ENVIRONMENTAL MONITORING PROGRAMS FOR OIL SHALE TRACT C-b

(SUPPLEMENTARY INFORMATION)

C-b SHALE OIL PROJECT

1700 BROADWAY
DENVER, COLORADO 80202

OCTOBER 1, 1976

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PREFACE

This environmental monitoring program was submitted to the Area Oil Shale Supervisor (AOSS) as part of the Detailed Development Plan (DDP) prepared for Tract C-b by Shell Oil Company and Ashland Oil, Inc. The DDP, including this program, was found by the AOSS to meet the terms and conditions of the lease. This monitoring program is adaptive and subject to being refined in light of final evaluation of the baseline environmental study, subsequent monitoring results, and the plant design. Any changes made will be with the concurrence of the AOSS.

C-b OIL SHALE VENTURE

Ashland Oil, Inc.
Occidental Oil Shale, Inc., Operator

ENVIRONMENTAL MONITORING PROGRAMS

TABLE OF CONTENTS

ENVIRONMENTAL MONITORING PROGRAMS

LIST OF TABLES

LIST OF FIGURES

VI. Environmental Monitoring Programs

A. Introduction

Section 1 (C) of the Stipulations requires the Lessee to conduct Baseline Programs for two consecutive years and thereafter to conduct Monitoring Programs to measure perceptible changes from the baseline conditions. The description of the baseline studies and the first year's results are set forth in Volume II. Section VI of the DDP describes the Monitoring Programs which Lessee proposes to carry out for the mining, construction and operation phases of the project following completion of the second year of Baseline Programs.

The purposes of the Environmental Monitoring Programs, as defined in Section 1 (C) of the Stipulations are to provide: 1) a record of changes from conditions existing prior to development operations, as established by the collection of baseline data; 2) a continuing check on compliance with the provisions of the Lease and Stipulations, and all applicable Federal, State, and local environmental protection and pollution control requirements; 3) timely notice of detrimental effects and conditions requiring correction; and 4) a factual basis for revision or amendment of the Stipulations.

The achievement of these objectives requires that monitoring of designated environmental parameters be conducted beginning six months prior to the commencement of development operations and until the termination of operations, or until the Area Oil Shale Supervisor determines, to his satisfaction, that environmental conditions consistent with the requirements of applicable statutes and regulations have been established. The Lease stipulates that after two years of baseline data collection the Lessee shall not be required to conduct a monitoring program on the leased lands until a date six months prior to the commencement of development operations.

The Monitoring Programs will compare data obtained during the baseline period with information developed during mining, construction, and operations in to identify significant and meaningful trends and changes. It must be recognized that there may be considerable difficulty in determining the cause of an observed change from baseline conditions because of the many variables which can cause changes. Most biological systems fluctuate around some mean value in response to environmental pressures, and observed departures from baseline conditions may reflect this inherent fluctuation. While a two-year baseline provides a gross value for measuring conditions, normal yearly fluctuations may vary significantly from any specific two-year period. The Monitoring Programs for Tract C-b are designed to take these fluctuations into account and allow statistical comparison of observed trends with baseline data. Inherent in this is the necessity of replicating the techniques used in the Baseline Programs.

The program presented in this section relies on our current knowledge of the Environmental Baseline. The final program, to be begun six months prior to commencