had not been directly contaminated by past disposal activities at AFP 44, and that the contamination which did exist in the lower zone was the result of contaminated water from the upper zone migrating to the lower zone through well casings which penetrated both the upper and lower zones in areas where contaminants existed in the upper zone.

Figure 2.E represents the approximate extent of contamination in the lower zone based on the results of lower zone monitoring and the hydraulic characteristics of the lower zone (which are reported in the RAP and supporting documents). Based on these facts, it is the USAF's opinion that the definition of lower zone contamination has been adequately defined.

Having already reviewed the preliminary designs for the reclamation wellfield system, EPA is aware that any uncertainty which may exist in the definition of the nature and extent of contamination in the lower zone is more than compensated for by the designs for the intended remedial activity. The reclamation wellfield design, as shown on Figure 2 of the RAP, identifies the proposed location of four lower zone extraction wells to remove contaminated water from the

lower zone. These wells are located so as to extract lower zone contaminated groundwater from areas known to be or which might be contaminated. Monitoring of lower zone water quality will be continued during the implementation of the remedial action to assure attainment of that result.

Thus, contamination in the lower zone has been adequately defined, and any uncertainty as to this definition would be cured through the "over-design" of the lower zone extraction system. The efficacy of the lower zone remedial action will be determined through continued lower zone groundwater quality monitoring. In the unlikely event that continued monitoring indicates that the lower zone action has not accomplished the desired result, further investigation may be performed. However, further investigation of groundwater quality in the lower zone is not presently necessary.

This comment also states that the extent of contamination in the aquitard has not been adequately defined. At AFP 44, the aquitard is a layer of clay and sandy clay ranging in thickness from approximately 50 to 160 feet. The aquitard is overlain by the upper zone of the regional aquifer, which is comprised of sand and gravel with some sand and sandy clay ranging in thickness from 60 to 100 feet. The sediments which comprise the upper zone of the

regional aquifer are in turn overlain by a layer of perching materials ranging in thickness from 25 to 50 feet.

The assumption of this comment is that contaminants have already migrated into the aquitard, which therefore warrants further investigation. We, however, are unaware of any facts which give credence to the assumption.

As discussed above, contamination in the lower zone appears limited to those areas where production wells penetrated both zones. If the observed contamination were the result of contaminants having migrated through groundwater in the upper zone and then through 50 to 100 feet of relatively impermeable clays in the aquitard into the lower zone, lower zone groundwater contamination would be far more widespread beneath the facility than it is given the extent to which high concentrations of contaminants are distributed in the upper zone of the regional aquifer beneath the facility. A comparison of Figures 2A through 2D of the RAP with Figure 2E will graphically assist in understanding this point. Thus, lower zone water quality analyses, which indicate an absence of contaminants in the majority of the lower zone, do not support a conclusion that contaminants have penetrated the aquitard.

Nevertheless, our fundamental response to this comment arises from the perspective of practical, cost-effective

decision making. The remedial action will be performed over an estimated ten-year period. As EPA stated in an earlier comment to the USAF on this point, investigation of the aquitard (which the USAF does not presently believe to be necessary) "need not be conducted before completing the upper regional aquifer remedial action." The proposed remedial action, of which continued groundwater quality monitoring in the upper and lower zones of the regional aquifer will be an integral part, has an estimated duration of at least ten years. If at the end of ten years, or at any time before, groundwater quality data indicate that the aquitard could be a continuing source of groundwater contamination, then consideration may be given to investing money in the performance of such an investigation. Presently, however, the expenditures associated with an investigation of the aquitard are economically unjustifiable.

> 2. Comment: The RAP should discuss the contamination found in perched zone monitor well B-9 which has consistently showed approximately 1000 ppb TCE over the past three years. This well is significant in that it is located adjacent to the present wastewater evaporation ponds and the former location of an unlined, backfilled wastewater holding pond. This discussion should include its possible source, effect on the remedial action, and need for additional remedial measures.

Response: Perched zone monitor well B-9 was drilled on June 16, 1981. The bore hole was drilled to 91 feet below

land surface. The well was cased to 90.4 feet, with the casing perforated from 80-90 feet. The construction details and lithologic logs for the well are contained in Appendix B of Volume III of the Hargis & Associates, Inc. Phase I Report.

B-9 was drilled into the area of the largest of the pre-1977 industrial wastewater holding ponds. Much of the area where this former pond was located was covered in 1977 by a single-lined evaporation pond, part of AFP 44's zero-discharge industrial wastewater treatment plant (IWWTP), which in turn is now overlain by the double-lined ponds with an intermediate leak detection system. Since 1981, all ponds used as part of the IWWTP have been monitored for leakage by a progressively-expanded neutron probe detection system (capable of detecting soil moisture content changes which would occur as a result of leakage from the impoundments) and by monitoring water level and quality changes in perched zone monitor wells.

In addition to the construction of monitor well B-9 as part of the Phase I investigation of historic AFP 44 disposal sites, soil boring C-4 was completed immediately adjacent to monitor well B-9, again in the area of the former unlined impoundment. See Figure 1 of the Phase I Investigation. This boring was completed to a depth of 90 feet.

Samples were collected from this boring on October 12, 1981 at five-foot intervals and analyzed for the presence of volatile organic compounds. The results of these analyses showed the following:

Depth of Sample Below Surface (feet)	TCE (ppb)	TCA (ppb)	DCE (ppb)
3.5	6	4	ND*
10	ND	ND	ND
15	2	ND	ND
20	ND	ND	ND
25	2	ND	ND
30	2	ND	ND
35	3	ND	ND
40	3	ND	ND
45	3	ND	ND
50	4	ND	ND
55	2	ND	ND
60	3	ND	ND
65	3	ND	ND
70	2	ND	ND
76	6	ND	ND
82	4	ND	ND
85	8	ND	ND
90	10	ND	ND

(*ND means none detected)

These results are reported in Appendix I of the Phase II Report.

Neutron logs taken from the neutron probe monitoring system around the current surface impoundments since 1981 have not shown any evidence of increased soil moisture content reflective of leakage from any of the impoundments, either as single-lined impoundments during the period of 1977-1984 or as double-lined surface impoundments since

1984. These results are reported in the following documents: Construction and Testing of Pilot Neutron Logging System, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, (Hargis & Montgomery, Inc. 1981); Results of Additional Testing, Pilot Neutron Logging System, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, (Hargis & Montgomery, Inc. 1982); Results of Construction and Testing of Neutron Logging System, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, (Hargis & Montgomery, Inc. 1983); Memorandum Report Evaluation of 1983 Quarterly Neutron Logs (Hargis & Associates, Inc. 1984); Results of Neutron Calibration Experiment at Neutron Logging Hole N-5 (Hargis & Associates, Inc. 1984); Memorandum Report Evaluation of 1984 Quarterly Neutron Logs (Hargis & Associates, Inc. 1985).

The comment suggests that the relatively constant levels of TCE found in monitor well B-9 may be the result of a continuing source of TCE filtering through the vadose zone into the zone of perched water which might be either the pre-1977 wastewater holding pond or the post-1977 impoundments. The data contradict the implications.

First, the analytic results of the samples taken from soil boring C-4 indicate that the soil column in the vicinity of perched zone monitor well B-9 is incapable of

being a source for constant perched zone contamination at a concentration in excess of 1000 ppb TCE. The concentrations of TCE found in the soils there are trace amounts, orders of magnitude below the TCE concentrations found in well B-9. The trace amounts of TCE in the soil column cannot result in relatively constant perched water concentrations found in B-9. Further evidence that historic disposal in the pre-1977 ponds is not a source of the continued TCE readings is found in the fact that no DCE was detected in the soil column. Even though there is no DCE in the soil column at C-4, the B-9 concentrations of DCE have also remained relatively constant since monitoring began.

The neutron probe data and perched zone monitor water levels gathered over the past four years indicate that the IWWTP impoundments, either as single-lined or double-lined ponds, have not leaked.

As is discussed in the RAP, contaminated water in the perched zone represents a potential continuing source of contamination to the upper regional aquifer. To address this potential problem, groundwater extraction wells constructed through the perched zone will be designed to drain perched water into the upper regional aquifer where they can be extracted for treatment. The purpose of this design is to assure that any slow migration of contaminated perched

zone water into the upper regional aquifer does not extend the time needed to remedy contamination in the upper zone of the regional aquifer. Continued monitoring of the perched zone will continue during the groundwater reclamation project to ensure that the perched zone does not continue to be a source of contamination in the upper regional aquifer.

E. Recent Agency Comments Concerning Possible AFP 44 TCE Sources Not Addressed By The RAP Or Prior USAF Investigations

Two agencies, EPA and COT, indicated that the USAF's investigations or analyses of historic AFP 44 disposal areas and their impact on the regional aquifer were inadequate based upon a failure to account for a potentially significant source of TCE located in the northwest corner of AFP 44. Because of their similarity, these comments are individually presented below and given a single response.

1. COT Comment

> Again, the 1982-83 belief that the plume emanating from AF Plant No. 44 terminates in the vicinity of Los Reales Road may have been reasonable based on the limited data available at that time. To maintain this interpretation of the data today requires that one assume both a major source of contamination south of Los Reales Road, which hasn't yet been discovered either by the Remedial Investigation Team or by the USAF, and that the industrial wastewater discharged by AF Plant No. 44 was free of TCE despite evidence to the contrary. A more likely interpretation of today's data is that the industrial wastewater discharged by AF

Plant No. 44 is a major source of groundwater contamination to the north of Los Reales Road.

Whether or not the computer modeling provides only secondary support is virtually irrelevant in explaining the concentrations found at M-36. The much lower concentration detected in the samples from monitoring wells off to the side of the main plume and south of M-36 are consistent with the concentrations found at M-36. Basically, the USAF has chosen to explain the high concentrations at M-36 by ignoring the industrial wastewater discharged by AF Plant No. 44 and by assuming an undetermined source south of Los Reales Road.

While the discharge from former wastewater treatment may not have contained significant levels of solvents (TCE concentrations were probably less than .1%) when compared with the large amounts of solvent phase waste disposed of in the southeast portion of the property, they were more than adequate to cause the bulk of contamination to the north of Los Reales Road.

2. <u>EPA Comment</u>

(5) The RAP indicates that the solute transport model was used as a secondary analytic tool to define the extent of AFP 44-caused contamination (page 8). Since data on actual disposal rates, locations, times, and contaminant movement rates is not presently available, intrepretations [sic] based on the solute transport modeling results themselves are questionable. If, however, the modeling is being used as an aid in interpreting hydrogeologic and other information then the model should include a potentially major source of TCE - solvent and solvent-contaminated rinsewater disposal during the 1950's and 1960's in the ditches located in the northwest corner of AFP 44. Peak disposal rates have been estimated at 1,250,000 gallons per week. Any solute transport modeling should include this source area, which the existing model does not.

Response:

Both ADHS (see comment B17 above) and The City of Tucson have suggested that the 1984 TCE concentrations found in monitor well M-36 contradict the USAF's conclusion with respect to the extent of contaminant migration from AFP 44. ADHS contends that the TCE contour lines drawn from AFP 44 in the RAP are patently inconsistent with observed TCE concentrations portrayed on Figure 2.A of the RAP - a contention that could only have been made without reference to the TCE concentrations on Figure 2.A of the RAP. The COT contends that the USAF has chosen to explain the high concentrations at M-36 by ignoring past industrial wastewater discharges at AFP 44, which COT suggests were more than adequate to explain not only the high concentrations of TCE at M-36, but the majority of the groundwater contamination in the area north of Los Reales Road. The EPA comment makes clear that the location of this purported, potentially major source of TCE through past industrial wastewater discharge is the northwest corner of AFP 44.

All of these comments, as well as the following comments concerning the RAP's conclusions as to the extent of contaminant migration, are made without reference to substantiating facts, but appear to be based on the recently published draft RIT Phase I Investigation Report. There-

fore, the USAF responses to the above comments regarding TCE disposal in the northwest corner of AFP 44, as well as other agency comments with respect to the extent of contamination migration from AFP 44 identified below, will be fully addressed, as they should be, in the USAF's detailed comments regarding the inadequacies of the RIT investigation.

For present purposes, however, several preliminary responses are appropriate. First, the assumption that disposal of TCE in the northwest corner of AFP 44 resulted in the "bulk of contamination to the north of Los Reales," or the TCE concentrations in well M-36, either on the basis of computer modeling or an interpretation of actual groundwater quality monitoring results is absurd. With respect to computer modeling, the RIT in fact developed a computer model scenario in which AFP 44 was the assumed sole source of TCE contamination in the TIA (the "Second Scenario"). In the Second Scenario, 0.12 gallons per day (gpd) of TCE were introduced into the upper zone of the regional aquifer for the period of 1955-1959 at the intersection of Old Nogales Road and the Hughes Access Road. Other potential TCE source points along the supposed industrial wastewater discharge route at AFP 44 were assumed and considered to have made a total contribution of approximately 1225.45 gallons of TCE into the upper zone. Given these figures, industrial

wastewater discharge at AFP 44 was assumed in the Second Scenario to be the single largest volumetric contributor of TCE contamination to the regional aquifer of any source in the TIA. See Figure 30.

Despite these liberal assumptions about the impact of industrial wastewater discharges on TCE concentrations in the aquifer, the computer projection of TCE transport from AFP 44, even using AFP 44 as a sole source and even after inputting a significant TCE input in the northwest corner of AFP 44, contradict the COT'S assertions. The RIT Second Scenario computer model does not even project the 1 ppb contour line that extends to the northernmost extent of measured TCE concentrations (Figure 31). Falling north (and downgradient) of the projected 1 ppb contour line are TCE concentrations of up to 77 ppb. Falling between the projected 1 ppb contour line and the projected 10 ppb contour in the area north of Los Reales Road are observed TCE concentrations of 1, 34, 43, 50, 80, 50, 36, 70 and 48 ppb. Only one of the observed concentrations accords with the Second Scenario's projected 1 ppb and 10 ppb contours. The much emphasized TCE concentration at M-36 (320 ppb by actual measurement in December 1984, reported as 270 ppb on Figure 31 based on an earlier measurement) falls at the edge of the projected 10 ppb contour.

In short, the computer modeling performed by the RIT in its Second Scenario, which assumes a remarkable contribution of TCE to the regional aquifer, contradicts the assertions that: (1) TCE-contaminated industrial wastewater (assuming such waters were significantly contaminated by TCE) discharged to the northwest corner of AFP 44 (assuming further that the transport mechanism allowed for significant migration of TCE into northwest corner soils and made this area a significant source of TCE contamination) was "a major source of groundwater contamination to the north of Los Reales Road"; (2) there are no other sources of TCE contamination in the TIA area contributing to the so-called "main plume"; and (3) high concentrations of TCE at M-36 are the result of contaminant migration from AFP 44.

Further preliminary responses to comments concerning the northwest corner of AFP 44 as a major source of TCE contamination and AFP 44's contribution to groundwater contamination at AFP 44 are contained in the attached copy of Hargis & Associates preliminary comments on the RIT report.

F. Recent Agency Comments Concerning the Extent of Contaminant Migration From AFP 44

EPA and the COT both made generalized comments with respect to the extent of groundwater contamination emanating

from AFP 44. Because of their similarity, these comments are presented individually below and given a single response.

> EPA Comment: Based on currently available information, it appears that the northern boundary of the contamination emanating from AFP 44 probably extends well beyond Los Reales Road as the RAP states. In addition, the RAP should explain the technical basis for the conclusion on the extent of AFP 44-caused contamination.
>
> COT Comment: Staff's comments on the Final Draft RAP remain essentially the same as those previously expressed in the letter of June 24, 1985 [in which COT provided earlier comments on a pre-publication version of the RAP]. Unfortunately, the response [from the USAF] of October 22 either misses the intention of the comments or simply states that the USAF interpretation of the data available to the USAF supports the conclusions in the RAP. We are of the belief that TCE contamination emanating from AF Plant No. 44 has migrated considerably north of Airport Wash and contributes the bulk of TCE contamination north of Los Reales Road. The facts to support our belief are contained in the Final Draft of the Remedial Investigation Report which has been supplied to the USAF [subsequent to the publication of the RAP].
>
> Staff never intended that the USAF undertake further remedial investigations north of Los Reales Road. However, assuming the bulk of contamination to the north resulted from AF Plant No. 44 activities, then it is reasonable to perform a technical evaluation to determine the portion of the contamination plume which can be cost effectively remediated using the proposed RAP.

Response: ADHS (through prior comments and in its draft RIT Phase I Report), EPA and COT have each expressed a

"belief" or an "apparent probability" that groundwater contamination emanating from AFP 44 extends well north of Los Reales Road, beliefs which differ substantially from the USAF's conclusions in this regard. Such beliefs are unaccompanied by any analysis of the recorded data. At the outset, however, it should be noted that, notwithstanding their contrary beliefs, these agencies have also endorsed the USAF's proposed remedial action south of Los Reales Road and encouraged its expeditious implementation. The comments regarding the extent of contamination emanating from AFP 44 do not raise substantive issues as to the necessity, advisability or feasibility of the proposed remedial action.

With respect to the EPA, ADHS and COT beliefs themselves, however, it is the USAF's opinion that such beliefs are not well-founded and indeed are contradicted by the facts. Since such beliefs are derived from the final draft RIT Phase 1 Report, it is the USAF's opinion that such beliefs are the product of highly questionable if not patently defective analyses of the facts that have been developed.

The USAF's initial response to the RIT Report is presented in the enclosed letter from Hargis & Associates, Inc. Hargis & Associates' initial review of the RIT Report

revealed major problems with the RIT Report's conclusions and analyses, including those summarized below:

a. Volume I concludes that AFP 44 is the predominant source of contaminants in groundwater north of Los Reales Road based upon the purported migration of contaminants from AFP through "unique hydrogeologic conditions" along the "longitudinal axis of the main plume" which extends from AFP 44 to Valencia Road. However:

1. lithologic logs from wells throughout the TIA area demonstrate that "unique hydrogeologic conditions" do not exist along any such "longitudinal axis";

2. groundwater quality data demonstrate that there is not a continuous narrow strip of high contaminant concentrations extending from AFP 44 to Valencia Road, or even from AFP 44 to Los Reales Road. The observed concentrations of TCE, DCE, chromium and chloroform in fact contradict the conclusion;

3. Volume I of the RIT Report disregards conclusions in Volume III of the Report concerning the existence of other contaminant sources north of AFP 44;

4. the Volume III Report on the Investigation of other sources dismisses some sources north of AFP 44 based on inadequate investigations, dismisses other sources based on questionable interpretations of the data

developed, and overestimates AFP 44 contributions to groundwater contamination through the use of analyses used elsewhere to reject other potential sources of groundwater contamination north of AFP 44;

5. not even RIT computer modeling of contaminant transport away from AFP 44, modeling which assumes that industrial wastewater discharges resulted in significant TCE contamination to the aquifer from the northwest corner of AFP 44 (a highly questionable assumption based on the USAF's detailed analysis of past AFP 44 disposal practices), projects contaminant migration which supports the sweeping conclusions of Volume I, and the isocontour lines projected by such modeling are themselves contradicted by observed contaminant concentrations actually measured from monitoring wells located throughout the TIA area.

These deficiencies are discussed at greater length in the attached letter from Hargis & Associates on the RIT Report. Detailed comments on the RIT Report are being prepared, and will constitute a complete response to these agency comments once finalized.

G. Recent Agency Comments Concerning Community Relations Plans

EPA and ADHS suggested that, while adequate, improvements could be made to the RAP's Community Relations

Plan. The USAF has already sponsored a variety of programs to inform the public about the proposed remedial action and to provide for public participation in the identification of an appropriate remedial response. Two major meetings with representatives from the press and a variety of public agencies and public interest groups were held during 1984, and the distribution of the RAP for public comment are reflective of the USAF's commitment in this regard.

The RAP's Community Relations Plan is based on USAF guidance which was developed in consultation with EPA. However, in order to assure that the public is fully informed as to the implementation of the AFP 44 remedial action program, the USAF will meet with EPA and ADHS to ensure that the RAP's Community Relations Plan is fully coordinated with the community relations efforts undertaken by them in conjunction with the RIT investigations, and to amend as appropriate the RAP's Community Relations Plan.

H. Recent Comments from ADWR

1. Comment: With regard to our comments on the previous draft, it is our opinion that the disclaimer appearing on page 5 of the final draft is sufficient to point out to the reader that technical differences may exist regarding such matters as the probable extent of groundwater contamination emanating from Air Force Plant #44. However, we believe that statements made prior to the disclaimer regarding the extent of contamination (such as on page 2, bottom) should be portrayed as the Air

Force's opinions, rather than as generally accepted belief.

Response: Please see the response to Comment B.2 above.

2. Comment: Also with regard to our comments on the previous draft [of the RAP], we are somewhat disappointed that continued groundwater monitoring (particularly of the perched zone) was not more fully addressed in the final draft RAP.

Notwithstanding these concerns, we believe that the final draft RAP is representative of a comprehensive analysis of the problem at hand, and presents a proposed remedial action that appears to be both appropriate and effective.

Response: As part of its remedial investigation, the USAF has constructed and/or routinely sampled and analyzed groundwater quality at over 104 perched zone and regional aquifer monitoring wells at and in the vicinity of AFP 44. An extensive monitoring system is already in place, and continued groundwater quality monitoring would be required for any remedial program analyzed. Since this factor was therefore one that would not influence the selection of a proposed remedial alternative, the issue was not exhaustively discussed for each alternative discussed in the RAP.

The specific groundwater quality program to be implemented in conjunction with the remedial action proposed by the RAP will, however, be developed as part of the

detailed design and operating procedures for the proposed system. We will work closely with the ADWR and others in developing a specific monitoring program for the AFP 44 groundwater reclamation project. Obviously, the monitoring program will include both the perched zone and the regional aquifer water in the treatment area, a fact which is made clear in the RAP.

The USAF appreciates ADWR's endorsement of the proposed remedial action plan. Your responsible comments and advice have been of great value in the development of the USAF investigations and remedial alternatives analysis, and we look forward to continued support from ADWR as we develop final design documents for the AFP 44 groundwater reclamation project, including its monitoring system.

I. Other Technical Comment

As part of their comments, several agencies have also made specialized technical comments on issues relevant to implementation of the proposed remedial action. These comments concern detailed engineering design matters and are not relevant to the feasibility or selection of an appropriate remedy. Such comments have been addressed and will continue to be reviewed by the hydrogeologic subcommittee of the AFP 44 Technical Review Committee as design documents for the proposed system are developed.

STAFF SUMMARY SHEET

	TO[1]	ACTION	SIGNATURE (Surname), GRADE AND DATE		TO	ACTION	SIGNATURE (Surname), GRADE AND DATE
1	JA	Appr	Ginsburg BG 14 Nov 85	6	CST	Proc	[illegible]
2	PL	Coord	M Smith Maj 19 NOV 85	7	CS	Rev	
3	SG	Coord		8	CV	Sign	[illegible] 20 Nov
4	PA	Coord	[illegible] 19 Nov 85	9			
5	DE	Coord		10			

SURNAME OF ACTION OFFICER AND GRADE	SYMBOL	PHONE	TYPIST'S INITIALS	SUSPENSE DATE
HARTE, Maj	JAM	27475	clh	

SUBJECT	DATE
Proposed Groundwater Remedial Action for AFP 44	19 Nov 85

SUMMARY

PROBLEM AND DISCUSSION:

1. USAF Plant 44 (AFP 44) is a Government-Owned, Contractor-Operated (GOCO) manufacturing facility in Tucson, Arizona operated by Hughes Aircraft Company on behalf of the AF. In 1981 the Air Force learned of the presence of contaminants in groundwater beneath the plant and with Hughes initiated a comprehensive environmental investigation to determine the source and extent of that contamination and the potential remedial measures available to protect public health and mitigate damage to the environment. That investigation, consisting of several related studies undertaken by consultants to the Air Force, is summarized in a Remedial Action Plan (RAP).

2. The RAP identifies the nature of the groundwater contamination problem at AFP 44 and analizes 18 remedial alternatives for its containment or resolution under the provisions of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 ("Superfund"). The Air Force has both the responsibility and authority to cleanup contamination caused by its hazardous waste management activities on its installations.

3. To initiate the proposed final remedial action of the withdrawal of contaminated groundwater, treatment of the contaminated water, and recharge of the underlying aquifer, the Air Force must execute a Record of Decision (Atch 1).

RECOMMENDATION:

4. Recommend CV approve the proposed remedial action and sign the Record of Decision.

Gordon A. Ginsburg

GORDON A. GINSBURG, Brig Gen, USAF
Staff Judge Advocate

2 Atch
1. Record of Decision
2. Summary

COPY TO (List all organizations to receive information copy)

[1] Originator will give each coordinating DCS/SSO a copy of signed out correspondence.

AF FORM DEC 83 1768 PREVIOUS EDITION WILL BE USED. HQ AFSC/CST OVERPRINT

AFBC-Andrews AFB DC 1984

HUGHES AIRCRAFT COMPANY CHRONOLOGICAL LIST OF ENVIRONMENTAL REPORTS

1. Field Investigations of Uncontrolled Hazardous Waste Sites, FIT Project, Preliminary Site Inspection Report, Hughes Aircraft Co., USAF Plant #44, Tucson, Arizona. EPA Contract No. 68-01-6056. Ecology and Environment, Inc., April 15, 1981.

2. Memorandum Report: Construction and Testing of Pilot Neutron Logging System, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, Hargis & Montgomery, Inc., December 18, 1981.

3. Phase I - Investigation of Subsurface Conditions in the Vicinity of Abandoned Waste Disposal Sites, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, Volumes I, II, and III, Hargis & Montgomery, Inc., January 15, 1982.

4. Phase II - Investigation of Subsurface Conditions in the Vicinity of Abandoned Waste Disposal Sites, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, Volumes I, II, and III, Hargis & Montgomery, Inc., March 12, 1982.

5. Memorandum Report: Results of Additional Testing, Pilot Neutron Logging System, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, Hargis & Montgomery, Inc., April 19, 1982.

6. Preliminary Reclamation Wellfield Design and Assessment of Water Treatment Alternatives, United States Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., August 9, 1982.

7. Digital Simulation of Containment Transport in the Regional Aquifer System, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., October 11, 1982.

8. Evaluation of Data Collected by Tucson Groundwater Contamination Study Task Force in the Vicinity of U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., February 4, 1983.

9. Results of Construction and Testing of Neutron Logging System, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, Hargis & Montgomery, Inc., March 3, 1983.

10. Interim Emergency Measures Cementing of Wells HAC-1, HAC-2, and HAC-4, U.S. Air Force Plant No. 44, Hargis & Montgomery, Inc., May 25, 1983.

11. Summary of 1982 Hydrologic Monitoring Program U.S. Air Force Plant No. 44, Tucson, Arizona, Volumes I and II, Hargis & Montgomery, Inc., July 15, 1983.

12. Construction of Monitor Wells M-21 Through M-28, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., September 12, 1983.

13. Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase I & Phase II Results, Malcolm Pirnie, Inc., September, 1983.

14. Environmental, Energy, and Resource Conservation Review of Air Force Plant 44, JRB Associates, October, 1983.

15. Analysis of Data Collected by Tucson Groundwater Contamination Study Task Force in the Vicinity of Tucson International Airport, Hargis & Montgomery, Inc., February 24, 1984.

16. Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase III Results, Malcolm Pirnie, Inc., February, 1984.

17. Memorandum Report: Recommendations for Pilot Reclamation System, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., May 30, 1984.

18. Memorandum Report: Evaluation of 1983 Quarterly Neutron Logs, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., June 22, 1984.

19. Memorandum Report: Evaluation of Water Use Alternatives, Proposed Reclamation Wellfield, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., October 11, 1984.

20. Construction of Monitor Wells M-29 Through M-39, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., October 16, 1984.

21. Results of Neutron Calibration Experiment-August 1984, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., October 25, 1984.

22. Construction of Perched Zone Monitor Wells S-1 Through S-19 U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., November 2, 1984.

23. Construction of Pilot Reclamation Wells U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., November 12, 1984.

24. Results of Neutron Calibration Experiment at Neutron Logging Hole N-5, November 1984, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., December 11, 1984.

25. Industrial Waste Treatment Facilities, EPA Part "B" Permit Application, Title 40 CFR Part 264, Hughes Aircraft Company, Tucson, Arizona, December 14, 1984.

26. Groundwater Treatment Facility, U.S. Air Force Major Project No. 1-84-114. Draft Technical Specifications. Hughes Aircraft Company, Tucson, Arizona, U.S. Air Force Plant No. 44. Volumes IA, IB, and II, Design Analysis, Metcalf and Eddy, February 29, 1985.

27. Design of Reclamation Wellfield, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., March 15, 1985.

28. Poor Quality Groundwater Withdrawal Permit Application, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., March 29, 1985.

29. Draft Remedial Action Plan, U.S. Air Force Plant No. 44, Tucson, Arizona, Hughes Aircraft Company, April 10, 1985.

30. Summary of 1984 Hydrologic Monitoring Program, U.S. Air Force Plant No. 44, Tucson, Arizona, Volumes I, II, and III, Hargis and Associates, Inc., May 31, 1985.

31. Installation Restoration Program Phase I, Records Search Final draft, Air Force Plant No. 44, Tucson, Arizona, Science Applications International Corp., May, 1985.

32. Evaluation of 1984 Quarterly Neutron Reports, Hargis and Associates, Inc., June 12, 1985.

33. Water Quality Results: January 1985 - June 1985, Hargis and Associates.

IMC 031

Karl S. Lytz	Latham & Watkins	(619) 236-1234
Billig J Russell	ASD/PMDA	AV 785-7714
Donald Ellermann	Hughes	602-295-8611
R.E. Morrison	Hughes	602-295-6896
D.E McNamara	Hughes	602-295-8351
David Mulliken	Latham & Watkins	(619) 236.1234
David R. Hargis	Hargist Assoc.	(619) 454-0165
George W. Schlossnagle	AFSC/DEMV	X6341
Walter F Werner	AFSC-PA	23241
Maj John Harte	AFSC/JA	
Brig Gen G Ginsburg	JA	
Col T Honeywill	CS	
Col (DA) S Shapiro	SG	
Maj Gen MT Smith	PL	
Lt Gen WE Thurman	CV	
Lt C K Keiber	PLM	
Mr. L. Keffer	PLM	

For CV meeting with PL, JA
Hughes Aircraft Company

76

TALKING PAPER

ON

REMEDIAL RESPONSE PROPOSAL FOR AFP 44, HUGHES/TUCSON

MAIN THRUST

THE AIR FORCE MUST IMPLEMENT A FINAL GROUNDWATER REMEDIAL PROGRAM IN RESPONSE TO HISTORIC WASTE DISPOSAL CAUSED ENVIRONMENTAL CONTAMINATION BENEATH ITS FACILITY IN TUCSON ARIZONA.

DISCUSSION

(1) BACKGROUND

United States Air Force Plant 44 (AFP 44) is a Government-Owned, Contractor-Operated manufacturing facility in Tucson, Arizona operated by Hughes Aircraft Company on behalf of the United States Air Force. In 1981 the Air Force learned of the presence of contaminants in the groundwater beneath the facility and together with Hughes initiated an extensive investigation to identify the source and extent of any groundwater contamination which might have been caused by activities at AFP 44. That investigation has shown that as a result of historic (although then environmentally acceptable) waste handling practices, groundwater beneath the facility is contaminated and that contamination has moved in the groundwater northwesterly from the facility's northern boundary to the vicinity of Los Reales Road.

(2) REMEDIAL ACTION PLAN

In responding to the presence of AFP 44-caused groundwater contamination under its authority under the Comprehensive Environmental Response, Compensation and Liability Act, the Air Force has completed a study examining several possible strategies of remedial action. The results of that study are exhaustively presented in a Remedial Action Plan (RAP). The RAP identified 18 alternatives for remedial action; however, six of these alternatives, including the no action alternative, were eliminated in the initial screening of the study. Twelve of the alternatives, each involving the withdrawal, treatment and reuse or recharge of groundwater, were more fully explored and evaluated (see attachment).

(3) PROPOSED ACTION

The National Contingency Plan at 40 CFR 300.68(j) provides that:

> The appropriate extent of remedy shall be determined by the lead agency's selection of the remedial alternative which the agency determines is cost-effective (i.e, the lowest cost alternative that is technologically feasible and reliable and which effectively mitigates and minimizes damages to and provides adequate protection of public health, welfare or the environment).

Consistent with the requirements of the National Contingency Plan and the Department of Defense's Installation Restoration Program, the Air Force has evaluated the alternatives' contribution to the protection of the public health and environment, as well as the alternatives' cost, technological feasibility and reliability, and environmental impacts. The resulting Air Force proposal is to implement the alternative of direct acquifer recharge of treated groundwater by recharge wells.

ACTION DESIRED

Approve and Sign Record of Decision to implement the program.

As of: 19 Nov 85
OPR: JA/Maj Harte
ext/7475

1 Atch
Attendance List

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE SYSTEMS COMMAND
ANDREWS AIR FORCE BASE, DC 20334

Record of Decision

Remedial Alternative Selection

Site: Air Force Plant 44, Tucson, Arizona

Analyses Reviewed:

I am basing my decision upon review of the following documents relating to the presence of groundwater contamination at Air Force Plant 44 and the evaluation of remedial alternatives at the plant.

- Remedial Action Plan (together with the documents and reports incorporated therein and as referenced in the attached)
- Responsiveness Summary
- Environmental Assessment and Finding of No Significant Impact
- Results of the Tucson Airport Area Remedial Investigation Phase I and the comments thereon by Air Force consultants
- Installation Restoration Program Phase I Report
- Staff and Consultant Summaries and Recommendations

Description of Selected Remedy:

- Construction of a reclamation wellfield to extract contaminated groundwater from the regional aquifer
- Withdrawal and treatment of the extracted groundwater to remove contaminants
- Reinjection of the treated water to the regional aquifer
- Monitoring of the groundwater to ensure the effectiveness of the remedial effort and to substantiate termination.

Declarations

Consistent with the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), and the National Contingency Plan (40 CFR Part 300), I have determined that the extraction of contaminated groundwater, its treatment and the

reinjection of treated water at Air Force Plant 44 is a cost-effective remedy, and that it effectively mitigates and minimizes damage to, and provides adequate protection of, the public health, welfare and the environment. The State of Arizona, the City of Tucson and the Environmental Protection Agency have been consulted and agree with the approved remedy, encouraging the Air Force to proceed with the remedy's implementation.

I have determined that the extent of groundwater contamination at Air Force Plant 44 has been persuasively demonstrated by the data and technical analyses referenced and discussed in the Remedial Action Plan. Implementation of the proposed remedial action program is necessary to prevent further harm to the environment. Any conflicting views with respect to the extent of the Air Force Plant 44 plume of contamination would not alter the necessity for the proposed actions. The selected remedy minimizes any potential impact upon any available remedy to the groundwater contamination in the Tucson International Airport Area outside of Air Force responsibility.

This action will require future operation and maintenance activities to support the treatment of contaminated groundwater at Air Force Plant 44. Data collected from the continued monitoring of the groundwater effected by Air Force Plant 44 activity will be analyzed to determine the point of treatment termination.

WILLIAM E. THURMAN
Lieutenant General, USAF
Vice Commander

SUMMARY OF REMEDIAL RESPONSE ACTIVITIES

AND REMEDIAL ALTERNATIVE SELECTION

Air Force Plant 44

Tucson, Arizona

Site Description and History

United States Air Force Plant 44 (AFP 44) is a United States-owned, contractor-operated defense systems manufacturing facility located in Tucson AZ. It occupies approximately 2,106 acres of land southwest of the Tucson International Airport. AFP 44 is operated for the Air Force by Hughes Aircraft Company and has been producing major defense systems for the United States since 1951.

In early 1981, the Environmental Protection Agency conducted a preliminary investigation of groundwater conditions and quality in the vicinity of the Tucson International Airport. The results of this investigation indicated the presence of contaminants in groundwater beneath AFP 44. Subsequent to this discovery, the Air Force and Hughes initiated an extensive review of historic waste handling practices at AFP 44 together with vigorous hygrogeological investigations into the environmental conditions existing at the plant. As part of those reviews and investigations, a groundwater quality assessment and monitoring program was established which now consists of 104 on-site and off-site groundwater quality monitoring wells. These investigations have demonstrated that hazardous wastes from AFP 44 have in fact been released into the groundwater beneath the plant as a result of pre-1977 waste management and disposal operations and that residuals of those wastes have over time migrated in a northwesterly direction beyond AFP 44's northern boundary. This plume of contamination from AFP 44, consisting in its farthest reaches of trichloroethylene--a once widely used industrial solvent or degreaser, now reaches in low concentrations to an area slightly north of Los Reales Road in Tucson.

Environmental investigations conducted by the Environmental Protection Agency, the Arizona Department of Health Services and Department of Water Resources, and the City of Tucson since 1981 have also confirmed the presence of groundwater contamination in the vicinity of the Tucson International Airport and well north of AFP 44. Those investigations identify--but do not fully explore--several known or potential sources of contamination from historic and present industrial and aviation related activities at or near the airport as well as from old waste disposal and landfill operations unrelated to the operations at AFP 44.

Air Force investigations into the scope and extent of groundwater contamination beneath its facility at AFP 44 have been conducted pursuant to its authority under Section 104 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 and Executive Order 12316. The Air Force manages its responsibility and authority for responding to a release or potential release of hazardous substances from AFP 44 under the provisions of the Installation Restoration Program (IRP), a four-phased effort of problem identification, confirmation, technology development, and implementation of remedial measures which is consistent with the program requirements of the National Contingency Plan. The identification and confirmation phases of the IRP have been on-going at the plant since 1981. Recently, the Air Force completed and published a Remedial Action Plan (RAP) analyzing several alternative cleanup options and proposing to initiate a final groundwater remedial measure. Source control and contaminant removal activities were conducted earlier.

Alternatives Evaluation

The Air Force's investigations identified a zone of perched groundwater overlying the regional aquifer system and separated from the regional acquifer by clays and other impermeable materials. Chromium, trichoroethylene (TCE), 1,1,1 trichloroethane (TCA) and 1, 1 dichloroethylene (DCE), together with lesser amounts of other contaminants, are found in the perched zone and in the upper zone of the regional aquifer. The Air Force goals with regard to its remedial program are to prevent to the maximum degree practicable any continued migration of these contaminants from Plant 44; to remove and dispose of contaminants in an environmentallly sound manner and in the most cost-effective and timely manner possible, rendering contaminated groundwater suitable for beneficial use; and to implement a program which meets all applicable and relevant local, state and federal agency requirements, which does not result in unwarranted lowering of the water level in the regional aquifer, which does not interfere with any other remedial actions conducted in the airport vicinity, and which is consistent with the goals of the Tucson Active Groundwater Management Area. In furtherance of those ambitious goals, the Air Force developed a Remedial Action Plan (RAP) assessing the extent of the Air Force Plant 44 caused groundwater contamination as identified and analyzed in several preceding investigations and reports under the IRP and other reports and investigations completed by other interested agencies. The RAP proposes a remedy most appropriate under the circumstances found and confirmed in these investigations: namely, the construction of a reclamation wellfield to extract contaminated groundwater from the regional aquifer, the withdrawal and treatment of the extracted groundwater to remove contaminants, and the reinjection of the treated water to the regional acquifer.

Eighteen potential alternatives were identified in the RAP to mitigate or remediate groundwater contamination. Six of these alternatives, including the no action alternative, were eliminated from consideration early in the analyses presented by the RAP for their failure to satisfy the goals established by the Air Force for its groundwater remedial program. Those alternatives eliminated included no action, containment of the contaminant plume by the installation of impermeable barriers, and four means of disposition consisting of (1) the withdrawal of contaminated groundwater and the disposal of the contaminated, untreated water into the public sewer system, (2) by deep-well injection, (3) by solar evaporation, or (4) in a permitted hazardous waste treatment or disposal facility. None of the alternatives eliminated provided any long-term confidence that public health and the environment would be protected and all suffered from the fact that a substantial amount of groundwater would be effectively withdrawn from any beneficial use for the forseeable future. The remaining 12 alternatives all consisted of withdrawal and treatment of contaminated groundwater by various means. (A summary of the 12 withdrawal and treatment alternatives is found at Table 2 of the RAP and is further summarized in the attachment.)

Additional criteria were considered in the evaluation of the remaining alternatives for technical and program policy reasons, particularly: that extraction at less than 2,000 gallons per minute would not effectively reclaim contaminated groundwater, that pumping and extraction might necessarily continue over a 20 year period, and that distribution or use of the treated water would need to be consistent with state statutory requirements and the local groundwater management plan, primarily, with respect to the latter, that drawdown of existing groundwater must be minimized and further degradation of groundwater quality prevented. The only alternative satisfying these criteria is the recharge of the regional acquifer with treated water: the preferred, proposed and approved remedy. Such remedy is cost effective and effective in reducing contamination through extraction and subsequent replacement of the contaminated groundwater with treated water. By all methods of analysis, the approved remedy offers the most protection to public health and best restores the effected environment. Furthermore, the approved remedy complies with all relevant and substantive environmental standards and is consistent with the National Contingency Plan and the Air Force's statutory response authority.

Other Remedial Response Activities

As noted previously, the Environmental Protection Agency, the Arizona Department of Health Services and Department of Water Resources and the City of Tucson--known collectively as the Remedial Investigation Team (RIT)--have studied similar problems of groundwater contamination in the general vicinity of the Tucson International Airport and north of AFP 44. The results of

these investigations have been exhaustively analyzed by the Air Force and its consultants in 1983 and 1984 and again, just recently, upon publication of the Tucson Airport Area Remedial Investigation Phase I in November 1985. The earlier investigations and reports of these interested state and federal agencies identified and confirmed the presence of substantial sources of groundwater contamination to the National Priorities List Tucson Airport Area other than and distinguishable from groundwater contamination caused by AFP 44. Indeed, in 1983 the agencies concerned concluded that the then available data supported a conclusion that the plume of contamination emanating from AFP 44 terminated south of Los Reales Road. In November 1984, in an unrebutted report, the Air Force's hydrogeologic consultants concluded, on the basis of extensive data gathering and analysis, that the low concentration, forward edge of the AFP 44 TCE contaminant plume had recently migrated to a point slightly north of Los Reales Road. Since that time the collection of additional data and resultant analysis by the Air Force has confirmed that 1984 assessment. While subsequent migration of contaminants in the acquifer system may have resulted in low concentrations of contaminants associated with waste disposal activities at AFP 44 moving slightly north of the plant towards other contaminant plumes, the Air Force has concluded that the AFP 44 plume of contamination is separate and distinct from the wide area of contamination located north and substantially downgradient of Los Reales Road as identified in the RIT November 1985 report.

The RIT's most recent report, prepared on behalf of the agencies under contract to the Arizona Department of Health Services is remarkable only in its technical deficiencies, from data collection to technical and scientific analysis. Three of the major issues presented in the report and noted for their flaws were commented on in some depth by the Air Force consultants. These comments were provided to the author agency at the close of the response period allowed for Air Force peer review. The comments addressed the areas of unsubstantiated conclusions or contradictory conclusions (by facts or related conclusions), in the inadequacies and inconsistencies in the source investigations reported and analyzed in the report, and the inability of computer model projections and their resultant conclusions to reproduce actual observed conditions or the conclusions of other parts of the report. The underlying assumption of the report, driving the investigation apparently to its ill-founded and hastily drawn conclusions, is that AFP 44 is the sole source of the majority of groundwater contamination observed in the vicinity of the Tucson International Airport. In the opinion of the Air Force consultant, such assumption and conclusion cannot be technically supported.

In order to support the necessary continuing remedial investigation efforts of the Arizona Department of Health Services and the other members of the RIT, the Air Force has offered assistance to correct the report's deficiencies. Such

offer was tendered to the state in October 1985 in response to its comments on the Air Force RAP--recognizing the possibility for technical dispute on the Air Force determination respecting the extent of contaminant migration from AFP 44. That offer was again made upon submission of comments to the RIT study, but emphasizing that any technical dispute between the Air Force and the RIT was in fact nonexistent, until such time, perhaps, as the state's fundamental technical and analytical errors were corrected. None of the issues presented by the RIT report, however, need alter the Air Force commitment to proceed with the implementation of a comprehensive groundwater remedial effort for the extent of contamination caused by AFP 44.

Attachment

Alternative	Compliance With Public Health/ Environmental Standards	Cost ($Million-1984)	Technological Feasibility
Discharge to Public Sewer System	Meets or exceeds health standards. Sewer system cannot accept inflow large enough to timely remedy contamination. Inconsistent with local groundwater management plans.	42.2	Moderate
AFP 44 Industrial Uses	Meets or exceeds health and environmental standards. Inadequate industrial water demand to satisfy remedial action goals.	0.3	High
Asarco Copper Mine Uses	Meets or exceeds health and environmental standards. Reliability of continued long-term use demand to meet remedial action needs unknown.	43.5	High
Farmers Investment Co. Irrigation	Meets or exceeds health standards, but inconsistent with local groundwater management plans. Long-term use demand unknown; at best seasonal, noncontinuous use.	79.1	Moderate
Papago Indian Irrigation	Meets or exceeds health standards, but inconsistent with local groundwater management plans. Long-term use demand unknown; at best seasonal, non-continuous use.	33.6	High
Golf Course Irrigation	Meets or exceeds health standards, but inconsistent with local groundwater management plans. Long-term use demand unknown; at best seasonal, non-continuous use. Inadequate irrigation demand to satisfy remedial action goals.	5.0	Moderate

Recreational Use at Santa Cruz Park	Meets or exceeds health standards, but inconsistent with local groundwater management plans.	37.3	High
Recharge to Santa Cruz River	Meets or exceeds health standards, but inconsistent with local groundwater management plans.	29.7	High
Davis-Monthan Domestic Use	Meets or exceeds health and environmental standards. Inadequate use demand to satisfy remedial action goals.	7.5	Moderate
Tucson Domestic Use	Meets or exceeds health and environmental standards.	24.7	High
Recharge by Percolation	Meets or exceeds health standards, but inconsistent with local groundwater management plans.	31.3	High
Recharge by Recharge Wells	Meets or exceeds health and environmental standards. Direct recharge allows greater rate of groundwater withdrawal, results in faster cleanup.	26.8	High

HARGIS + ASSOCIATES, INC.
Consultants in Hydrogeology

2223 Avenida De La Playa Suite 300
La Jolla, California 92037
(619) 454-0165

87

November 13, 1985

RECEIVED
NOV 13 1985
KARL S. LYTZ

Mr. Charles H. Alford
Environmental and Energy Programs
Aeronautical Systems Division
Wright-Patterson AFB
Dayton, Ohio 45433-6503

RE: Comments on "Results of the Tucson Airport Area Remedial Investigation Phase I", prepared by the Arizona Department of Health Services

Dear Mr. Alford:

Pursuant to your request, we have reviewed the final draft report entitled "Results of the Tucson Airport Area Remedial Investigation Phase I", (Phase I Report), prepared by the Arizona Department of Health Services (DOHS) and their contractors. Because of the severe time constraints imposed on the USAF for submittal of comments, we have only addressed the major concerns we have with respect to the Phase I Report. These comments are necessarily preliminary. There are many other factors which need to be discussed regarding the technical adequacy of the data collected, the interpretation and analysis of the data, and its presentation in the draft report in order to understand fully the technical shortcomings of the Report and its conclusions.

The comments presented below primarily address three broad areas: (1) unsubstantiated conclusions or conclusions contradicted by the facts presented in Volume I of the Phase I Report regarding the extent of contamination emanating from AFP 44; (2) inadequacies and inconsistencies of the potential source investigation reported and analyzed in Volumes I and III of the Phase I Report; and, (3) the inability of the "scenario two" computer model projections to reproduce actual observed conditions, and the inconsistency between the "scenario one" model projections and the conclusions reached in Volume I.

Phoenix office
2222 South Dobson Road Suite 401
Mesa, Arizona 85202
(602) 345-0868

Tucson office:
1735 East Fort Lowell Road Suite 5
Tucson, Arizona 85719
(602) 881-7300

As you know, the Phase I Report and Volume I in particular, suggest that AFP 44 is the sole source of the majority of the groundwater contamination occurring in the vicinity of the Tucson International Airport (TIA). Based on our four years of study in this area, it is my professional opinion that the ADHS Report overestimates the extent of contamination which was actually caused by past disposal practices at AFP 44. It is also my professional opinion that the major conclusions presented in the ADHS Phase I Report are incorrect, or at best unsubstantiated, and in many cases are contradicted by the facts.

A. The Longitudinal Axis Theory

The Volume I - Summary Report prepared by Schmidt suggests that AFP 44 is the source of the majority of groundwater contamination in the TIA, and that "The distribution of TCE in the upper and undivided aquifers is related to subsurface geologic conditions, the present direction of groundwater flow, and the permeability of the coarse-grained deposits" (page 76). In fact, Volume I hypothesizes that "unique hydrogeologic conditions" exist in a narrow zone in the upper regional aquifer referred to throughout the Phase I Report as the so-called "longitudinal axis" of the plume. The Report suggests that the geologic conditions along this so-called longitudinal axis alone are responsible for extensive distribution of contaminants in the upper regional aquifer, and basically dismisses the impact on aquifer conditions of other potential sources located north of AFP 44. Inspection of the data presented on Plate 9, however, clearly indicates that the location and nature of sources north of AFP 44 are important factors in determining the distribution of contaminants in the groundwater system. The data, in fact, contradicts the existence of the so-called longitudinal axis and the claimed extent of contamination north of Los Reales Road caused by AFP 44.

For example, Plate 9 presents concentrations of TCE contoured for the upper and undivided aquifers based on data collected from monitor wells north of AFP 44 during the period September through December 1984. These contours are drawn without regard for the location of potential sources north of AFP 44 in the Airport area. Notwithstanding the fact that the drafters of this Plate were not confident enough in their conclusions to draw a 100 parts per billion (ppb) or 50 ppb TCE contour through the one-mile wide area lying between the northern boundary of AFP 44 and Los Reales Road, the implication of Plate 9 and the clear suggestion of the text of the Phase I Report are that these contours should extend to AFP 44.

However, data presented on Plate 9 indicate that the 100 ppb contour of TCE emanating from AFP 44 does not extend north of monitor well TAS-2, and that the 100 ppb contour emanating from other potential sources north of the plant does not extend south of monitor well TAS-5.

As noted above, however, the contours of TCE concentration presented on Plate 9 imply that there is a zone of groundwater containing TCE concentrations greater than 100 ppb that is about 500 feet wide extending from the vicinity of the northern boundary of the plant to just south of Valencia Road. While the hydrogeologic conditions that would account for this distribution of TCE are not presented, the Phase I Report contends that the high concentration contours could possibly be extended to AFP 44 based on the "unique hydrogeologic conditions" in the so-called "longitudinal axis." Not only do the measured TCE levels from monitor wells constructed throughout the one-mile area between the northwest corner of AFP 44 and Los Reales Road contradict this hypothesis, but the actual geologic data collected during the drilling of monitoring wells throughout this area indicate that there are no "unique hydrogeologic conditions" that might result in the narrow zone of high TCE concentration as depicted on Plate 9. Inspection of lithologic data from monitor wells constructed in the area is instructive. There are, for example, three monitoring wells located in approximately the middle of this hypothetical zone of high TCE

concentration, i.e., along the so-called "longitudinal axis": Monitor well M-36, located just west of the intersection of Los Reales Road and the Old Nogales highway, with a concentration of 300 ug/l TCE; monitor well SF-7 located about 3,000 feet northwest of well M-36, with a concentration of 220 ug/l TCE; and monitor well WR-56C located about 1,000 feet north-northwest of monitor well SF-7, with a TCE concentration of about 170 ug/l. Examination of lithologic logs compiled during drilling of these monitor wells indicate a typical sequence of alluvial basin deposits consisting of an interbedded sequence of sandy clay, clayey sand, clay, gravelly sand, and sandy gravel. This lithology is typical of most monitoring wells constructed in the vicinity of the Tucson airport, and is not remarkably different from the lithology of other monitor wells located outside of the hypothetical zone of high TCE concentration.

A subsurface geologic cross-section is presented as Plate 3, which extends from monitoring well M-12 located in the northwest corner of AFP 44 to monitor well SF-6, which is located approximately 4 miles north of AFP 44 near Irvington Road. Monitor wells M-36, SF-7, and WR-56C are included on this cross-section, as are other monitor wells that are located outside of the hypothetical narrow zone of high TCE concentrations. Lithologic logs for monitor wells located outside the hypothetical narrow zone of high concentrations indicate geology similar to the three monitoring wells located within the zone. For example, monitor well SF-4 is located south of monitor well SF-7 and is outside the area of high TCE concentrations. The geologic cross-section presented on Plate 3 indicates that the geologic conditions encountered at monitor well SF-4 are similar to conditions encountered at monitor well SF-7. Lithologic data presented on Plate 3 indicate about 16 feet of saturated sand and gravel in monitor well SF-7 and about 18 feet of saturated sand and gravel in the upper zone of monitor well SF-4.

Monitor well M-36 is also located in the hypothetical zone of high TCE concentration, as is monitor well TAS-5, located about 1,000 feet south of

monitor well M-36 outside of the zone of high TCE concentration. Lithologic data presented on Plate 3 for these two monitor wells indicate similar lithologic conditions were encountered in both wells. Lithologic data presented on Plate 3 indicates about 13 feet of saturated sand and gravel in monitor well M-36, and about 9 feet of saturated sand and gravel in monitor well TAS-5.

Lithologic data from all five of these monitor wells indicate similar geologic conditions. In addition, lithologic data obtained from other monitor wells constructed north of AFP 44 and south of Los Reales Road indicate hydrogeologic conditions similar to the three monitor wells located in the hypothetical area of high concentration. The lithologic data collected for monitor wells in this area do not indicate any unique hydrogeologic conditions which might rationally explain a continuous narrow zone of high TCE concentrations extending from AFP 44 to the area north of Los Reales Road.

Contours of equal TCE concentration presented on Plate 9 are inconsistent with the water quality data presented in the Volume I - Summary Report. Water quality data from samples collected in monitor wells south of monitor well M-36 and north of the AFP 44 property boundary (an area approximately one mile wide) indicate that the concentration of TCE in the groundwater is less than 50 ug/l in the area west of Old Nogales Highway. Water quality data collected in monitor well TAS-5, TAS-4 and TAS-1 indicate TCE concentrations of 47, 30, and 43 ug/l TCE, respectively. These data indicate the the 50 and 100 ug/l contours of equal TCE concentration drawn but not completed on Plate 9 do not extend south of monitor well TAS-5, and cannot be extended further south to AFP 44.

Moreover, the measured concentration of other principal contaminants other than TCE found in the TIA area are also inconsistent with the Phase I Report's implications that AFP 44 is a major source of contamination in the area north of Los Reales Road. Contours of equal chromium concentration in

groundwater presented on Plate 8, for example, are also inconsistent with water quality data presented in the Volume I-Summary Report. As is the case with TCE, the drafters of Plate 8 have again not drawn the purported contours for chromium in the area between the northern boundary of AFP 44 and Los Reales Road. Water quality data from samples collected in monitor wells located south of well M-36 show that the concentration of chromium in groundwater is 0.01 mg/l or less in the area west of the Old Nogales Highway. These data indicate that the 0.04 mg/l contour does not extend south of monitor well M-36. Because chromium was not detected in monitor well TAS-5 and M-34, the 0.03, 0.02, 0.01 mg/l contours of equal chromium concentration depicted on or suggested by Plate 8 cannot be extended south of monitor well TAS-5.

Additional water quality data partially discussed in the Volume I - Summary Report provide further clarification of the distribution and potential sources of contaminants in the groundwater system. For example, Table 15 in the Volume I - Summary Report indicates that chloroform was detected at concentrations ranging from 4 to 54 ug/l in groundwater samples collected from monitoring wells located north of Los Reales Road. Data presented in Table 15 also indicate that chloroform was not detected in groundwater samples collected from monitoring wells located south of Los Reales Road and north of AFP 44. These data indicate that contaminated groundwater south of Los Reales Road originated from different sources than contaminated groundwater north of Los Reales Road.

Similarly, data presented in Table 14 of the Volume I - Summary Report indicate that concentrations of 1,2-trans-dichloroethylene (1,2-trans-DCE) were detected at concentrations ranging from 2 to 13 ug/l in groundwater samples collected from monitoring wells constructed north of Los Reales Road. Data presented in Table 14 also indicate that 1,2-trans-dichloroethylene was not detected in groundwater samples from monitoring wells constructed south of Los Reales Road and north of AFP 44. These data also indicate that contaminated groundwater south of Los Reales Road originated

from different sources than contaminated groundwater north of Los Reales Road.

In addition, water quality data presented in Table 13 indicate that concentrations of 1,1-dichloroethylene (DCE) in water samples collected from monitoring wells constructed north of Los Reales Road ranged from 2 to 23 ug/l. Data presented in Table 13 also indicate that concentrations of DCE in groundwater samples collected from monitoring wells located south of Los Reales Road ranged from 4 to 7 ug/l. These data indicate decreasing concentrations of DCE north of the AFP 44 plant boundary and south of Los Reales Road, and increasing concentrations of DCE north of Los Reales Road. This data also indicates that contaminated groundwater south of Los Reales road originated from different sources than contaminated groundwater north of Los Reales Road.

In summary, Volume I of the Phase I Report suggests that AFP 44 "appears" to be responsible for most of the TCE plume extending from AFP 44 northward to Irvington Road. The Report associates this widespread distribution to "unique hydrogeologic conditions" along the so-called "longitudinal axis" of the plume.

This theory of "unique hydrogeologic conditions" is not supported by the data collected in the area. First, there is no geologic data to support the hypothesis that "unique hydrogeologic conditions" account for high concentrations in a narrow zone extending from AFP 44 into the area north of Los Reales Road. Lithologic logs for wells drilled throughout the TIA area do not indicate the existence of such a zone. In fact, Plates 8 and 9 of the Volume I Report acknowledges this by indicating that the narrow zone or "longitudinal axis" is located between monitor wells TAS-4 and M-34. Attempting to prove the theory through implications based on an acknowledged lack of data to substantiate the hypothesis is a very questionable form of analysis.

More important, however, is the fact that lithologic logs for the wells which the Phase I Report acknowledge as being constructed along the "longitudinal axis" in fact contradict the hypothesis. For example, wells WR-56C, SF-7, and M-36 are depicted as being squarely within the narrow zone of high concentration for TCE and chromium on Plates 8 and 9. The lithologic logs for these wells, however, are not substantially different from the lithologic logs for monitor wells which are located at varying distances east and west of the so-called "longitudinal axis." The similarity of lithologies encountered in wells claimed to be on the "longitudinal axis" and those claimed not to be on the "longitudinal axis" indicates that the distribution and concentration of TCE in the upper aquifer cannot, as the Phase I Report suggests, be explained on the basis of "unique hydrogeologic conditions" and a single source area at AFP 44.

Second, the purported narrow zone of high concentrations indicated by isoconcentration contours drawn on Plates 8 and 9 for chromium and TCE are not consistent with the concentrations actually measured in monitor wells. It is also worth noting that the isoconcentration contours on Plates 8 and 9 are not even drawn in the one-mile area south of Los Reales Road and north of AFP 44.

The water quality data obtained from the monitor wells in the one-mile area south of Los Reales Road and north of AFP 44 would contradict the extension of the isoconcentration contours from the area north of Los Reales Road southward to AFP 44. The measured concentrations of TCE and chromium obtained from wells located south of Los Reales Road simply do not support the conclusion that AFP 44 is the predominant source of groundwater contamination in the area north of Los Reales Road.

B. Investigation of Potential Sources

As discussed above, the Phase I Report's conclusion that AFP 44 is the predominant source of groundwater contamination north of Los Reales Road is based on an interpretation that is either unsupported or contradicted by the facts. The other major problems with this conclusion are: (1) the analysis presented in Volume I disregards the conclusions contained in the Volume III source investigation report with respect to sources located north of AFP 44, and (2) the actual investigation of other sources north of AFP 44 appears to be inadequate, and the analysis of the data is suspect.

1. Volume I Analysis:

Schmidt's evaluation of other sources north of AFP 44 dismisses important sources of groundwater contamination. Several examples illustrate this point.

a. TAA Landfill: In Volume III, Rampe reports that TCE was used by Grand Central Aircraft Company, which occupied the TAA hangars from 1950-1954. Waste TCE was disposed of in the TAA Landfill (located north of AFP 44, but south of Los Reales Road on TAA property) "which may have received as much as 2,400 gallons of TCE per year according to a reliable witness." Based on the estimates of the "reliable witness", 4,800 to 9,600 gallons of TCE may have been disposed of in the TAA Landfill by Grand Central Aircraft from 1950-1954. Analytic results for soil samples taken at 60 to 90 foot depths indicated trace levels of TCE in deep soils beneath the landfill. Rampe concluded that the TAA landfill should be considered a source of groundwater contamination.

Both Rampe and Schmidt, however, attempt to discount the TAA landfill as a source of TCE contamination. While acknowledging that the absence of TCE from shallow soils in the landfill could simply reflect the fact that TCE disposed of 31 years ago would

have already migrated through shallow soils, Schmidt concludes that the traces of TCE at depth in soils do not provide unequivocal evidence of the TAA's having been a source of TCE contamination to groundwater. Alternatively, Rampe suggests that the TCE data could indicate that these soils could have come into contact with groundwater contaminated by TCE from another source upgradient.

Schmidt concludes that the absence of TCE from monitor well M-34 in 1984 which is located immediately downgradient of the landfill, casts substantial doubt upon the TAA Landfill as having been an important source of groundwater contamination. "[E]xperience with other sources in similar hydrogeologic settings," apparently confirm this conclusion.

Rampe's alternative theory to explain the presence of TCE in deep soils beneath the TAA landfill is interesting, but is certainly a remote possibility in light of the fact that there are no recorded historic water levels which would explain the presence of TCE at a depth of 60 feet. Schmidt's reliance on M-34 to "cast substantial doubt" on the landfill as a significant source of TCE contamination is questionable. Water quality data collected in a monitor well adjacent to a source that was active 31 years ago may not conclusively demonstrate that the landfill was not a source of contamination. Data from wells downgradient of the potential source should also be considered.

Wells M-36 and TAS-5, for example, are located downgradient of the TAA Landfill. These wells contained high concentrations of TCE in December 1984 - 300 ppb and 47 ppb, respectively. Instead of assessing the relevance of these concentrations with respect to the TAA Landfill, the Phase I Report attempts to associate these contaminant levels with AFP 44, based on the hypothetical

"longitudinal axis" theory. In short, this Phase I Report attempts to explain away data concerning the TAA Landfill in order to advance an unsupported alternate theory of contaminant origin and migration.

b. TAA Hangars: In the Volume III evaluation of potential sources, Rampe concludes that the hangar area is a possible source of groundwater contamination. This conclusion is based on documentation of TCE and chromium use in section 3007 responses, from eyewitness accounts of solvent use and disposal, and from the detection of TCE, DCE and chromium in soil samples. Data from soil samples collected by ADHS near the Tucson Airport hangar areas are presented in Table 4 of the Volume III report. Soil boring No. 2 was drilled west of Old Nogales Highway along the historic wastewater flow path from the hangar area. Trace concentrations of TCE, 16ug/l of DCE, and 10 mg/l of chromium were detected in soils from this borehole. Despite these concentrations, deeper soil samples were not collected and a monitor well was not constructed at this location. Similarly, soil boring No. 3 was drilled just northwest of the hangar area at the entrance to the industrial center. Soil samples from this boring contained 5 ug/l TCE, 281 ug/l DCE, and 142 mg/l chromium. These are the highest concentrations of DCE and chromium ever detected in soil samples taken anywhere in the entire airport area, including AFP 44. Nevertheless, soil samples were not collected from depths greater than 20 feet, and a monitor well was not constructed at this location.

Despite the data collected from the shallow soils in these areas which strongly suggests the need for further investigation, Volume I of the Phase I Report dismisses the hangars as a potential source of TCE contamination based on the fact that "disposal of TCE in the TAA Hangar areas has not been documented,

and no significant TCE was found to the northwest at the WR-54 set of monitor wells." Although the source investigation may not have documented TCE disposal, TCE is certainly present in soils in this area. Data from the WR-54 wells alone are not sufficient to dismiss this area as a TCE source for the same reasons discussed in the above section on the TAA Landfill.

The conclusion in the Volume I - Summary Report that TCE concentrations in groundwater from the TAA hangar area source appear to be less than 50 ppb has no basis in the data presented in Volume I or in Volume III. Rampe describes historical operations at the TAA hangar area including careless wastewater handling practices and accounts of run off from the hangar area crossing the Old Nogales Highway through culverts, and emptying into an open wash adjacent to a residential area. Lawsuits were filed due to the pollution of domestic wells from the run off. Based on the location of drainages both north and south of the hangar area, and groundwater flowpaths from these drainages, high TCE concentrations measured north of Los Reales Road may have originated from the hangar area sources.

c. Fire Drill Areas: Data collected at three fire-drill training areas in the TIA area were evaluated by Rampe. Volume III concludes that the data indicate that the fire-drill training area near the runway in Section 19 does not appear to be a significant source of TCE to the groundwater. Soil borings drilled by ADHS near the fire-drill training area south of the runway in Section 19 indicated trace concentrations of TCE, DCE and 8.2 mg/l of chromium. Subsequent shallow soil borings drilled in the area by ADHS detected no TCE or DCE. Monitor well TAS-3, however, is located approximately 1,500 feet west and downgradient of the former fire-drill training area in Section 19, and groundwater samples collected from this well indicate

concentrations of 93 ug/l TCE. TCE detected in monitor well TAS-3 may have originated from disposal activity at the former fire-drill training area, from run off leaving the area, or from other activities in the area. In any event, the nature of this potential source has not been thoroughly evaluated and cannot be disregarded.

A soil boring drilled by ADHS in the area of the current fire-drill training area in Section 20 indicated 721 ug/l TCE and 155 ug/l of DCE. This data is presented in Table 5 in the Volume III report. These TCE concentrations represent the highest concentrations of TCE measured in a soil sample in the airport area. Rampe states, however, that "...the fire pits near runway 29 are probably located too far east to contribute contaminants to the main plume," and attributes this conclusion to Schmidt. Schmidt's conclusion is based on the observation that the current fire-drill training area is located about 10,500 feet east via groundwater flow paths from the "main plume." Nevertheless, Rampe states that "...the extent of groundwater contamination, if any, emanating from the fire-drill areas near runway 29 is unknown, due to the lack of wells in the immediate vicinity." Obviously, a potential source cannot be discounted because there is no groundwater quality data in the area. Similarly, Schmidt concludes that "...hydrogeologic conditions in the vicinity..." indicate that "...pollutants from this facility would not be expected to have reached the Old Nogales Highway." Schmidt then concludes that the fire-drill training area is therefore not a source of TCE pollution in the main plume. If there are no monitor wells in the area, and if no water quality data has been collected, then one must question the author's knowledge of "hydrogeologic conditions in the vicinity" of the fire-drill

groundwater samples collected from this well indicate

2. Investigation of Other Sources:

The fact that the conclusions presented in the Volume III - Source Evaluation are not adequately discussed in the Volume I - Summary Report is compounded by the apparent inadequacy of the source investigation itself. Potential sources are eliminated based on soil sample analyses from one soil boring, from walk-through and drive-by "inspections" conducted in the early 1980's, from the lack of witnesses to disposal activities, and from inappropriate analyses of existing data. Standing and running water observed in historical aerial photographs is considered indicative of a potential source in some cases, but not in others.

Interestingly enough, Rampe states on page 14 of Volume III that:

> "The absence of contaminants in such media [shallow soils and perched groundwater] does not conclusively indicate that disposal did not occur, however, since chemicals can be flushed away or degrade over the long periods of time considered in this study."

He then contradicts his own statement by dismissing drainage channels north of the hangar area as potential sources of contamination based on analyses of shallow soil samples. These drainage channels from Gates Learjet and the Runway 3 area are not considered further based on results of analyses of soil samples from one soil boring. The old fire-drill area now covered by a Gates Learjet parking lot is also dismissed as a potential source based on analyses of soil samples. Several examples will further illustrate my concerns.

A waste disposal area near the end of Runway 3 could not be located by ADHS from available aerial photographs, yet this potential source was eliminated from further consideration based

on the lack of volatile organic contaminants in "...shallow soil samples from the area." If the location of the site was not known, how could the results of analyses of soil samples be expected to yield any meaningful data?

Gates Learjet, Inc. has operated a facility south of Los Reales Road and north of AFP 44 from 1976 to the present. Activities have included airplane assembly, instrument panel assembly, and aircraft surface preparation and painting. This facility was dismissed as a potential source based on a walk-through inspection of the facility by EPA in 1983. "The results of this inspection characterized this as an 'extremely clean' facility. No improper waste disposal practices were documented...The inspection team recommended that no further investigation be conducted at the facility." No documentation was presented regarding waste handling and disposal practices between 1978 and 1983.

The Volume III - Source Investigation analysis relies heavily on the interpretation of aerial photographs. Standing and running water observed in aerial photographs is used to indicate a potential source of contamination in the case of AFP 44, but not in the cases of Consolidated Aircraft Company or Douglas Aircraft Company during their occupancy of the TAA hangars.

Rampe states that aerial photographs provided considerable insight into the relative quantities of wastewater disposed "as judged from phreatophyte growth." The validity of this judgment is questionable. How does one separate the phreatophytic growth in natural drainages due to rainfall and run off from the phreatophytic growth due to wastewater runoff? The criteria used in this exercise are not presented.

West-Cap Arizona is an electronics manufacturing firm which has been located near the corner of Plumer Avenue and Elvira Road since 1963. The firm estimated annual TCE use at 2,000 gallons annually in 1980 and 1981. Rampe concludes that "...it appears likely that TCE has been used at West-Cap since 1963." A floor drain in a building at the southwestern corner of the facility received unknown quantities of waste TCE. The eventual outfall of this drain was not determined by the ADHS investigation. Rampe concludes that West-Cap is a possible source of TCE to the groundwater, and that more monitor wells are needed to assess the groundwater quality in the area.

The Burr-Brown facility has been located about 1,000 feet north of the West-Cap facility since 1965. Rampe reports the potential for disposal of hazardous materials, including TCE, down an abandoned well prior to 1976. Rampe concludes that Burr-Brown should be considered a highly probable source of "local" groundwater contamination. No data is presented for the conclusion that the potential disposal of TCE down a wellbore from 1965 to 1976 would constitute a source of "..local groundwater contamination in 1984." There is no data to support a conclusion of "local" groundwater contamination.

The net result of the source investigation is that a number of significant sources north of AFP 44 are discounted on the basis of specious logic or inadequate investigations. On the other hand, the contributions of AFP 44 sources to groundwater contamination appear to be grossly overstated, if not inaccurately reported.

In that regard, I am particularly concerned by the conclusions that the northwest corner of AFP 44 is described as a significant source of TCE contamination based on the purported TCE

concentrations in historic industrial wastewater discharges from the Plant. I am unaware of any evidence which supports this contention, and strongly recommend review of this issue with reference to the JRB Phase I IRP report.

C. Computer Modeling

A two dimensional digital groundwater flow model coupled with a contaminant transport model was used to simulate conditions in the upper aquifer. These studies were conducted by the Arizona Department of Water Resources, and are presented in a separate report entitled "Contaminant Transport Modeling."

Two scenarios were simulated. The first scenario assumed that TCE in groundwater north of Los Reales Road originated from the TAA Hangar area. The total volume of TCE in the plume north of Los Reales Road was calculated using March 1984 TCE concentrations. Schmidt's analysis of the modeling results for the first scenario conclude that the modeled TCE concentrations agreed closely with observed concentrations at AFP 44, but deviate from observed cncentrations by more than "...an order of magnitude in the area immediately downgradient...of the facility." Schmidt does not discuss possible reasons for this variation from observed values in the downgradient area, the most probable of which could be the fact that all of the TCE in groundwater south of Los Reales Road does not originate from AFP 44. Potential source areas ignored in the modeling study include the TAA landfill located about 1/2 mile south of Los Reales Road on Old Nogales Highway, and the fire-drill training areas and washes along the runways east of Old Nogales Highway and north of AFP 44. If these sources are considered, then results of modeling in scenario one suggest that the one ppb isocentration contour for TCE originating from AFP 44 is located several hundred feet south of Los Reales Road as of September 1984. The anomalous concentrations of TCE in groundwater south of Los Reales Road and north of

AFP 44 are probably the result of other contaminant sources. This factor is not discussed in the Schmidt report. Inspection of the scenario one modeling results presented in Figure 28 of the ADWR Report indicates good agreement between measured and simulated TCE concentrations at AFP 44 extending northward toward Los Reales Road. Anomalous measured concentrations of TCE measured in monitor wells TAS-5 and M-36 are both downgradient of other potential sources in the Airport area. If a portion of the TCE in groundwater south of Los Reales Road originates from other sources such as the TAA landfill, then simulation of the plume downgradient of AFP 44 might indicate much better agreement with measured TCE concentrations in groundwater extending northward from the area of monitor well TAS-5. Introduction of contaminants into the groundwater system from these other sources was not attempted in the modeling studies.

The second scenario in the modeling effort assumed wastewater recharge to the aquifer system in the northwest corner of AFP 44, and elimination of the TAA hangar area as a source. This is contrary to the conclusions reached by Rampe in the Volume III Report of source evaluations, and contrary to Schmidt's own conclusion as to the existence of other sources in the Airport area. In the second modeling scenario, the TCE in the plume north of Los Reales Road was assumed to enter the groundwater uniformly with this additional recharge. This is not a realistic assumption. Although no documentation is available on the volume of TCE used with time either at AFP 44 or in the TAA hangar area, it is most improbable that TCE in wastewater was discharged to the land surface at a uniform rate. Comparison of the results of the second scenario with results of the first scenario indicate that TCE in groundwater north of Los Reales Road did not originate from wastewater infiltrating into the aquifer system at the northwest corner of AFP 44. Concentrations as great as 77 ug/l TCE are located north of the 1 ug/l isocentration contour. In addition, measured concentrations ranging from 43 to 80 ug/l TCE lie in the area between the 1 and 10 ug/l isocentration contours. Furthermore, the 270 ug/l TCE measured in monitor well M-36, located just south of Los Reales Road and east of the Old Nogales

Highway, lies between the 10 and 100 ug/l isocentration contour. Results of the second scenario simulation also indicate that the 100 ug/l isocentration contour emanating from AFP 44 does not extend west of the Old Nogales Highway.

It is clear from the results of the two modeling scenarios that the introduction of additional contaminant sources in the TAA hangar area are required in order to produce TCE concentrations in the groundwater north of Los Reales Road that reasonably simulate the observed concentrations. Although little is known about volumes or rates of disposal, there is adequate information about location of potential sources to provide a framework for modeling. There is also a range of reasonable volumes of material disposed that has not been considered in the analysis of the modeling results. Results of the modeling indicate that the observed concentrations and distribution of TCE in the groundwater north of Los Reales Road are not consistent with the theory of a single source at AFP 44. The modeling results demonstrate that additional sources are required north of AFP 44 to reasonably simulate the observed concentration and distribution of TCE in groundwater north of AFP 44.

D. Summary

As discussed above, there are very significant questions about the technical basis and adequacy of the Phase I Investigation and Report. Not all issues are discussed here because of the time constraints imposed and these comments are far less than the page by page review which is clearly warranted. In overview, the Phase I effort does not alter any of our prior conclusions with respect to the extent of contaminant migration from AFP 44.

I strongly recommend that a meeting with the Phase I Report staff be held in order to discuss completely all of our concerns about the accuracy and adequacy of this investigation and analysis.

Sincerely,

HARGIS + ASSOCIATES, INC.

David R. Hargis

Dr. David R. Hargis

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
II.	SUMMARY OF PRIOR INVESTIGATIVE EFFORTS ANALYSES, AND STUDIES	6
III.	SUMMARY OF THE NATURE AND EXTENT OF CONTAMINATION	14
	A. Soils Contamination	14
	B. Perched Zone	15
	C. Regional Aquifer	16
IV.	POTENTIAL RISKS	18
	A. Volatile Organic Compounds	19
	B. Chromium	27
V.	OBJECTIVES	28
	A. Extent of Remedy	29
	B. Compliance with Relevant Drinking Water Standards and Criteria	30
	C. Consistency of Remedy With The Standards Of Other Relevant Laws	37
VI.	REMEDIAL ALTERNATIVE ANALYSIS:	
	Initial Screening	39
	A. Source Control	41
	B. No Action	46
	C. Containment by Impermeable Barriers	49
	D. Withdrawal of Groundwater	51
	E. Cost and Feasibility Comparisons	79
	F. Summary Of Alternative Uses And Conclusions	84

Page

VII. ANALYSIS AND CONCEPTUAL DESIGN OF A GROUNDWATER RECLAMATION, TREATMENT AND RECHARGE SYSTEM 87

A. Groundwater Reclamation and Recharge Wellfields 87

B. Groundwater Treatment Alternatives. 94

C. Pilot Reclamation Project 95

D. Master Schedule 96

E. Scope of the Project. 97

VIII. COMMUNITY RELATIONS PLAN. 100

A. Purpose 101

B. Participating Units 102

C. External Agencies Involved. 103

D. Site Background and Brief History of Environmental Activities to Date 103

E. Responsibilities for Continued Public Affairs/Community Relations Activities Relating to Remedial Actions at AFP 44. 105

IX. DEMONSTRATION OF PROGRAM COMPLIANCE WITH SUBSTANTIVE STANDARDS OF OTHER LAWS 114

A. Substantive Standards Regarding Groundwater Rights and Impacts. 114

B. USAF Installation Restoration Program Phase IV Management Guidance. 116

C. National Contingency Plan 121

D. National Environmental Policy Act 122

E. Resource Conservation and Recovery Act. 124

F. Underground Injection Control Requirements and Federal Sole Source Aquifer Requirements. 126

G. Floodplain Management 127

H. National Ambient Air Quality Standards. 127

X. REFERENCES. 129

APPENDIX

LIST OF TABLES

NUMBER	TITLE	FOLLOWING PAGE
1	Applicable, Relevant Standards and Target Treatment Levels	35
2	Project Alternatives Cost Comparison Sheet	79
3	Technical Evaluation of Project Alternatives	79
4	Remedial Action Plan Proposed Master Schedule	96
5	Discharge to Public Sewer System	Appendix
6	A.F.P. Industrial Use	Appendix
7	Industrial Use by ASARCO Copper Mine	Appendix
8	Irrigation by Farmers Investment Co.	Appendix
9	Irrigation by Papago Indians	Appendix
10	Irrigation by Golf Courses	Appendix
11	Recreational Water Use at Park	Appendix
12	Recharge to Santa Cruz River	Appendix
13	Domestic Use by Davis-Monthan Air Force Base	Appendix
14	Domestic Use by City of Tucson	Appendix
15	Recharge Through Percolation	Appendix

LIST OF FIGURES

NUMBER	TITLE	FOLLOWING PAGE
1	Range of TCE Concentrations in Groundwater	Appendix
2	Reclamation Wellfield	Appendix
2a	TCE Concentrations, Regional Aquifer - Upper Zone	Appendix
2b	DCE Concentrations, Regional Aquifer - Upper Zone	Appendix
2c	TCA Concentrations, Regional Aquifer - Upper Zone	Appendix
2d	Total Chromium Concentrations, Regional Aquifer - Upper Zone	Appendix
2e	Concentration of TCE, TCA, DCE and Total Chromium, Regional Aquifer - Upper Zone	Appendix
3	Direct Discharge to Public Sewer System	56
4	A.F. Plant 44 Industrial Use	66
5	Industrial Use by ASARCO Mine	67
6	Use of Treated Groundwater for Irrigation	68
7	Use of Treated Groundwater for San Xavier Reservation Irrigation	69
8	Use of Treated Groundwater for Golf Course Irrigation	70
9	Recreational Water Use	71
10	Groundwater Recharge to Santa Cruz River	73
11	Domestic Water Use by Davis-Monthan Air Force Base	74
12	Domestic Water Use by City of Tucson	75

NUMBERS	TITLE	FOLLOWING PAGE
13	Proposed Project Task Flow Chart	115
14	Recharge Well Schematic	93
15	Reclamation Well Schematic	93
16	Location Plan	95
17	Site Plan	95

I. INTRODUCTION

United States Air Force Plant No. 44 ("AFP 44") is a U.S. government-owned, contractor-operated defense systems manufacturing facility located in Tucson, Arizona, in the general vicinity of the Tucson International Airport ("TIA"). AFP 44 is operated for the United States Air Force ("USAF") by the Hughes Aircraft Company ("Hughes"), and has been producing defense systems for the United States Armed Forces since 1951.

In response to a concern that industrial activities may have degraded groundwater quality in the vicinity of the TIA, EPA conducted a preliminary investigation of groundwater conditions in early 1981 which indicated the presence of contaminants in groundwater beneath the facility. In light of this discovery, the USAF and Hughes initiated an extensive review of historic waste handling practices and environmental investigations at AFP 44 in 1981 to determine whether contamination may have been caused by hazardous waste handling practices employed at the facility.

Since 1981, several major investigations of soil and groundwater conditions have been completed. A groundwater quality monitoring program was also initiated in 1981 which has been on-going since then. That program is now comprised of 103 on-site and off-site groundwater quality

monitoring wells which have been sampled and analyzed regularly during the past four years. Also, a number of analytic studies have been performed to identify feasible methods of remediating groundwater contamination, including the field testing of a pilot groundwater reclamation project at AFP 44.

The prior investigations, the results of which are summarized in subsequent sections of this document and presented in detail in separate supporting documentation, demonstrate that hazardous waste handling practices employed at AFP 44 prior to the commencement of operations at the facility's present zero-discharge industrial wastewater treatment plant ("IWWTP") in 1977 resulted in groundwater contamination beneath the facility, notwithstanding the fact that these pre-1977 practices had been coordinated with various environmental agencies and were regarded as the best accepted practices of their day. Over time, this contamination has migrated (primarily in the upper zone of the regional aquifer) in a northwesterly direction beyond the facility's northern boundary. The "plume" of contaminated groundwater emanating from AFP 44 is believed to terminate in the vicinity of Los Reales Road. The investigations and other continuing monitoring programs performed as part of the IWWTP operations have also demonstrated that operations

at the facility since 1977 have not caused or contributed to groundwater contamination beneath AFP 44.

In light of this evidence, appropriate remedial alternatives need to be evaluated for possible implementation at and in the vicinity of AFP 44 to mitigate that groundwater contamination which was caused by pre-1977 waste handling practices. Under Section 104 of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, 42 U.S.C. § 9604, the President is authorized to respond to such releases of hazardous wastes into the environment, and has delegated the responsibility and authority for conducting remedial investigations and for identifying and implementing responses to releases from Department of Defense (DOD) facilities to the DOD (Executive Order 12316). DOD facilities include government-owned, contractor-operated facilities such as AFP 44. (Memorandum Of Understanding Between The Department of Defense And The Environmental Protection Agency For The Implementation Of P. L. 96-510 (CERCLA), August 12, 1983).

Pursuant to these laws, delegations and agreements, the USAF's authority and responsibility for response action is limited to releases from AFP 44, and does not extend to contamination not caused by AFP 44. In recognition of this limitation, and based upon the evidence that

the extent of AFP 44 contamination terminated in the vicinity of Los Reales Road, it was decided in 1983 by all relevant agencies that investigations of groundwater contamination north of Los Reales Road would be conducted under the auspices of EPA Region IX which has the delegated authority for responding to releases of hazardous substances in that area.

Accordingly, this draft RAP summarizes the results of prior investigations and studies, and analyzes remedial alternatives that may be appropriate for responding to environmental conditions south of Los Reales Road known to have been caused by past operations at AFP 44. The purpose of this analysis is to ensure that any remedial action implemented at AFP 44 provides for a timely and cost-effective program which is consistent with a permanent remedy to mitigate the migration of hazardous wastes into the environment caused by pre-1977 handling practices at AFP 44, and which otherwise complies with the requirements of the Comprehensive Environmental Response, Compensation and Liability Act of 1980, 42 U.S.C. § 9601 et seq., Executive Orders 12088 and 12316, the National Contingency Plan, 40 C.F.R. Part 300 ("NCP"), the National Environmental Policy Act, 42 U.S.C. § 4321 et seq., and, to the maximum degree possible, the substantive standards of other relevant federal, state or

local environmental laws and regulations. The draft RAP will be finalized subsequent to the receipt of public comments which will be summarized, responded to and made part of the final RAP.

The USAF wishes at the outset to recognize the valuable assistance of the many agencies which have aided in the development of this analysis. In particular, we acknowledge the contribution of the members of the AFP 44 Technical Review Committee ("TRC") - consisting of the Arizona Department of Health Services ("ADHS"), the Arizona Department of Water Resources ("ADWR"), the City of Tucson and EPA, Region IX - whose advice and comment on earlier drafts of this remedial alternatives analysis have significantly aided in the identification of the proposed remedial alternative for AFP 44. Notwithstanding that assistance, however, the conclusions contained herein are solely those of the USAF.

II. SUMMARY OF PRIOR INVESTIGATIVE EFFORTS, ANALYSES AND STUDIES

The United States Environmental Protection Agency, Region IX, commenced a preliminary investigation of environmental conditions at AFP 44 in 1981. The EPA gathered information concerning historic waste handling practices at the facility, and conducted a site visit on March 5, 1981. A limited number of water samples were taken from existing on-site wells, analyses of which indicated the presence of trichloroethylene ("TCE"), 1,1,1-trichloroethane ("TCA"), 1,1-dichloroethylene ("DCE") and chromium in groundwater beneath AFP 44, together with lesser amounts of other contaminants.

A Phase I investigation of environmental conditions at AFP 44 was commenced in early 1981 (Hargis & Montgomery, 1982) which included extensive research on past waste handling practices at the facility, soil sample analyses in former waste disposal areas, and the construction of monitoring wells to determine ambient groundwater quality. The results of the Phase I investigation indicated the presence of contaminants in groundwater that could be associated with past waste handling practice at the facility, and recommended further investigations to define more completely the nature and extent of the groundwater contam-

ination. Consequently, a more expansive Phase II investigation of hydrogeologic conditions was performed.

These two investigative programs included the installation of 59 groundwater monitoring wells located in a zone of perched water which is present beneath a portion of AFP 44, and in the upper and lower zones of the regional aquifer. Additional wells were constructed as part of a continued groundwater monitoring program at and in the vicinity of AFP 44. The entire groundwater monitoring system presently consists of 103 groundwater monitoring wells. The purpose of the continuing monitoring program was to supplement and expand the data base gathered during the Phase I and II investigations to provide detailed information for use in the identification and design of actions to remedy groundwater quality degradation caused by past waste handling practices at AFP 44.

In addition to the extensive groundwater field investigations, appropriate response measures were performed at several historical disposal sites at the facility which had been identified as potential sources of the observed groundwater contamination. (All potential sources at AFP 44 are described in detail in Installation Restoration Program, Phase I - Records Search, Air Force Plant 44, Tucson, Arizona (Science Applications International Corp., 1985)).

For example, pre-1977 wastewater ponds and sludge drying beds were excavated, backfilled with clean fill and capped with caliche. It is probable that none of the historic disposal areas continue to be active sources of groundwater contamination. Also, certain on-site wells which provided the potential for cross-contamination from the upper to the lower zone of the regional aquifer were cemented and sealed. Interim Emergency Measures, Cementing of Wells HAC-1, HAC-2 and HAC-4, U.S. Air Force Plant No. 44 (Hargis & Montgomery, Inc., May 25, 1983).

In addition to the actual field investigations performed at and in the vicinity of AFP 44 during the past four years, the USAF developed a digital computer model to simulate contaminant transport and groundwater flow in the regional aquifer. This model has been used to assist in the location of groundwater monitor wells and as a secondary analytic tool for defining the nature and extent of groundwater contamination emanating from AFP 44. Details of this effort are described in Digital Simulation of Contaminant Transport in the Regional Aquifer System, U.S. Air Force Plant No. 44, Tucson, Arizona (Hargis & Montgomery, Inc., October 11, 1982).

The results of these investigations, the continuing groundwater monitoring program and computer modeling

efforts are fully presented in the Phase I Investigation of Subsurface Conditions in the Vicinity of Abandoned Waste Disposal Sites, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona (Hargis & Montgomery, Inc., January 15, 1982), the Phase II Investigation of Subsurface Conditions in the Vicinity of Abandoned Waste Disposal Sites, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona (Hargis & Montgomery, Inc., March 12, 1982) (see Appendices 2 and 3), Summary of 1982 Hydrologic Monitoring Program, U.S. Air Force Plant No. 44, Tucson, Arizona (Hargis & Montgomery, Inc., July 15, 1983), Summary of 1983 Hydrologic Monitoring Program, U.S. Air Force Plant No. 44, Tucson, Arizona (Hargis & Montgomery, Inc., March 14, 1984), Summary of 1984 Hydrologic Monitoring Program, U.S. Air Force Plant No. 44, Tucson Arizona (Hargis & Associates, Inc., May 31, 1985), Digital Simulation of Contaminant Transport in the Regional Aquifer System, U.S. Air Force Plant No. 44, Tucson, Arizona (Hargis & Montgomery, Inc., October 11, 1982) and Installation Restoration Program, Phase I - Records Search, Air Force Plant 44, Tucson, Arizona (Science Applications International Corp., 1985) (all incorporated by reference).

As noted above, the USAF efforts at AFP 44 have been paralleled by a coordinated investigative program con-

ducted by ADHS, ADWR, EPA, and the City of Tucson into groundwater contamination and sources north of AFP 44. (The TIA area has long been regarded as a vicinity which warrants a highly prioritized remedial investigation, and is included on the "Superfund" National Priorities List.) All data, information, analyses and reports developed by the USAF have been provided to the Superfund Field Investigation Team ("FIT"), and the data collected by the FIT through 1983 have been provided to the USAF.

The USAF analyzed the data and reports for areas located north (and downgradient) of AFP 44 provided to it by the Field Investigation Team ("FIT"). Based on these analyses and the prior conclusions of the FIT Team and AFP 44 TRC members, it is apparent that significant known and potential historic sources of groundwater contamination exist north of AFP 44. Included among the known or potential sources of groundwater contamination in the greater TIA area downgradient of AFP 44, as identified by ADHS (1983), Ecology & Environment, Inc. (1982 a,b) and the Pima County Wastewater Management Department (1983), are: the TIA Runway 3 Dump; TAC (Tucson Aviation Center) Abandoned Disposal Pond; TAC Drainage Channels; TAA Landfill; Gates Learjet, TAA Hanger and a variety of others. The USAF's analyses of the FIT data are contained in: Evaluation of Data Collected

by Tucson Groundwater Contamination Study Task Force in the Vicinity of U.S. Air Force Plant No. 44, Tucson, Arizona (Hargis & Montgomery, Inc., February 4, 1983); and Analysis of Data Collected by Tucson Groundwater Contamination Study Task Force in the Vicinity of Tucson International Airport, Tucson, Arizona(Hargis & Montgomery, Inc., June, 1984) (both incorporated by reference).

Based on the data collected by the USAF, and the USAF's analysis of the data previously collected by the FIT, it was concluded in 1983 that the "plume" of contaminated groundwater emanating from AFP 44 had not migrated north of Los Reales Road. Other members of the AFP 44 TRC concurred in this conclusion, as documented in the Final Community Relations Plan, Tucson Airport Area Site, Tucson Arizona (CH2M Hill, July 25, 1983). The approximate extent of the AFP 44 contaminant plume in 1983, together with the groundwater analytic results developed by the FIT investigations north of AFP 44, are depicted in Figure 1.

During 1984, the USAF installed eleven new off-site monitoring wells to confirm the extent of contaminant migration from AFP 44. Construction of Monitor Wells M-29 Through M-39, U.S. Air Force Plant No. 44, Tucson, Arizona (Hargis & Associates, Inc., October 16, 1984). A number of other groundwater monitoring wells were also

installed during 1983 and 1984. Construction of Monitor Wells M-21 Through M-28, U.S. Air Force Plant No. 44, Tucson, Arizona (Hargis & Montgomery, Inc., September 12, 1983); Construction of Perched Zone Monitoring Wells S-1 Through S-19, U.S. Air Force Plant No. 44, Tucson, Arizona (Hargis & Associates, Inc., November 2, 1984).

While groundwater quality monitoring was ongoing, the USAF initiated analyses of potential remedial alternatives. Reports detailing these analytic efforts include: Preliminary Reclamation Wellfield Design and Assessment of Water Treatment Alternatives, United States Air Force Plant No. 44, Tucson, Arizona (Hargis & Montgomery, Inc., August 9, 1982); Conceptual Study For Treatment of Reclaimed Water at USAF Plant No. 44, Phase I & Phase II Results (Malcolm Pirnie, September 1983); Conceptual Study For Treatment of Reclaimed Water at USAF Plant No. 44, Phase III Results (Malcolm Pirnie, February 1984).

Based upon these prior remedial alternative analyses (most of which are presented in full in this document) it was decided that a pilot groundwater reclamation system should be designed, constructed and operated for the purpose of verifying through actual field operations the technical feasibility and performance characteristics of such a system. A pilot system (consisting of two groundwater

extraction wells, a treatment plant to remove the various volatile organic compounds and chromium found in the AFP 44 plume of contaminated groundwater, and two wells to recharge treated water back into the aquifer) commenced operations in April, 1985. Data obtained from the past several months of operation have confirmed that such a system is capable of reducing the concentrations of contaminants in extracted groundwater to levels exceeding those considered safe for drinking water.

Perched zone water is not and cannot (because of its volume) be employed for any beneficial use. However, possible that some migration of contaminated water fr perched zone to the underlying upper zone of the regi aquifer may occur.

C. Regional Aquifer

Hydrogeologic investigations at AFP 44 indi that a regional aquifer system occurs beneath AFP 44 sisting of upper and lower zones separated by a clay aquitard. The investigations, together with the cont groundwater quality monitoring program in both zones regional aquifer, indicate that TCE, TCA, DCE and chr exist in the upper zone of the regional system, and h migrated off-site to varying extents. Concentrations have been detected beneath the complex at AFP 44 in t upper zone. Concentrations of chromium have migrated upper zone to points just beyond the plant's northern boundary. TCE and a lesser amount of DCE have migrated in the upper zone beyond the plant's northern boundary, potentially to the extent depicted in Figure 2, with concentratio decreasing with distance from AFP 44.

The extent of AFP contaminant migration in upper zone has been determined on the basis of the ex body of groundwater analytic data gathered during the

four years. Based on the data obtained during 1984, it has been concluded that the leading low concentration edge of the AFP 44 contaminant plume may have migrated to the area just north of Los Reales Road which already contained much higher concentrations of volatile organic compounds and other contaminants from sources other than AFP 44 (Figure 2). Individual maps depicting the range of TCA, TCE, DCE and chromium concentrations are presented in Figures 2A through D.

The lower zone does not appear to have been directly contaminated by sources at AFP 44. However, contaminants have been detected in specific areas of the lower zone, apparently as the result of the mixing of groundwater from the upper and lower zones through on-site wells which formerly penetrated both zones. As noted above, these wells were sealed in 1982 and 1983 to prevent futher occurrence of this process. The extent to which contaminants have migrated in the lower zone of the regional aquifer is significantly less than in the upper zone, as depicted in Figure 2E.

IV. POTENTIAL RISKS:

Remedial actions in response to releases of hazardous substances may be undertaken by the President in order to protect the public health, welfare or the environment. CERCLA § 104(a). In the present case, past releases of hazardous substances at AFP 44 have resulted in the contamination of a portion of an aquifer which in light of contamination is presently not used as a source of drinking water or other beneficial use, but might be employed for such purposes if the water quality complied with relevant water qualtiy standards and criteria.

A number of studies have been undertaken to establish standards for the allowable concentrations of certain contaminants in drinking water. Such standards are normally set at limits considered to be extremely safe for the constituents of concern. Drinking water standards have not been formally adopted for many substances, including most of the substances of concern at AFP 44, although administrative rulemakings to establish such standards for TCE, TCA and DCE have been initiated.

In order to identify treatment objectives and goals for any remedial groundwater program at AFP 44, however, the USAF has looked to the drinking water standards and criteria established or identified for us by EPA and

ADHS. In some instances, numerical values for allowable concentrations of the relevant volatile compounds have changed during the past several years. Since the affected groundwater area south of Los Reales Road is not presently used and since the objective of any proposed remedial groundwater treatment program for AFP 44 will be to meet or exceed relevant drinking water standards or criteria, an exhaustive presentation of potential health risks associated with the nature and degree of the contaminants has not been and need not be undertaken here. The treatment objectives and goals established for the purpose of this analysis are identified in Section V, and a summary of the studies underlying the identification of the target treatment levels is provided below.

A. Volatile Organic Compounds.

The risks associated with TCE, TCA and DCE are the subject of continuing research. Human epidemiology data concerning the carcinogenic risks of TCE, TCA and DCE are extremely limited; consequently, animal experiments have been conducted from which the potential human risk is extrapolated. (49 Fed. Reg. 24330, 24339, 1984). Because of this continuing research, the following sections concerning the potential health risks associated with TCE, TCA and DCE are reproduced from the preamble of a regulation pro-

posed by EPA concerning recommended and maximum concentration limitations for those volatile organic compounds in drinking water. (49 Fed. Reg. 24330, 1984).

1. Trichloroethylene

"Trichloroethylene has been shown to exhibit non-carcinogenic bioeffects at high (non-environmental) doses in humans and several other animal species, including dogs, rabbits, guinea pigs, rats and mice. The major effects demonstrated are liver and kidney damage, central nervous system effects and depression in myocardial contractility.

In the calculation of a suggested Adjusted ADI [acceptable daily intake] for trichloroethylene, liver toxicity was used as the most sensitive end-point with respect to adverse health effects, not including the potential carcinogenic risk that may result from exposure to the chemical. A study in which rats were exposed to trichloroethylene through inhalation with resulting elevation of liver weights was used to calculate a suggested Adjusted ADI of 0.257 mg/l. This value was calculated based upon a minimal-effect-level of 300 mg/m3 (55 ppm), since rats exposed to this dose level (5 days a week for 14 weeks) showed elevation of liver weights. An uncertainty factor of 1000 was applied due to the fact that an animal study, where

the no-observed-adverse-effect-level was not identified, was used and because the study was only of 14 weeks duration. One hundred percent exposure from drinking water and a 70 kg adult consuming 2 liters of water per day were assumed in the calculations.

The NAS has not calculated a chronic non-carcinogenic Suggested No-Adverse-Response Level (equivalent to an Adjusted ADI) for trichloroethylene, because every long-term study, with the exception of the National Cancer Institute (NCI) carcinogenesis investigation, involves trichloroethylene administration by inhalation. The NCI bioassay did not determine a "no-effect level" and thus it was not considered appropriate for use in the deviation of a chronic, noncarcinogenic value.

Bacterial mutagenicity studies have shown trichloroethylene to be mutagenic in several systems, including metabolically activated Salmonella typhimurium and E. coli K12 strain; however, a later study reported trichloroethylene to be non-mutagenic in the Ames test system.

Commercial grade trichloroethylene was tested by the National Cancer Institute (NCI) (1976) and was reported to induce hepatocellular carcinomas in male and female mice by oral gavage. A repeat bioassay by the National

Toxicology Program (1983) using purified trichloroethylene in corn oil found it to cause hepatocellular carcinomas in both sexes of mice, at a dose of 1,000 mg/kg per day, five days per week for 2 years, administered by gavage. Trichloroethylene was not carcinogenic in female rats under the test conditions and the results in male rats were determined to be insufficient to make an adequate evaluation of the carcinogenicity. The doses administered to the rat were 1,000 and 500 mg/kg/day.

The International Agency for Research on Cancer (IARC) has concluded that trichloroethylene has limited evidence of carcinogenicity, based upon experimental animal studies and inadequate evidence from available human data. This means that the data suggest a carcinogenic effect in one species, but lack of confirmation in others. The World Health Organization (1981) has recommended a tentative guideline value of 30 ug/l for trichloroethylene in drinking water.

EPA's Carcinogen Assessment Group has used the linearized non-threshold multi-stage model to calculate projected excess cancer risk estimates extrapolated from high dose animal studies. For trichloroethylene, these estimates were based upon the NCI bioassay data. Calculated

risks corresponding to various doses are listed in Table 7. [See Table 7 at 49 Fed. Reg. 24330, 24340]."

2. 1,1,1-Trichloroethane

"The principal toxic effects of 1,1,1-trichloroethane from . . . (non-environmental) dose exposure in animals and humans are depression of the central nervous system, increase in liver weight and cardiovascular changes.

Liver toxicity was used as the most sensitive end-point with respect to adverse health effects, not including the potential carcinogenic risk, in the calculation of an adjusted ADI for 1,1,1-trichloroethane. An inhalation study which examined exposure of mice to 1,1,1-trichloroethane was used to calculate a suggested Adjusted ADI of 1.0 mg/l. This study demonstrated changes in the livers of the mice at various dose levels.

Two animal bioassays by the National Cancer Institute (NCI) have been completed in rats and mice (1977, 1983). In the earlier bioassay, rats and mice were treated with 1,1,1-trichloroethane in corn oil by gavage. Because only 3 percent of the animals survived to the end of the experiment, due in part to chronic murine pneumonia which was determined to be the most probable cause of the high incidence of natural deaths among the animals, it was con-

cluded that carcinogenicity could not be determined from this study. A repeat carcinogenesis bioassay of 1,1,1-trichloroethane was conducted in which doses of 3,000 or 1,500 mg/kg were administered by gavage to both sexes of mice, and rates (sic) were given [doses] of 750 or 375 mg/kg. In the preliminary report of this study, 1,1,1-trichloroethane was carcinogenic in both male and female mice showing an increased incidence of hepatocellular carcinomas but not in rats; however, these initial results have been questioned.

1,1,1-trichloroethane has been tested for mutagenicity in several test systems. Both negative and positive results were reported in mutagenicity tests in various Salmonella typhimurium strains, and 1,1,1-trichloroethane was not shown to be mutagenic in studies using yeast as an indicator organism.

EPA's Carcinogen Assessment group has used the linearized non-threshold multi-stage model to calculate preliminary excess cancer risk estimates extrapolated from the preliminary reported incidence of hepatocellular carcinomas in female mice in the study cited above. Calculated risks corresponding to various doses are listed in Table 7. [See Table 7 at 49 Fed. Reg. 24330, 24340].

Similar calculations were made by the NAS (Drinking Water and Health, Vol. V) except that the average of the results in both male and female mice were used as the basis.

The latest bioassay data, on 1,1,1-trichloroethane is currently undergoing audit by the National Toxicolgy Program ("NTP") and a final report has not been issued." (49 Fed. Reg. 24330, 24341).

3. 1,1-Dichloroethylene

"1,1-Dichloroethylene has been shown to cause liver and kidney injury in animals from high dose exposures. Liver damage in rats, mice and guinea pigs has been documented, along with renal toxicity, CNS depression and sensitization of the heart.

An Adjusted ADI of 350 ug/l for 1,1-Dichloroethylene considering adverse health effects not including the potential carcinogenic risk was calculated based upon toxic liver effects using a NOAEL of 10 mg/kg and 100 percent exposure from drinking water.

The NAS (1983) has calculated a chronic, suggested-no-adverse-response level (equivalent to an adjusted ADI) of 0.1 mg/l based upon non-carcinogenic effects only for 1,1-Dichloroethylene from data in the National Toxicology Program bioassay (1982) in rats and mice. A no-observed-adverse-effect level of 2 mg/kg was

used and an uncertainty factor of 100, and complete absorption from the GI tract. Twenty percent exposure from drinking water and a 70 kg adult consuming 2 liters of water per day were assumed in the calculations, along with conversions from a 5 d/week dosing regime to a 7 d/week exposure.

1,1-dichloroethylene was found to be mutagenic with microsomal activation in Salmonella typhimurium and E. coli test systems. However, mutagenicity was not observed with V79 Chinese hamster cells or in dominant lethal studies in mice and rats.

1,1-dichloroethylene was shown to produce kidney adenocarcinomas in mice and rats in one study (Maltoni, 1977). However, most of the other studies have failed to demonstrate significant carcinogenic activity of the chemical. A study by the National Toxicology Program (1982) examined 1,1-dichloroethylene exposures of 1 mg/kg or 5 mg/kg 5 times per week in rats and 2 mg/kg or 10 mg/kg 5 times per week in mice. In this bioassay, there was no evidence that 1,1-dichloroethylene was carcinogenic for either the rats or the mice. However, there was some question as to whether the maximum tolerated dose had been used in this study. The NAS (1983) has concluded that information on 1,1-dichloroethylene is not sufficient to reach a definite conclusion on the carcinogenicity of the compound.

EPA's Carcinogen Assessment Group found 1,1-dichloroethylene to have limited evidence of carcinogenicity in animals. They have used the linearized, non-threshold, multi-stage model to calculate projected excess cancer estimates extrapolated from high-dose animal studies. For 1,1-dichloroethylene, these estimates were based on results of inhalation studies in mice and rats. Calculated risks corresponding to various doses are listed in Table 7. [See 49 Fed. Reg. 24330, 24340]. EPA's SAB has recently questioned validity of this study result. This tentative classification of 1,1 DCE as a carcinogen will be reexamined." (49 Fed. Reg. 24330, 24343).

B. Chromium

Extensive studies have been performed with respect to the risks associated with the presence of chromium in drinking water, and resulted in the establishment by EPA of a maximum contaminant level for chromium in drinking water as specified in 40 C.F.R. Part 141. In the interest of brevity, the risks assessments performed in support of the adoption of that EPA regulation are incorporated by reference.

V. OBJECTIVES

In light of the known hydrogeologic conditions and in appreciation of the risk assessments described above, identification of an appropriate remedial alternative(s) is necessary for the detailed design and implementation of a cost-effective program for mitigating the adverse environmental impacts and potential health risks associated with the migration of hazardous substances from AFP 44. The objectives of the remedial action program ultimately selected and implemented will be:

(1) to prevent to the maximum practicable degree any continued migration of the AFP 44 plume of contaminated groundwater;

(2) to render groundwater contaminated by sources at AFP 44 suitable for beneficial use;

(3) to meet applicable or relevant standards and criteria of Federal (or, where appropriate, state and local) environmental and public health laws to the maximum extent practicable;

(4) to achieve those results in a cost-effective and timely manner; and

(5) to implement a program which does not result in unwarranted drawdown impacts in the regional aquifer, which does not interfere with the performance of remedial

action programs conducted by others in the greater TIA vicinity, and which is consistent with the goals of the Tucson Active Management Area groundwater management plan.

A. Extent of Remedy:

In further refinement of objective (2) above, it is important to identify at the outset of this analysis the extent of remedy sought from any groundwater treatment program. In this regard, the National Contingency Plan provides that:

> The appropriate extent of remedy shall be determined by the lead agency's selection of the remedial alternative which the agency determines is cost-effective (i.e. the lowest cost alternative that is technologically feasible and reliable and which effectively mitigates and minimizes damages to and provides adequate protection of public health, welfare or the environment).

40 C.F.R. § 300.68(j).

In light of the analytic requirements of the NCP, however, a variety of remedial alternatives are considered in this document, including the alternatives of taking no action and other alternatives which entail no treatment of

contaminated groundwater. With respect to treatment alternatives, the levels to which water will be treated must be considered in determining their cost-effectiveness since marginal increments of contaminant reduction might only be achieved at additional costs which greatly exceed the benefit gained. Accordingly, ranges of contaminant concentrations and the cost of treatment to those levels have been considered at appropriate discussions in this analysis.

B. Compliance with Relevant Drinking Water Standards and Criteria.

In light of the goals of this program, target treatment levels have been selected which meet or exceed the levels of contaminant concentration considered safe by relevant regulatory agencies for drinking water. Attainment of drinking water quality standards also would result in compliance with a variety of other federal and state laws, including regulations potentially applicable to the recharge of treated water back into the aquifer from which it was withdrawn. The target treatment levels for chromium, TCE, TCA and DCE are identified below. The bases for the identified target levels are as follows:

1. Chromium: The maximum concentration limitation for chromium in drinking water is 0.05 parts per

million (ppm). This standard is established by the National Interim Primary Drinking Water Regulations, 40 C.F.R. Part 141, and is the target treatment level for chromium in any remedial water treatment alternative implemented at AFP 44.

2. Volatile Organic Compounds: There are no formally adopted federal drinking water maximum contaminant limitations (MCLs) for TCE, TCA or DCE. In 1982, however, EPA published an advance notice of proposed rulemaking to revise 40 C.F.R. Part 141 (the National Interim Primary Drinking Water Regulations) so as to establish recommended maximum contaminant limitations (RMCLs) for certain organic compounds. 47 Fed. Reg. 9350 (1982). RMCLs are health goals, not enforceable standards, and are set at a level where "no known or anticipated adverse effects on the health of persons occur and which allows an adequate margin of safety."

While the advance notice of rulemaking did not propose specific MCLs, it included a table indicating the options being evaluated by EPA concerning the appropriate MCL (i.e. legal standard) for certain organic compounds, including TCE and TCA but not DCE . The potential range of MCLs then being considered fell "roughly within an upper limit lifetime exposure risk range of 1 in 10,000 (i.e. one excess cancer death per 10,000 population) to 1 in 1,000,000

[i.e. 10^{-6}] as estimated by conservative relative risk computation models using data from animal tests." 47 Fed. Reg. 9357.

The potential MCLs with a 10^{-6} cancer risk for TCE and TCA identified there were 5 ppb and 1000 ppb respectively. The 10^{-6} cancer risk rate was premised on the consumption of 2 liters of water per day containing 5 ppb of TCE, or 1000 ppb of TCA, by a 70 kilogram adult every day for 70 years. If consumed at that rate for that period of time, one person in a million might die from cancer related to the ingestion of TCE or TCA.

EPA has explained a 10^{-6} cancer risk as follows:

> As an example of what 10^{-6} would mean in terms of the U.S. population, a total of 20 cases of cancer would result if 10 percent of the population were exposed at a dose level equivalent to a 10^{-6} risk for 70 years. Stated another way, that would be one-third of a cancer case per year as an upper limit in the U.S. population compared to the appropriately [sic] 500,000 annual cancer deaths that occur. The actual number of cases attributable to that particular substance would probably be less and perhaps none at all would occur unless some

additive or synergistic interaction with other substances resulted in enhanced toxicity.

49 Fed. Reg. 24330, 24348 (1984).

Subsequent to that advance notice, EPA published a proposed rulemaking to revise 40 C.F.R. Part 141. (49 Fed. Reg. 24330, June 12, 1984). The proposed rule, if promulgated as written, would establish RMCLs for certain organic compounds. For TCE and DCE, the proposed RMCL was zero; for TCA, the proposed RMCL is 0.2 milligrams per liter, i.e. 200 ppb. 49 Fed. Reg. 24352. The proposed rule acknowledged that the recommended RMCLs for TCE and TCA are based only on "limited evidence of animal carcinogenicity . . . ." (49 Fed. Reg. 24348). The Environmental Health Committee of EPA's Science Advisory Board ("SAB") has concluded that there is presently insufficient evidence to classify TCE as a human carcinogen. (SAB, December 17, 1984).

The most recent EPA proposals with respect to safe concentrations of TCE, TCA and DCE in drinking water is currently pending before the Office of Management and Budget. Under the present proposal, EPA is recommending the following MCL's and RMCL's for those substances:

	Proposed RMCL	Proposed MCL
TCE	0	5 ppb
TCA	200 ppb	200 ppb
DCE	7 ppb	7 ppb

As is the case with federal criteria concerning drinking water quality, Arizona has not formally adopted numerical MCLs for the volatile organic compounds TCE, TCA and DCE. ADHS has stated, however, that it too operates on the premise that the presence of such compounds in drinking water should accord with the theoretical 10^{-6} cancer risk level. Previous correspondence among EPA, ADHS and the USAF indicated that appropriate treatment levels would be as follows: 5 ppb TCE, 0.033 ppb DCE, 1000 ppb TCA (ADHS 1982). The 1000 ppb TCA standard was revised in subsequent discussions to 16.8 ppb, apparently based on earlier assessments that 16.8 ppb TCA constituted a 10^{-6} cancer risk. Thus, based on earlier discussions which predated the more recent EPA proposed rulemakings, the target treatment levels for TCE, TCA and DCE at AFP 44 were set as follows: 5 ppb TCE; 16.8 ppb TCA; 0.033 ppb DCE. These levels have served as the basis for analyzing groundwater treatment alternatives.

These target treatment levels represent very conservative safety limits. As is evident from the table

below, the target treatment levels meet the most recent proposals by EPA for TCE, meet the existing MCL for Chromium, and exceed by several orders of magnitude the most recent EPA proposals for TCA and DCE. Since drinking water quality standards, recommended contaminant levels or advisories may continue to rise or fall as they have in some instances over the past few years, the target treatment levels identified below will continue to be used as the objectives for treatment plant performance and the goals for aquifer restoration.

APPLICABLE, RELEVANT STANDARDS AND

TARGET TREATMENT LEVELS

	Proposed RMCL	Proposed MCL	Treatment Target
Trichlorethylene	0	5 ppb	5 ppb
1,1,1, Trichlorethane	200 ppb	200 ppb	16.8 ppb
1,1 Dichloroethylene	7 ppb	7 ppb	0.033 ppb
Chromium (total)	--	.05 ppm (final)	.05 ppm

*Source, Proposed Promulgation of Recommended Maximum Contaminant Levels and Proposal of Maximum Contaminant Levels, U.S. EPA, Acting Assistant Administrator for Water, 1985.

C. Consistency of Remedy With the Standards of Other Relevant Laws

Based upon the fact that Tucson is underlain by and reliant upon a sole source aquifer, it is important that laws concerning groundwater uses and impacts be considered in evaluating possible remedial alternatives. Of particular interest in that regard are the substantive standards of the Arizona Groundwater Management Act (and the associated Tucson Arizona Active Management Area management plan) and Arizona regulations contained in the State groundwater protection program. These provisions are briefly summarized below. Compliance with the substantive standards of other relevant laws is discussed in Section IX.

1. Arizona Groundwater Management Act ("AGMA")

The AGMA was enacted in 1980 to institute a comprehensive groundwater conservation and management program in Arizona. While allowing for the continuation of historic groundwater usage under a system of Grandfathered Rights, additional groundwater extraction and new uses were made subject to strict conservation requirements and development restrictions.

Active groundwater management areas were formed under the Act in areas of the State particularly reliant upon groundwater availability. The Tucson Active Management

Area ("TAMA") is one such area. In general, and especially in active management areas, groundwater may be withdrawn or used only pursuant to a Grandfathered Right or a permit. The objectives of the TAMA management plan include: achievement of "safe-yield," i.e. equilibrium of groundwater extraction and recharge rates; protection of existing water users and property owners from unreasonably increased damage; prevention of water quality degradation; and, reduction or elimination of land subsidance. To obtain these objectives, the permitting of new groundwater extraction or new groundwater uses is extremely restrictive.

2. State Groundwater Protection Permit

State regulations concerning activities which may adversely impact groundwater quality appear at ACRR § R9-20-202 *et seq*. These regulations require the filing of a notice of disposal of certain activities which may impact groundwater quality, and may require the issuance of a permit which establishes conditions that assure that activities do not result in any measurable change to the physical, chemical or biological character of groundwater caused by the addition of pollutants or wastes.

VI. REMEDIAL ALTERNATIVE ANALYSIS: Initial Screening

A number of alternative response actions could be appropriate for implementation at AFP 44, and an evaluation of the broad range of alternatives is necessary to determine which would provide the optimum remedial alternative. Not all of possible alternatives, however, deserve detailed consideration. Accordingly, the following criteria have been used as the basis for determining which remedial alternatives warrant more detailed analysis:

(1) Cost: the magnitude of capital expenditures necessary to construct and operate the facilities required;

(2) Environmental Impact: the degree to which the alternative is likely to minimize future danger to or threat of harm to the environment; the degree to which the alternative can be expected to mitigate existing adverse environmental conditions; the degree to which the alternative may create additional adverse environmental impacts; and, the timeliness of the mitigation achievable under the alternative;

(3) Public Health: the degree to which the alternative is likely to minimize danger to or threat of harm to the public health and welfare;

(4) Regulation Compliance: the scope of activity necessary to meet the substantive standards of any relevant regulatory provisions associated with each activity; and

(5) Feasibility: the engineering and technological feasibility of implementing each alternative.

The range of potential remedial options fall into four broad categories:

1. Remove or contain contamination at its source;

2. Leave the contaminated water in the ground, either taking no action or containing it with barriers to prevent further migration;

3. Remove the contaminated groundwater from the aquifer through wells and dispose of the extracted, untreated water elsewhere;

4. Remove the contaminated groundwater from the aquifer, treat the water, and use the treated water for groundwater recharge or other beneficial use.

A preliminary discussion of the various remedial options appears below, with emphasis on the decision elements specified above. Since this section presents an initial screening of possible alternatives in order to identify those options which warrant further detailed analysis, the discussions below are not exhaustive, nor are they intended to be.

A. Source Control

The National Contingency Plan, 40 C.F.R. Part 300, states that source control remedial actions "may be appropriate if a substantial concentration of hazardous substances remain at or near the area where they were originally located and inadequate barriers exist to retard migration of substances into the environment. Source control remedial actions may not be appropriate if most substances have migrated from the area where originally located . . ." (40 C.F.R. § 300.60(e)(2)).

The objectives of the Phase I and Phase II investigations at AFP 44 included locating potential sources of trace metal and organic contaminants and determining the residual concentration of contaminants in the soils (Hargis

& Montgomery, Inc., 1982). The data presented in these reports comprises the remedial investigation addressing source control.

1. Soils:

The Phase I and Phase II investigations conducted at AFP 44 in 1981 included collection of 683 soil samples from 31 borings drilled at abandoned waste disposal pits, ponds and ditches. Chemical analyses were performed on 359 soil samples to determine the concentrations of TCE, TCA and DCE. Concentrations of TCE reported in the soil samples were usually less than 10 ppb (parts per billion), but were as high as 45 ppb (Hargis & Montgomery, Inc., 1982). TCA was detected in only 7 of the 31 borings and concentrations reported were usually less than 5 ppb, but were as high as 11 ppb. DCE was detected only in 2 soil borings at concentrations less than 5 ppb.

Chromium and other trace metal concentrations in 344 soil samples were analyzed by extraction procedure toxicity methods outlined by the EPA in Testing Methods for Evaluating Solid Waste (May 1980). The extraction procedure toxicity method is designed to determine the leachability of substances from a solid waste or soil that is subject to infiltration and percolation of rainfall. Results of analyses for chromium indicate that concentrations of chromium

in the extracts leached from the soil samples are much less than the 5 mg/l (milligrams per liter) concentration characteristic of extraction procedure toxicity, with the exception of one sample. The sample which exceeded the extraction procedure toxicity limit was located in a pond which was previously excavated and refilled, and which is now covered over by an asphalt parking lot. Chromium concentrations for 321 of the 344 extracts leached from the soil samples are less than 5 ppm.

Results of the Phase I and Phase II investigation indicate that the solvent disposal pits located in the area west of Building 801 and north of the wastewater treatment plant were probably the principal sources of TCE, TCA and DCE that had migrated to the regional aquifer. Residual concentrations of TCE, TCA and DCE in the soils in this area are low, and indicate that these abandoned pits are no longer sources of contamination.

Results of the trace metal analyses by extraction procedure toxicity indicate that the abandoned sludge disposal pits east of Building 801, which are now covered by a paved parking lot, were the principal source of chromium that migrated to the regional aquifer beneath AFP 44. The mobility of trace metals is related to the pH of the soils, which ranges from about 8 to 10 at AFP 44. Although scat-

tered residual concentrations of chromium occur in the soils beneath the abandoned pits, the absence of percolating fluid to mobilize the chromium, and the alkaline nature of the soils, effectively eliminate this source of contamination.

An additional conclusion of the Phase II investigation and subsequent monitoring was the delineation of a perched groundwater zone (above the regional aquifer) with a surface area beneath AFP 44 of about 100 acres. The saturated thickness of the perched groundwater ranges from less than one foot to 24 feet. Water levels and contaminant concentrations in the perched groundwater have been monitored since 1981.

Analysis of water level data indicates that the water levels in the perched groundwater zone beneath AFP 44 appear to fluctuate in response to rainfall and runoff events, especially near the topographically low areas where the accumulation of surface runoff occurs. There is no data to indicate that percolation of surface runoff through the unsaturated zone has increased contaminant concentrations in the perched groundwater since 1981. In fact, the concentrations of TCE, TCA, DCE and chromium in groundwater samples from the perched zone wells have generally decreased. Soils therefore do not appear to be a continuing source of contamination in the perched zone, so that additional con-

trol measures beyond those already undertaken with respect to soils or the prevention of stormwater percolation through soils are considered to be unnecessary.

2. Perched Zone:

The perched zone occurs in an area of low permeability clays which prevent or retard the downward migration of water to the regional aquifer below. Given this geology, it is unlikely that contaminated water in the perched zone constitutes a significant source of contamination to the regional aquifer. Given the very limited thickness of the saturated perched zone (1-24 feet), it is technologically infeasible to pump water from this area. Given the depth of the perched zone beneath land surface, the cost of excavating this area for the purpose of removal actions would be completely disproportionate to any benefit gained. Allowing contaminated groundwater to remain in the perched zone would probably have little direct environmental impact, and the presence of contaminated groundwater in the perched zone itself presents no direct risk to public health and welfare.

However, in the event that groundwater reclamation of the upper region aquifer were to be performed, it would be wise to facilitate drainage of contaminated perched water into the upper regional aquifer by constructing groundwater

extraction or recharge wells through the perched zone in a manner which allowed perched water to flow down well casings down the upper regional aquifer. Once in the upper regional aquifer, the contaminated perched water could be extracted for treatment through the groundwater reclamation system designed to extract water from the upper zone of the regional aquifer. Such a program, coupled with continued perched zone and upper regional aquifer monitoring, would greatly diminish any concern that slow leakage from the perched zone might necessitate any needlessly prolonged operation of the reclamation program.

B. No Action

Under this alternative, no efforts would be undertaken to remedy groundwater contamination in the regional aquifer caused by prior waste handling practices at AFP 44, and no direct capital expenditures would be made. Not mitigating the existing groundwater conditions, however, would probably require continuing and expanding the groundwater quality monitoring activities for the purpose of documenting the migration of the contaminants in the groundwater.

This alternative does not mitigate or minimize any harm that has occurred or may occur to the environment. Since no activity would be required under this alternative, no additional adverse environmental impacts associated with

a remedial activity would be created. Further environmental damage could result, however, as a result of the continued transport of contaminants already in the aquifer through the regional system. Failure to mitigate existing groundwater conditions could also complicate, lengthen or defeat any other remedial actions taken downgradient from AFP 44 in the area north of Los Reales Road.

In order to evaluate further the environmental impact of the "no action" alternative, future movement of the AFP 44 TCE contaminant plume was simulated using a two-dimensional digital computer model of solute transport and dispersion (Konikow and Bredehoeft, 1978). Results of the evaluation indicate that the contaminant concentrations at AFP 44 would be reduced from about 5,000 ppb to less than 5 ppb after a period of approximately 30 years. However, concentrations of TCE in the regional aquifer northwest of AFP 44 would increase as the high contaminant concentrations zones presently located in the vicinity of AFP 44 would migrate downgradient for a distance of approximately two miles during the 30 year period. Due to dispersion, peak concentrations would decrease from about 5,000 ppb to about 2,000 ppb as the contaminant plume migrated.

Although peak concentrations would decrease, the areal extent of the plume would increase. Within 30 years,

the 10 ppb contour of TCE concentration might extend more than three miles north-northwest of the northern Plant boundary. The contaminant plume currently emanating from AFP 44 could increase contaminant concentrations in approximately 25 private and municipal wells to concentrations greater than the target treatment levels. After 50 years, the 10 ppb contour of TCE concentration might extend about five miles north-northwest of AFP 44. The highest concentration of contaminants would be about 1,000 ppb, and about 54 existing private and municipal wells would be contaminated and contain concentrations of contaminants greater than the target treatment levels. (Both of these calculations assume - contrary to fact - the absence of contaminants from other sources downgradient of AFP 44.)

A no action alternative is generally unacceptable unless the adverse environmental impacts associated with other remedial alternatives would cause greater environmental or health danger than no action. The potential adverse impacts of other possible remedial actions are discussed below, some of which would result in few or no significant adverse environmental impacts. Accordingly, the no action alternative is not justifiable based on environmental considerations.

C. Containment by Impermeable Barriers

Under this concept, slurry walls, grout curtains, or sheet pilings would be constructed around the perimeter of the contaminanted groundwater plume emanating from AFP 44 to prevent its further migration.

Because of the areal extent of the groundwater contamination plume and the depth to the base of the contaminated zone of the aquifer in the vicinity of AFP 44 (approximately 180 to 220 feet), the construction of an impermeable barrier to contain the groundwater plume would require the emplacement of a massive structure. Significant engineering problems would have to be overcome, and the acquisition of land rights, easements and rights-of-ways for construction of such barriers would be extremely complicated and time-consuming, assuming such acquisitions could ever be completed. The costs associated with such an effort have not been calculated, but would appear to be disproportionate to any benefit achieved.

This construction theoretically could be of some benefit in preventing or at least retarding the horizontal migration of contaminants through the aquifer. Nevertheless, insufficient hydrogeologic data is available to conclude with certainty that the emplacement of impermeable barriers would prevent the horizontal migration of contam-

inants. Accordingly, this alternative does not provide an assured mechanism by which to minimize and/or mitigate potential harm to the public health, welfare and environment. Furthermore, since this alternative would do nothing more than contain the migration, it does not provide a means for making contaminated water suitable for beneficial use.

A construction project of this magnitude would certainly have adverse impacts on the environment. The emplacement of slurry walls to encircle completely the plume could require massive excavations throughout a large area in the vicinity of the TIA. Such an effort could: (1) significantly disrupt the local ecology; (2) generate extensive particulate and hydrocarbon emissions during the excavation and construction phase that would require considerable mitigation measures; and, (3) potentially alter the direction and rate of flow in the upper regional aquifer, possibly affecting domestic and municipal wells, and other remedial actions downgradient from AFP 44.

Existing groundwater conditions do not pose a direct and immediate threat to the public health and welfare since alternative water sources are presently available. Nevertheless, the state of existing groundwater conditions do have long term implications for water availability and usage in the Tucson area. To the degree they could be suc-

cessful, groundwater containment measures might prevent further contamination of the aquifer, and thus maintain the status quo.

The number and degree of regulatory complications involved in containing contaminants in groundwater subject to State of Arizona groundwater management authority are unknown. While the construction of impermeable barriers is a known technology which has been used with varying degrees of success at other sites around the country, we are unaware of any circumstance in which such barriers have been used for the containment of a groundwater contamination plume in geological circumstances similar to those in the vicinity of AFP 44, or on such a massive scale.

D. Withdrawal of Groundwater

Construction and operation of a reclamation wellfield to extract contaminated groundwater from the regional aquifer would prevent further migration of the contaminated plume and reduce contaminant concentrations in the groundwater. The reclamation wellfield would have to be operated continuously to control effectively the migration of the plume. The most rapid and effective reduction in contaminant concentrations can be accomplished by pumping at the maximum possible rate within the limitations of the aquifer's hydraulic characteristics. Pumping at lesser

rates would result in groundwater having to be pumped for a longer period of time in order to treat the same volume of water. However, because of the processes of contaminant dispersion in groundwater, as more time elapses a greater volume of water would become contaminated so that a pumping project of long duration would result in larger volume of water having to be treated to achieve the same result.

Continuous operation of the proposed reclamation wellfield at the maximum pumping rate is an important factor in this initial screening of water use alternatives. Stopping the pumping or reducing it to a minimal level for a period of time would allow the regional groundwater flow to re-establish control of the contaminant plume and possibly transport it so far downgradient that the wellfield would no longer be in an optimal location for the extraction of contaminants.

An estimation of the maximum possible pumping rate and associated duration of pumping has been made with the assistance of a two-dimensional digital computer model of solute transport and dispersion (Konikow and Bredehoeft, 1978). Approximately 20 years of pumping at 2,000 gpm would be required for efficient cleanup process. Therefore, any off-site disposal plan for treated or untreated groundwater would have to be operational for a period of at least 20

years on a continuous basis in order to complete the remedial action. If the extraction process were forced to cease because of the termination of a disposal or alternate use, the contaminant plume could start migrating and dispersing again, thus lengthening the reclamation time projections and increasing costs. In addition, the costs of identifying a replacement disposal method or alternative use and constructing new pipelines and/or other facilities are so significant that evaluating the 20-year reliability factor is an important consideration.

If the water is extracted from the aquifer and not treated to remove the contaminants, the costs of a treatment facility will be avoided. However, the water disposal options under this alternative are limited by the need to prevent the contaminants from re-entering potable water supplies. Treating the water expands the possibilities for disposal or use, including the option of recharging treated water back into the aquifer from which it was withdrawn.

Preliminary reclamation wellfield design indicates that the reclamation wellfield could be operated at a maximum withdrawal rate of about 2,000 gpm (gallons per minute) for any use or disposal of extracted groundwater that does not involve recharge of water back into to the aquifer from which it was withdrawn. About 20 years would be required

for removal of the contaminated groundwater at a continuous pumping rate of 2,000 gpm. If the reclamation wellfield is operated in conjunction with recharge of the water via recharge wells, however, a withdrawal rate of about 4,200 gpm could be maintained. Preliminary wellfield design indicates that about 10 years would be necessary for removal of the contaminated groundwater at a continuous pumping rate of 4,200 gpm.

The operation of a reclamation wellfield will result in drawdown impacts in the regional aquifer in the area of AFP 44. Drawdown estimates based on preliminary reclamation wellfield design indicate that after 20 years of pumping without artificial recharge five feet of drawdown in the regional aquifer might occur as far north as Drexel Avenue. However, preliminary drawdown estimates based on complementary reclamation and recharge wellfield designs indicate that after ten years of pumping at 4,200 gpm, less than one foot of drawdown in the regional aquifer would occur north of Los Reales Road. In addition to achieving an optimum pumping rate for the reclamation wellfield, artificial recharge of the aquifer would minimize drawdown impacts.

Surface discharge of the water would require that it be transported from the wellfield to a distribution point

for industrial, agricultural, municipal, or domestic use. In developing these alternatives, the use of untreated water for industrial and irrigation purposes was considered. Extensive studies would be required to determine the fate of the volatile organics TCE, TCA, and DCE in water used for industrial purposes such as cooling towers, or as process water for copper mines. The fate of the volatile organics in the water used as irrigation water for golf courses or agricultural crops would also have to be determined. Extensive studies would be required to guarantee that secondary contamination of the groundwater system would not occur after industrial or agricultural use of the water. Expensive control systems may need to be constructed to prevent or limit such contamination. Transport of the water through canals or pipelines to the point of use also creates an opportunity for secondary contamination due to leaks, breaks, or other integrity problems with the conveyance structures during transport of the water. The Arizona Department of Health Services (ADHS) regulations adopted pursuant to Arizona statutes require the maintenance and protection of surface and groundwater quality so as not to impair the uses which have, are, or will be made of the water for every purpose. The risks of secondary contamination of the groundwater system inherent in transport and

use of untreated groundwater appear to outweigh the economic benefit of non-treatment of the water. Nevertheless, several alternative disposal options for untreated groundwater are discussed below in Section 1, although agricultural uses are not included since it would be almost impossible to prevent some contamination of water supplies with this usage.

All of the following options that do not include recharge via wells will require the expenditure of about $1,654,461 in capital costs and $133,000 per year in operating and maintenance costs (1984 dollars) to build and operate a wellfield with a minimum of 17 wells, 5.8 miles of collector pipeline, and necessary electrical feeders and controls in the immediate vicinity of AFP 44 for a period of at least 20 years. The method of operation of the wellfield and the level of contamination to which the aquifer would be restored would be the same for all of the disposal alternatives discussed below.

1. Disposal of Untreated Groundwater

a. Direct Discharge to Public Sewer System

This alternative involves pumping the groundwater to Pima County's Roger Road sewage treatment facility via a pipeline as shown on Figure 3. The cost of constructing the pipelines and pumping stations necessary for this alterna-

tive has been estimated at $4,300,000 and the annual operating cost would be about $800,000. The costs of any capital improvements to the existing Roger Road Treatment Plant that would be needed to handle the increased sewage flows and to provide for any treatment required at that facility prior to subsequent discharge of the water are unknown, and the costs of acquiring necessary right-of-ways have not been calculated.

In the absence of treatment, the conveyance of contaminated groundwater to the public sewer system would create further disposal problems, most of which would only increase risks of harm or threat of harm to the public health and welfare and the environment. Failure to recharge the aquifer from which the groundwater has been extracted would also result in a non-productive depletion of a water resource and in undesirable water level declines in the area. Such effects would be inconsistent with the goals and requirements of the Tucson Active Management Area groundwater management plan. These water level declines could affect other water users in the area, and might affect other groundwater remedial action programs undertaken downgradient from AFP 44.

A permit to discharge to the Pima County Wastewater System and a Poor Quality Water Withdrawal Permit from

the Arizona Department of Water Resources may be required. Additionally, pipeline easements for approximately six (6) miles of piping and lift station sites would have to be acquired.

Construction of a pipeline to carry the untreated groundwater to the Roger Road Treatment Plant is technically possible without causing a significant impact on current land use patterns or creating new major sources of air or water pollution. However, since the pipeline would be located along the Santa Cruz River, there is a possibility of flood damage to the pipeline sometime during the projected 20-year lifespan of the project.

Dilution of the contaminants from the extracted groundwater in Tucson's general sewage flow could reduce their concentrations to acceptable limits. However, the Director of the Pima County Wastewater Management Department has indicated that the Department would not accept untreated groundwater, and in any event, the treated wastewater from the Roger Road facility is dumped into the Santa Cruz riverbed and eventually recharges to the regional aquifer, thus creating the possibility of secondary contamination.

b. Injection of Untreated Water to a Containment Strata

This alternative would entail pumping the extracted, untreated groundwater into a deep geologic strata where containment would be assured. Precise cost figures for this alternative are unknown. Nevertheless, the cost of such recharging of untreated groundwater would be significantly higher than the cost associated with recharge of treated groundwater into the same aquifer from which it was withdrawn since this alternative would require construction of wells into a deep geologic strata below the regional aquifer system. Additional and potentially significant costs might be required to locate a suitable containment strata.

This disposal alternative would obviously require further hydrogeologic investigation in order to identify a geologic strata into which the untreated groundwater could be recharged without risk of contaminating usable aquifers. Failure to recharge the aquifer from which the groundwater had been withdrawn would also result in drawdown impacts in the area of AFP 44, and could adversely affect other remedial actions undertaken in the TIA area and other uses of the aquifer downgradient. Although removal of contaminated groundwater would provide for the immediate elimination of

any further migration of the plume, this benefit is outweighed by the other adverse environmental impacts and costs associated with this alternative.

Reinjection technology has been verified in practice. Nevertheless, in the absence of data as to the depths and hydrologic parameters of deep strata into which the untreated water would have to be recharged, if such an area exists in the vicinity of AFP 44, the construction and operation of such a reinjection system could pose considerable engineering difficulties. Furthermore, injection of the contaminated groundwater could require an Underground Injection Control Permit, as well as a permit from the Arizona Department of Health Services under the regulations at A.C.R.R. § R9-20-200 et seq, and could be prohibited by the substantive standards of such regulations altogether.

c. Solar Evaporation

The untreated groundwater extracted from the aquifer could be discharged into holding basins for solar evaporation. As a practical matter, an area of land suitable for such use is not available, especially since the rate at which groundwater must be extracted would result in a requirement for extremely large evaporation basins.

d. Disposal at a Permitted Hazardous Waste Treatment Facility

As is the case with solar evaporation, this alternative is also not practical. The nearest existing permitted disposal sites are located in California. Recent amendments to the Resource Conservation Recovery Act prohibit the disposal of free liquids containing hazardous wastes in landfills. In any event, the cost and logistics of transportation associated with the scale of activity required under this alternative are prohibitive.

2. Alternative Uses For Treated Groundwater

Twelve alternatives for the surface discharge or beneficial use of treated water from the proposed reclamation wellfield are evaluated below. For most of the alternative uses, water which is currently being pumped from existing wells could be replaced by water from the reclamation wellfield. The reclamation wellfield cannot be pumped at a rate less than 2,000 gpm and efficiently reclaim contaminated groundwater. Hence, any proposed water use must be capable of accepting 2,000 gpm on a continuous basis. Preliminary reclamation wellfield design and simulations indicate that about 20 years of continuous pumping would be necessary for aquifer restoration. Accordingly, another

criterion for use of the treated water is an operational life of at least 20 years.

A third criterion for an acceptable alternative use is consistency with the substantive standards of the Arizona Groundwater Management Act and the Tucson Active Management Area groundwater management plan. Certain uses could be prohibited by law and may be inconsistent with relevant substantive standards. Certain surface discharge alternatives might require or be inconsistent with the regulatory standards under the State Groundwater Protection Permit. For discharge to a surface water source, consistency of the use under the National Pollution Discharge Elimination System (NPDES) may be relevant.

The costs discussed earlier for constructing and operating a reclamation wellfield would remain constant for these alternatives. In addition, this alternative would require the construction of a centrally-located groundwater treatment plant at AFP 44. Capital costs of constructing the treatment plant would be approximately $10,635,579, and annual operating and maintenance costs for a 20-year period would be $6,860,000 in 1984 dollars. These costs would also be constant for all the alternatives except recharge. The level of treatment and extent of aquifer restoration would be the same for every treatment alternative to be discussed.

a. Direct Discharge to Pima County Sewer System

Subsequent to treatment, the extracted groundwater would be pumped into the sewer system for transport to a Pima County sewage treatment facility. Implementation of this alternative would require construction of a pipeline and pumping stations from the treatment plant to the main trunk line of the sewer system which is located about six miles northwest of AFP 44. (See Figure 3). The cost of constructing the necessary pipelines and pumping stations has been estimated at $4,300,000. Annual operating costs for the water conveyance system are estimated to be about $800,000. The cost of acquiring necessary right-of-ways for the pipeline construction and sites for the pumping stations have not been calculated.

The Director of the Pima County Wastewater Management Department has indicated that the county probably could not accept an inflow of 2,000 gpm because the county treatment plant is currently operating at near capacity. Pursuant to Pima County Industrial Wastewater Ordinance No. 1982-154 and No. 1983-5, the Director has set the acceptable TCE, TCA and DCE treatment levels for discharge into the sewer system. The Director has set the limit as non-detectable as defined by the EPA (U.S. Environmental

Protection Agency). The EPA approved Method 601 for analyzing purgeable halocarbons defines non-detectable as 0.03 ug/l (micrograms per liter) for TCA, 0.12 ug/l for TCE, and 0.13 ug/l for DCE. These limits for TCE, TCA and DCE are lower than EPA's proposed standards for drinking water. Discharge of water which meets or exceeds drinking water quality into the sewer system would be neither cost-effective nor consistent with the groundwater management plan. Further aspects of this option are included in the previous section on the direct discharge of untreated water to the sewer system. In addition, this plan has little merit since the same end result of discharging to the Santa Cruz riverbed could be accomplished closer to AFP 44 at lower cost.

b. Industrial Use By Tucson Electric Power Company Irving Road Station

Treated groundwater from the reclamation wellfield would be pumped to the Tucson Electric Power Company (TEPCO), Irvington Road Station for use as cooling water. TEPCO currently pumps water from wells at the Irvington Road Station to supply the water needs at the site. The majority of this pumping could be replaced by water from AFP 44. Pumping would have to continue from the TEPCO wells for domestic supply at the Irvington Station.

Implementation of this alternative would require construction of a pipeline and pumping stations from AFP 44 to the TEPCO site, a distance of about six miles. The cost of constructing the necessary pipelines and pumping stations has been estimated to be $3,500,000. Annual operating costs for the water conveyance system are estimated to be about $400,000. Pipeline easements and sites for the pumping stations are not included in these estimates.

The total dissolved solids (TDS) content of the groundwater beneath AFP 44 is, in general, greater than the TDS of the water from the Irvington Station wells. This fact might result in greater water consumption at the Irvington Station as the water could be circulated through the cooling towers fewer times. Water from the Irvington Station is eventually discharged to the county sewer system. Mr. R.W. Sarau, Assistant Vice President for Power Production at TEPCO, has stated that TEPCO believes this alternative impractical and unwarranted.

c. Industrial Use by AFP 44

Treated groundwater from the reclamation wellfield could be used to supply industrial water for AFP 44. This use would replace pumping from City of Tucson wells currently supplying water to AFP 44.

Implementation of this alternative would require construction of pipelines on site. (See Figure 4). The cost for constructing pipelines has been estimated at about $130,000. Annual operating and maintenance costs are estimated at about $15,000.

The industrial water requirements of AFP 44 have been significantly reduced by the operation of AFP 44's Industrial Wastewater Treatment Plan which recycles approximately 75% of all industrial process waters. Accordingly, AFP 44's demand would be for only about 310 gpm of the 2,000 gpm which would be produced by a reclamation wellfield operating without recharge wells. It would be inconsistent with the goal of aquifer reclamation to pump the the wellfield only at the rate at which AFP 44 could use the water. To implement this alternative, an additional use for the majority of the pumped water would be required.

d. Industrial Use by ASARCO Copper Mine

Treated groundwater from the reclamation wellfield could be pumped to the ASARCO pumping station for industrial use at the ASARCO copper mine. Wells currently being pumped by ASARCO for industrial water supply could be retired. Implementation of this alternative would require construction of a pipeline and pumping stations to ASARCO's pumping station located at Pima Mine Road and U.S.Interstate 19, a

distance of about 7.5 miles. (See Figure 5). Water from the reclamation wellfield would be connected to the existing 18-inch pipeline which pumps water to the mine for process water, dust control and fire protection. A second smaller diameter pipeline would be constructed to the ASARCO plant site to transport water from existing ASARCO wells for domestic uses. The second pipeline would be about 3.5 miles long, and would also require a pumping station.

The cost of constructing the necessary pipeline and pumping stations has been estimated to be about $5,700,000. The annual operating and maintenance costs have been estimated at about $800,000. The costs for acquiring the necessary right-of-ways and sites for pumping stations have not been estimated.

Historic water use at the ASARCO mine has been about 3,500 gpm. However, the 20 year reliability of a continuous water demand for the copper mine is questionable.

e. Irrigation Use by Farmers Investment Company

Treated groundwater from the reclamation wellfield would be pumped to Farmers Investment Company (FICO) distribution system for use as irrigation water on FICO's Sahuarita Farm. About 13 percent of the water currently pumped by FICO could be replaced by water from AFP 44.

Implementation of this alternative would require construction of a pipeline and pumping stations from AFP No. 44 to the FICO distribution system located in the northeast 1/4 of Section 3, Township 19 South, Range 13 East, a distance of about 21 miles. (See Figure 6)

The cost of constructing the pipeline and pumping stations has been estimated to be about $11,400,000. Annual operation and maintenance costs have been estimated at about $2,300,000. The cost for acquiring pipeline easements and sites for pump stations are not included in these cost estimates.

Water demand for irrigation use at Sahuarita Farms would not be continuous as water use is minimal for three or four months every year. Significant new irrigation uses of groundwater would be inconsistent with the provisions of the AGMA and the TAMA groundwater management plan. In addition, the guaranteed continuation of water demand for 20 years could be questionable due to the pressures of urban expansion.

f. Irrigation Use by Papago Indian San Xavier Reservation

Treated groundwater from the reclamation wellfield would be pumped to the San Xavier Reservation distribution

system for use as irrigation water on the reservation. Water currently pumped from the reservation for irrigation use could be replaced by water from AFP 44. Implementation of this alternative would require construction of a pipeline and pumping station from AFP 44 to the San Xavier distribution system located in the northwest 1/4 of Section 2, Township 16 South, Range 13 East, a distance of about five miles. (See Figure 7).

The cost of constructing the pipeline across the Santa Cruz River and the pumping station has been estimated to be about $2,800,000. Annual operation and maintenance costs have been estimated at $450,000. The costs for acquiring pipeline easements and a site for the pumping station are not included in this cost estimate.

Use of the reclamation wellfield water for irrigation of crops would be seasonal and would not meet the criterion of continuous use. The reclamation wellfield must be pumped continuously to effectively curtail migration of contaminants downgradient.

g. Irrigation Use for Golf Courses

Treated groundwater from the reclamation wellfield would be pumped to two golf courses for irrigation use. The golf courses considered for this application are the golf course at Davis-Monthan Air Force Base, and the City of

Tucson Fred Enke Golf Course. Water currently being pumped for these uses could be replaced by water from AFP 44. Implementation of this alternative would require construction of a pipeline and pumping stations from AFP 44 to the golf course water distribution systems. For the Davis-Monthan Golf Course, the point of use is T. 14 S., R. 14 E., Section 36, and for the Fred Enke Golf Course, the point of use is T. 14 S., R. 15 E., Section 33. (See Figure 8). The Fred Enke Golf Course is about 13 miles from the site of the proposed treatment plant at AFP 44. About 22 miles of distribution pipeline would be needed to distribute water to both golf courses and to satisfy pipeline right-of-way requirements.

The cost of constructing the pipeline and the pumping stations has been estimated to be about $3,700,000. Annual operation and maintenance costs have been estimated at about $250,000. The cost estimate does not include acquisition of pipeline easements or sites for the pumping stations.

Disruption of traffic and lifestyles would occur in south-central Tucson during construction since the pipeline would traverse urban areas and arterial roadways. Acquiring right-of-ways and coordinating with other utili-

ties in an urban area such as this would be very expensive and time consuming.

The combined water use for both golf courses is about 600 gpm, or less than one-third of the water which would be pumped by a reclamation wellfield without recharge. Irrigation water is not applied continuously to the golf courses, hence storage facilities would be necessary. Irrigation use for golf courses would not satisfy either the criterion for continuous demand or the criterion of sufficient water demand for an alternative use for the reclamation wellfield water.

h. Recreational Use for the Proposed Santa Cruz River Park

Treated groundwater from the reclamation wellfield would be pumped to a recreational impoundment along the Santa Cruz River. The Santa Cruz River Park is scheduled for completion to Ajo Road by 1989. Implementation of this alternative would require construction of a pipeline and pumping station from AFP 44 to a recreational impoundment downstream from Ajo Road. (See Figure 9).

The cost of constructing the pipeline and the pumping stations has been estimated to be about $4,700,000. Annual operation and maintenance costs are estimated at about $540,000. The cost of acquiring pipeline easements

and sites for construction of the pumping stations has not been included.

The master plan for the Santa Cruz River is to complete the park system to the San Xavier Reservation. It is anticipated that the southernmost section of the park will be completed by 1994. The possibility of changing the construction order of the park matrices for utilization of reclaimed water in a southern section of the park was considered. Further evaluation of the Santa Cruz River Park alternative ceased in June, 1984 after the City of Tucson Water and City of Tucson Parks and Recreation Departments held a meeting to discuss the potential use of reclaimed water from AFP No. 44 for the Santa Cruz River Park. Their conclusions were: (1) 2,000 gpm would be less than required for water recreation opportunities; (2) major storage facilities would be required for effective use as irrigation water for the park; (3) reclaimed effluent will tentatively be available for the park in about 1989 providing the same benefit to the park on a long-term basis; and, (4) water quality at the target treatment levels could offer greater benefits at lower cost for other uses.

i. Groundwater Recharge to the Santa Cruz River

Treated groundwater from the reclamation wellfield

would be pumped to the Santa Cruz River and allowed to percolate into the river bed to recharge the regional aquifer. Implementation of this alternative would require construction of a pipeline from AFP 44 to the Santa Cruz River. (See Figure 10).

The cost of constructing the pipeline has been estimated to be about $2,100,000. Annual operation and maintenance costs are estimated at about $290,000. The cost of acquiring pipeline right-of-ways has not been included in this cost estimate.

The use of the reclaimed water for surface discharge into the Santa Cruz River and subsequent recharge of the regional aquifer would require a recharge efficiency analysis from the ADWR. A NPDES Permit may also be required. Discharging water of drinking quality into the Santa Cruz River is not consistent with the State's groundwater management plan because more efficient methods of aquifer recharge can be implemented at comparable costs.

j. Drinking Water Supply For Davis-Monthan Air Force Base

Treated groundwater from the reclamation wellfield would be pumped to Davis-Monthan Air Force Base for use as drinking water. The water from wells currently pumped to supply drinking water at the Air Force Base could be

replaced by the reclaimed water. Implementation of this alternative would require construction of a pipeline and pumping stations from AFP 44 to the Davis-Monthan drinking water system. The distribution point would be a 12-inch pressurized pipeline at Craycroft and Comanche in Section 26, T. 15 S., R. 14 E. (See Figure 11).

The cost of constructing the pipeline and the pumping stations has been estimated to be about $3,900,000. Annual operation and maintenance costs are estimated at about $380,000. The cost of acquiring pipeline easements and sites for construction of the pumping stations has not been included.

Disruption of traffic patterns and lifestyles would occur in south-central Tucson during construction since the pipeline traverses urban areas and arterial roadways.

Davis-Monthan Air Force Base currently has grandfathered rights to about 2,500 acre-feet per year. Water demand at the Base is only about 1,550 gpm. As 2,000 gpm could not be used on a continuous basis at the Air Force Base, storage facilities would have to be constructed. Water demand at the Base would not satisfy either the criterion of continuous demand, or of sufficient demand for an alternative use for reclamation wellfield water.

k. Municipal Water Supply For the City of Tucson

Treated groundwater from the reclamation wellfield would be pumped to a distribution point in the City of Tucson Water Department pipeline for use in the municipal water supply. Water currently pumped from City of Tucson Water wells could be replaced by water from the AFP 44 reclamation wellfield. Implementation of this alternative would require construction of a pipeline to City of Tucson well SC-7. (See Figure 12).

The cost of constructing the pipeline has been estimated to be about $700,000. Annual operation and maintenance costs are estimated at about $110,000.

The City of Tucson Water distribution system at well SC-7 can accommodate 3,000 gpm. Interruptions to the flow of water into the City system would be acceptable if advance notice were given to City of Tucson systems operators. Tucson Water would require some guarantee that all federal, state and county regulations for drinking water standards would be met for the life of the wellfield.

After reviewing prior drafts of this Remedial Action Plan for AFP 44, a letter was received from Tucson Water which endorsed the alternative of recharging the reclaimed water via wells. The reasons stated were: (1) to

simplify legal considerations; (2) to minimize the drawdown impact north of Los Reales Road where the Tucson Groundwater Contamination Task Force is investigating groundwater contamination; and, (3) to permit the most rapid implementation of a remedial action at AFP 44.

1. Groundwater Recharge by Percolation Ponds

Treated groundwater from the reclamation wellfield would be pumped to percolation ponds on AFP 44 for recharge to the regional aquifer. Implementation of this alternative would require construction of about 25 acres of percolation ponds and pipelines from the treatment plan to the ponds.

The cost of constructing the ponds and pipeline distribution system has been estimated to be about $3,600,000. Annual operation and maintenance costs are estimated at about $300,000. Compliance with the substantive standards of the State Groundwater Protection Permit program and NPDES regulations might be necessary.

The percolation ponds would be built on AFP 44 and could only be built in areas that would not conflict with existing facilities or planned new construction. The recharge efficiency of ponds on AFP 44 would probably be poor due to the overall low permeability of the alluvial sediments occurring above the water table at the plant site.

The recharge efficiency of the ponds would decrease with time due to the clogging effects of algae growth and sedimentation. The ponds would have to be dried out and scraped periodically. Evaporation from the ponds would also occur. The percolation ponds do not provide an optimal recharge system as they would only provide limited mitigation of the drawdown impacts in the regional aquifer.

m. Direct Recharge Water Use Alternative

For evaluation of the direct recharge alternative, the first two of the three criteria used for evaluating treated groundwater alternatives do not apply. The pumping rate for the reclamation wellfield can be increased to 4,200 gpm as the aquifer can sustain higher pumping rates with the recharge wells operating. The recharge well alternative would be able to accommodate the 4,200 gpm as the reclamation and recharge wellfields would be designed concurrently to provide optimum withdrawal and recharge rates for the system. The total operating time of the reclamation system can be reduced as compared to the surface discharge alternatives, thus providing for a faster clean up. The operational life of the recharge well system would be the same as the reclamation wellfield system. Recharge wells have a long history of use in both groundwater management and petroleum recovery.

The third criterion for evaluating the alternatives, consistency with the State's groundwater management plan, will also be satisfied by the direct recharge alternative since this program would minimize drawdown impacts, contribute to the attainment of safe-yield and help prevent further degradation of groundwater quality.

Treated groundwater from the proposed reclamation wellfield would be pumped to a system of recharge wells located on or adjacent to AFP 44. Implementation of this alternative would require construction of about 16 recharge wells and the distribution pipelines from the treatment plant to the wells.

The cost of constructing the necessary pipelines and recharge wells has been estimated at about $2,600,000. Annual operating and maintenance costs are estimated at about $110,000.

For construction and operation of the recharge wells, an underground injection control permit from the EPA may be necessary. The recharge well alternative is consistent with the State's groundwater management plan as the drawdown impacts to existing and potential water users would be minimized.

E. Cost and Feasibility Comparisons

Tables 2 and 3 provide comparisons of the costs and technical feasibilities of all the remedial possibilities that have been previously considered. The following two sections explain how these tables were derived; and tables 5 through 15 plus the report Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase III Results, Malcolm Pirnie, Inc., February, 1984, all in the Appendix, break down the listed expenditures of table 2 in much greater detail.

1. The table "Project Alternatives Cost Comparison Sheet" has been designed to allow a rapid comparison of the total costs of all the project alternatives while still providing as much detail as possible on the derivation of these costs.

Question marks have been inserted where data are not adequate to estimate costs. The amount of water in gallons-per-minute that each alternative is designed for is determined by hydrologic limitations on the maximum long-term pumpage rate. Those alternatives with less than a 2,000 gpm rate are limited by their specific usage and would have to be combined with another alternative to provide a system with the ability to distribute 2,000 GPM or more. For this reason, those costs that would be duplicated in

TABLE 3

TECHNICAL EVALUATION OF PROJECT ALTERNATIVES

PROJECT ALTERNATIVE	PERFORMANCE	RELIABILITY	IMPLEMENT-ABILITY	SAFETY	TOTAL
NO ACTION	1	5	5	1	12
CONTAINMENT BY IMPERV. BARR.	1	1	1	1	4
WITHDRAWAL WITHOUT TREATMENT					
DISCH. TO PUBLIC SEWER SYSTEM	1	3	2	2	8
REINJECTION OF UNTREATED WATER	1	2	1	2	6
SOLAR EVAPORATION	2	2	1	2	7
DISPOSAL AT A PERMITTED HAZARDOUS WASTE TREATMENT FAC.	1	2	1	2	6
WITHDRAWAL WITH TREATMENT					
DISCH. TO PUBLIC SEWER SYSTEM	2	3	2	3	10
AFP 44 *INDUSTRIAL USE	1	4	5	2	12
IND. USE BY ASARCO COPPER MINE	3	2	3	3	11
IRRIGATION BY FARMERS INVEST. CO.	2	2	2	3	9
IRRIGATION BY PAPAGO INDIANS	3	2	4	4	13
IRRIGATION BY GOLF COURSES	1	2	2	2	7
RECREATIONAL WATER USE AT PARK	3	3	2	3	11
RECHARGE TO SANTA CRUZ RIVER	3	4	4	4	15
DOMESTIC USE BY DAVIS-MONTHAN	2	3	2	2	9
DOMESTIC USE BY CITY OF TUCSON	3	5	5	4	17
RECHARGE THRU PERCOLATION	2	2	3	4	11
RECHARGE THRU RECHARGE WELLS	5	4	4	5	18

such a combined system are not shown, nor are the total costs for those alternatives. An economic assumption has been made that the rates of inflation and return on investment would be approximately equal over the lifetime of these projects. This greatly simplifies the computations of costs in constant 1984 dollars.

A detailed description of each column listing follows:

a. Capital for Reclamation Wellfield. This column shows the cost for design and construction of the groundwater reclamation wellfield. This cost includes well construction and development, pumps, variable frequency drives (VFDs), buildings at the well sites, an interconnecting system of pipelines, electrical power supply construction, and all other equipment required to extract groundwater at a rate of approximately 2,000 or 4,200 gallons per minute and deliver it to the treatment plant. The higher design pumping rate will require a more complex reclamation wellfield.

b. Capital For Treatment Plant. This is the cost for design and construction of a treatment plant to remove contaminants from the water delivered by the reclamation wellfield. The treatment plant cost includes the carbon adsorption system, stripping columns, chemical mixing

tanks, pressure filters, clearwell, clarifiers, tanks, filters, compressors, presses, control building, control computer, pumps, VFD's, interconnecting piping, electrical power supply, and all support materials required to treat the water and reduce concentrations to the target treatment levels.

c. Capital For Water Disposal System. This is the cost for design and construction of the water disposal systems to deliver the treated water to the specified application. This cost includes all piping from the treatment plant to the site of water disposal, pumping booster stations (pumps, VFD's, building), electrical power supply and other equipment required to deliver water to the site. The "Recharge through Percolation" alternative includes the construction of percolation ponds and the "Recharge Through Recharge Wells" alternative includes well construction and development costs.

d. A+B+C Total Capital Investment. This column shows the sum of Columns A, B and C, and is the total cost for design and construction of all the facilities needed for each application.

e. Lifetime (20 years) Operating Costs for the Reclamation Wellfield in 1984 Dollars. This is the amount required to run the reclamation wellfield for 20

years with no cost escalation and includes electric power, maintenance and operator's labor, and replacement or repair of all equipment in the reclamation wellfield.

f. Lifetime (20 years) Operating Costs For the Treatment Plant System in 1984 Dollars. This is the amount required to run the treatment plant for 20 years with no cost escalation and includes electric power, chemicals, maintenance and operator's labor, sludge disposal, and replacement or repair of all equipment in the treatment plant.

g. Lifetime (20 years) Operating Cost of the Water Disposal System in 1984 Dollars. This is the amount required to run the water disposal system for 20 years with no cost escalation and includes electric power, maintenance and operator's labor, and repair or replacement of all equipment in the system.

h. Total Lifetime (20 years) Operating Costs in 1984 Dollars. This is the sum of Columns E, F and G and is the total cost for maintaining and operating the reclamation wellfield, treatment plant, and water disposal systems with no cost escalator.

i. D+H Total Cost in 1984 Dollars. This column shows the total cost of design, construction, operat-

ing and maintenance of each of the alternative systems for 20 years with no cost escalation.

2. The table "Technical Evaluation of Project Alternatives" quantifies the preceding discussions on the project alternatives by ranking each option on a 1-to-5 scale in the following categories:

a. Performance. A score of 5 indicates the highest level of feasibility to solve the stated problem in the most efficient, cost-effective, and timely manner possible.

b. Reliability. A high score would relate to both the mechanical and structural dependability of the system and the projected consistency of use of the water disposal option.

c. Implementability. The high score would be for a system that demonstrated a relative ease of installation with few technical difficulties or disruptions of community activities. A system that would be operational quickly would also receive a higher score.

d. Safety. A score of 5 would indicate both the least hazardous system to workers and the community during construction and operation and the lowest risk to the community over the long term.

F. Summary of Alternative Uses and Conclusions

The "no action alternative" is not acceptable since other remedial options are available which would produce greater benefit than harm. The construction of impermeable containment barriers to minimize or prevent further migration of contaminants likewise appears unacceptable since the cost and engineering difficulties may be prohibitive given the hydrogeologic conditions in the vicinity of AFP 44, and since this alternative would not result in a restoration of the groundwater resource. The alternative of not treating extracted water creates a variety of disposal problems and other potential adverse environmental impacts, including unnecessary drawdown impacts on the regional aquifer, which far outweigh the benefits gained from merely withdrawing and disposing of contaminated water without treatment.

Since the "no action" and "no treatment" alternatives, including plume containment alternatives, raise substantial environmental, engineering feasibility and/or cost-effectiveness concerns, only those alternatives which entail treatment of contaminated water will receive further detailed analysis.

As to the potential use alternatives for treated water discussed above, irrigation use for golf courses,

drinking water supply for Davis-Monthan Air Force Base, and industrial use by Hughes Aircraft Company each have insufficient water demand. Irrigation use of the treated water for agricultural purposes at FICO's Sahuarita Farms or at the San Xavier Reservation will not receive detailed analysis because of their seasonal demand for the water and because irrigation uses are potentially inconsistent with or proscribed by the Arizona Groundwater Management Act and the TAMA groundwater management plans. Industrial use of the treated water by ASARCO's copper mine is not a viable alternative because continued water demand for 20 years cannot be assured. Industrial use by TEPCO, recreational use by the Santa Cruz River Park, and municipal use by the City of Tucson are not favored by the companies or agencies involved. In any event, all of the potential alternative uses for treated water, whether considered individually or collectively, have the additional disadvantage of doubling the required operating life of the reclamation program since the maximum groundwater extraction rate is dramatically reduced in the absence of aquifer recharge.

Direct discharge to the sewer system of the treated water is not a viable alternative, as treatment of the water to target treatment levels for discharge into the sewer system is not consistent with the State's groundwater

management plan. Direct discharge to the Santa Cruz River and recharge by percolation ponds are not consistent with the State's groundwater management plan, especially since more efficient methods of recharge are available at comparable costs.

Direct recharge of treated groundwater to the regional aquifer via recharge wells is the preferred alternative. The recharge well alternative is cost-effective, ranking third in initial capital investment and second in life of project costs among the withdrawal with treatment options. (Table 2). The technical evaluation (Table 3) also illustrates the overall advantages of this choice. The alternative of direct recharge via wells would accomplish groundwater cleanup in the least amount of time, and with the least drawdown impact in the regional aquifer system. This alternative is consistent with the State's groundwater management plan and is also the only alternative to be endorsed by both the EPA and City of Tucson Water Department for implementation at AFP 44.

In light of the preceding initial screening of remedial alternatives, the reclamation, treatment, and recharge alternative receive detailed evaluation in the following section.

VII. ANALYSIS AND CONCEPTUAL DESIGN OF A GROUNDWATER RECLAMATION, TREATMENT AND RECHARGE SYSTEM

This section provides further evaluation of groundwater reclamation, treatment and recharge alternatives, and presents a conceptual design for such a program. Substantive standards and guidelines developed in the National Contingency Plan, the USAF Installation Restoration Program (IRP), the National Environmental Policy Act, and other relevant federal, state and local environmental statutes and regulations are followed and considered. Detailed cost-effectiveness, non-cost criteria and public health analyses, as specified in the IRP, have already been discussed at some length in Section VI.

A. Groundwater Reclamation and Recharge Wellfields

Reclamation and recharge wellfields have been studied, designed and field tested as an interactive unit in order to maximize the timeliness and cost-effectiveness of their operation. The first step in this process was development of a comprehensive understandings of the hydrogeologic characteristics of that portion of the regional aquifer where remedial actions are intended and of the manner in which the area of contamination is affected by the regional hydrologic system. Furthermore, knowledge of the specific chemical nature and concentrations of all contam-

inants that have been introduced into the area of concern has been acquired. Extensive remedial investigations and studies of the groundwater contamination and the hydrogeology at AFP 44 have been conducted (as discussed in Sections II and II). The results of these efforts have been assimilated into a computer model of the hydrogeology at AFP 44 which projects the effects of different conceptual well-field designs.

The report Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase III Results, Malcolm Pirnie, Inc., February 1984, presents an initial conceptual wellfield design that was developed in 1983 based on the data available at the time. Although more recent data requires some adjustment to that prelminary design, that design is still generally valid for most areas at AFP 44. For this reason, together with the fact that that report contains a detailed analysis of engineering requirements for the wellfields, the cost elements developed there were used for the Cost Comparisons Sheet (Table 2). However, data that has been acquired since 1983 regarding contaminant concentrations to the northwest of AFP 44 (as discussed in Section II) has made that reports' wellfield location design obsolete in certain respects.

The following subsections amplify and amend the detailed analysis and conceptual design of the wellfield presented in the Malcolm Pirnie report in order to account for the most recent data available.

1. Design of Well Locations and Operation

A new reclamation and recharge wellfield system has been recently designed. (Design of Reclamation Wellfield, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc. March 15, 1985.) Approximately 19 extraction wells would be constructed at or near the locations shown on Figure 2. Fifteen of the extraction wells would be designed to pump contaminated groundwater from the upper zone of the regional aquifer, and four wells would be designed to pump the more limited area of contaminated groundwater from the lower zone. Approximately 16 injection wells would be located primarily along the periphery of the plume (Figure 2). All but two of these injection wells would be completed solely in the upper aquifer zone. Although the conceptual design of the wellfield has been finalized, the precise number and exact location of wells, and the discharge and recharge rates for individual wells in the system could change in response to hydrogeologic conditions encountered during actual drilling operations at the proposed well sites.

Contaminated groundwater will be pumped from the aquifer via the extraction wells to the treatment plant, and then discharged to the aquifer after treatment via the recharge wells. The reclamation wellfield has been designed to minimize any further migration of the plume, to assure capture of the plume, and to minimize the time required to reclaim contaminated water. The recharge wells have been designed and located to control groundwater gradients and stabilize the plume, to minimize regional water level effects of the reclamation system, to prevent any excessive water level declines in the vicinity of extraction wells in order to maintain well discharge rates, and to minimize any interference with other remedial actions that may be implemented north of Los Reales Road.

The reclamation wellfield was initially designed based on the location of the plume and known hydrogeologic conditions, including direction of groundwater movement, and lithologic and hydraulic characteristics of the aquifer. A fine-grid groundwater flow computer model was developed to "fine-tune" the design of the wellfield, to estimate optimum pumping and injection rates at individual wells, to assure capture of the plume, to predict regional water level impacts, and to estimate required clean-up times. The computer program which was selected for this groundwater flow

model is described in Techniques of Water Resources Investigations of The United States Geological Survey, Book 7, Chapter C1 (Trescott, Pinder and Larson, 1976). This two-dimensional finite-difference model was designed to simulate the response of a wide variety of aquifers to hydraulic stresses, and is suitable for application to the unconfined, heterogeneous aquifer in the area of the proposed reclamation wellfield.

Computer simulations indicate that the optimum sustained pumping rate of the extraction wells would be about 4,000 gpm from the upper zone of the regional aquifer and 130 to 185 gpm from the lower zone. Individual well pumping rates will probably vary between 150 and 400 gpm for upper zone wells, and between 25 and 50 gpm for lower zone wells. The composite concentrations of TCE, TCA, DCE, and chromium that would be discharged to the treatment system at the commencement of pumping are estimated to be 400 ug/l, 5 ug/l, 85 ug/l, and 0.06 mg/l, respectively.

Computer simulations indicate that approximately 10 years will be required for operation of the majority of the wells in the reclamation wellfield, and that after this period, less than one foot of drawdown would occur north of Los Reales Road. Approximately two to five pore volumes of groundwater would be removed and treated from the area dur-

ing 10 years of wellfield operation. After 10 years of operation, it is possible that small localized zones of contaminated groundwater would remain which would require operation of selected extraction and recharge wells beyond 10 years.

The actual effects of the reclamation system on water levels and the reduction of contaminant concentrations will be determined through systematic monitoring of the extracted groundwater quality and by monitor wells located in and adjacent to the area of remedial activity. Final designs of the monitoring program will be developed after completion of the exact engineering design and specifications of the wellfield.

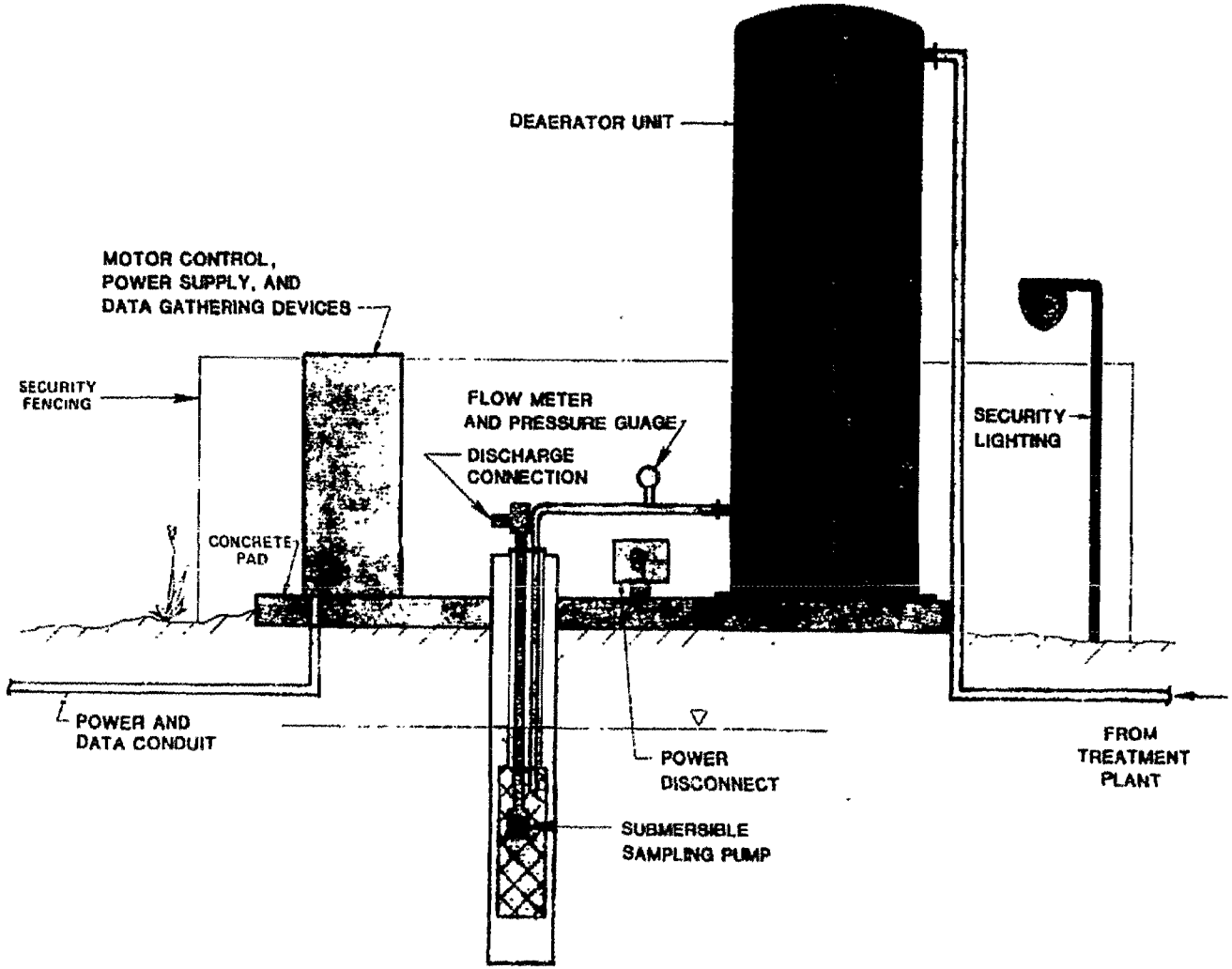
2. Design of Engineering Aspects

The pipelines and electrical conduits for the wellfields discussed above have not yet been designed for the current plan. However, their general routing and construction materials will be similar to the detailed analysis in the Malcolm Pirnie Reports since the number of wells and their locations are approximately the same. Land leases for well locations and right-of-way privileges will need to be acquired on Papago Indian Reservation and Tucson Airport Authority properties. In addition, a major gas pipeline,

railroad property, and the Nogales Highway will need to be crossed in several locations.

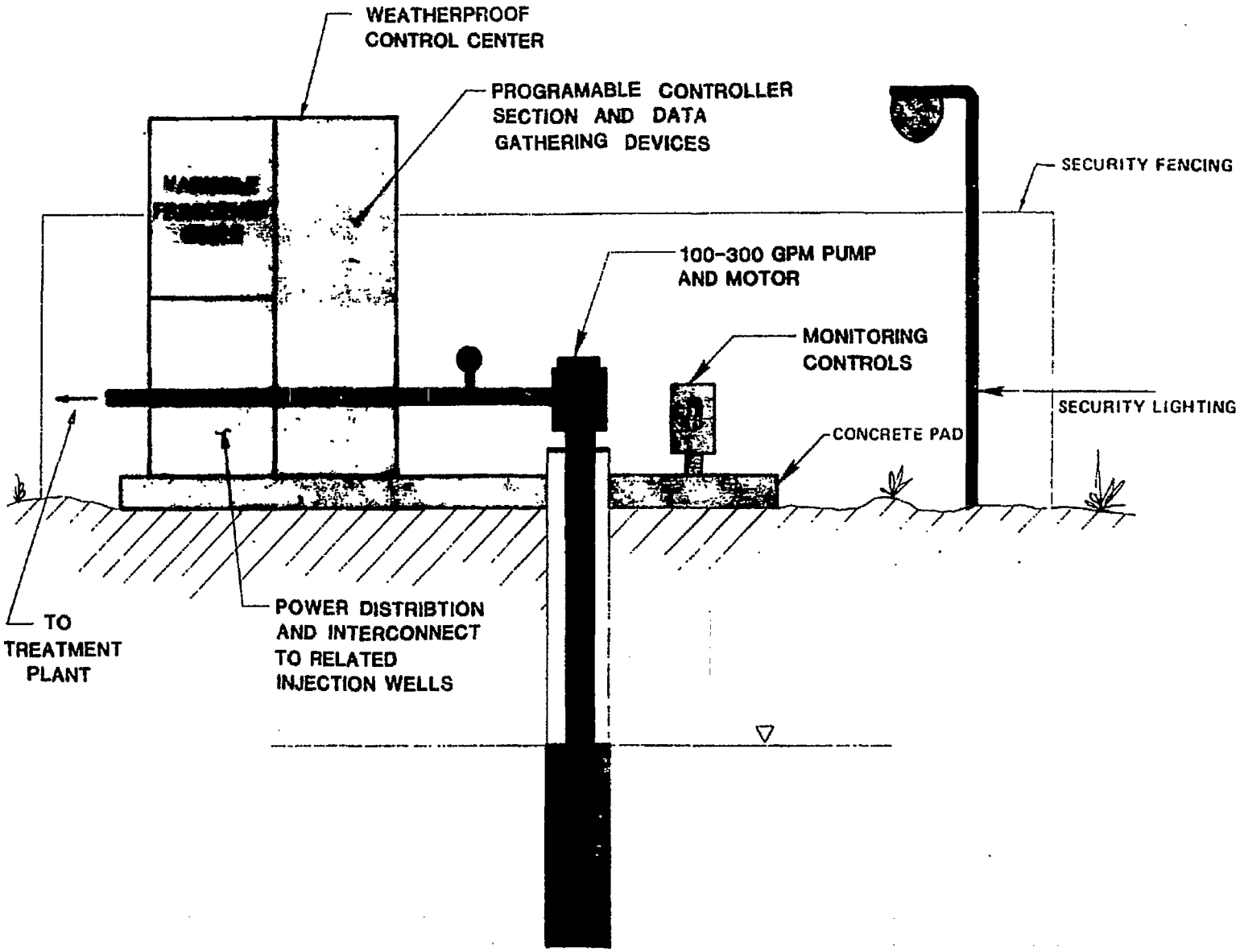
Figures 14 and 15 show schematic diagrams of proposed wellhead construction. A deaerator unit will be added at each recharge well to prevent the introduction of dissolved gasses into the aquifer which could cause clogging of the well.

The proposed reclamation and recharge wellfield design is based on known and proven technologies. Construction of this system presents no peculiar engineering difficulties, and the completed system would be a reliable means of assuring continued extraction and recharge of groundwater throughout the estimated operational lifetime of this program. Furthermore, the proposed wellfield is designed to minimize drawdown impacts in the aquifer, and not to alter groundwater gradients outside of the program area. Actual operation of the system would not create any significant known or anticipated additional adverse environmental impacts, and routine inspection and maintenance of the system will be performed to verify that result. Every phase of this system's design and implementation has been and will continue to be coordinated with relevant federal and state agencies to assure these results.



RECHARGE WELL SCHEMATIC (ABOVE GROUND)

FIGURE 14



RECLAMATION WELL SCHEMATIC (ABOVE GROUND)

FIGURE 15

217

The proposed reclamation and recharge wellfield will effectively attain the objectives identified in Section V of this document in all relevant areas south of Los Reales Road.

B. Groundwater Treatment Alternatives

Various groundwater treatment alternatives are analyzed in the report, Conceptual Study for the Treatment of Reclaimed Water at USAF Plant No. 44, Phase I & Phase II Results, Malcolm Pirnie, Inc., September 1983. This report describes pilot and bench scale tests that were conducted to evaluate several treatment technologies, compares the results obtained from these testings, and develops a conceptual design for a groundwater treatment facility. Their recommendations for use of a packed column aeration process to remove volatile organic compounds and a chemical reduction/precipitation process with ferrous sulfate to remove chromium are still being included in the current study. However, a new ion-exchange method for chromium treatment (also discussed in the Malcolm Pirnie analyses) has been further evaluated during the Pilot Reclamation Project discussed below and will be used as a substitute for reduction/precipitation.

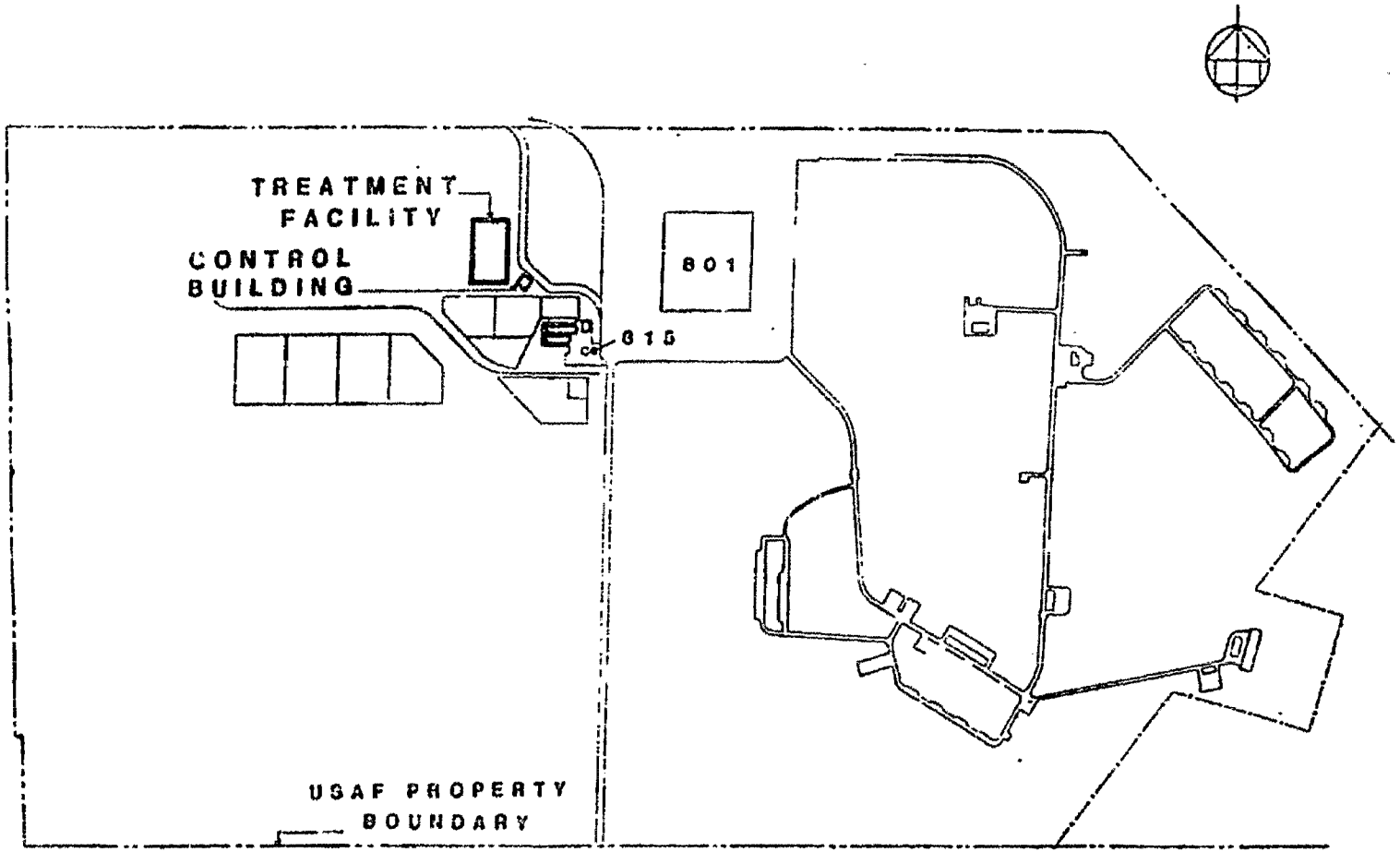
Since the area at AFP 44 of combined chromium and volatile organic contamination in the regional aquifer is

less than half of the total area containing volatile organic contaminants, the extracted groundwater that contains only volatile organic compounds will be kept separate in the pipeline and treatment systems so that it will only need to undergo the air stripping process to attain the target treatment levels. Therefore, the chromium treatment process will be designed to a capacity somewhat less than 4,200 gpm since it will be receiving only the portion of water that is contaminated by chromium. The air stripping process will be used to treat all the water to be reclaimed at AFP 44. Figures 16 and 17 show the conceptual location and site plans for the central treatment facility.

C. Pilot Reclamation Project

A pilot reclamation project, a small scale version of the proposed remedial alternative was placed into operation in April 1985 to evaluate well design and operations, hydraulic and contaminant-transport responses of the aquifer to sustained pumping, contaminant monitoring methods, and the efficacy of the proposed air-stripping and chromium ion-exchange treatment systems.

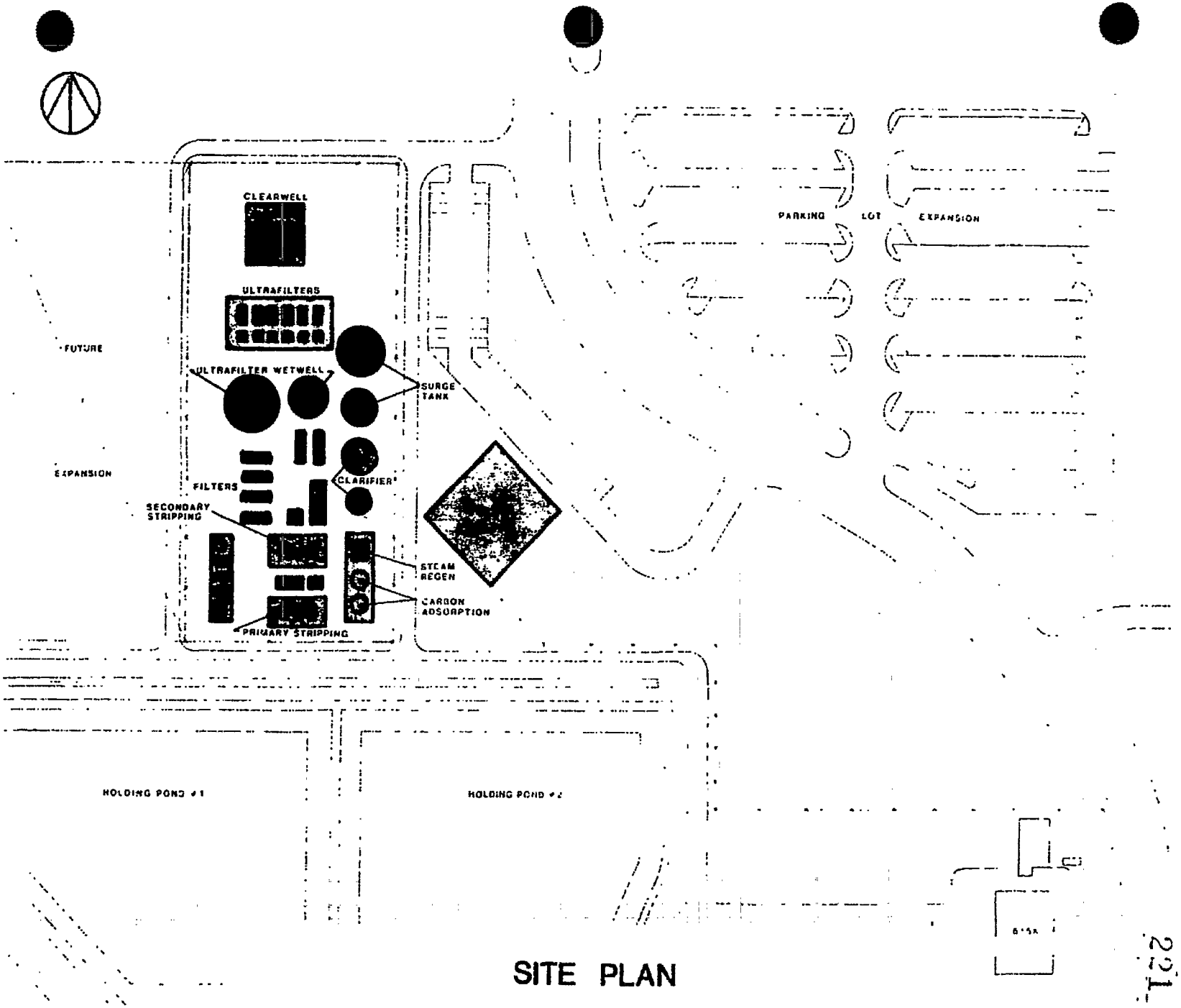
During the pilot program, groundwater has been pumped from two reclamation wells, E1 and E2 (Figure 2), treated in a small treatment facility near well E1, and recharged back into the regional aquifer through wells I1



LOCATION PLAN

[redacted]

FIGURE 16



SITE PLAN

FIGURE 17

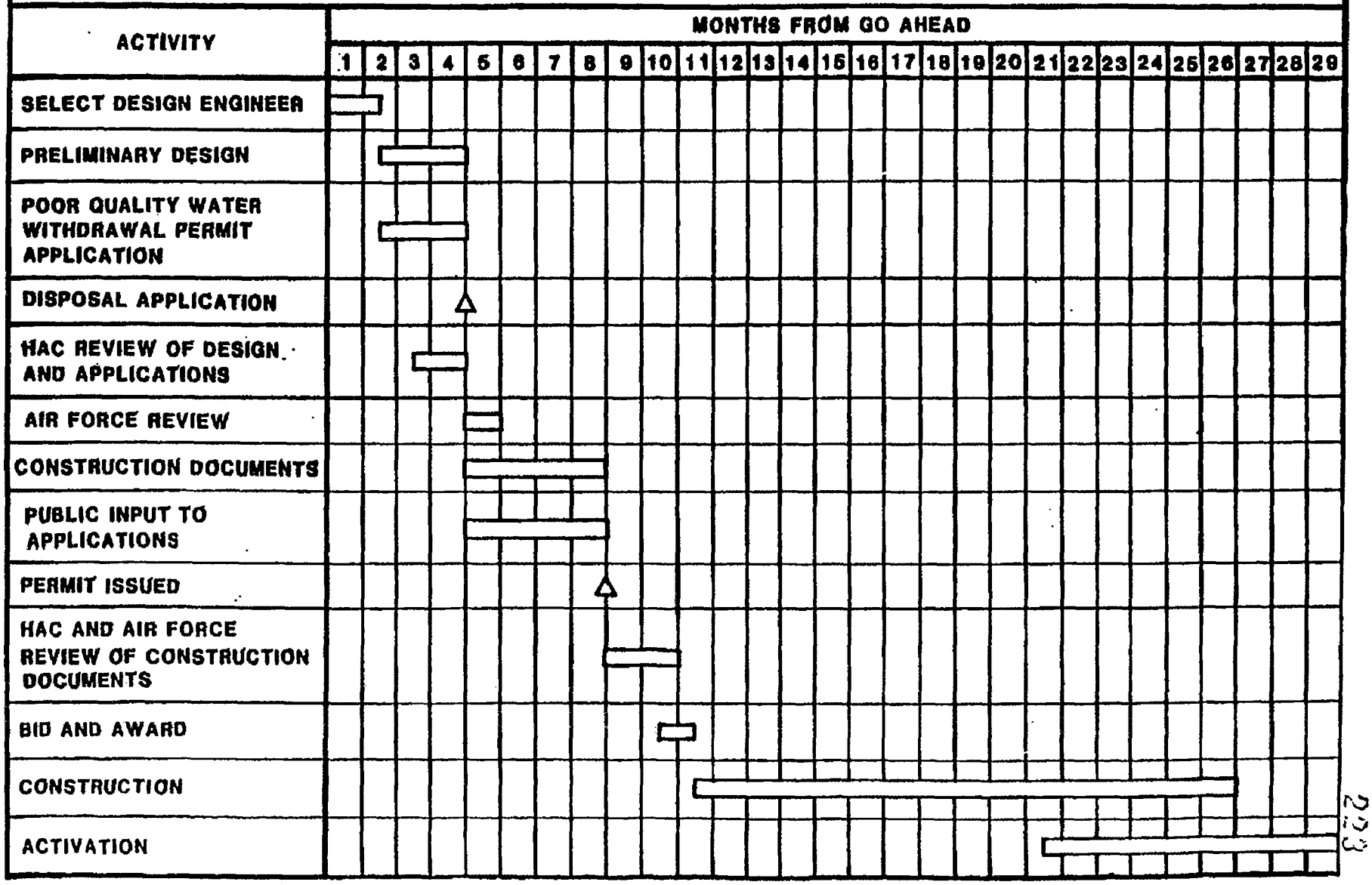
and I2. The data obtained from this field operation have confirmed the efficacy of the proposed reclamation, treatment and recharge remedial alternative. Specifically, the pilot plant has demonstrated the ability: 1) to attain the target treatment levels for TCE, TCA, DCE and chromium; and, 2) to handle and treat the trace levels of other contaminants that have been found in the plume, including toluene, 1-2 dichloroethane, chloroform and 1-2 dichloropropane.

D. Master Schedule

The time to implement the Remedial Action Plan is expected to be twenty-nine (29) months from the go ahead date. The following schedule (Table 4) shows the estimated sequence and duration of events.

REMEDIAL ACTION PLAN
PROPOSED MASTER SCHEDULE
USAF PLANT NO 44

TABLE 4



223

E. Scope of the Project.

As described in Section III, significant investigative and analytic efforts have been undertaken by the USAF to define completely the nature of groundwater contamination south of Los Reales Road and to obtain the necessary understanding of the hydrogeologic conditions in that area. The information obtained about that area during the last four years has allowed for the development and design of a proposed remedial action which can effectively treat the types of contaminants and volume of water found in that area, and which can also prevent the highest contaminant concentrations of the AFP 44 plume from migrating to the area north of Los Reales Road.

In 1983, the USAF and members of the AFP 44 TRC concluded that the USAF should focus its efforts in the area south of Los Reales Road based on the determination that available evidence supported the conclusion that contaminants from AFP 44 had not migrated north of that vicinity. Accordingly, the FIT team undertook the responsibility for investigating groundwater conditions and contaminant sources for the area north of Los Reales Road, and for analyzing remedial alternatives which might be appropriate for implementation in that area. The FIT investigation is nearly complete; its analysis of remedial alternatives is on-going.

Based on the data obtained during 1984, the USAF concluded that the low concentration, forward edge of the AFP 44 contaminant plume had migrated slightly north of Los Reales Road, intermingling with a zone of preexisting contamination just north of Los Reales Road caused by sources other than AFP 44. As noted above, this is the area under FIT team investigation and analysis.

The groundwater reclamation project proposed here is directed at the area south of Los Reales Road where the source of contamination is known to have originated predominantly from AFP 44. The nature and extent of the contamination present there are also known to be treatable under the processes proposed. Delay in the implementation of the program could result in further migration of high levels of contaminants into the area of the Superfund study for which the appropriate remedial alternatives have not yet been identified.

Accordingly, it is the USAF's belief that the proposed reclamation program for the area south of Los Reales Road should be implemented as soon as possible. Implementation of this program will prevent further degradation of the aquifer, and will have minimum impact on any remedial alternative selected for the area north of Los Reales Road. In the event the FIT feasibility study concludes that a ground-

water reclamation program is appropriate for the area north of Los Reales Road and that the types and concentrations of contaminants found there are susceptible to treatment processes of the kind used at AFP 44, consideration could be given to expanding the USAF facilities as a part of the Superfund remedial program.

VIII. COMMUNITY RELATIONS

A. Introduction

This community relations plan has been prepared for the Installation Restoration Program (IRP) of Air Force Plant 44, Tucson, Ariz.

The objective of this plan is to identify, consider and respond to issues and concerns of the Tucson community at large and specifically to the citizens who live and work in the vicinity of Air Force Plant 44; to establish related community relations efforts and goals; and to explain handling of news releases and press queries.

B. Background

United States Air Force Plant No. 44 (AFP 44) is a government-owned contractor-operated defense manufacturing facility located in Tucson, AZ. It occupies approximately 2,106 acres of land southwest of the Tucson International Airport (TIA), and constitutes an extensive manufacturing complex of 1,061,104 square feet of floor space.

AFP 44 began operations in 1951 as the prime production plant for the Falcon air-to-air missile. Since that time, it has been significantly expanded and is presently the primary production source for the Army's TOW Missile, the Air Force's Maverick Missile, the Navy's

Phoenix Missile, and the Marine Corp.'s Angle Rate Bombing System. As the primary production facility for major weapons systems for the armed services, AFP 44 is an integral part of the U.S. national defense effort.

The plant employs approximately 7,500 Tucson area residents, has an annual payroll of $190.4 million and spends nearly $400 million each year for commodities from firms in Tucson and throughout the state.

The main manufacturing complex was constructed for Hughes by the Del Webb Corp. in 1951. The U.S. Government purchased the plant from Hughes that same year and awarded Hughes a facilities contract to operate it.

Before production began, representatives from Hughes conferred with the Arizona Department of Health, now Arizona Department of Health Services (ADHS), to discuss appropriate treatment alternatives for the waste streams that would be generated in the manufacturing process.

These discussions resulted in Hughes designing a facility to treat liquids used in the plating processes to be employed at AFP 44. The design drawings and specifications were approved by ADHS, and the facility was immediately constructed and placed into operations. For its time, it was regarded by ADHS as one of the most superior of such facilities in the state.

This treatment facility continued to operate at AFP 44 until 1977. It was expanded and improved a number of times to incorporate the most current waste treatment technologies. As was the case with the original treatment plant, each upgrade and expansion proposal was reviewed and approved by ADHS before it was implemented.

In response to increasing national environmental awareness of the late 1960's and early 1970's, the Air Force and Hughes assessed the wastewater handling and disposal practices at AFP 44 and determined that significant improvements should be made. It was decided in 1971 that a state-of-the-art "zero discharge" hazardous waste management facility should be constructed, that is, a facility which would not discharge any contaminants whatsoever into the nation's waters.

Actual design of this new facility began in 1974 and in 1975 the completed plans were forwarded to ADHS, the Environmental Protection Agency (EPA) and the City of Tucson Department of Water and Sewers for review, comment and approval. The new facility received enthusiastic endorsement from all those agencies and construction began immediately.

The present waste treatment facility has been in full-scale operation since 1977. Approximately 80

percent of AFP 44's wastewater is treated and recycled for use in the process shops. The other 20 percent is lost to evaporation.

The ability to recycle 80 percent of the water used in industrial processes has significantly reduced the plant's demand for water from outside sources. The efficiency and safety record developed in the operation of this zero-discharge hazardous waste treatment facility has resulted in awards of merit presented by the Arizona Water and Pollution Control Association in 1978, 1979, 1980 and 1981. It also has been visited and studied by various industrial representatives as a model for safe and efficient operations, and for its design and performance characteristics.

In 1979 the EPA financed an ADHS study of wastewater surface impoundments in the greater TIA area. As part of the study, ADHS representatives were taken on a tour of AFP 44 surface impoundments which had been used to handle the product of the former waste treatment facility prior to 1977. Also as part of the greater TIA investigation, a field team sponsored by EPA obtained groundwater samples from four wells located at AFP 44. Analyses of these samples indicated the presence of trichloreothylene (TCE) in the groundwater in the vicinity of AFP 44.

This rudimentary information was inadequate, however, for determining the nature or extent of groundwater contamination in the vicinity of AFP 44, or whether AFP 44 was the source of the contamination. The presence of TCE could have been caused by another source and transported to AFP 44 by movement of water in the regional aquifer system.

The Air Force's own investigations of environmental conditions at the plant have been underway since early 1981. These investigations have revealed that industrial solvents trichloroethylene (TCE), 1,1,1-trichloroethane (TCA), and 1,1-dichloroethylene (DCE) have leached into the groundwater beneath the plant and migrated north, off the site, to the vicinity of Los Reales Road.

Chromium also was found in the groundwater but it had not migrated as far north as the volatile organic solvents.

The root cause of the contamination emanating from the plant is how industrial wastewater was disposed of from 1951 until 1977, although these disposal practices were acceptable at the time and in conformance with all federal, state and local standards and regulations.

From 1951 until 1962, industrial wastewaters were treated in the then state-of-the-art wastewater treatment plant then discharged to dry streambeds and ditches west of Building 801, the main manufacturing building. From 1962 until 1977, general industrial wastes and industrial wastewater from the plant were treated and then disposed of via ditches into evaporation ponds --both lined and unlined-- and pits.

The Air Force investigation report identifies these areas as the probable sources of groundwater contamination caused by AFP 44. Four of the five pre-1977 ponds were excavated and backfilled in 1980. The fifth pond was backfilled in 1976. It occupied an area presently covered by lined evaporation ponds which are part of the existing zero-discharge industrial wastewater treatment facility at AFP 44.

There have been no environmental problems at AFP 44 since the existing zero-discharge industrial wastewater treatment plant began operation in 1977.

The objectives of the draft Remedial Action Plan are to prevent to the maximum practicable degree any continued migration of contaminants from AFP 44 and to remove and dispose of those contaminants in the plume emanating from AFP 44 in an environmentally acceptable manner;

to achieve these results in the most cost-effective and timely manner possible; and to implement a program which does not result in unwarranted drawdown in the regional aquifer, does not interfere with the performance of remedial action programs conducted by others in the greater Tucson International Airport vicinity, and is consistent with the goals of the Tucson Active Management Area groundwater management plan.

C. History of Community Relations Activities

Community relations activities through April 17, 1985, have consisted primarily of planning and coordination meetings between Air Force and Hughes officials and officials from federal, state and local regulating agencies, elected officials, and the Papago Indian Tribal Council.

On April 17, 1985, startup of a pilot groundwater reclamation facility at AFP 44 was announced jointly by The Air Force and Hughes, ushering in Phase III of the air Force's four-phased Installation Restoration Program at the plant. Invited were elected officials from all levels of government and representatives from public media outlets throughout the state. Attendees were briefed on environmental activities at the plant to date including AFP 44's zero-discharge industrial wastewater treatment facil-

ity, double-lined holding ponds with sensors to detect leaks, above ground pipes which enable day and night visual inspection -- all designed to prevent future contamination of the environment; and the pilot air stripping groundwater treatment plant designed to cleanse groundwater contaminated as a result of past disposal practices.

Since the April 17 program, community relations have continued in the form of meetings between Air Force and Hughes personnel and elected and appointed officials of state and local governments, as well as answering media queries to inform the public at large, and answering questions and concerns of individuals.

D. Community Relations Work Plan

1. Mailing List

A mailing list is maintained for mailings to regulatory agencies, government officials, media, and other interested parties. The mailing list is continually updated. It is used to send out news releases, fact sheets, notices and other important information concerning the IRP at Plant 44. It is also used for mailing information updates to all interested parties to keep them current on the progress of the IRP.

2. Information Repositories

The following sites are being used as repositories for technical reports pertaining to the IRP. They have the capacity to store and make available other pertinent information concerning the program:

Tucson Public Library

Main Library	200 S. Gay
Columbus Branch	4350 E. 22nd
Himmel Branch	1035 N. Treat Ave.
Mission Branch	3770 S. Mission Rd.
Valencia Branch	202 W. Valencia Rd.
Wilmot Branch	530 N. Wilmot Rd.
Woods Memorial Branch	3455 N. 1st Ave.
Government Reference Library	1st Floor City Hall
El Pueblo Library	101 W. Irvington Rd.
El Rio Library	1390 W. Speedway Blvd.
Namini Library	7300 N. Shannon Rd.
South Tucson Library	141 W. 29th

University of Arizona Science and Engineering Library (Reserve Book Room), Bldg. 54.

Phoenix Public Library, Main Branch (Business and Science Dept.), 12 E. McDowell Rd.

3. Central Information Contact

Mr. Arthur Shacter has been designated the person to contact for information concerning the Plant 44 IRP. Mr. Shacter's address is AFPRO, Hughes Missile Systems Group, ATTN. Art Shacter, RAP Com Rel Officer, P. O. Box 11337, Tucson, AZ 85734. Any questions concerning the IRP should be directed to him. He will route all questions of a highly technical nature to the person most knowledgeable in the subject area.

4. Media Information

The media have been interested in the cleanup effort at Plant 44. This interest has not waned as the project continues. Press releases are prepared and will continue to be prepared for any activity, decision, update or other important milestone connected with the cleanup endeavor. Media inquiries, releases and answers are coordinated through the appropriate Air Force Officials and are answered as quickly as possible.

Media visits are granted whenever possible on site. The local, regional and national media have access to documents and general information at the repositories and through the periodic news releases on major events and milestones and fact sheet updates.

5. Speakers Bureau

Speakers will be made available from Air Force Plant 44 who can address any audience with a desire for information concerning the IRP. These speakers are available by contacting the Central Information Contact listed in paragraph D3 of this annex.

6. Public Comment Period

The general public will have the opportunity to review the remedial action plan at the local information repositories and comment through the central information contact throughout the IRP. A three-week comment period from Oct. 4 through Oct. 25, 1985 will be provided after release of the Remedial Action Plan on Oct. 4, 1985. News media will be notified of the comment period and copies of the Remedial Action Plan will be available at the local information repositories. Public meetings will be considered as one means of presenting the study findings, discussing alternatives responding to questions, and receiving public comment.

7. Responsiveness Summaries

A responsiveness summary will be prepared following the three-week comment period to summarize the comments received on the draft Remedial Action Plan. This summary will be placed at the public repositories and

distributed to those persons and agencies on the mailing list as appropriate.

8. Implementation of this Plan

The commander of Air Force Plant 44 will be responsible for the implementation of all portions of this plan. Assistance will be provided on request and as appropriate by Aeronautical Systems Division Office of Public Affairs, Wright-Patterson AFB, Ohio, and Air Force Systems Command Office of Public Affairs, Andrews AFB, Md.

IX. DEMONSTRATION OF PROGRAM COMPLIANCE WITH SUBSTANTIVE STANDARDS OF OTHER LAWS

A. Substantive Standards Regarding Groundwater Rights and Impacts

The State of Arizona adopted a Groundwater Management Act in 1980 for the purpose of safeguarding the state's groundwater resources and providing a plan to assure the adequacy of those resources to meet future demands for water. This Act establishes several Active Management Areas throughout the State. AFP 44 is located within the Tucson Active Management Area (TAMA). The proposed remedial action program discussed above has been coordinated with and will continue to be coordinate relevant substantive aspects of this program.

Arizona groundwater management regulations provide for a system that grants rights for the use of acceptable quality groundwater and for a permitting process for the withdrawal of poor quality groundwater. The USAF currently is entitled to withdraw and use approximately 235 million gallons of water per year from the AFP 44 site. Under the remedial action alternative discussed above, the USAF would need to withdraw approximately 2.7 billion gallons of water per year. In addition, because contamination exists in the groundwater underlying AFP 44, the ADWR requires a Poor

Quality Water Withdrawal Permit for the proposed groundwater pumping component of the recommended remedial action alternative.

Accordingly, the USAF has been working closely with ADWR regarding permitting issues, remedial action requirements, and potential impacts on the groundwater system. Representatives of ADWR, ADHS and USAF have met regularly to discuss remedial action investigations and alternatives, including the remedial action program's substantive compliance with relevant groundwater regulations. Figure 13 presents a proposed task flow chart which provides for such compliance consistent with the need to perform an expeditious remediation of environmental conditions at AFP 44.

Documents which have been or will be provided to the State include a detailed description of the hydrogeologic characteristics of the area, an inventory of wells, and a detailed design of the reclamation wellfield and monitor well system. The technical basis for the reclamation wellfield design and pumping regime will be discussed.

The USAF has also been coordinating with ADWR and ADHS the groundwater recharge component of the recommended remedial alternative. New regulations adopted by ADHS in July, 1984 prohibit the disposal of any wastes or pollutants

which may adversely affect groundwater quality. The USAF has discussed and will continue to inform ADHS about specific details of possible treatment and recharge phases of the remedial action at AFP 44 to insure that this program complies with the substantive requirements of all new regulations.

The USAF will take all possible steps to comply with relevant groundwater rights and permitting requirements. The remedial action program involves the direct recharge of extracted, treated groundwater directly to the aquifer from which it originated with no consumptive use in order to restore this resource to a condition suitable for beneficial use. Recharge of the treated water will result in no significant adverse impacts on the groundwater rights of others or on groundwater quality.

B. USAF Installation Restoration Program Phase IV Management Guidance

This guidance document describes the USAF policy for assuring that remedial actions are performed in a timely and cost-effective manner which is consistent with Department of Defense environmental quality program policies. Section III.A.4 of that document provides instructions for the development of a remedial action plan. The following is

an item-by-item demonstration of compliance with the Guidance instructions in the preparation of this plan:

1. Conceptual plan view drawings of the overall site, showing general locations for project actions and facilities appear in the appendix of this Remedial Action Plan in Figures 10B, 10C and 13 of the report Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase III Results, February 1984, Malcolm Pirnie, Inc.

2. Conceptual layouts for individual facilities and other items to be installed appear in the appendix of this Remedial Action Plan in Figures 11, 12, 14, 17, 18, 19, 20, 21, 22, and 23 of the report Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase III Results, February 1984, Malcolm Pirnie, Inc.

3. Conceptual design criteria and rationales for the recommended remedial action alternative are presented throughout this Remedial Action Plan. Design criteria and rationales include target treatment levels, groundwater pumping and recharge rates, environmental impact considerations and cost. Target treatment levels, pumping and recharge rates and cost factors are discussed in Section VII of this Remedial Action Plan as well as the report in the appendix entitled Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase I & Phase II

Results, September 1983, Malcolm Pirnie, Inc. Because environmental impact factors are of utmost importance in the planning of a remedial action program, every discussion of a remedial alternative includes consideration of relevant environmental impact factors. These considerations have served as the basis for eliminating specific alternatives from further analysis. To receive a final, detailed analysis an alternative must not create any new, more significant danger or threat of danger to the public health and welfare and the environment, and must minimize and mitigate any existing dangers or threats of danger. In accordance with these prerequisites, the final alternative is proposed because it minimizes and mitigates any existing dangers to the environment and optimally protects the environment from any new dangers in a manner consistent with the requirements of the National Contingency Plan.

4. A description of types of equipment required, including approximate capacity, size, and materials of construction appears in detail in the appendix of this Remedial Action Plan in the report Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase III Results, February 1984, Malcolm Pirnie, Inc.

5. An operational description of process units appears in the appendix of this Remedial Action Plan in sec-

tion V of the report Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase I & Phase II Results, September 1983, Malcolm Pirnie, Inc.

6. There are no unique structural concepts required for the facilities which would be involved in the implementation of the recommended remedial action alternative.

7. A description of operation and maintenance requirements for the recommended remedial alternative appears in section VII of this Remedial Action Plan.

8. Right-of-way requirements arise in planning the construction of pumping and recharge wells and distribution systems beyond the boundaries of USAF-owned property at the AFP 44 site. A listing of types of right-of-ways required appears in section VII of this Remedial Action Plan.

9. The USAF desires, through this Remedial Action Plan, to provide evidence satisfactory to all reviewing agencies and to the public that the recommended remedial action alternative minimizes and mitigates existing dangers to the public health and welfare and the environment as well as protects the public and the environment from any new exposure to harm, thus complying with the substantive

requirements of the National Environmental Policy Act, 42 U.S.C. § 4321 et seq.

10. Section VII of this Remedial Action Plan contains a discussion of additional engineering data required to proceed with design.

11. All standard construction permits will be obtained, and a discussion of environmental permit requirements appears throughout this Remedial Action Plan.

12. The report Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase III Results in the appendix of this Remedial Action Plan developed a detailed cost estimate for the recommended remedial action alternative. The dollar amounts are being withheld until the completion of bidding processes in connection with this project.

13. An order-of-magnitude operations and maintenance cost estimate was prepared as part of the report, Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase III Results which appears in the appendix of this Remedial Action Plan.

14. A preliminary project master schedule appears in Section VII.D of this Remedial Action Plan.

C. National Contingency Plan

Part 300 of Title 40 of the Code of Federal Regulations is the National Oil and Hazardous Substances Pollution Contingency Plan, also known as the National Contingency Plan. Subpart F of 40 C.F.R. Part 300, Hazardous Substance Response, presents methods and criteria for determining the appropriate extent of response to hazardous substances releases. The following discussion demonstrates the compliance of this Remedial Action Plan with the requirements listed in 40 C.F.R. § 300.68 for the preparation of remedial action programs.

This Remedial Action Plan develops remedial action alternatives as required by 40 C.F.R. § 300.68(g). Section VI of this Remedial Action Plan contains the discussion of the development of the alternatives and includes a consideration of no action as one of the alternatives.

Section VI of this Remedial Action Plan screens the alternatives through a comparison of costs, expected effects of the alternative and technical aspects of the alternative following the requirements of 40 C.F.R. § 300.68(h), and Section VII of the plan presents a detailed analysis of the alternative that remains after the initial screening (40 C.F.R. § 300.68(i)).

The proposed conceptual remedial alternative incorporates the greatest extent of remedy possible with established technology that can be verified through established analytical techniques in accordance with 40 C.F.R. § 300.68(j).

Finally, protection of the public health and welfare and the environment is a fundamental concern of this plan.

D. National Environmental Policy Act

The National Environmental Policy Act of 1969, 42 U.S.C. § 4321 et seq., and its implementing regulations, 40 C.F.R. Parts 1500-1508 and 32 C.F.R. Part 989 among others, require that federal agencies analyze the potential environmental impacts and alternatives to proposed actions in addition to the economic and technical considerations relevant to the selection of a recommended course of action. In the selection of an appropriate remedial action as a response to a release of hazardous substances into the environment, the National Contingency Plan similarly requires that the environmental impacts of alternative remedial actions be analyzed.

Throughout this Remedial Action Plan, extensive consideration has been given to the environmental impacts associated with each of the remedial alternatives analyzed

for the purpose of identifying that option which maximizes environmental restoration. The program of groundwater reclamation, treatment and recharge recommended here is believed to accomplish that result with respect to groundwater contamination emanating from AFP 44 located south of Los Reales Road in a manner which results in no significant adverse impacts to the environment. Specifically:

1. The extraction of contaminated groundwater will not result in any significant disruption of flow in the regional aquifer system through drawdown impacts since treated groundwater will be recharged to the regional system, thus minimizing drawdown impacts;

2. The groundwater treatment system to be employed is designed to reduce contaminant levels to those which make the water safe for beneficial uses;

3. The volatile organic air-stripping treatment process and the chromium treatment process have been designed to eliminate any significant level of emissions to the atmosphere;

4. Any liquid waste stream produced by the groundwater treatment plant will be recycled through the nearby industrial wastewater treatment plan at AFP 44;

5. The groundwater treatment and withdrawal systems will be operated long enough to ensure that groundwater in the treatment area will be restored;

6. Treatment of the groundwater resolves any concerns about disposal problems;

7. Recharge of the treated water will prevent adverse drawdown impacts in the regional aquifer and disruption of other groundwater remedial programs which may be undertaken in the TIA area;

8. The wellfield and treatment plant have been designed and located so as not to interfere with future use of the area. The recharge and reclamation wells will be located in areas which are not noted for unusual environmental sensitivity, and their operation will not otherwise significantly disrupt the environment.

Upon the final selection of the appropriate remedial action program (subsequent to the receipt and analysis of public comments on this plan), the USAF will again review the environmental impacts of the final plan in order to insure that it will be consistent with the standards of NEPA.

E. Resource Conservation and Recovery Act

The Resource Conservation and Recovery Act of 1976, 42 U.S.C. § 6901 *et seq.*, as amended, and its imple-

menting regulations, 40 C.F.R. Parts 264 and 265, among others, generally require that hazardous waste management practices be conducted in a manner which protects human health and the environment. Subchapter III of RCRA prescribes comprehensive requirements for the generators, transporters, or those owners and operators of treatment, storage or disposal facilities relating to the management of hazardous wastes.

Although the remedial plan identifies a treatment scheme not involving the off-site storage, destruction, treatment or disposal of hazardous wastes such that the remedial action might be expected to comply with the procedural and substantive requirements of Subchapter III, the standards and criteria of RCRA have nevertheless been a part of the analysis and screening of potential remedial action alternatives. In that regard, alternatives which might employ the bulk or containerized disposal of extracted liquid contaminants have been dismissed for being inconsistent with prohibitions and limitations on such disposals under RCRA. On the other hand, substantial consideration has been given to the potential for hazardous waste generation as part of the treatment plant operations identified in the plan. Concerns arising from such potential are more fully addressed in the treatment facility design documents and in

the recently submitted RCRA final permit application for AFP 44.

F. Underground Injection Control Requirements and Federal Sole Source Aquifer Requirements (Groundwater Protection Strategy)

Several Federal requirements programs, advisories or policy statements on groundwater protection parallel, if not complement, the State of Arizona's comprehensive program to safeguard groundwater resources. The discussion of that program at paragraph A above, and the summary contained in an appendix to this remedial action plan demonstrates how such program and its underlying concerns have shaped the analysis of remedial alternatives and selection of the preferred remedial action involving extraction, treatment and recharge of contaminated groundwater.

Reliance on the substantive standards of the Arizona program should adequately address the policy issues of similar relevant Federal programs. Suffice it to say that the remedial action program involves the recharge of water treated to drinking water quality back into the aquifer from which it was withdrawn, employing no consumptive use, for the purpose of restoring the contaminated aquifer to a condition suitable for beneficial use. In other words, the Air Force will be injecting water of

better than drinking water quality direct to the aquifer underlying AFP 44, thus avoiding entirely any substantive concerns which might arise with respect to degradation of groundwater quality.

G. Floodplain Management

In accordance with the provisions of Executive Order 11988, 24 May 1977, as amended, it has been determined that the proposed remedial action program will not occur in a floodplain. Further analysis, then, of alternatives to avoid adverse effects and incompatible development in a floodplain is irrelevant to this study.

H. National Ambient Air Quality Standards

National primary and secondary ambient air quality standards promulgated under the Clean Air Act, 42 U.S.C. § 7401 *et seq.*, 40 C.F.R. Part 50, are established to protect public health or the environment from any known or anticipated adverse effects of a pollutant. This remedial action program has been designed taking into consideration control requirements on air emission sources to ensure maintenance of the national ambient air quality standards.

The only standard of concern with respect to this remedial plan is Pima County Regulations which limit total volatile organic compound emissions from a facility to 40 pounds per day.

Two air-stripping towers are contained in each treatment process with 90% of the VOC's being removed in the first stripping tower. Carbon adsorption filters will be installed on the first stage towers. Total VOC emissions from the second stage towers, together with other VOC emissions from AFP 44, will not exceed the 40 pound/day limit.

X. REFERENCES

Analysis of Data Collected by Tucson Groundwater Contamination Study Task Force in the Vicinity of Tucson International Airport, Tucson, Arizona, Hargis & Montgomery, Inc., June, 1984.

Computer Model of Two Dimensional Solute Transport and Dispersion in Groundwater, U.S.G.S., Konikow & Bredehoft, 1978.

Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase I & Phase II Results, Malcolm Pirnie, Inc., September, 1983.

Conceptual Study for Treatment of Reclaimed Water at USAF Plant No. 44 Phase III Results, Malcolm Pirnie, Inc., February 1984.

Construction of Monitor Wells M-29 Through M-39, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., 1984.

Design of Reclamation Wellfield, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Associates, Inc., March 15, 1985.

Digital Simulation of Contaminant Transport in the Regional Aquifer System, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., October 11, 1982.

Evaluation of Data Collected by Tucson Groundwater Contamination Study Task Force in the Vicinity of U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., February 4, 1983.

Methods for Organic Chemical Analyses of Municipal and Industrial Wastewater, United States Environmental Protection Agency, EPA-600/4-82--57, July 1982.

Phase I Investigation of Subsurface Conditions in the Vicinity of Abandoned Waste Disposal Sites, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, Hargis & Montgomery, Inc., January 15, 1982.

Phase II Investigation of Subsurface Conditions in the Vicinity of Abandoned Waste Disposal Sites, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona, Hargis & Montgomery, Inc., March 12, 1982.

Summary of 1982 Hydrologic Monitoring Program, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., July 15, 1983.

Summary of 1983 Hydrologic Monitoring Program, U.S. Air Force Plant No. 44, Tucson, Arizona, Hargis & Montgomery, Inc., March 14, 1984.

Techniques of Water Resources Investigations of the United States Geological Survey, Book 7, Trescott, Pinder, and Larson, 1976.

Testing Methods for Evaluating Solid Waste, Physical/Chemical Methods, United States Environmental Protection Agency, EPA-SW-846, July 1982.

JANUARY 15, 1982

PHASE I

INVESTIGATION OF SUBSURFACE CONDITIONS IN THE VICINITY OF ABANDONED WASTE DISPOSAL SITES HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY TUCSON, ARIZONA

VOLUME I

HARGIS & MONTGOMERY, INC.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

CONTENTS

PAGE

- CONCLUSIONS 1
- RECOMMENDATIONS 3
- INTRODUCTION 7
- HISTORIC WASTE DISPOSAL 9
  - WASTE DISPOSAL SITES 10
    - Ditches 10
    - Ponds 11
    - Pits 12
- GEOLOGIC FRAMEWORK 13
  - REGIONAL GEOLOGY 13
    - Surficial Deposits 13
    - Fort Lowell Formation 14
    - Tinaja Beds 14
    - Pantano Formation 14
  - SITE GEOLOGY 15
    - Regional Aquifer 16
    - Perched Zone 16
- GROUNDWATER CONDITIONS 19
  - OCCURRENCE AND MOVEMENT 19
    - Perched Zone 19
    - Regional Aquifer 20
  - GROUNDWATER PUMPAGE 21
  - HISTORIC WATER LEVEL CHANGES 22
- CHEMICAL CHARACTER OF WATER 24
  - GROUNDWATER 24
    - Phase I Water Sampling 24
    - Perched Zone 25
      - Common Ions 26
      - Trace Metals 26
      - Organics 27
      - Conclusions 28

CONTENTS ---

PAGE

Regional Aquifer..... 28
Common Ions..... 29
Trace Metals..... 30
Organics..... 31
Conclusions..... 32

CONCENTRATION OF TRACE METALS AND ORGANICS IN SOIL SAMPLES..... 34
TRACE METALS..... 34
Conclusions..... 36
ORGANIC CONSTITUENTS..... 37
Conclusions..... 38

REFERENCES..... 39

TABLES

TABLE-

1 SUMMARY OF WATER SAMPLES COLLECTED FROM WELLS, HUGHES AIRCRAFT COMPANY, TUCSON, ARIZONA

2 LABORATORY DETECTION LIMITS FOR TRACE METALS

CONCENTRATION OF ORGANIC CONSTITUENTS IN SOIL SAMPLES

ILLUSTRATIONS

266

FIGURE	
1	PROPOSED PHASE II INVESTIGATION
2	APPROXIMATE LOCATIONS OF ABANDONED PONDS, PITS, AND DISPOSAL SITES
3	LOCATION OF HYDROGEOLOGIC CROSS SECTIONS
4	HYDROGEOLOGIC CROSS SECTION A-A'
5	HYDROGEOLOGIC CROSS SECTIONS B-B' AND C-C'
6	HYDROGEOLOGIC CROSS SECTION D-D'
7	1952 WATER LEVEL CONTOURS
8	1960 WATER LEVEL CONTOURS
9	1970 WATER LEVEL CONTOURS
10	1980 WATER LEVEL CONTOURS
11	PUMPAGE FROM WELL HAC-1
12	PUMPAGE FROM WELL HAC-3
13	PUMPAGE FROM CITY OF TUCSON WELL SC-7
14	WATER LEVEL HYDROGRAPH FOR WELL HAC-1
15	WATER LEVEL HYDROGRAPH FOR CITY OF TUCSON WELL SC-7
16	CHEMICAL TYPES OF GROUNDWATER
17	CONCENTRATION OF TOTAL CHROMIUM IN WATER SAMPLES
18	CONCENTRATION OF TCE IN WATER SAMPLES
19	CONCENTRATION OF TCA IN WATER SAMPLES
20	CONCENTRATION OF DCE IN WATER SAMPLES
21	CONCENTRATION OF TCE IN SOIL SAMPLES

APPENDICES*

APPENDIX	
A	AERIAL PHOTOS
B	DRILLING, CONSTRUCTION, AND LITHOLOGIC LOGS OF SOIL BORINGS
C	DRILLING, CONSTRUCTION, AND LITHOLOGIC LOGS OF MONITOR WELLS
D	LITHOLOGIC LOGS FOR HAC PRODUCTION WELLS AND CITY OF TUCSON WELL SC-7
E	WATER SAMPLE COLLECTION AND DOCUMENTATION
F	RESULTS OF CHEMICAL ANALYSES FOR ROUTINE CONSTITUENTS IN WATER SAMPLES
G	RESULTS OF CHEMICAL ANALYSES FOR TRACE METAL CONSTITUENTS IN WATER SAMPLES
H	RESULTS OF CHEMICAL ANALYSES FOR ORGANIC CONSTITUENTS IN WATER SAMPLES
I	RESULTS OF CHEMICAL ANALYSES FOR EPA PRIORITY POLLUTANTS IN WATER SAMPLES
J	ANALYTICAL AND SAMPLE EXTRACT PROCEDURES FOR SOIL SAMPLES
K	CHEMICAL ANALYSES OF TRACE METAL CONSTITUENTS IN SOIL SAMPLES

*(*VOLUME III)*

PHASE I
INVESTIGATION OF SUBSURFACE CONDITIONS IN THE VICINITY OF ABANDONED WASTE DISPOSAL SITES HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY TUCSON, ARIZONA

CONCLUSIONS

Analysis of geologic and hydrologic data collected at the Hughes Aircraft Company Manufacturing Facility in Tucson, Arizona indicates the following:

1. Hughes Aircraft Company has disposed of fluids containing a variety of trace metals and industrial solvents into pits, ponds, and ditches on the facility property for approximately 30 years.

2. High concentrations of chromium and organic solvents found in groundwater obtained from wells on the property are a result of the past waste disposal practices of Hughes Aircraft Company.

3. High concentrations of chromium and organic solvents found in groundwater obtained from City of Tucson well SC-7 might be a result of the past disposal practices of Hughes Aircraft Company.

4. Historic waste disposal practices at the Hughes Aircraft Company facility have resulted in percolation of wastewater to the regional aquifer system. The continuity of the aquifer system and the direction of regional groundwater movement have enabled contaminants to migrate for an undetermined distance northwest of the facility property boundary.

RECOMMENDATIONS

In order to define the distribution of contaminants in the regional aquifer, it is necessary to expand the current investigation. More information is needed to determine the volume of groundwater that has been contaminated beneath the facility property, the concentration of the contaminants in the aquifer, and the extent of contaminated fluid in the perched groundwater zone beneath the abandoned wastewater disposal ponds. The investigation should determine which disposal sites were used to dispose of organic solvents, and the residual concentration of the contaminants in the soil at these sites.

In addition, the investigation should determine the contribution of contaminants from Hughes Aircraft Company facility wastewater disposal practices to off-site groundwater contamination. Because of the nature of the regional groundwater flow system in the vicinity of the Hughes Aircraft Company facility, it appears that contaminants have been transported for some unknown distance northwest of the facility property. Other industrial activities in the same area may have also contributed similar contaminants to the aquifer.

The recommended tasks for the investigation include drilling additional soil borings at disposal sites, analysis of soil samples for volatile organic acids, construction of additional monitoring wells in the perched and regional groundwater systems, and compilation of a predictive finite-difference digital computer model of groundwater flow and contaminant transport for the regional aquifer.

The tasks are summarized as follows:

1. Construct and sample confirmatory soil borings at seven selected sites *(Figure 1)*. The proposed confirmatory borings would be located adjacent to previous soil borings that indicated the presence of contamination in the subsurface. Analysis of soil samples from the confirmatory borings are required to verify the concentration of contaminants that are present in the soils.

2. Construct and sample exploratory soil borings at nine additional selected sites *(Figure 1)*. These borings would be located in areas where migration of waste products into the subsurface environment might have occurred from known disposal pits, ponds, or ditches. Analysis of soil samples collected from the exploratory soil borings would verify whether additional suspected waste disposal sites were sources for migration of waste products into the subsurface, and would indicate the relative strength of contaminant concentrations at the disposal sites.

3. Construct and sample monitor wells in the perched groundwater zone at nine sites *(Figure 1)*. Eight of the proposed monitor wells would be located down-gradient of abandoned pits, ponds, or ditches. A ninth monitor well would be located up-gradient of potential contaminant sources. Analysis of water samples collected

from these wells would define the concentration and extent of contaminants in the perched groundwater zone.

4. Construct and sample 19 monitor wells in the regional aquifer system *(Figure 1)*. These wells are to be constructed in the vicinity of selected abandoned disposal ponds, pits, and ditches. Analysis of groundwater samples collected from these monitor wells will define the distribution and concentration of contaminants in the regional aquifer at the Hughes Aircraft Company facility. The wells would also be used to obtain data on the hydraulic character of the regional aquifer. The transport rate and dispersion of contaminants in the regional aquifer system can be estimated from these data.

5. Aquifer tests should be conducted at production wells HAC-1, HAC-3, and HAC-4 *(Figure 1)*. The purpose of the aquifer tests is to provide data on the hydraulic character of the regional aquifer. These data are required for estimation of the rate of contaminant movement in the regional aquifer system.

6. In order to estimate the portion of off-site contamination that might be the result of historic waste disposal practices at the Hughes Aircraft Company facility, a computer model of groundwater flow and contaminant transport in the area is proposed. The computer model will provide estimates of the areal extent of the contaminant

plume in the regional aquifer system, and the concentration of contaminants within the plume. The computer model appears to be the only tool available to determine the contribution of Hughes Aircraft Company to the off-site aquifer contamination.

HARGIS & MONTGOMERY, INC.

7.

274

PHASE I
INVESTIGATION OF SUBSURFACE CONDITIONS IN THE VICINITY OF ABANDONED WASTE DISPOSAL SITES HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY TUCSON, ARIZONA

INTRODUCTION

Pursuant to a request from Mr. David L. Mulliken, Attorney, Latham & Watkins, this summary report of the Phase I Investigation of the impact of historical waste disposal practices on groundwater quality at the Hughes Aircraft Company *(HAC)* Manufacturing Facility in Tucson, Arizona, has been compiled. The objectives of the Phase I Investigation were as follows:

1. Locate potential sources of trace metal and organic contaminants found in groundwater samples collected in wells tapping the regional aquifer system.

2. Determine if historic waste disposal practices of Hughes Aircraft Company might be

the source of organic and trace metal contaminants detected in wells down-gradient of the manufacturing facility.

Disposal of a variety of liquid and non-liquid wastes has occurred at the HAC facility since 1951. Liquid wastes were transported in a variety of pipes and ditches to several unlined holding ponds, or were released to the surrounding desert. Some liquid wastes, including oils and solvents, were apparently transported to several pits for disposal by evaporation and infiltration into the soils. Some flammable solvents were ignited and used in fire-fighting exercises. Solid wastes, including drums, barrels, metal scraps, and cafeteria garbage, were buried in trenches or pits. The Phase I Investigation included drilling large-diameter soil borings at those locations identified as waste disposal sites *(Figure 2)*. Soil samples were collected and analyzed to determine the concentrations of trace metals and organic contaminants. Monitoring wells were constructed in both the upper and lower zones of the regional aquifer system, and in a perched groundwater zone discovered in the vicinity of the abandoned wastewater disposal ponds *(Figure 2)*. Groundwater samples have been collected from these wells and analyzed to determine the concentration of contaminants.

Water samples were collected by HAC personnel from the unlined wastewater disposal ditch located west of Building 801 during the period 1971 to 1977. These samples were analyzed for chromium, cyanide, and pH by the HAC laboratory. Historical water quality data prior to 1971 are not available. Wastewaters have been discharged to lined evaporation and holding ponds since 1977.

HISTORIC WASTE DISPOSAL

Information concerning historic waste disposal practices at the HAC facility has been compiled from site maps, aerial photos, disposal records, and discussions with HAC employees. Data indicate that on-site disposal of wastes at the HAC facility began in 1951 *(Spaulding, 1980)*. These wastes included fluids which were discharged to excavated pits, unlined ponds, and a network of unlined ditches.

A wastewater treatment plant became operational in 1977 at the HAC facility. The treatment plant receives process rinse waters and cooling tower blowdown waters. Approximately 75 percent of the water is treated and recycled, and 25 percent is pumped into lined evaporation ponds.

Wastes disposed of at the HAC facility comprise two general types: general industrial wastes, and industrial wastewaters *(Spaulding, 1980)*. General industrial wastes include the following: oils, sludges, paints, solvents, metals, and chemicals. The chemicals comprise sulfuric, chromic, hydrofluoric, nitric, hydrochloric, and phosphoric acids. The metals include cadmium, chromium, copper, gold, nickel, lead, and tin. These waste products are produced by the facility plating, heat treatment, and paint processes. Amounts of these materials disposed of prior to 1977 are not known.

Industrial wastewater primarily comprises rinse water from plating processes, cooling tower blowdown, and some concentrated solutions of chrome and cyanide. From 1951 to 1970, HAC estimates that 1,250,000 gallons of rinse water were disposed of per

week. During the same period, HAC estimates that 15,000 gallons of concentrated solutions, including chrome and cyanide, were disposed of per week. From 1970 to 1977, approximately 20,000 gallons of rinse water and 160 gallons of concentrated solutions were disposed of per week.

WASTE DISPOSAL SITES

General industrial wastes and industrial wastewaters were disposed of in ponds, ditches, and pits at the HAC facility during the period 1951 to 1977. Historic disposal sites were either located in the field by HAC personnel, or interpreted from review of site plan maps and aerial photos *(Figure 2)*. Disposal site locations were confirmed by reviewing the sequence of aerial photos of the facility area for the period 1953 to 1976 *(Appendix A, Figures A-1 through A-17)*.

Ditches

A network of unlined ditches was used at the HAC facility to transport industrial wastewaters to the area west of Building 801 when operation of the facility began in 1951. These ditches are apparent on aerial photos of the facility property for the period 1953 through 1976 *(Appendix A)*. Phreatophytic vegetation developed along and adjacent to the ditches and wastewater disposal ponds. The vegetation appears as dark areas on the aerial photos. The density of this vegetation indicates the greater availability of water in these areas due to the discharge of wastewater.

Ponds

Prior to 1962, wastewaters were apparently discharged to dry streambeds and ditches west of Building 801 *(Appendix A, Figures A-1 and A-3)*. Although well-defined ponds are not obvious on the aerial photographs until 1962, small ponds may have formed along the streambeds and ditches.

Five ponds were utilized for disposal of industrial wastewaters during the period 1962 to 1977. Two small lined ponds were located east of Building 801, and three larger unlined ponds were located west of and beneath the existing evaporation ponds *(Figure 2)*.

The two ponds constructed east of Building 801 were first recognized on aerial photos from the year 1962 *(Appendix A, Figure A-4)*. Both ponds were lined with a thin plastic membrane and the northern pond was also lined with clay. These two ponds received precipitated heavy metal sludges and chemicals used for neutralization of industrial wastes. Both ponds were excavated and refilled in 1980. An asphalt parking lot was constructed over the abandoned ponds in the third quarter of 1981.

Two unlined holding ponds were constructed west of the existing evaporation ponds to receive industrial wastewaters *(Figure 2)*. The first pond was recognized on aerial photos taken in 1964 *(Appendix A, Figure A-6)*. The second unlined holding pond appears in aerial photo coverage for the year 1969 *(Appendix A, Figure A-10)*. Both ponds were excavated and refilled in 1980.

The largest unlined wastewater holding pond was located beneath the existing evaporation pond 4 *(Figure 2)*, and was first detected on aerial photos for the year 1973 *(Appendix A, Figure A-15)*. This pond was backfilled in 1976 during construction of evaporation pond 4.

Pits

General industrial wastes were disposed of in excavated pits during the period 1952 through 1977. Eight abandoned disposal pits were located on the property by HAC personnel *(Figure 2)*. Inspection of aerial photos indicated about ten additional suspected disposal pits might have been used during the period 1952 to 1977.

HAC personnel have indicated that three areas around the HAC facility were used for disposal of general industrial wastes, including the solvents trichloroethylene *(TCE)* and TCA. One area, located in the southern portion of the facility property, was apparently used for waste disposal from 1951 to 1955 *(Figure 2)*. Several disposal pits were located in the cleared area which is evident on a 1953 aerial photo *(Appendix A, Figure A-2)*. The second area was in the southeastern portion of the facility property and was apparently used for waste disposal from 1955 to 1966 *(Figure 2)*. This disposal area appears as a clearing on aerial photos from 1967 and 1969, although the area was no longer used for disposal after 1966 *(Appendix A, Figures A-9 and A-11)*. Pits located in the area west and northwest of Building 801 were used for waste disposal from 1966 to 1977 *(Figure 2)*. These pits also appear as cleared areas on the aerial photos *(Appendix A, Figures A-8, A-10, A-12, A-15, and A-16)*.

The precise nature and quantities of wastes disposed of in the pits in these areas is not known.

GEOLOGIC FRAMEWORK

The project area is located in the Tucson Basin, which is a broad, northwest-trending alluvial valley encompassing about 750 square miles in Pima County, southeastern Arizona. The basin is bounded by a nearly continuous ring of mountains and extends for a distance of about 50 miles from the Santa Rita Mountains in the south, to the Tortolita Mountains in the north.

REGIONAL GEOLOGY

The mountains surrounding the Tucson Basin consist of crystalline igneous, metamorphic, volcanic, and sedimentary rocks. These rock units range in age from Precambrian to late Tertiary.

The valley floor is underlain by several thousand feet of alluvial basin fill sediments interbedded locally with volcanic flows, agglomerates, and tuffaceous sediments. The basin fill sediments include, in descending order: (1) surficial deposits, (2) Fort Lowell Formation, (3) Tinaja Beds, and (4) Pantano Formation.

Surficial Deposits

The surficial deposits overlie the Fort Lowell Formation and comprise terrace gravels, stream channel and floodplain deposits. These thin deposits are mainly gravel and gravelly sand with localized sand and sandy silt. The surficial deposits range in thickness from a featheredge to several tens of feet.

Fort Lowell Formation

The Fort Lowell Formation overlies the Tinaja Beds, and consists predominantly of silty gravel near the basin margins, grading to a silty sand and clayey silt toward the central part of the basin. The Fort Lowell Formation is 300 to 400 feet thick near the center of the basin, and thins toward the mountains *(Davidson, 1973)*.

Tinaja Beds

The Tinaja Beds comprise sand and gravel at the margins of the basin, and grade to gypsiferous, clayey silt and mudstone in the central portions of the basin. The Tinaja Beds range in thickness from a featheredge to as much as 5,000 feet. The Tinaja Beds have been interpreted as a sedimentary detrital filling of a subsiding basin. The central part of the Tucson Basin is a triangular-shaped down-faulted block, bounded by the Santa Cruz fault, an un-named fault running parallel to Rillito and Tanque Verde Creeks, and another un-named fault that trends northeast through the basin *(Davidson, 1973)*. In much of the down-faulted block, the Tinaja Beds are divided into two parts. The lower part comprises a clayey silt to mudstone, and the upper part comprises a clayey gravel to clayey silt. Outside of the down-faulted block, the Tinaja Beds are a gravelly or pebble sand *(Davidson, 1973)*.

Pantano Formation

The Pantano Formation is a reddish-brown, silty sandstone, which includes gravel with interbedded volcanic flows and tuffaceous sediments. The thickness of the Pantano is estimated to range from a few hundred to 1,000 feet *(Davidson, 1973)*.

SITE GEOLOGY

Based on Davidson's *(1973)* description of the basin fill deposits, it appears that the upper 175 to 225 feet of the alluvium at the HAC facility is probably the Fort Lowell Formation. The underlying clayey sediments, encountered to a depth of 600 feet, appear to correlate with the Tinaja Beds. The entire thickness of the Tinaja Beds has not been penetrated by drillholes on the HAC facility property, and the depth to the top of the underlying Pantano Formation is not known.

The nature and distribution of geologic materials in the HAC facility area has been further defined by samples obtained from soil borings and monitor wells constructed at the site, and from interpretation of drilling logs. The soil borings were constructed with augers, and soil samples were collected directly from the auger blades. A description of the construction and sampling procedures, and lithologic logs for the soil borings appear in *Appendix B*. The monitor wells were drilled utilizing air rotary and fluid rotary drilling methods, and samples were described from the drill cuttings. Construction details and lithologic logs for the monitor wells appear in *Appendix C*.

Driller's logs for Hughes Aircraft Company wells HAC-1, HAC-2, and HAC-3 were obtained from Hughes Aircraft Company *(Appendix D)*. Driller's logs were not available for well HAC-4 and the Credit Union well. A driller's log for well SC-7 was obtained from the City of Tucson, Water Department *(Appendix D, Table D-4)*. Hydrogeologic cross sections have been constructed based on the lithologic logs and driller's logs.

Regional Aquifer

Hydrogeologic cross section A-A' has been constructed for the HAC facility area from driller's logs of the HAC production wells, the City of Tucson well SC-7 and lithologic logs of the monitor wells constructed on the facility property *(Figure 3)*. Lithologic logs and driller's logs for these wells indicate the regional aquifer comprises a sequence of sand and gravel, sandy clay, clayey sand, and clay extending to a depth of at least 600 feet below land surface at the HAC facility.

The aquifer has been divided into upper and lower zones based on lithology and measured water levels. Water levels in the upper aquifer zone are several tens of feet higher than water levels in the lower aquifer zone. The upper aquifer zone comprises fine-to-coarse sand with gravel, occasional lenses of cobbles, and lenses of clay to a depth of about 200 feet. The upper aquifer zone is probably the source of most of the groundwater produced by wells in the area *(Figure 4)*. The permeability of this zone appears to be much greater than the underlying zone.

The lower aquifer zone comprises clayey sediments underlying the upper aquifer zone to a depth of at least 600 feet *(Figure 4)*. These clayey sediments are interbedded with thin lenses of sand, sandy clay, and clayey sand.

Perched Zone

Subsurface conditions between land surface and the regional water table beneath the HAC facility have been defined by soil borings. Hydrogeologic cross sections B-B', C-C', and D-D' have been constructed through the area west of Building 801 from lithologic logs of the soil borings *(Figures 5 and 6)*.

Hydrogeologic cross section B-B' was constructed between soil borings B-1, B-2, and B-3, which were drilled at the site of abandoned wastewater disposal ponds *(Figure 3)*. These soil borings indicate that the alluvial materials above the water table comprise primarily sand, gravel, clayey sand, and sandy clay *(Figure 5)*. A red-brown clay unit was encountered in all three borings at a depth of about 80 feet below land surface. This clay unit is a perching layer of low permeability which restricts the downward migration of percolating groundwater. The water level in this perched zone is about 80 to 85 feet below land surface, which is about 25 to 40 feet above the regional water table.

Hydrogeologic cross section C-C' was constructed between soil borings B-5, B-4, and B-13 in the area north of the holding ponds and west of well HAC-1 *(Figure 3)*. These soil borings indicate that the alluvial materials above the water table in this area comprise primarily clayey sand, interbedded with lesser thicknesses of sand, gravel, and sandy clay *(Figure 5)*. A red-brown clay unit, similar to that encountered in soil borings B-1, B-2, and B-3, was also encountered in soil borings B-4, B-5, and B-13. This clay unit occurs at depths ranging from about 80 feet below land surface in soil boring B-13, to 93 feet below land surface in soil boring B-4. Perched groundwater was not encountered in this area.

Hydrogeologic cross section D-D' was constructed between soil borings B-9, B-14, B-7, and B-6 along the northern margin of the wastewater holding ponds and evaporation ponds *(Figure 3)*. Soil borings in this area encountered primarily clayey sand, interbedded with sandy clay, and thin sand lenses *(Figure 6)*. The red-brown clay unit was encountered at a depth ranging from about 70 to 80 feet below land surface *(Figure 6)*. The water

level in the perched zone was about 80 feet below land surface in boring B-9, and about 82 feet below land surface in boring B-7.

Based on the 15 soil borings constructed for the Phase I Investigation, it appears that the abandoned, unlined, wastewater disposal ponds that were used prior to 1977 were located in an area where the surficial materials are predominantly sand and sandy clay. The shallow alluvial materials between land surface and the water table throughout the facility area have sufficient permeability to allow wastewater to percolate to the regional aquifer system.

GROUNDWATER CONDITIONS

The regional aquifer system in the Tucson Basin comprises a thick sequence of alluvial basin fill sediments. The regional aquifer system in the vicinity of the HAC facility has been defined by lithologic logs of HAC production wells, monitor wells, and the City of Tucson well SC-7 *(Appendices C and D)*. The aquifer system at the HAC facility comprises coarse sand and gravel from the water table to a depth of about 200 feet. These permeable deposits are underlain by clay and sandy clay, with thin lenses of gravelly sand, to a depth of at least 600 feet *(Figure 4)*.

OCCURRENCE AND MOVEMENT

Groundwater occurs under unconfined and semi-confined conditions in the basin fill sediments in the vicinity of the HAC facility. Groundwater occurs under unconfined conditions in a perched zone in the vicinity of the abandoned wastewater holding ponds, and in the upper zone of the regional aquifer system. Groundwater occurs under semi-confined conditions in the lower zone of the regional aquifer system.

Perched Zone

Perched groundwater was encountered in exploration borings B-1, B-2, B-3, B-7, and B-9 at depths of 80 to 85 feet below land surface, or about 25 to 40 feet above the regional water table. The perched zone has apparently formed within, and directly above, an extensive red-brown clay unit found consistently beneath the HAC facility. The red-brown clay unit was encountered

at depths of about 70 to 90 feet below land surface. The occurrence of the perched groundwater appears to be related to percolation of wastewater from unlined ponds and ditches at the HAC facility. Percolation of natural runoff which entered the unlined ditches may have also contributed to the groundwater in the perched zone.

Regional Aquifer

Water levels measured in the HAC production wells, and monitor wells completed in the upper aquifer zone, indicate a depth to water ranging from about 100 to 140 feet below land surface *(Figure 4)*. Water levels measured in monitor wells M-1B and M-2C, completed in the lower aquifer zone, indicate a depth to water ranging from about 150 to 225 feet below land surface *(Figure 4)*. The difference in water levels between the upper and lower zones of the regional aquifer indicates that there is potential for downward movement of groundwater from the upper to the lower zone.

The direction of regional groundwater flow beneath the HAC facility is northwest, with a hydraulic gradient of about 15 feet per mile. Water level contour maps compiled for the years 1952, 1960, 1970, and 1980 indicate that the direction of regional groundwater movement and the hydraulic gradient have not changed significantly in the vicinity of the HAC facility since 1952 *(Figures 7 through 10)*.

A comparison of the 1952 and 1980 water level contour maps reveals significant changes in the groundwater flow regime along the Santa Cruz River, three to five miles northwest and west of the HAC facility *(Figures 7 and 10)*. Large groundwater withdrawals from wells along the river have produced depressions in

the water table surface, and reversed the direction of groundwater flow from northwest to southwest in T. 14 S., R. 13 E. *(Figure 10)*. The 1980 water level contour map also indicates a cone of depression southwest of the HAC facility *(Figure 10)*. This depression has apparently been caused by pumping from City of Tucson wells SC-10, SC-11, SC-6, and SC-16.

Comparison of the water level contours from 1952 to 1980 indicate a steepening of the water table gradient in a zone about one mile wide, extending from sections 15 and 22 of T. 15 S., R. 13 E. into section 31 of T. 14 S., R. 14 E. *(Figures 7 through 10)*. This zone is located about three miles northwest of the HAC facility. The gradient of the water table surface in this zone has ranged from about 70 feet per mile in 1952 *(Figure 7)*, to over 100 feet per mile in 1980 *(Figure 10)*. The steep gradient in this zone may be related to a decrease in aquifer transmissivity associated with faulting. Davidson *(1973)* has suggested the presence of two faults which would parallel this zone on the north and south.

GROUNDWATER PUMPAGE

Pumping of groundwater from production wells HAC-1, HAC-3, and City of Tucson well SC-7, influences the direction and rate of groundwater movement in the regional aquifer in the vicinity of the HAC facility. Historic groundwater withdrawals from wells HAC-1 and HAC-3 have been summarized for the period 1964 through 1980 based on data provided by Hughes Aircraft Company *(Figures 11 and 12)*. These data indicate that the total pumpage from well HAC-1 during the period 1964 through 1979 was about 1,200 million gallons. Average annual pumpage was about 75 million gallons *(Figure 11)*. Total pumpage from well HAC-3 during

the period 1964 through 1980 was about 1,440 million gallons. Average annual pumpage was about 85 million gallons *(Figure 12)*.

Historic pumpage from City of Tucson well SC-7 has been summarized for the period 1956 through 1980 based on data provided by the City of Tucson *(Figure 13)*. Total pumpage from well SC-7 during this period was about 3,550 million gallons. Average annual pumpage was about 142 million gallons *(Figure 13)*.

Pumping from well HAC-1 was discontinued in April 1979. Well HAC-3 has not been used since May 1981. The City of Tucson well SC-7 was also taken out of service in May 1981.

Well HAC-2 and the Credit Union well have not been pumped except for initial well testing immediately following the construction of each well. Well HAC-4 provides back-up water supply for fire protection.

HISTORIC WATER LEVEL CHANGES

The regional water table ranges in depth from about 100 to 140 feet beneath land surface at the HAC facility. The elevation of the water table ranges from about 2,465 to 2,485 feet above mean sea level *(Figure 10)*.

Water levels at well HAC-1 have declined about one foot per year since 1952 *(Figure 14)*. The depth to water at well HAC-1 has declined from about 101 feet below land surface in 1952, to 134 feet in 1980, for a net decline of 33 feet.

Water levels at City of Tucson well SC-7 have declined about 1.5 feet per year since 1947 *(Figure 15)*. The depth to water at well SC-7 ranged from 53 feet below land surface in 1947, to 99 feet in 1980, for a net decline of 46 feet.

Water levels along the Santa Cruz River to the west and northwest of the HAC facility declined as much as 100 feet during the period 1952 through 1980. The greatest water level decline has occurred near several pumping centers located along the Santa Cruz River in T. 14 S. and T. 15 S., R. 13 E. *(Figure 10)*.

CHEMICAL CHARACTER OF WATER

291

GROUNDWATER

The chemical character of groundwater in the HAC facility area has been defined by laboratory analyses of groundwater samples collected from production wells, monitor wells, and soil exploration borings. Three production wells, seven monitor wells, and five soil borings have been sampled on the facility property *(Table 1)*. Additional water quality data from production well SC-7, located west of the HAC facility, were obtained from the City of Tucson, Water Department.

The HAC production wells and City of Tucson well SC-7 have been sampled since the 1950's. Prior to 1971, chemical analyses of HAC production wells consisted of common ions only. Analyses for trace metals were not performed. Similarly, analyses for trace metals at well SC-7 were not reported until the mid-1960's.

Phase I Water Sampling

During the months of May and June 1981, five monitor wells and 15 soil borings were constructed at the HAC facility. Five of the 15 soil borings were completed as monitor wells in the perched groundwater zone.

Groundwater samples have been collected monthly from production wells HAC-1, HAC-3, HAC-4, and the Credit Union well since May 1981. Monitor wells M-1A, M-1B, M-2A, M-2B, and M-2C have been sampled monthly as they were completed. Chemical analyses include determination of concentrations of routine constituents, selected trace metals, and volatile organics. Routine

constituents comprise common ions and cyanide. Selected wells have also been sampled periodically for EPA priority pollutants *(Table 1)*.

Analyses for routine constituents and trace metals were performed by BC Laboratories, Inc., Bakersfield, California. Analyses for volatile organics and EPA priority pollutants were performed by Jacobs Laboratories, Pasadena, California. All water samples were collected and processed according to standard techniques *(Appendix E)*.

Water samples collected from well HAC-1, the Credit Union well, and the perched zone monitor well B-1 were analyzed for EPA organic priority pollutants. The EPA priority pollutants include volatile organic compounds, acid compounds, base/neutral compounds, and pesticides. A total of 113 compounds were analyzed by Jacobs Laboratories.

Stiff diagrams have been prepared for groundwater samples collected from the perched groundwater zone and the regional aquifer *(Figure 16)*. The shape of the Stiff diagram is characteristic of a particular chemical type of water. Samples of groundwater from the same aquifer, subject to similar hydrogeochemical processes, usually exhibit similarly shaped Stiff diagrams. The Stiff diagrams can often be used to identify groundwater from different zones in an aquifer system, and can also be used to identify areas where percolation of wastewater has occurred.

Perched Zone

Perched groundwater was encountered in soil borings B-1, B-2, B-3, B-7, and B-9, and in monitor well M-2A *(Figure 2)*.

The water level in the perched groundwater zone is about 25 to 40 feet above the regional water table.

COMMON IONS: Groundwater in the perched zone is a sodium sulfate and calcium sulfate type. Calcium and sodium are the principal cations, and sulfate is the principal anion in solution *(Figure 16)*. The total dissolved solids content of samples collected from the perched zone ranged from about 700 to 1,150 mg/l *(milligrams per liter) (Appendix F, Tables F-1 through F-6)*.

TRACE METALS: Significant concentrations of chromium, iron, manganese, and zinc have been detected in groundwater samples obtained from the perched zone. Borings B-1, B-2, B-3, and B-9 were completed in the perched zone in or near the abandoned wastewater disposal ponds *(Figure 2)*. Concentrations of trace metals in groundwater samples obtained from these borings are as high as 0.16 mg/l for chromium, 0.13 mg/l for iron, 1.10 mg/l for manganese, and 1.80 mg/l for zinc *(Appendix G, Tables G-1 through G-6)*. Chromium, iron, and manganese have also been detected in the perched groundwater at monitor well M-2A *(Appendix G, Table G-6)*. Total chromium ranged in concentration from 0.09 to 0.12 mg/l. Manganese and iron concentrations have ranged from 0.01 to 0.08 mg/l, and none detected to 0.13 mg/l, respectively.

The EPA has established limits for concentrations in drinking water of 0.05 mg/l for chromium, 0.05 mg/l for manganese, 0.30 mg/l for iron, and 5.0 mg/l for zinc. Consequently, concentrations of chromium and manganese in the perched groundwater exceed the limits for drinking water. The limit for manganese appears in the *Secondary Drinking Water Standards* which are based on property protection and aesthetic criteria. The limit for chromium appears in the *Primary Drinking Water Regulations*

which are based on health related criteria. The concentrations of chromium detected in the September sampling of wells in the perched zone ranged from none detected at boring B-7, to 0.12 mg/l at monitor well M-2A *(Figure 17)*.

ORGANICS: TCE, TCA, and 1,1-dichloroethylene *(DCE)* were detected in all perched zone monitor wells *(Appendix H, Tables H-1 through H-6)*. TCE concentrations in all samples collected from the perched groundwater zone ranged from none detected to more than 1,300 ppb *(parts per billion)*. Concentrations of TCE in samples collected in September 1981 indicate a range from 12 ppb at boring B-7, to more than 1,300 ppb at boring B-3 *(Figure 18)*.

TCA concentrations ranged from 5 ppb at boring B-9, to 390 ppb at boring B-7 *(Appendix H, Tables H-1 through H-6)*. The concentrations of TCA detected in the September 1981 samples indicated a range from 5 ppb to 380 ppb *(Figure 19)*.

Concentrations of DCE in the perched groundwater range from 20 ppb at monitor well M-2A to 540 ppb at boring B-3 *(Appendix H, Tables H-1 through H-6)*. The concentrations of DCE detected in the September 1981 samples ranged from 20 ppb to 480 ppb *(Figure 20)*.

A water sample collected from monitor well B-1 in September 1981 was analyzed for the EPA total organic priority pollutants, which include TCE, TCA, DCE, and 110 other organic compounds *(Appendix I, Table I-1)*. The pollutants detected included 260 ppb TCE, 390 ppb DCE, 360 ppb TCA, 65 ppb toluene, and 52 ppb of the base/neutral compound bis(2-ethylhexyl) phthalate *(Appendix I, Table I-1)*. No pesticides were found in the sample.

CONCLUSIONS: The presence of EPA priority pollutants TCE, TCA, DCE, toluene, and bis(2-ethylhexyl) phthalate in the perched zone indicates that percolation of liquid wastes did occur from the abandoned, unlined wastewater holding ponds, and from the ditch located north of the evaporation ponds. These organic substances are man-made, and do not occur naturally in the perched groundwater.

The presence of hexavalent chromium in the perched zone exceeding ambient concentrations in the regional aquifer also indicates that wastewater has percolated to the perched groundwater zone from overlying surface disposal sites and ditches. The high concentrations of manganese might be related to the natural occurrence of manganese oxide in desert alluvial soils, or to percolation of wastewater. The concentration of iron and zinc in the perched groundwater zone might also be related to natural occurrence of these elements in the soils, or to percolation of wastewater.

Regional Aquifer

Groundwater samples from the regional aquifer were obtained from production wells HAC-1, HAC-3, and HAC-4, and from monitor wells HAC-2, Credit Union, M-1A, M-1B, M-2B, and M-2C. Water quality data obtained from these wells and from City of Tucson well SC-7 have been used to define the chemical character of groundwater in the regional aquifer system. Summaries of chemical analyses of water samples from the HAC production wells and monitor wells are contained in *Appendices F, G, H,* and *I.* Production wells HAC-1, HAC-3, HAC-4, and SC-7; and monitor wells HAC-2 and the Credit Union, are perforated in both the upper and lower aquifer zones. Because the upper aquifer zone is

more permeable than the lower zone, most of the water produced is from the upper aquifer zone. Consequently, the water samples collected from these wells are primarily representative of the upper aquifer zone.

COMMON IONS: Groundwater in the upper zone of the regional aquifer is predominantly a calcium bicarbonate type *(Figure 16)*. The upper aquifer zone extends from the water table to a depth of about 200 feet, and comprises coarse sand and gravel with lenses of clayey sand and sandy clay *(Figure 4)*. Water samples from the lower zone of the regional aquifer have been obtained from wells M-1B and M-2C. Groundwater from the lower aquifer zone is a sodium sulfate to sodium bicarbonate type *(Figure 16)*. The difference in the chemical character of groundwater in the upper and lower aquifer zones is probably the result of differences in permeability and circulation, ion exchange between the groundwater and the aquifer materials, and the presence of soluble salts in the aquifer.

The chemical character of groundwater obtained from the Credit Union well is anomalous when compared to other wells penetrating the regional aquifer. Groundwater obtained from the Credit Union well is a calcium sulfate type, with an average total dissolved solids content of about 650 mg/l *(Figure 16)*. Groundwater obtained from other wells penetrating the upper zone of the regional aquifer is a calcium bicarbonate type with average total dissolved solids contents ranging from about 260 to 390 mg/l *(Figure 16)*. The chemical character of groundwater from the Credit Union well is similar to groundwater in the perched zone, and suggests that this well has been contaminated by percolating wastewater.

Unlike the groundwater obtained from the Credit Union well, the chemical character of groundwater at well SC-7 is similar

to that observed for other wells penetrating the upper zone of the regional aquifer in the vicinity of the HAC facility *(Figure 16)*. Groundwater obtained from City of Tucson well SC-7 is a calcium bicarbonate type, with a total dissolved solids content of about 340 ppm.

TRACE METALS: Chromium, zinc, manganese, and arsenic have been detected in groundwater obtained from monitor wells penetrating the regional aquifer at the HAC facility *(Appendix G)*. Chromium is the only trace metal detected in the regional aquifer which exceeds the drinking water standard of 0.05 mg/l. The total chromium content at well HAC-1 has ranged from 0.02 to 0.41 mg/l, with most concentrations greater than 0.20 *(Appendix G, Table G-7)*. The total chromium content at the Credit Union well has ranged from 0.11 to 0.20 mg/l *(Appendix G, Table G-11)*. Groundwater samples obtained from other wells perforated in the upper zone of the regional aquifer have chromium contents less than 0.05 mg/l *(Figure 17)*. Monitor wells M-2C and M-1B, which are perforated only in the lower aquifer zone, also have chromium contents less than 0.05 mg/l *(Figure 17)*.

Results of chemical analyses for chromium in groundwater samples obtained from City of Tucson well SC-7 are available for the period 1964 to 1981. Chromium contents during this period have ranged from none detected to 0.07 mg/l *(Appendix G, Table G-26)*. The highest concentration of 0.07 mg/l was reported in 1977. Since 1978, the chromium concentrations in the groundwater have remained at 0.03 mg/l, which is below the 0.05 mg/l standard.

Minor amounts of zinc and manganese have been detected in some groundwater samples obtained from the regional aquifer. These constituents are probably derived naturally from the basin

fill sediments. Fluoride and arsenic were also detected in monitor well M-2C, which taps the lower aquifer zone *(Appendix F, Table F-15; Appendix G, Table G-15)*. Similar concentrations of arsenic and fluoride have been reported for wells northwest of the HAC facility in the vicinity of the projected surface trace of the Santa Cruz fault *(Laney, 1972)*. The projected surface trace of the Santa Cruz fault is located about 2,000 feet west of the HAC facility.

ORGANICS: TCE was detected in eight of nine wells completed in the regional aquifer at the HAC facility. Significant concentrations were detected in samples obtained from wells HAC-1, HAC-4, the Credit Union, and M-2B *(Figure 18)*. Concentrations of TCE in these wells have ranged from 89 ppb at well HAC-4 to 2,700 ppb at the Credit Union well *(Appendix H, Tables H-7, H-10, H-11, and H-14)*. TCE concentrations in the other wells were less than 10 ppb.

TCA was detected in samples collected from wells HAC-1 and the Credit Union *(Appendix H, Tables H-7 and H-11)*. Samples collected in September 1981 from these wells indicated TCA concentrations of 13 ppb at well HAC-1, and 6 ppb at the Credit Union Well *(Figure 19)*.

DCE was detected in five wells completed in the regional aquifer at the HAC facility. Significant concentrations of DCE were detected in water samples obtained from wells HAC-1 and the Credit Union *(Appendix H, Tables H-7 and H-11)*. The concentrations of DCE present in the September 1981 samples were 47 ppb in well HAC-1, and 160 ppb in the Credit Union well *(Figure 20)*. DCE concentrations in the other wells were less than 10 ppb.

Water samples obtained from wells HAC-1 and the Credit Union were analyzed for EPA priority pollutants *(Appendix I, Tables I-2 and I-3)*. The only priority pollutants detected in well HAC-1 were TCE, TCA, and DCE. Acid compounds, base/neutral compounds, and pesticides were not found in the water sample. Several of the EPA priority pollutants were detected in the Credit Union well, including TCE, TCA, DCE, 1,2-trans-dichloroethylene, phenol, and di-n-butyl phthalate *(Appendix I, Table I-3)*.

Water samples were collected from City of Tucson well SC-7 in March and May 1981 by EPA *(Ecology and Environment, Inc., 1981)*. Analysis of these water samples by EPA indicated TCE concentrations of 77 and 66 ppb *(Figure 18)*, and DCE concentrations of 11 and 2.1 ppb *(Figure 20)*.

CONCLUSIONS: The occurrence of TCE, DCE, and TCA in the perched groundwater zone and in the regional aquifer indicates that these organic compounds were constituents of the wastewaters discharged at the HAC facility. Because TCE, TCA, and DCE are not naturally occurring substances, the presence of these compounds in the upper zone of the regional aquifer system indicates that infiltration and percolation of wastewaters has occurred, and that wastewater has reached the regional aquifer system.

The presence of elevated chromium concentrations in water samples obtained from wells perforated in the upper aquifer zone also indicates that percolation of wastewater to the regional aquifer system has occurred in the HAC facility area. The absence of chromium in water samples obtained from monitor wells perforated only in the lower aquifer zone indicates that migration of contaminants to the lower aquifer zone has not occurred.

The zinc, manganese, arsenic, and fluoride detected in groundwater samples obtained from the regional aquifer are probably naturally occurring and unrelated to wastewater disposal practices.

The presence of toluene and bis(2-ethylhexyl) phthalate in the perched groundwater zone also indicates that organic compounds were discharged to the unlined wastewater disposal ponds, and that fluids from these ponds percolated to the perched groundwater zone. The 1,2-trans-dichloroethylene, phenol, and di-n-butyl phthalate detected in the Credit Union well suggest that wastewaters of a different origin may have affected the groundwater quality in the area of the Credit Union.

CONCENTRATION OF TRACE METALS AND ORGANICS IN SOIL SAMPLES

Soil samples were collected from 15 borings drilled at abandoned waste disposal pits, ponds, and ditches *(Figure 2)*. A total of 401 soil samples were collected and analyzed in order to determine the nature and concentration of wastes disposed of at known or suspected waste disposal sites. Concentrations of trace metals and organics significantly greater than laboratory detection limits were used to verify the location and type of waste disposed of at each site. The soil samples were prepared and analyzed for trace metals by BC Laboratories, Inc., Bakersfield, California, in accordance with procedures and methods recommended by the EPA *(Appendix J)*. Analyses for TCE, TCA, and DCE were performed on 77 selected soil samples by Jacobs Laboratories, Pasadena, California, in accordance with procedures and methods recommended by the EPA *(Appendix J)*.

TRACE METALS

Soil sample extracts were analyzed for 14 selected trace metals: iron, manganese, copper, molybdenum, lead, chromium, selenium, cadmium, mercury, silver, zinc, nickel, arsenic, and barium *(Appendix K)*. Detection limits for the trace metals analyzed in the soil sample extracts are presented in *Table* 2.

Exploration borings B-1, B-2, B-3, B-9, B-10, and B-11 were drilled at the sites of abandoned wastewater and sludge disposal ponds. These sites were used to dispose of waste fluids and sludges containing high concentrations of various metals. Analyses of soil samples collected from these borings

indicate high metal concentrations in the upper five to 10 feet of soil *(Appendix K, Tables K-1 through K-3, and K-9 through K-11)*.

Borings B-1, B-2, and B-3 were drilled at the site of two abandoned disposal ponds located west of the wastewater treatment plant *(Figure 2)*. Trace metal concentrations greater than the detection limits were reported for chromium, copper, cadmium, zinc, and nickel in the upper 10 feet of soil. In general, the greatest concentrations of trace metals were found in the upper two to three feet of soil.

Borings B-10 and B-11 were drilled at the site of two abandoned sludge disposal ponds located east of Building 801 *(Figure 2)*. Boring B-11 penetrated a plastic membrane and a clay layer which lined the bottom of the northern disposal pond. Boring B-10 penetrated a plastic membrane which lined the southern disposal pond. Trace metal concentrations greater than the detection limits for chromium, cadmium, nickel, arsenic, copper, silver, and zinc, were reported in soil samples from borings B-10 and B-11 *(Appendix K, Tables K-10 and K-11)*. Significant concentrations of these elements were limited to the upper six feet of soil at boring B-10. Significant concentrations of trace metals were detected in boring B-11 to a depth of 10.5 feet, which was the maximum depth of the soil boring.

Boring B-9 was drilled at the site of an abandoned disposal pond which was located beneath portions of evaporation ponds 3 and 4 *(Figure 2)*. Boring B-9 penetrated a layer of green clay in the depth interval 3.00 to 3.75 feet *(Appendix K, Table K-9)*. This clay layer appears to have been the bottom of the pond. Precipitates of copper and other metals probably cause the green color in the clay. Concentrations of manganese, copper, cadmium, zinc, and nickel in the green clay were 1.6, 110, 3.4, 7.0, and 1.65 mg/l, respectively.

Exploration borings B-4, B-5, B-6, B-12, B-I3, and B-15 were drilled at the site of suspected abandoned waste disposal pits. Significant concentrations of trace metals were not reported for soil samples from these borings *(Appendix K, Tables K-4, K-5, K-6, K-12, K-13, and K-15)*.

Exploration borings B-7, B-8, and B-14 were drilled in, or adjacent to, the ditch which is located north of the holding ponds and evaporation ponds *(Figure 2)*. Significant concentrations of trace metals were not reported for soil samples obtained from these borings *(Appendix K, Tables K-7, K-8, and K-14)*.

Conclusions

Based on the results of chemical analyses of soil sample extracts, it appears that the unlined, abandoned wastewater disposal ponds, and the sludge disposal ponds were probably the principal disposal sites for wastewater and sludge containing trace metals. Chemical analyses of soil samples obtained beneath suspected disposal pits and ponds indicate that significant trace metal concentrations usually occurred in the upper 10 feet of soils. The mobility of trace metals is related to the pH of the soils. The pH of the soils at the HAC facility ranged from about 8 to 10 *(Appendix K)*. The alkaline nature of the soils beneath the abandoned disposal ponds and sludge ponds probably caused attenuation of most of the trace metals in the upper 10 feet of soils.

Chemical analyses of soil samples obtained beneath suspected disposal pits indicate that the pits are probably not sources of trace metal contamination for the groundwater system.

Manganese was consistently detected throughout the depth interval penetrated by the soil borings. The source of manganese in the soil samples is probably manganese oxide, which occurs as a thin, black varnish or coating on soil particles. The low solubility of manganese in alkaline soils, and the natural occurrence of the manganese oxide in soils, suggests that manganese would be a naturally occurring trace metal in the type of soil found at the HAC facility *(Harmsen, 1977)*.

ORGANIC CONSTITUENTS

Chemical analyses were performed on 77 selected soil samples from the soil borings to determine the concentrations of TCE, TCA, and DCE *(Table 3)*. Concentrations of TCE were found in all borings except B-11 *(Figure 21)*. Concentrations of TCE were usually less than 20 ppb, but were as high as 45 ppb. Concentrations of TCA were reported only in soil samples from borings B-9 and B-13. DCE was not detected in any of the soil samples.

The highest concentrations of TCE were found in soil samples collected from borings B-12, B-13, and B-15, which were drilled at suspected waste disposal pits *(Figure 2)*. TCE concentrations in soils at these three sites averaged about 20 ppb, with concentrations as high as 45 ppb *(Table 3)*. In general, TCE concentrations increased with depth, which might reflect the volatile nature of TCE and the decreasing effect of evaporation with depth.

Borings B-4, B-5, and B-6 were drilled at the sites of suspected waste disposal pits *(Figure 2)*. TCE concentrations in these borings ranged from none detected to 13 ppb.

Borings B-1, B-3, and B-9 were drilled at abandoned disposal pond sites north and west of the lined evaporation ponds. TCE concentrations in soil samples from these borings averaged about 8 ppb and ranged from none detected to 32 ppb *(Table 31)*.

Boring B-10 was drilled through an abandoned sludge disposal pond located east of Building 801 *(Figure 2)*. TCE concentrations in soil samples obtained from boring B-10 ranged from none detected to 5 ppb. TCE was not detected in the soil samples obtained from boring B-11, which was also drilled through an abandoned sludge pond located east of Building 801.

Borings B-7, B-8, and B-14 were drilled along the drainage ditch north of the evaporation and holding ponds *(Figure 21)*. Concentrations of TCE in soil samples from these borings ranged from 3 to 36 ppb.

Conclusions

Results of chemical analyses of soil samples indicate that TCE was discharged in wastewater to the unlined ditch and abandoned disposal ponds, and was also disposed of in several pits at the HAC facility. In general, concentrations of TCE in the soils were greatest at the sites of suspected disposal pits. Based on these data, it is concluded that the disposal pits in the areas of borings B-12, B-13, and B-15 were the principal disposal sites for TCE.

Concentrations of TCE as high as 45 ppb were detected at a depth of 95 feet, which was the maximum depth of samples analyzed. These data indicate that TCE is mobile in the subsurface, and is probably not significantly attenuated by the soils. It is concluded that TCE has probably percolated to the regional aquifer system beneath the HAC facility.

REFERENCES

Davidson, E. S., 1973, *Geohydrology and water resources of the Tucson basin, Arizona*. U. S. Geological Survey Water-Supply Paper 1939-E.

Ecology and Environment, Inc., 1981, *Field investigations of uncontrolled hazardous waste sites*. Task Report to the Environmental Protection Agency, Contract no. 68-01-6056, Preliminary Site Inspection Report, April 15, 1981.

Environmental Protection Agency, 1980, *Test methods for evaluating solid waste, physical/chemical methods*. Waste Characterization Branch, Office of Solid Waste, May 1980.

Harmsen, K., 1977, *Behaviour of heavy metals in soils*. Centre for Agricultural Publishing and Documentation, Wageningen, Netherlands, Agricultural Research Report no. 866.

Laney, R. L., 1972, *Chemical quality of the water in the Tucson Basin, Arizona*. U. S. Geological Survey Water-Supply Paper 1939-D.

Spaulding, E. K., 1980, *Written communication to U. S. Environmental Protection Agency*, Manager Environmental Health and Safety, Hughes Aircraft Company, Tucson Manufacturing Division, August 8, 1980.

TABLES

TABLE 1

SUMMARY OF WATER SAMPLES COLLECTED FROM WELLS
HUGHES AIRCRAFT COMPANY, TUCSON, ARIZONA

WELL IDENTIFICATION	DATE SAMPLED - 1981														
	1/22[a]	1/31[a]	3/5[a]	5/6[b]	5/18[b]	5/26[b]	5/27[a]	6/5[b]	6/24[b]	7/2[b]	7/15[b]	7/30[b]	8/3[b]	9/11[b]	9/12[b]
HAC-1	T,R		T		T,R		T			T,R			O,T	O,T,C,P	
HAC-2		T,R			T,R		T			T,R			O,T	O,T	
HAC-3	T,R		T		T,R		T			T,R			O,T	O,T	
HAC-4	T,R		T		T,R		T			T,R			O,T	O,T	
CREDIT UNION					T,R	T				T,R			O,T	O,T,C,P	
M-1A						T,R					T,R		O	O,T	
M-1B						T,R					T,R		O	O,T	
M-2A				T,R								O,T,R			O,T
M-2B						T,R					T,R		O	O,T	
M-2C								T,R			T,R		O	O,T	
B-1									T,R			O,T			O,T,C,P
B-2									T,R			O,T,R			O,T
B-3									T,R			O,T			O,T
B-7									T			O,T			O,T
B-9									T,R			O,T,R			O,T

EXPLANATION

Chemical Analyses:

- O - Volatile organics
- T - Trace metals
- R - Common ions
- C - Cyanide
- P - EPA priority pollutants

[a]Samples collected by Hughes Aircraft Company

[b]Samples collected by Hargis & Montgomery, Inc.

HARGIS & MONTGOMERY, INC
TUCSON, ARIZONA

TABLE 2

LABORATORY DETECTION LIMITS
FOR TRACE METALS

CONSTITUENTS	DETECTION LIMIT *(milligrams per liter)*
Iron	0.1
Manganese	0.05
Copper	0.05
Molybdenum	0.1
Lead	0.05
Chromium	0.025
Selenium	0.01
Cadmium	0.01
Mercury	0.2
Silver	0.05
Zinc	0.05
Nickel	0.01
Arsenic	0.01
Barium	1.0

(From BC Laboratories, Inc., Bakersfield, California)

TABLE 3

CONCENTRATION OF ORGANIC CONSTITUENTS IN SOIL SAMPLES

BORING NUMBER	DEPTH OF SAMPLE[1]	TCE (ppb)[2]	TCA (ppb)	DCE (ppb)
B-1	0-1	ND[3]	ND	ND
	1-2	2	ND	ND
	3-4	4	ND	ND
	7-8	8	ND	ND
	14-15	11	ND	ND
	30-31	7	ND	ND
	35-36	20	ND	ND
	50-51	15	ND	ND
	70-71	3	ND	ND
	77-78	18	ND	ND
B-3	5-6	5	ND	ND
	7-8	3	ND	ND
	19-20	2	ND	ND
	45-46	8	ND	ND
	80-81	2	ND	ND

Analyses performed by Jacobs Laboratories, Pasadena, California

[1]Depth below land surface, in feet.
[2]Parts per billion.
[3]None detected.

TABLE 3
CONCENTRATIONS OF ORGANIC CONSTITUENTS IN SOIL SAMPLES

BORING NUMBER	DEPTH OF SAMPLE[1]	TCE (ppb)[2]	TCA (ppb)	DCE (ppb)
B-4	1-2	2	ND[3]	ND
	6-7	5	ND	ND
	20-21	3	ND	ND
	54-55	7	ND	ND
	90-91	6	ND	ND
B-5	1-2	12	ND	ND
	6-7	9	ND	ND
	20-21	6	ND	ND
	49-50	3	ND	ND
	84-85	ND	ND	ND
B-6	1-2	2	ND	ND
	5-6	ND	ND	ND
	21-22	13	ND	ND
	49-50	5	ND	ND
	95-96	4	ND	ND

Analyses performed by Jacobs Laboratories, Pasadena, California

[1]Depth below land surface, in feet.
[2]Parts per billion.
[3]None detected.

312

TABLE 3
CONCENTRATIONS OF ORGANIC CONSTITUENTS IN SOIL SAMPLES

BORING NUMBER	DEPTH OF SAMPLE[1]	TCE (ppb)[2]	TCA (ppb)	DCE (ppb)
B-7	1-2	3	ND[3]	ND
	7-8	6	ND	ND
	35-36	12	ND	ND
	59-60	4	ND	ND
	65-66	10	ND	ND
	80-81	3	ND	ND
	84-85	13	ND	ND
B-8	1-2	13	ND	ND
	4-5	11	ND	ND
	5-6	11	ND	ND
B-9	1-2	17	ND	ND
	3-3.75	6	11	ND
	9-10	5	ND	ND
	39-40	11	ND	ND
	74-75	32	ND	ND

Analyses performed by Jacobs Laboratories, Pasadena, California

[1]Depth below land surface, in feet.
[2]Parts per billion.
[3]None detected.

TABLE 3
CONCENTRATIONS OF ORGANIC CONSTITUENTS IN SOIL SAMPLES

BORING NUMBER	DEPTH OF SAMPLE[1]	TCE (ppb)[2]	TCA (ppb)	DCE (ppb)
B-10	1-1.1	ND	ND[3]	ND
	7-8	ND	ND	ND
	29-30	ND	ND	ND
	49-50	5	ND	ND
	69-70	2	ND	ND
	94-95	4	ND	ND
B-11	1-2	ND	ND	ND
	3-4	ND	ND	ND
	5-6	ND	ND	ND
	7-8	ND	ND	ND
B-12	2-3	16	ND	ND
	11-12	29	ND	ND
	21-22	12	ND	ND
	44-45	34	ND	ND
	74-75	18	ND	ND

Analyses performed by Jacobs Laboratories, Pasadena, California

[1]Depth below land surface, in feet.
[2]Parts per billion.
[3]None detected.

TABLE 3
CONCENTRATIONS OF ORGANIC
CONSTITUENTS IN SOIL SAMPLES

BORING NUMBER	DEPTH OF SAMPLE	TCE (ppb)	TCA (ppb)	DCE (ppb)
B-13	1-2	6	ND [3]	ND
	4-5	11	ND	ND
	9-10	7	ND	ND
	13-14	14	2	ND
	29-30	10	ND	ND
	40-41	33	ND	ND
	49-50	35	ND	ND
	75-76	11	ND	ND
	80-81	25	ND	ND
	94-95	41	ND	ND
B-14	10-11	36	ND	ND
	24-25	14	ND	ND
B-15	3-4	5	ND	ND
	8-10	11	ND	ND
	16-18	24	ND	ND
	44-45	32	ND	ND
	94-95	45	ND	ND

Analyses performed by Jacobs Laboratories, Pasadena, California

[1]Depth below land surface, in feet.
[2]Parts per billion.
[3]None detected.

ILLUSTRATIONS

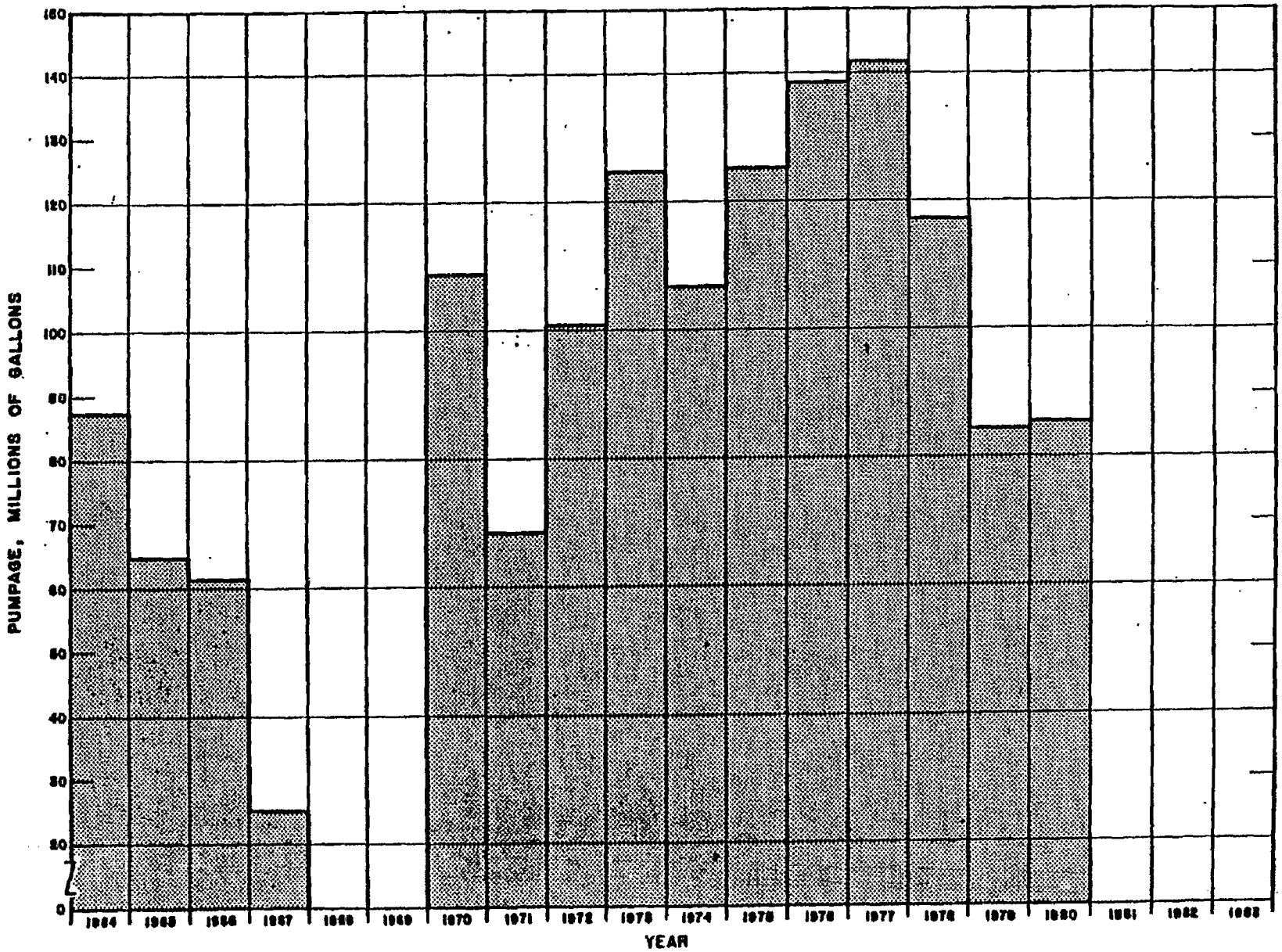


FIGURE 12. PUMPAGE FROM WELL HAC-3

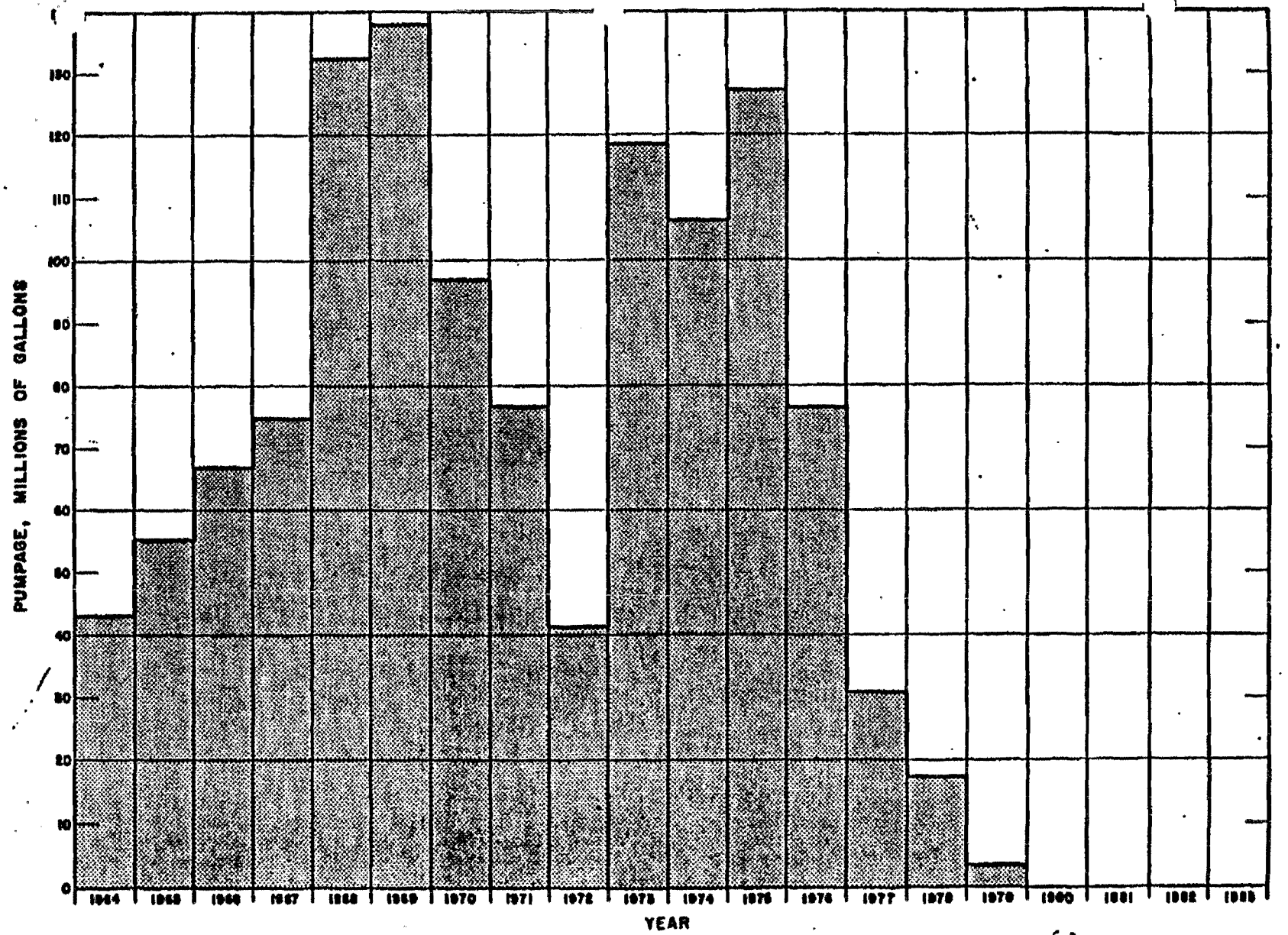


FIGURE 11. PUMPAGE FROM WELL HAC-1

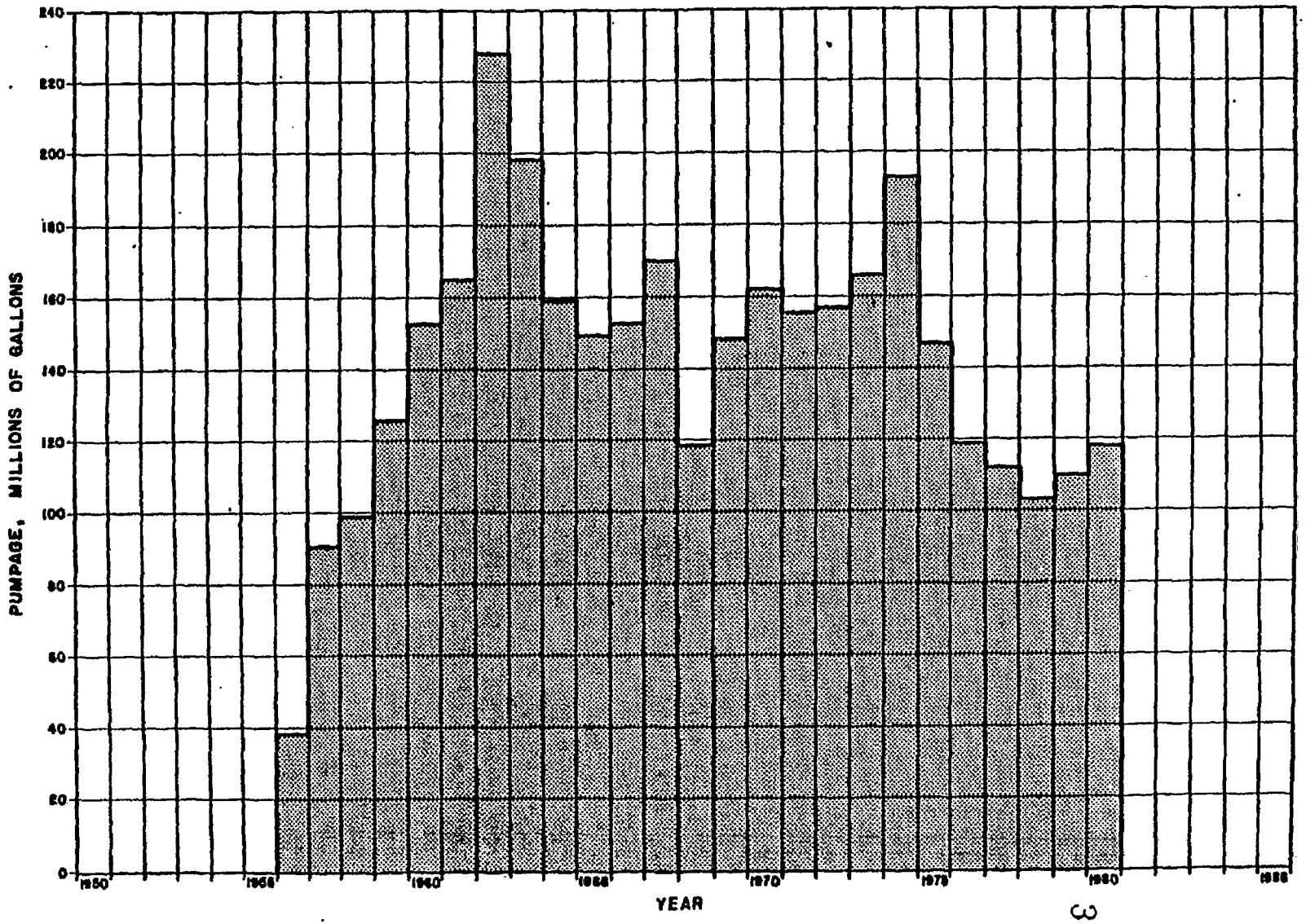


FIGURE 13. PUMPAGE FROM CITY OF TUCSON WELL SC-7

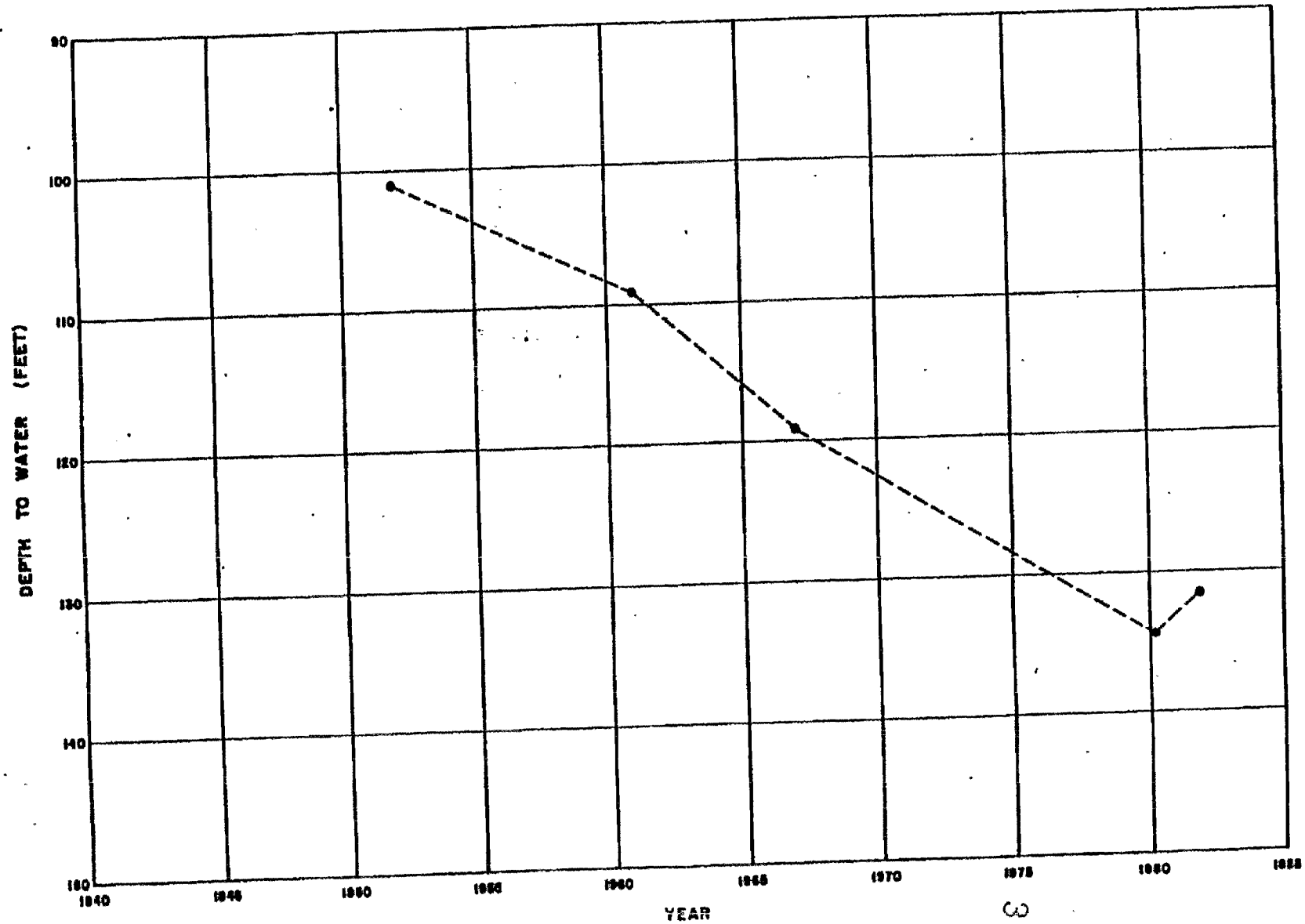


FIGURE 14. WATER LEVEL HYDROGRAPH FOR WELL HAC-1

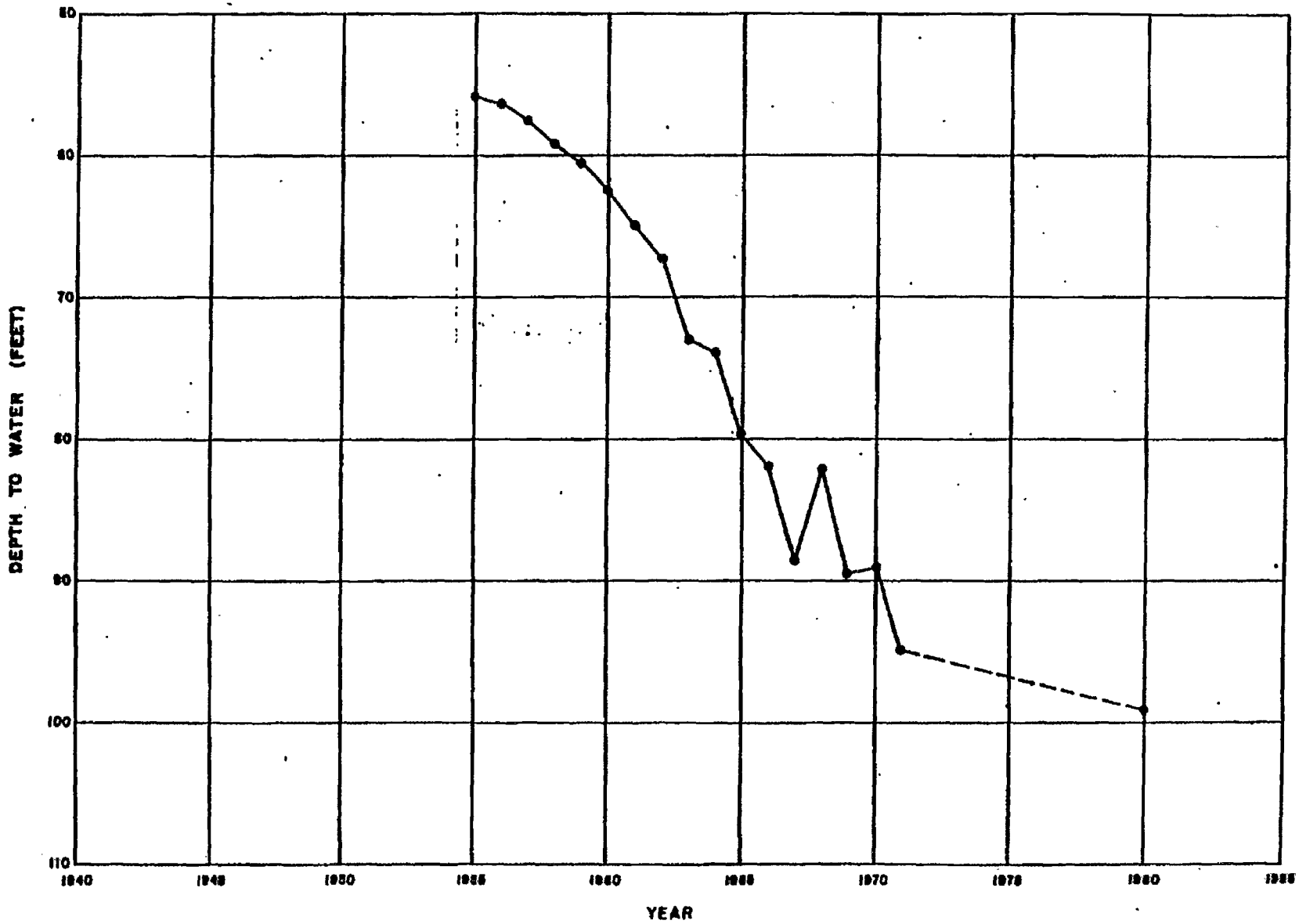


FIGURE 15. WATER LEVEL HYDROGRAPH FOR CITY OF TUCSON WELL SC-7

MARCH 12, 1982

PHASE II
INVESTIGATION OF SUBSURFACE CONDITIONS IN THE VICINITY OF ABANDONED WASTE DISPOSAL SITES HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY TUCSON, ARIZONA

VOLUME I

REGISTERED GEOLOGIST
CERTIFICATE NO.
11364
DAVID R.
HARGIS
Date Signed 3/12/82
ARIZONA, U.S.A.

HARGIS & MONTGOMERY, INC.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

CONTENTS

	PAGE
CONCLUSIONS	1
RECOMMENDATIONS	4
INTRODUCTION	5
HYDROGEOLOGIC CONDITIONS	8
REGIONAL AQUIFER	8
Upper Zone	9
Lower Zone	9
PERCHED ZONE	10
HYDRAULIC CHARACTER OF REGIONAL AQUIFER	12
LONG-TERM AQUIFER TESTS	12
Well HAC-1 Aquifer Test	13
Well HAC-3 Aquifer Test	13
Well HAC-4 Aquifer Test	14
SHORT-TERM AQUIFER TESTS	14
CONCLUSIONS	15
CHEMICAL QUALITY OF WATER	17
GROUNDWATER	17
Phase II Water Sampling	17
Perched Zone	18
Common Ions	18
Trace Metals	19
Organics	19
Conclusions	20
Regional Aquifer	21
Common Ions	22
Trace Metals	22
Organics	23
Conclusions	24

CONTENTS ---

338

PAGE

CONCENTRATION OF TRACE METALS AND ORGANICS IN SOIL SAMPLES..... 27

TRACE METALS..... 27

Conclusions..... 28

ORGANIC CONSTITUENTS 28

Conclusions 29

REFERENCE CITED..... 30

TABLES

TABLE

1 WATER LEVELS IN THE REGIONAL AQUIFER

2 WATER LEVELS IN THE PERCHED ZONE

3 SUMMARY OF AQUIFER PARAMETERS

ILLUSTRATIONS

FIGURE		
1	WELLS AND SOIL BORINGS	(In pocket, Volume II)
2	LOCATION OF HYDROGEOLOGIC CROSS SECTIONS	(In pocket, Volume II)
3	HYDROGEOLOGIC CROSS SECTIONS	(In pocket, Volume II)
4	WATER LEVEL CONTOURS, PERCHED ZONE	(In pocket, Volume II)
5	SCHEMATIC DIAGRAM OF TEST PUMP ASSEMBLY	
6	CONCENTRATION OF TCE, TCA, DCE, AND TOTAL CHROMIUM IN PERCHED ZONE	(In pocket, Volume II)
7	CONCENTRATION OF TOTAL CHROMIUM IN REGIONAL AQUIFER	(In pocket, Volume II)
8	CONCENTRATION OF TCE IN REGIONAL AQUIFER	(In pocket, Volume II)
9	CONCENTRATION OF TCA IN REGIONAL AQUIFER	(In pocket, Volume II)
10	CONCENTRATION OF DCE IN REGIONAL AQUIFER	(In pocket, Volume II)

APPENDICES

340

APPENDIX	
A	DRILLING, CONSTRUCTION, AND LITHOLOGIC LOGS OF SOIL BORINGS
B	DRILLING, CONSTRUCTION, AND LITHOLOGIC LOGS OF MONITOR WELLS
C	WATER SAMPLE COLLECTION AND DOCUMENTATION
D	CONCENTRATION OF ROUTINE CONSTITUENTS IN WATER SAMPLES
E	CONCENTRATION OF TRACE METALS IN WATER SAMPLES
F	CONCENTRATION OF ORGANICS IN WATER SAMPLES
G	RESULTS OF CHEMICAL ANALYSES FOR EPA PRIORITY POLLUTANTS IN WATER SAMPLES
H	ANALYTICAL AND SAMPLE EXTRACT PROCEDURES FOR SOIL SAMPLES
I	CONCENTRATION OF TRACE METALS AND ORGANIC CONSTITUENTS IN SOIL SAMPLES

PHASE II

INVESTIGATION OF SUBSURFACE CONDITIONS IN THE VICINITY OF ABANDONED WASTE DISPOSAL SITES HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY TUCSON, ARIZONA

CONCLUSIONS

Analysis of geologic and hydrologic data collected at the Hughes Aircraft Company *(HAC)* Manufacturing Facility in Tucson, Arizona during the Phase II investigation indicates the following:

1. Concentrations of trichloroethylene *(TCE)* greater than 10,000 ppb *(parts per billion)* occur in the regional aquifer beneath the HAC facility site. High concentrations of chromium, 1,1,1-trichloroethane *(TCA)*, and 1,1-dichloroethylene *(DCE)* also occur in the regional aquifer beneath the HAC facility.

2. Solvent disposal pits located in the area west of Building 801 and north of the wastewater treatment plant were probably the principal

sources of TCE, TCA, and DCE that have contaminated the regional aquifer. Residual concentrations of these organic compounds in the soils in this area are low, and indicate that these abandoned pits are no longer sources of contamination.

3. The abandoned sludge disposal pits east of Building 801 were the principal source of chromium that has contaminated the regional aquifer. Although scattered high residual concentrations of chromium occur in the soils beneath the abandoned pits, the absence of percolating fluid to mobilize the chromium effectively eliminates this source of contamination.

4. Contamination of the regional aquifer north of the HAC facility property boundary has probably occurred as a result of historic waste disposal practices at the HAC facility. TCE concentrations greater than 2,000 ppb, DCE concentrations greater than 100 ppb, and TCA concentrations greater than 10 ppb probably occur in the regional aquifer north of the HAC facility property boundary.

5. Contamination of the regional aquifer with chromium has apparently been limited to a small area beneath the HAC facility due to historic pumping of production well HAC-1. Although some of the chromium contamination may extend north of the facility property

boundary in the vicinity of the Credit Union well, the contribution of historic disposal practices to off-site chromium contamination is probably small.

6. The perched groundwater zone discovered in the area beneath the abandoned wastewater disposal ponds and ditches is apparently confined to an area of about 100 acres on the HAC facility property. Contaminated groundwater in the perched zone does not pose an immediate threat to water quality in the regional aquifer off-site.

RECOMMENDATIONS

The data collected during the Phase I and Phase II investigations provide an adequate base to design a groundwater clean-up system at the HAC facility. The extent and concentration of contaminants in the regional aquifer northwest of the HAC facility are unknown. The following are recommended:

1. Monthly sampling and chemical analysis of groundwater for inorganic and organic constituents from the monitor wells and HAC production wells should continue.

2. A groundwater recovery and treatment system should be designed and implemented as soon as possible for the regional aquifer beneath the HAC facility.

PHASE II

INVESTIGATION OF SUBSURFACE CONDITIONS IN THE VICINITY OF ABANDONED WASTE DISPOSAL SITES HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY TUCSON, ARIZONA

INTRODUCTION

Pursuant to a request from Mr. David L. Mulliken, Attorney, Latham & Watkins, this summary report of the Phase II investigation at the Hughes Aircraft Company *(HAC)* Manufacturing Facility in Tucson, Arizona has been prepared. The objectives of the Phase II investigation were as follows:

1. Define the distribution of contaminants in the regional aquifer system.

2. Determine which sites were used to dispose of organic solvents, and determine the residual concentration of contaminants in the soils.

3. Estimate the contribution of contaminants from the HAC facility to off-site groundwater contamination.

The design of the Phase II investigation was based on data collected during the Phase I investigation, which was conducted from May through October 1981 *(Hargis & Montgomery, Inc., 1982)*. The Phase I investigation comprised drilling exploratory soil borings at suspected disposal sites, collection of soil samples from the borings for determination of contaminant concentrations, and construction of monitor wells for collection of groundwater samples. During the Phase I investigation, a zone of perched groundwater was discovered beneath the area of the abandoned wastewater disposal ponds. Selected soil borings were completed as monitor wells in this perched groundwater zone. Chemical analyses of water samples collected from these wells indicated the presence of contaminants in the perched groundwater.

Data collected during the Phase I investigation indicated that the regional aquifer system in the HAC facility area comprises two distinct water-bearing zones. They have been designated the upper and lower zones, and are separated by a clay unit which restricts water movement between the zones *(Hargis & Montgomery, Inc., 1982)*. Chemical analyses of water samples collected from monitor wells penetrating the upper and lower zones indicated that the zones contain groundwater of different chemical quality, and that contamination of the aquifer beneath the site has apparently been limited to the upper zone. The Phase I investigation also included determination of historic water level changes, pumpage volumes, and the direction of groundwater movement in the regional aquifer system.

The Phase II investigation included drilling additional soil borings at known and suspected disposal sites *(Figure 1)*. Soil samples collected from the soil borings were analyzed for selected organic compounds. Monitor wells were constructed in the perched groundwater zone, and in the upper and lower zones of the regional aquifer, to determine the distribution and concentration of

contaminants. Pumping tests were conducted in production wells HAC-1, HAC-3, and HAC-4 to provide data on the hydraulic character of the regional aquifer.

HYDROGEOLOGIC CONDITIONS

The regional geologic setting, local structural features, and hydrogeologic conditions at the HAC facility were described in the report of the Phase I investigation *(Hargis & Montgomery, Inc., 1982)*. The Phase I investigation comprised construction and sampling of soil borings and monitor wells completed in the perched groundwater zone and regional aquifer. During the Phase II investigation, the areal extent and hydrogeologic character of the regional aquifer and perched groundwater zone at the HAC facility were further defined with data obtained from additional monitor wells and soil borings. Lithologic logs of materials penetrated by the soil borings and monitor wells defined the geologic nature of the perched zone and regional aquifer *(Appendices A and B)*. Hydrogeologic cross sections were constructed based on these data *(Figure 2)*. Additional data concerning the hydraulic character of the regional aquifer was obtained from pumping tests in monitor wells and the HAC production wells.

REGIONAL AQUIFER

The nature of the regional aquifer in the HAC facility area has been defined by data obtained from monitor wells and the HAC production wells. A total of 24 monitor wells have been constructed in the regional aquifer at the HAC facility during the Phase I and Phase II investigations *(Figure 1)*. Hydrogeologic cross sections constructed from lithologic logs of the monitor wells indicate that the regional aquifer comprises an upper zone and lower zone separated by a thick sequence of clayey sediments. An extensive clay layer also occurs above the water table. This clay layer retards the downward migration of fluids and has caused the development of a perched groundwater zone above the regional water table.

Upper Zone

The upper zone of the regional aquifer comprises gravell sand with some clayey sand and sandy clay. The upper zone ex tends from the water table to a depth of about 200 feet, and ranges in thickness from about 60 to 100 feet *(Figure 3)*. Groundwater occurs in the upper zone under unconfined conditions. Monitor wells perforated only in the upper zone indicate that the water table occurs at depths of about 100 to 140 feet beneath the HAC facility *(Table 1)*.

The upper zone is underlain by a zone of clay and sandy clay ranging in thickness from about 100 to 160 feet *(Figure* This clay unit restricts the movement of groundwater between the upper and lower zones of the regional aquifer.

Lower Zone

The lower zone of the regional aquifer comprises clayey sand with lenses of gravelly sand and sandy clay. The comple thickness of the lower zone has not been penetrated by wells the HAC facility area. The lower zone extends from about 300 below land surface to an unknown depth *(Figure 3)*.

Water levels measured in wells perforated only in the lo zone are significantly lower than water levels measured in mo tor wells perforated only in the upper zone. The water level difference between the upper zone and the lower zone ranges f about seven feet at wells M-1A and M-1B, to about 115 feet at wells M-2B and M-2C *(Table 1)*. The difference in water level between the two zones indicates there is potential for downwa movement of groundwater from the upper zone to the lower zone

350

PERCHED ZONE

The perched groundwater zone comprises sandy clay and clay, and overlies the upper zone of the regional aquifer *(Figure 3)*. The perched zone underlies about 70 to 120 feet of unsaturated alluvial sediments *(Figure 3)*. These sediments consist of alternating mixtures of sandy clay, clayey sand, gravelly sand, and caliche.

The perching clay retards vertical migration of fluids beneath the HAC facility, causing perched groundwater zones to develop beneath sources of percolating water. Perched groundwater was encountered in several soil borings and perched zone monitor wells constructed in the area of the abandoned wastewater holding ponds *(Figure 1)*. Perched groundwater was also encountered in holes constructed along the drainage ditch located north of the holding and evaporation ponds at the wastewater treatment plant *(Figure 1)*. The perched groundwater body in these areas has a surface area of about 100 acres, and a saturated thickness ranging from less than one foot to as much as five feet *(Figure 4)*. Water levels measured in the perched zone monitor wells ranged from about 80 to 100 feet below land surface *(Table 2)*. The sources of water to the perched groundwater zone probably include percolation of natural runoff and wastewater from the abandoned wastewater holding ponds and ditches.

Water level contours of the perched groundwater zone indicate that a mound of groundwater occurs in the vicinity of monitor wells B-9 and M-2A *(Figure 4)*. This mound occurs beneath the abandoned wastewater disposal ponds and also beneath an excavated area south of well M-2A. The area near well M-2A receives runoff from the drainage ditch located north of the holding and evaporation ponds. The perched groundwater mound suggests that the abandoned wastewater disposal ponds, and the excavated area south of well M-2A, are probably the sources of

the water in the perched groundwater zone. The ditch north of the holding and evaporation ponds, and the abandoned percolation bed located east of holding pond no. 2, might also be sources of the perched groundwater *(Figure 1)*.

Perched groundwater was also encountered in monitor wells P-6 and P-10 *(Figure 4)*. The perched groundwater observed in these two wells is probably not continuous with the perched groundwater body in the vicinity of monitor wells B-9 and M-2A. Perched groundwater in the vicinity of well P-6 may result from percolation of runoff which ponds next to the railroad embankment. Perched groundwater in the vicinity of well P-10 might result from percolation of runoff in the nearby arroyo, and percolation of discharge from the NPDES *(National Pollution Discharge Elimination System)* west discharge *(Figure 4)*.

HYDRAULIC CHARACTER OF REGIONAL AQUIFER

Hydraulic properties of the upper and lower zones of the regional aquifer were determined from aquifer pumping tests. Long-term aquifer tests were conducted at production wells HAC-1, HAC-3, and HAC-4. Short-term aquifer tests were conducted in 21 monitor wells during the Phase II investigation.

Data from these pumping tests were used to determine the aquifer coefficients of transmissivity and storage.

LONG-TERM AQUIFER TESTS

Long-term aquifer tests, ranging from three to four days in duration, were conducted at production wells HAC-1, HAC-3, and HAC-4. Tests were conducted at these wells to determine hydraulic properties in the upper zone of the regional aquifer.

Pumping equipment was removed from each well and a submersible test pump installed. Because wells HAC-1, HAC-3, and HAC-4 are perforated in both the upper and lower zones of the regional aquifer, an inflatable packer was attached to the bottom of the test pump assembly in order to seal off the lower aquifer zone. The packer was placed at a depth of 236 feet in wells HAC-1 and HAC-3, and at a depth of 223 feet in well HAC-4 *(Figure 5)*.

Water level measurements in the pumped wells and monitor wells were obtained with electric sounders. Pumping rates at wells HAC-1 and HAC-3 were measured with a cumulating flowmeter installed in the discharge line. Pumping rates at well HAC-4 were measured with an orifice plate and pitot tube. All well discharge was piped to holding ponds at the wastewater treatment plant.

Well HAC-1 Aquifer Test

The aquifer test at well HAC-1 comprised pumping well HAC-1 at an average discharge rate of 478 gpm *(gallons per minute)* for four days, and measuring water level drawdown and recovery in wells HAC-1, M-3A, M-3B, M-5, M-11, and M-20 *(Figure 1)*. Pumping at well HAC-1 started at 0830 hours on December 15, 1981 and ended at 1000 hours on December 19, 1981. Water level recovery was measured for a period of about 3-1/2 days after pumping stopped.

Analysis of aquifer test data indicates that the transmissivity of the upper zone of the regional aquifer in the vicinity of well HAC-1 is about 25,000 gpd/ft *(gallons per day per foot width of aquifer at 1:1 hydraulic gradient)*. The aquifer test data indicate a storage coefficient of about 0.09 *(Table 3)*. Under conditions of long-term pumping, the storage coefficient would probably approach 0.15.

Based on a saturated thickness of about 70 feet, the average permeability of the upper aquifer zone in the vicinity of well HAC-1 is estimated to be about 360 gpd/ft^2 *(gallons per day per square foot) (Table 3)*.

Well HAC-3 Aquifer Test

The aquifer test at well HAC-3 comprised pumping well HAC-3 at an average discharge rate of about 508 gpm for four days, and measuring water level drawdown and recovery in wells HAC-3, M-1A, and M-1B *(Figure 1)*. Pumping at well HAC-3 started at 1720 hours on December 5, 1981 and stopped at 1720 hours on December 9, 1981. Water level recovery was measured for a period of about four days after pumping stopped.

Analysis of aquifer test data indicates that the transmissivity of the upper zone of the regional aquifer in the vicinity of well HAC-3 is about 40,000 gpd/ft *(Table 3)*. Under conditions of long-term pumping, the storage coefficient would probably approach 0.15.

Based on a saturated aquifer thickness of about 75 feet, the average permeability of the upper aquifer zone in the vicinity of well HAC-3 is estimated to be about 530 gpd/ft^2 *(Table 3)*.

Well HAC-4 Aquifer Test

The aquifer test at well HAC-4 comprised pumping well HAC-4 at an average discharge rate of 134 gpm for three days and measuring water level drawdown and recovery in well HAC-4 and monitor well M-16 *(Figure 1)*. Pumping at well HAC-4 commenced at 0830 hours on November 29, 1981 and ended at 0830 hours on December 2, 1981. Water level recovery was measured in wells HAC-4 and M-16 for about 2-1/2 days after pumping stopped.

Analysis of aquifer test data indicates that the transmissivity of the upper zone of the regional aquifer in the vicinity of well HAC-4 is about 30,000 gpd/ft. The test data indicate a storage coefficient of about 0.09 *(Table 3)*. Under conditions of long-term pumping, the storage coefficient would probably approach 0.15.

Based on a saturated thickness of about 85 feet, the average permeability in the vicinity of well HAC-4 is estimated to be about 350 gpd/ft^2 *(Table 3)*.

SHORT-TERM AQUIFER TESTS

Short-term aquifer tests were performed in 20 Phase II monitor wells, and Phase I monitor well M-1B. Short-term tests

comprised pumping each well for a period of about six hours, and measuring water level drawdown and recovery in the well. These tests were conducted to provide additional data concerning the coefficient of transmissivity in the upper and lower zones of the regional aquifer.

A submersible test pump was initially installed in each well. The discharge line at each well was equipped with a cumulating flowmeter and/or an orifice pipe and pitot tube system for measuring discharge rate.

Analysis of water level recovery data provides an estimate of the transmissivity of the aquifer in the vicinity of each monitor well *(Table 3)*. Results of these analyses indicate that the transmissivity of the upper zone of the regional aquifer ranges from about 100,000 to less than 1,000 gpd/ft, and the transmissivity of the lower zone of the regional aquifer ranges from about 200 to 3,000 gpd/ft *(Table 3)*.

The estimated permeability of the upper zone of the regional aquifer ranges from about 6 to 1,400 gpd/ft^2 *(Table 3)*. The permeability of the lower zone ranges from about 1 to 20 gpd/ft^2 *(Table 3)*.

CONCLUSIONS

Analysis of aquifer tests indicates that the average coefficient of transmissivity of the upper zone of the regional aquifer is about 30,000 gpd/ft at the HAC facility. Results of aquifer tests indicate that the transmissivity of the upper zone tends to increase to the west and northwest across the HAC facility property.

Analysis of water level drawdown data collected in monitor wells during the long-term aquifer tests indicates a coefficient of storage in the upper zone of about 0.09. The coefficient of storage would probably approach 0.15 after sustained pumping of several months or years.

The average permeability of the upper zone of the regional aquifer in the HAC facility area is estimated to be on the order of 100 to 1,000 gpd/ft^2. The average permeability of the lower zone is estimated to be on the order of 1 to 10 gpd/ft^2.

CHEMICAL QUALITY OF WATER

GROUNDWATER

The chemical character of groundwater in the HAC facility area has been defined by laboratory analyses of groundwater samples collected from production wells, monitor wells, and soil borings. Three production wells, seven monitor wells, and five soil borings were sampled on the facility property during the Phase I investigation *(Hargis & Montgomery, Inc., 1982)*. Water quality data from production well SC-7, located west of the HAC facility, were obtained from the City of Tucson Water Department. Additional water quality data have been obtained from these wells during the Phase II investigation, and from monitor wells constructed in the regional aquifer and perched groundwater zone during the Phase II investigation.

Phase II Water Sampling

During the period October through December 1981, 29 monitor wells were constructed at the HAC facility. Nine monitor wells were constructed in the perched groundwater zone and 20 monitor wells were constructed in the upper and lower zones of the regional aquifer.

Groundwater samples have been collected monthly from production wells HAC-1, HAC-3, HAC-4, and the Credit Union well since May 1981. The monitor wells have been sampled monthly as they were completed. Chemical analyses have included determination of routine constituents, selected trace metals, and volatile organics. Routine constituents comprise common ions and cyanide. Selected wells have also been sampled for EPA *(Environmental Protection Agency)* priority pollutants.

Analyses for routine constituents and trace metals were performed by BC Laboratories, Inc., Bakersfield, California.

Analyses for volatile organics, EPA priority pollutants, and cyanide were performed by Jacobs Laboratories, Pasadena, California. All water samples were collected and processed according to standard techniques *(Appendix C)*.

Water samples collected from monitor well M-6, perforated in the upper zone of the regional aquifer, and monitor well P-10, perforated in the perched groundwater zone, were analyzed for EPA priority pollutants. The EPA priority pollutants include volatile organic compounds, acid compounds, base/neutral compounds, and pesticides. A total of 113 compounds were analyzed by Jacobs Laboratories.

Perched Zone

Perched groundwater was encountered in monitor wells C-3, P-1, P-6, P-8, P-10, and B-19 constructed during the Phase II investigation *(Figure 4)*. Perched groundwater was also encountered in soil borings B-1, B-2, B-3, B-7, B-9, and monitor well M-2A constructed during the Phase I investigation *(Figure 4)*.

COMMON IONS: Groundwater in the perched zone is generally a sodium sulfate or calcium sulfate type. Calcium and sodium are the principal cations, and sulfate is the principal anion in solution *(Appendix D, Tables D-1 through D-11)*. The total dissolved solids content of water samples collected from the perched zone ranged from about 400 to 1,200 mg/l *(milligrams per liter)*. In general, when the perched groundwater has a total dissolved solids content less than 500 mg/l, it is a calcium or sodium bicarbonate type. When the perched groundwater has a total dissolved solids content more than 500 mg/l, it is usually a calcium sulfate type.

TRACE METALS: Significant concentrations of chromium, iron, manganese, and zinc have been detected in groundwater samples obtained from the perched zone. Borings B-1, B-2, B-3, and B-9 were completed in the perched zone in or near the abandoned wastewater disposal ponds *(Figure 1)*. Concentrations of trace metals in groundwater samples obtained from these borings are as high as 0.16 mg/l for chromium, 0.13 mg/l for iron, 1.10 mg/l for manganese, and 1.80 mg/l for zinc *(Appendix E, Tables E-1 through E-3 and E-5)*. Chromium, iron, manganese, and zinc have also been detected in the perched groundwater at monitor well M-2A *(Appendix E, Table E-7)*. The concentration of total chromium in the perched zone has ranged from none detected at well P-10, to 0.21 mg/l at well B-3 *(Figure 6)*. The chromium content of the perched groundwater appears to be greatest in the area of the abandoned wastewater disposal ponds.

The EPA has established limits for concentrations in drinking water of 0.05 mg/l for chromium, 0.05 mg/l for manganese, 0.30 mg/l for iron, and 5.0 mg/l for zinc. Consequently, concentrations of chromium and manganese in the perched groundwater exceed the limits for drinking water. The limit for manganese appears in the *Secondary Drinking Water Standards* which are based on property protection and aesthetic criteria. The limit for chromium appears in the *Primary Drinking Water Regulations* which are based on health related criteria.

ORGANICS: Trichloroethylene *(TCE)*, 1,1,1-trichloroethane *(TCA)*, and 1,1-dichloroethylene *(DCE)* were detected in all perched zone monitor wells containing groundwater except for wells P-6 and P-10 *(Appendix F, Tables F-1 through F-12)*. TCE concentrations in all samples collected from the perched groundwater zone ranged from none detected to more than 1,600 ppb *(parts per billion)*. The highest concentrations of TCE in the perched groundwater zone occur in monitor wells P-1, B-1, B-2, B-3, and B-9, which were constructed in the area of the abandoned wastewater disposal ponds *(Figure 6)*.

360

Maximum TCA concentrations detected in the perched groundwater have ranged from none detected to 390 ppb *(Figure 6)*. The highest TCA concentration of 390 ppb was found in monitor well B-7, located north of the holding ponds along the drainage ditch *(Figure 6)*. TCA concentrations ranging from 55 ppb at well B-9, to 380 ppb at well B-1, were detected in the area of the abandoned wastewater disposal ponds.

Maximum concentrations of DCE in the perched groundwater zone have ranged from none detected to 690 ppb *(Figure 6)*. The highest DCE concentration of 690 ppb was found in monitor well B-3, located in the area of the abandoned wastewater disposal ponds. DCE concentrations ranging from 390 to 480 ppb were detected in monitor wells B-1, B-2, and B-9, which are also located in the area of the abandoned wastewater disposal ponds. Significant concentrations of DCE were also found in perched zone monitor wells B-19, B-7, and C-3 which are located along the drainage ditch *(Figure 6)*.

Monitor well P-10 was located near the NPDES west discharge in order to determine the effect of this discharge on the perched groundwater zone. A water sample collected from well P-10 in November 1981 was analyzed for the EPA total organic priority pollutants, which include TCE, TCA, DCE, and 110 other organic compounds *(Appendix G, Table G-1)*. The only pollutant detected was bis(2-ethylhexyl) phthalate at 25 ppb.

<u>CONCLUSIONS</u>: The distribution and concentrations of chromium, TCE, TCA, and DCE in the perched groundwater zone indicate that the ditch located north of the holding and evaporation ponds, and the abandoned wastewater disposal ponds, were sources of organic contaminants that percolated to the perching clay.

Production wells HAC-1, HAC-3, HAC-4, and SC-7, and monitor well HAC-2 are perforated in both the upper and lower aquifer zones. Because the upper aquifer zone is more permeable than the lower zone, most of the water produced from these wells is from the upper aquifer zone. Consequently, the water samples collected from these wells are primarily representative of the upper aquifer zone.

COMMON IONS: The upper aquifer zone extends from the water table to a depth of about 200 feet *(Figure 3)*. Groundwater in the upper zone of the regional aquifer is predominantly a calcium bicarbonate type with a total dissolved solids content less than about 500 mg/l. Exceptions are groundwater obtained from upper zone monitor wells M-5, M-3A, M-7, M-11, and the Credit Union. The total dissolved solids content of groundwater obtained from these wells ranged from about 550 mg/l in well M-7, to about 1,100 mg/l in well M-5 *(Appendix D)*.

The lower aquifer zone occurs below a depth of about 300 feet *(Figure 3)*. Groundwater in the lower aquifer zone is a sodium sulfate or sodium bicarbonate type with a total dissolved solids content ranging from about 250 to 400 mg/l *(Appendix D)*.

TRACE METALS: Chromium, zinc, manganese, and arsenic have been detected in groundwater obtained from monitor wells penetrating the regional aquifer at the HAC facility *(Appendix E)*. Chromium is the only trace metal detected in the regional aquifer which exceeds the drinking water standards. Groundwater samples obtained from wells perforated in the upper zone have maximum chromium contents ranging from less than 0.01 mg/l to 0.50 mg/l *(Figure 7)*. The highest chromium concentrations in the upper zone occur in the area between monitor well M-20, which is located in the vicinity of the two abandoned sludge disposal pits east of Building 801, and production well HAC-1. Another

area of high chromium content in groundwater in the upper aquifer zone occurs in the area between monitor well M-7 and the Credit Union well *(Figure 7)*.

Groundwater samples obtained from monitor wells perforated in the lower aquifer zone have maximum chromium concentrations ranging from less than 0.01 mg/l to 0.02 mg/l *(Figure 7)*.

Minor amounts of zinc and manganese have been detected in some groundwater samples obtained from the regional aquifer. These constituents may be derived naturally from the basin fill sediments. Significant concentrations of fluoride and arsenic were detected in monitor wells M-2C and M-3B, which tap the lower aquifer zone *(Appendix D, Tables D-15 and D-17; Appendix E, Tables E-15 and E-17)*. Similar concentrations of fluoride and arsenic have been reported from other wells penetrating the lower aquifer zone in other areas of the Tucson Basin.

ORGANICS: TCE has been detected in all groundwater monitoring wells perforated in the upper zone of the regional aquifer, except for monitor wells M-1A and M-15 *(Figure 8)*. TCE has also been detected in monitor wells M-3B and M-12B, which penetrate the lower zone of the regional aquifer. Concentrations of TCE in the upper zone range from about 13,000 ppb at monitor well M-11, to 3 ppb at well M-19 *(Appendix F)*. The highest concentration of TCE in the upper zone occurs in the area north of the holding ponds and west of production well HAC-1 *(Figure 8)*. Concentrations of TCE in groundwater in this area range from about 8,000 to 13,000 ppb.

Concentrations of TCE in the lower aquifer zone were 86 ppb in well M-3B, and 2 ppb in well M-12B *(Appendix F, Tables F-18 and F-28)*. TCE has not been detected in the lower aquifer zone at monitor wells M-1B and M-2C *(Appendix F, Tables F-14 and F-16)*.

TCA has been detected in monitor wells only in the area west of production well HAC-1 and north of the evaporation and holding ponds *(Figure 9)*. TCA has not been detected in monitor wells perforated only in the lower aquifer zone. TCA concentrations in groundwater samples obtained from wells perforated in the upper aquifer zone range from 630 ppb in monitor well M-11, to 1 ppb in well M-8 *(Appendix F)*. The highest concentration of TCA in the upper zone occurs in the vicinity of well M-11, and appears to be approximately coincident with the area of highest TCE concentrations *(Figure 9)*.

DCE has been detected in monitor wells located in the area west of monitor well M-20 and north of the evaporation and holding ponds *(Figure 10)*. DCE has been detected in the lower aquifer zone only at monitor well M-3B *(Appendix F)*. DCE concentrations in groundwater samples obtained from wells perforated in the upper aquifer zone range from 3,320 ppb to none detected *(Figure 10)*. The highest concentration of DCE in the upper aquifer zone occurs in the vicinity of well M-5, and also appears to be approximately coincident with the areas of highest TCE and TCA concentrations.

Because of its location near the NPDES west discharge, a groundwater sample obtained from monitor well M-6 was analyzed for EPA priority pollutants *(Appendix G, Table G-2)*. Pollutants detected included TCE, DCE, chloroform, tetrachloroethylene, 1,2-trans-dichloroethylene, TCA, and trichlorofluoromethane. Except for TCE and DCE, these pollutants were detected at levels of 20 ppb or less.

<u>CONCLUSIONS</u>: Because TCE, TCA, and DCE are not naturally occurring substances, the presence of these compounds in the upper zone of the regional aquifer system indicates that percolation of wastewater to the regional aquifer has occurred. The distribution and concentrations of TCE, TCA, and DCE in the

upper zone indicates that the principal area of waste disposal for these organic compounds was in the area located west of Building 801 and north of the evaporation and holding ponds. The distribution and concentration of TCE in the upper zone also indicates that a secondary disposal site for TCE was located in the southeastern portion of the HAC facility property in the vicinity of monitor well M-18.

Contamination of the upper aquifer zone north of the HAC facility property has probably occurred due to waste disposal practices at the HAC facility. Groundwater samples obtained from monitor wells tapping the upper aquifer zone on the HAC facility property suggest that groundwater in the upper zone north of the facility property boundary might contain TCE concentrations greater than 2,000 ppb, DCE concentrations greater than 100 ppb, and TCA concentrations greater than 10 ppb. This groundwater contamination is probably the result of historic waste disposal practices at the HAC facility.

The concentration and distribution of TCE and DCE in the lower aquifer zone suggests that contamination of the lower zone has occurred only in the area west of Building 801 and north of the holding ponds. The low concentrations of DCE in the lower zone are not significant. The concentration of TCE in well M-3B is 86 ppb, and indicates that vertical migration of contaminated groundwater from the upper zone to the lower zone has occurred, or that production well HAC-1 has acted as a conduit for movement of groundwater from the upper zone to the lower zone.

The concentration and distribution of chromium in the upper aquifer zone suggests that the principal source of chromium contamination was seepage from the abandoned sludge disposal pits located east of Building 801. It appears that the plume of chromium-contaminated groundwater has been contained by the pumping of production well HAC-1. The additional plume of chromium-

contaminated groundwater in the vicinity of the Credit Union well and monitor well M-7 might have originated from the same source, or could have originated from seepage from the abandoned wastewater disposal ponds. The low chromium contents in groundwater obtained from wells perforated in the lower aquifer zone indicate that chromium contamination of the lower zone has not occurred.

CONCENTRATION OF TRACE METALS AND ORGANICS IN SOIL SAMPLES

Soil samples were collected from 16 borings drilled during the Phase II investigation at abandoned waste disposal pits, ponds, and ditches *(Figure 1)*. A total of 282 soil samples were collected and analyzed to determine the nature and concentration of volatile organics disposed of at known or suspected waste disposal sites. Twenty soil samples collected from boring C-8 were also analyzed for selected trace metals. The soil samples were prepared and analyzed for trace metals by BC Laboratories, Inc., Bakersfield, California, in accordance with procedures and methods recommended by the EPA *(Appendix H)*. Analyses for TCE, TCA, and DCE were performed by Jacobs Laboratories, Pasadena, California, in accordance with procedures and methods recommended by the EPA *(Appendix H)*.

TRACE METALS

Soil boring C-8 was drilled at the site of two abandoned sludge disposal pits east of Building 801 *(Figure 1)*. Soil borings constructed and sampled during the Phase I investigation indicated significant concentrations of metals in the upper five to 10 feet of soil *(Hargis & Montgomery, Inc., 1982)*. Boring C-8 was constructed to confirm the earlier findings, obtain soil samples at greater depths, and determine whether a perched groundwater body was present in the subsurface beneath the abandoned sludge disposal pits.

Soil sample extracts from boring C-8 were analyzed for 14 selected trace metals: iron, manganese, copper, molybdenum, lead, chromium, selenium, cadmium, mercury, silver, zinc, nickel, arsenic, and barium *(Appendix I, Table I-1)*. Results of these

analyses indicate high chromium concentrations extending to a depth of about 75 feet below land surface. Significant concentrations of other metals were not detected in these samples.

Conclusions

Analysis of soil samples from boring C-8 confirms the Phase I investigation finding that the abandoned disposal pits east of Building 801 were probably the principal disposal sites for sludge containing trace metals. The chromium concentrations at depth indicate that fluids containing high concentrations of chromium percolated through the subsurface materials beneath the sludge disposal pits.

ORGANIC CONSTITUENTS

Chemical analyses were performed on 282 soil samples from the Phase II soil borings to determine the concentrations of TCE, TCA, and DCE *(Appendix I, Tables I-2 through I-17)*. Low concentrations of TCE were detected in all of the soil borings. Concentrations of TCE were usually less than 10 ppb, but were as high as 26 ppb. TCA was detected only in borings B-19, C-1, C-2, C-4, and C-5 *(Appendix I)*. Concentrations of TCA were usually less than 5 ppb, but were as high as 10 ppb. DCE was detected only in soil borings C-2 and C-5 at concentrations less than 5 ppb.

The highest concentrations of TCE were found in samples collected from borings B-16, B-19, B-23, and C-7 *(Appendix I, Tables I-2, I-5, I-8, and I-16)*. Boring B-16 is located in the area west of Building 801, and boring B-19 is located in a known disposal pit. Boring B-23 is located south of the holding ponds in an area assumed to be

representative of native, uncontaminated conditions. Boring C-7 is located in a known disposal pit. TCE concentrations greater than 10 ppb in boring B-23 were associated with clays, which might contain organic material that would interfere with the analysis. Data obtained from boring B-23 suggests that TCE concentrations for the soils less than about 10 ppb are probably not meaningful.

Conclusions

Results of chemical analyses of soil samples for volatile organics indicate that TCE is present in at least trace amounts at all of the suspected disposal sites. Results of these analyses confirm the findings of the Phase I investigation that TCE was discharged in wastewater to the unlined ditch and abandoned disposal ponds, and was also disposed of in several pits at the HAC facility. Although concentrations of TCA and DCE in the soils are low, their presence in borings C-1, C-2, C-4, and C-5 indicates that fluids in the drainage ditch and the abandoned wastewater disposal ponds contained organic solvents.

REFERENCE CITED

Hargis & Montgomery, Inc., 1982. *Phase I investigation of subsurface conditions in the vicinity of abandoned waste disposal sites, Hughes Aircraft Company Manufacturing Facility, Tucson, Arizona.* Prepared for Latham & Watkins, San Diego, California; January 15, 1982.

TABLES

TABLE 1

WATER LEVELS IN THE REGIONAL AQUIFER

WELL IDENTIFIER	DATE MEASURED	MEASURING POINT ELEVATION (ft, msl)	DEPTH TO WATER (feet)	WATER LEVEL ELEVATION (ft, msl)
Upper Zone				
M-1A	2-08-82	2,622.25	141.15	2,481.10
M-2B	12-24-81	2,576.74	112.25	2,464.49
M-3A	1-23-82	2,599.71	127.78	2,471.93
M-4	2-08-82	2,589.47	118.78	2,470.69
M-5	12-24-81	2,592.26	130.06	2,462.20
M-6	1-22-82	2,589.92	123.44	2,466.48
M-7	1-23-82	2,580.01	121.58	2,458.43
M-8	11-30-81	2,571.83	108.28	2,463.55
M-9	11-27-81	2,579.91	114.85	2,465.06
M-10	12-24-81	2,575.59	110.24	2,465.35
M-11	1-22-82	2,595.95	125.28	2,470.67
M-12A	1-23-82	2,568.07	105.79	2,462.28
M-13	12-24-81	2,567.17	104.84	2,462.33
M-14	12-01-81	2,573.28	108.46	2,464.82
M-15	1-23-82	2,608.91	124.94	2,483.97
M-16	1-23-82	2,611.19	125.00	2,486.19
M-17	1-25-82	2,623.16	128.22	2,494.94
M-18	12-15-81	2,643.26	142.42	2,500.84
M-19	12-04-81	2,616.81	118.64	2,498.17
M-20	1-23-82	2,605.08	126.42	2,478.66
CREDIT UNION	1-22-82	2,577.61	114.21	2,463.40

TABLE 1
WATER LEVELS IN THE REGIONAL AQUIFER

WELL IDENTIFIER	DATE MEASURED	MEASURING POINT ELEVATION *(ft, msl)*	DEPTH TO WATER *(feet)*	WATER LEVEL ELEVATION *(ft, msl)*
Lower Zone				
M-1B	1-25-82	2,622.67	148.05	2,474.62
M-2C	2-08-82	2,576.40	228.07	2,348.33
M-3B	2-08-82	2,601.37	144.61	2,456.76
M-12B	1-23-82	2,569.52	182.45	2,387.07
Composite				
HAC-1	1-22-82	2,602.60	131.18	2,471.42
HAC-2	1-22-82	2,597.43	120.17	2,477.26
HAC-3	12-05-81	2,619.25	140.98	2,478.27
HAC-4	11-29-81	2,612.25	143.00	2,469.25

TABLE 2

WATER LEVELS IN THE PERCHED ZONE

WELL IDENTIFIER	DATE MEASURED	MEASURING POINT ELEVATION (ft, msl)	DEPTH TO WATER (feet)	WATER LEVEL ELEVATION (ft, msl)
P-1	2-08-82	2,580.68	103.45	2,477.23
P-2	1-23-82	2,580.92	dry	---
P-3	1-23-82	2,571.84	dry	---
P-4	2-08-82	2,567.23	dry	---
P-5	1-23-82	2,570.56	dry	---
P-6	2-08-82	2,568.08	94.52	2,473.56
P-7	1-23-82	2,578.86	dry	---
P-8	2-08-82	2,582.48	90.17	2,492.31
P-10	2-08-82	2,590.07	95.13	2,494.94
B-1	2-08-82	2,574.88	81.54	2,493.34
B-2	2-08-82	2,576.45	83.33	2,493.12
B-3	2-08-82	2,577.23	86.87	2,490.36
B-4	1-23-82	2,599.12	dry	---
B-5	1-23-82	2,598.78	dry	---
B-6	1-23-82	2,595.23	dry	---
B-7	2-08-82	2,590.72	88.18	2,502.54
B-9	2-08-82	2,581.44	84.49	2,496.95
B-10	7-30-81	2,605.30	dry	---
B-12	1-23-82	2,619.32	dry	---
B-13	1-23-82	2,596.09	dry	---
B-15	1-23-82	2,643.12	dry	---
B-19	2-08-82	2,589.50	dry	---
C-3	2-08-82	2,582.38	89.21	2,493.17

TABLE 3

SUMMARY OF AQUIFER PARAMETERS

LONG-TERM TESTS

WELL	TRANSMISSIVITY (gpd/ft)[1]	SATURATED THICKNESS (feet)	PERMEABILITY (gpd/ft²)[2]	STORAGE COEFFICIENT[3]
HAC-1	25,000	70	360	0.09
HAC-3	40,000	75	530	0.001
HAC-4	30,000	85	350	0.09

SHORT-TERM TESTS

WELL	TRANSMISSIVITY (gpd/ft)[1]	SATURATED THICKNESS (feet)	PERMEABILITY (gpd/ft²)[2]	AQUIFER ZONE
M-1B	3,000	150	20	Lower
M-3A	19,000	70	270	Upper
M-3B	200	150	1	Lower
M-4	7,000	85	80	Upper
M-5	50,000	75	670	Upper
M-6	18,000	35	510	Upper
M-7	15,000	70	210	Upper
M-8	70,000	65	1,100	Upper
M-9	40,000	70	570	Upper
M-10	40,000	70	570	Upper
M-11	20,000	50	400	Upper
M-12A	20,000	55	360	Upper
M-12B	300	125	2	Lower
M-13	55,000	60	900	Upper
M-14	100,000	70	1,400	Upper
M-15	400	70	6	Upper
M-16	35,000	85	400	Upper
M-17	50,000	70	710	Upper
M-18	10,000	40	250	Upper
M-19	1,000	70	15	Upper
M-20	15,000	40	375	Upper

[1] *Gallons per day per foot width of aquifer at 1:1 hydraulic gradient.*

[2] *Gallons per day per square foot.*

[3] *Dimensionless; ratio of the volume of water released per unit surface area of aquifer per unit decline in hydraulic head.*

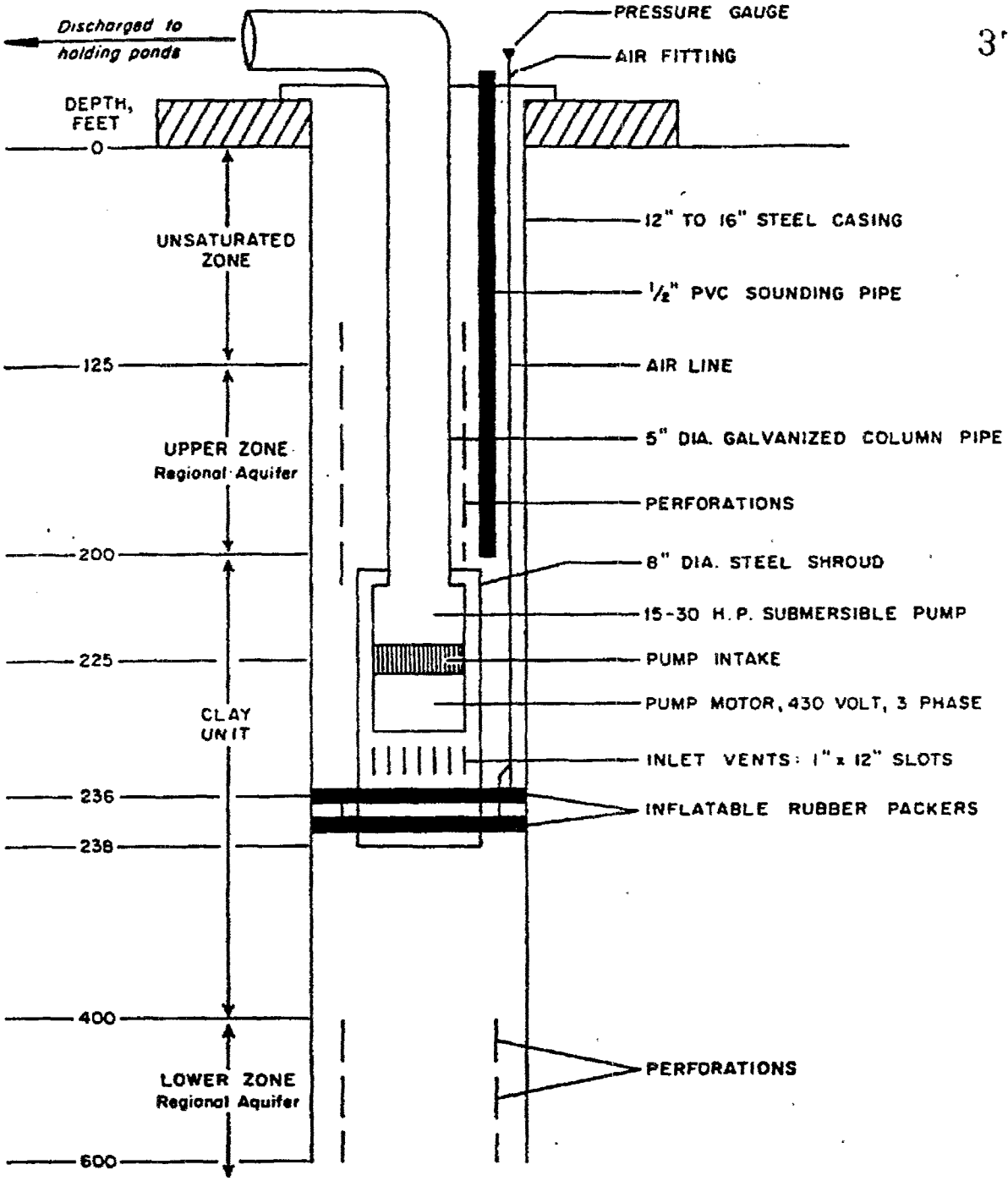


FIGURE 5. SCHEMATIC DIAGRAM OF TEST PUMP ASSEMBLY

Special Study Report

385

CONCEPTUAL STUDY FOR TREATMENT OF RECLAIMED WATER AT USAF PLANT NO. 44 PHASE I & PHASE II RESULTS

Hughes Aircraft Company
Tucson, Arizona

United States Air Force
Contract Number F33657-81-E-2096

September 1983

MALCOLM PIRNIE

ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

TABLE OF CONTENTS

		PAGE
I.	INTRODUCTION	I-1
II.	PHASE I - TREATMENT ALTERNATIVES	II-1
	A. VOC REMOVAL PROCESSES	II-1
	1. Aeration	II-1
	2. Adsorption	II-2
	B. HEXAVALENT CHROMIUM REMOVAL PROCESSES	II-3
	1. Reduction/Precipitation	II-3
	2. Ion Exchange	II-4
	3. Reverse Osmosis	II-5
	C. SUMMARY	II-6
III.	PHASE II - VOC REMOVAL	III-1
	A. PACKED COLUMN AERATION	III-1
	1. Description of Testing Equipment	III-1
	2. Description of Treatability Tests	III-3
	3. Results of Testing Program	III-4
	4. Process Design Criteria Selection	III-8
	B. ADSORPTION PROCESSES	III-9
	1. Description of Testing Equipment	III-10
	2. Description of Treatability Tests	III-11
	3. Results of Testing Program	III-11
	4. Process Design Criteria	III-13
IV.	CHROMIUM REMOVAL	IV-1
	A. REDUCTION/PRECIPITATION	IV-1
	1. Description of Treatability Tests	IV-1
	2. Results of Treatability Tests	IV-1
	3. Solids Handling	IV-3
	4. Design Criteria Selection	IV-3
	B. ION EXCHANGE	IV-4
	1. Description of Treatability Tests	IV-4
	2. Results of Testing Program	IV-4
	3. Process Design Criteria	IV-5
	C. ADSORPTION	IV-7

TABLE OF CONTENTS
(continued)

		PAGE
V.	CONCEPTUAL DESIGN OF RECOMMENDED SYSTEM	V-1
	A. PRELIMINARY SIZING OF PACKED TOWERS	V-1
	B. CONCEPTUAL DESIGN CRITERIA	V-2

LIST OF FIGURES

Number	Description	Following Page
1	Diagram of Pilot Air Stripping Column	III-1
2	Mass Transfer Relationship Well No. 4	III-7
3	Mass Transfer Relationship Well No. 11	III-7
4	Packing Height vs. Air:Water Ratio	III-7
5	Required Packing Height	III-8
6	Carbon Mini-Column System	III-10
7	Carbon Usage Rates	III-11
8	Process Flow Schematic - 5,000 gpm	V-4
9	Process Flow Schematic - 2,000 gpm	V-4

LIST OF TABLES

Number	Description	Page Number
1	Estimated Initial VOC and Chromium Concentrations	I-2
2	Target Treatment Levels	I-2
3	Well Water Characterization	III-2
4	Pilot Air Stripping Column Results	III-7
5	Henry's Law Constants	III-8
6	Mass Transfer Coefficients (1/Hr) at 25 gpm/Ft^2	III-10
7	Air Stripping Design Criteria	III-9
8	Mini-column Carbon Study	III-12
9	Chromium Removal Studies Reduction/Precipitation	IV-2
10	Design Criteria Reduction/Precipitation	IV-4
11	Chromium Removal Studies Ion Exchange	IV-6
12	Design Criteria Ion Exchange	IV-7
13	Chromium Removal Via Adsorption	IV-8
14	Battery Limits Capital Cost Estimate for Packed Tower Process	V-3

I. INTRODUCTION

As part of a groundwater remediation program to prevent migration of groundwater containing volatile organic compounds (VOC's) and chromium, and to remove VOC's and chromium from the aquifer, the Hughes Aircraft Company (HAC), under contract with the U.S. Air Force, retained Malcolm Pirnie, Inc. (Malcolm Pirnie) to perform a conceptual study of water treatment processes that can be used to remove these constituents. The study has been divided into three phases:

Phase I	-	Scoping study to select candidate processes
Phase II	-	Laboratory and pilot evaluation of candidate process trains
Phase III	-	Preliminary economic evaluation of most successful candidate processes

This report discusses the Phase I and Phase II findings. During Phase I, eight candidate processes were identified and screened for applicability to this Project. Candidate treatment processes are described along with the reasoning used to either eliminate or include the process for further consideration. In addition, the testing program for the four processes considered in Phase II is described.

The VOC's found in the groundwater by others at concentrations greater than 20 ug/l include trichloroethylene (TCE), 1,1 dichloroethylene (DCE) and 1,1,1 trichloroethane (TCA). Chromium was found in the ground water in the hexavalent form (Cr^{+6}).

The firm of Hargis and Montgomery (Hargis) has performed a hydrogeologic investigation of the site and estimated the initial concentrations of VOC's and chromium in a proposed withdrawal well system. The concentrations were developed for two flow scenarios, 2000 gpm and 5000 gpm, and are presented in Table 1 along with Hargis' range of estimated VOC levels.

TABLE 1

Estimated Initial VOC and Chromium Concentrations

	2000 gpm	5000 gpm	Range
TCE (ug/L)	900	1000	±20%
DCE (ug/L)	110	140	±100%
TCA (ug/L)	7	9	±500%
Chromium (mg/L)	0.05	0.07	±0.03 mg/L

A range of target treatment levels was developed by the U.S. Air Force (USAF) in conjunction with the Arizona Department of Health Services (ADHS) and the U.S. Environmental Protection Agency (USEPA). There is only one chromium target level, 0.05 mg/L, which is a USEPA drinking water standard. The target treatment levels are presented in Table 2.

TABLE 2

Target Treatment Levels

	TCE (ug/L)	DCE (ug/L)	TCA (ug/L)	Chromium (mg/L)
Lowest	5	0.033	16.8	0.05
Medium	50	10	50	0.05
Highest	270	40	168	0.05

II. PHASE I - TREATMENT ALTERNATIVES

A. VOC REMOVAL

Aeration using either a diffused aeration system or a packed tower, and adsorption using either activated carbon or synthetic resin were evaluated to remove VOC's in a desk top analysis. The initial VOC concentrations and the target treatment levels presented in Section I served as the basis for evaluating aeration and adsorption processes.

1) Aeration

a) Diffused Aeration. This technique has been used to remove VOC's from groundwater by bubbling air into a basin containing the contaminated groundwater. Removal efficiencies of 94 percent have been achieved in a diffused air system with a 10 minute hydraulic contact time and an air: water ratio of 30:1 (ft^3/ft^3). However, TCE removals with a packed tower with random media and similar air:water ratios have been significantly higher (99.7%). The air blower in a diffused aeration system must be sized to overcome a relatively large pressure drop (10 to 15 feet of water) while the pressure drop in a packed tower is less than 8 inches of water.

Based upon our experience on other projects, the diffused aeration process was eliminated because this process is less efficient and more costly than the packed column both from a capital and an operating standpoint.

b) Plate Column with Catenary Grid. The principal advantage of this system over towers packed with random media was reported to be the possible ability to accomplish similar VOC removals in a shorter column height. Therefore, this might have application where restrictions on column height were a consideration. However, based on our recent experience on other projects, the ability of the units to attain low levels of VOC's in the tower effluent does not seem to be as

well documented and reproducible as with random packed systems. Since this project calls for studying the ability of a system to reach very low levels of VOC, it was decided that this system has not been proven enough to offer any significant advantages over a packed column system. Hence the catenary grid system was not considered for further evaluation.

c) Packed Column With Random Media. Based upon our experience, air stripping utilizing a packed column design is the most cost effective process to remove VOC's from water to low levels. Two 25 foot high packed towers designed by Malcolm Pirnie at approximately the same air to water ratio have achieved 99.7 percent removal of TCE. Diffused aeration, while also effective, is not as efficient as packed tower aeration. When compared to other VOC removal techniques, packed tower air stripping systems are noted for higher treatment efficiencies, ease of operation and relatively low capital and operating costs. The packed tower was selected for further evaluation.

2) Adsorption

Adsorption onto either activated carbon or a synthetic resin has been used to remove VOC's and was recommended for evaluation during Phase II. Testing would be conducted in a bench-scale continuous flow system called a mini- column. Because of the small quantity of adsorbent, VOC breakthrough is achieved normally in a matter of hours rather than weeks or months as is the case with larger scale adsorption columns. Effluent samples will be monitored for VOC's. These results will be used to estimate carbon and resin usage rates. It is noted that these bench scale tests do not establish the optimum design of a full scale adsorption system rather carbon usage to achieve various target treatment levels. Larger scale pilot testing is required to determine the optimimum size and arrangement of the contactors. Typical adsorption

systems are designed at liquid loading rates of 3-6 gallons/minute-square foot and an empty bed contact time of 10-20 minutes. These criteria which are commonly used will be used to develop a preliminary design and capital cost for a system.

Carbon/resin regeneration was not evaluated in the bench scale tests. If carbon adsorption is attractive, it was assumed that carbon regeneration would be accomplished off-site. Additional regeneration studies would be required. The principal advantage of the synthetic resin is that regeneration is accomplished in-situ using a hot inert gas.

B) HEXAVALENT CHROMIUM REMOVAL PROCESSES

Four processes were evaluated to remove hexavalent chromium: reduction/precipitation, ion exchange, reverse osmosis (RO), and adsorption using activated carbon. If in the full scale system the chromium levels in the groundwater are found to be consistently below the treatment objective, then alternate chromium treatment strategies can be considered, e.g. by passing the total flow or a fraction of the flow around the treatment system.

1) Reduction/Precipitation

The reduction/precipitation process is the most commonly used technique to remove hexavalent chromium from water and wastewater. In this process hexavalent chromium is reduced to trivalent chromium, which precipitates as chromium hydroxide within a specific pH range. The precipitate is removed by a solid-liquid separation process such as filtration. Filtration is expected to be the most suitable separation process because of the relatively low chromium (0.1 mg/L) levels; hence the quantity of the precipitate will be low. The need to handle and dispose the precipitate are the principal disadvantages of the reduction/precipitation process.

Hexavalent chromium can be reduced either by adding a chemical reducing agent (such as ferrous sulfate or sodium metabisulfite) or by an electrochemical process where a consumable iron electrode in the presence of an electric current yields ferrous ions that ultimately reduce hexavalent chromium. A major disadvantage of the electrochemical reduction process is the hydroxides form a gelatinous preciptitate around the electrodes. A solution of hydrochloric acid must be circulated through the system routinely to remove any gelatinous precipitate that is formed.

In addition, the control of ferrous ion dosage is more difficult in an electrochemical reduction system than in a chemical reduction system using ferrous ion dosage, and control of sludge production is more difficult in an electrochemical system. Considering the need for cleaning and the potential for higher sludge production rates, the electrochemical system was eliminated from further consideration.

To assess the efficacy of any system, the following parameters would have to be evaluated:

- Type of reducing agent
- Optimum dosage
- Optimum operating pH
- Required reaction times

Both ferrous sulfate and sodium metabisulfite seemed to be acceptable reducing agents. Polymer addition would also have to be evaluated as it is believed that it will be necessary to increase the particle size and enhance the filterability of the precipitate. Studies would be conducted to determine optimum chemical dosage required to achieve the target treatment levels. Neither testing of the filtration or solids handling processes would be performed during Phase II due to the limited quantity of water available for testing.

2) Ion Exchange

Ion exchange is a process that has been used to remove hexavalent chromium. Hexavalent chromium is generally present as either the dichromate or chromate anion. An anion exchange resin is capable of removing these anions. Recent ion exchange tests conducted on groundwater in Scottsdale, Arizona indicate that relatively long run times can be achieved before chromium breakthrough occurs. The required regenerant volumes are reported to be low.

A major disadvantage of ion exchange is that the regenerant stream must be either treated to remove hexavalent chromium via a reduction/precipitation process or handled off-site by an approved contract disposal firm. Also, the regenerant stream would have high salt levels that would require that this stream be disposed of in the brine ponds.

Ion exchange was recommended for evaluation in a small continuous bench scale column study. The resin would be regenerated to determine whether or not chromium could be removed from the resin. An advantage of the small bench scale tests is that they do not require a great deal of time or a large quantity of water.

3) Reverse Osmosis

Reverse Osmosis (RO) was considered as a means of removing both chromium and VOC's from the groundwater. RO is reported to reject chromium, in excess of 95 percent while the rejection of VOC's is expected to be in the range of only 85-90 percent.

After review of the raw water quality data, it was determined that the permeate (treated water) recovery will probably be limited to 80 percent by volume; that is, 20 percent of the influent flow to an RO system will be rejected as brine. Silica or calcium sulfate solubility limits further concentration of the brine reject stream. This reject stream potentially represents a significant loss of water from the aquifer,

400 gpm for a 2,000 gpm system or 1,000 gpm for a 5,000 gpm system. This water must be managed either by further treatment for chromium and VOC removal or by disposal in evaporation ponds, thus requiring additional facilities at a significant capital expense.

Considering its relatively high capital and operating costs, RO initially was thought to be a viable alternative only if this process could achieve sufficient chromium and VOC reduction in a single process. While chromium reduction is sufficient, the VOC rejection is not sufficient to meet the treatment objectives. Further treatment of the permeate for VOC removal would be required. Upon consideration of these factors, RO was eliminated from further consideration in Phase II.

4) Adsorption

It has been reported by others that activated carbon has been successfully used to remove hexavalent chromium from water containing organics. A possible explanation is that an organometallic complex is formed which is adsorbable. Based upon the reported results, testing of adsorption processes to remove hexavalent chromium will be conducted.

C. SUMMARY

In summary, the following processes were selected for further evaluation in Phase II:

- Aeration utilizing a packed column
- Adsorption, with activated carbon or a suitable synthetic resin to remove VOC's and hexavalent chromium
- Reduction/Precipitation using ferrous sulfate or sodium metabisulfite.
- Ion Exchange

III. PHASE II - VOC REMOVAL PROCESSES

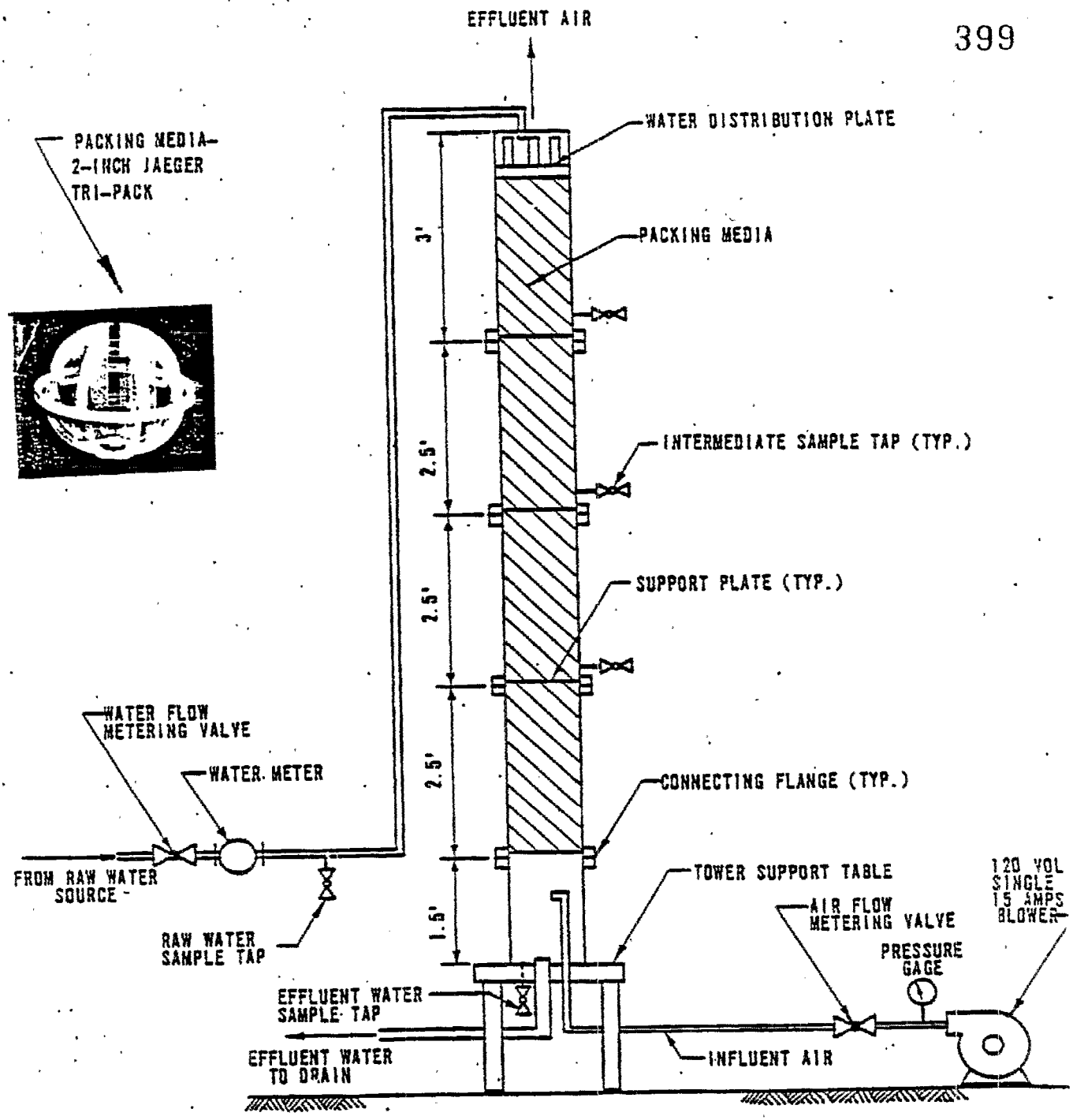
A. PACKED COLUMN AERATION

As part of this study, a pilot-scale testing program was conducted at HAC Wells M-4 and M-11 to evaluate the packed column aeration process. Analysis of the ground water for TCE, DCE and TCA along with other parameters was completed; the results are presented in Table 3. The results of the packed tower tests were analyzed to develop design criteria for a full-scale treatment facility. A description of the pilot tests and an evaluation of the test results are presented in this Section.

1) Description of Testing Equipment

The treatability tests were conducted using a pilot aeration column, which was designed and fabricated by Malcolm Pirnie. The pilot column consists of influent piping and valves, the column and packing media, a blower and a support structure. A schematic diagram of the pilot column is shown in Figure 1. Raw water was pumped from the well through the water meter to the top of the column. This flow trickles down through the packing media, and discharges by gravity flow. Air is forced by two Rotron regenerative blowers through a metering valve to the bottom of the column, counter current to the water flow, and into the atmosphere. Sample taps are provided on the influent line, at three locations along the side of the column, and at the bottom of the column for collecting raw and treated water samples.

The column is 12 inches in diameter and is constructed of PVC pipe in five sections for variation of packing depth and ease of handling. The maximum packing depth is 9.7 feet, and the overall column height is 12 feet. An orifice-type liquid distributor is used to distribute water at the top of the column. Support plates have been placed between each column section to provide intermediate support of the media



HUGHES AIRCRAFT COMPANY
TREATMENT OF RECLAIMED W
DIAGRAM OF PILOT
AIR STRIPPING COLU

MALCOLM
PIRNIE

TABLE 3

Well Water Characterization

	Well No. 11	Well No. 4
Trichloroethylene (ug/L) range	1,637-2103	1,494-1,913
1,1 Dichloroethylene (ug/L) range	161-230	501-601
1,1,1 Trichloroethane (ug/L) range	14-20	22-29
TOC (mg/L)	<1	NA
Cr(+6) (mg/L)	0.008	NA
Cr (Total) (mg/L)	<0.04	<0.04
TDS (mg/L)	393	NA
Ca (mg/L)	20	NA
Mg (mg/L)	15.2	NA
SO_4^{-2} (mg/L)	80	NA
Alkalinity (mg/L as $CaCO_3$)	150	NA
pH	7.2	NA
Temp (°F) Field	77	77

NA = Not Analyzed

and to redistribute water and air flow to reduce channelization in the column. The column is designed to receive a maximum hydraulic loading of 50 gallons per minute. Each blower has a range of 0 to 160 cubic feet per minute.

The packing material used for the tests at wells M-4 and M-11 was 2-inch Jaeger Tri-Packs. Several other types of packing material have been evaluated in previous tests. Based upon our experience the Tri-Packs have been found to have the same mass transfer characteristics as other packings that were evaluated but at a lower pressure drop, and therefore, were selected for testing at this site.

2) Description of Treatability Tests

The rate at which a volatile organic compound is removed from water by aeration (or the mass transfer rate) depends on several factors:

- hydraulic loading rate (or water flow rate)
- air flow rate
- air:water (A:W) ratio
- available surface area for mass transfer (function of packing)
- water temperature
- physical and chemical properties of the compound (Henry's Law Constant)

The latter three factors were constant and were not altered during the tests. The factors which were varied during the pilot tests were the water flow rate, the air flow rate and the A:W ratio. The water and air flow rates were varied during the pilot tests, to obtain several A:W ratios. VOC removals at these various conditions were used to develop a VOC mass transfer relationship.

The pilot column was set up at each well and operated at several A:W ratios. The water and air flow rates were adjusted for each run to yield the desired A:W ratio; the column was operated for about 15 minutes prior to sampling to reach a steady state condition.

For each run, influent and effluent samples were collected, the air and liquid flow rates were maintained constant, and the air and water temperatures were recorded. Samples were collected in properly prepared sample vials for VOC analysis prepared in accordance with EPA protocol. Analyses for VOCs were conducted at Malcolm Pirnie's laboratory with a gas chromatograph utilizing method 5030 (purge and trap) with either a Halogen Specific Detector (HSD) or a Flame Ionization Detector (FID). Column influent and effluent samples were collected during selected runs for adsorption and ion exchange testing.

3) Results of Testing Program

The aeration test results show that high VOC removal efficiencies were achieved in the pilot packed tower. The test results are presented in Table 4 for TCE, DCE and TCA.

In general, the test results indicate the following:

1. High VOC removals were obtained from the water in both wells via the a packed tower. Even with no forced draft, about 50 percent removal of TCE, DCE, and TCA was achieved.

2. A mass transfer relationship was determined for each VOC and is presented in Table 6.

3. Increasing the A:W ratio results in higher removal efficiencies.

These conclusions are expanded upon in the following sections. Also, design criteria based on the results of the pilot tests are presented at the end of this chapter.

TABLE 4

PILOT AIR STRIPPING COLUMN RESULTS

Concentration as (ug/L)

Run No.	Water Flowrate (GPM)	Air Flowrate (CFM)	Ratio (Ft^3/Ft^3)	TCE INF	TCE EFF	Percent Removal	1,1 DCE INF	1,1 DCE EFF	Percent Removal	1,1,1 TCA INF	1,1,1 TCA EFF	Percent Removal
M-11												
1	20	0		1,877	910	51.5	181	84	53.6	17	7.5	55.9
2	36	160	33/1	1,904	92	94.9	173	3.3	98.1	15	<0.5	>96.7
3	15	160	80/1	2,103	20	99.0	230	1.9	99.2	20	<0.5	>97.5
4	32	160	37/1	1,637	78	95.2	161	4.5	97.2	14	<0.5	>96.4
5	19	152	60/1	1,677	56	96.7	173	3.4	98.0	15	0.64	95.7
6	24	128	40/1	1,942	70	96.4	209	3.9	98.1	17	0.53	96.9
7	28	75	20/1	1,772	93	94.8	199	5.3	97.3	14	0.72	94.9
8	21	140	50/1	1,881	64	96.6	199	3.6	98.2	16	0.58	96.4
9	40	160	30/1	1,750	179	89.8	199	5.3	97.3	14	1.3	90.7
10	17	160	70/1	1,927	40	97.9	205	2.5	98.8	16	0.32	98.0
11	30	120	30/1	1,764	98	94.4	182	5.2	97.1	14	0.67	95.2
12	20	80	30/1	1,909	75	96.1	221	<0.5	>99.8	17	<0.5	>97.1
M-4												
1	36	160	33/1	1,913	84	95.6	601	18	97.0	29	1.2	95.9
2	15	160	80/1	1,502	43	97.1	516	7.8	98.5	29	1.7	94.1
3	32	160	37/1	1,611	65	96.0	541	17	96.9	23	1.1	95.2
4	19	152	60/1	1,563	42	97.3	529	12	97.7	24	1.0	95.8
5	24	128	40/1	1,605	63	96.1	508	16	96.9	24	1.3	94.6
6	28	75	20/1	1,494	70	95.3	510	16	96.9	23	1.1	95.2
7	21	140	50/1	1,441	60	95.8	501	15	97.0	22	1.2	94.5
8	40	160	30/1	1,607	78	95.1	534	20	96.3	24	1.2	95.0

NOTE: Water Temperature 77°F
Packing height 9.69 Ft.
INF - Tower Influent
EFF - Tower Effluent

Removal Efficiency - The data in Table 4 show that the packed column aeration process is capable of achieving high VOC removals. Consistently high VOC removals were achieved (greater than 95 percent range) with only 9.7 feet of packing media.

In dilute solutions, the principal factor that affects the ability to strip a VOC from the liquid phase to the gas phase is the Henry's Law Constant. A compound with a high Henry's Law Constant is more easily stripped from water using aeration than one with a lower constant. The Henry's Law Constants of the various VOC's are presented in Table 5.

TABLE 5

Henry's Law Constants

VOC	H(atm) (1)
DCE	736
TCE	569
TCA	424

(1) Values of H are given at the ambient groundwater temperature of 77°F

One would expect from this table of Henry's Law Constants that DCE should be the easiest to strip, while TCA should be the most difficult. The data for the most part bear this out. For a given run, the removal efficiency of DCE is generally higher than that of TCE and TCA which are roughly comparable.

The packed column tests show some VOC removals (50 percent TCE, DCE, TCA) are achieved even with no forced draft. Therefore, under full-scale operation of the column, these VOC removals may be expected even if the column is operated without the blowers on-line.

Mass Transfer Relationships - VOC mass transfer relationships were developed for Well No. 4 and No. 11 test results. For each run, a mass transfer coefficient was calculated from

the water flow rate, the A:W ratio, and the water temperature. A plot of the mass transfer coefficient (Kla) as a function of the liquid loading rate was developed for each VOC and plotted as shown on Figure 2 for well M-4 and on Figure 3 for M-11.

The mass transfer coefficients differ for each compound, again in accordance with their Henry's Law Constants: DCE is greater than TCE and TCA. The mass transfer coefficients at well M-4 are generally lower than the mass transfer coefficients at well M-11. Table 6 illustrates this point at a liquid loading rate of 25 gpm/Ft^2.

TABLE 6

Mass Transfer Coefficients (1/Hr) at 25 gpm/Ft^2

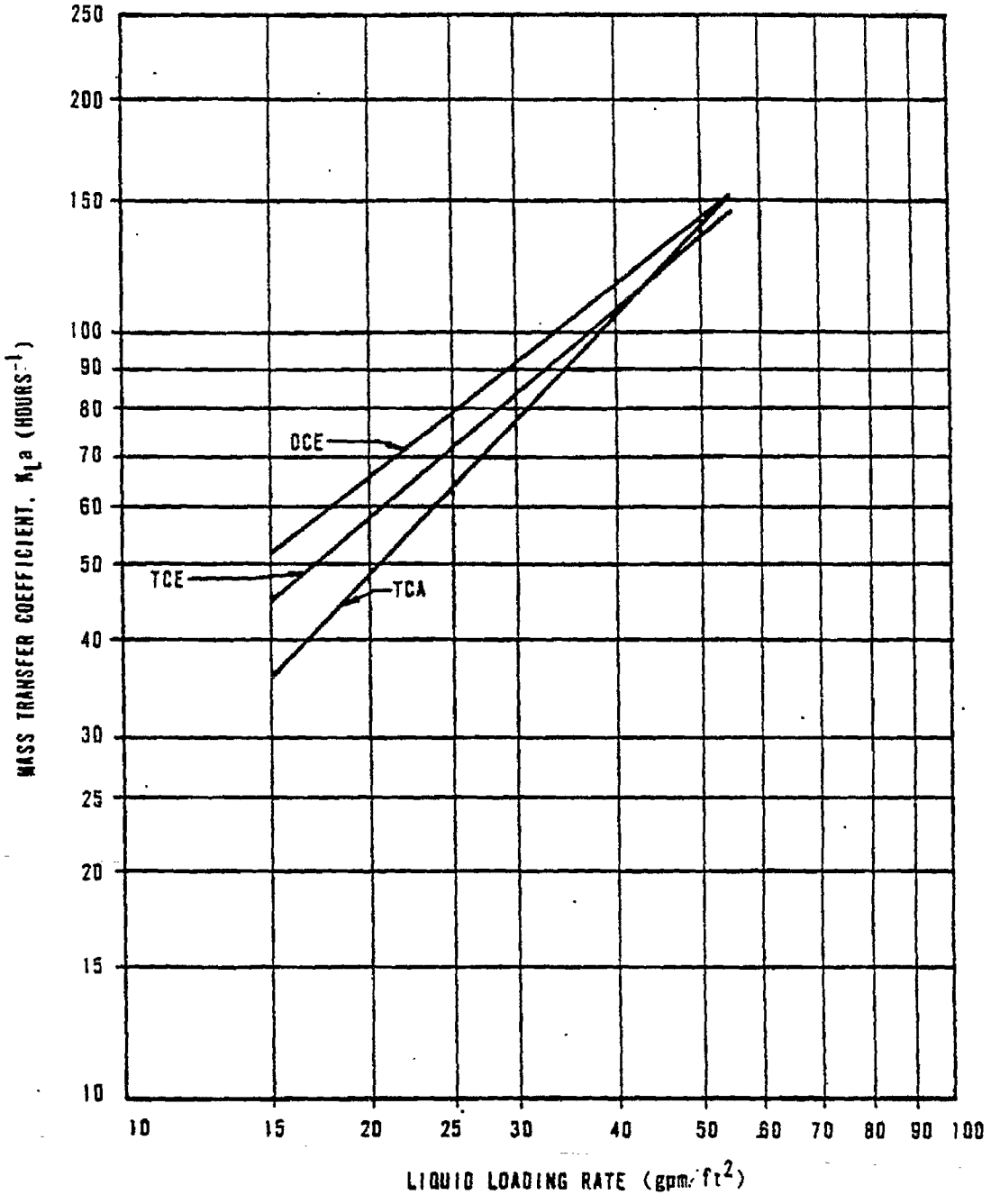
	Well M-4	Well M-11
DCE	80.0	88.7
TCE	72.7	77.6
TCA	64.3	76.0

The mass transfer relationships developed from testing at well M-4 were used to size the full scale aeration systems.

A:W Ratio - In general, increasing the A:W ratio increases VOC removal efficiencies. A relationship describing the packing height as a function of the A:W ratio was developed for the most stringent target effuent levels for TCE, DCE, and TCA. To meet the most stringent TCA target treatment level a packing height of only four feet (without safety factor) would be required independent of the A:W ratio.

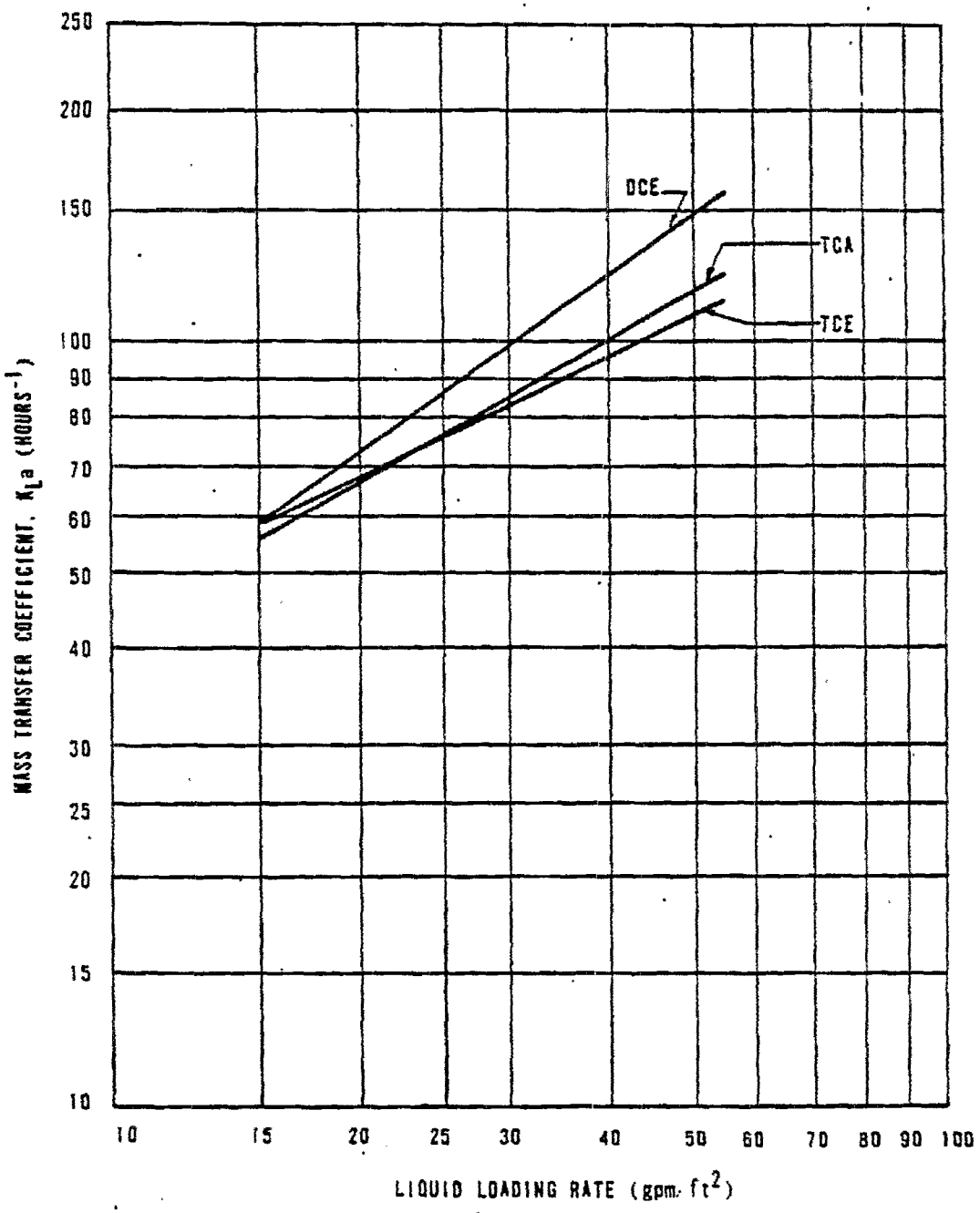
The relationship between packing height and air to water ratio for TCE, DCE, and TCA is shown in Figure 4. As shown in figure increasing the A:W ratio decreases the packing height required to achieve the specified removal efficiency. The results show that the packing height dependence upon the A:W ratio is not that significant. An A:W ratio of 30:1 was

FIGURE 2



MALCOLM PIRNIE

HUGHES AIRCRAFT COMPANY
TREATMENT OF RECLAIMED WATER
MASS TRANSFER RELATIONSHIP
WELL NO. 4

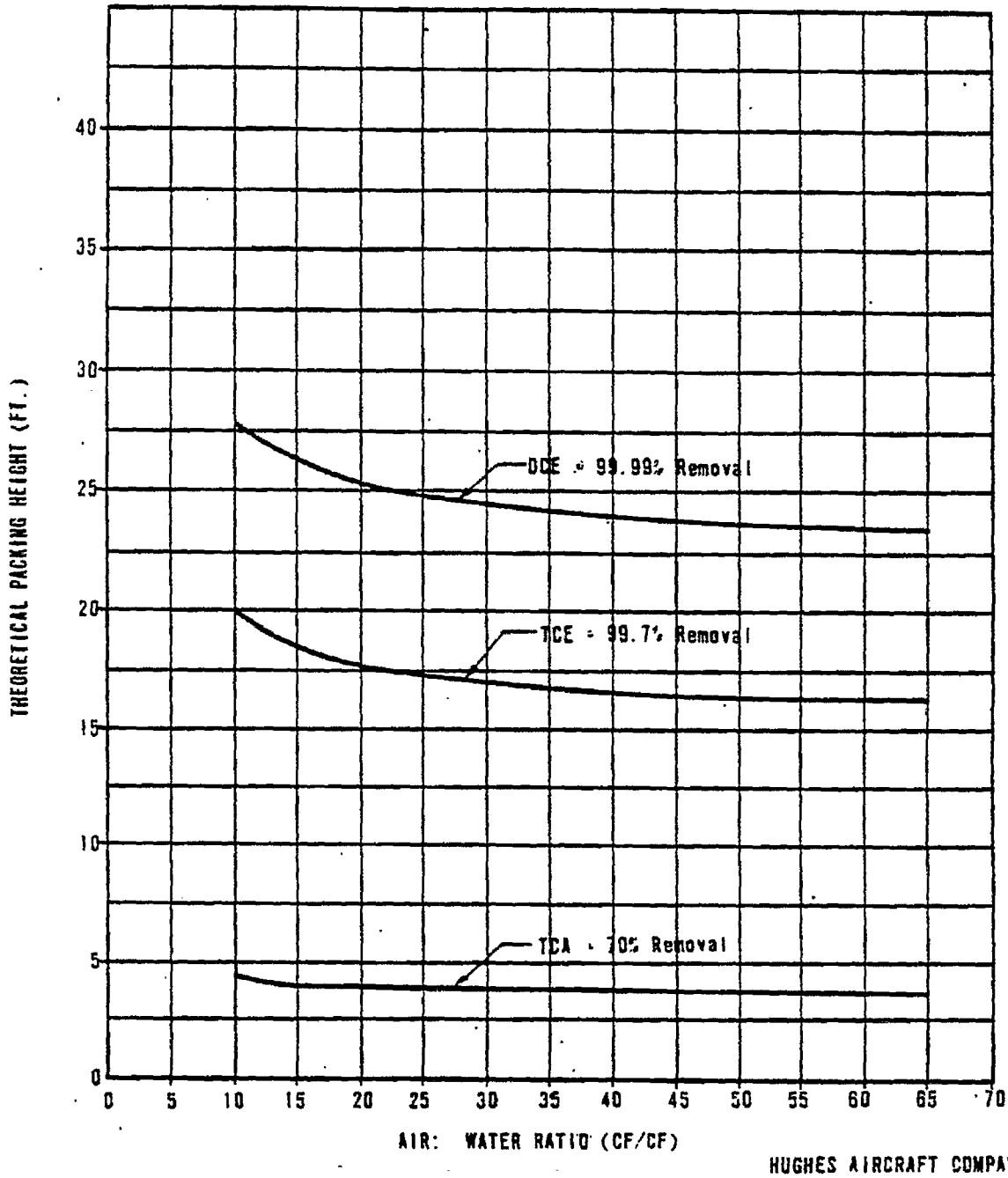


HUGHES AIRCRAFT COMPANY
TREATMENT OF RECLAIMED WATER
MASS TRANSFER RELATIONSHIP
WELL NO. 11

MALCOLM PIRNIE

FIGURE 4

408



HUGHES AIRCRAFT COMPANY
TREATMENT OF RECLAIMED WATER
PACKING HEIGHT
VS
AIR: WATER RATIO

MALCOLM PIRNIE

selected as a basis for column sizing. At an A:W ratio of 30:1 all three packing height versus A:W ratio curves are relatively flat, away from the knee of the curve. It is recommended in the sizing of full scale systems that the operating points be far from the knee of the curve so that fluctuations in either the air or liquid flowrates do not adversely effect the system performance.

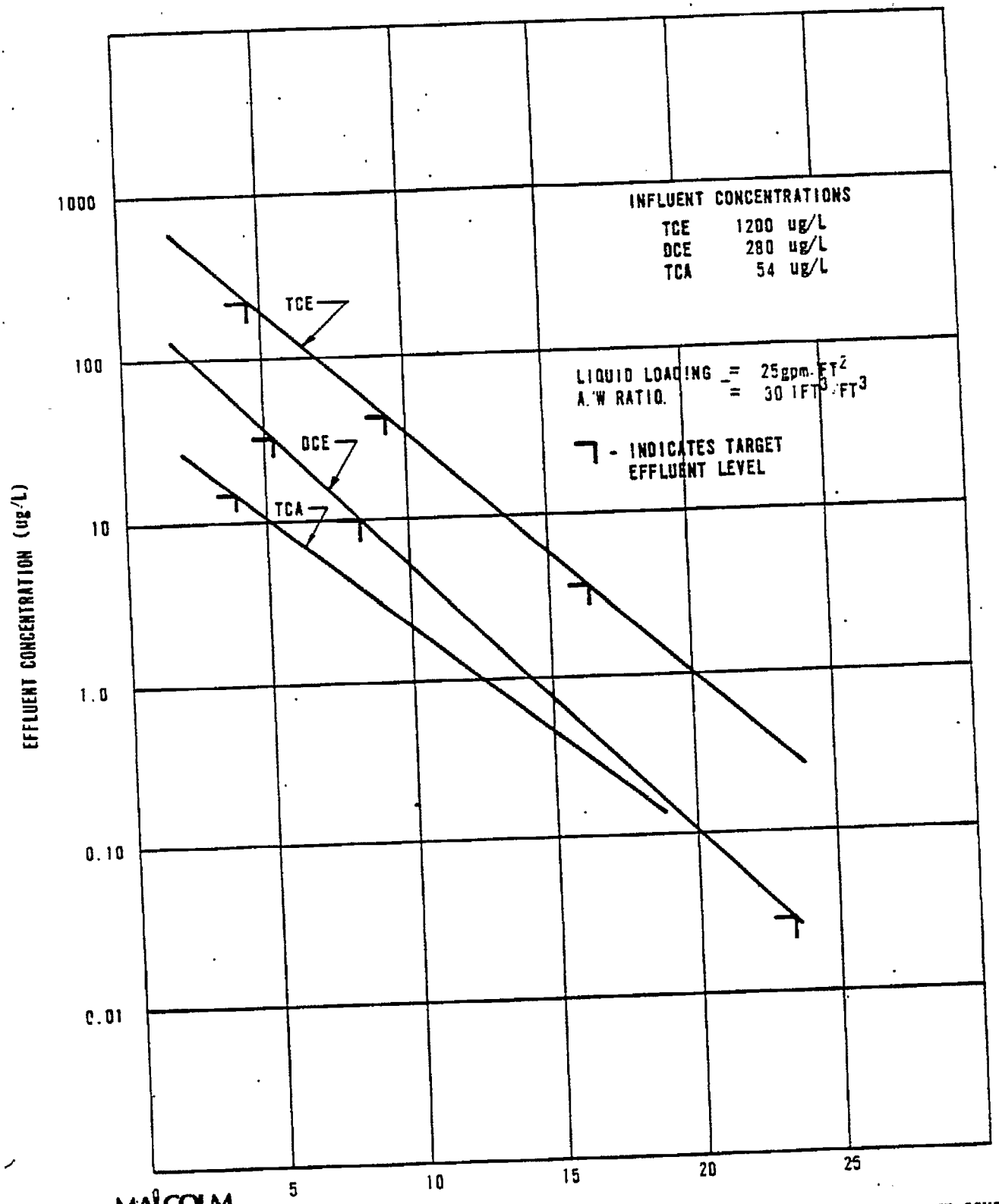
4) Design Criteria Selection

The performance of an air stripping system is a function of the column height and the A:W ratio. In order to determine which compound controls the height of the stripping column, a relationship was developed between effluent concentration and packing height for each compound. The influent levels used in this development are the initial VOC levels plus the range as estimated by Hargis and Montgomery for the 5000 gpm withdrawal rate. These estimated influent concentrations are presented in Section I of this report. An A:W ratio of 30:1 was also used in this analysis.

Figure 5 illustrates the relationship between effluent concentration and packing height for each VOC. The results show that the packing height requirements are highest to remove DCE to the target level of 0.033 ug/L. Approximately 24 feet of packing was calculated to meet that target effluent level. However, it is noted that the detection limit for the VOC's is generally on the order of 0.1 ug/L. Further the standard deviation of any DCE value around 0.1 ug/L is approximately 0.10 ug/L. The performance of the air stripping column has been projected to meet the most stringent requirement of 0.033 ug/L using the mass transfer relationships developed from pilot testing and assuming that suitable analytical techniques were available at this low level. However, any effluent limitations (required for permitting purposes) would have to be set higher because of analytical constraints.

FIGURE 5

410



MALCOLM PIRNIE

HUGHES AIRCRAFT COMPANY
TREATMENT OF RECLAIMED WATER
REQUIRED PACKING HEIGHT

The required packing height for the other target effluent concentrations can be determined directly from Figure 5.

The recommended process design criteria to meet the DCE concentrations are presented in Table 7. Based upon our experience a liquid loading rate of 25 gpm/Ft^2 is recommended for preliminary sizing purposes. The maximum column diameter has been limited to 12 feet because columns with a diameter larger than 12 feet require field fabrication rather than shop fabrication. Two columns operating in parallel are required to treat flows of 5,000 gpm while only one column is required to treat a flow of 2,000 gpm.

TABLE 7

Air Stripping Design Criteria

	DCE	DCE
Flow (gpm)	2,000	5,000
Mass Transfer Coefficient (Kla)	80	80
A:W Ratio (Ft^3/Ft^3)	30:1	30:1
Air Flowrate (CFM) Total	8,000	8,000
Calculated Packing Height (Ft) without Safety Factor	24.5	24.5
Column Surface Area Ft^2	80	200

It is noted that additional packing is always added to the calculated height as a factor of safety. It is also noted that a packed column will be have to be approximately 7 feet higher than the specified packing height to allow for inlet and outlet devices.

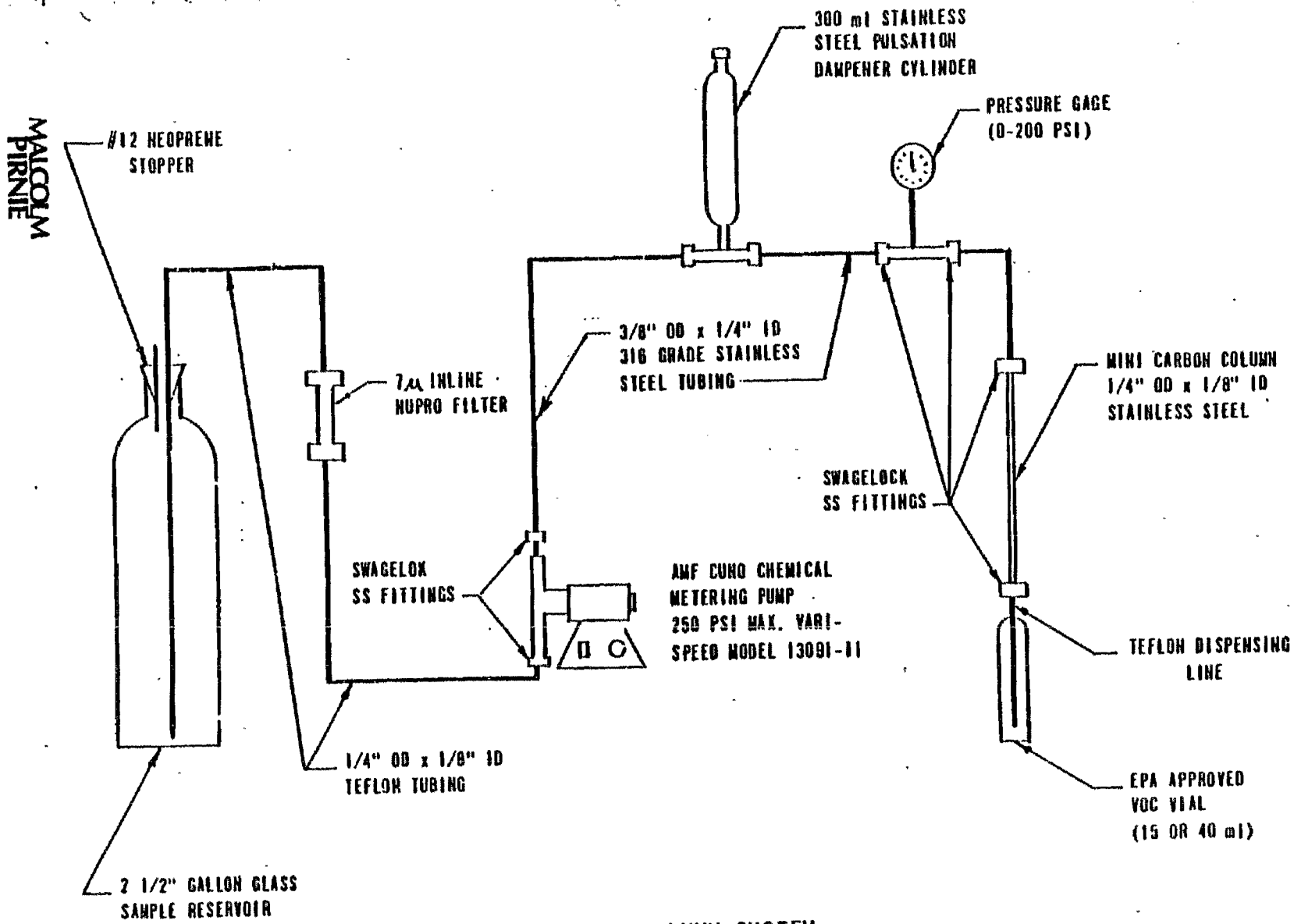
B. ADSORPTION PROCESSES

Mini-column tests were conducted to evaluate granular activated carbon (GAC) and a molecular sieve resin. The tests were conducted using water from well M-11. Three types of samples were tested: raw water, pilot aeration column effluent, and pilot aeration column effluent aerated further to reduce the level of VOC's prior to carbon testing. The

purpose of the tests was to determine the effectiveness of GAC or resin to remove VOC's and to develop carbon usage rates to meet the various treatment objectives. A description of the pilot tests and an evaluation of the test results are presented in this Section.

1) Description of Testing Equipment

The treatability tests were conducted using a dynamic mini-column adsorption system. The mini-column system, which was designed and fabricated by Malcolm Pirnie, consists of a glass sample container, a chemical metering pump, and a teflon and stainless steel mini-column (3.2 mm inside diameter x 15 cm long). A schematic diagram of the mini-column system is presented in Figure 6. The materials used in the mini-column system which are in contact with the water samples are either glass, teflon, or stainless steel. These inert materials are used to avoid sample contamination. Water is pumped from the sample reservoir to a 1/4-inch diameter stainless steel tube which conveys the water to the mini-carbon column. The mini-column influent line includes a 300 ml cylinder to dampen flow pulsations and a pressure gage to monitor system pressure. Following the pulsation dampener and pressure gage, the water passes through the mini-column. The column holds 0.10 gram of ground GAC or resin which has been heat treated to remove any adsorbed contaminants. The GAC was ground to a 100 x 200 mesh; the resin was ground to a 70 x 100 mesh due to the inability to pump through the smaller mesh size. Following compaction via vibration, the bed depth is about 1 inch. The bed is held in place with 1/2 inch of glass wool packed into the bottom of the column. The mini-column effluent is conveyed to a sample vial via teflon tubing. The teflon effluent line discharges below the liquid surface in the sample vial to minimze volatilization of the VOCs contained in the mini-column effluent.



CARBON MINI-COLUMN SYSTEM

MALCOLM PIRNIE

FIGURE 6

2) Description of Treatability Tests

The removal of a volatile organic compound by adsorption depends on several factors including:

- Type of GAC or resin
- Temperature of the water
- Chemistry of the compound

The latter two factors were constant and were not varied during the tests on well M-11 samples. Carborundum GAC 30 and a molecular sieve resin provided by Union Carbide were evaluated in the mini-column tests.

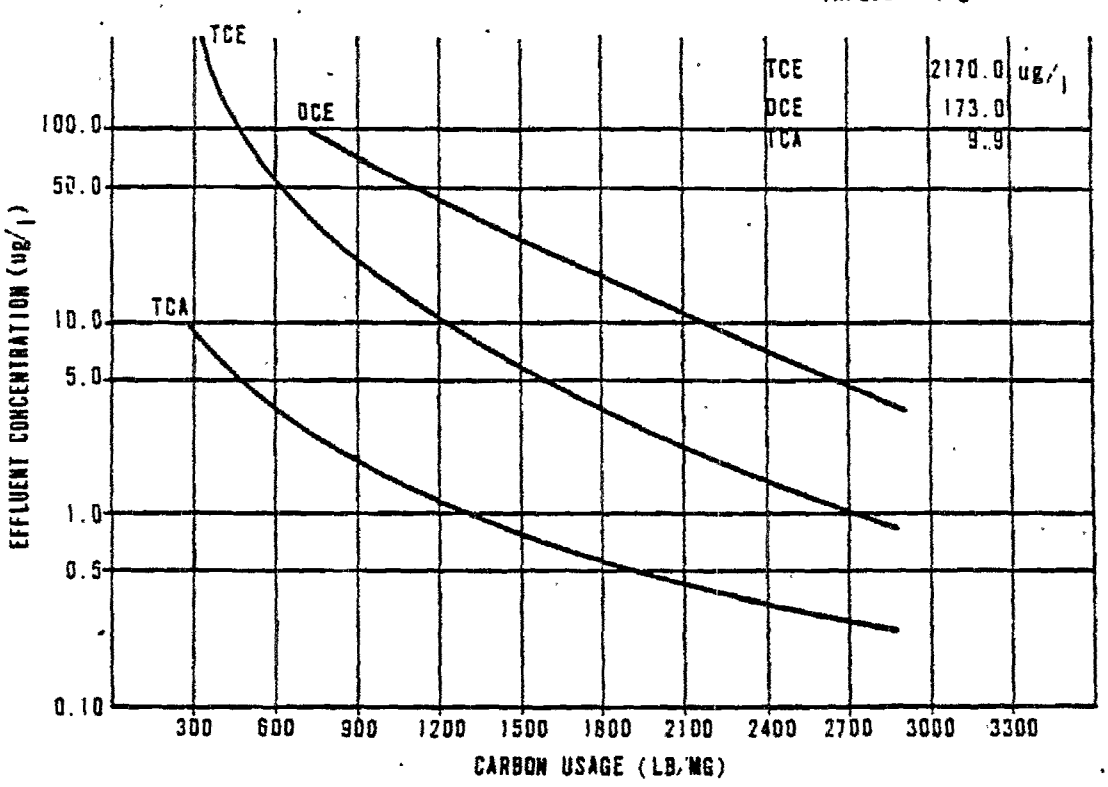
Representative samples of raw water and pilot aeration column effluent were obtained from well M-11 during the aeration treatability tests and shipped to the Malcolm Pirnie laboratory. Mini-column tests using carbon and resin were also conducted on the raw well water.

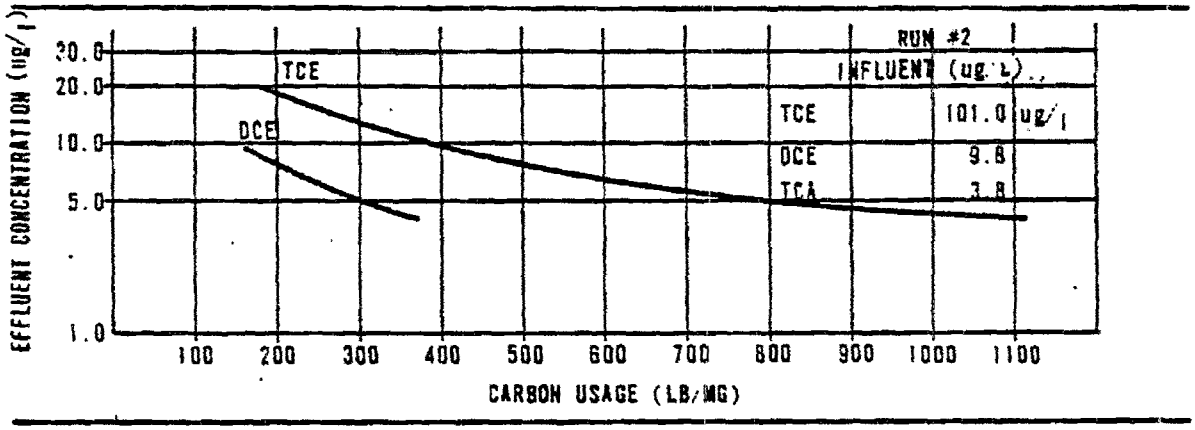
3) Results of Testing Program

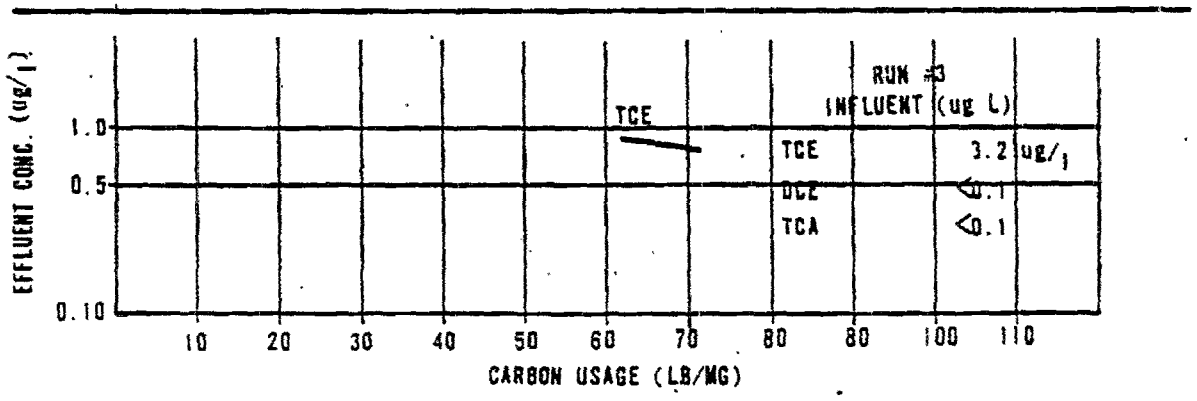
Breakthrough Characteristics - The results of the mini-column tests are presented in Table 8. It is noted that the resin clearly did not perform as well as carbon on the raw water sample and on this basis was eliminated from further testing and evaluation.

Breakthrough curves for each VOC were developed from the data. The breakthrough curves were used to develop carbon usage rates to reach various effluent concentrations. The relationship between effluent concentration and carbon usage is shown in Figure 7 for all three carbon runs.

Carbon Usage - The estimated carbon usage to reduce the DCE concentration in raw water to 10 ug/L was approximately 2,150 pounds per million gallons (Lb/MG) or 15,480 Lb/day to treat a flow of 5,000 gpm. For this carbon usage rate an on-site carbon regeneration system would be required. Due to high carbon usage rates and high cost of carbon regeneration and contact equipment, adsorption is not cost effective to treat raw water.







MALCOLM PIRNIE

HUGHES AIRCRAFT-COMPANY
TREATMENT OF RECLAIMED WATER
CARBON USAGE RATES

TABLE 8

A) Mini-column Carbon Study

Results

	Effluent Volume (ml)	1,1 DCE	1,1,1 TCA	TCE
Run #1				
Initial		193	17	2,170
	291	3.6	0.27	0.84
	1,023	85	2.3	22
	1,917	169	6.4	116
	2,997	173	9.9	476
Run #2				
Initial		9.8	3.8	101
	300	<0.5	<0.5	1.8
	2,263	4.1	<0.5	10.4
	5,399	10.4	<0.5	23
Run #3				
Initial		<0.1	<0.1	3.2
	2,670	<0.1	<0.1	<0.1
	11,722	<0.1	<0.1	0.75
	13,410	<0.1	<0.1	0.90

B) Mini-column Resin Study

Results

Initial		134	11	1,548
	40	10	2.8	18
	553	84	5.9	394
	1,735	91	4.4	440

NOTE:
(1) Initial sample for run #3 was collected after run was completed
(2) Halogen specific detector used for run #1,2
(3) Flame ionization detector used for run #3,4

IV. CHROMIUM REMOVAL

Bench scale treatability studies were conducted using water collected from well M-11 to evaluate reduction/precipitation, ion exchange, and carbon/molecular sieve resin adsorption as means of removing chromium.

A. REDUCTION/PRECIPITATION

1) Description of Treatability Tests

Raw water samples collected from well M-11 were used in this study. An analysis of the water indicated that there was less than 0.04 mg/L total chromium and 0.008 mg/L hexavalent chromium (Cr^{+6}). The difference in detection limit is due to the nature of the analytical procedures used for each test. Total chromium was analyzed via atomic adsorption with detection limit of 0.04 mg/L while Cr^{+6} was measured via a colorimetric technique with a detection limit of 0.005 mg/L.

Since low levels of chromium were found in the samples from well M-11 the samples were spiked with potassium dichromate to increase the hexavalent chromium concentration to 0.2 mg/L. Hargis estimates of the initial total chromium concentration in the 5,000 gpm scenario are 0.07 ± 0.03 mg/L.

Jar tests were conducted on the spiked water. Ferrous sulfate ($FeSO_4$) and sodium metabisulfite ($Na_2S_2O_5$) were the reducing agents tested. The results of the jar tests are presented in Table 9.

2) Results of Treatability Tests

$FeSO_4$ was added in varying dosages (10-50 mg/L as $FeSO_4$) at the ambient water pH of 7.2. Hexavalent chromium was reduced from 0.2 mg/L to less than 0.01 mg/L within 3 minutes at all $FeSO_4$ dosages. Caustic (NaOH) then was added to raise the pH to 8 to form chromium and iron hydroxide precipitates; the samples were mixed for another 5 minutes. The samples were filtered to remove precipitates and were found to have less than 0.04 mg/L total chromium.

TABLE 9

Chromium Removal Studies
REDUCTION/PRECIPITATION

REDUCTION STEP					PRECIPITATION STEP				
Reducing Agent	Dosage (mg/L)	Reaction Time (minutes)	Cr^{+6} Remain (mg/L)	TSS Produced (mg/L)	NaOH Dosage (mg/L)	pH	Reaction Time (minutes)	TSS Produced (mg/L)	Total Cr (mg/L)
$FeSO_4$	10	3	<0.01	2	16	8	5	4	<0.04
	30	3	<0.01	5	26	8	5	14	<0.04
	50	3	<0.01	7	32	8	5	26	<0.04
$FeSO_4$	5	3	NA	NA	5	7.5	5	1	0.06
	10	3	NA	NA	8	7.5	5	2	0.04
$FeSO_4$	5	3	NA	NA	11	8.0	5	2	0.04
	10	3	NA	NA	15	8.0	5	5	<0.04
$FeSO_4$	5	3	NA	NA	25	8.5	5	2	0.04
	10	3	NA	NA	30	8.5	5	4	<0.04
$Na_2S_2O_5$	5	2	0.16	<1					
	10	2	0.15	<1					
	20	2	0.10	<1					
$Na_2S_2O_5$	5	10	0.16	<1					
	10	10	0.15	<1					
	20	10	0.10	<1					
$Na_2S_2O_5$	5	20	0.16	NA					
	10	20	0.14	NA					
	20	20	0.09	NA					

Initial Cr^{+6} concentration (mg/L) = 0.2 mg/L
Initial pH = 7.2
NA = Not Analyzed

In subsequent tests, lowering the $FeSO_4$ dosage to 5 mg/L caused the effluent total chromium to rise to 0.04 mg/L at pH's of 8.0 and 8.5, and 0.06 mg/L at pH=7.5. In addition, at a dosage of 10 mg/L $FeSO_4$ and a pH of 7.5 the effluent total chromium was 0.04 mg/L.

Sodium metabisulfite was also tested as a reducing agent, but was found to be not as effective as $FeSO_4$ at the ambient pH of 7.2. Sodium metabisulfite is generally more effective at a lower pH.

In summary reduction/precipitation using $FeSO_4$ was found to be an effective process for chromium removal. The recommended $FeSO_4$ dosage for reduction of Cr^{+6} to Cr^{+3} is 10 mg/L; a pH of 8 is recommended for hydroxide precipitation.

3) Solids Handling

The amount of solids produced during the precipitation process was measured. At the recommended $FeSO_4$ dosage (10 mg/L) and pH (8), 5 mg/L TSS were produced. It is anticipated that these solids could be removed via multi-media pressure filters. The filters would require periodic backwashing; the backwash solids would be thickened, dewatered and then sent to off-site disposal.

It is recommended that pilot reduction/precipitation and filtration studies be conducted to: (a) generate sufficient sludge quantities so that solids handling alternatives can be evaluated and (b) evaluate both standard and high rate filtration systems.

4) Design Criteria Selection

The design criteria developed from the bench scale reduction/precipitation testing are summarized in Table 10.

TABLE 10

Design Criteria
Reduction/Precipitation

$FeSO_4$ Dosage (mg/L)	10
Reaction Time for Reduction (min)	5
pH for Precipitation	8
Reaction Time for Precipitation (min)	5
TSS produced (mg/L)	5

B. ION EXCHANGE

1) Description of Treatability Testing

The treatability studies were conducted using a 25 ml buret (3/8 inch inside diameter). A strong base Type 1 anion exchange resin, Amberlite IRA-402 manufactured by Rohm and Haas was used in the testing. A resin volume of 6 ml was used which this resulted in a bed depth of 3.75 inches. The resin was converted into the chloride form by passing sodium chloride through the resin.

A positive displacement pump was used to continuously feed sample to the buret at a nominal rate of 2 ml/min. This feed rate resulted in an empty bed contact time of 3 minutes. The column was operated in a downflow mode. Samples were collected periodically and analyzed for hexavalent chromium.

2) Results of Testing Program

The results of the ion exchange treatability study are summarized in Table 11. The sample from well M-11 was again spiked with potassium dichromate to achieve an influent Cr^{+6} concentration of 0.20 mg/L. Cr^{+6} was removed to levels below the target of 0.05 mg/L initially and remained below 0.05 mg/L until approximately 2200 bed volumes of flow had passed through the resin, which was sooner than anticipated. The

levels continued to increase until the end of the test when the effluent Cr^{+6} concentration dropped. It is not understood why the effluent Cr^{+6} levels dropped near the end of the test.

The resin was regenerated using sodium chloride. Approximately 50 percent of the influent chrome was recovered after regenerating with what was thought to be a sufficient volume of regenerant. Additional regenerant would have been required to remove more chromium from the resin.

3) Process Design Criteria

To apply the results of the treatability tests to the design of a full scale ion exchange facility, the following process design criteria were established:

- Maximum water flowrate and loading rate
- Empty bed contact time
- Maximum influent and effluent concentrations
- Frequency of resin regeneration

These design criteria were then utilized to determine the number of contactors, contactor dimensions, and the quantity of resin required.

The following is a preliminary design of an ion exchange system for treating 2,000 gpm of groundwater containing 0.2 mg/L hexavalent chromium to meet the treatment objective of 0.05 mg/L total chromium. The number of contactors and contactor dimensions was based upon a loading rate of 4.8 gpm/Ft^2 and an EBCT of 10 minutes. These design criteria are summarized in Table 12.

TABLE 11

Chromium Removal Studies
Ion Exchange

DATE	EFFLUENT VOLUME (ml)	FEED RATE (ml/min)	Cr^{+6} mg/L
8/11	initial		.20
8/12	2,050		<0.005
	5,008		<0.005
8/15	10,498		0.016
	10,846	1.97	0.017
	11,186		0.021
	11,261		0.026
	11,575	1.81	0.026
	12,870	1.76	0.055
8/16	12,985	1.67	0.11
	13,183	2.10	0.11
	13,401	1.75	0.11
	13,539	1.79	0.12
	14,684		0.06
	14,756		0.09

Resin: Rohm & Haas IRA - 402 Strong Base anionic form
Column: 3/8" Diameter Buret
Resin volume = 6 ml

TABLE 12

Design Criteria
Ion Exchange

No. Contactors:	4
Hydraulic Capacity:	500 gpm per contactor
Contactor Diameter:	11.5 feet
Contactor Height:	12 feet
Depth of Resin:	6.75 feet
Resin per Contactor:	675 Ft^3
Resin Regeneration Frequency:	Twice a month

An order of magnitude estimate of this ion exchange system is about $2,000,000. A major portion of this cost is the resin itself, valued at approximately $600,000. The cost does not include the additional cost of facilities to treat the spent regenerant for chromium removal. The cost for the ion exchange system and the facilities to treat the regenerate wastes will be significantly higher than the cost of a reduction/precipitation alternative. It is noted to that a smaller ion exchange system could be provided which would require more frequent resin regeneration; but at a lower capital cost.

In summary, ion exchange did achieve the treatment objective of 0.05 mg/L. More extensive pilot testing would be required to determine if a full scale system could be developed for this particular application. However, the cost of the ion exchange system, and regenerant treatment system along with the uncertainty of the resin's ability to be regenerated and render ion exchange unattractive for chromium removal.

C. ADSORPTION

A raw water sample from well M-11 was spiked with 0.2 mg/L of hexavalent chromium. During the dynamic mini-column testing of GAC and the molecular sieve resin, samples were taken and analyzed for hexavalent chromium. The results of these tests are presented in Table 13.

TABLE 13

Chromium Removal Via Adsorption

Effluent Volume (ml)	Cr^{+6} Concentration (mg/L) GAC	Molecular Sieve Resin
Initial	0.20	0.22
40	0.08	0.22
112	0.14	NA
331	0.16	NA
505	0.17	NA
1063	0.19	NA

Hexavalent chromium immediately broke through beyond the 0.05 mg/L target level during testing of both the GAC and molecular sieve resin. Some chromium removal was achieved with GAC. As expected, none was achieved with the resin. It was concluded from these results that adsorption of chromium onto either GAC or the molecular sieve resin is not an effective treatment process for removing chromium.

V. CONCEPTUAL DESIGN OF RECOMMENDED SYSTEM

As discussed in Section III, an aeration process using a packed column is recommended to reduce the VOC levels down to the various target levels. A chemical reduction/precipitation process is recommended to remove hexavalent chromium while a multi-media filtration process is recommended to remove the chromium precipitate. The filter backwash which contains the chromium precipitate would be transferred to an equalization tank and then to a sedimentation process to remove the precipitate from backwash waste. The iron and chromium precipitates that settle out in the clarifier would be transferred to a storage tank and then pumped to a sludge dewatering process such as a recessed plate pressure filter or two twin wire multi-roll compression belt filter. After dewatering the solids would be hauled offsite for disposal. Based upon a recommendation by Hargis and Montgomery to remove all particles greater than 0.5 microns prior to recharge, a cartridge filter system is recommended following the dual media filtration system.

A. PRELIMINARY SIZING OF PACKED TOWERS

As discussed in Section I, a range of target treatment levels were developed by USAF in conjunction with the ADHS and USEPA. One of the principal objectives of this study is to describe treatment alternatives that would meet the target treatment levels. As shown in Figure 5, the effluent VOC level remaining in the packed column effluent is controlled primarily by the packing height. In sizing a packed tower additional packing is added to the calculated packing height to account for variations in the VOC levels in the influent to the column, for variations in the liquid loading to the tower and as a factor of safety for the mass transfer relationship.

The calculated packing height for each target treatment level was obtained from Figure 5. The recommended packing

height was determined as follows: Four feet of packing was added to the calculated packing height to allow for variations in the influent VOC concentration and variations in the liquid loading. The packing height was further increased by 25 percent as a factor of safety. The overall tower height is approximately seven feet higher than the packing height to provide space for the air and liquid inlet and outlet devices. As indicated previously the tower was sized at a hydraulic loading of 25 gpm/ft^2 with a maximum column diameter equal to 12 feet. 25 feet was used as the practical maximum height for a packed tower. Columns were sized for flow conditions of 2,000 gpm and 5,000 gpm. Capital cost estimate was prepared for the various packed column alternatives. Both the sizing and cost estimates are presented in Table 14. It is noted that the cost estimate does not include the cost for any of the other facilities such as withdrawal and recharge wells, distribution piping, chromium removal or solids handling systems. However, provisions were made for an installed spare packed tower. The purpose of Table 14 is to illustrate the sizing and relative cost sensitivity to meet the various target levels. The cost to achieve the lowest VOC levels is high because of the requirement for a two stage column system and added cost for an intermediate pumping station and an additional blower, piping, foundations, electrical work and instrumentation.

B. CONCEPTUAL DESIGN CRITERIA

Process flow diagrams of the treatment system recommended to treat flows of 2,000 gpm and 5,000 gpm and reduce the DCE

TABLE 14

Capital Cost Estimate for Packed Tower Process[1]

Matrix:

Flow	Compound	Target Level (ug/l)	Number of Trains[2]	Columns Per Train	Overall Height (Ft)	Capital Cost ($)
5,000 gpm						
	TCE	5	3	2	20	876,000
		50	3	1	24	378,000
		270	3	1	17	319,000
	DCE	0.033	3	2	25	960,000
		10	3	1	23	370,000
		40	3	1	19	336,000
	TCA	16.8	3	1	17	319,200
		50	-	-	-	-
		168	-	-	-	-
2,000 gpm						
	TCE	5	2	2	20	599,000
		50	2	1	24	260,000
		270	2	1	17	221,000
	DCE	0.033	2	2	25	655,000
		10	2	1	23	254,000
		40	2	1	19	232,000
	TCA	16.8	2	1	17	221,000
		50	-	-	-	-
		168	-	-	-	-

1. Costs are for the packed tower process alone.

2. Includes 1 spare.

level to 0.033 ug/l are presented in Figure 8 and Figure 9. The unit sizing criteria that were used to prepare the flow sheets are summaried as follows:

1) Packed Column(s)

- o Liquid Loading - 25 gpm/ft^2
- o Packing Height (calculated) - 24 feet
- o Packing Height recommended - 36 feet
- o Provide two - 25 foot high columns
- o A/W ratio - 30/1 (ft^3/ft^3)
- o Pressure Drop - approximately 5 inches water
- o Provide installed spare packed towers

2) Reduction/Precipitation

- o Ferrous sulfate dosage - 10 mg/l
- o Reaction time for reduction - 5 minutes
- o Reaction time for precipitation - 5 minutes
- o Provide spare reaction tank with mixer
- o Sodium hydroxide dosage to raise pH to 8.0 = 15 mg/l
- o Suspended solids produced = 5 mg/l

3) Dual-Media Filtration

- o Hydraulic loading = 4 gpm/ft^2
  Provide one space filter
- o Polymer dosage - 3 mg/l
- o Use filtered effluent for backwash
- o Backwash frequency - assume once/day
- o Backwash volume - 15 gpm/ft^2 for 15 min.

4) Cartridge Filtration

- Provide vessel with disposable filter cartridge to remove particles greater than 0.5 microns.
- Provide spare vessel and cartridges

5) Solids Handling

- Backwash storage tank to contain 125% of the daily backwash flow
- Hydraulic loading - 400 gpd/ft^2
- Provide spare clarifier
- Polymer dosage - 5 mg/l
- Sludge storage tank
- Recessed Plate pressure filter
  - Assume cake solid concentration = 30%
  - Assume cake bulk density = 68 lb/ft^3
  - Assume two filtration cycles/week

Special Study Report

432

CONCEPTUAL STUDY FOR TREATMENT OF RECLAIMED WATER AT USAF PLANT NO. 44 PHASE III RESULTS

Hughes Aircraft Company
Tucson, Arizona

United States Air Force
Contract Number F33657-81-E-2096

February 1984

MALCOLM PIRNIE

ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

TABLE OF CONTENTS

	PAGE
I. INTRODUCTION	I-1
II. PHASE I - TREATMENT ALTERNATIVES	II-1
A. VOC REMOVAL PROCESSES	II-1
1. Aeration	II-1
2. Adsorption	II-2
B. HEXAVALENT CHROMIUM REMOVAL PROCESSES	II-3
1. Reduction/Precipitation	II-3
2. Ion Exchange	II-4
3. Reverse Osmosis	II-5
C. SUMMARY	II-6
III. PHASE II - VOC REMOVAL	III-1
A. PACKED COLUMN AERATION	III-1
1. Description of Testing Equipment	III-1
2. Description of Treatability Tests	III-3
3. Results of Testing Program	III-4
4. Process Design Criteria Selection	III-8
B. ADSORPTION PROCESSES	III-9
1. Description of Testing Equipment	III-10
2. Description of Treatability Tests	III-11
3. Results of Testing Program	III-11
4. Process Design Criteria	III-13
IV. CHROMIUM REMOVAL	IV-1
A. REDUCTION/PRECIPITATION	IV-1
1. Description of Treatability Tests	IV-1
2. Results of Treatability Tests	IV-1
3. Solids Handling	IV-3
4. Design Criteria Selection	IV-3
B. ION EXCHANGE	IV-4
1. Description of Treatability Tests	IV-4
2. Results of Testing Program	IV-4
3. Process Design Criteria	IV-5
C. ADSORPTION	IV-7

TABLE OF CONTENTS
(continued)

	PAGE
V. CONCEPTUAL DESIGN OF RECOMMENDED SYSTEM	V-I
A. PRELIMINARY SIZING OF PACKED TOWERS	V-1
B. CONCEPTUAL DESIGN CRITERIA	V-2
VI. PHASE III RESULTS - CAPITAL AND OPERATING COST ESTIMATES	
A. SYSTEM DESCRIPTION	VI-1
B. ESTIMATING PROCEDURE AND ILLUSTRATIONS	VI-2
1. Reclaim and Recharge Piping	VI-3
2. Treatment Plant Piping and Equipment	VI-3
3. Ultrafiltration Alternate	VI-5
4. Electrical System	VI-6
5. Instrumentation	VI-7
6. Site Work and Structural	VI-7
C. COST SUMMARY	VI-8
APPENDIX	

MALCOLM PIRNIE

LIST OF FIGURES

Number	Description	Following Page
1	Diagram of Pilot Air Stripping Column	III-1
2	Mass Transfer Relationship Well No. 4	III-7
3	Mass Transfer Relationship Well No. 11	III-7
4	Packing Height vs. Air:Water Ratio	III-7
5	Required Packing Height	III-8
6	Carbon Mini-Column System	III-10
7	Carbon Usage Rates	III-11
8	Process Flow Schematic - 5,000 gpm	V-4
9	Process Flow Schematic - 2,000 gpm	V-4
10	Reclamation and Recharge Piping Layout	VI-3
11	Reclamation Well Schematic	VI-3
12	Recharge Well Schematic	VI-3
13	Treatment Plant Site Plan	VI-3
14	Process Flow Schematic - 5,000 gpm	VI-4
15	Energy Saving and VFD Use	VI-7
16	Energy Saving and VFD Use	VI-7
17	CRT Display - Total Well Fields	VI-7
18	CRT Display - Reservation	VI-7
19	CRT Display - TAA	VI-7
20	CRT Display - Hughes Central	VI-7

LIST OF FIGURES

Number	Description	Following Page
21	CRT Display - FACO	VI-7
22	CRT Display - Typical Recharge Well Display	VI-7
23	CRT Display - Typical Reclaimation Well Display	VI-7
24	Project Schedule	VI-10

LIST OF TABLES

Number	Description	Page Number
1	Estimated Initial VOC and Chromium Concentrations	I-2
2	Target Treatment Levels	I-2
3	Well Water Characterization	III-2
4	Pilot Air Stripping Column Results	III-7
5	Henry's Law Constants	III-8
6	Mass Transfer Coefficients (1/Hr) at 25 gpm/Ft^2	III-10
7	Air Stripping Design Criteria	III-9
8	Mini-column Carbon Study	III-12
9	Chromium Removal Studies Reduction/Precipitation	IV-2
10	Design Criteria Reduction/Precipitation	IV-4
11	Chromium Removal Studies Ion Exchange	IV-6
12	Design Criteria Ion Exchange	IV-7
13	Chromium Removal Via Adsorption	IV-8
14	Battery Limits Capital Cost Estimate for Packed Tower Process	V-3
15	Construction Cost - 5,000 gpm System	VI-9
16	Cost Matrix	VI-10

VI. CAPITAL AND OPERATING COST ESTIMATES

A water treatment system was developed during the screening and pilot testing phases to remove volatile organic compounds (VOC's) and chromium from the groundwater at the Hughes Aircraft Company facility in Tucson, Arizona. This section of the report describes the proposed system and presents estimates of the capital cost and the operation and maintenance costs.

A. SYSTEM DESCRIPTION

The water treatment process that was developed in the second phase of this study included a packed tower air stripping system to remove VOC's followed by a reduction/precipitation process to remove chromium and final cartridge filtration. A system to remove the solids generated by the reduction/precipitation process was also selected. This solids handling system includes clarification and dewatering facilities (via a recessed plate filter press) to reduce the volume of sludge requiring ultimate disposal.

Additional facilities which may be required are described in the following section. Further study is recommended to confirm the need for these additional facilities. The capital cost and the operation and maintenance cost for these facilities were for the most part included in this estimate.

A vapor carbon adsorption system may be required to reduce the VOC emission rate into the atmosphere. The system has been sized to remove VOC's from the discharge of the first stage packed towers which emit the largest quantity of VOC's. Due to relatively low VOC concentration in the tower discharge to the atmosphere (10 ppm by volume), the carbon system is expected to remove only 50 to 80 percent of the applied VOC's. Further study is recommended prior to final design to develop conceptual design criteria and performance estimates.

For purposes of the cost estimate a cleaning system has been provided to remove inorganic scale such as calcium carbonate from the media in the packed tower. Dilute mineral acid will be recirculated through the towers to dissolve scale. The acid solution will be collected and recirculated from a separate sump. Provisions to clean the media with a solution of chlorine and water has also been provided. The purpose of this step is to remove biological growth that might attach to media.

Final treatment including pH adjustment and chlorination prior to injection has been provided. Final effluent chlorination should prevent biological growth in the water distribution system while final pH adjustment has been provided to prevent solids precipitation and potential fouling of the recharge well. Further study is recommended to determine the need for final pH control prior to recharge.

Ultrafiltration has been considered as an alternative to the proposed process of pressure filtration followed by cartridge filtration. Ultrafiltration was evaluated in case the particle size of the solids in the flow to the injection wells needed to be less than one micron which is the expected particle size in the pressure and cartridge filtration scheme. It is noted that pressure filtration followed by two stage cartridge filtration might be an alternative to ultrafiltration.

B. ESTIMATING PROCEDURE

A detailed cost estimate was developed for the collection, conveyance, treatment, distribution and injection facilities for a flow of 5000 gpm. The height of the packed tower(s) was varied to meet the various target treatment objectives. The cost to meet the various target treatment levels was determined by adding the cost of the packed tower

systems (required to meet the target treatment levels) to the cost of all of the facilities. It is noted that the cost of the remaining treatment and conveyance facilities is a function of the flowrate and the number and location of the reclamation and injection wells and not on the VOC levels.

Also it is noted that the target chromium level may be achievable by blending. Some cost savings could be realized if chromium treatment is not required.

The cost estimate for the 2000 gpm system was developed by factoring the 5000 gpm estimate down to reflect a reduction in the size of the collection, treatment, and injection facilities.

The capital cost estimate was developed starting with preliminary layouts of required wells, treatment and conveyance facilities. Mechanical costs were developed for the most part from budget vendor quotations. Piping costs were developed from quantity take offs of pipes, valves and other fittings. The electrical and instrumentation estimate was also developed from quantity take offs of required equipment.

1) Reclamation and Recharge Piping

A preliminary layout of the reclamation and recharge well system is presented in Figures 10A, B and C. The number and siting of the reclamation and injection wells was developed by Hargis and Montgomery (Hargis). A schematic of a typical reclamation and recharge well is shown in Figure 11 and Figure 12. The piping layout represents a cost effective method of conveying water to and from the water reclamation plant.

2) Treatment Plant Piping and Equipment

The cost of in plant piping was developed from a preliminary piping layout. A site plan of the water treatment facility that also shows a motor list is presented in Figure 13. A process flow schematic of the water treatment system

equipment is presented as Figure 14. Installed spares have been provided for all mechanical equipment and most of the tankage.

The proposed system includes a chlorination system to provide the capability of adding chlorine to the treatment plant influent and effluent.

The air stripping system consists of three parallel trains of two packed towers with an intermediate sump used to repump the water to the second stage packed towers. Each train is sized to handle 2500 gpm of reclaimed water. One train has been provided as a standby. A media acid wash system which include a separate sump, pumps and piping has also been provided should the packed media ever require cleaning.

The packed tower effluent flows into a chemical reaction tank where ferrous sulfate is added to reduce hexavalent chromium to the trivalent form. The pH of the stream is then raised with sodium hydroxide to about 8 to precipitate chromium and ferric hydroxides. Mechanical agitators are provided in each reaction tank to promote adequate contact of the chemicals with water. Ferrous sulfate and sodium hydroxide storage and feeding facilities have been provided. Ferrous sulfate will be delivered as a bulk solid; the feed solution would be made up upon delivery and stored as a liquid. Sodium hydroxide will be purchased and stored as a 50 percent aqueous solution. Spare reaction tanks with mixers have also been provided.

A transfer pump pumps the water through a static mixer where polymer is added as a coagulant and to enhance the removals of precipitated metal hydroxides prior to pressure filtration. A complete polymer make up and storage system has been provided.

Four horizontal pressure filters have been provided, each sized to handle approximately 1700 gpm. One spare filter pump

is provided. Each filter is divided into four separate compartments to allow backwashing of each compartment, with the effluent from the other three compartments. This feature eliminates the need for a separate tank to store water used for backwashing.

Effluent from the backwashing step is collected and stored prior to pumping to a clarifier for solid/liquid separation. Polymer is added in line to aid in coagulation. A second polymer make up and storage facility has been provided. Sludge from the bottom of the clarifier is transferred to a sludge storage tank prior to dewatering on a recessed plate filter press. Dewatered sludge will be collected in a dumpster or dump truck and periodically hauled away. Clarifier supernatant and filter press filtrate will be recirculated back to the reduction/precipitation system.

Cartridge filtration using disposable cartridges has been provided after filtration to reduce the particle size of any solids that may be in the treated water to one micron. A clearwell has been provided after cartridge filtration to provide some storage of the treated water should the capacity of the injection wells be temporarily exceeded.

Final treatment facilities to adjust the pH of the treated water and to add chlorine have been provided.

Analytical equipment to allow for Hughes to analyze samples for VOC's and chromium in the effluent has been provided.

3) Ultrafiltration Alternate

An ultrafiltration (UF) system has been considered as an alternate to pressure and cartridge filtration for solids removal. A staged system would be required to achieve a recovery of about 98 percent. A reject stream of 2 percent, or 100 gpm would be sent to the solids handling system already provided.

Due to the high flowrates required through the system, internal recirculation and storage would be required. Because of recirculation, the pumping requirements of a 5000 gpm UF system would actually be 16,000 gpm. At the required pressure drop of 20 psi through the UF system, the power requirement would be approximately 250 hp. This is significantly higher than the 50 hp power requirement of the pressure/cartridge filtration system.

The cost for a 5000 gpm UF system which includes the pumps, membrane, modules, internal storage and membrane washing system would be about _____ . Since the capital and operation and maintenance costs for an ultrafiltration system is considerably higher than the costs for pressure and cartridge filtration, the pressure and cartride filtration alternative is recommended and is included in the cost estimate.

4) Electrical System Description

The proposed work includes the following: Two 5000 KVA oil transformers with secondary switch gear will be added onto the existing main outdoor substation. A total of 6 feeders at 4160 volts will run underground from the main outdoor substation to the various loads. The loads will include a new unit substation rated 112.5 KVA at each reclamation well (17 total), a new double ended 1500 KVA substation at the new treatment plant and the existing treatment plant substation. Each of these substations will be supplied from two separate feeders. The two 5000 KVA transformers and dual feeder arrangement will essentially provide a loop type distribution system. This would provide load transfer capability that might result from feeder breakdown. This also insures power availability for additional wells that might be required.

The unit substations at the reclamation wells will have interlocked primary switches, transformer section and 480 volt secondary distribution panel. Each substation will include a

variable frequency controller for the reclamation well pump water. Low voltage power will run from the distribution panels to the closest recharge wells. All reclamation and recharge wells will be interconnected for signal transmission. Lighting and security using intrusion detection and equipment tamper devices at each well.

The new electrical units at the treatment plant will include the substation described above, 480 volt motor control centers, variable frequency controllers, and all transformers, panels, switches, and interconnecting conduit and cable required for a complete installation. Lighting, grounding, security and communication system is also included.

5) Instrumentation

An instrumentation and control system proposed by the Allen-Bradley Company is included in the appendix. The proposed system is a computer control system designed to be a distributed process control system. The base system consists of four PLC-3 programmable controllers with remote I/O for monitoring and control of reclamation and injection wells and fifth PLC-3 for the treatment plant. The control system has been designed based on the use of variable speed drives (VFD) to run the pumps at the wells and the treatment plant. VFD's have been utilized based upon the energy and cost savings as illustrated in Figures 15 and 16.

The system provides for measurement and remote display of pressure, flow, and temperature in all process water lines within the plant as well as in the conveyance and distribution systems. Flow will be controlled remotely. The pH in the reduction/precipitation system and in the final effluent will be monitored and controlled remotely. The water level in each reclamation and injection well will also be monitored remotely. Typical CRT displays attainable are depicted in figures 17 through 22.

ALLEN-BRADLEY

ALLEN-BRADLEY DRIVES DIVISION

ENGINEERING DATA	APPLICATION
HUGHES AIRCRAFT	Centrifugal Pump
Energy Savings Application for 50HP Centrifugal	
Pump using Variable Speed vs. Throttling	INDUSTRY:

SYSTEM DATA

PUMP: 50HP centrifugal pump described by curves in figures 1-3.

MOTOR: 50HP, 1750 RPM, TEFC enclosure, 95% efficiency at full load and speed.

DRIVE: 50KVA, Bulletin 1350 adjustable frequency AC drive

97% efficient at full load and speed

90% efficient at ½ load and speed

VALVE: Effect on system shown by curves in figure 2.

AVERAGE SYSTEM OPERATING POINT: 55% flow = 300 GPM

BHP COMPARISON BETWEEN VARIABLE SPEED AND THROTTLING

	THROTTLING		VARIABLE SPEED	
FLOW (GPM)	HEAD (FT.)	BHP*	HEAD (FT.)	BHP*
550	250	35	250	35
300	277	21	90	7

*BHP = (Flow x Head)/3960 (for water)

CALCULATION OF ANNUAL POWER USAGE

$$\text{KW HR Usage} = \text{BHP} \times \frac{1}{\text{Eff. Motor \& Control}} \times .746\text{KW/HP} \times \text{hours of operation}$$

THROTTLING VALVE METHOD:

$$\text{KWH} = 21\ \text{HP} \times \frac{1}{.95} \times .746\ \text{KW/HP} \times 8760\ \text{HRS}$$

8760 HRS = YEAR ROUND 24 HRS./DAY

= 144457 KWH

VFD USE JUSTIFICATION
ENERGY SAVING
50 HP

FIGURE 15

AC DRIVE METHOD:

$$7HP \times \frac{1}{.95} \times .746\ KW/HP \times 8760\ HRS$$

$$= 48152\ KWH$$

Energy Saving = (144457KWH - 48152KWH)

= 96305KWH x .055¢/KWH
= $5,297 savings per year

NOTE: The heads used in this example were calculated from the reclamation system, actual heads may vary in the installed system changing the energy savings figure.

ALLEN-BRADLEY

ALLEN-BRADLEY DRIVES DIVISION

ENGINEERING DATA	APPLICATION
HUGHES AIRCRAFT	Centrifugal Pump
Energy Savings Application for 25HP Centrifugal	
Pump using Variable Speed vs. Throttling	INDUSTRY

SYSTEM DATA

PUMP: 25HP centrifugal pump

MOTOR: 25HP, 1750 RPM, TEFC enclosure, 95% efficiency at full load and speed.

DRIVE: 25KVA, Bulletin 1334 adjustable frequency AC drive

97% efficient at full load and speed

90% efficient at ½ load and speed

VALVE: Effect on system shown by curves in figure 2.

AVERAGE SYSTEM OPERATING POINT: 60% flow = 1200 GPM (typical for pump systems)

BHP COMPARISON BETWEEN VARIABLE SPEED AND THROTTLING

	THROTTLING		VARIABLE SPEED	
FLOW (GPM)	HEAD (FT.)	BHP*	HEAD (FT.)	BHP*
2000	50	25	50	25
1200	66	20	18	6

*BHP = (flow x Head)/3960 (for water)

CALCULATION OF ANNUAL POWER USAGE

$$\text{KW HR Usage} = \text{BHP} \times \frac{1}{\text{Eff. Motor Control}} \times .746\text{KW/HP} \times \text{hours of operation}$$

THROTTLING VALVE METHOD:

$$\text{KW} = 20\ \text{HP} \times \frac{1}{.95} \times .746\ \text{KW/HP} \times 8760\ \text{HRS}$$

8760 HRS = YEAR ROUND 24 HRS./DAY

= 137578 KWH

VFD USE JUSTIFICATION
ENERGY SAVING
25 HP

FIGURE 16

AC DRIVE METHOD:

$$6HP \times \frac{1}{.95} \times .746\ KW/HP \times 8760\ HRS$$

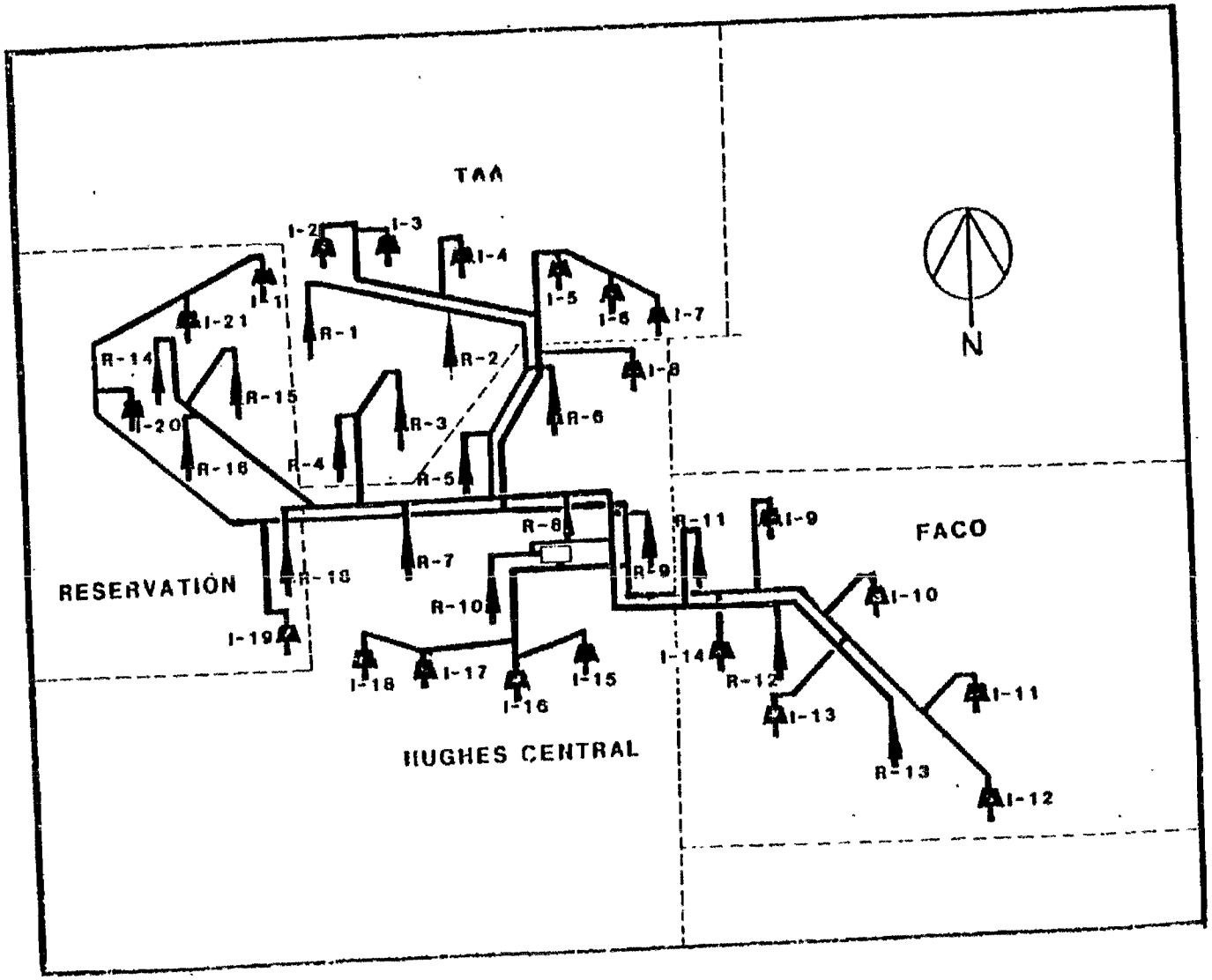
$$= 41273\ KWH$$

Energy Savings =

137578 = 41273 KWH

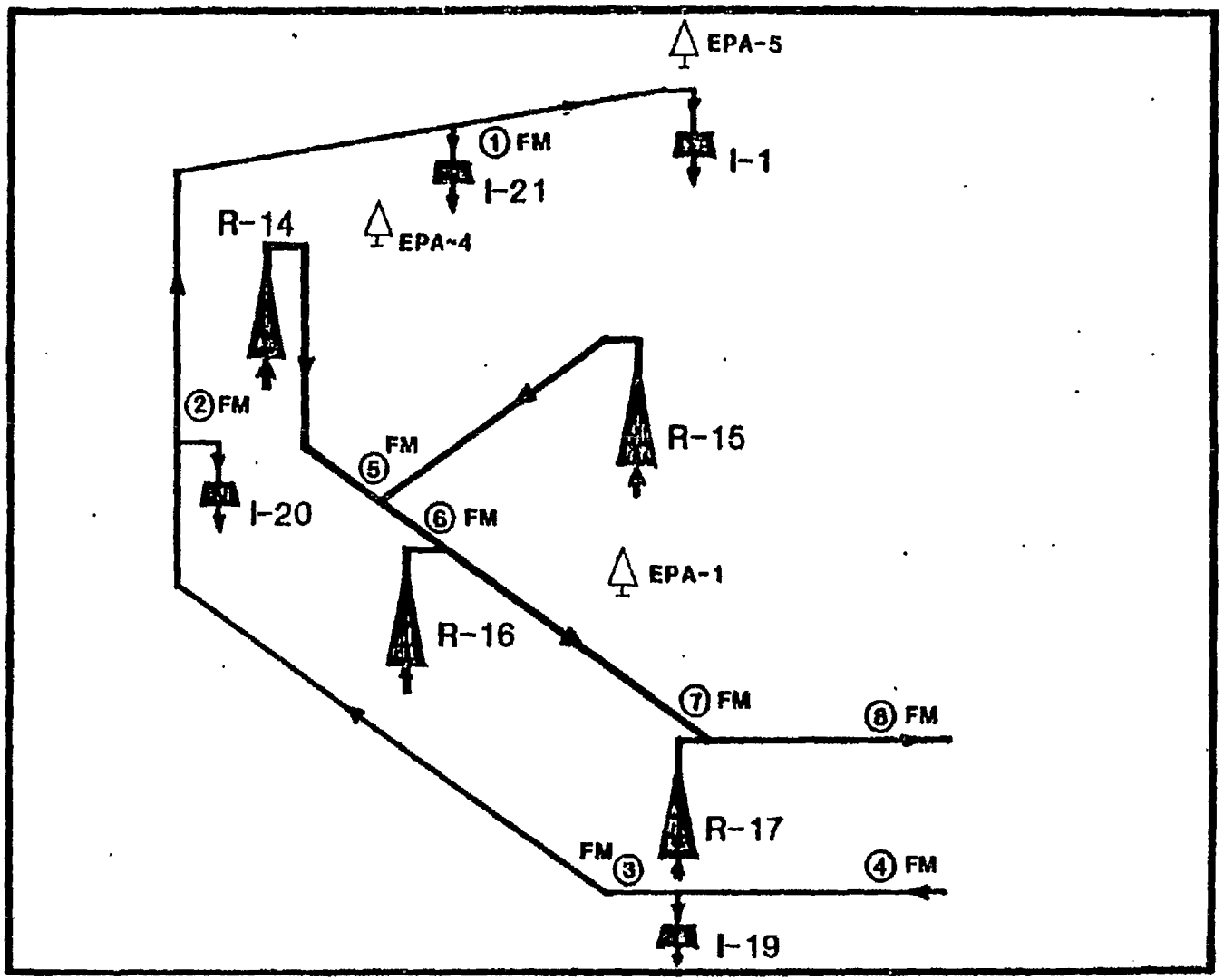
= 96305 KWH x .055¢/KWH
= $5,296 Savings per year

NOTE: This example is an estimate only as the actual heads and GPM rates were not know for the process plant.



TOTAL WELL FIELDS

COLORGRAPH VIDEO DISPLAY
TOUCH ZOOM IN CAPABILITY
WELL FIELDS

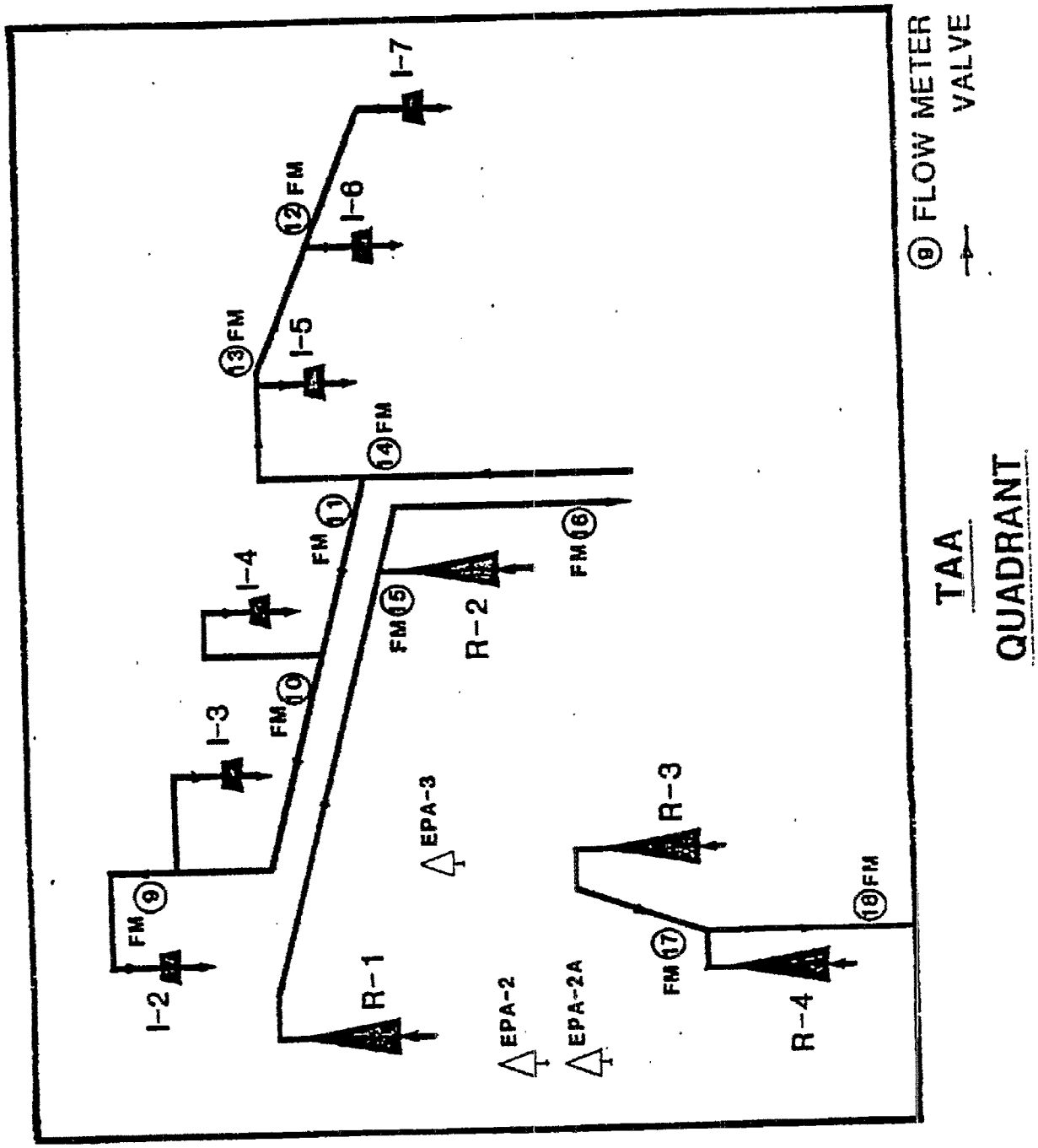


RESERVATION QUADRANT

① FLOW METER
VALVE

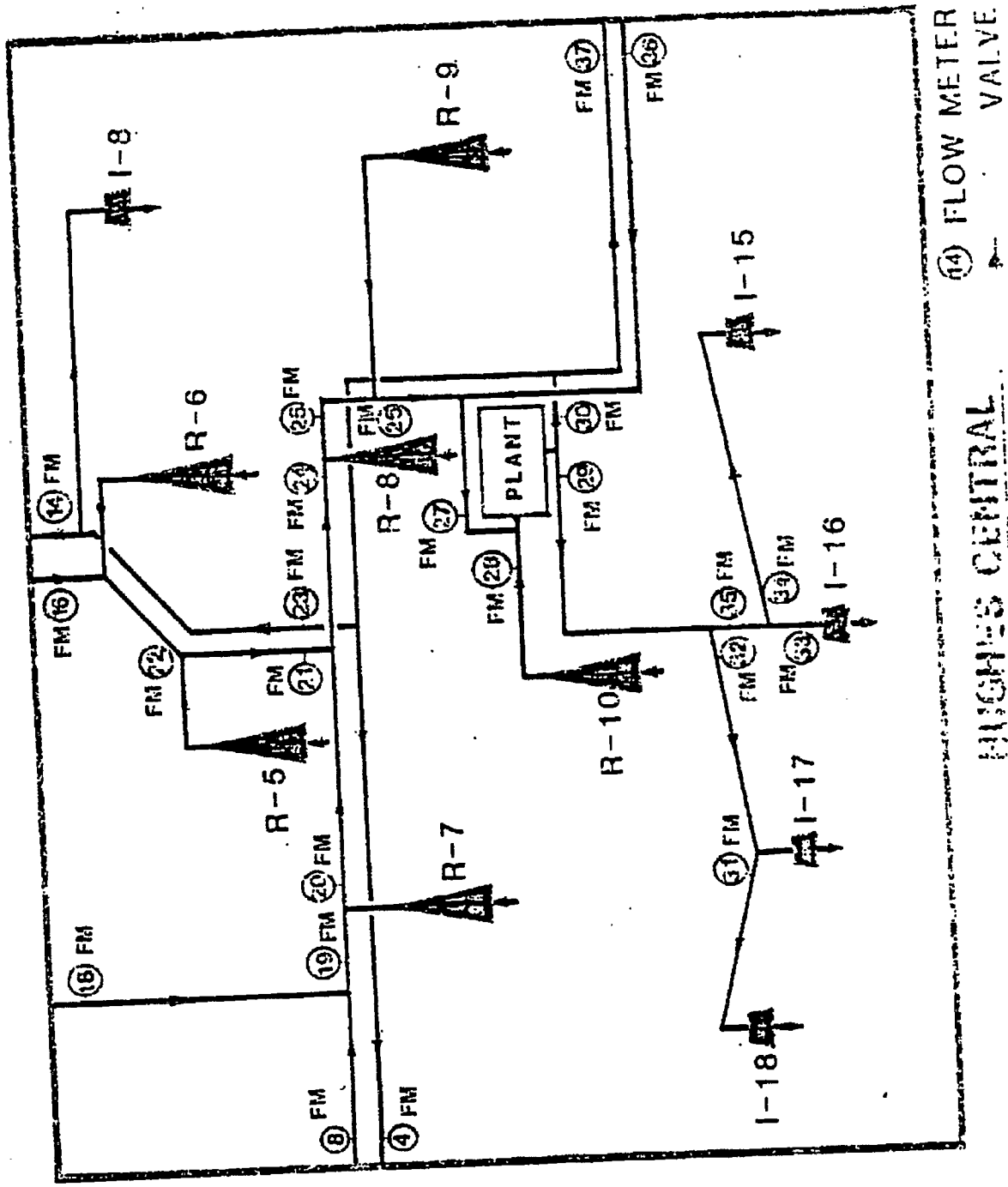
COLORGRAPH VIDEO DISPLAY
TOUCH ZOOM IN CAPABILITY
ONE OF FOUR SECTIONS

FIGURE 18



COLORGRAPH VIDEO DISPLAY
TOUCH ZOOM IN CAPABILITY
TWO OF FOUR SECTIONS

FIGURE 19

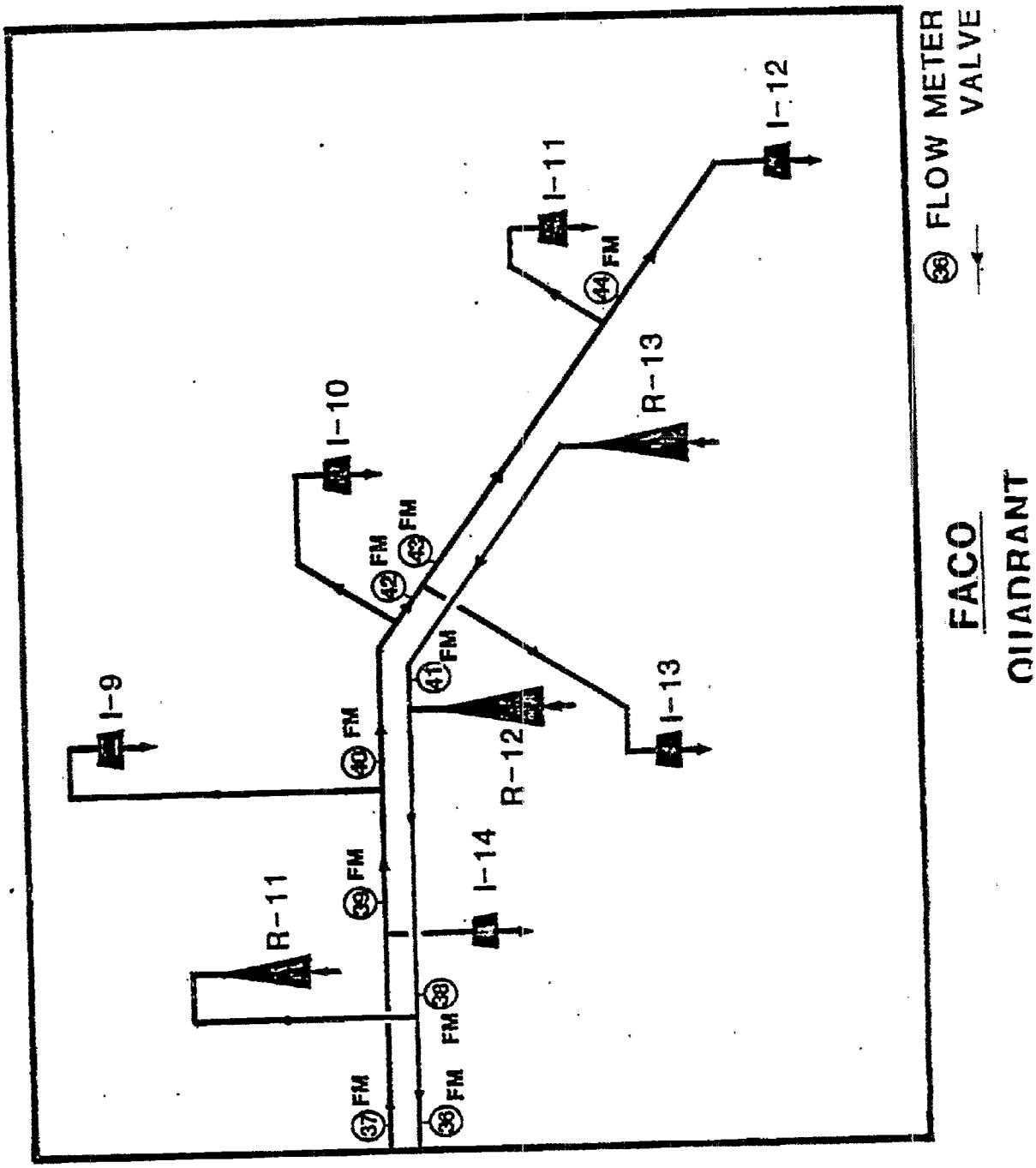


COLORGRAPH VIDEO DISPLAY

TOUCH ZOOM IN CAPABILITY

THREE OF FOUR SECTIONS

'RE 2



COLORGRAPH VIDEO DISPLAY

TOUCH ZOOM IN CAPABILITY

FOUR OF FOUR SECTIONS

FIGURE 21

TIME _____

DATE _____

RECHARGE WELL I-21

VALVE OPEN ● VALVE CLOSED ●

FLOW RATE _____ GPM

TOTAL GALLONS LAST 24 HOURS _____ GAL

TOTAL GALLONS LAST 7 DAYS _____ GAL

PRESSURE ● HI-LO ● SAFE _____ PSI

LEVEL ● HI-LO ● SAFE _____ FT

TRESPASS ● SECURE ●

TYPICAL

COLORGRAPH VIDEO DISPLAY

ONE OF 21 RECHARGE WELLS

FIGURE 22

TIME _____
DATE _____

RECLAMATION WELL R-16

PUMP IN OPERATION	OFF ● ON ●		
GPM FLOW		_____	GPM
VFD FREQUENCY		_____	CY
RPM		_____	RPM
TOTAL GALLONS LAST 24 HOURS		_____	GAL
TOTAL GALLONS LAST 7 DAYS		_____	GAL
TOTAL RUN TIME		_____	HRS
KWH READOUT		_____	KWH
VOLTAGE UNDED ●	OVER VOLTAGE ●	_____	VOLTS
AMPS	OVER CURRENT ●	_____	AMPS
ROTOR TEMP	OVER HEAT ●	_____	°C
HEAD PRESSURE		_____	PSI
PHASE LOSS ●	POWER OFF ●	_____	
SHORT CKT ●	STALL ●		
TRESPASS ●	SECURE ●		
	● PC CUTOUT		

● AUDIO REPORT
● VFD BY PASS _____
● VFD FREQUENCY MANUAL ● UP ● DOWN _____

TYPICAL
COLORGRAPH VIDEO DISPLAY
ONE OF 17 RECLAMATION WELLS

FIGURE 23

6) Site Work & Structural

The site work and structural estimate includes the cost to provide equipment pads, in ground tankage, a building, and fencing at the treatment plant site. The estimate also includes site work at each well location, as well as a provision for unimproved roadways.

C. COST SUMMARY

The estimated project cost for the 5000 gpm water reclaimation system is This estimate includes an allowance for the first year cost for operating and maintenance, consulting and contract analytical services. A breakdown of this cost estimate is presented in Table 15. Backup for the construction cost estimate is appended.

A matrix was developed to compare the project cost as a function of target effluent concentration. The matrix is presented in Table 16. The results show that the cost to achieve the lowest target effluent levels is not significantly different than the cost to achieve high effluent levels.

TABLE 15

CONSTRUCTION COST ESTIMATE - 5000 GPM SYSTEM

Reclamation Wells, Piping, Valves and Fittings

Reclamation Well Pumps

Recharge Wells, Piping, Valves and Fittings

Water Treatment Plant Piping, Valves and Fittings

Civil/Architectural, Sitework, Structural and Roadways

Electrical and Lighting, Power and Distribution

Treatment Plant Process and Analytical Equipment

Instrumentation and Controls

Construction Cost

First Year Operation and Maintenance

First Year Analytical and Hydrogeological Consulting Services

A&E Services

Hughes Engineering Support

Total Project Cost

TABLE 16

COST MATRIX
5000 gpm

Target Objective (ug/l)	Resultant Effluent (ug/l)		Total Project Cost ($)
TCE	DCE	TCA	
5	0.6	0.4	
50	8	4	
270	70	11	
DCE	TCE	TCA	
0.033	0.5	.04	
10	80	6	
40	250	10	
TCA	TCE	DCE	
16.8	400	75	

APPENDIX

ELECTRICAL ESTIMATE BACKUP

MALCOLM PIRNIE

A. Reclamation and Recharge Wells

Item	Material	Quantity	Labor Hours	Materials ($)
1.	3' x 3' x 3' Handhole	31	62	
2.	Excavation & Backfill	31	124	
3.	Gravel Sump	31	62	
4.	6' x 8' x 6' Manhole	37	74	
5.	Excavation & Backfill	37	296	
6.	Gravel Sump	37	111	
7.	Patch	37	148	
8.	Trench & Backfill 24"W x 36"D	30,450'		
9.	Trench & Backfill 18"W x 36"D	22,800'		
10.	Roadway cut (concrete)	150'	Included in Mechanical Estimate	
11.	Roadway Cut (asphalt)	360'		
12.	Railway Cut (tracks)	30'		
13.	Parking lot cut (asphalt)	900'		
14.	Roadway repair (concrete)	300'	30	
15.	Roadway repair (asphalt)	1,800'	54	
16.	R.R. cut repair	30'	7	
17.	Rubble remove	10	20	
18.	Public area safeguards	lot	40	
19.	Grade & Level	38	38	
20.	Above grade splice box on manhole	6	24	
21.	8'-6" x 8'-6" x 7' manhole	1	2	
22.	Excavate & Backfill	1	8	
23.	Gravel sump	1	3	
24.	Patch	1	4	
25.	Above grade splice box	5	5	
26.	Reclamation wells	17	17	
27.	Rechange wells	21	21	
28.	2' x 3' 3' handhole	38	76	
29.	Excavate	38	76	
30.	Sump	38	38	
31.	4" PVC conduit	74,600'	7,460	
32.	2" PVC conduit	89,400	4,470	
33.	4" End bells	208	124	
34.	2" End bells	214	47	
35.	4" Adapters	208	124	
36.	2" Adapters	214	47	
37.	Pull line in empty conduit	10,000'	30	
38.	4" Caps or plugs	32	19	
39.	4" Spacer	14,920	746	
40.	2" Spacer	17,880	894	
41.	Tie downs (pairs & cross)	10,650	532	
42.	500 MCM 5KV shielded cable	199,100'	5,973	
43.	4/0 XHHW cable	68,000'	1,700	
44.	1/0 XHHW cable	101,550'	1,827	
45.	#2 XHHW cable	67,700'	974	

MALCOLM PIRNIE

Item	Material	Quantity	Labor Hours	Materials ($)
46.	Twin axial cable	59,500'	AB Proposal	AB Proposal
47.	Twin axial termination	66	AB Proposal	AB Proposal
48.	5KV triple splice	36	72	
49.	5KV Single splice	30	45	
50.	4 PR. #18 SH. cable Belden 9388	59,000'	AB Proposal	AB Proposal
51.	PVC solvent	160 QTS	8	
52.	5 KV terminations	222	333	
53.	4 PR. #18 SH terminations	78	AB Proposal	AB Proposal
54.	4 PR. #18 SH splice	66	AB Proposal	AB Proposal
55.	5 KV cable rack	888	88	
56.	Unistrut clamp support	148	74	
57.	150 Watt H.P.S. lamp	38	9	
58.	150 Watt H.P.S. mayfair luminaire	38	114	
59.	4" x 4" x 14' poles	38	114	
60.	Pole bases	38	76	
61.	Photo cell	38	9	
62.	Auger for chem rod	68	136	
63.	Chem ground rod	68	136	
64.	4/0 Bare Cu wire	1,200'	28	
65.	Cadweld connections	102	153	
66.	Brooks boxes #1-RT	68	68	
67.	Salt mix	68	136	
68.	Sub stations	17	136	
69.	112½ KVA trnasf. 4160/277/480	17	272	
70.	Oil SW	17	136	
71.	Interlocks	17	68	
72.	Dist. 125 Amp. main bkr.	17	238	
73.	5-20A 3 Pole branches	-	-	
74.	5-20A 1 Pole branches	-	-	
75.	6 KVA transformer	38	380	
76.	480 V low fusing disc.	38	-	
77.	Enclosure & panel	38	-	
78.	W.P. Duplex outlet - FSD 3/4"	38	19	
79.	Crouse hinds DS 222	38	19	
80.	Variable Freq. Drive Allen Bradley 1350 W/PC.	17	170	
81.	Set anchor	17	102	
82.	1¼ reducer	340	20	
83.	1¼ elbow	85	38	
84.	Ericksons & misc. mat.	68	680	
85.	#4 THHN wire	1,100'	13	

MALCOLM PIRNIE

Item	Material	Quantity	Labor Hours	Materials ($)
86.	#8 THHN wire	280'	2	
87.	Low voltage panel terminations	38	152	
88.	Flow valve connection	48	48	
89.	Motion sensores (set of 8)	32	768	
90.	Bases	128	128	
91.	Motor heat sensor	17	34	
92.	Strut mount set up	38	142	
93.	Conc base	38	114	
94.	1½" Reducers	170	10	
95.	1½" Elbows	51	28	
96.	1½" Locknuts & bushings	34	15	
97.	1½" Ericksons	34	20	
98.	#1 THHN wire	800'	12	
99.	#8 THHN wire	200'	1	
100.	1¼" Sealtite	68	10	
101.	1¼" 90° - Sealtite connectors	68	17	
102.	1 2/4" Myers hubs w/ground	34	20	

MALCOLM PIRNIE

B. Water Treatment Plant

Item	Material	Quantity	Labor Hours	Materials ($)
1.	2-1500 KVA Xfmrs	2	64	
2.	2 Oil SWS 800A	2	24	
3.	Kirk keys set up	5	20	
4.	Ground fault	2	24	
5.	Dist. (5-800; 6-400)	1	42	
6.	Tie breaker	1	4	
7.	2-1800 AMP main breakers	2	32	
8.	480 Dist. 800 AMP main bkr.	1	54	
9.	1-400; 2-200; 4-100			
10.	4-60			
11.	300 KVA Transf. 480/120/208	1	32	
12.	120/208 Dist. 600 AMP main bkr.	1	42	
13.	2-400; 2-200			
14.	277/480 panel 42 CKT	2	48	
15.	120/208 panel 42 CKT	2	48	
16.	Hand holes 2' - 6" x 3' x 3'	18	54	
17.	Var. freq. drive - Allen Bradley #1350	4	64	
18.	Var. freq. drive - Allen Bradley #1340	27	432	
19.	200 HP motor JB & conn.	4	68	
20.	40 HP motor JB & conn.	10	40	
21.	25 HP motor JB & conn.	13	39	
22.	20 HP motor JB & conn.	4	12	
23.	5 HP motor JB & conn.	23	40	
24.	400A disconnect NEMA 3	4	41	
25.	100A disconnect NEMA 3	10	37	
26.	60A disconnect NEMA 3	17	59	
27.	30A disconnect NEMA 3	23	59	
28.	P.C. control	54	81	
29.	MCC - 7 sections Allen Bradley 2100	1	56	
30.	800 Main	1	12	
31.	Comb. starters	32	128	
32.	4" PVC conduit	510'	86	
33.	3" PVC conduit	1,730'	173	
34.	2" PVC conduit	12,800'	806	
35.	4" Adapters	30	18	
36.	3" Adapters	60	24	
37.	2" Adapters	360	79	
38.	4" Spacers	130	6	
39.	3" Spacers	430	21	
40.	2" Spacers	3,200	160	
41.	Tie downs	700	35	
42.	Concrete	200	50	
43.	4" End bells	16	9	

MALCOLM PIRNIE

Item	Material	Quantity	Labor Hours	Materials ($)
44.	3" End bells	32	12	
45.	2" End bells	120	26	
46.	Trench & Backfill	2,880'	172	
47.	4" Rigid conduit	80'	16	
48.	3" Rigid conduit	160'	20	
49.	2" Rigid conduit	90'	7	
50.	4" Elbows	22	55	
51.	3" Elbows	48	76	
52.	2" Elbows	270	175	
53.	4" DLN & Gr. Bush	16	14	
54.	3" DLN & GR. Bush	32	20	
55.	2" DLN & GR. Bush	180	99	
56.	500 MCM 5KV cable	480'	18	
57.	500 MCM - XHHW cable	6,450'	251	
58.	250 MCM - XHHW cable	500'	13	
59.	4/0 - XHHW cable	2,300'	55	
60.	300 MCM - XHHW cable	960'	27	
61.	1/0 - XHHW cable	350'	6	
62.	#6 - THHN cable	4,000	36	
63.	#8 - THHN cable	8,700	69	
64.	#10 - THHN cable	23,000	161	
65.	#12 - THHN cable	42,000	210	
66.	14' Poles	22	44	
67.	22' Poles	5	15	
68.	Luminaires 150W	61	122	
69.	Bldg luminaires 150W	13	26	
70.	Pole bases - concrete	27	27	
71.	150 W HPS lamps	74	14	
72.	Photocell	2	3	
73.	Contactor 60 AMP, 3 pole	2	6	
74.	I.O. Rack for MCC (AB2183)	1	16	
75.	Misc control monitoring	32	32	
76.	Flow valve	20	20	
77.	Press. valve	20	20	
78.	400A fuses	30	6	
79.	200A fuses	6	1	
80.	60 fuses	90	15	
81.	30 fuses	130	22	
82.	100 fuses	30	6	
83.	1½" sealtite	40'	6	
84.	1" sealtite	80'	8	
85.	3/4" sealtite	100'	7	
86.	3" sealtite	16'	4	
87.	3" sealtite connectors	8	4	
88.	1½" sealtite connectors	20	5	
89.	1" sealtite connectors	40	6	
90.	3/4" sealtite connectors	50	6	
91.	½" sealtite connectors	60	6	

MALCOLM PIRNIE

Item	Material	Quantity	Labor Hours	Materials ($)
92.	½" sealtite	120	6	
93.	Cable tray 12"	200'	50	
94.	Support racks	24	24	
95.	Strut stanchions - SS	54	108	
96.	F.A. System - master	1	12	
	Stations	4	4	
	Detectors	12	12	
	Alarms	5	5	
	Annunc. panel	1	8	
97.	Ultrasunic level	6	96	
98.	Fed. Em. battery system	4	32	
99.	TM-6 W/PS 300-2CKT	4	16	
100.	Remote horn & beacon	4	8	
101.	T.V. monitor - pan type	4	64	
102.	Interface to existing	4	32	
103.	Tie to A-B instrumentation	1	-	
104.	2' x 4' layin fixtures	64	64	
105.	2-96" industrial fixtures	35	52	
106.	40W Rapid start warm white	260	13	
107.	96" warm white	70	7	
108.	Exit lights w/EMG - battery pack	8	12	
109.	Bug-units 18" x 48"	16	32	
110.	4" SQ duplex cover plate	40	30	
111.	4" SQ Switch cover plate	22	16	
112.	SQ & blank	20	10	
113.	FS-1 Box with plate	18	18	
114.	FS-2 Box with plate	12	24	
115.	4" SQ & plt & hanger	150	97	
116.	P.A. system - AMP & ties	1	16	
117.	Ceiling speaker	18	18	
118.	Volume control	2	3	
119.	Yard speaker	5	20	
120.	½" flex conduit	400'	12	
121.	½" connector	150	10	
122.	½ EMT conduit	2,200'	77	
123.	3/4" EMT conduit	2,800'	112	
124.	1" EMT conduit	1,800'	90	
125.	½" connector	410	36	
126.	3/4" connector	530	53	

Item	Material	Quantity	Labor Hours	Materials ($)
127.	1" connector	320	41	
128.	½" ST & anchor	330	33	
129.	3/4" ST & anchor	420	50	
130.	1" ST & anchor	270	40	
131.	#12 THHN wire	57,200'	286	
	Subtotal			
	Materials			
	Labor - hrs @ $27.00/hr			
	Overhead @ 10% (material only)			
	Profit @ 10% (material only)			
	Escalation @ 5%			
	Main substation Papago Power Inc.* (Quotation 1/31/84)			
	Total Cost			

*Proposal and detailed description of system under separate cover denoted as Appendix A.

MALCOLM PIRNIE

INSTRUMENTATION ESTIMATE BACKUP

MALCOLM PIRNIE

Item	Material	Quantity	Labor Hours	Materials ($)
1.	40 x 90 x 18 3R enclos.	38	608	AB Proposal
2.	120 x 90 x 18 3R enclos.	4	96	AB Proposal
3.	80 x 90 x 18 3R enclos.	1	20	AB Proposal
4.	Data Hiway term kit	4	20	AB Proposal
5.	Data Hiway conn kit	27	27	AB Proposal
6.	I/D terminations	74	74	AB Proposal
7.	Data Hiway RS232 modules	12	48	AB Proposal
8.	Colorgraphic terminals	4	16	AB Proposal
9.	Intelligent panel	4	8	AB Proposal
10.	Ribbon cable mtng kit	12	12	AB Proposal
11.	PC document unit	1	4	AB Proposal
12.	Software & cables	1	8	AB Proposal
13.	Maint kit	1	2	AB Proposal
14.	Console set & install	1	16	AB Proposal
15.	ID processor unit	2	8	AB Proposal
16.	System processor	1	4	AB Proposal
17.	Sec. video monitors	3	12	AB Proposal
18.	Sec. tape recorders	3	6	AB Proposal
19.	Term. in sec console	38	9	AB Proposal
20.	Term in remote enclos.	1,792	268	AB Proposal
21.	Term in central console	674	101	AB Proposal
22.	Misc. tape, conn, screws, seals	43	344	
23.	Equip rental to set enclos. and eq.	6 weeks	240	
24.	Trench & backfill (24" x 36")	400	28	
25.	4" PVC	2,000	250	
26.	4" spacers	400	20	
27.	4" adapters	20	12	
28.	Tie downs	160	8	
29.	Contrete	35	8	
30.	Handholes	4	8	
31.	Roadway cut (asphalt)	180	18	
32.	Asphalt repair	360	10	
33.	Rubble remove	3	6	
34.	4" Bells	50	30	
35.	Cable tray 12"	100	25	
36.	4" PVC Sch 80	300	51	
37.	4" PVC SCH 80 ELB.	20	30	
38.	Support racks	26	26	
39.	4" strut clamps	60	7	
40.	Belden 9429 cable (16-20)	5,700	222	
41.	Plywood back board 4' x 8' x 3/4	4	16	
42.	Spacers & supports	Lot	32	
43.	1½ EMT	450	22	
44.	½ EMT	500	17	
45.	1½ ELB	15	6	
46.	½ Coup & conn	120	10	
47.	1½ Coup & conn	80	12	

MALCOLM PIRNIE

Item	Material	Quantity	Labor Hours	Materials ($)
48.	½ STR & CB	70	1	
49.	1½ STR & CB	60	3	
50.	4" x 6" x 8" SCJB	10	3	
51.	4" SQ & cover	20	5	
52.	#14 THHN Str.	14,000	67	
53.	4" x 6" W.W.	60	5	
54.	Remove & reinstall following			
55.	L&N recorders	14	56	
56.	L&N integrator	4	16	
57.	L&N indicator	2	8	
58.	L&N electroma	8	32	
59.	L&N remote meter	8	32	
60.	GE ammeters	7	21	
61.	Graphic symbols (sm) (new)	76	19	
62.	Push buttons (new)	56	56	
63.	Bakelite tags (new)	90	18	
64.	Graphic symbol (lge) (new)	30	15	
65.	16' display cabinet 14 gauge 84" HT w/back doors	2	96	
66.	Supply fan	4	12	
67.	Lighting	8	24	
68.	L&N recorders Model 141-304-03-L0077-6-AO-048-188-012-056	36	108	
69.	L&N analyzer model 7084-11-208 L&N PH electrode	4	12	
70.	Push button SQD 9001	75	75	
71.	Graphic symbols (LG)	50	25	
72.	Graphic symbols (SM)	125	31	
73.	Graphic trace	700	175	
74.	Tags	150	30	
75.	Horns DR Alarm	4	8	
76.	Transformer 9 KV	1	6	

Subtotal

Materials
Labor 3784 Hrs @ $27.00/hr

Overhead @ 10% (materials only)
Profit @ 10% (materials only)
Escalation @ 5% (material only)

*Allen-Bradley quotation
Allen-Bradley system preparation

Total Cost

*Proposal under separate cover denoted as Appendix B.

MALCOLM PIRNIE

CIVIL/ARCHITECTURAL ESTIMATE

MALCOLM PIRNIE

A. Water Treatment Plant

Item	Material	Cost
1.	Control Building 70' x 100' x 20' high	
2.	Perimeter fence 250' x 200' x 7' high	
3.	Clarifiers 2-25' diameter by 14' deep	
4.	Backwash collection tank 1-60' diameter by 12' deep	
5.	Stripping column/blower pads	
6.	Pump pads, 6 pads	
7.	Sludge holding tank 1-25' diameter by 12' deep	
8.	Tank farm 15' x 30' x 7' high with intermediate walls	
9.	Pressure filter pad 65' x 40' x 18" thick	
10.	Clear well 60' diameter x 9' deep	
11.	Site concrete 250' x 200' x 6" thick	
12.	Carbon adsorption system pad and shed 62' x 30' x 18" thick	
13.	Intermediate clearwell 55' x 25' x 6' w/cover	
14.	Media washing sump 25' x 9' x 6'	

B. Remote Sites

1.	Unimproved roadway 57,000 lineal feet x 15' wide	
2.	38 remote well sites a) Electrical pad b) Pump pads c) Perimeter fence 30' x 30' x 7' high d) Gates	
3.	Grading and sitework	
4.	17 Utility buildings (prefab at rec wells)	
	Total	

[1]Includes overhead and profit

MALCOLM PIRNIE

RECLAMATION AND RECHARGE WELLS, SITE AND

WATER TREATMENT PLANT PIPING

MALCOLM PIRNIE

A) Reclamation Wells and Piping

Item	Material	Quantity	Labor ($)	Materials ($)
1.	Pipe PVC ring tite 6" Ø	13,800 LF		
2.	Pipe PVC ring tite 8" Ø	11,000 LF		
3.	Pipe PVC ring tite 10" Ø	4,450 LF		
4.	Pipe PVC ring tite 12" Ø	2,000 LF		
5.	Pipe PVC ring tite 14" Ø	1,250 LF		
6.	Pipe PVC ring tite 16" Ø	950 LF		
7.	Fittings ring tite ells 6" Ø	54 ea		
8.	Fittings ring tite ells 8" Ø	5 ea		
9.	Fittings ring tite ells 10" Ø	1 ea		
10.	Fittings ring tite ells 12" Ø	4 ea		
11.	Fittings ring tite ells 14" Ø	2 ea		
12.	Fittings ring tite ells 16" Ø	6 ea		
13.	Fitting ring tite tees 6" Ø	41 ea		
14.	Fitting ring tite tees 8" Ø	41 ea		
15.	Fitting ring tite tees 10" Ø	1 ea		
16.	Fitting ring tite tees 12" Ø	3 ea		
17.	Fitting ring tite tees 14" Ø	2 ea		
18.	Fitting ring tite tees 16" Ø	3 ea		
19.	Fitting flange w/mechanical joint 6"	314 ea		
20.	Fitting flange w/mechanical joint 8"	10 ea		
21.	Fitting flange w/mechanical joint 10"	6 ea		
22.	Fitting flange w/mechanical joint 12"	4 ea		
23.	Fitting flange w/mechanical joint 16"	2 ea		
24.	Valves check 6" Ø	17 ea		
25.	Butterfly valves 6" Ø	17 ea		
26.	Pressure sensors 6" pipe	17 ea		
27.	Valves 6" Ø butterfly	68 ea		
28.	Pressure gauge 0-100 PSI	17 ea		
29.	Temp. gauge 0-100° F	17 ea		
30.	Gate valves galv Stl 1¼"	17 ea		
31.	Bell reducers galv Stl. 2" x 1¼"	17 ea		
32.	Flowmeters sensors and fittings (saddles) 6" Ø	21 ea		
33.	Flowmeters sensors and fittings (saddles) 8" Ø	5 ea		
34.	Flowmeters sensors and fittings (saddles) 10" Ø	3 ea		
35.	Flowmeters sensors and fittings (saddles) 12" Ø	2 ea		
36.	Flowmeters sensors and fittings (saddles) 14" Ø	1 ea		
37.	Pipe copper ¼" S.J. w/supports	3,400 LF		
38.	Pipe galv Stl. 1¼" Ø w/supports	8,560 LF		
39.	Pipe galv Stl. 2" Ø	17,460 LF		

Item	Material	Quantity	Labor ($)	Materials ($)
40.	Fittings galv Stl. thrp ells 1½"	33 ea	723	
41.	Fittings galv St. thrp tees 1½"	2 ea	68	
42.	Fittings galv Stl. thrp unions 1½"	17 ea	244	
43.	Fittings galv Stl. thrp ells 2"	13 ea	324	
44.	Fittings galv Stl. thrp tees 2"	11 ea	480	
45.	Valves check valves 1½" galv stl.	17 ea	270	
46.	Trench 26,725 LF 4' x 3' deep	20,300 CY	60,900	
47.	Backfill 26,775 LF 4' x 3' deep	20,300 CY	109,600	
48.	Thrust blocking at each turn and valve	300 ea	-	

Material cost
Labor cost
Overhead @ 10% of material cost
Profit @ 10% of material cost
Escalation @ 5% of material cost

Total cost
Reclamation wells (12" diameter)

Total cost

(1) Includes labor, materials, overhead and profit

MALCOLM PIRNIE

B. Recharge Wells and Piping

Item	Material	Quantity	Labor ($)	Materials ($)
1.	Control valves 6" Ø	21		
2.	PVC ring tite blue brute piping 6" Ø	22,550 LF		
3.	PVC ring tite blue brute piping 8" Ø	13,300 LF		
4.	PVC ring tite blue brute piping 10" Ø	13,100 LF		
5.	PVC ring tite blue brute piping 12" Ø	1,700 LF		
6.	PVC ring tite blue brute piping 14" Ø	800 LF		
7.	PVC ring tite blue brute piping 16" Ø	1,300 LF		
8.	PVC ring tite fittings ells 6" Ø	123 ea		
9.	PVC ring tite fittings ells 8" Ø	1 ea		
10.	PVC ring tite fittings ells 10" Ø	2 ea		
11.	PVC ring tite fittings ells 12" Ø	2 ea		
12.	PVC ring tite fittings ells 14" Ø	2 ea		
13.	PVC ring tite fittings tees 6" Ø	73 ea		
14.	PVC ring tite fittings tees 8" Ø	6 ea		
15.	PVC ring tite fittings tees 10" Ø	5 ea		
16.	PVC ring tite fittings tees 12" Ø	3 ea		
17.	PVC ring tite fittings tees 14" Ø	1 ea		
18.	PVC ring tite fittings tees 16" Ø	2 ea		
19.	Mechanical clamp 6" Ø	424 ea		
20.	Mechanical clamp 8" Ø	10 ea		
21.	Mechanical clamp 10" Ø	4 ea		
22.	Mechanical clamp 12" Ø	8 ea		
23.	Valves check 6" Ø steel body	21 ea		
24.	Copper tubing ¼" S.J. w/supports	4,200 LF		
25.	Pipe 1½" galv Stl. Threaded w/supports	12,840 LF		
26.	Pipe 2" galv Stl. threaded w/supports	26,180 LF		
27.	Fitting galv stl. threaded 1½" Ø Ells	51 ea		

MALCOLM PIRNIE

Item	Material	Quantity	Labor ($)	Materials ($)
28.	Fitting galv stl. threaded 1½" Ø Tees	2 ea		
29.	Fitting galv stl. threaded 1½" Ø Unions	21 ea		
30.	Fitting galv stl. threaded 2" Ø Ells	20 ea		
31.	Fitting galv stl. threaded 2" Ø Tees	16 ea		
32.	Valves check stl body 1½" threaded	21 ea		
33.	Pressure sensors 6" Ø	21 ea		
34.	Butterfly valve 6" Ø flanged	105 ea		
35.	Pressure gauge 0-250 psig	21 ea		
36.	Temperature gauge 9"	21 ea		
37.	Gate valves galv stl. 1½" threaded	21 ea		
38.	Bell reducers galv stl. 2" x 1½"	21 ea		
39.	Plug PVC 6" Ø ring tite	21 ea		
40.	Flow meters sensors, fittings 6" Ø	23 ea		
41.	Flow meters sensors, fittings 8" Ø	5 ea		
42.	Flow meters sensors, fittings 10" Ø	2 ea		
43.	Flow meters sensors, fittings 12" Ø	4 ea		
44.	Trench 40,160 LF 5' wide 3' deep.	21,000		
45.	Backfill and grade 4' wide x 3' deep	21,000		
46.	Thrust blocking at each turn and valve	320 ea		

Material cost
Labor cost
Overhead @ 10% of material cost
Profit @ 10% of material cost
Escalation @ 5% of material cost

Sub total

42. Recharge wells (21)
21 x 11,400 =

Total

MALCOLM PIRNIE

C) Water Treatment Plant Piping

Item	Material	Quantity	Labor ($)	Materials ($)
1.	Water line black steel 16" Ø welded	400 LF		
2.	Water line black steel 12" Ø welded	300 LF		
3.	Water line black steel 10" Ø welded	250 LF		
4.	Water line black steel 4" Ø welded	1,350 LF		
5.	Water line black steel 2" Ø threaded	200 LF		
6.	Water line black steel 1" Ø threaded	200 LF		
7.	Polymer CPVC pipe ½" Ø	240 LF		
8.	Polymer CPVC pipe 1 Ø	280 LF		
9.	Fittings B/S 16" welded Ell	47 ea		
10.	Fittings B/S 12" welded Ell	45 ea		
11.	Fittings B/S 10" welded Ell	30 ea		
12.	Fittings B/S 4" welded Ell	78 ea		
13.	Fittings B/S 2" threaded Ell	9 ea		
14.	Fittings B/S 1" threaded Ell	5 ea		
15.	Fittings B/S 16 welded Tee	20 ea		
16.	Fittings B/S 12 welded Tee	15 ea		
17.	Fittings B/S 10 welded Tee	14 ea		
18.	Fittings B/S 4 welded Tee	47 ea		
19.	Fittings B/S 2" threaded Tee	7 ea		
20.	Fittings B/S 1" threaded Tee	1 ea		
21.	Fittings B/S 2" Ø threaded union	8 ea		
22.	Valves flanged 16" butterfly	10		
23.	Valves flanged 12" butterfly	15		
24.	Valves flanged 10" butterfly	20		
25.	Valves flanged 4" butterfly	40		
26.	Valves threaded 2" gate	2 ea		
27.	Flanges welded w/gaskets & boltups 16" Ø	88 ea		
28.	Flanges welded w/gaskets & boltups 12" Ø	64 ea		
29.	Flanges welded w/gaskets & boltups 10" Ø	100 ea		
30.	Flanges welded w/gaskets & boltups 4" Ø	294 ea		
31.	Air line galv steel 2" Ø	180 LF		
32.	Fittings galv steel 2" Ø threaded ell	12 ea		
33.	Fittings galv steel 2" Ø threaded tee	13 ea		
34.	Valves 2" gate stl.	15 ea		
35.	Fittings CPVC ½" Ell	15 ea		

MALCOLM PIRNIE

Item	Material	Quantity	Labor ($)	Materials ($)
36.	Fittings CPVC ½" Tees	11 ea		
37.	Fittings CPVC 1" Ells	14 ea		
38.	Fittings CPVC 1" Tees	3 ea		
39.	Valves gate ½" CPVC socket weld	16 ea		
40.	Valves gate CPVC socket weld	3 ea		
41.	Chlorine piping black stl. threaded ½" Ø	320 LF		
42.	NAOH piping (CPVC socket weld 1" Ø	120 LF		
43.	$FeSO_4$ piping (CPVC) socked weld 1" Ø	140 LF		
44.	Fitting chlorine piping ½" Ø Ells B/stl.	9 ea		
45.	Fitting NaOH CPVC 1" Ells	14 ea		
46.	Fitting NaOH CPVC 1" Tees	2 ea		
47.	Fittings $FeSO_4$ piping CPVC Ells 1" Ø	11 ea		
48.	Fittings $FeSO_4$ piping CPVC Tees 1" Ø	2 ea		
49.	Valves gate CPVC	8 ea		
50.	Butterfly control valves 16" flanged	6		
51.	Butterfly control valves 12" flanged	3		
52.	Butterfly control valves 10" flanged	4		
53.	Butterfly control valves 4" flanged	4		
54.	Butterfly control valves 2" threaded	4		
55.	Butterfly control valves 1" threaded	2		
56.	Butterfly control valves ½" threaded	2		
57.	Flow meters/sensors/saddles/ housing 16"	6		
58.	Flow meters/sensors/saddles/ housing 12"	3		
59.	Flow meters/sensors/saddles/ housing 10"	3		
60.	Flow meters/sensors/saddles/ housing 4"	7		
61.	Flow meters/sensors/saddles housings 2"	2 ea		
62.	Flow meters/sensors/saddles housings 1"	2		
63.	Flow meters/sensors/saddles housings ½"	2		

Item	Material	Quantity	Labor ($)	Materials ($)
64.	Safety check valves flanged 10"	3		
65.	Safety check valves flanged 4"	14		
66.	Safety check valves threaded 2"	2 ea		
67.	Safety check valves threaded 1"	2 ea		
68.	Bell reducers welded 16"	23 ea		
69.	Bell reducers welded 12"	1 ea		
70.	Bell reducers welded 4"	16 ea		
71.	Bell reducers threaded 2"	4 ea		
72.	Bell reducers threaded 1"	4 ea		
73.	Flex connections 16" Ø	8 ea		
74.	Flex connections 10" Ø	8 ea		
75.	Flex connections 4" Ø	14 ea		
76.	Flex connections 2" Ø	4 ea		
77.	Flex connections 1" Ø	4 ea		
78.	In line stainless stl mixers	4 ea		
79.	Pressure sensors	30 ea		
80.	Temperature sensors	4 ea		
81.	Blind flanges/gaskets/boltup 4"	4 ea		
82.	Cap 2" stl pipe	2 ea		
83.	Flow measuring devices 2" Ø	4 ea		
84.	Control valves butterfly 2" Ø	4 ea		
85.	Pressure sensors 2" Ø	4 ea		
86.	Flex connections 2" Ø	1 ea		
87.	Bell reducers 2" Ø	1 ea		
88.	30" Ø Ductwork	25 LF		
89.	48" Ø Ductwork	125 LF		
90.	6" Ø PVC piping	600 LF		
91.	6" Ø Valves	12 ea		
92.	2" Ø PVC piping	250 LF		

Material cost
Labor cost
Overhead @ 10% of material cost
Profit @ 10% of material cost
Escalation @ 5% of material cost

Total cost

MALCOLM PIRNIE

Treatment Plant

Item	Material	Quantity	Materials ($)	Labor ($)
1.	Packed column & media	6		
2.	Recessed plate filter press package	2		
3.	Pressure filters	4		
4.	Blowers	6		
5.	Intermediate pumps	3		
6.	Transfer pumps	7		
7.	Clarifier feed pumps	2		
8.	Sludge transfer pumps	2		
9.	Filter press feed pumps	2		
10.	Compressor	1		
11.	Mixers	6		
12.	Clarifier mechanism	2		
13.	Polymer makeup, storage & feeding system package	2		
14.	Caustic storage tank	1		
15.	Caustic feed pumps	3		
16.	Ferrous sulfate feed pumps	2		
17.	Acid storage tank	1		
18.	Acid transfer pumps	2		
19.	Acid metering pumps	-		
20.	Acid cleaning recirculation pump	2		
21.	Chlorination equip. include analyzer & controller	-		
22.	Cartridge filters	2		
23.	Building sump pump	2		
24.	pH probe indicator/controller	2		
25.	Carbon adsorbers	2		
26.	Package boilers	2		
27.	Fuel oil storage tank	1		
28.	Analytical equipment (GC)	-		
	Material cost			
	Labor cost			
	Overhead @ 10% of material cost			
	Profit @ 10% of material cost			
	Escalation @ 5% of material cost			
	Total			

MALCOLM PIRNIE

FIRST YEAR
OPERATION AND MAINTENANCE

COST ESTIMATE - 5000- gpm

Power

Chemicals

Maintenance

Operating labor

Sludge Disposal

Total

MALCOLM PIRNIE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

HAZARDOUS SITE CONTROL DIVISION

Remedial Planning/ Field Investigation Team (REM/FIT)

ZONE II

CONTRACT NO. 68-01-6692

CH2M HILL

Ecology & Environment

FINAL COMMUNITY RELATIONS PLAN TUCSON AIRPORT AREA SITE TUCSON, ARIZONA

July 25, 1983

EPA 07.9V09.0

COMMUNITY RELATIONS PLAN
TUCSON AIRPORT SITE
TUCSON, ARIZONA

1.0 SITE BACKGROUND

The Tucson Airport Area site covers approximately 24 square miles, and is located in the southwestern section of Tucson in Pima County. It encompasses the Tucson International Airport, Hughes Aircraft Company facility, portions of the San Xavier Indian Reservation and residential areas of South Tucson west of the airport. Ground water contaminated with organic and metallic compounds, primarily trichloroethylene (TCE) and hexavalent chromium, has been discovered at the site.

The ground water underlying the Tucson Airport Area site is part of the Tucson Basin, a major aquifer system in the area. The City of Tucson uses this aquifer as its principal source of water supply. The Tucson area, with a population of 517,000, is one of the largest metropolitan areas in the country totally dependent on ground water for its drinking water supply.

Ground water contamination in the vicinity of the Tucson Airport was discovered in March 1981 by an EPA Field Investigation Team (FIT) during an Uncontrolled Hazardous Waste Site Investigation of Hughes Aircraft (AFP-44). The Hughes site was selected for review as a result of the Arizona Surface Impoundment Assessment which was conducted by the Arizona Department of Health Services and published in December, 1979. Initial well water samples had shown concentrations of TCE ranging from 0.3 parts per billion (ppb) to 4,600 ppb. A later report put the TCE level as high as 13,000 ppb. Other pollutants detected included TCA (trichloroethane), DCE (dichloroethylene), and hexavalent chromium.

Based upon data available to date, Los Reales Road has been designated as the northern most boundary of the contaminant plume emanating from the Hughes Aircraft Company facility, also known as Air Force Plant #44. This facility is owned by the U.S. Air Force and operated by Hughes Aircraft Company. The Air Force is conducting remedial activities in accordance with its Installation Restoration Program (IRP). A Memorandum of Agreement (MOA) is currently being negotiated between EPA, the State of Arizona and the City of Tucson, and the Air Force and Hughes Aircraft Company (HAC) to specify responsibilities and activities of each party for remedial investigation and cleanup south of Los Reales Road.

Superfund remedial activities will occur north of Los Reales Road and will be conducted by the State of Arizona through a Cooperative Agreement or by any private parties found to be

responsible for the contamination. Work may be performed outside the stipulated area as necessary to define the contamination sources and its migration.

The land use in the nonresidential part of the area is medium and heavy industrial manufacturing. Between 1940 and 1960 the primary industry in the area was aircraft manufacturing and retrofitting. The hazardous substances that were and continue to be generated in the area, primarily by aircraft industries, include heavy metals (copper, nickel, chromium, zinc, cadmium, and lead), solvents (TCE 1,1 dichloroethylene (DCE) and 1,1,1, trichloroethane (TCA)), and oils and paints. Although the present industries currently reclaim or treat most waste, disposal in unlined holding ponds or pits was a common practice in the past. The total volume of wastes disposed of in this manner cannot be accurately estimated.

From March 1981 through the present, the EPA, State, and City have conducted an investigation to determine the extent and sources of ground water contamination in both the northern and southern portions of the site. The investigation has included a well inventory, a well sampling program, and requests sent under Section 3007 of RCRA for information on solvent use and disposal.

Because the initial evidence of ground water contamination was found on and near the Hughes facility, most of the investigation has been concentrated south of Los Reales Road. This has included surface and subsurface soil sampling and the construction of five (5) monitoring wells. In addition, Hargis and Montgomery, Inc., a hydrogeological consultant to Hughes Aircraft and the Air Force, conducted an investigation of the subsurface conditions at the Hughes facility. Hargis and Montgomery also conducted solute transport modeling to estimate the extent of the contamination emanating from the facility. The primary conclusions of these investigations is that the facility is a major source of ground water contamination and that the extent of the contamination reaches northwesterly to Los Reales Road.

The EPA, State, and City investigation of the area north of Los Reales Road has found 30 wells that are contaminated with TCE at concentrations ranging from 0.3 ppb to greater than 400 ppb. Six municipal and six private wells have concentrations that exceed 5 ppb, the State Action Level. However, the extent and sources of contamination are as yet unknown. Six (6) more monitoring wells have recently been constructed, five (5) of which will be dedicated to finding sources north of Los Reales Road. However, because of the large area involved, a Remedial Investigation is needed to complete the investigation and to identify the sources and extent of the contamination north of Los Reales Road.

A review of tests and records seems to indicate that the contaminants are a result of disposal practices that occurred 20 or 30 years ago (ADHS News Release 8/2/82). The only responsible parties identified to date for areas south of Los Reales Road are Hughes Aircraft and the Air Force.

The current MOA will specify the responsibilities and activities of each of the parties through all phases of remedial actions south of Los Reales Road. Should additional information indicate that the federally caused portion of the contamination extends farther north than Los Reales Road, the site will be reevaluated through a process established in the MOA.

EPA Region 9 initiated enforcement activities for those areas north of Los Reales Road by sending RCRA Section 3007 and CERCLA Section 104 letters to 22 companies in the northern portion of the site. Responses to these letters have been referred to FIT for further analysis and/or site inspections. Based on the review of the responses, site inspection reports, and the results of the remedial investigation, Notice Letters will be sent to those companies determined to be potential responsible parties.

2.0 COMMUNITY RELATIONS ASSESSMENT

2.1 History of Community Relations Activities

Since the initial detection of TCE in wells near the Tucson Airport, press and other media coverage has been fairly regular. The Arizona Daily Star and the Tucson Citizen have carried numerous articles and editorials on the TCE situation. When new areas or levels of contamination have been detected, the press coverage has been extensive. As monitoring efforts produce routine findings, and if no new areas of contamination are detected, the press coverage usually decreases. Television coverage appears to have been good, and is often cyclical in approach as with the newspapers. Generally, both government and citizen representatives feel that the media has been and could continue to be the most effective vehicle for public information. Interviewees feel that the local media has done a good job of describing the technical issues and facts.

One formal public meeting has been held to discuss the Tucson Airport Area TCE problem. That meeting was held in City Hall, Tucson, on September 30, 1982. Approximately 20 citizens and an equal number of government representatives (local, state, and Federal) attended. Most of the people interviewed during this assessment felt that the media coverage of the meeting was very good. They expressed the opinion that in some instances good media reporting could be as, or more, effective in reaching the public, than a public meeting.

The Arizona Department of Health Services held an additional public meeting on April 20, 1983. The meeting was attended by about 20-30 people who asked a variety of questions.

Several other meetings with legislative committees, health organizations, and county agencies have been open to the public, with little public attendance. In addition, ADHS has conducted numerous briefings for the mayor and City Council of Tucson and the Pima County Board of Supervisors.

CHRONOLOGY OF COMMUNITY RELATIONS FOR TUCSON AIRPORT SITE

Date: 5/15/81
Activity: News Release to press
Agency: ADHS
Content: Issued initial TCE findings. Announced meeting to be held with City, Hughes Aircraft.

Date: 7/2/81
Activity: News Release
Agency: ADHS
Content: EPA confirmation of TCE findings. City wells shut down. Monitoring program initiated.

Date: 8/13/81
Activity: New Release
Agency: ADHS
Content: Public update on sampling results.

Date: 9/10/81
Activity: Informal News Release (by telephone contact)
Agency: ADHS
Content: Sampling Results

Date: 11/2/81
Activity: Information News Release (by telephone contact)
Agency: ADHS
Content: Sampling Results

Date: 4/23/82
Activity: Informal News Release (by telephone contact)
Agency: ADHS
Content: Sampling Results

Date: 8/2/82
Activity: News Release
Agency: ADHS
Content: Study findings indicate TCE contamination is result of historical activities, not ongoing activities.

Date: 8/9/82
Activity: News Release
Agency: ADHS
Content: Working committee established with all parties represented. Memoranda of Agreement discussed. Superfund/CERCLA/DOD roles discussed. Programming Plans.

Date: 9/2/82
Activity: News Release
Agency: ADHS
Content: Air Force activities in investigations announced.

Date: 9/30/82
Activity: Public Meeting
Agency: Mayor's Office, City of Tucson
Content: Twenty members of public, numerous agencies involved.

Date: 2/4/83
Activity: New Release
Agency: ADHS
Content: EPA approved $895,000 (Superfund) for Remedial Investigations and Remedial Feasibility Studies.

Date: Continuous
Activity: News telecasts and newspaper articles have occurred somewhat regularly throughout this time frame.

During March 1983, the Arizona Department of Health Services established a toll free number in Tucson to answer questions concerning the site. The number was available over a weekend and 18 to 20 telephone calls were logged. (Some constraints in the taping process may have affected the number of telephone calls that were recorded.) The issues identified during those telephone calls are listed in the following section. Since that time a few letters have been received from local interest groups. These letters are also discussed below.

2.2 Community Relations Issues and Actors

The attached Table 1 lists the individuals, agencies, and groups that were interviewed during the preparation of this Community Relations Plan. It also includes a summary of their comments.

Table 1

TUCSON AIRPORT CRP INTERVIEWS SUMMARY

TOPIC AREAS / INTERVIEWEES	ADHS P. Bielka R. Gentry J. Dyckstra	State Senator J. Hawhinney Assist. Maj. Leader	State Senator G. Lunn Drafter, State Superfund Bill	City of Tucson T. Jefferson, W.D. T. J. Harrison Assist. Atty.	Governor's Office T. Milton-Goddard Staff to Health/Tucson	Ariz. Daily Star Jane Kay "Lead" Reporter Onsite	Sierra Club Alex Daly Also PIMA Adv. Comms.	Glenn Thompson Prof. of Hydrology, University of Arizona
PUBLIC UNDERSTANDING	Somewhat confused.	Ill-informed and confused. See little action, lots of study.	Confused. Don't understand "health issues."	Not too well informed. Concerns are mostly individualistic.	Yes on TCE. Not on what is being done.	Generally o.k. Not enough info. out.	Confused. In dark.	Little understanding.
PUBLIC NEEDS	Coordinated info. issuance. Information center. Info. papers.	Education.	Better info. disbursement.	More info. on health. Information mailing.	Better info. One source for info.	Better info. on what, where, when, how.	More info. Better understanding of issues.	Education. More involvement in process.
PUBLIC MEETINGS	Not successful to date. Try more. Keep low key.	-	Only good for press coverage.	No more until have products to discuss.	Not good. Media disbursement better.	Not that beneficial.	Not that helpful.	Not effective. Media coverage better.
PRESS/MEDIA COVERAGE	ADHS been attacked. Not consistent. Some inaccuracies.	Too sensational.	Too sensational.	Too sensational.	Good. Should be more involved.	Hard to get good info. Too many sources.	Accurate. Should have better access to data.	Accurate and good.
BEST CONDUITS FOR INFORMATION DISBURSEMENT (CREDIBILITY)	ADHS (maybe reg. office) Tucson Water Policy Committee (existing).	ADHS o.k. but internal problems. City best.	ADHS and city. City most important locally.	City. ADHS too, but "outsider." Water Dept.	ADHS and city. City best.	ADHS and Tucson Water. Tucson Water very credible.	A central technical committee of citizens and of university.	ADHS and city water. City water best. Most credible.
SUGGESTED ACTIONS	Controlled disbursement. Info. center. Newsletters. Press briefing.	Educate public. Go beyond TCE. Est. city as center.	One source for info. Better coord. with city/ADHS More info. out.	More education. Mailings with water bills. Better tech. information.	Info. center Phone line Repository More info. Disburse via Tucson.	Establish good tech. contacts for public. Media workshop. TV programs.	Newsletter. Repository. Phone line. TV programs.	More public involvement. Info. sheets.

PD904.086.1

Past community relations activities have responded to community problems or public concerns as they arose. Information has been disseminated through a variety of sources, which at times has been confusing to the general public. Interviewees did not feel that the health issues were generally understood. In general, the detected TCE levels appear to concern those people who live in the immediate area of contamination, but do not appear to openly concern the general Tucson population.

Interviewees felt that the public does not perceive much difference between the site north of Los Reales Road (Superfund area) and south of Los Reales Road (Air Force Plant #44). The public has little understanding of the Air Force's response to the situation. EPA is perceived as the source for guidance and funding, but is perceived as being slow to act. EPA is also expected to generate response and cooperation from the Air Force, which some interviewees felt has been lacking to date.

The Arizona Department of Health Services is the most visible entity in the program, and has maintained good credibility on most accounts. However, they lack a local presence in Tucson.

The Tucson Water Department appears to be maintaining good credibility. Because of their local presence they may be in a favorable position to assist ADHS in future community relations activities.

Issues raised during local interviews, telephone response to the toll free number and recent letters are summarized below.

Primary Issues

- Health effects of TCE - at what level(s) does TCE become a health hazard? What are the long term impacts of exposure? (Interviews, telephone response.)

- What is the extent of the TCE and other contaminants in the ground water supply? Where are they moving, and how can they be treated? (Interviews, telephone response.)

- Since the source of contamination appears to be primarily through long term soil leaching, how can the extent of (possible) contamination be determined and how can it be cleaned up before seepage reaches the ground water? Could this be just the beginning of a long series of contaminations reaching the ground water? How can the contaminated soil areas be identified, and how can they be cleaned up? (Interviews.)

Secondary Issues

- What are the possible long-term impacts to Tucson business development, growth planning, and regional/national image? (Interviews.)

- Can the Air Force be held responsible for all that they should be responsible for, given the apparent autonomy they have regarding CERCLA? Why isn't Hughes Aircraft held responsible for these activities when they reaped the benefits (profits) of the activities. Who is responsible for all sources of the contamination? (Interviews and telephone response.)

- Can TCE move through the food chain if it occurs in water used for cropland or livestock irrigation? (Telephone response.)

- If private well contamination requires hookup to the city water system, who is responsible for paying for the hookup? (Telephone response.)

Recent letters from the League of Women Voters and the Southwest Environmental Services have requested information on project status, cleanup methods, sources of contamination, cleanup cost and funding.

3.0 COMMUNITY RELATIONS OBJECTIVES AND TECHNIQUES

3.1 Community Relations Objectives

The Community Relations Plan will be implemented by the Arizona Department of Health Services, with assistance from U.S. EPA Region 9. The following list of objectives are intended to guide the community relations activities that occur at the Tucson Airport Site. It is important that both community relations and technical personnel remain sensitive to changing community conditions which may require a change in community relations strategy.

1. Heighten the general public knowledge of the issues and problems related to the site. The general consensus of those interviewed, as demonstrated by public comments and inquiries received by state senators and the Tucson Water Department, is that the public has not been well-informed in the past. Appropriate means to provide better information and raise the level of public understanding should be implemented.

2. Provide consistent, well-organized, and understandable information to the public. Public confusion is partially a result of the publication of technical information that has been misinterpreted. When highly technical data are used, information should be "decoded" in a technically accurate manner and then distributed through a consistent and credible source.

3. Provide regular updates of the overall program to give confidence to the public that the problem is being fully pursued. There is some public perception that the clean-up of the ground water is hopeless and that nothing can be done.

4. Provide the media with timely, detailed, accurate information on a regular basis throughout the Remedial Investigation/Feasibility Study. The media provides an effective source of public information in the Tucson area.

5. Provide local residents and local and state officials with the opportunity to comment on remedial action alternatives identified during the feasibility study, prior to final selection of a remedy. A 3-week comment period will be provided for public review of the feasibility study.

6. Maintain an ongoing awareness of community concerns and information needs, and modify this community relations plan as necessary to reflect required changes.

7. Clearly describe the roles and responsibilities of the participating Federal and State agencies.

8. Provide a data repository in Tucson where appropriate documents, reports and related information will be available for public use.

9. Provide the public with clear information on the separate activities at the Tucson Airport and Air Force Plant #44 sites.

3.2 <u>Community Relations Techniques</u>

1. Establish Tucson field investigation coordination office and information repository.

   Information distribution must be consistent, accurate and readily accessible to the public. To accomplish this, the Arizona Department of Health Services (lead agency for site cleanup and community relations) will establish a Tucson field investigation coordination office. The Tucson office will also act as a repository for general and technical information concerning the site.

An announcement will be made of the office's opening. A press release and radio public service announcement will be distributed. TCE Update will include an article on the office's function and resources.

2. Prepare technical data for public distribution.

   Technical data will be summarized for public review. Tucson area public interest groups have a history of involvement in water issues and thus can be expected to desire access to technical information. Well written report summaries, including technical explanations, will be prepared to allow meaningful public review.

   A Data summaries and reports will be available for public review at the Tucson field investigation coordination office and the ADHS office in Phoenix.

3. Distribute regular newsletters.

   TCE Update, a newsletter, will be mailed to affected and/or interested groups or persons every 2 to 4 months. This will provide a regular source of information on the progress of the program. The fact sheets outlined below may be a major source of information for the TCE Updates.

   Copies of the TCE Update will be available at the Tucson field investigation coordination office and the ADHS office in Phoenix.

4. Establish a telephone information line.

   A telephone information number will be published to provide the public with a central contact point. This information telephone will be located at the Tucson field investigation office. Periodic radio announcements will publicize the telephone information line number and all reports and newsletters will include the number.

5. Assist with media programs to educate and inform area residents.

   Most individuals interviewed during the preparation of this assessment feel that the local media has fairly represented information concerning the site. ADHS and the City of Tucson will continue to assist local television and newspapers with public education programs including coverage of the issues, studies and results. Local television stations have expressed interest in such programming and one station recently scheduled a series on statewide ground water contamination. ADHS will contact local media to determine the type of infor-

mation that will be useful and will encourage public education programs on the TCE issue. ADHS will assist local media with these programs, but will not have sufficient staff resources to produce special programs. Educating press staff on the technical issues will allow clearer coverage of upcoming activities. ADHS and the City of Tucson will work closely with the media, to maximize the opportunity to increase community understanding.

6. Public meetings.

Public meetings have not been viewed as an effective community relations technique in Tucson. Attendance has been poor, and meetings are not considered an effective means to reach the general public by those interviewed. If public interest warrants, however, public meetings may occur at selected times when substantial data or issues can be discussed. Properly advertised and presented, they may be a beneficial public information tool. A public meeting in the immediate area of the Tucson Airport may be appropriate at the conclusion of the remedial investigation. The need for public meetings will be gaged as the Remedial Investigation proceeds. If study results show significant contamination, public interest may increase substantially. The need for further public meetings will be carefully reviewed once the Remedial Investigation has been completed. A public meeting to accept comments on the Feasibility Study may be appropriate toward the end of the 3-week comment period on that document.

7. Briefings of local officials.

The Tucson Airport Area Site Policy and Technical Committees include representatives from ADHS, EPA Region 9, the City of Tucson, U.S. Air Force, and Arizona Department of Water Resources. ADHS will inform these individuals of upcoming activities and study results by mail or telephone calls. State legislators, including Senator J. Mawhinney and Senator G. Lunn, have expressed interest in this site. They will be regularly briefed on the progress of site activities.

8. Press releases and briefings.

Press releases will be prepared at appropriate times throughout remedial activities. Press briefings will be prepared when significant findings occur. At a minimum, press releases will occur at the following times:

- At the outset of the Remedial Investigation to identify the work to be done and when results are expected to be available.

- At the completion of the Remedial Investigation, or whenever significant test or study results are available.

- At the completion of the Feasibility Study to identify alternative remedial ations.

- Throughout the Remedial Investigation/Feasibility Study to announce public meetings, activities (such as the location of the information office), or other activities of note.

9. Fact sheets.

Fact sheets will be prepared as appropriate and will provide more detailed data and analysis than can be included in a press release or other information source. The preparation of fact sheets is discretionary and is largely dependent on the complexity of the data to be presented. ADHS will prepare and distribute fact sheets to accompany each of the press releases outlined above as appropriate. Fact sheets will be available at the Tucson field investigation coordination office and may serve as the major source for newsletter articles.

10. Telephone survey.

A recent telephone survey was extremely useful in determining public awareness and concerns. Additional surveys will be held at selected times in the study process to again gage the level of public concern. Three such surveys will occur over the Remedial Investigation/Feasibility Study time frame.

11. Mailing list.

ADHS will prepare a mailing and distribution list for the TCE Update, fact sheets, press releases and other information documents. A distribution list for report copies will also be prepared. Regular updates of these mailing and distribution lists will occur.

12. Community discussions.

Community discussions will take place as new groups and organizations emerge showing interest and/or concern with site activities.

13. Community relations plan review and update.

This community relations plan will be carefully reviewed each quarter and revised as appropriate. Special attention will be directed at the community relations activities schedule. Appropriate revisions will be made.

14. Public comment.

ADHS will actively seek public comment on the Feasibility Study. Press releases, TCE Update, and radio announcements will notify the public of the report's availability two weeks prior to the comment period. A public meeting will be held at the onset of the 3-week public comment period.

4.0 PERSONNEL ALLOCATION

The following personnel allocations are based on the techniques described in the previous section. A 12-month time frame for the Remedial Investigation/Feasibility Study has been assumed. Personnel allocations for each task are outlined below. Budget information is contained in the following section. Personnel allocations and budgets are limited to tasks to be completed by the community relations specialist, and graphics support. The project manager's time for review, local briefings, and public meeting attendance, as well as clerical support, have been included in the technical program budget.

1. Establish Tucson field investigation coordination office and information repository.

The Tucson field investigation coordination office will be established within the technical program budget. It is expected that the field office secretary will spend approximately 1 hour per week responding to public phone calls and operating the information repository. It is expected that the community relations specialist will spend an average of 4.5 hours per week answering general phone calls and coordinating community relations activities.

Community Relations Specialist
4.5 hrs per week x 52 weeks 234 hrs

2. Prepare technical data for distribution.

Summaries of technical data will be prepared at the conclusion of the Remedial Investigation and Feasibility Study phases. A two- to three-page executive summary is expected. It is also assumed that a minimum of one

test result summary will also be prepared. This is a total of three technical summaries over the 12-month project.

Community Relations Specialist
16 hrs each summary x 3 — 48 hrs

Graphics support
2 hrs each summary x 3 — 6 hrs

3. Distribute TCE Updates.

Currently, TCE Update newsletters are distributed every 2 to 4 months. It is expected that four to six TCE Updates will be distributed during the RI/FS.

Community Relations Specialist
9 hrs each x 4 — 36 hrs

4. Establish telephone information line.

The telephone information line will be located at the field investigation coordination office. The cost of that telephone line is included in the technical program budget. Costs associated with public inquiries have been included in Item 1 above.

5. Assist with media programs to educate and inform area residents.

It is expected that ADHS will assist local television and newspaper staff in the preparation of three public information programs/articles during the RI/FS.

Community Relations Specialist
24 hrs each program x 3 — 72 hrs

Graphics support
8 hrs each program x 3 — 24 hrs

6. Public meetings.

Public meetings will be held at the conclusion of the remedial investigation and the feasibility study phases. Meeting notices will be distributed to interested groups, citizens, and local officials.

Community Relations Specialist
16 hrs x 2 meetings — 32 hrs

Graphics support
24 hrs x 2 meetings — 48 hrs

7. Briefings of local officials.

Local official briefings will generally be conducted by the project manager and are included in the technical program budget. Assistance provided by the Community Relations Specialist has been included in Item 1 above.

8. Press releases and briefings.

Press releases will be issued at appropriate times during the RI/FS. It is expected that five press releases will be issued during the project. Two press briefings will be held to coincide with completion of the remedial investigation and feasibility study phases.

Community Relations Specialist	
3 hrs/press release x 5	15 hrs
5 hrs/press briefing x 2	10 hrs

9. Fact sheets.

It is expected that six fact sheets will be prepared during the RI/FS.

Community Relations Specialist	
9 hrs per fact sheet x 6	54 hrs

10. Telephone survey.

Three telephone surveys will be conducted during the RI/FS. These will be conducted at the Tucson field investigation office.

Community Relations Specialist	
9 hrs per survey x 3	27 hrs

11. Mailing list.

The current mailing list will be updated at the outset of the RI/FS. It will be revised as necessary during the study.

Community Relations Specialist	
10 hrs	10 hrs

Personnel Allocation Summary

Community Relations Specialist

Total: 538 hrs

Graphics support

Total: 78 hrs

5.0 BUDGET

For the purposes of this budget, salary rate assumptions have been made based on discussions with ADHS. The following hourly wage rates are used for each personnel classification:

Community Relations Specialist	$10.35/hr
Graphics support	$15.00/hr

Overheads were determined based on ADHS July 1, 1983, rates:

Fringe benefits	21.14%
Indirect costs	31.7

Salaries

Community Relations Specialist 538 hrs x $10.35/hr	$ 5,568.30
Graphics, outside professional service, and printing support 78 hrs x $15.00/hr	1,170.00
Total salaries	$ 6,738.30

Overheads

Fringes $5,568 x 21.14%	$ 1,177.08
Indirect (salary + fringe) $6,745 x 31.7%	2,138.29
Total overheads	$ 3,315.37

Other Direct Costs

Reproduction and supplies	$ 2,500.00
Travel costs	1,464.00
Total other direct costs	$ 3,964.00

Budget Summary

Salaries	$ 6,738.30
Overheads	315.37
Other direct costs	3,964.00
Total	$14,017.67

TUCSON ACTIVITIES SCHEDULE
COMMUNITY RELATIONS

	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
• Develop Mailing List	-----											
• Establish Repositories	-----											
• TCE Update	•		•		•		•		•		•	
• Press Release	•		•					•				•
• Press Briefings	-	-	-	-	As Needed		-	-	-	-	-	-
• Elected Official Briefings	•		•	-	As Needed		-	-	-	-	-	•
• Fact Sheets	•			•			•					•
• Public Meeting	-	-	-	-	As Appropriate		-	-	-	-	-	•
• Office Announcement	•			•		•	•		•		----------	
• Review CRP			•									•

PD224.023.1

B407795 TUCSON 3/33
mailist 508

Mary Beth Carlile
SAWARA
465 W. Congress
Chamber of Commerce Building
Tucson, AZ 85705

Dave Baron
Center for Law in the Public Interest
39 N. Tucson Blvd.
Tucson, AZ 85716

Priscilla Robinson
Southwest Environmental Services
P O Box 223
Tucson, AZ 85702

Lois Kulakowski
League of Women Voters
4560 E. Broadway Room 17
Tucson, AZ 85711

Tres English
Sierra Club
129 S. Irving
Tucson, AZ 85719

Alex Dely
Bertram Russell Society
6150 E. 31st
Tucson, AZ 85711

Patty Overall
Junior League
3120 W. Via Celeste
Tucson, AZ 85718

The Honorable Morris Udall
The U. S. House of Representative
235 Cannon House Office Building
Washington D.C. 20515

The Honorable John McCain
The U.S. House of Representative
1123 Longworth House Office Building
Washington D.C. 20515

The Honorable Jim McNulty
The U. S. House of Representative
1338 Longworth House Office Building
Washington D.C. 20515

The Honorable Dennis DeConcini
United States Senate
SH 328
Washington D.C. 20510

The Honorable Barry Goldwater
United States Senate
337 Russell Senate Office Building
Washington D.C. 20510

Senator Usdane
Senator Mawhinney
Senator Lunn
Senator Kolbe
Senator Hill
Senator Gonzales

Representative De Long
Representative Morales
Representative Messinger
Representative Skelly
Tucson Lobbyist, Bill Sheldon

Patricia A. Nolan
Director
Pima County Health Dept.
151 W. Congress
Tucson 85701

Jack Hensley
Pima County Health Dept.
151 W. Congress
Tucson 85701

Tom Swanson
Executive Director
Pima Association of Governments
405 S. Transamerica Bldg.
Suite 411
Tucson 85701

Carol Dorsey, PAG
405 Transamerica Bldg.
Tucson, AZ 85701

Pima County Board of Supervisors
131 W. Washington 11th Floor
Tucson, AZ 85701

Pima County Board of Health
c/o Pat Nolan, Director
Pima County Health Dept.
151 W. Congress
Tucson, AZ 85701

R. McIntosh
IBM
General Production Division
Tucson 85744

Ron Eagan
Arizona Air National Guard, C.E.
P.O. Box 11037
Tucson, Arizona 85734

Tom Milton-Goddard
Office of the Governor
1700 W. Washington
Phoenix 85007

M. F. McNulty
ADWR
99 E. Virginia
Phoenix 85004

Terry Turner
ADWR
99 E. Virginia
Phoenix 85004

Mayor and City Council
Box 27210
Tucson, AZ 85726

William Ealy, Dep. City M.
Box 27210
Tucson, AZ 85726

T.J. Harrison
City Attorney's Office
P. O. Box 27210
Tucson 85726

Frank Brooks, Director
Tucson Water
City of Tucson
P. O. Box 27210
Tucson, Arizona 85726

Bruce Johnson
Tucson Water
P. O. Box 27210
Tucson 85726

Tom Jefferson
Tucson Water
P. O. Box 27210
Tucson 85726

Lt. Gen. Robert M. Bond
Vine Commander-AFSC
Andrews AFB, MD 20334

Gordon Ginsburg
Brigadier General, USAF
Staff Judge Advocate
HQ/AFSC
Andrews AFB, MD 20334

Col. T. J. Lewis
HQ Air Force Systems Command
DCS Engineering & Services
Andrews AFB, MD 20334

Barry Hatfield, Chief
Facilities Mgmt. Division
Air Force ASD/PMDA
Wright Patterson AFB, OH 45433

Capt. Christopher Kernan
HQ/AFSC/JAM
Andrews AFB, Maryland 20334

Major Keith Roberts
AFPRO - Hughes Aircraft/JA
P. O. Box 92463
Los Angeles, CA 90009

Charles Alford
Environmental Program Manager
Air Force ASD/PMDA
Wright-Patterson AFB, Ohio 45433

John Deummel
HQ AFSC/PAM
Andrews AFB, Maryland 20334

Maj. Stephen Termaath
Air Force & Engng. & Serv. Ctr.
Tyndall AFB, Florida 32403

Bernard Lindenburg
Hazardous Waste Program
Air Force Engng. & Services
Tyndall AFB, Florida 32403

L. F. Boyd
ASD/DEI
Wright-Patterson AFB
Ohio 45433

Mr. A. H. J. Meuller
Vice President
Manager, Manufacturing Divisi
Hughes Aircraft Company
P. O. Box 11337
Tucson 85734

E. K. Spaulding
Environmental Health & Safe
Hughes Aircraft Company
P. O. Box 11337
Tucson 85734

Dwain Oliver
Environmental Health & Safety
Hughes Aircraft Company
P. O. Box 11337
Tucson 85734

David R. Hargis
Hargis & Montgomery
Consultants in Hydrogeology
1735 E. Ft. Lowell
Tucson 85719

David L. Mulliken
Latham and Watkins
Suite 2100, 701 B Street
San Diego, CA 92101

Table #5

ESTIMATE DETAILS

PROJECT: Ground Water Reclamation
ACCOUNT: Water Disposal System #1
City of Tucson Sewer

ESTIMATE NO.
SHEET NO. 1 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS UNIT PRICE	MATERIALS AMOUNT	LABOR UNIT M.H.	LABOR TOTAL M.H.	LABOR RATE	LABOR AMOUNT	SUB-CONTRACT UNIT PRICE	SUB-CONTRACT AMOUNT	TOTAL
MECHANICAL:										
Pipe Steel										
18" Ø Steel Pipe	45,073 Ft.	20.00	905,517.00	6	27,043.8	29.85	807,257.00			1,712,774.00
18" Ø Steel Elbow 90°	28	470.00	13,160.00	24	672	29.85	20,059.00			33,219.00
18" Ø Steel Elbow 45°	2	530.00	1,060.00	24	48	29.85	1,433.00			2,493.00
18" Ø Steel Tee	16	625.00	10,000.00	36	576	29.85	17,194.00			27,194.00
18" Ø Butterfly Valve	1	3,068.00	3,068.00	10	10	29.85	299.00			3,367.00
18" Ø Flanges	4	225.00	900.00	12	48	29.85	1,433.00			2,333.00
18" Ø Reducers	24	310.00	7,440.00	24	576	29.85	17,194.00			24,634.00
PIPE STEEL										
12" Ø Steel Pipe	120 Ft.	24	2,880.00	1.6	192	29.85	5,731.00			8,611.00
12" Ø Elbows 90°	20	335.00	6,700.00	4	80	29.65	2,372.00			9,072.00
12" Ø Butterfly Valves	24	430.00	10,320.00	14.12	339	29.65	10,048.00			20,368.00
12" Ø Check Valves	12	1,175.00	14,100.00	14.12	169	29.65	5,011.00			19,111.00
12" Ø Flange	144	160.00	23,040.00	5.33	768	29.85	22,925.00			45,965.00
12" Ø Reducer	24	200.00	4,800.00	10.67	256	29.85	7,642.00			12,442.00
12" Ø Flex Connectors	24	350.00	8,400.00	14.12	339	29.65	10,051.00			18,451.00
Pumps 2,345 GPM 150 HP	12	22,150.00	265,800.00	17.2	206	29.65	6,108.00			271,908.00
Flow Meter	1	6,225.00	6,225.00	14.1	14.1	29.65	418.00			6,643.00
Thrust Blocks @ Elbows	50	35.00	1,750.00	3	150	18.34	2,751.00			4,501.00
Excavation 4' x 6' x 45,073 Ft.	40,065 C/Yds	1.13	45,273.00	.04	1603	35.13	56,313.00			101,586.00
Back Fill	40,065 Yds³	.48	19,231.00	5.05			202,328.00			221,559.00
ROAD CROSSINGS										
Bore & Casing Beneath R.R. Tracks (3)	180'	38.17	6,870.00	285			51,300.00			58,170.00
Cross Old Nogales Highway (1)	100'	2.89	289.00	18.65			1,865.00			2,154.00
Cross 2 Lane Asphalt Road (11)	550'	2.89	1,590.00	18.29			10,060.00			11,650.00
Cross I-19 (1)	60'	38.17	2,290.00	200			12,000.00			14,290.00
Cross Dirt Roads (7)	350'	.75	263.00	16.1			5,635.00			5,898.00
Cross Valencia (1)	60'	2.89	173.00	18.29			1,097.00			1,270.00
Cross Drexel (1)	50'	2.89	145.00	18.29			914.00			1,059.00
ARCHITECTURAL										
Slabs and Fence			450.00				1,050.00			1,500.00
Subtotal			1,361,734.00				1,280,488.00			2,642,222.00

Table #5

ESTIMATE DETAILS

PROJECT: Ground Water Reclamation
ACCOUNT: Water Disposal System #1

ESTIMATE NO.
SHEET NO. 2 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
ELECTRICAL										
1 Power Company changes for delivery to site and transformation										30,000.00
2 Site conduit, wire, trenching, for incoming service and distribution at 480 V. 3 phase										24,000.00
3 Site grounding, lighting, security, telephone and control/monitor computer system										61,800.00
4 Pump variable frequency drive equipment, housing controls and installation for pumps										420,580.00
5 Telephone Co. charges for communications for monitor control at site										5,000.00
Subtotal										541,380.00

Table #5

ESTIMATE DETAILS

PROJECT: Ground Water Reclamation
ACCOUNT: Water Disposal System #1

ESTIMATE NO.
SHEET NO. 3 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
Subtotal from 1 of 3										2,642,222.00
Subtotal from 2 of 3										541,380.00
Subtotal										3,183,602.00
Overhead	10%									318,360.00
Subtotal										3,501,962.00
Profit	10%									350,196.00
Subtotal										3,852,158.00
Bond	1%									38,522.00
Subtotal										3,890,680.00
Sales Tax	4%of 65%									101,158.00
Subtotal										3,991,838.00
HAC Engineering (Administration)	7%									279,431.00
Subtotal										4,271,269.00
Contingency Allowance										25,000.00
Subtotal										4,296,269.00
Engineering Start-up and Shake Down										25,000.00
Total Project Cost										4,321,269.00

Table #6

ESTIMATE DETAILS

PROJECT:
ACCOUNT: A.F.P INDUSTRIAL USE

ESTIMATE NO
SHEET NO. 1 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
MECHANICAL										
6" Ø Pipe	400	22.00	8,800.00	.67	268	21.34	5,719.00			14,519.00
6" Ø Elbows 90°	12	78.00	936.00	2.67	32	20.58	659.00			1,595.00
6" Ø Tees	2	110.00	220.00	4	8	20.58	165.00			385.00
6" Ø Buttefly Valve	5	150.00	750.00	8	40	20.58	823.00			1,573.00
6" Ø Check Valve	3	220.00	660.00	8	24	20.58	494.00			1,154.00
6" Ø Flange	32	35.00	1,120.00	4	128	21.34	2,732.00			3,852.00
6" Ø Flex Connection	4	200.00	800.00	6	24	20.58	494.00			1,294.00
6" Ø to 4" Ø Reducers	4	78.00	312.00	2.67	11	20.58	226.00			538.00
6" Ø Flow Meter	1	2,325.00	2,325.00	9.23	9.23	20.58	190.00			2,515.00
Pumps. 310 GPM 5 HP	2	1,553.00	1,553.00	17.2	34.4	20.58	708.00			2,261.00
Thrust Blocks	12	35.00	420.00	3	36	18.34	660.00			1,080.00
Excavation 400' 4' x 6'	356 yds.	1.13	402.00	.04	14	35.13	492.00			894.00
Back Fill	356 yds.	.48	171.00	.14	50	35.13	1,757.00			1,928.00
ROAD CROSSINGS										
Cross Gravel Road 2	50	.75	38.00	.43	22	41.90	922.00			960.00
Cross Asphalt Road 1	60	3.64	218.00	.43	26.	41.90	1,089.00			1,307.00
Structural										
Fence & Slab	2	50	100.00	3	6	38.89	234.00			334.00
SUBTOTAL										36,189.00

Table #6

ESTIMATE DETAILS

PROJECT:
ACCOUNT: A.F.P. INDUSTRIAL USE.

ESTIMATE NO.
SHEET NO. 2 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
ELECTRICAL										
#1 Pump site grounding, lighting, security, telephone, computer FPU Total of (1) locations										11,100.00
#2 Pump variable frequency drive equipment, enclosure etc. Complete total of (1) units/locations										33,500.00
#3 Site power for service entrance and pump branch circuits total of (1) locations										3,000.00
#4 Power company charges for delivery of energy to sites at 480 volts 3 phase total of (1) locations.										5,000.00
#5 Telephone company charges for delivery of service to sites total of (1) locations.										1,000.00
Subtotal										53,600.00

Table #6

ESTIMATE DETAILS

PROJECT:
ACCOUNT: SYSTEM A.F.P. INDUSTRIAL USE

ESTIMATE NO
SHEET NO 3 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M H	TOTAL M H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
Subtotal from 1 of 3										36,189.00
Subtotal from 2 of 3										53,600.00
Subtotal										89,789.00
Overhead	10%									8,979.00
Subtotal										98,768.00
Profit	10%									9,877.00
Subtotal										108,645.00
Bond	1%									1,086.00
Subtotal										109,731.00
Sales Tax	4% of 65%									2,853.00
Subtotal										112,584.00
HAC Engineering (Administration)	7%									7,881.00
Subtotal										120,465.00
Contingency Allowance										5,000.00
Subtotal										125,465.00
Engineering Start-up and Shake Down										5,000.00
Total Project Cost										130,465.00

Table #7

ESTIMATE DETAILS

PROJECT:
ACCOUNT: INDUSTRIAL USE BY ASARCO COPPER MINE

ESTIMATE NO.
SHEET NO. 1 of 3
PREPARED BY: D. Bloxham DATE: 10/18/84
CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
MECHANICAL										
18" Ø Pipe	71,060'	25.50	1,812,030.00	.6	42,636	20.98	894,503.00			2,706,533.00
18" Ø Elbows 90°	25	470.00	11,750.00	24	600	20.98	12,588.00			24,338.00
18" Ø Elbows 45°	5	530.00	2,650.00	24	120	20.98	2,518.00			5,168.00
18" Ø Tees	16	625.00	10,000.00	36	576	20.98	12,085.00			22,085.00
18" Ø Butterfly Valves	1	3,195.00	3,195.00	10	10	20.58	206.00			3,401.00
18" Ø Check Valve	1	5,860.00	5,860.00	10	10	20.58	206.00			6,066.00
18" Ø Flanges	4	225.00	900.00	12	48	20.98	1,007.00			1,907.00
18" Ø x 12" Ø Reducers	24	310.00	7,440.00	24	576	20.98	12,085.00			19,525.00
12" Ø Pipe	100'	24.00	2,400.00	1.6	160	20.98	3,357.00			5,757.00
12" Ø Elbows 90°	20	335.00	6,700.00	4	80	20.98	1,678.00			8,378.00
12" Ø Butterfly Valves	24	430.00	10,320.00	14.12	339	20.58	6,977.00			17,297.00
12" Ø Check Valves	12	1,175.00	14,100.00	14.12	169	20.58	3,478.00			17,578.00
12" Ø Flange	96	160.00	15,360.00	5.33	512	20.98	10,742.00			26,102.00
12" Ø Reducers	24	200.00	4,800.00	10.67	256	20.98	5,371.00			10,171.00
12" Ø Flex Connectors	24	350.00	8,400.00	14.12	339	20.98	7,112.00			15,512.00
18" Ø Flow Meter	1	9,618.00	9,618.00	14.5	14.5	20.58	229.00			9,917.00
Pumps 1755 GPM 150 H.P.	12	24,950.00	299,400.00	17.2	206	20.98	4,322.00			303,722.00
Thrust Blocks	50	35	1,750.00	3	150	18.34	2,751.00			4,501.00
Excavation 71,060 Ft. 4'x6'	63,165 yds^3	1.13	71,376.00	.04	2,527	35.13	88,774.00			160,150.00
Back Fill	63,165 "	.48	30,319.00	.14	8,843	35.13	310,655.00			340,974.00
Road Crossings										
Old Nogales Highway	60'	2.89	173	.43	26	41.90	1,089.00			1,262.00
Boring Beneath R.R. Tracks	30'	35	1050	9.14	274	31.27	8,568.00			9,618.00
Cross El Paso Natural Gas Line (1)	120'	.75	90	.43	52	41.90	2,178.00			2,269.00
Cross Santa Cruz River (1)	150'	.75	113	.43	65	41.90	2,724.00			2,837.00
Cross Asphalt 2 Lane Roads (10)	500'	3.56	1820	.43	215	41.90	9,009.00			10,829.00
Cross Grave Roads (10)	500'	.75	375	.43	215	41.90	9,009.00			9,384.00
ARCHITECTURAL										
Slabs and Fences	15 yards	50	800.00	3	48	38.89	907.00			1,707.00
SUBTOTAL										3,746,988.00

517

Table #7

ESTIMATE DETAILS

PROJECT:
ACCOUNT: INDUSTRIAL USE BY ASARCO COPPER MINE

ESTIMATE NO.
SHEET NO. 2 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
ELECTRICAL										
#1 Pump site grounding, lighting, security, telephone, computer FPU Total of (4) locations										61,800.00
#2 Pump variable frequency drive equipment, enclosure etc. Complete total of (4) units/locations										330,350.00
#3 Site power for service entrance and pump branch circuits total of (4) locations										24,000.00
#4 Power company charges for delivery of energy to sites at 480 volts 3 phase total of (4) locations.										30,000.00
#5 Telephone company charges for delivery of service to sites total of (4) locations.										5,000.00
Subtotal										451,150.00

Table #7

ESTIMATE DETAILS

PROJECT:
ACCOUNT: INDUSTRIAL USE BY ASARCO COPPER MINE

ESTIMATE NO.
SHEET NO. 3 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
Subtotal from 1 of 3										3,746,988.00
Subtotal from 2 of 3										451,150.00
Subtotal										4,198,138.00
Overhead	10%									419,814.00
Subtotal										4,617,952.00
Profit	10%									461,795.00
Subtotal										5,079,747.00
Bond	1%									50.797.00
Subtotal										5,130,544.00
Sales Tax	4%of 65%									133,394.00
Subtotal										5,263,938.00
HAC Engineering (Administration)	7%									368,476.00
Subtotal										5,632,414.00
Contingency Allowance										25,000.00
Subtotal										5,657,414.00
Engineering Start-up and Shake Down										25,000.00
Total Project Cost										5,682,414.00

Table #8

ESTIMATE DETAILS

PROJECT: IRRIGATION BY FARMERS INVESTMENT CO.

ACCOUNT:

ESTIMATE NO.

SHEET NO. 1 of 3

PREPARED BY: D. Bloxham DATE 10/18/84

CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
MECHANICAL										
18" Ø Pipe	117,375'	25.50	2,993,063.00	.6	70,425	20.98	1,477,517.00			4,470,580.00
18" Ø Elbows 90°	76	470.00	35,720.00	24	1,824	20.98	38,268.00			73,988.00
18" Ø Elbows 45°	7	530.00	3,710.00	24	168	20.98	3,525.00			7,235.00
18" Ø x 12" Ø Reducers	72	310.00	22,320.00	24	1,728	20.98	36,254.00			58,574.00
18" Ø Butterfly Valve	1	3,195.00	3,195.00	10	10	20.58	206.00			3,401.00
18" Ø Check Valve	1	5,860.00	5,860.00	10	10	20.58	206.00			6,066.00
18" Ø Tee	48	625.00	30,000.00	36	1,728	20.98	36,253.00			66,253.00
18" Ø Flange	4	225.00	900.00	12	48	20.98	1,007.00			1,907.00
12" Ø Pipe	3,600'	24.00	86,400.00	1.6	5,760	20.98	120,845.00			207,245.00
12" Ø Elbow 90°	60	335.00	20,100.00	4	240	20.98	5,035.00			25,135.00
12" Ø Flanges	324	160.00	51,840.00	5.33	1,727	20.98	36,232.00			88,072.00
12" Ø Reducers	72	200.00	14,400.00	10.67	769	20.98	16,134.00			30,534.00
12" Ø Butterfly Valves	72	430.00	30,960.00	14.12	1,017	20.58	20,930.00			51,890.00
12" Ø Check Valve	36	1,175.00	42,300.00	14.12	509	20.58	10,476.00			52,766.00
12" Ø Flex Connection	72	350.00	25,200.00	14.12	1,017	20.98	21,337.00			46,537.00
18" Ø Flow Meter	1	9,716.00	9,716.00	14.5	14.5	20.58	299.00			10,015.00
Pumps 2345 GPM 150 HP	36	27,445.00	988,020.00	17.2	619	20.98	12,987.00			1,001,007.00
Thrust Blocks	39	35	1,365.00	3	117	18.34	2,146.00			3,511.00
Excavation 117,375 4' x 6'	104,333 yds	1.13	117,896.00	.04	4,173	35.13	146,598.00			264,494.00
Back Fill	104,333 yds	.48	50,080.00	.14	14,607	35.13	513,144.00			563,224.00
ROAD CROSSINGS										
2 Lane Asphault paved Roads (15)	750'	2.89	2,168.00	.43	323	41.90	13,534.00			15,702.00
Cross Dirt Roads (9)	450'	.75	338.00	.43	194	41.90	8,129.00			8,467.00
Cross El paso Natural Gas Line (1)	120'	.75	90.00	.43	52	41.90	2,179.00			2,269.00
ARCHITECTURAL										
Slabs and Fence	48 yds.	50.00	2,400.00	3	144	38.89	5,601.00			8,001.00
SUBTOTAL										7,066,883.00

Table #8

ESTIMATE DETAILS

PROJECT: IRRIGATION BY FARMERS INVESTMENT CO.

ACCOUNT:

ESTIMATE NO.

SHEET NO. 2 of 3

PREPARED BY: D. Bloxham DATE. 10/18/84

CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
ELECTRICAL										
#1 Pump site grounding, lighting, security, telephone computer EPU Total of (12) Locations										185,400.00
#2 Pump variable frequency dirve equipment enclosure ect. complete total of (12) units locations.										991,000.00
#3 Site power for service entrance and pump branch circuits total of (12) locations										72,000.00
#4 Power company charges for delivery on energy to sites at 480 volts 3 phase total of (12) locations										90,000.00
#5 Telephone company charges for delivery of service to sites total of (12) locations										1,500.00
SUBTOTAL										1,339,900.00

Table #8

ESTIMATE DETAILS

PROJECT:
ACCOUNT: SYSTEM
IRRIGATION SYSTEM BY FARMERS INVESTMENT CO

ESTIMATE NO.
SHEET NO. 3 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
SUBTOTAL FROM 1 of 2										7,066,883.00
SUBTOTAL FROM 2 of 3										1,339,900.00
SUBTOTAL										8,406,783.00
OVERHEAD	10%									840,672.00
SUBTOTAL										9,247,461.00
PROFIT	10%									924,746.00
SUBTOTAL										10,172,207.00
BOND	1%									101,723.00
SUBTOTAL										10,273,930.00
SALES TAX	4% of 65%									267,122.00
SUBTOTAL										10,541,052.00
HAC ENGINEERING (ADMINISTRATION)	7%									737,833.00
SUBTOTAL										11,278,925.00
CONTINGENCY ALLOWANCE										100,000.00
SUBTOTAL										11,378,925.00
ENGINEERING START-UP AND SHAKE DOWN										50,000.00
TOTAL PROJECT COST										11,428,925.00

Table #9

ESTIMATE DETAILS

PROJECT:
ACCOUNT: IRRIGATION BY PAPAGO INDIANS

ESTIMATE NO.
SHEET NO. 1 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
MECHANICAL										
18" Ø Pipe	32,391'	25.50	825,970.00	.6	19,435	20.98	407,745.00			1,233,715.00
18" Ø Elbows 90°	24	470.00	11,280.00	24	576	20.98	12,085.00			23,365.00
18" Ø Elbows 45°	1	530.00	530.00	24	24	20.98	42.00			572.00
18" Ø Butterfly Valve	1	3,195.00	3,195.00	10	10	20.58	206.00			3,401.00
18" Ø Check Valve	1	5,860.00	5,860.00	10	10	20.58	206.00			6,066.00
18" Ø Flanges	4	225.00	900.00	12	48	20.98	1,007.00			1,907.00
18" Ø Tee	10	625.00	6,250.00	36	360	20.98	7,553.00			13,803.00
18" Ø x 12" Ø Reducer	16	310.00	4,960.00	24	384	20.98	8,056.00			13,016.00
12" Ø Pipe	40'	24.00	960.00	1.6	64	20.98	1,343.00			2,303.00
12" Ø Elbows 90°	14	335.00	4,690.00	4	56	20.98	1,175.00			5,865.00
12" Ø Butterfly Valve	16	430.00	6,880.00	14.12	226	20.58	4,651.00			11,531.00
12" Ø Check Valve	8	1,175.00	9,400.00	14.12	113	20.58	2,326.00			11,726.00
12" Ø Flange	112	224.00	25,088.00	5.33	597	20.98	12,525.00			37,613.00
12" Ø Flex Connection	16	350.00	5,600.00	14.12	226	20.98	4,742.00			10,342.00
18" Ø Flow Meter	1	9,716.00	9,716.00	14.5	14.5	20.58	299.00			10,015.00
Pumps 2342 GPM 150 HP	8	27,445.00	219,560.00	17.2	138	20.98	2,895.00			222,455.00
Thrust Blocks	12	35	420.00	3	36	18.34	660.00			1,080.00
Excavation	26,000 yds	1.13	29,380.00	.04	1040	35.13	36,535.00			65,915.00
Back Fill	26,000 yds	.48	12,480.00	.14	3640	35.13	127,873.00			140,353.00
ROAD CROSSINGS										
Old Nogales Highway (1)	60'	2.89	173.00	.43	26	41.90	1,089.00			1,262.00
Boring & Casing Beneath R.R. Tracks	60'	35	2,100.00	9.14	548	31.27	17,136.00			19,236.00
Cross El Paso Natural Gas (1)	120'	.75	90.00	.43	52	41.90	2,179.00			2,269.00
Cross Dirt Roads (5)	50'	.75	38.00	.43	22	41.90	922.00			960.00
Cross Santa Cruz River (1)	150'	.75	113.00	.43	65	41.90	2,724.00			2,837.00
ARCHITECTURAL										
Slabs & Fence (2)	8	50.00	400.00	3	24	38.89	933.00			1,333.00
SUBTOTAL										1,842,940.00

Table #9

ESTIMATE DETAILS

PROJECT:
ACCOUNT: IRRIGATION BY PAPAGO INDIANS

ESTIMATE NO.
SHEET NO. 2 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
ELECTRICAL										
#1 Pump site grounding, lighting, security, telephone, computer FPU Total of (2) locations										30,900.00
#2 Pump variable frequency drive equipment, enclosure etc. Complete total of (2) units/locations										165,200.00
#3 Site power for service entrance and pump branch circuits total of (2) locations										12,000.00
#4 Power company charges for delivery of energy to sites at 480 volts 3 phase total of (2) locations.										15,000.00
#5 Telephone company charges for delivery of service to sites total of (2) locations.										2,500.00
Subtotal										225,600.00

Table #9

ESTIMATE DETAILS

PROJECT:
ACCOUNT: SYSTEM
IRRIGATION BY PAPAGO INDIANS

ESTIMATE NO
SHEET NO. 3 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
Subtotal from 1 of 3										1,842,940.00
Subtotal from 2 of 3										225,600.00
Subtotal										2,068,540.00
Overhead	10%									206,854.00
Subtotal										2,275,394.00
Profit	10%									227,539.00
Subtotal										2,502,933.00
Bond	1%									25,029.00
Subtotal										2,527,962.00
Sales Tax	4%of 65%									65,727.00
Subtotal										2,593,689.00
HAC Engineering (Administration)	7%									181,558.00
Subtotal										2,775,247.00
Contingency Allowance										25,000.00
Subtotal										2,800,247.00
Engineering Start-up and Shake Down										20,000.00
Total Project Cost										2,820,247.00

Table #10

ESTIMATE DETAILS

PROJECT:
ACCOUNT: GOLF COURSE IRRIGATION

ESTIMATE NO.
SHEET NO. 1 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE:

MECHANICAL DESCRIPTION	QUANTITY	MATERIALS UNIT PRICE	MATERIALS AMOUNT	LABOR UNIT M.H.	LABOR TOTAL M.H.	LABOR RATE	LABOR AMOUNT	SUB-CONTRACT UNIT PRICE	SUB-CONTRACT AMOUNT	TOTAL
6" Ø Pipe P.V.C.	120,475'	5.71	687,912.00	.21	25,300	19.85	502,205.00			1,190,117.00
6" Ø Elbow 90° P.V.C.	102	4.59	468.00	.5	51	19.85	1,012.00			1,480.00
6" Ø Elbow 45° P.V.C.	8	13.45	108.00	.5	4	19.85	80.00			188.00
6" Ø Butterfly Valve	38	150.00	5,700.00	8	304	20.98	6,378.00			12,078.00
6" Ø Check Valve	20	220.00	4,400.00	8	160	20.98	3,357.00			7,757.00
6" Ø Tee P.V.C.	18	21	378.00	.31	6	19.85	118.00			496.00
6" Ø Flange P.V.C.	188	15	2,820.00	.25	47	19.85	933.00			3,753.00
6" Ø Flex Connection	36	200	7,200.00	6	216	20.85	4,504.00			11,704.00
6" Ø x 4" Ø Reducers P.V.C.	36	21	756.00	.31	11	19.85	218.00			974.00
6" Ø Flow Meter	1	2,325.00	2,325.00	9.23	9.23	20.98	193.00			2,518.00
Pumps 310 GPM 25 HP	18	1,553.00	27,954.00	17.2	310	20.98	6,504.00			34,458.00
Thrust Blocks	30	35	1,050.00	3	90	18.34	1,651.00			2,701.00
Excavation	106,025.00	1.13	119,808.00	.04	4,241	35.13	148,986.00			268,794.00
Backfill	106,025.00	.48	50,892.00	.14	14,844	35.13	521,470.00			572,362.00
ROAD CROSSINGS										
Bore E Casings under R.R. Tracks (3)	180'	35	6,300	9.14	1,645	31.28	51,445.00			57,745.00
Bore under I-10 (1)	60'	35	2,100	9.14	548	31.27	17,136.00			19,236.00
Cross Benson Highway (1)	60'	2.89	174	.43	26	41.90	1,090.00			1,264.00
Cross El Paso Natural Gas Line (2)	240'	.75	180	.43	103	41.90	4,316.00			4,496.00
Cross 2 lane asphalt road on base (10)	500'	2.89	1,445	.43	215	41.90	9,009.00			10,454.00
Cross 2 lane asphalt road off base (10	500'	2.89	1,445	.43	215	41.90	9,009.00			10,454.00
ARCHITECTURAL										
Slab and Fence (8)	24	50.00	1,200	3	72	38.89	2,800.00			4,00.00
SUBTOTAL										2,217,026.00

Table #10

ESTIMATE DETAILS

PROJECT:
ACCOUNT: GOLF COURSE IRRIGATION

ESTIMATE NO
SHEET NO. 2 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
ELECTRICAL										
#1 Pump site grounding, lighting, security, telephone, computer FPU Total of (8) locations										123,600.00
#2 Pump variable frequency drive equipment, enclosure etc. Complete total of (8) units/locations										311,900.00
#3 Site power for service entrance and pump branch circuits total of (8) locations										3,800.00
#4 Power company charges for delivery of energy to sites at 480 volts 3 phase total of (8) locations.										60,000.00
#5 Telephone company charges for delivery of service to sites total of (8) locations.										10,000.00
Subtotal										509,300.00

Table #10

ESTIMATE DETAILS

PROJECT:
ACCOUNT: GOLF COURSE IRRIGATION

ESTIMATE NO
SHEET NO. 3 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M H	TOTAL M H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
Subtotal from 1 of 3										2,217,026.00
Subtotal from 2 of 3										509,300.00
Subtotal										2,726,326.00
Overhead	10%									272,633.00
Subtotal										2,998,959.00
Profit	10%									299,896.00
Subtotal										3,298,855.00
Bond	1%									32,989.00
Subtotal										3,331,844.00
Sales Tax	4%of 65%									86,628.00
Subtotal										3,418,472.00
HAC Engineering (Administration)	7%									239,293.00
Subtotal										3,657,765.00
Contingency Allowance										25,000.00
Subtotal										3,682,765.00
Engineering Start-up and Shake Down										20,000.00
Total Project Cost										3,702,765.00

Table #11

ESTIMATE DETAILS

PROJECT: Recreational Water Use @ Park
ACCOUNT:

ESTIMATE NO:
SHEET NO: 1 of 3
PREPARED BY: D. Bloxham DATE: 10/19/84
CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M H	TOTAL M H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
MECHANICAL										
18" Ø Pipe	55,440'	25.50	1,413,720.00	.6	33,264	20.98	697,879.00			2,111,599.00
18" Ø Elbow 90°	21	470.00	9,870.00	24	504	20.98	10,574.00			20,444.00
18" Ø Elbow 45°	4	530.00	2,120.00	24	96	20.98	2,014.00			4,134.00
18" Ø Tee	12	625.00	7,500.00	36	432	20.98	9,063.00			16,563.00
18" x 12" Reducer	18	310.00	5,580.00	24	432	20.98	9,063.00			14,643.00
18" Ø Butterfly Valve	1	3,195.00	3,195.00	10	10	20.58	206.00			3,401.00
18" Ø Check Valve	1	5,800.00	5,800.00	10	10	20.58	206.00			6,006.00
18" Ø Flange	4	225.00	900.00	12	48	20.98	1,007.00			1,907.00
18" Ø Flow Meter	1	9,618.00	9,618.00	14.5	14.5	20.58	298.00			9,916.00
12" Ø Pipe	120	24.00	2,880.00	1.6	192	20.98	4,028.00			6,908.00
12" Ø Elbow 90°	15	335.00	5,025.00	4	60	20.98	1,259.00			6,284.00
12" Ø x 6" Ø Reducer	18	200.00	3,600.00	10.67	192	20.98	4,028.00			7,628.00
12" Ø Butterfly Valve	18	430.00	7,740.00	14.12	254	20.58	5,227.00			12,967.00
12" Ø Check Valve	9	1,175.00	10,575.00	14.12	127	20.58	2,614.00			13,189.00
12" Ø Flex Connector	8	350.00	2,800.00	14.12	113	20.98	2,371.00			5,171.00
12" Ø Flange	72	160.00	11,520.00	5.33	384	20.98	8,056.00			19,576.00
Pumps 2345 GPM 200 H.P.	9	36,242.00	326,181.00	17.2	155	20.98	3,252.00			329,433.00
Thrust Blocks	11	35	385.00	3	33	18.34	605.00			990.00
Excavation	49,280 Yds^3	1.13	55,686.00	.04	1971	35.13	69,241.00			124,927.00
Back Fill	49,280 Yds^3	.48	23,654.00	.14	6899	35.13	242,362.00			266,016.00
ROAD CROSSINGS										
Boring & Casing Under RR Tracks (3)	180'	35	6,300.00	9.14	1,645	31.27	51,439.00			57,739.00
Old Nogales Highway (1)	60'	2.89	173.00	.43	26	41.90	1,089.00			1,262.00
2 Lane Asphalt Road (18)	900'	3.64	3,276.00	.43	387	41.90	16,215.00			19,491.00
Cross I 19 Boring & Casing (1)	60'	35	2,100.00	9.14	548	31.27	17,136.00			19,236.00
Cross Dirt Roads (6)	300'	.75	225.00	.43	129	41.90	5,405.00			5,630.00
Valencia (1)	60'	3.64	218.00	.43	26	41.90	1,089.00			1,307.00
Drexel (1)	60'	3.64	218.00	.43	26	41.90	1,089.00			1,307.00
Irvington (1)	60'	3.64	218.00	.43	26	41.90	1,089.00			1,307.00
Ajo Road (1)	60'	3.64	218.00	.43	26	41.90	1,089.00			1,307.00
29th St. (1)	60'	3.64	218.00	.43	26	41.90	1,089.00			1,307.00
ARCHITECTURAL SLAB										
Slab & Fencing	12	50	600.00	3	36	38.89	1,400.00			2,000.00
SUB TOTAL										3,093,595.00

Table #11

ESTIMATE DETAILS

PROJECT: Recreational Water Use @ Park

ACCOUNT:

ESTIMATE NO.

SHEET NO. 2 of 3

PREPARED BY: D. Bloxham DATE 10/18/84

CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
ELECTRICAL										
#1 Pump site grounding, lighting, security, telephone, computer FPU Total of (3) locations										46,350.00
#2 Pump variable frequency drive equipment, enclosure etc. Complete total of (3) units/locations										259,200.00
#3 Site power for service entrance and pump branch circuits total of (3) locations										39,450.00
#4 Power company charges for delivery of energy to sites at 480 volts 3 phase total of (3) locations.										22,500.00
#5 Telephone company charges for delivery of service to sites total of (3) locations										3,750.00
Subtotal										371,250.00

Table #11

ESTIMATE DETAILS

PROJECT:
ACCOUNT: SYSTEM
Recreational Water Use at Park

ESTIMATE NO
SHEET NO 3 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
Subtotal from 1 of 3										3,093,595.00
Subtotal from 2 of 3										371,250.00
Subtotal										3,464,845.00
Overhead	10%									346,485.00
Subtotal										3,811,330.00
Profit	10%									381,133.00
Subtotal										4,192,463.00
Bond	1%									41,925.00
Subtotal										4,234,388.00
Sales Tax	4%of 65%									110,094.00
Subtotal										4,344,482.00
HAC Engineering (Administration)	7%									304,114.00
Subtotal										4,648,596.00
Contingency Allowance										25,000.00
Subtotal										4,673,596.00
Engineering Start-up and Shake Down										20,000.00
Total Project Cost										4,693,596.00

Table #12

ESTIMATE DETAILS

PROJECT:
ACCOUNT: Recharge to Santa Cruz River

ESTIMATE NO
SHEET NO. 1 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
MECHANICAL										
18" Ø Pipe	25,336'	25.50	646,068.00	.6	15,202	20.98	318,938.00			965,006.00
18" Ø Elbow 90°	12	470.00	5,640.00	24	288	20.98	6,042.00			11,682.00
18" Ø Elbow 45°	4	530.00	2,120.00	24	96	20.98	2,014.00			4,134.00
18" Ø Tee	6	625.00	3,750.00	36	216	20.98	4,532.00			8,282.00
18" Ø x 12" Ø Reducer	8	310.00	2,480.00	24	192	20.98	4,028.00			6,508.00
18" Ø Butterfly Valve	1	3,195.00	3,195.00	10	10	20.58	206.00			3,401.00
18" Ø Check Valve	1	5,800.00	5,800.00	10	10	20.58	206.00			6,006.00
18" Ø Flanges	4	225.00	900.00	12	48	20.98	1,007.00			1,907.00
18" Ø Flow Meter	1	9,418.00	9,418.00	14.5	14.5	20.58	298.00			9,716.00
12" Ø Pipe	40'	24.00	960.00	1.6	64	20.98	1,343.00			2,303.00
12" Ø Elbow 90°	5	335.00	1,675.00	4	20	20.98	420.00			2,095.00
12" Ø Reducers	6	200.00	1,200.00	10.67	64	20.98	1,343.00			2,543.00
12" Ø Butterfly Valves	6	430.00	2,580.00	14.12	85	20.58	1,750.00			4,330.00
12" Ø Check Valves	3	1,168.00	3,504.00	14.12	42	20.58	864.00			4,368.00
12" Ø Flex Connectors	6	350.00	2,100.00	14.12	85	20.98	1,783.00			3,883.00
12" Ø Flanges	24	160.00	3,840.00	5.33	128	20.98	2,685.00			6,525.00
Thrust Blocks	5	35	105.00	3	15	18.34	275.00			380.00
Pumps 2345 GPM 200 H.P.	3	36,242.00	108,726.00	17.2	52	20.98	1,091.00			109,817.00
Excavation	22,802 Yds^3	1.13	25,766.00	.04	912	35.13	32,039.00			57,805.00
Back Fill	22,802 Yds^3	.48	10,945.00	.14	3,192	35.13	112,135.00			123,080.00
ROAD CROSSING										
Boring under R.R. Tracks (3)	180	35	6,300.00	9.14	1,645	31.27	51,439.00			57,739.00
Old Nogales Highway (1)	60	2.89	173.00	.43	26	41.90	1,089.00			1,262.00
Asphalt Roads (11)	550'	3.64	2,002.00	.43	237	41.90	9,930.00			11,932.00
Cross I-19 Bored & Casing (1)	60'	35	2,100.00	9.14	548	31.27	17,136.00			19,236.00
Dirt Roads (4)	200'	.75	150.00	.43	86	41.90	3,603.00			3,753.00
ARCHITECTURAL										
Slab & Fencing	4	50	200.00	3	12	38.89	467.00			667.00
SUBTOTAL										1,428,360.00

Table #12

ESTIMATE DETAILS

PROJECT:
ACCOUNT: Recharge to Santa Cruz River

ESTIMATE NO
SHEET NO 2 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
ELECTRICAL										
#1 Pump site grounding, lighting, security, telephone, computer FPU Total of (1) locations										15,450.00
#2 Pump variable frequency drive equipment, enclosure etc. Complete total of (1) units/locations										86,400.00
#3 Site power for service entrance and pump branch circuits total of (1) locations										13,150.00
#4 Power company charges for delivery of energy to sites at 480 volts 3 phase total of (1) locations.										7,500.00
#5 Telephone company charges for delivery of service to sites total of (1) locations.										1,250.00
Subtotal										123,750.00

Table #12

ESTIMATE DETAILS

PROJECT: System
ACCOUNT: Recharge to Santa Cruz River

ESTIMATE NO
SHEET NO. 3 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
Subtotal from 1 of 3										1,428,360.00
Subtotal from 2 of 3										123,750.00
Subtotal										1,552,110.00
Overhead	10%									155,211.00
Subtotal										1,707,321.00
Profit	10%									170,732.00
Subtotal										1,878,053.00
Bond	1%									18,781.00
Subtotal										1,896,834.00
Sales Tax	4%of 65%									49,318.00
Subtotal										1,946,152.00
HAC Engineering (Administration)	7%									136,231.00
Subtotal										2,082,383.00
Contingency Allowance										20,000.00
Subtotal										2,102,383.00
Engineering Start-up and Shake Down										20,000.00
Total Project Cost										2,122,383.00

Table #13

ESTIMATE DETAILS

PROJECT:
ACCOUNT: DOMESTIC USE BY DAVIS MONTHAN AIR FORCE BASE

ESTIMATE NO.
SHEET NO. 1 of 3
PREPARED BY: D. Bloxham DATE: 10/18/84
CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
MECHANICAL										
12" Ø Pipe P.V.C.	75,300'	14.58	1,097,874.00	.31	23,343	20.98	489,736.00			1,587,610.00
12" Ø Elbows 90° P.V.C.	58	60.00	3,480.00	.8	46	20.98	965.00			4,445.00
12" Ø Elbows 45° P.V.C.	4	61.00	244.00	.8	3	20.98	63.00			307.00
12" Ø Tee P.V.C.	10	86.00	860.00	1.5	15	20.98	315.00			1,175.00
12" Ø Reducers P.V.C.	20	60.00	1,200.00	.8	16	20.98	336.00			1,536.00
12" Ø Butterfly Valves	21	430.00	9,030.00	14.12	297	20.58	6,112.00			15,142.00
12" Ø Check Valves	6	1,175.00	7,050.00	14.12	85	20.58	1,750.00			8,800.00
12" Ø Flanges P.V.C.	94	30.00	2,820.00	.4	38	20.98	797.00			3,617.00
12" Ø Flex Connectors	20	350.00	7,000.00	14.12	23	20.98	483.00			7,483.00
12" Ø Flow Meter	1	6,223.00	6,223.00	14.12	14	20.98	294.00			6,517.00
Pumps 1550 GPM 100 HP	10	17,468.00	174,680.00	17.2	172	20.98	3,609.00			178,289.00
Thrust Blocks	56	35	1,960.00	3	168	18.34	3,081.00			5,041.00
Excavation	66,880 Yds^3	1.13	75,574.00	.04	2,675	35.13	93,973.00			169,547.00
Backfill	66,880 Yds^3	.48	32,102.00	.14	9,363	35.13	328,922.00			361,024.00
ROAD CROSSINGS										
Boring & Casing Under RR Track (3)	180'	35	6,300.00	9.14	1,645	31.27	51,445.00			57,745.00
Boring & Casing Under I-10 (1)	60'	35	2,100.00	9.14	548	31.27	17,136.00			19,236.00
Benson Highway	60'	2.89	174.00	.43	26	41.90	1,090.00			1,264.00
Cross El Paso Natural Gas line (2)	240'	.75	180.00	.43	103	41.90	4,316.00			4,496.00
2 lane Asphalt Roads off base (10)	500'	2.89	1,445.00	.43	215	41.90	9,009.00			10,454.00
2 lane Asphalt Roads on Base (7)	350'	2.89	1,012.00	.43	151	41.90	6,327.00			7,339.00
ARCHITECTURAL										
Slab & Fence	20	50	100	3	60	38.89	2,334.00			2,434.00
Subtotal										2,453,501.00

Table #13

ESTIMATE DETAILS

PROJECT:
ACCOUNT: DOMESTIC USE BY DAVIS MONTHAN AIR FORCE BASE

ESTIMATE NO.
SHEET NO. 2 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
ELECTRICAL										
#1 Pump site grounding, lighting, security, telephone, computer FPU Total of (5) locations										77,250.00
#2 Pump variable frequency drive equipment, enclosure etc. Complete total of (5) units/locations										299,200.00
#3 Site power for service entrance and pump branch circuits total of (5) locations										33,000.00
#4 Power company charges for delivery of energy to sites at 480 volts 3 phase total of (5) locations.										37,500.00
#5 Telephone company charges for delivery of service to sites total of (5) locations										6,250.00
Subtotal										453,200.00

Table #13

ESTIMATE DETAILS

PROJECT:
ACCOUNT: SYSTEM
DOMESTIC USE BY DAVIS MONTHAN AIR FORCE BASE

ESTIMATE NO
SHEET NO. 3 of 3
PREPARED BY: D. Bloxham DATE 10/18/84
CHECKED BY: DATE

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H.	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
Subtotal from 1 of 3										2,453,501.00
Subtotal from 2 of 3										453,200.00
Subtotal										2,906,701.00
Overhead	10%									290,670.00
Subtotal										3,197,371.00
Profit	10%									319,737.00
Subtotal										3,517,108.00
Bond	1%									35,171.00
Subtotal										3,552,279.00
Sales Tax	4%of 65%									92,359.00
Subtotal										3,644,638.00
HAC Engineering (Administration)	7%									255,125.00
Subtotal										3,899,763.00
Contingency Allowance										25,000.00
Subtotal										3,924,763.00
Engineering Start-up and Shake Down										20,000.00
Total Project Cost										3,944,763.00

Table #14

ESTIMATE DETAILS

PROJECT:
ACCOUNT: DOMESTIC USE BY CITY OF TUCSON

ESTIMATE NO.
SHEET NO. 1 of 3
PREPARED BY: D. Bloxham DATE: 11/18/84
CHECKED BY: DATE:

DESCRIPTION	QUANTITY	MATERIALS		LABOR				SUB-CONTRACT		TOTAL
		UNIT PRICE	AMOUNT	UNIT M.H	TOTAL M.H.	RATE	AMOUNT	UNIT PRICE	AMOUNT	
MECHANICAL										
18" Ø Pipe	6625'	25.50	168,938.00	.6	3975	20.98	83,396.00		-	252,334.00
18" Ø Elbow 90°	8	470.00	3,760.00	24	192	20.98	4,028.00			7,788.00
18" Ø Elbow 45°	2	530.00	1,060.00	24	48	20.98	1,007.00			2,067.00
18" Ø Flange	2	225.00	450.00	12	24	20.98	503.00			953.00
18" Ø Tee	4	625.00	2,500.00	36	144	20.98	3,021.00			5,521.00
18" Ø x 12" Ø Transition	6	310.00	1,860.00	24	144	20.98	3,021.00			4,881.00
18" Ø Butterfly Valve	1	3,195.00	3,195.00	10	10	20.98	206.00			3,401.00
18" Ø Check Valve	1	5,800.00	5,800.00	10	10	20.58	206.00			6,006.00
18" Ø Flow Meter	1	9,619.00	9,619.00	14.5	14.5	20.58	298.00			9,917.00
12" Ø Pipe	40	24.00	960.00	1.6	64	20.98	1,343.00			2,303.00
12" Ø Elbow 90°	4	335.00	1,340.00	4	16	20.98	336.00			1,676.00
12" Ø Flange	24	160.00	3,840.00	5.33	128	20.98	2,685.00			6,525.00
12" Ø Butterfly Valves	6	430.00	2,580.00	14.12	85	20.58	1,750.00			4,330.00
12" Ø Check Valve	3	1,175.00	3,525.00	14.12	42	20.58	864.00			4,389.00
12" Ø Flex Connection	6	350.00	2,100.00	14.12	85	20.98	1,783.00			3,883.00
Pump 2350 75 H.P.	3	12,405.00	37,215.00	17.2	52	20.98	1,091.00			38,306.00
Thrust Block	18	35.00	630.00	3	54	18.34	990.00			1,620.00
Excavation	5,885	1.13	6,650.00	.04	235	35.13	8,256.00			14,906.00
Backfill	5,885	.48	2,825.00	.14	824	35.13	28,947.00			31,772.00
ROAD CROSSINGS										
Boar and case under RR Tracks (8)	60	35	2,100.00	9.14	548	31.27	5,009.00			7,109.00
Old Nogales Highway (1)	60	2.89	173.00	.43	26	41.90	1,089.00			1,262.00
El Paso Natural Gas Line (1)	120	.75	90.00	.43	52	41.90	2,179.00			2,269.00
ARCHITECTURAL										
Slab and fencing	4	50	200.00	3	12	38.89	467.00			667.00
Subtotal										413,885.00

RECLAIMED WATER
USE
ALTERNATIVES
DIRECT DISCHARGE TO
PUBLIC SEWER SYSTEM
GRAPHIC SCALE
MILES
0
.25
.50
1.0
NORTH
DIST. PIPING
PUMP STATION
FIG. 3
TUCSON
SANTA
CRUZ
VALLEY
RODEO ROAD SEWAGE
TREATMENT PLANT
INTERNATIONAL
TUCSON
Park
Sunnyside
Jr. High Sch
Sunset
Mission
Park
Liberty
Park
Mission
Park
Sunset
Park
Jefferson
Park
Pueblo
Gardens
Pueblo
Gardens
Sunset
Park
Sunset
Park
Sunset
Park

RECLAIMED WATER
USE
ALTERNATIVES
VAR 44
INDUSTRIAL USE
NORTH
GRAPHIC SCALE
MILES
0
.25
.50
1.0
PUMP STATION
DISTRIBUTION PIPING
FIG. 4
RESERVATION
SANTA
INTERNATIONAL
AIRPORT
TUCSON
SOUTHERN
PACIFIC
TUCSON

TUCSON MUNICIPAL AIRPORT
AFP 44
FELIX RANCH
SAN XAVIER DEL BAC MISSION
SAHUARITA BUTTE
XAVIER
SAN XAVIER INDIAN RESERVATION
ORO VERDE FARMS
SOUTHERN PACIFIC
SAHUARITA
ASARCO COPPER MINE
SAHUARITA
RANCH
DUVAL
SAN IGNACIO DE LA CANADA
CONTINENTAL
AMADO WELL
DISTRIBUTION PIPING
PUMP STATION
NORTH
GRAPHIC SCALE
0 .50 1.0 1.5 2.0 3.0
MILES
RECLAIMED WATER USE ALTERNATIVES
INDUSTRIAL USE BY ASARCO MINE

FIG. 5

FIG. 9
RECLAIMED WATER USE ALTERNATIVES
TO USE TREATED GROUNDWATER FOR IRRIGATION
DISTRIBUTION PIPING
PUMP STATION
NORTH
GRAPHIC SCALE
MILES
0 0.1 0.5 1.0 2.0 0.5
SAN XAVIER INDIAN RESERVATION
SAN XAVIER DEV. CO.
ATIRAUHAB BUTTE
TUCSON MUNICIPAL AIRPORT
VEP 44
LEEK RANCH
ATIRAUHAB
SOUTHERN PACIFIC
ORO VERDE RANCH
ATIRAUHAB
SOMERING & DRISKOS
RANGE
ATIRAUHAB
TUCSON NOGALES HIGHWAY
SAN IGNACIO DE LA CANADA
CONTINENTAL
ATIRAUHAB FARM

SAN XAVIER INDIAN RESERVATION
IRRIGATION SYSTEM
DISTRIBUTION PIPING
PUMP STATION
NORTH
GRAPHIC SCALE
0 .25 .50 1.0
MILES
RECLAIMED WATER
USE
ALTERNATIVES
USE OF TREATED
GROUNDWATER
FOR SAN XAVIER
RESERVATION IRRIGATION
FIG. 7

FRED ENKE GOLF COURSE
DAVIS MONTHAN GOLF COURSE
DISTRIBUTION PIPING
PUMP STATION
NORTH
0 .50 1.0 1.5
MILES
GRAPHIC SCALE
RECLAIMED WATER USE ALTERNATIVES
USE OF TREATED GROUNDWATER FOR GOLF COURSE IRRIGATION

FIG. 8

PROPOSED
SANTA CRUZ
RIVER PARK
SANTA CRUZ VALLEY
DOMINION
HOSPITAL
DIST. PIPING
PUMP STATION
FIG. 9
NORTH
0
.50
.25
1.0
MILES
GRAPHIC SCALE
RECLAIMED WATER
USE
ALTERNATIVES
RECREATIONAL
WATER USE

RECLAIMED WATER
USE
ALTERNATIVES
GROUNDWATER
RECHARGE
TO SANTA CRUZ RIVER
GRAPHIC SCALE
MILES
0
.25
.50
1.0
NORTH
PUMP STATION
DISTRIBUTION PIPING
FIG. 10
TUCSON
INTERNATIONAL
AIRPORT
SANTA CRUZ RIVER
ENERGY PARK

DAVIS-MONTHAN
AIR FORCE BASE
DISTRIBUTION PIPING
PUMP STATION
NORTH
GRAPHIC SCALE
MILES
0
.25
.50
1.0
RECLAIMED WATER
USE
ALTERNATIVES
DOMESTIC WATER USE
BY DAVIS-MONTHAN
AIR FORCE BASE
FIG. 11

FIG. 12
RECLAIMED WATER
USE
ALTERNATIVES
DOMESTIC WATER USE
BY
THE CITY OF TUCSON
DISTRIBUTION PIPING
PUMP STATION
NORTH
GRAPHIC SCALE
MILES
0
.25
.50
1.0
TUCSON
SOUTHERN
PACIFIC
SANTA
CRUZ
RIVER
TUCSON
WEF 2C-1

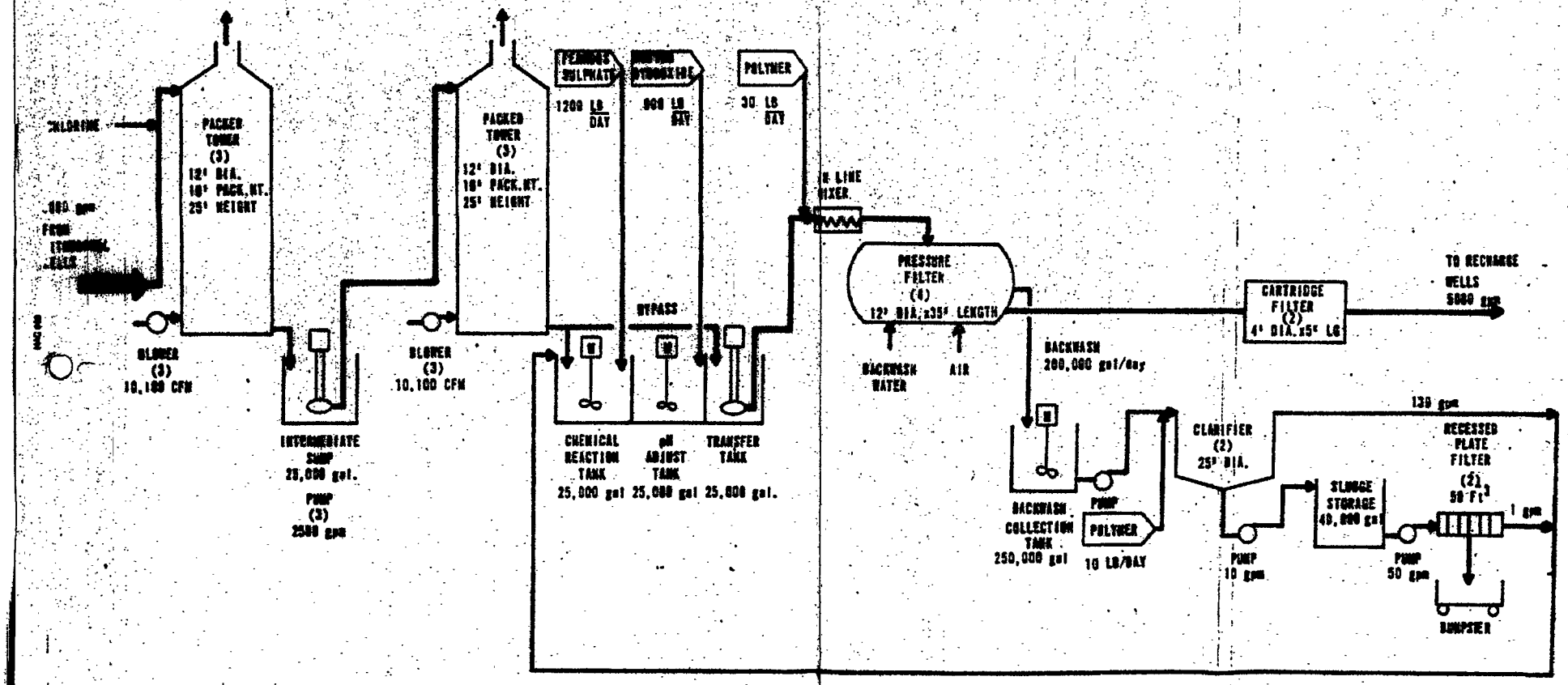
TABLE 3

PROJECT ALTERNATIVES COST COMPARISON SHEET

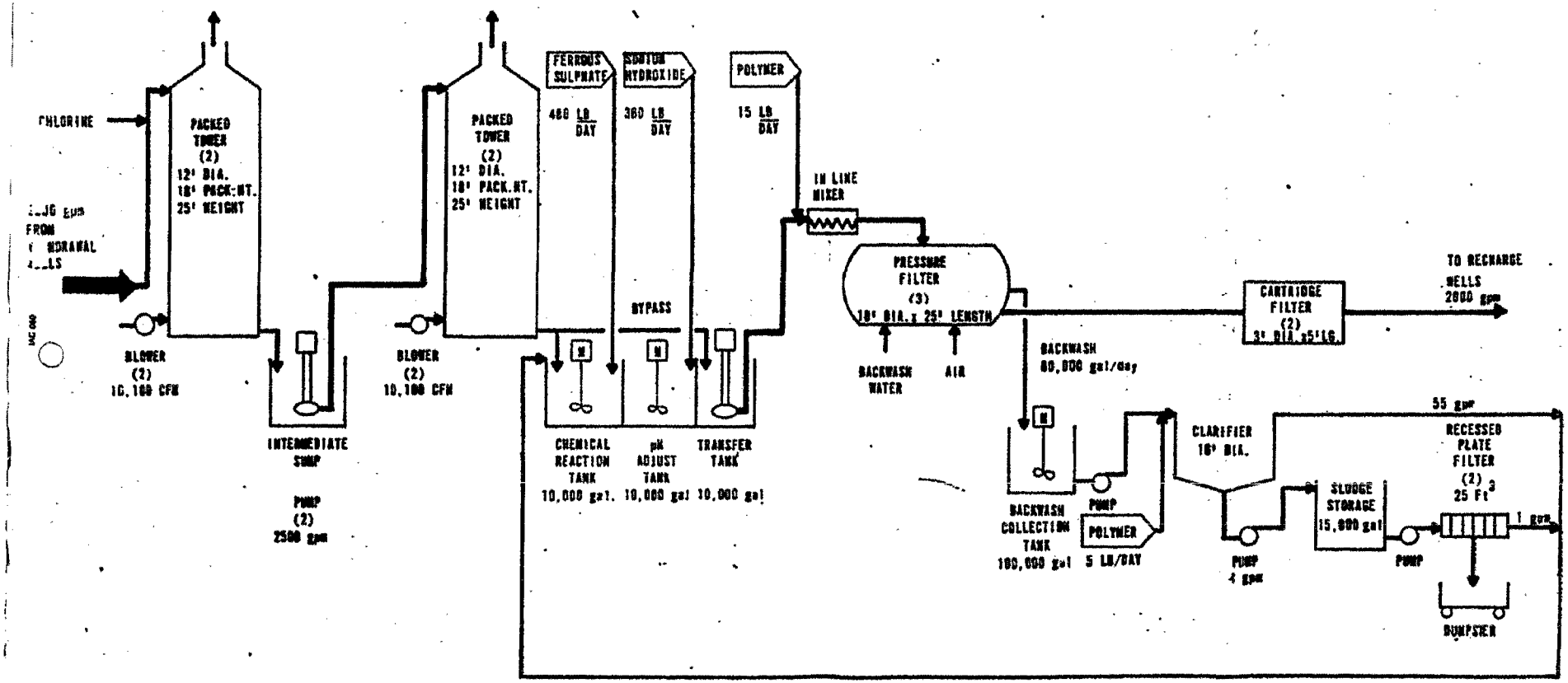
PROJECT ALTERNATIVE	Amount to Water	Capital for Reclamation Millilitl	Capital for Treatment Plant	Capital for Water Disposal System	Total Capital Investment	Lifetime (20Yr) Operating Costs Recl. Millitl in 1984 Dollars	Lifetime (20Yr) Operating Costs Treatment Syst. in 1984 Dollars	Lifetime (20Yr) Operating Costs Water Disposal in 1984 Dollars	Total Lifetime Costs in 1984 Dollars	Total Costs in 1984 Dollars
		A	B	C	D=A+B+C	E	F	G	H=E+F+G	I=D+H
NO ACTION	0	0	0	0	0	0	0	0	0	0
CONTAINMENT BY IMPERV. BARR.	0	0	0	0	0	0	0	0	0	0
WITHDRAWAL WITHOUT TREATMENT	———	———	———	———	———	———	———	———	———	———
DISCH. TO PUBLIC SEWER SYSTEM	5000 GPM	1,824,684	0	4,354,158	6,178,842	0	5,000,000	18,583,050	24,583,050	30,761,892
REINJECTION OF UNTREATED WATER	5000 GPM	1,824,684	0	0	0	0	5,000,000	0	0	0
SOLAR EVAPORATION	5000 GPM	1,824,684	0	0	0	0	5,000,000	0	0	0
HAZARDOUS WASTE TREATMENT FAC. DISPOSAL AT A PERMITTED	5000 GPM	1,824,684	0	0	0	0	5,000,000	0	0	0
WITHDRAWAL WITH TREATMENT	———	———	———	———	———	———	———	———	———	———
DISCH. TO PUBLIC SEWER SYSTEM	5000 GPM	1,824,684	10,834,672	4,354,158	16,188,830	5,000,000	10,177,600	25,243,050	40,420,650	56,609,480
MAP 44 INDUSTRIAL USE	310 GPM			120,448				308,030		
IND. USE BY ASARCO COPPER MINE	5000 GPM	1,824,684	10,834,672	2,384,174	17,243,424	5,000,000	8,038,000	12,583,050	25,203,050	43,446,474
IRRIGATION BY FARMERS INVEST. CO.	5000 GPM	1,824,684	10,834,672	11,854,252	23,817,628	5,000,000	8,038,000	24,888,030	37,926,030	61,743,658
IRRIGATION BY PAPAGO INDIANS	5000 GPM	1,824,684	10,834,672	5,058,145	17,717,501	5,000,000	8,038,000	8,366,300	21,404,300	39,121,801
IRRIGATION BY GOLF COURSES	600 GPM			3,107,380				2,850,080		
RECREATIONAL WATER USE AT PARK	5000 GPM	1,824,684	10,834,672	4,698,362	16,857,638	5,000,000	8,038,000	10,918,000	23,956,000	40,813,638
RECHARGE TO SANTA CRUZ RIVER	5000 GPM	1,824,684	10,834,672	2,155,383	14,814,739	5,000,000	8,038,000	2,122,040	15,215,040	30,029,779
DOMESTIC USE BY DAVIS-MONTHAN	1,250 GPM			3,944,103				1,245,200		
DOMESTIC USE BY CITY OF TUCSON	5000 GPM	1,824,684	10,834,672	168,258	12,827,614	5,000,000	8,038,000	5,305,040	11,343,040	24,170,654
RECHARGE THRU PERCOLATION	5000 GPM	1,824,684	10,834,672	3,304,261	15,863,618	5,000,000	8,038,000	2,205,100	15,243,100	31,106,718
RECHARGE THRU RECHARGE WELLS	4500 GPM	5,202,848	12,131,484	5,008,388	22,342,700	1,170,000*	5,315,316*	1,152,658*	8,020,000*	30,362,700
						*LIFETIME FIGURED TO BE 10 YEARS				

PROPOSED
PROJECT TASK FLOW CHART
PHASE III
GROUNDWATER RECLAMATION PROGRAM
HYDROGEOLOGY
ENGINEERING
REPORTS

FIGURE 13

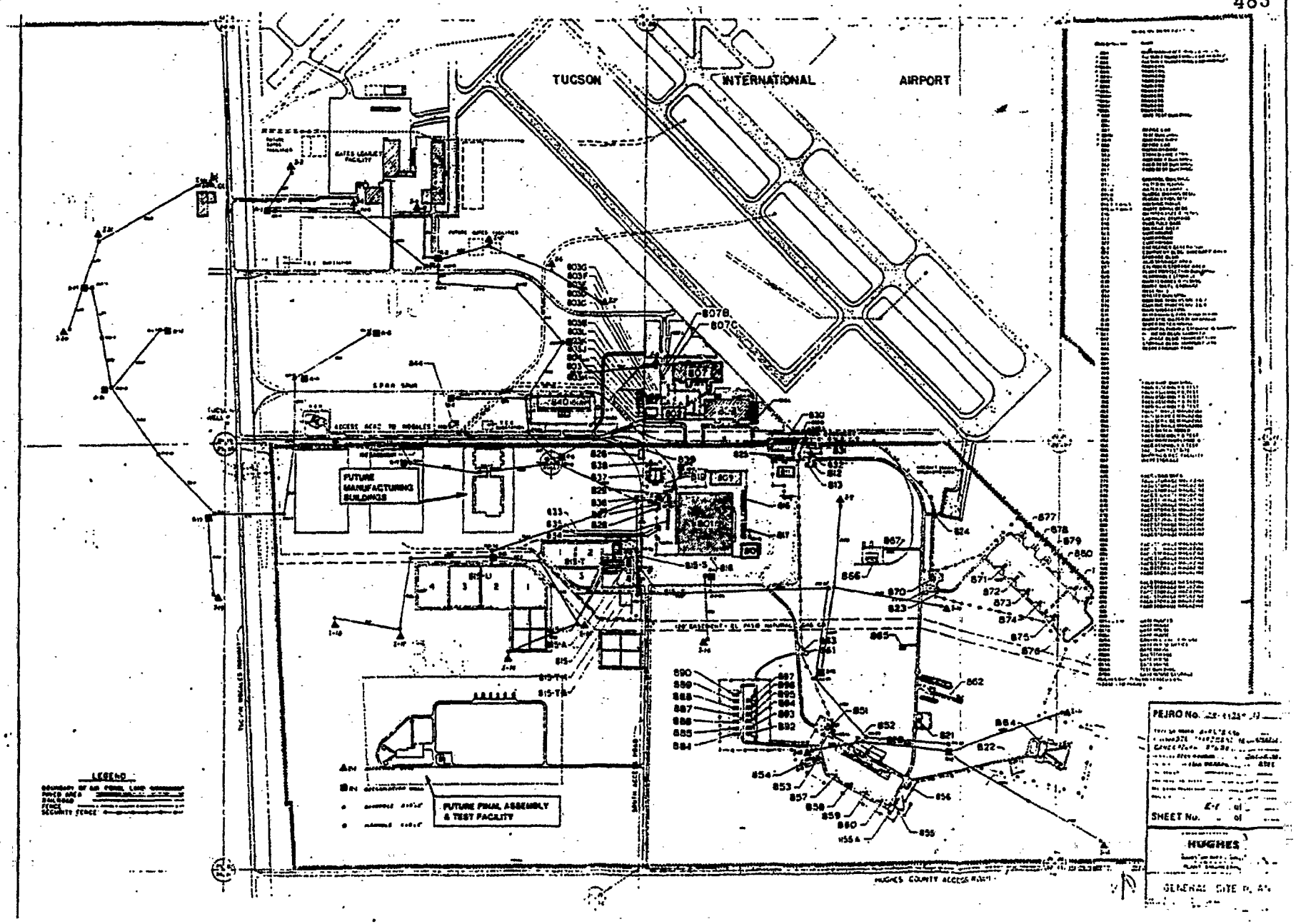


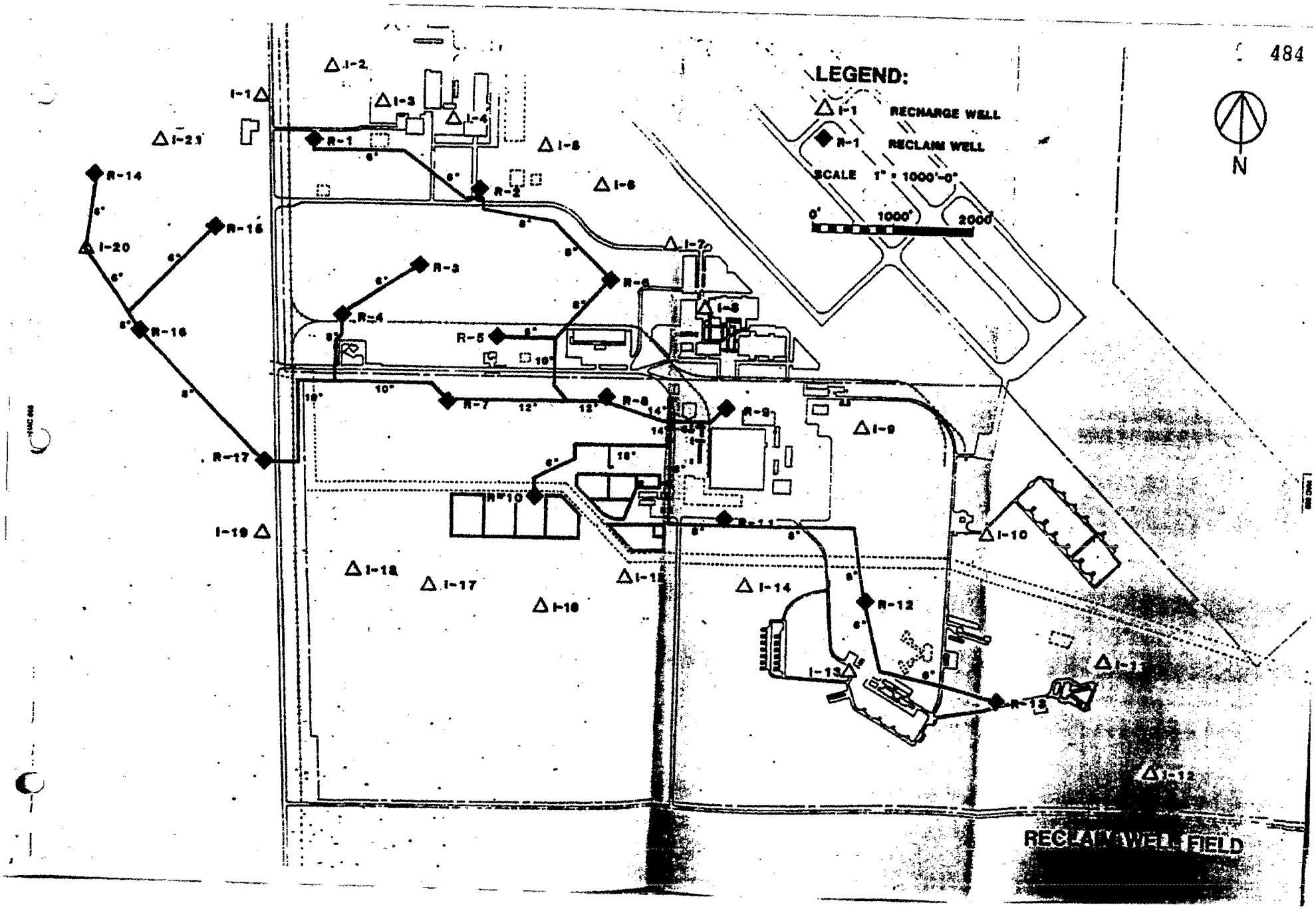
HUGHES AIRCRAFT COMPANY
TREATMENT OF RECLAIMED WATER
PROCESS FLOW SCHEMATIC
5000 GPM

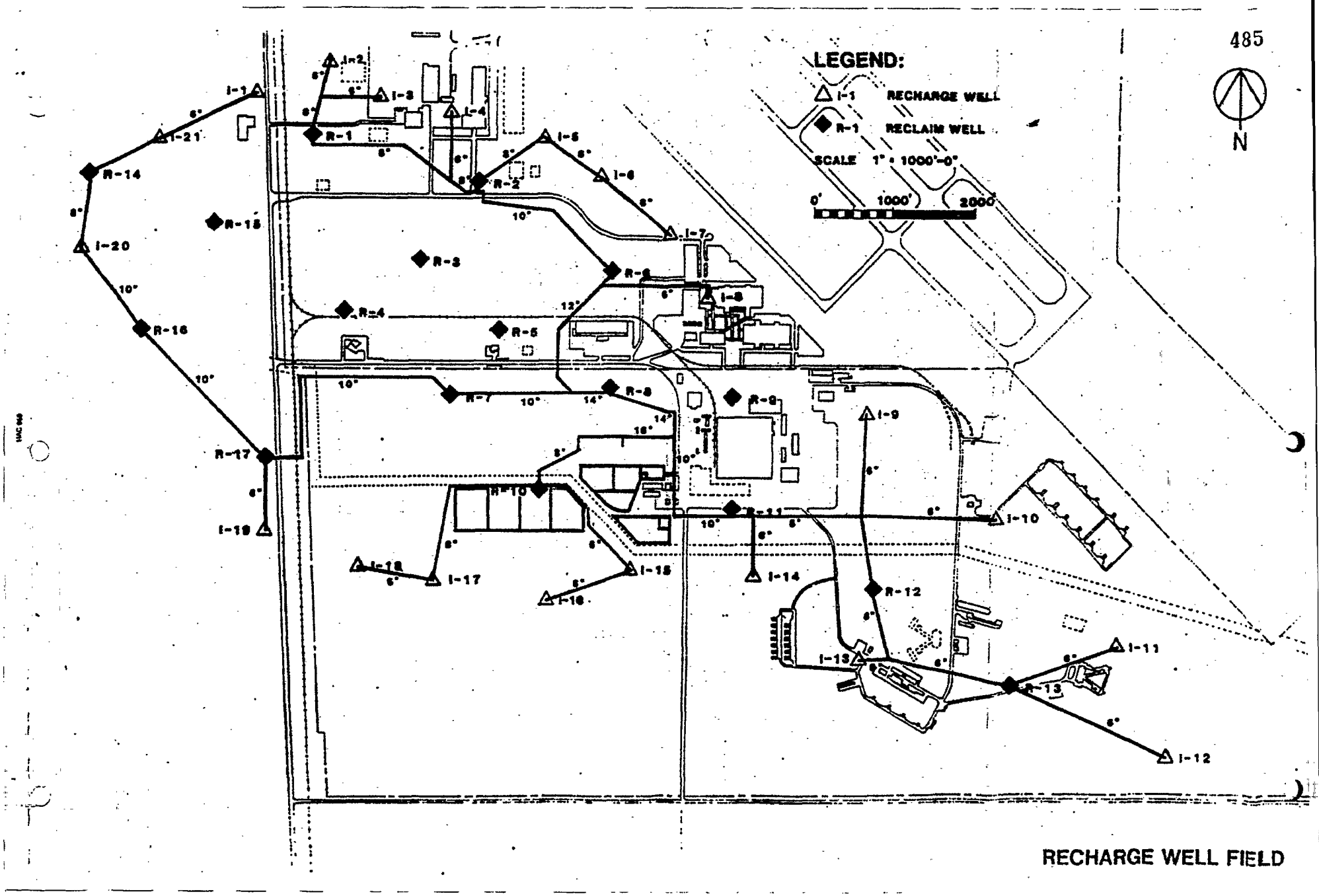


MALCOLM PIRNIE

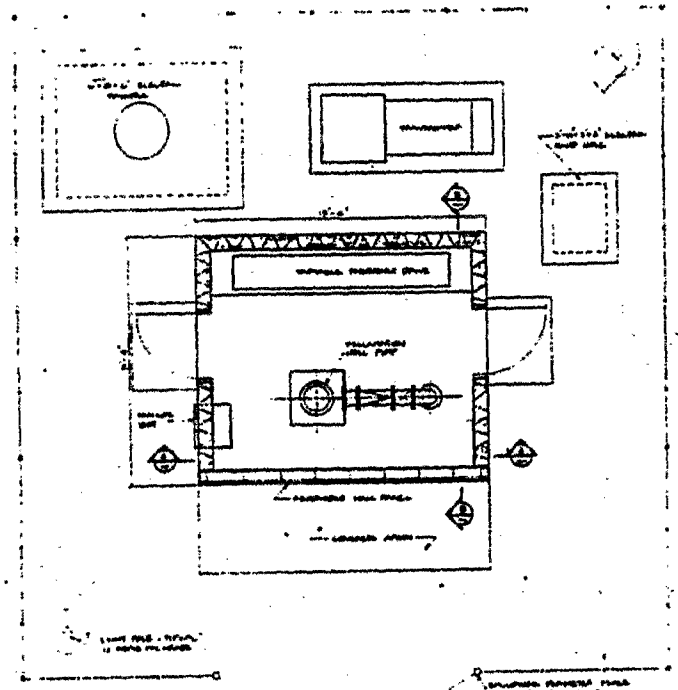
HUGHES AIRCRAFT COMPANY
TREATMENT OF RECLAIMED WATER
PROCESS FLOW SCHEMATIC
2000 GPM


TUCSON
INTERNATIONAL
AIRPORT
FUTURE MANUFACTURING BUILDINGS
FUTURE FINAL ASSEMBLY & TEST FACILITY
LEGEND
HUGHES
SHEET No.

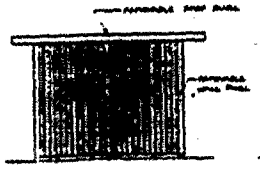

LEGEND:
I-1 RECHARGE WELL
R-1 RECLAIM WELL
SCALE 1" = 1000'-0"
0' 1000' 2000'
N
RECLAIM WELL FIELD



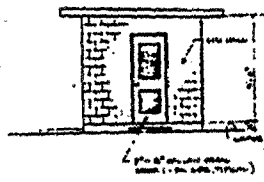
RECHARGE WELL FIELD



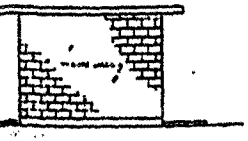
PLAN



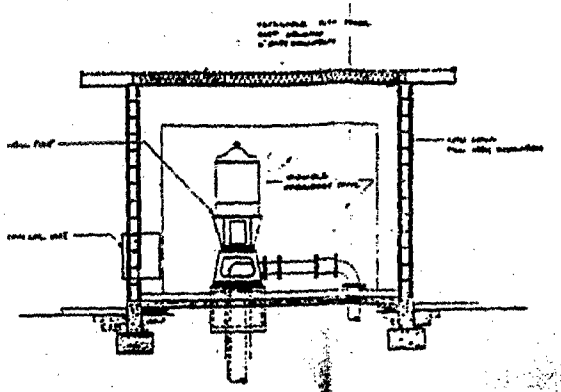
FRONT ELEVATION



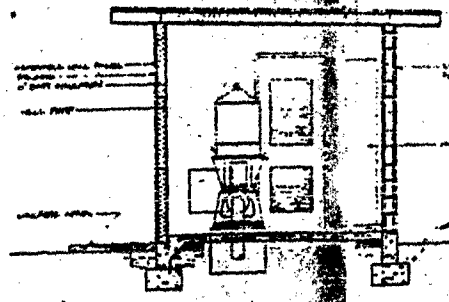
SIDE ELEVATION



REAR ELEVATION



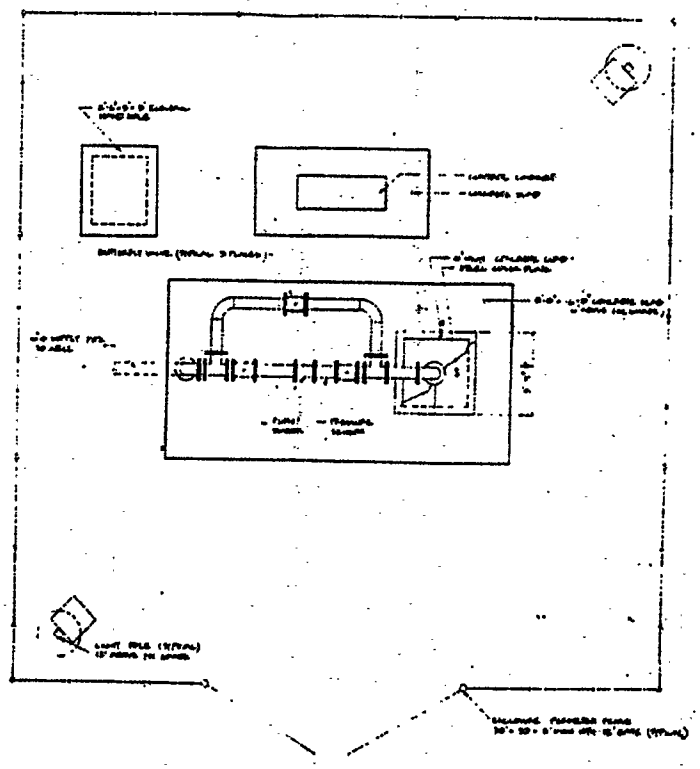
SECTION "A-A"



SECTION "B-B"

REVISIONS

NOTES

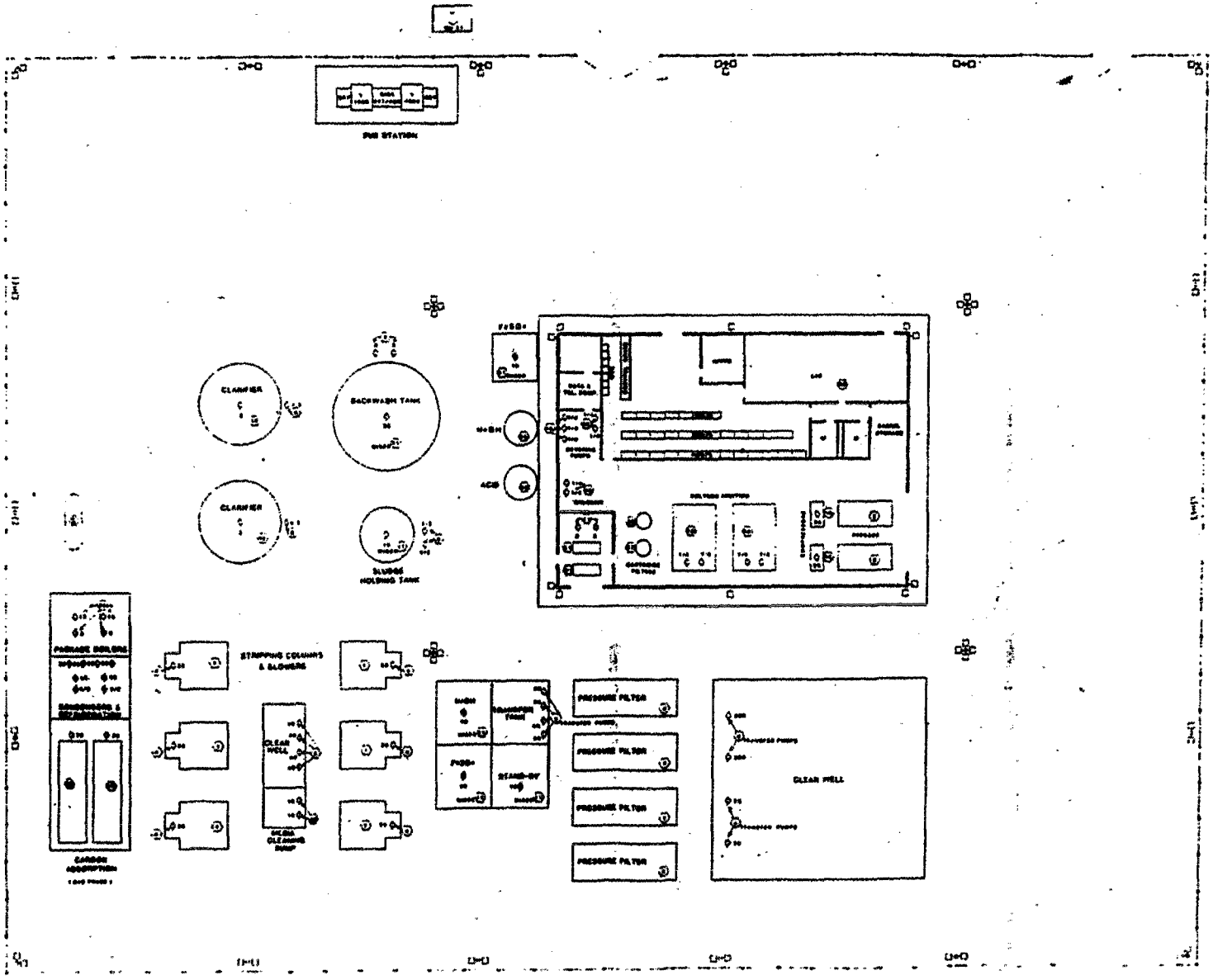


PLAN

REVISIONS

HUGHES

RECHARGE WELL LAYOUT



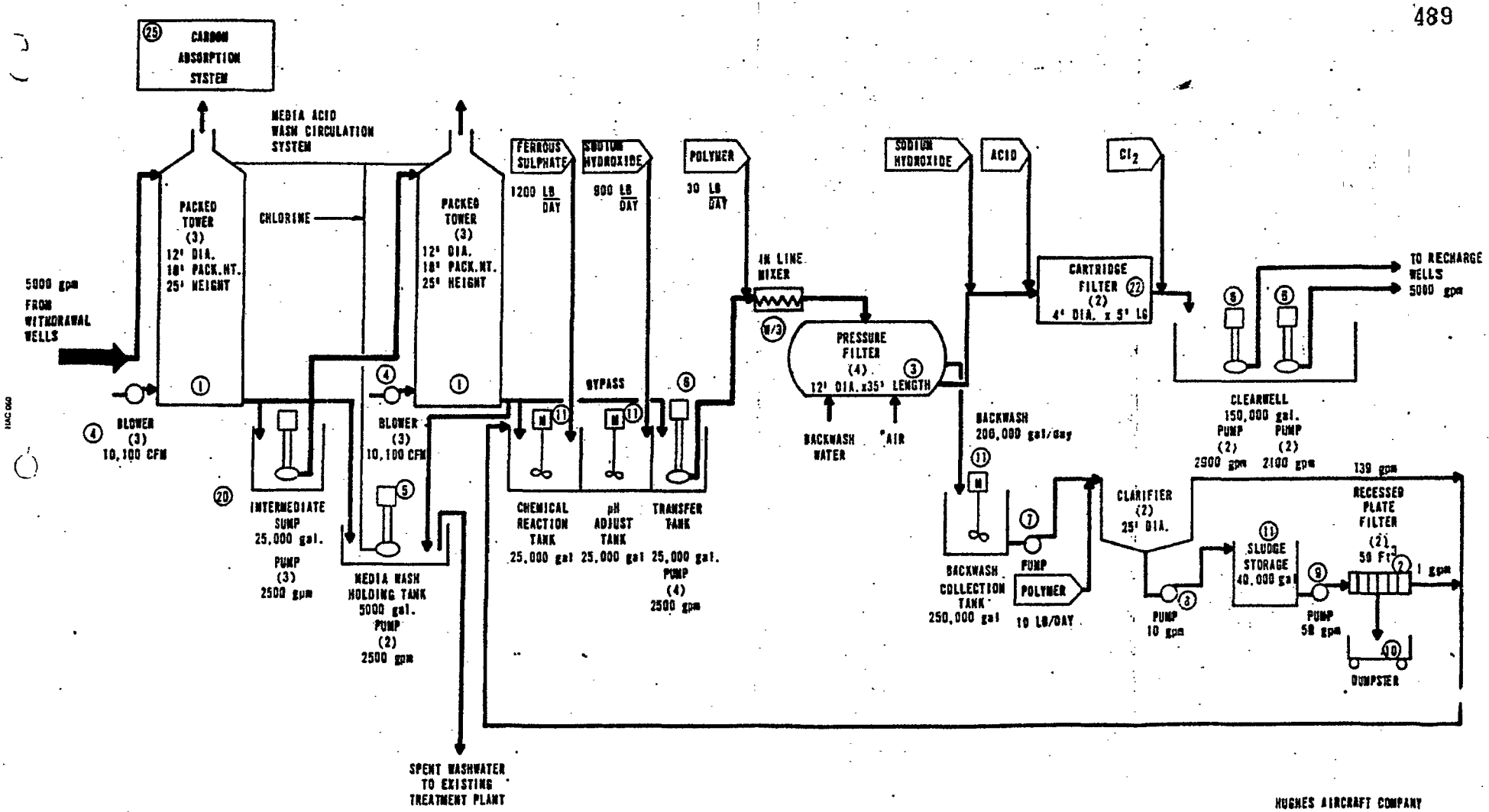
REVISIONS

NORTH

LEGEND

HUGHES

WATER PURIFICATION PLANT

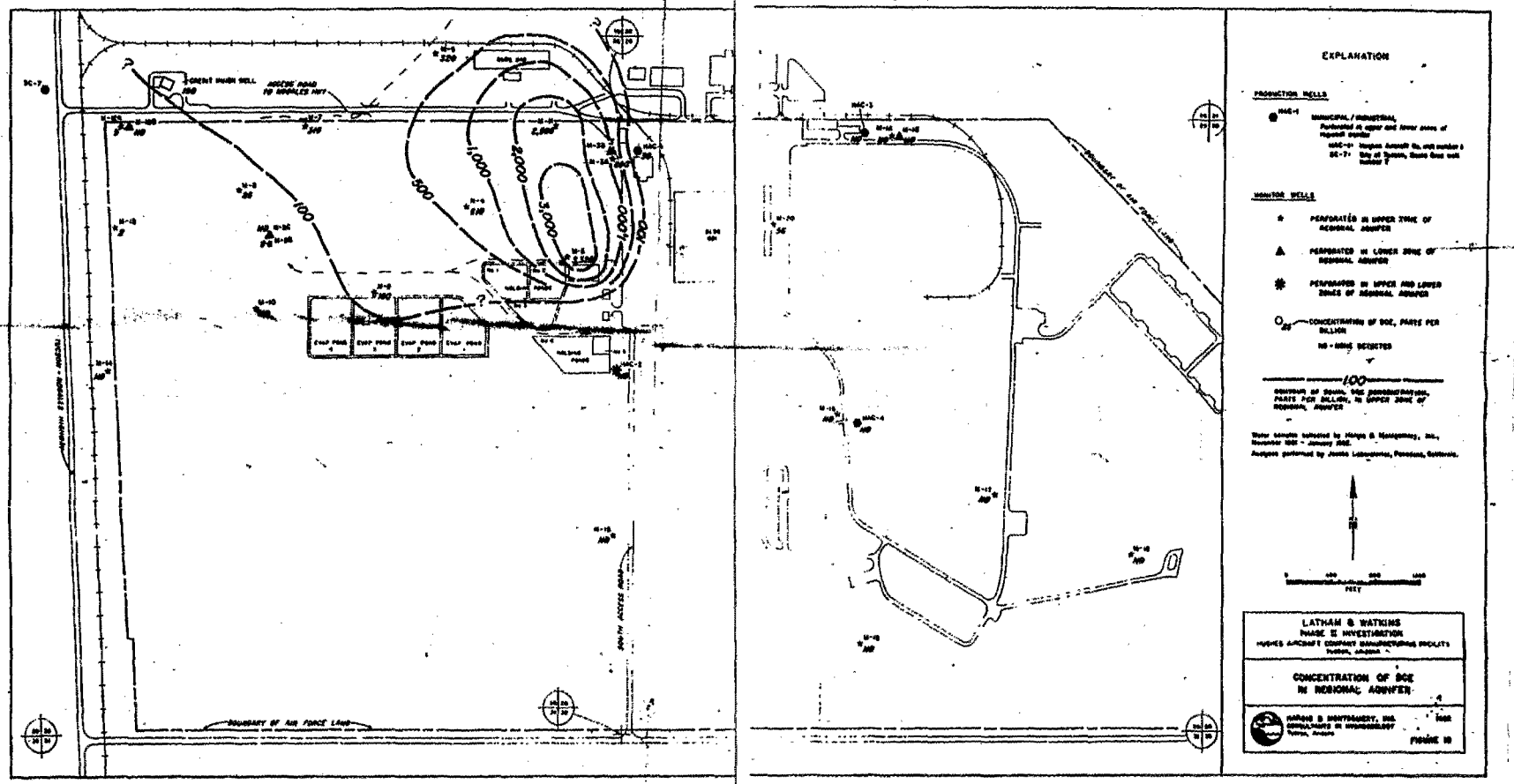


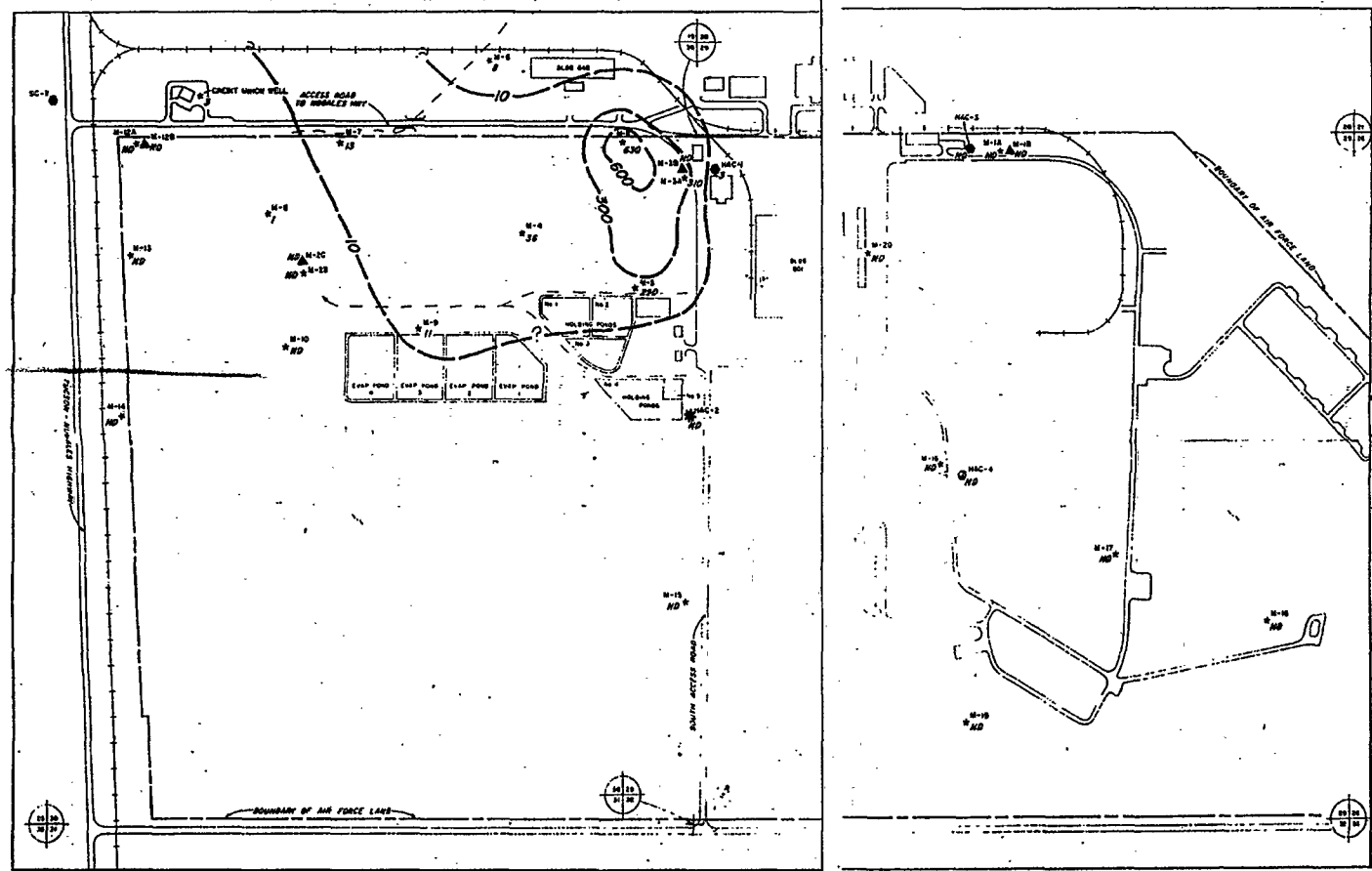
MALCOLM PIRNIE

(1) Corresponding numbers on figure 13

HUGHES AIRCRAFT COMPANY
TREATMENT OF RECLAIMED WATER
PROCESS FLOW SCHEMATIC
5000 GPM

FIGURE 14


EXPLANATION
PRODUCTION WELLS
MUNICIPAL / INDUSTRIAL
MONITOR WELLS
PERFORATED IN UPPER ZONE OF REGIONAL AQUIFER
PERFORATED IN LOWER ZONE OF REGIONAL AQUIFER
PERFORATED IN UPPER AND LOWER ZONES OF REGIONAL AQUIFER
CONCENTRATION OF DCE, PARTS PER BILLION
ND - NONE DETECTED
100
CONTOUR OF EQUAL DCE CONCENTRATION, PARTS PER BILLION, IN UPPER ZONE OF REGIONAL AQUIFER
FEET
LATHAM & WATKINS
PHASE II INVESTIGATION
HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY
TUCSON, ARIZONA
CONCENTRATION OF DCE
IN REGIONAL AQUIFER
HARDING & MONTGOMERY, INC.
CONSULTANTS IN HYDROGEOLOGY
FIGURE 10
BOUNDARY OF AIR FORCE LAND
SOUTH ACCESS ROAD
100
500
1,000
2,000
3,000
1,000
100



EXPLANATION

PRODUCTION WELLS

MAC-1 — MUNICIPAL / INDUSTRIAL
Perforated in upper and lower zones of regional aquifer
MAC-1: Hughes Aircraft Co. well number 1
SC-1: City of Tucson, Santa Cruz well number 1

MONITOR WELLS

★ PERFORATED IN UPPER ZONE OF REGIONAL AQUIFER

▲ PERFORATED IN LOWER ZONE OF REGIONAL AQUIFER

✱ PERFORATED IN UPPER AND LOWER ZONES OF REGIONAL AQUIFER

O_{56} — CONCENTRATION OF TCA, PARTS PER BILLION
ND = NONE DETECTED

10 — CONTOUR OF EQUAL TCA CONCENTRATION, PARTS PER BILLION, IN UPPER ZONE OF REGIONAL AQUIFER

Water samples collected by Harris & Montgomery, Inc., November 1981 - January 1982.

Analyses performed by Jacobs Laboratories, Pasadena, California.

N

0 400 800 1200
FEET

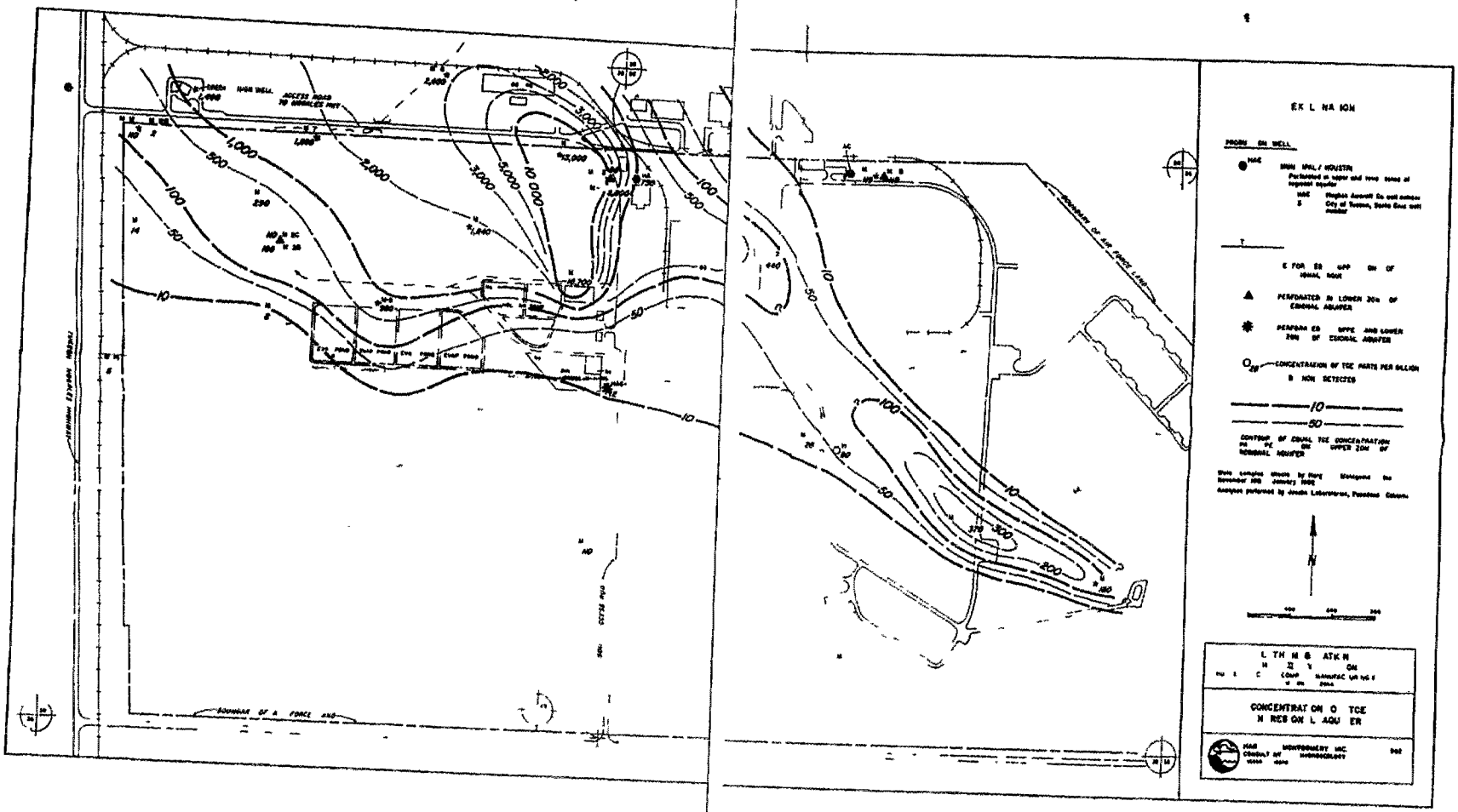
LATHAM & WATKINS
PHASE II INVESTIGATION
HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY
Tucson, Arizona

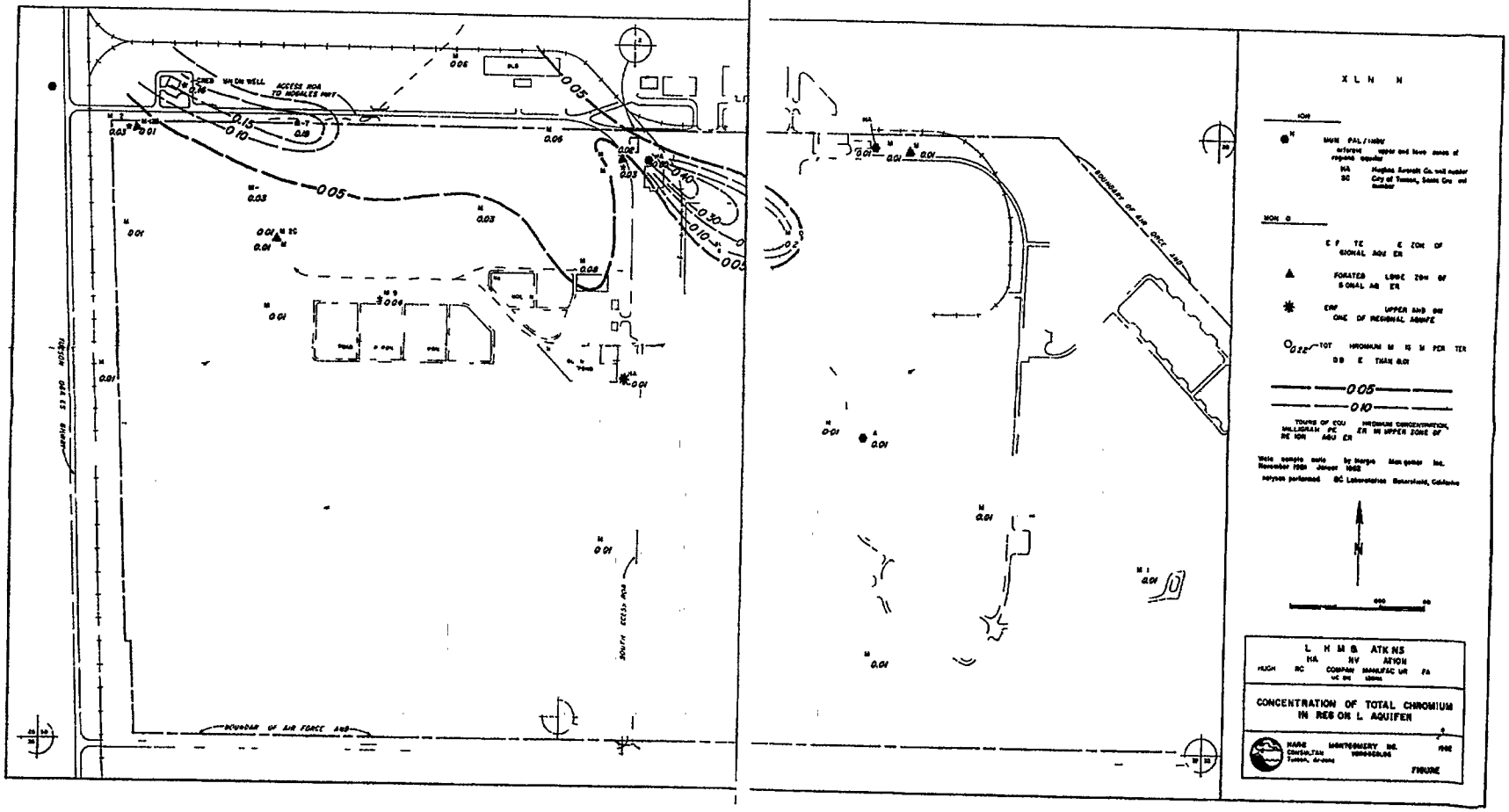
CONCENTRATION OF TCA IN REGIONAL AQUIFER

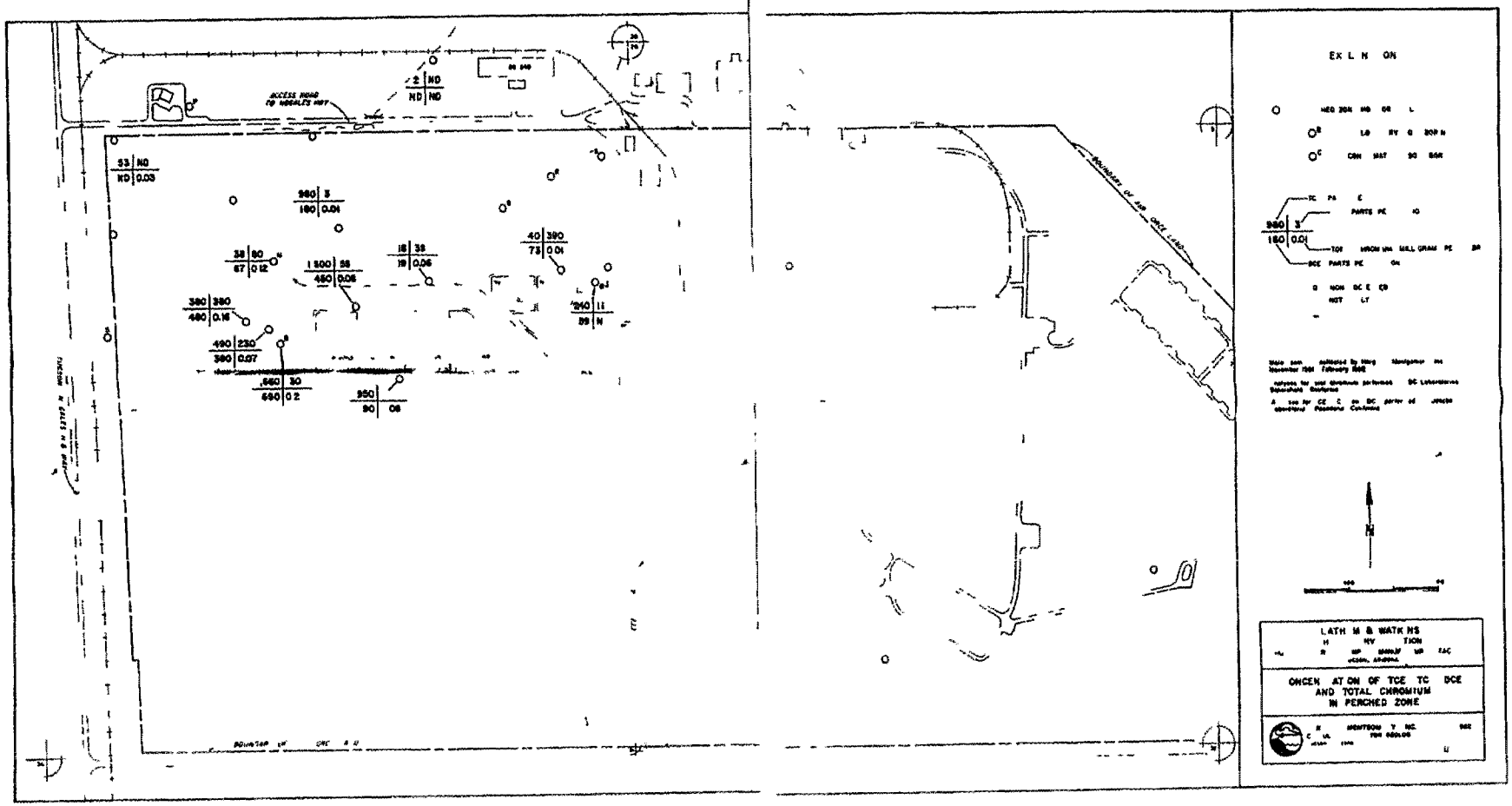
HARRIS & MONTGOMERY, INC.
CONSULTANTS IN HYDROLOGY
Tucson, Arizona

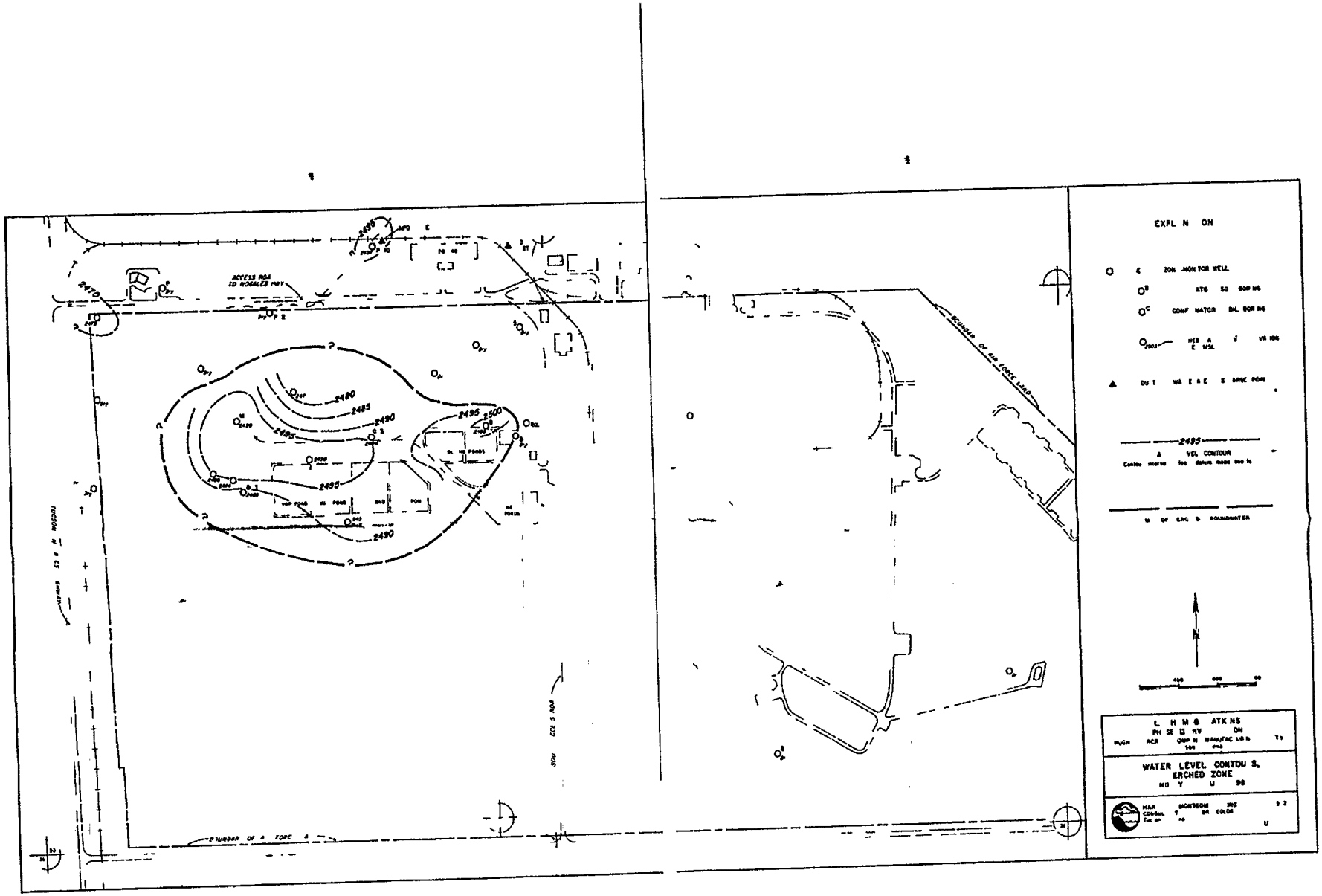
1982

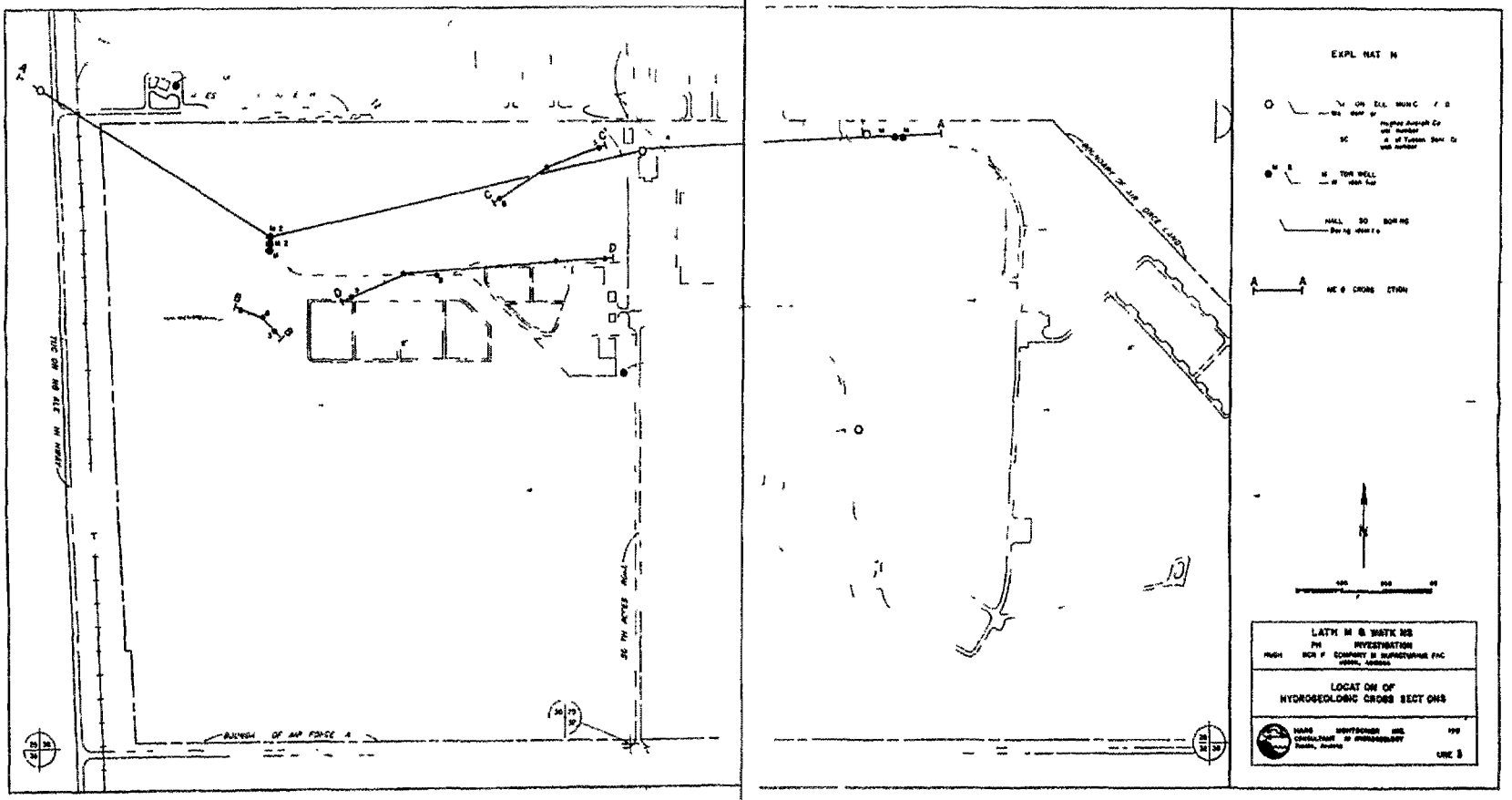
FIGURE 9

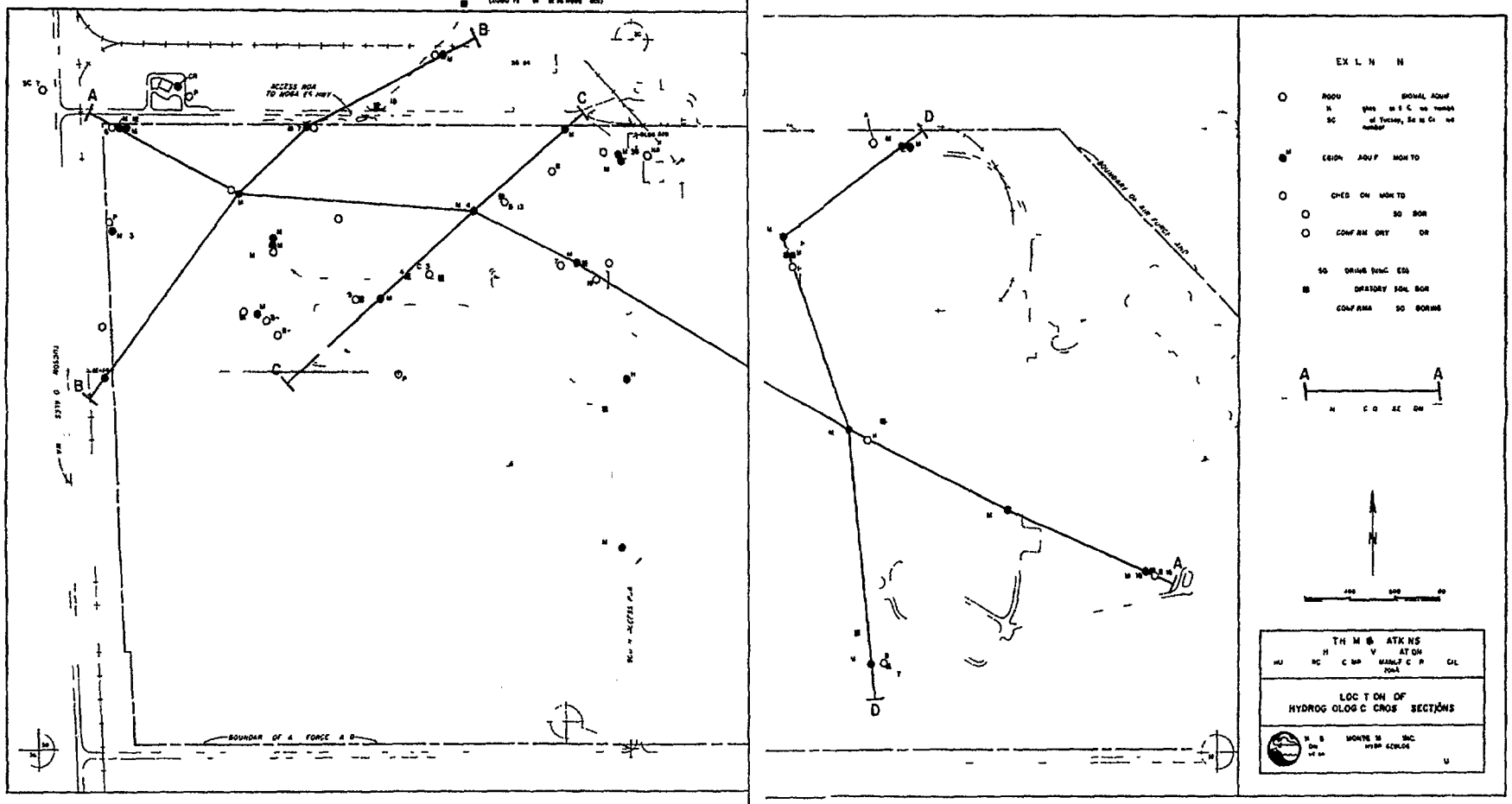

EXPLANATION
PROBE OR WELL
PERFORATED IN LOWER 20% OF
PERFORATED IN UPPER AND LOWER
CONCENTRATION OF TCE PARTS PER BILLION
NON DETECTED
CONTOUR OF EQUAL TCE CONCENTRATION
UPPER 20% OF
CONCENTRATION OF TCE
IN RESTON AQUIFER
MONTGOMERY INC.
BOUNDARY OF AIR FORCE LAND
ACCESS ROAD TO GRAVEL PIT
SOIL SITE
10
50
100
500
1,000
2,000
3,000
5,000
10,000
N

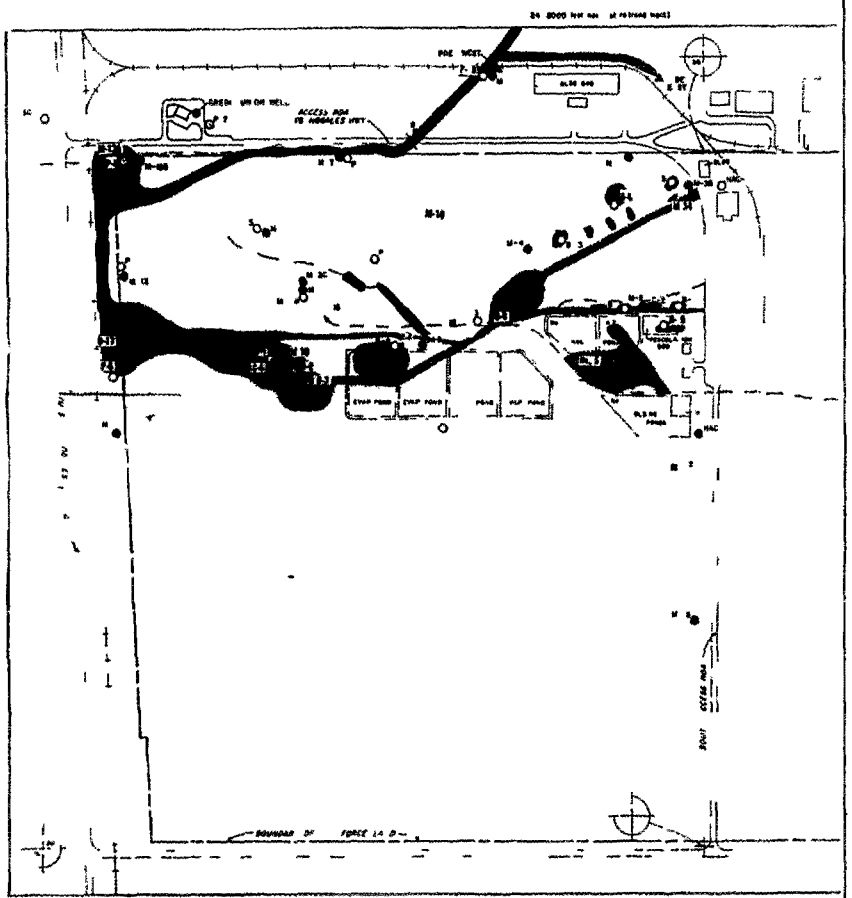

CONCENTRATION OF TOTAL CHROMIUM
IN RES OR L AQUIFER
FIGURE
BOUNDARY OF AIR FORCE AND
SOUTH ACCESS ROAD
ACCESS ROA
TO HOGALES HWY
WALDON WELL
HIGHWAY
0.05
0.10
0.30

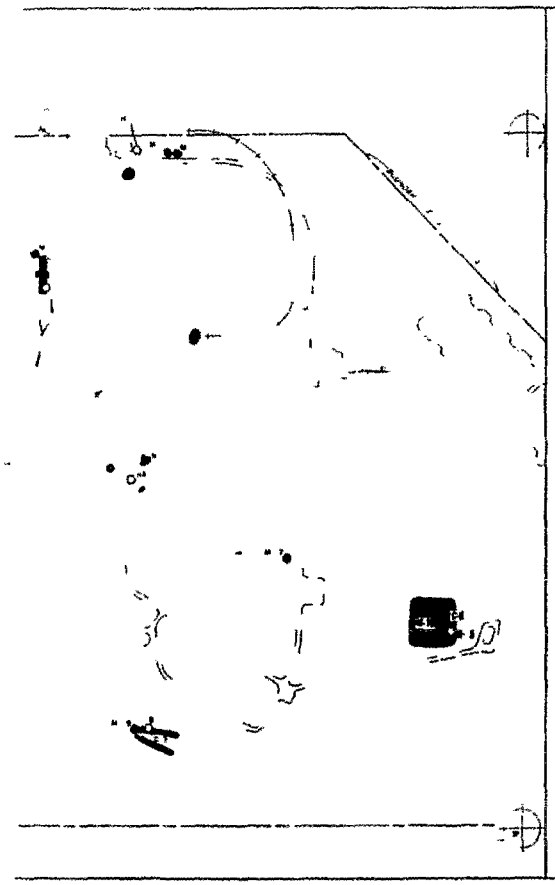

ACCESS ROAD TO NEBALTS HWY
2 | ND
ND | ND
53 | ND
ND | 0.03
980 | 3
180 | 0.01
38 | 80
67 | 0.12
1 500 | 58
450 | 0.05
18 | 38
19 | 0.06
40 | 390
73 | 0.01
390 | 390
480 | 0.16
490 | 230
380 | 0.07
660 | 30
680 | 0.2
950
90 | 08
240 | 11
39 | N
BOUNDARY OF SAN ONCE LAND
EX L N ON
LATH M & WATK NS
ONCEN AT ON OF TCE TC DCE
AND TOTAL CHROMIUM
IN PERCHED ZONE

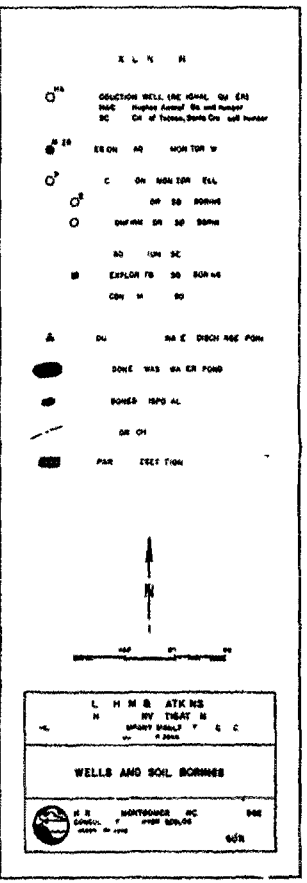

EXPL N ON
ZONE MONITOR WELL
ATS SO BOR NG
COMP MATOR DIL BOR NG
HED A
E MSL
VE ION
DU T WA E R E S ARBC PORT
2495
A VEL CONTOUR
Contou nterval fee datum mean sea le
M OF ERC D ROUNDWATER
N
400 800 90
L H M & ATK NS
PH SE II HV ON
PLUGH RCR COMP N MANUFAC LIR N TY
WATER LEVEL CONTOU S,
ERCHED ZONE
RU Y U 98
MAR MONTGOM INC
CONSUL T DR COLOR
Tel 6
U
ACCESS ROA TO HOGALES PORT
BOUNDARY OF AIR FORCE LAND
BOUNDARY OF A FORC A
TUCSON N ES RAILWAY
POR S 223 ROAD
2470
2480
2485
2490
2495
2500

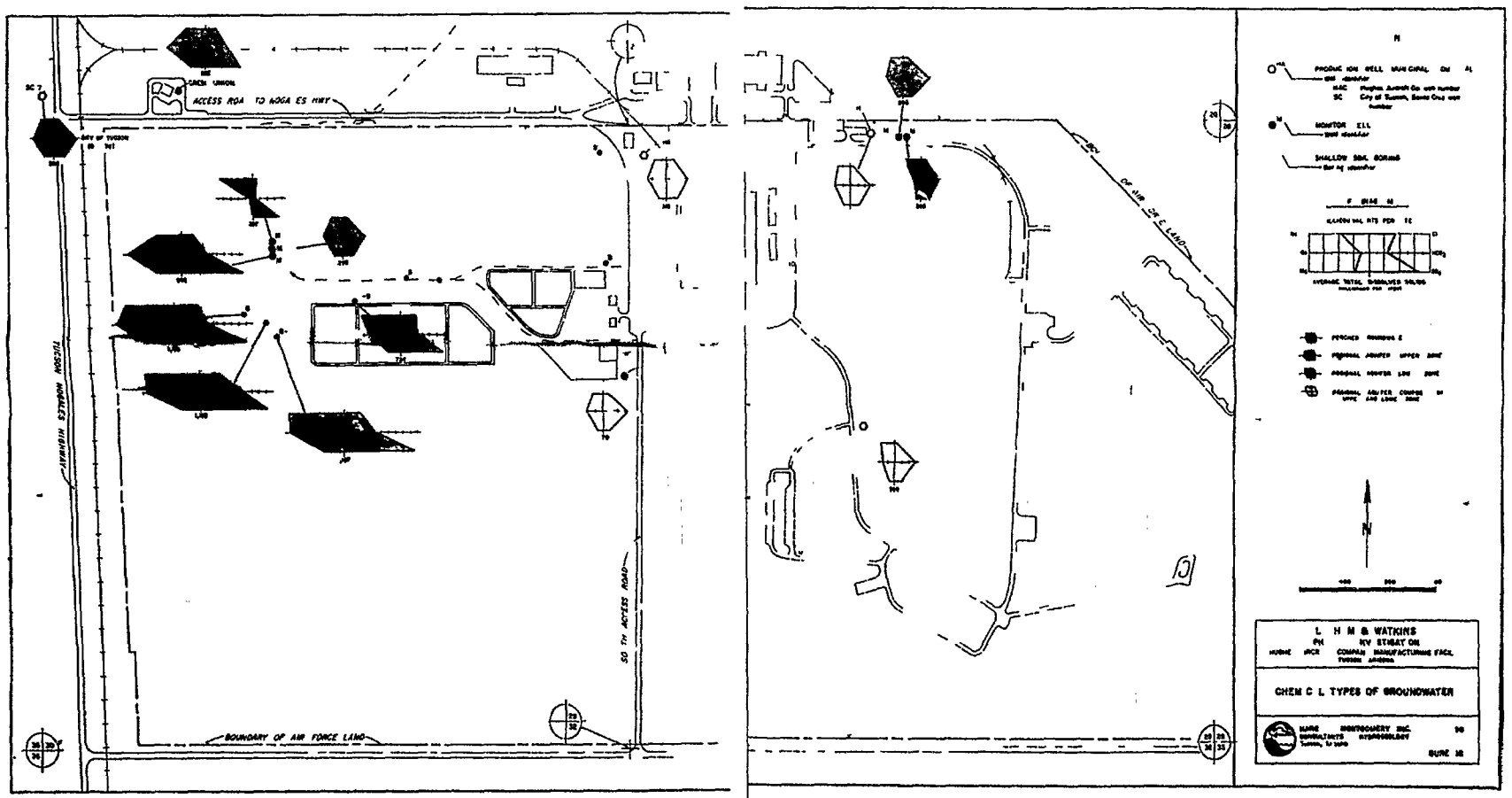

EXPL NAT N
LATH M & WATK NS
LOCAT ON OF
HYDROGEOLOGIC CROSS SECT ONS

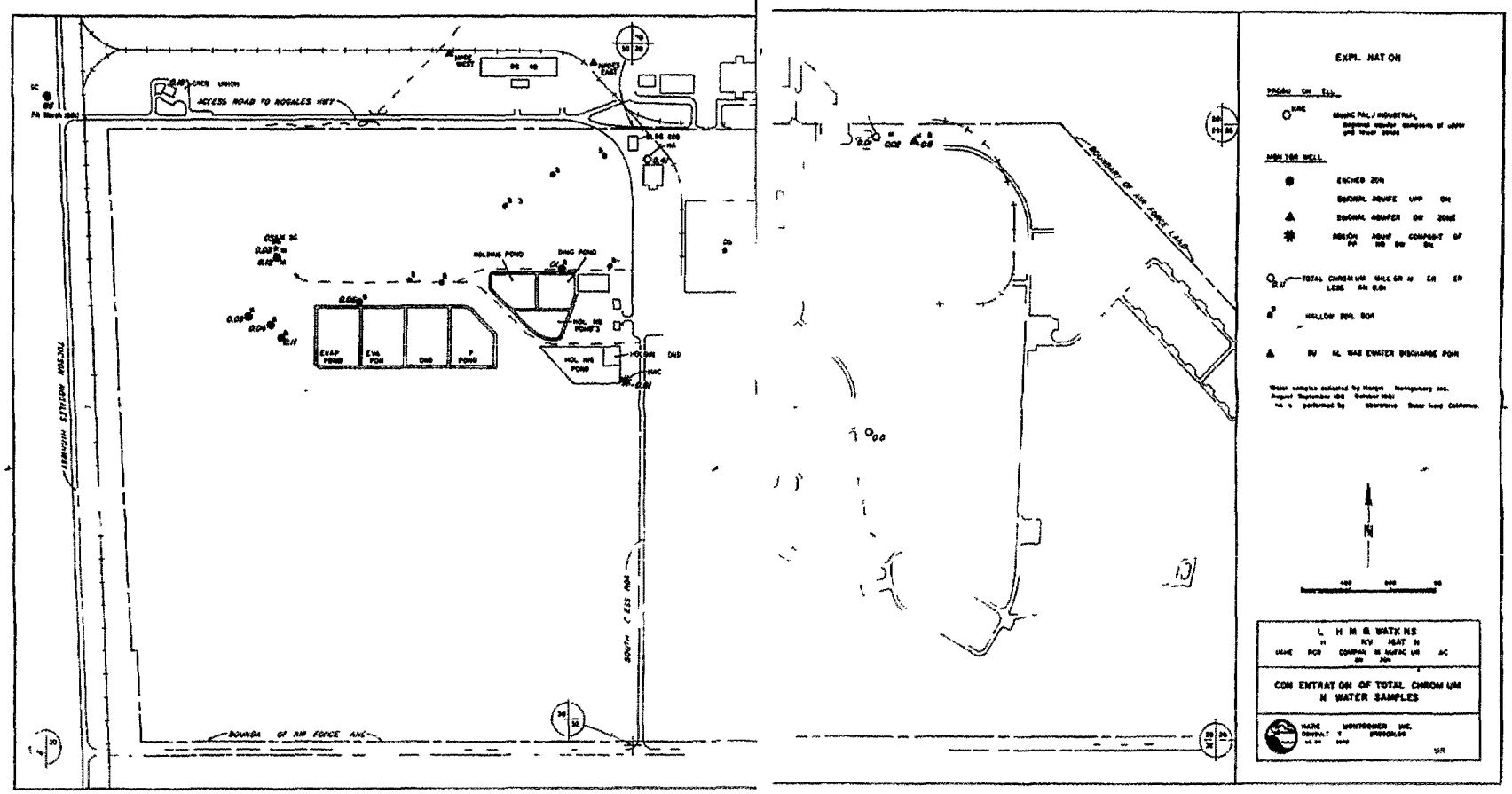

A
B
C
D
ACCESS ROA
TO MORA TK HWY
BOUNDAR OF A FORCE A
BOUNDARY OF AIR FORCE AREA
EX L N N
SIGNAL AQUIF
EGION AQU F MON TO
CH ED ON MON TO
SO BOR
CONF RM ORY OR
SO DRIVE SOIL EDS
DRATORY SOIL BOR
CONF RMA SO BORING
N
TH M ATK NS
LOC T ON OF
HYDROG OLOG C CROS SECTIONS

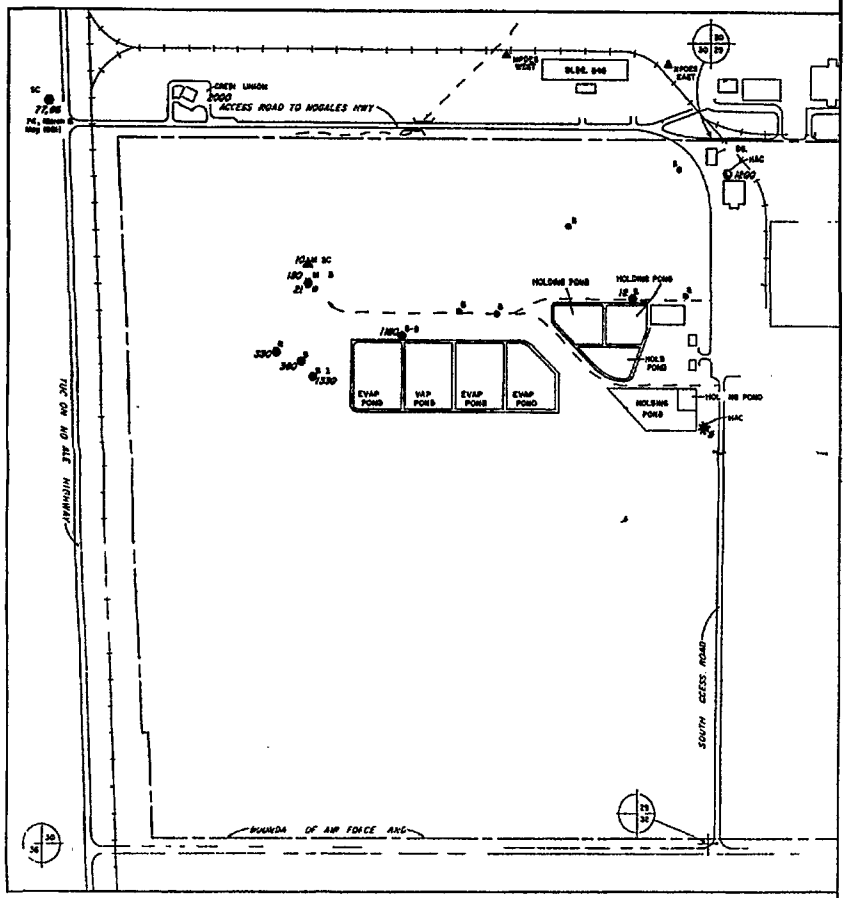

ACCESS ROA
TO NOGALES HWY
BOUNDARY OF FORCE LA D
SOUTH

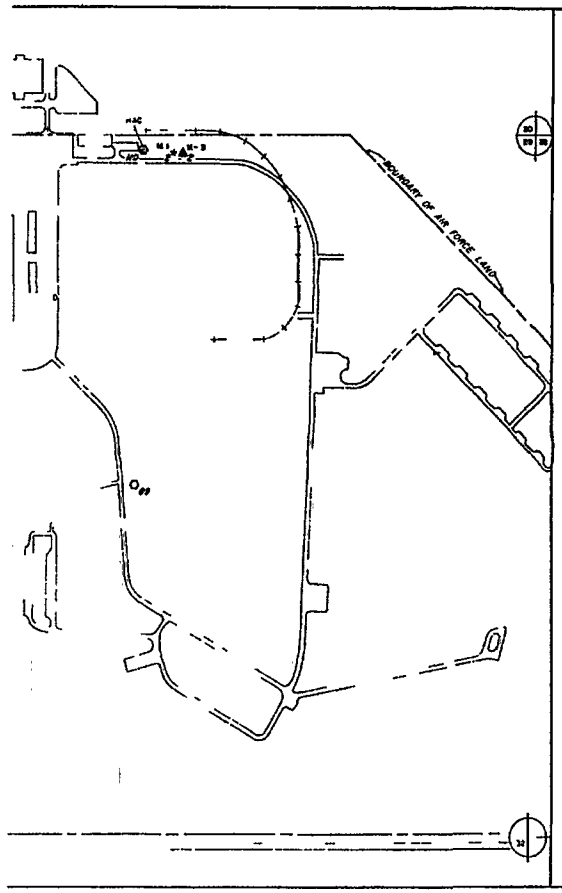



WELLS AND SOIL BORINGS


ACCESS ROA TO NOGA ES HWY
TUCSON NOGALES HIGHWAY
BOUNDARY OF AIR FORCE LAND
SO TH ACCESS ROAD
N
L H M & WATKINS
CHEM C L TYPES OF GROUNDWATER


ACCESS ROAD TO NOGALES HWY
HIGHWAY 82 NOGALES
SOUTH CLESS AVE
BOUNDARY OF AIR FORCE LAND
HOLDING POND
DWG POND
EVAP POND
EVA POND
DWG
P POND
HOL WS POND
HOL WS POND 2
HOL WS
DWG
HWC
EXPLANATION
CONCENTRATION OF TOTAL CHROMIUM IN WATER SAMPLES
MONTGOMERY INC.
N





EXPLANATION

PRODUCTION WELL

MUNICIPAL/INDUSTRIAL
Regional aquifer composite of upper and lower zones

MONITOR WELLS

ERCHES ZONE

REGIONAL AQUIFER UPPER ZONE

REGIONAL AQUIFER LOWER ZONE

REGIONAL AQUIFER COMPOSITE OF UPPER AND LOWER ZONE

CONCENTRATION OF TCE PARTS PER BILLION
ND NON DETECTED

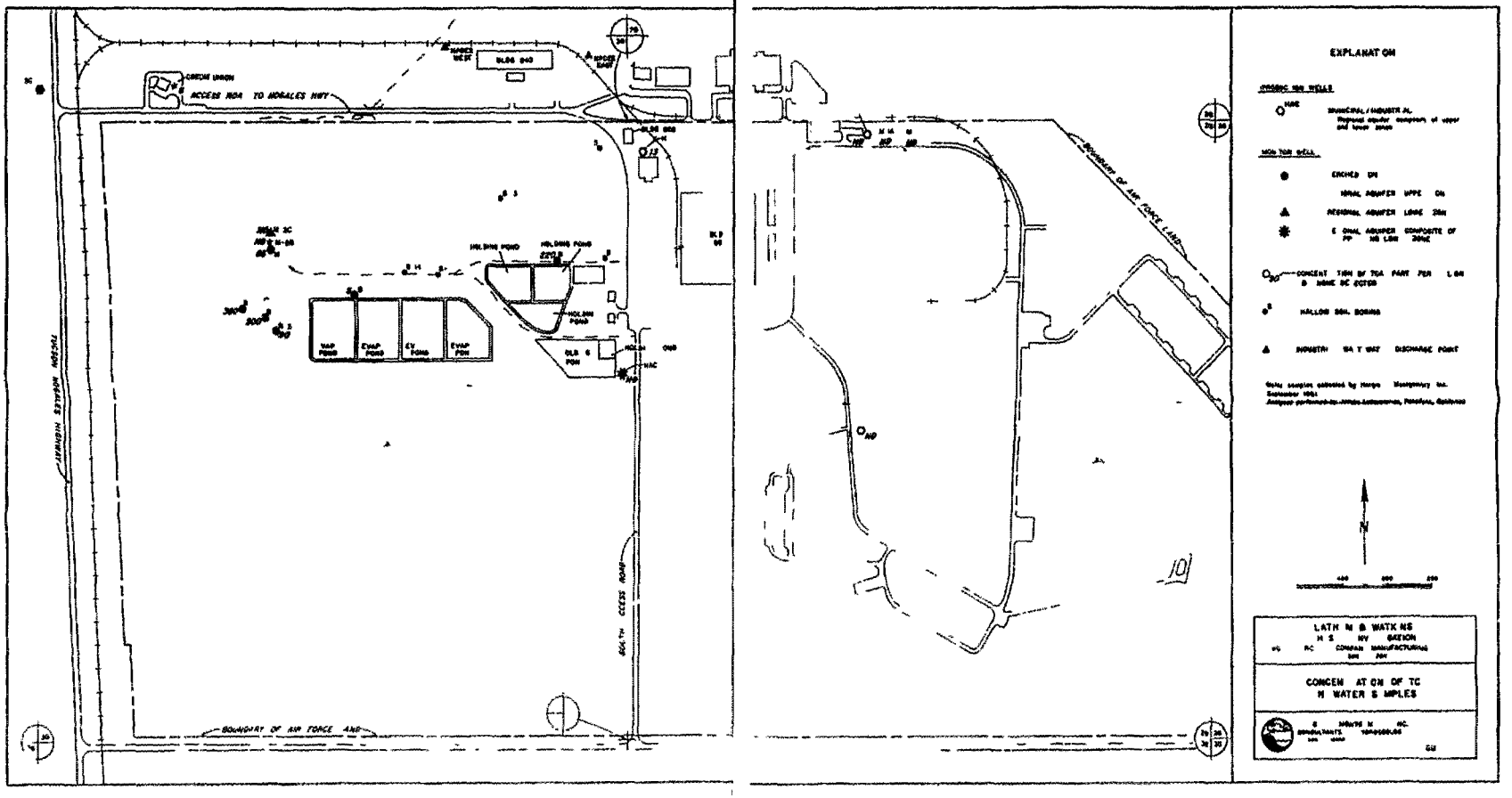
HALLOW SOIL BORING

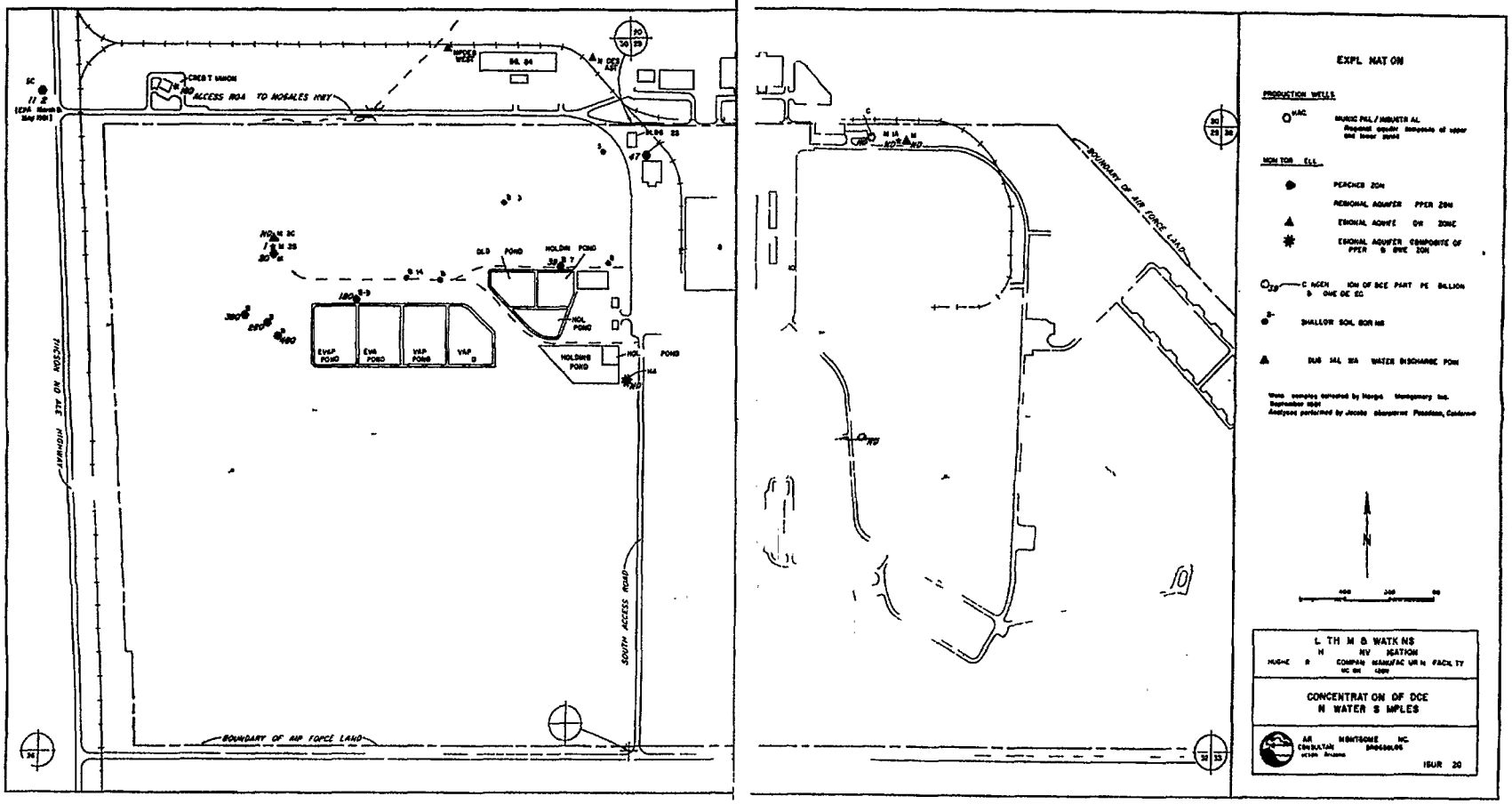
INDUSTRIAL WASTEWATER DISCHARGE POINT

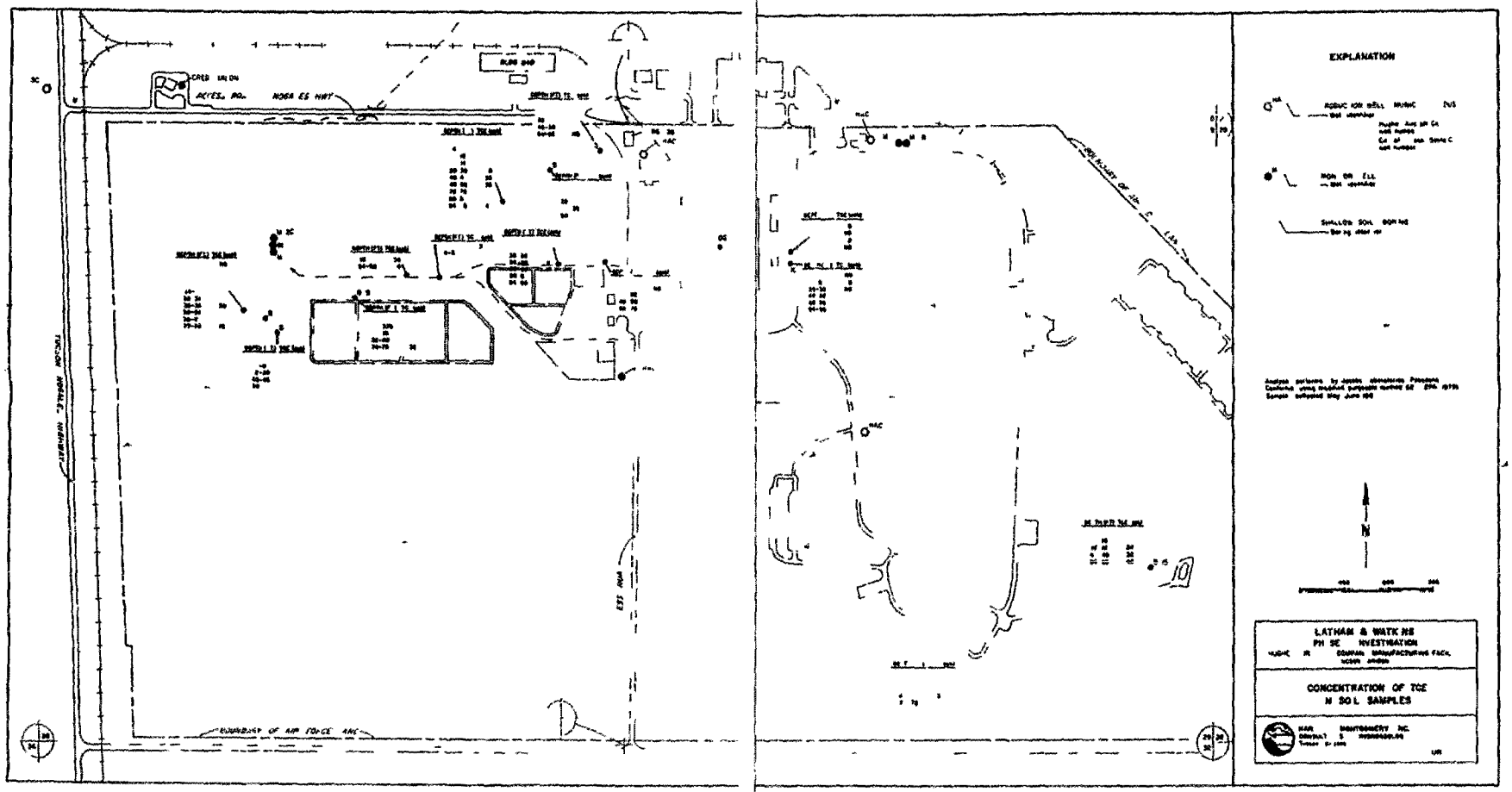
Water samples collected by Morgan Montgomery, Inc.
September 1984
Analysis performed by Jordan Laboratories, Pasadena California

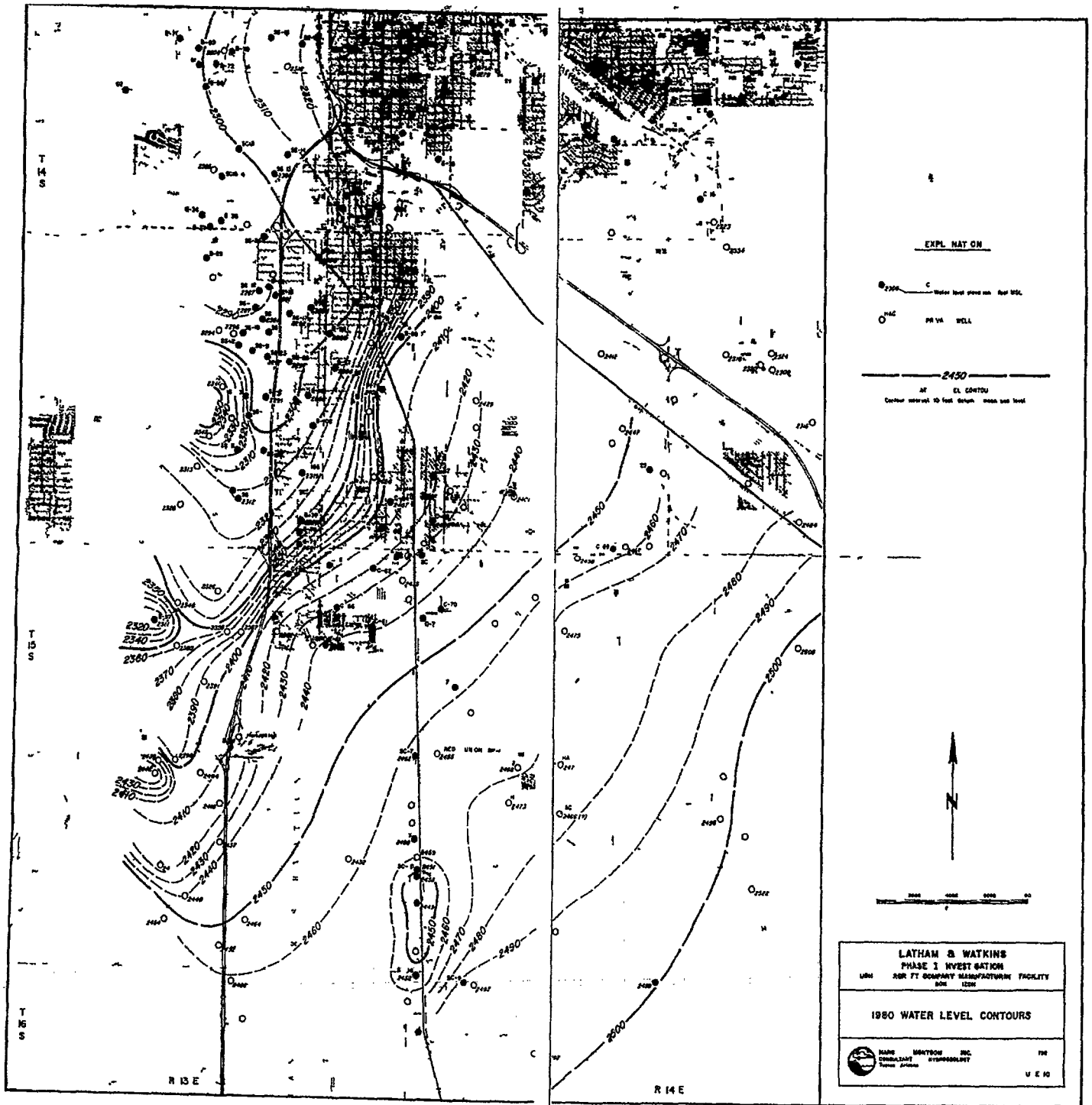
N

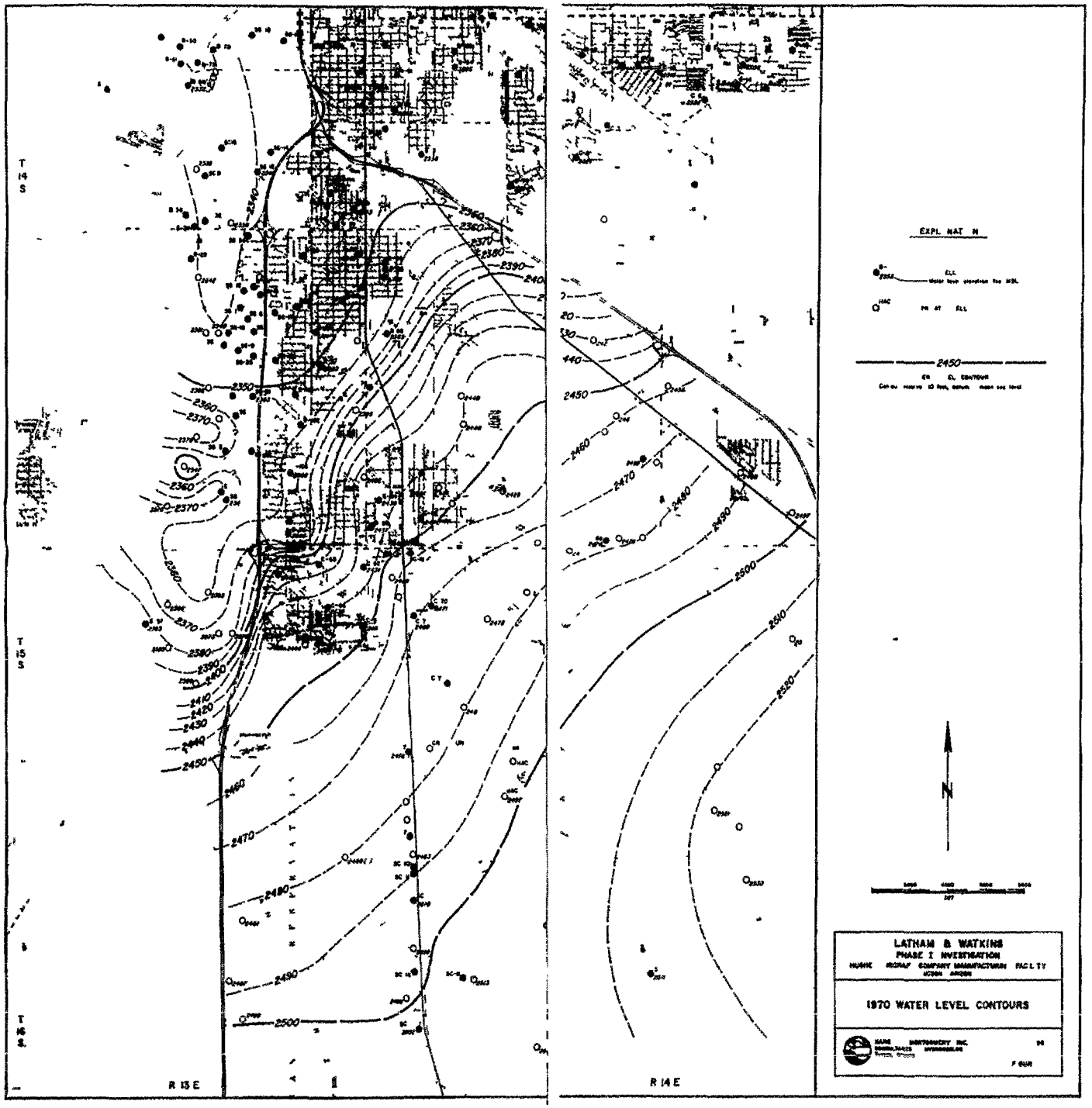
L HAM & WATKINS
INVESTIGATION
HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY
CONCENTRATION OF TCE IN WATER SAMPLES
CONSULT WESTON
MONTROSE INC. TORRANCE, CA
GW 18

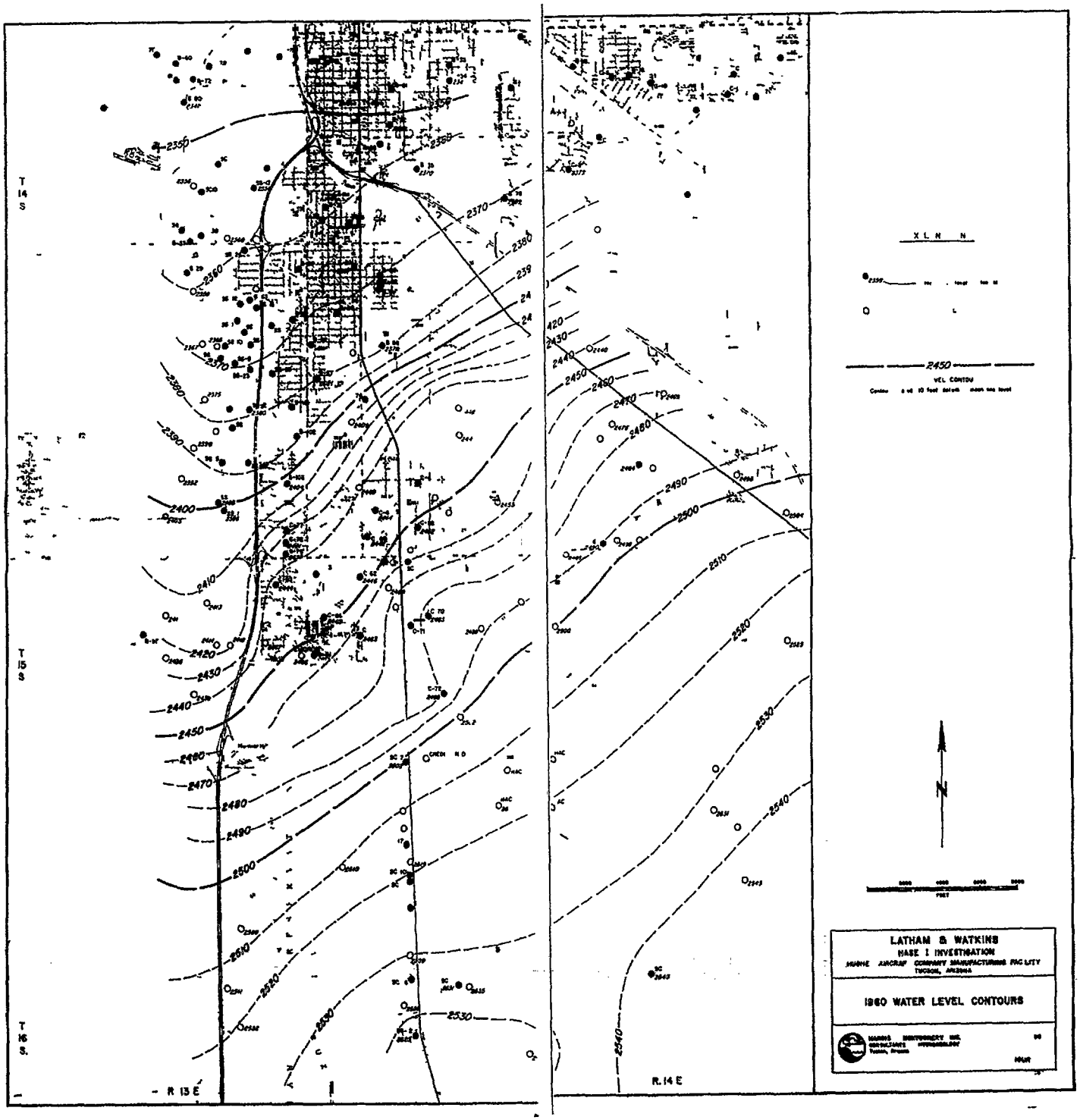

ACCESS ROA TO MORALES HWY
TUCSON MORALES HIGHWAY
BOUNDARY OF AIR FORCE LAND
SOUTH ACCESS ROAD
HOLDING POND
EVAP POND
EXPLANATION
LATHAM & WATKINS
CONCENTRATION OF TCA
IN WATER SAMPLES

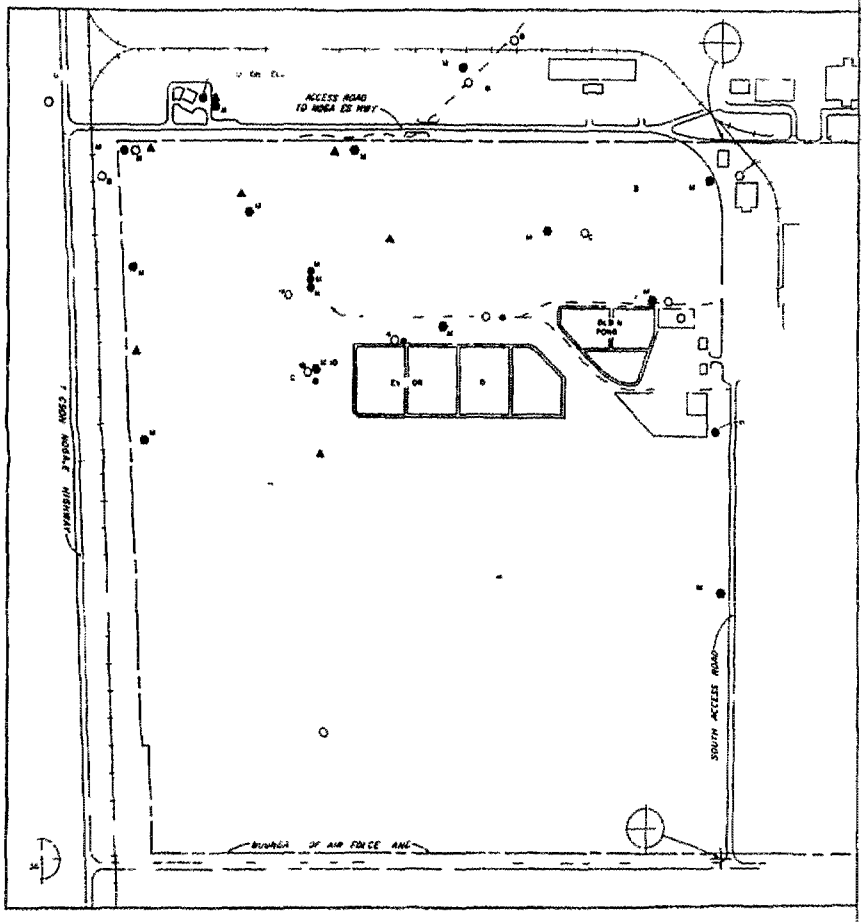

ACCESS ROA TO NOGALES HWY
TUCSON ALT ON NOGALES HIGHWAY
SOUTH ACCESS ROAD
BOUNDARY OF AIR FORCE LAND
EVAP POND
EVA POND
VAP POND
HOLDING POND
HOL POND
POND
EXPL NAT ON
PRODUCTION WELLS
MONITOR ELL
PEACHES ZON
REMONAL AQUIFER PPER ZON
EMONAL AQUIFER OW ZONE
EMONAL AQUIFER COMPOSITE OF PPER & OWE ZON
SHALLOW SOIL BOR NS
WATER DISCHARGE PON
CONCENTRAT ON OF DCE N WATER S MPLES
ISUR 20

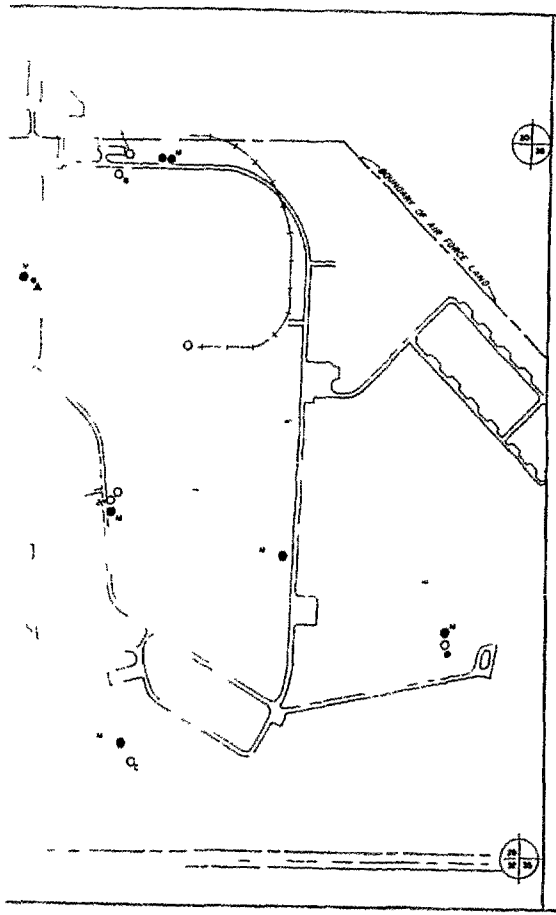

EXPLANATION
LATHAM & WATKINS
PH SE INVESTIGATION
CONCENTRATION OF TCE
IN SOIL SAMPLES
BOUNDARY OF AIR FORCE AFC
N


EXPLANATION
2450
CONTOUR
N
LATHAM & WATKINS
PHASE I INVESTIGATION
1980 WATER LEVEL CONTOURS
T 14 S
T 15 S
T 16 S
R 13 E
R 14 E


T 14 S
T 15 S
T 16 S
R 13 E
R 14 E
EXPL NAT N
2450
N
LATHAM & WATKINS
PHASE I INVESTIGATION
1970 WATER LEVEL CONTOURS


T 14 S
T 15 S
T 16 S.
R 13 E
R. 14 E
2350
2360
2370
2380
2390
2400
2410
2420
2430
2440
2450
2460
2470
2480
2490
2500
2510
2520
2530
2540
2450
VEL CONTOU
N
LATHAM & WATKINS
HASE I INVESTIGATION
MARNE AIRCRAF COMPANY MANUFACTURING FAC LITY
TUCSON, ARIZONA
1960 WATER LEVEL CONTOURS





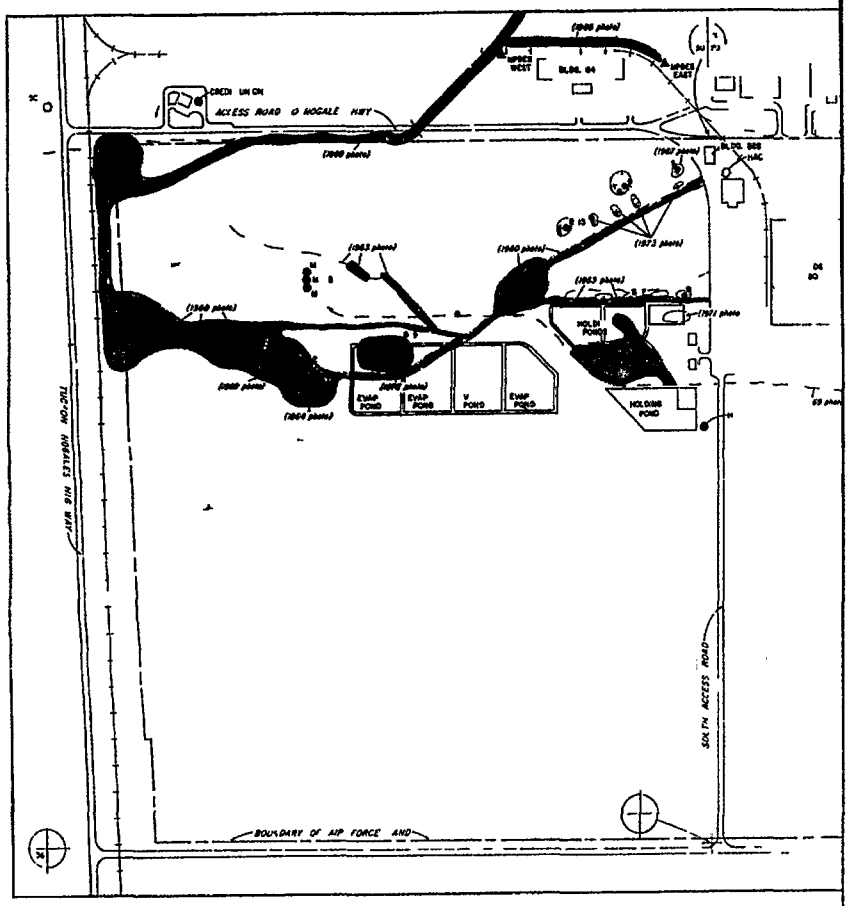
X L NAT ON

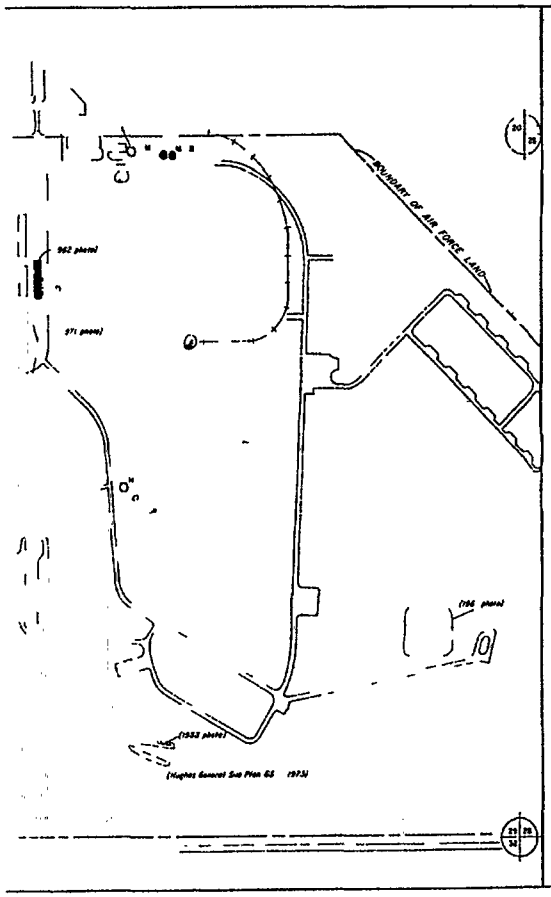
PR PO

LATH M & WATKINS
H NVES GATION

ROPOSED PH SE II NVEST GATION

F GUR





EXPLANATION

COUCTION ELL MUN PALLINGUS
HAC Hughes Aircraft Co.
SC Cd. of Tucson Sewer Cr

SHALLOW SOIL SOR

INDUSTRIAL WASTEWATER SCHARGE POIN

SANDONED WAST WA POND

S DONED DISPOSAL PI

OR CHANNEL

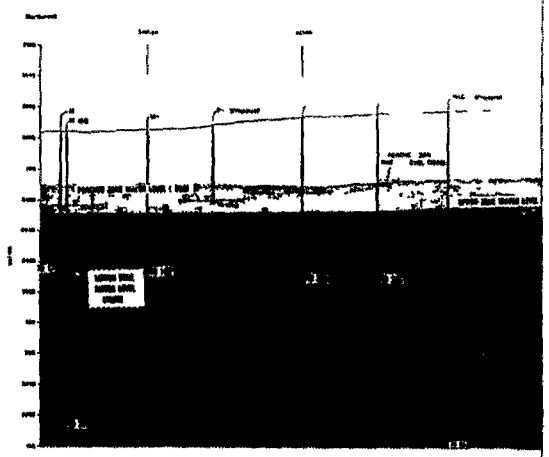
PAR AK VEG ATION

L TH N & WATK NS
N I NVE GATION
USA CR F COMPAN MANUFACTUR PAC
TUCSON ARIZONA

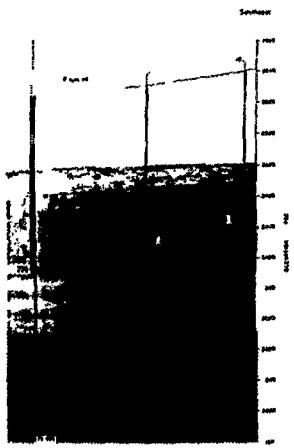
P OX MATE LOCATIONS
OF S NDONED ONDS PITS
ND D SPOS L SITES

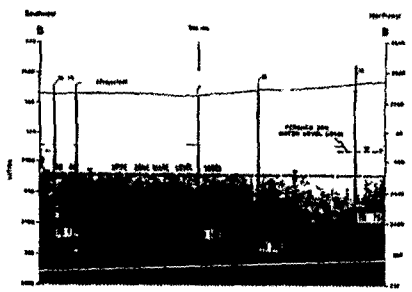
HAR MONTG MERY INC.
SERVICE NT
Tucson, Arizona
HYDROGEOLOG

6U

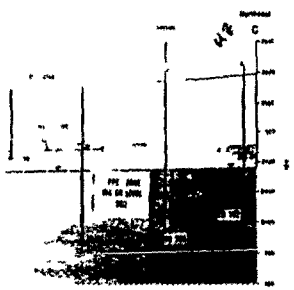


HYDROGEOLOGIC CROSS SECTION A

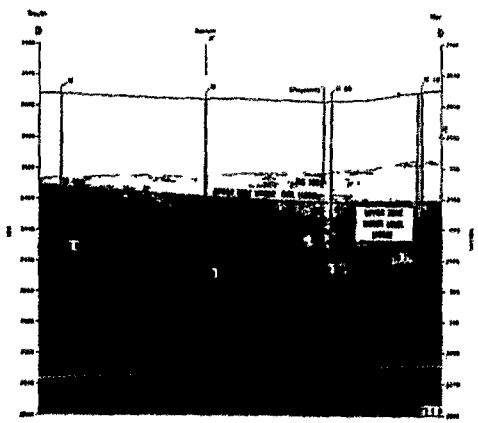




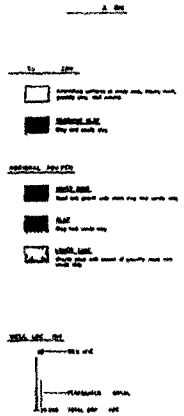
HYDROGEOLOGIC CROSS SECTION B B



HYDROGEOLOGIC CROSS SECTION C C

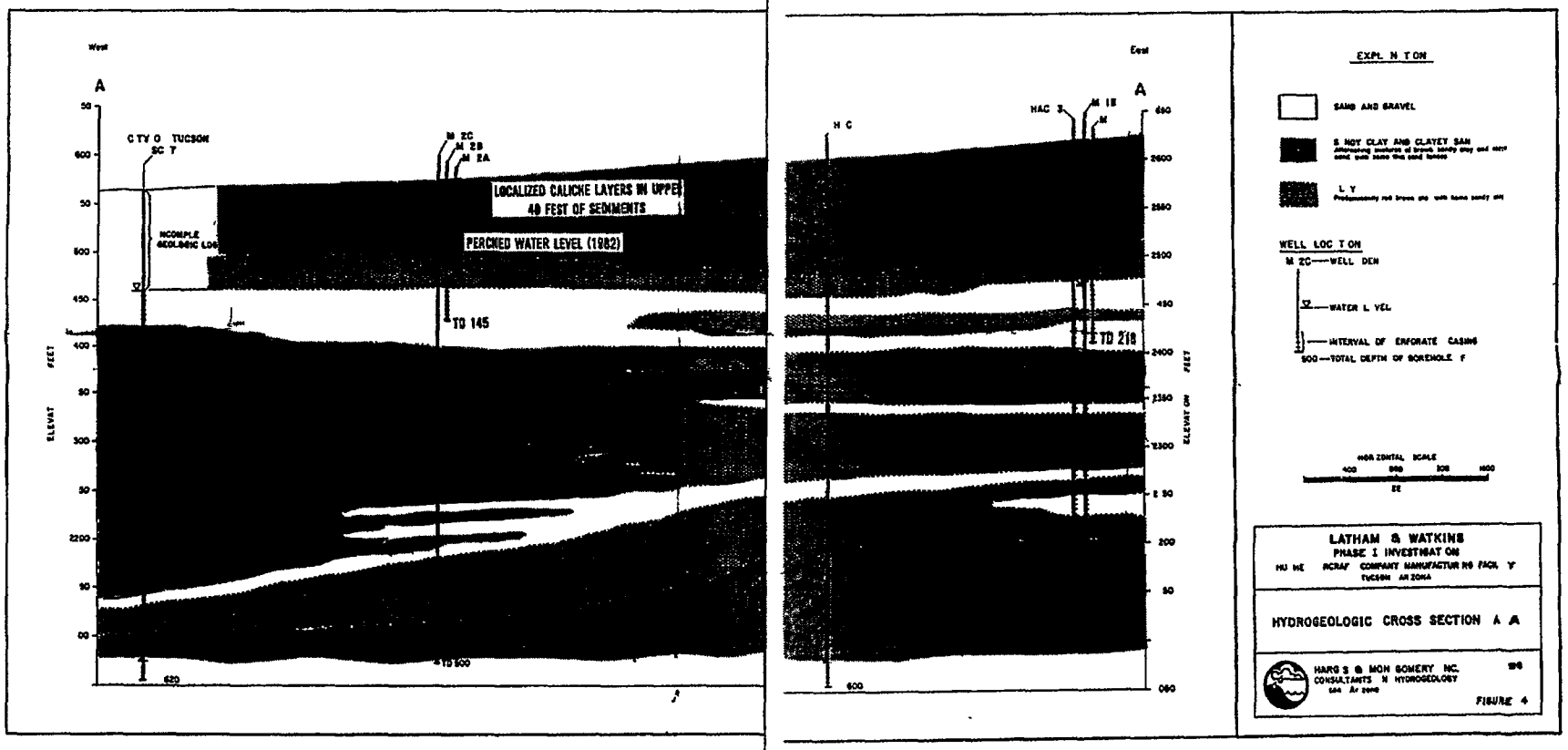


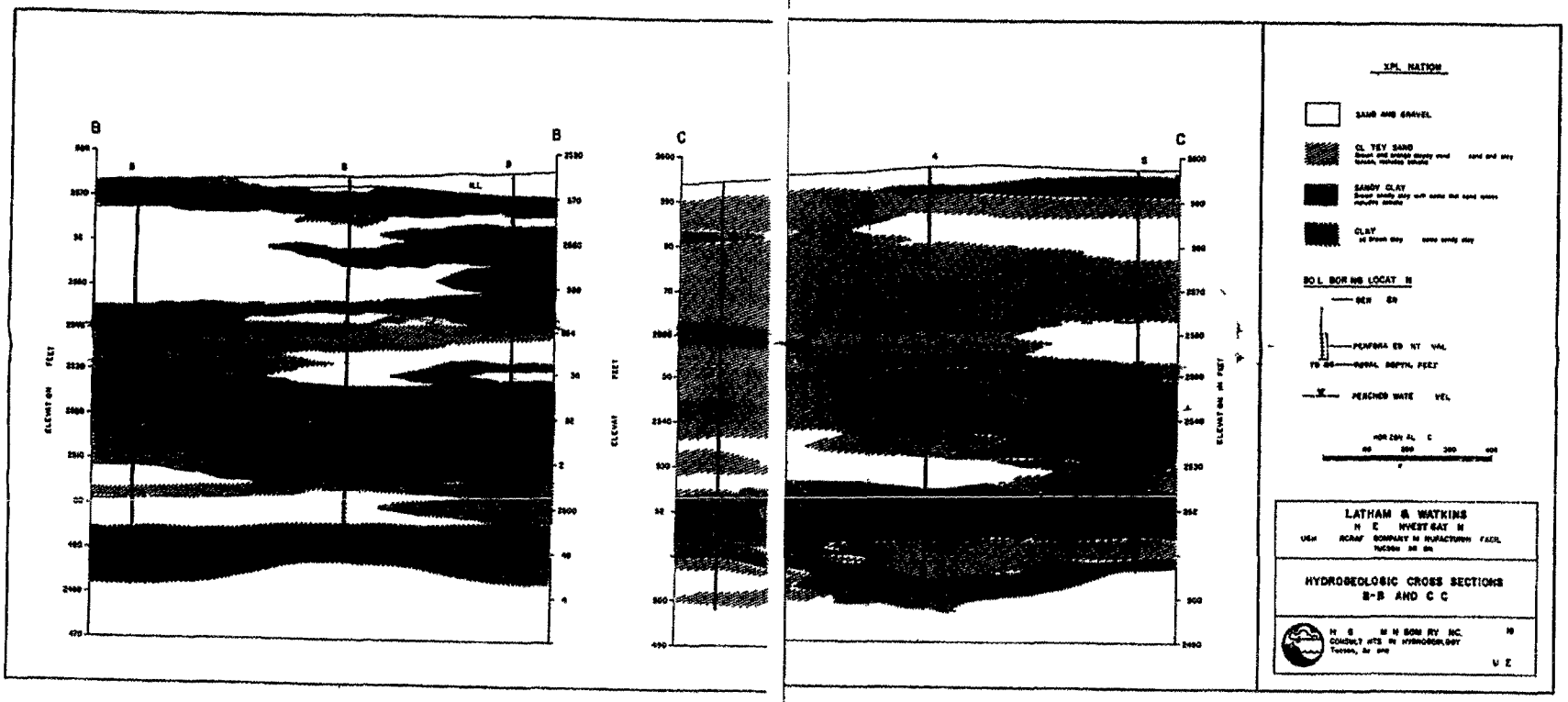
HYDROGEOLOGIC CROSS SECTION D D

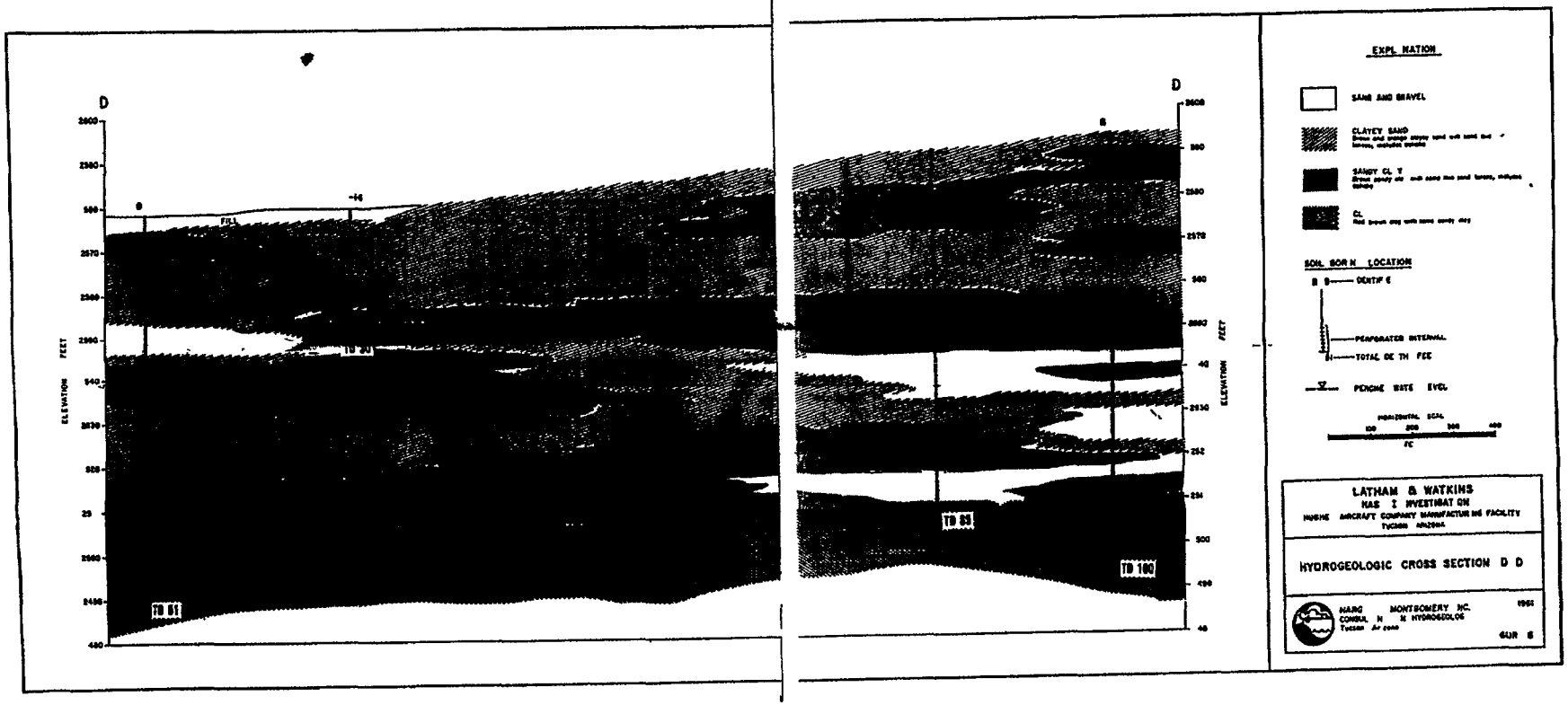


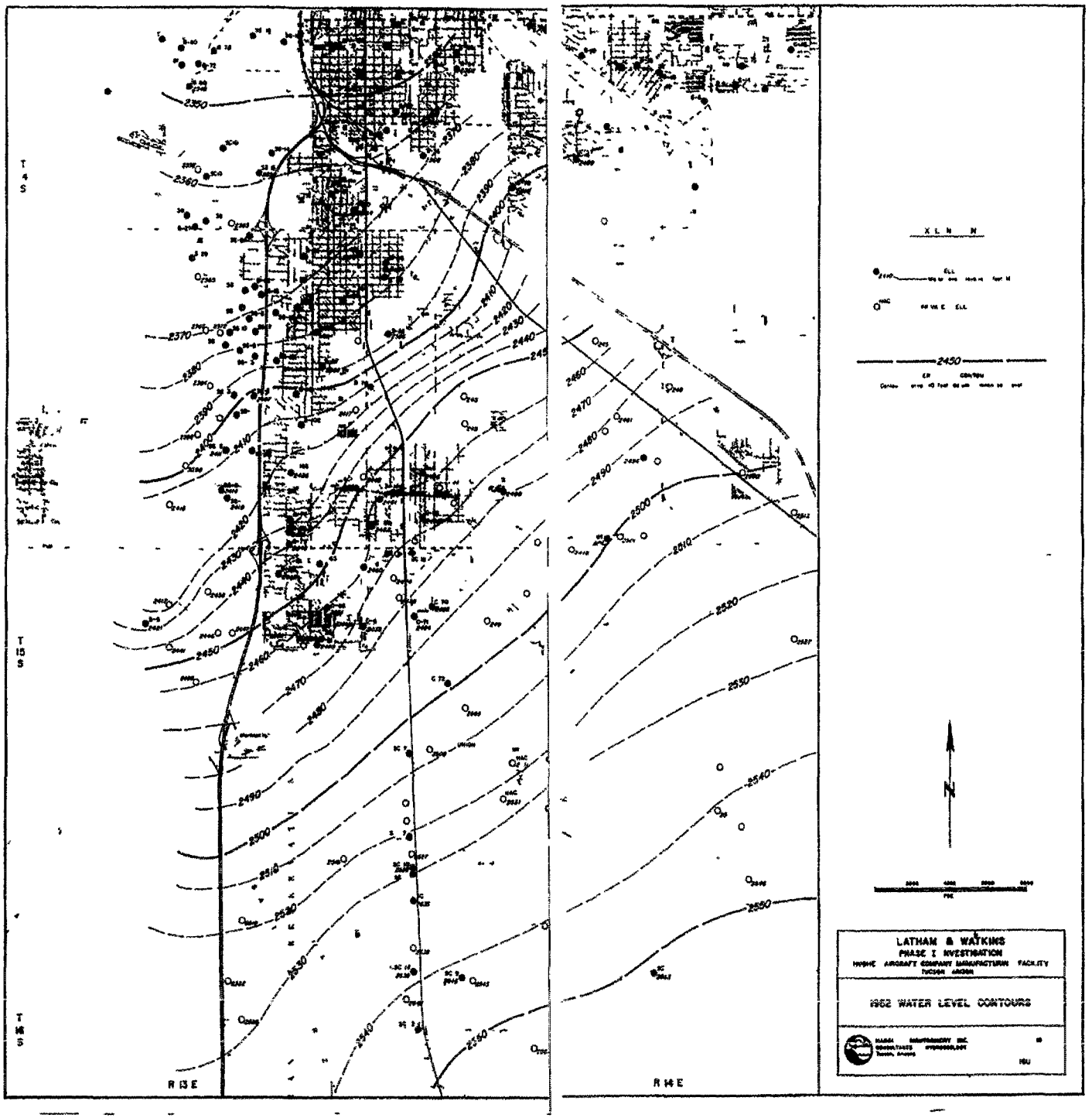
HYDROGEOLOGIC CROSS SECTION

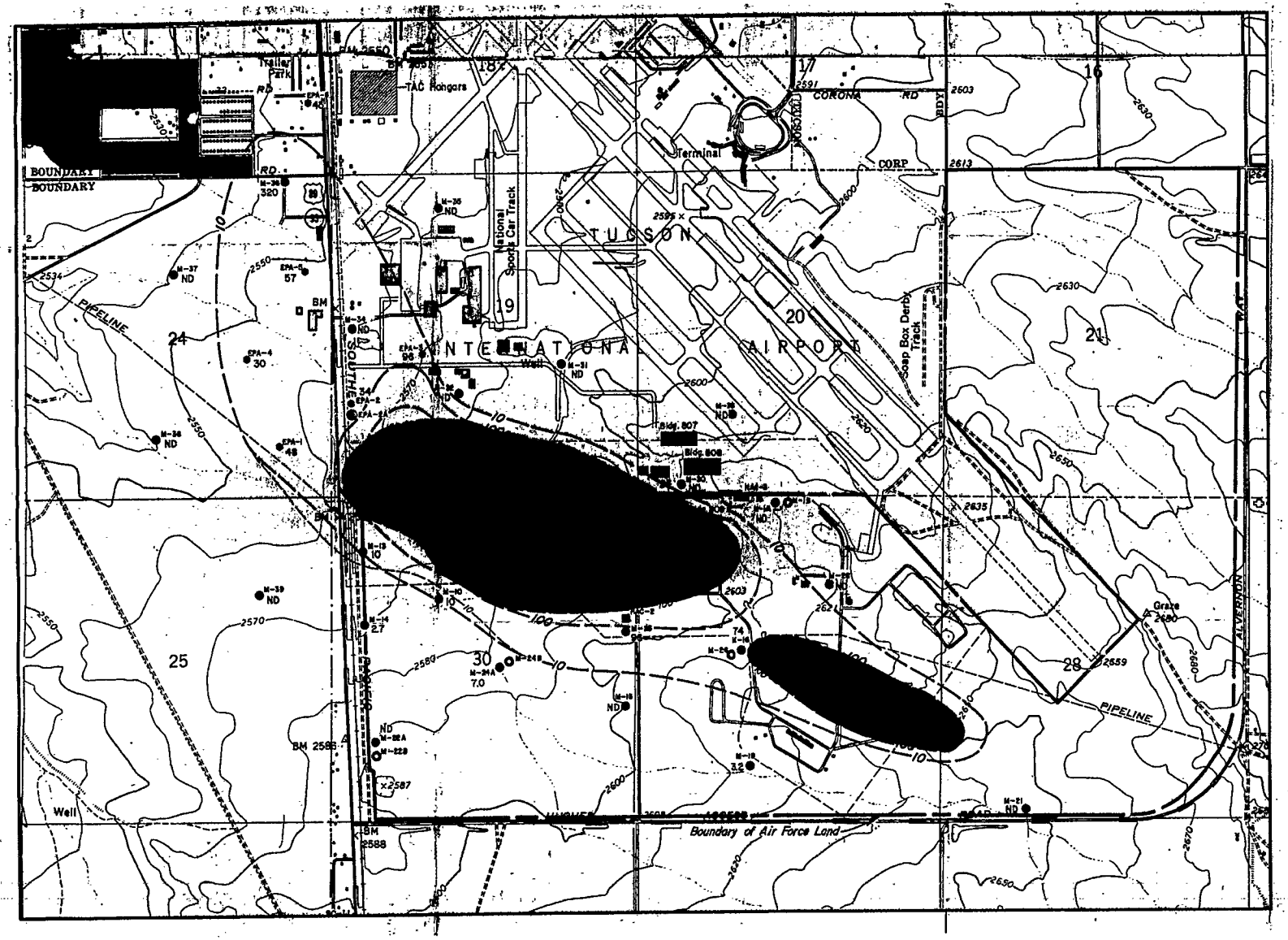
FIGURE


West
A
C TY O TUCSON
SC T
INCOMPLE
GEOLOGIC LOG
M ZC
M ZB
M ZA
LOCALIZED CALICHE LAYERS IN UPPE
40 FEST OF SEDIMENTS
PERCHED WATER LEVEL (1982)
TD 145
TD 500
ELEVAT FEET
H C
HAC 3
M 1B
M
TD 218
600
East
A
ELEVAT ON FEET
EXPL N T ON
SAND AND GRAVEL
S NOY CLAY AND CLAYEY SAN
L Y
WELL LOC T ON
M ZC—WELL DEN
WATER L VEL
INTERVAL OF ENFORATE CASING
500—TOTAL DEPTH OF BOREHOLE F
HOR ZONTAL SCALE
LATHAM & WATKINS
PHASE I INVESTIGAT ON
TUCSON AR ZONA
HYDROGEOLOGIC CROSS SECTION A A
HARG S & MON GOMERY INC.
CONSULTANTS N HYDROGEOLOGY
FIGURE 4


B
B
C
C
ELEVATION FEET
XPL NATION
SAND AND GRAVEL
CLAYEY SAND
SANDY CLAY
CLAY
LATHAM & WATKINS
HYDROGEOLOGIC CROSS SECTIONS
B-B AND C C


D
D
ELEVATION FEET
ELEVATION FEET
FILL
TD 81
TD 100
EXPLANATION
SAND AND GRAVEL
CLAYEY SAND
SANDY CLAY
CL
SOIL BORING LOCATION
IDENTIFIER
PERFORATED INTERVAL
TOTAL DEPTH FEET
PIEZOMETER WATER LEVEL
HORIZONTAL SCALE
FEET
LATHAM & WATKINS
HAZARDOUS INVESTIGATION
HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY
TUCSON ARIZONA
HYDROGEOLOGIC CROSS SECTION D D
HARDING LAWSON ASSOCIATES
CONSULTING HYDROGEOLOGISTS
Tucson Arizona
1991
FIGURE 6


T 14 S
T 15 S
T 16 S
R 13 E
R 14 E
2350
2360
2370
2380
2390
2400
2410
2420
2430
2440
2450
2460
2470
2480
2490
2500
2510
2520
2530
2540
2550
N
LATHAM & WATKINS
PHASE I INVESTIGATION
HUGHES AIRCRAFT COMPANY MANUFACTURING FACILITY
TUCSON, ARIZONA
1962 WATER LEVEL CONTOURS



EXPLANATION

- M-4 — HAC UPPER ZONE MONITOR WELL
- M-EC — HAC LOWER ZONE MONITOR WELL
- EPA-1 — EPA UPPER ZONE MONITOR WELL
- EPA-2A — EPA LOWER ZONE MONITOR WELL
- HAC-3 — HAC PRODUCTION WELL
- HAC-4 — ABANDONED HAC PRODUCTION WELL
- M-7 5,000 — TCE CONCENTRATION, MICROGRAMS PER LITER, December 1984
- 100 — CONTOUR OF EQUAL TCE CONCENTRATION Micrograms per liter, December 1984
- 100 — CONTOUR OF EQUAL TCE CONCENTRATION Micrograms per liter, December 1983
- AREA OF TCE CONCENTRATION Greater Than 100 micrograms per liter, December 1983

ND = none detected, detection limit 1 microgram per liter

N

0 500 1,000 FEET

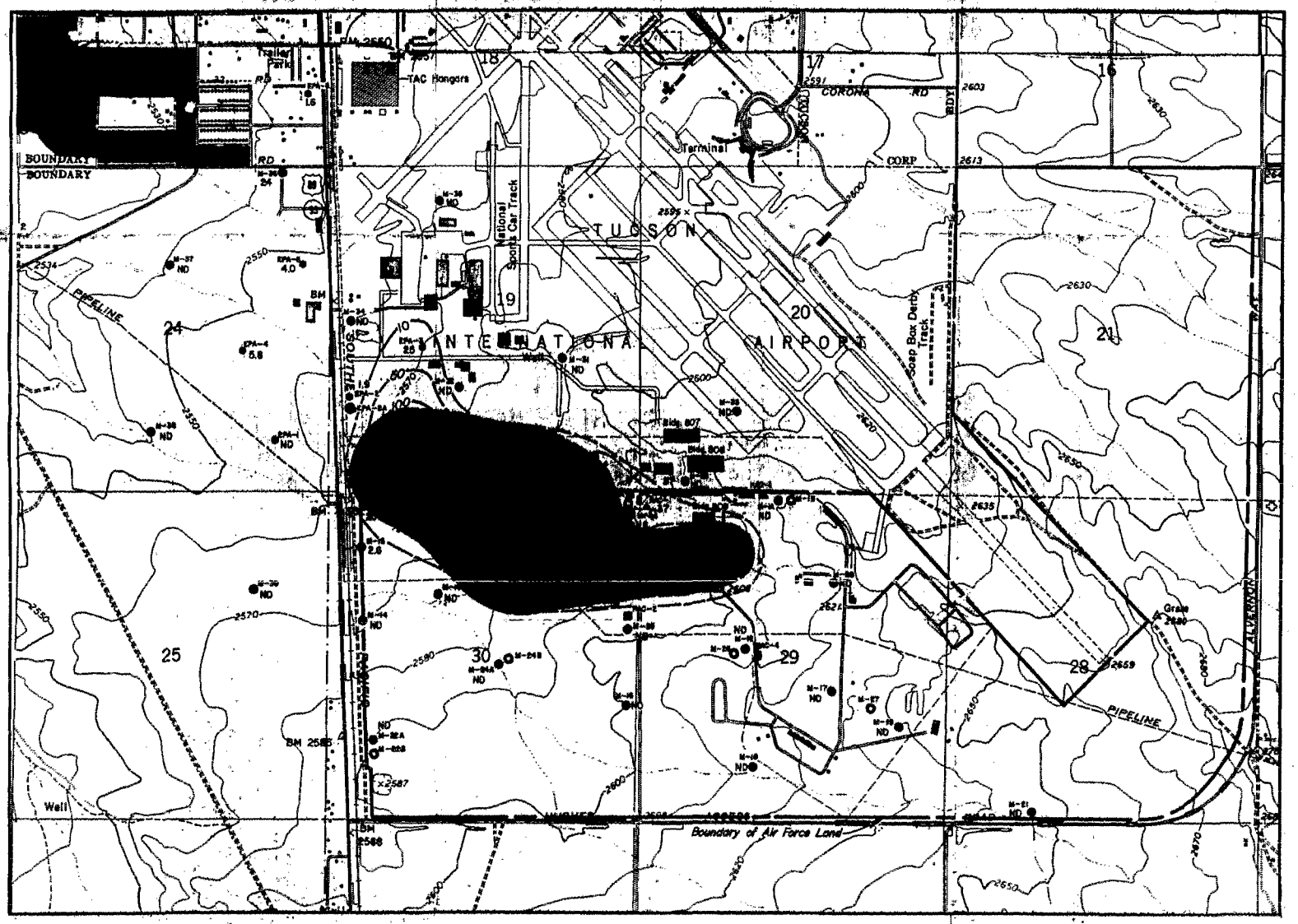
U.S. AIR FORCE PLANT No. 44
TUCSON, ARIZONA
1984 MONITORING PROGRAM SUMMARY

TCE CONCENTRATIONS
REGIONAL AQUIFER—UPPER ZONE

Hargis & Associates, Inc.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

Prepared By Reviewed By

FIGURE 2A



EXPLANATION

- M-4 — HAC UPPER ZONE MONITOR WELL
- M-2C — HAC LOWER ZONE MONITOR WELL
- EPA-1 — EPA UPPER ZONE MONITOR WELL
- EPA-2A — EPA LOWER ZONE MONITOR WELL
- HAC-3 — HAC PRODUCTION WELL
- HAC-4 — ABANDONED HAC PRODUCTION WELL
- M-7 / 850 — DCE CONCENTRATION, MICROGRAMS PER LITER, December 1984
- 50 — CONTOUR OF EQUAL DCE CONCENTRATION Micrograms per liter, December 1984
- 100 — CONTOUR OF EQUAL DCE CONCENTRATION Micrograms per liter, December 1983
- AREA OF DCE CONCENTRATION Greater than 10 micrograms per liter, December 1983

ND = none detected, detection limit 1 microgram per liter

0 500 1,000 FEET

U.S. AIR FORCE PLANT No. 44
TUCSON, ARIZONA
1984 MONITORING PROGRAM SUMMARY

DCE CONCENTRATIONS
REGIONAL AQUIFER—UPPER ZONE

Hargis & Associates, Inc. 1984
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

Prepared by [illegible] Reviewed by [illegible]

FIGURE 2B

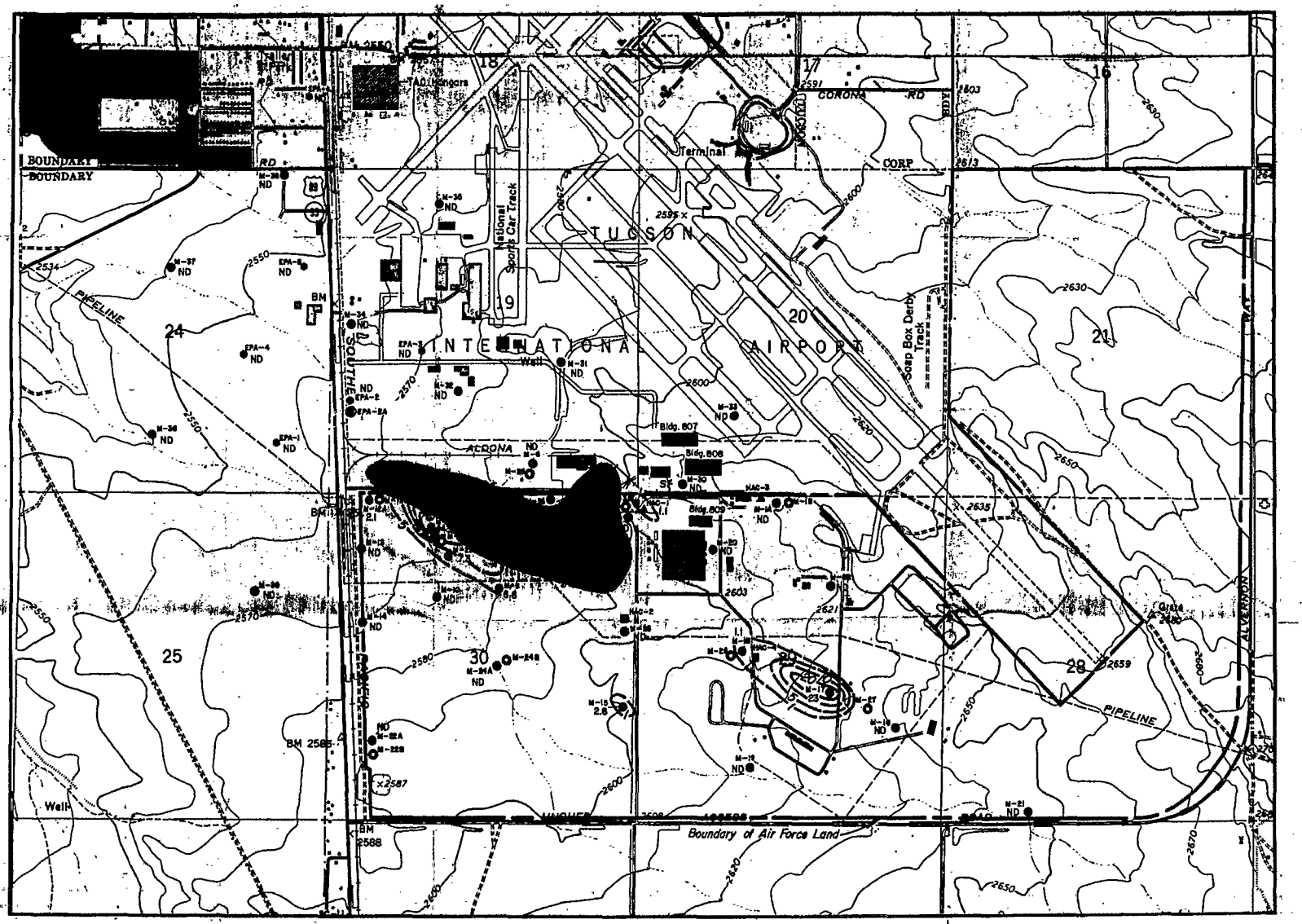
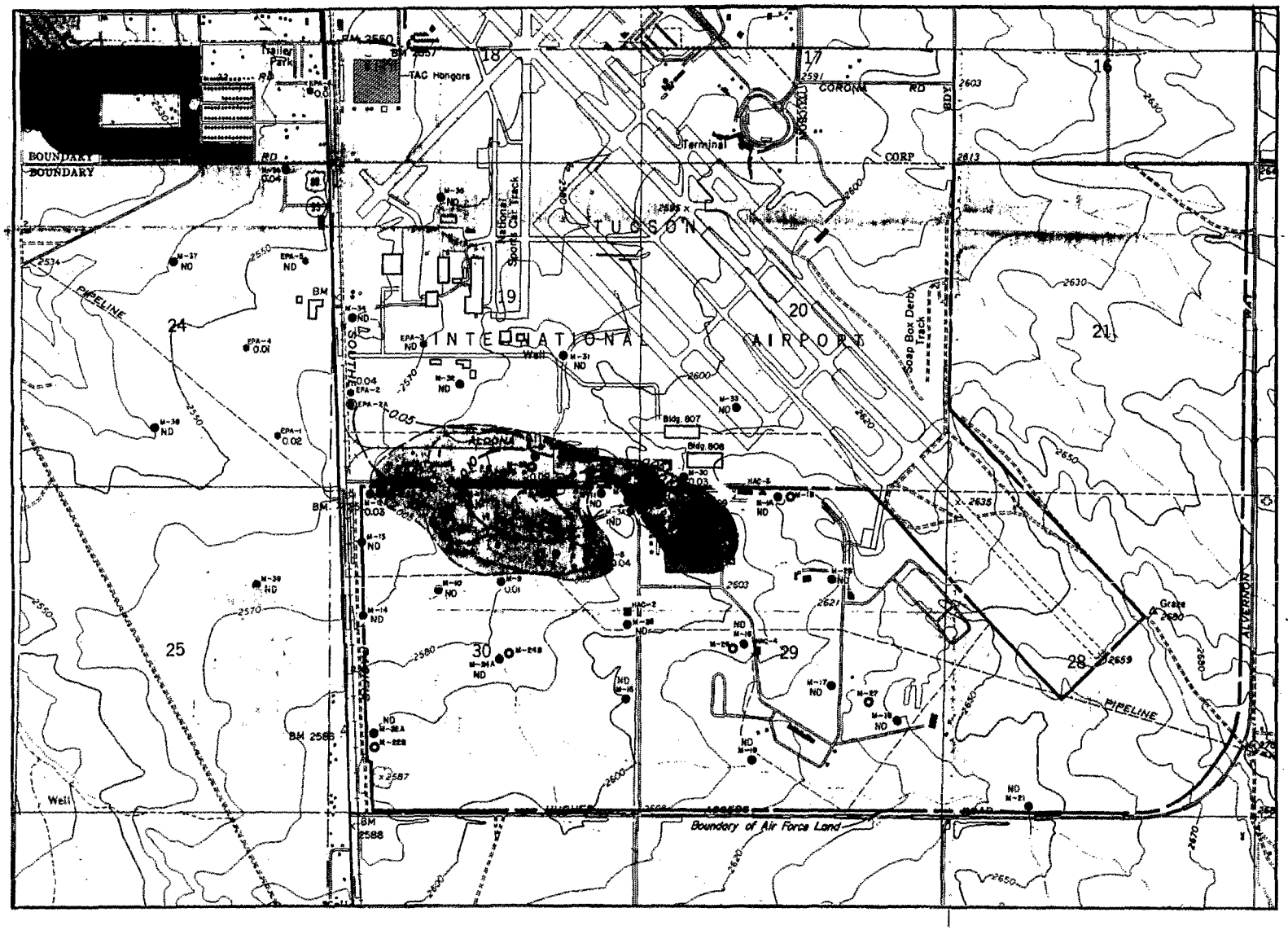

BOUNDARY
BOUNDARY
TAC Hangars
Terminal
CORONA RD
CORP
TUCSON
INTERNATIONAL AIRPORT
National Sports Car Track
Soap Box Derby Track
SOUTHERN PACIFIC
ALVERNON
PIPELINE
ARIZONA
Bldg. 807
Bldg. 808
Bldg. 809
Well
Boundary of Air Force Land
BM 2588
BM 2585
BM 2550
EXPLANATION
M-4 HAC UPPER ZONE MONITOR WELL
M-20 HAC LOWER ZONE MONITOR WELL
EPA-1 EPA UPPER ZONE MONITOR WELL
EPA-2A EPA LOWER ZONE MONITOR WELL
HAC-3 HAC PRODUCTION WELL
HAC-4 ABANDONED HAC PRODUCTION WELL
M-7 13 TCA CONCENTRATION, MICROGRAMS PER LITER, December 1984
10 CONTOUR OF EQUAL TCA CONCENTRATION Micrograms per liter, December 1984
5 CONTOUR OF EQUAL TCA CONCENTRATION Micrograms per liter, December 1983
AREA OF TCA CONCENTRATION Greater than 5 micrograms per liter, December 1983
ND=none detected, detection limit 1 microgram per liter
0 800 1,600 FEET
U.S. AIR FORCE PLANT No. 44
TUCSON, ARIZONA
1984 MONITORING PROGRAM SUMMARY
TCA CONCENTRATIONS
REGIONAL AQUIFER-UPPER ZONE
Hargis & Associates, Inc.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

FIGURE 2.C



EXPLANATION

- M-4 — HAC UPPER ZONE MONITOR WELL
- M-2C — HAC LOWER ZONE MONITOR WELL
- EPA-1 — EPA UPPER ZONE MONITOR WELL
- EPA-2A — EPA LOWER ZONE MONITOR WELL
- HAC-3 — HAC PRODUCTION WELL
- HAC-4 — ABANDONED HAC PRODUCTION WELL
- M-7 / 0.10 — TOTAL CHROMIUM CONCENTRATION, MILLIGRAMS PER LITER, December 1984
- 0.10 — CONTOUR OF EQUAL TOTAL CHROMIUM CONCENTRATION Milligrams per liter, December 1984
- 0.10 — CONTOUR OF EQUAL TOTAL CHROMIUM CONCENTRATION Milligrams per liter, December 1983
- AREA OF TOTAL CHROMIUM CONCENTRATION Greater than 0.05 milligrams per liter, December 1983

ND = not detected, detection limit 0.01 milligrams per liter

N

0 500 1,000 FEET

U.S. AIR FORCE PLANT No. 44
TUCSON, ARIZONA
1984 MONITORING PROGRAM SUMMARY

TOTAL CHROMIUM CONCENTRATIONS
REGIONAL AQUIFER - UPPER ZONE

Hargis & Associates, Inc.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA

Prepared By Reviewed By

FIGURE 2.D

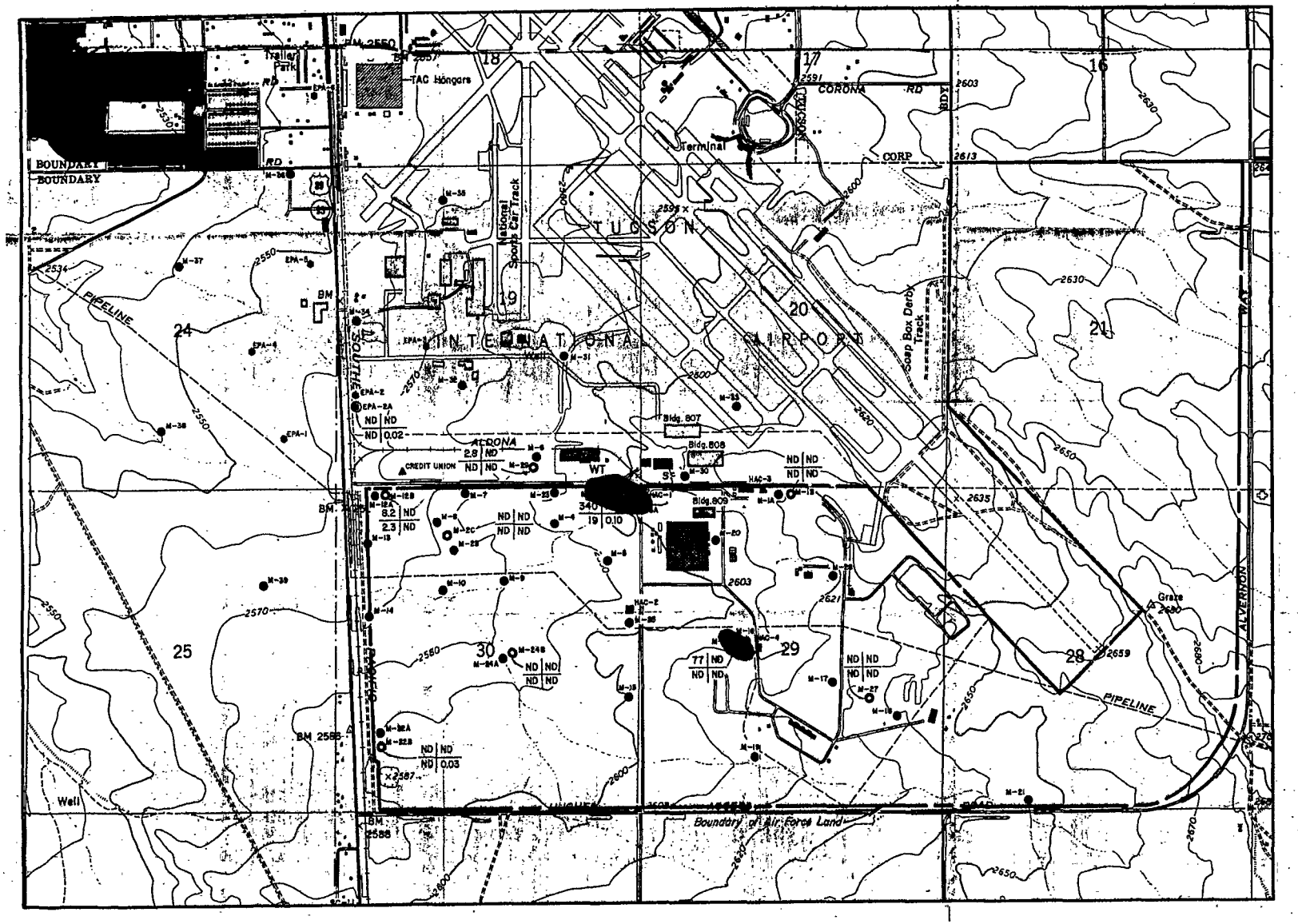

TUCSON
INTERNATIONAL
AIRPORT
Terminal
CORONA RD
CORP
ALVERNON
PIPELINE
ARIZONA
CREDIT UNION
TAC Hangars
Trailer Park
National Sports Car Track
Soap Box Derby Track
Bldg. 807
Bldg. 808
Bldg. 809
Boundary of Air Force Land
Graze
Well
BOUNDARY
EXPLANATION
M-4 HAC UPPER ZONE MONITOR WELL
M-2C HAC LOWER ZONE MONITOR WELL
EPA-1 EPA UPPER ZONE MONITOR WELL
EPA-2A EPA LOWER ZONE MONITOR WELL
HAC-3 HAC PRODUCTION WELL
HAC-4 ABANDONED HAC PRODUCTION WELL
APPROXIMATE AREA OF TCE CONCENTRATIONS GREATER THAN 10 MICROGRAMS PER LITER
TCE Concentration, in micrograms per liter
2.8 ND — TCA Concentration, in micrograms per liter
ND ND — TOTAL CHROMIUM Concentration, in milligrams per liter
DCE Concentration, in micrograms per liter
ND = None Detected
NOTE: Detection limit for TCE, TCA, and DCE is one microgram per liter. Detection limit for TOTAL CHROMIUM is 0.01 milligram per liter.
All water samples collected in December 1984.
FEET
U.S. AIR FORCE PLANT No. 44
TUCSON, ARIZONA
1984 MONITORING PROGRAM SUMMARY
CONCENTRATION OF TCE, TCA, DCE, AND TOTAL CHROMIUM REGIONAL AQUIFER – LOWER ZONE
Hargis & Associates, Inc.
CONSULTANTS IN HYDROGEOLOGY
TUCSON, ARIZONA
1985
Prepared By
Reviewed By

FIGURE 2E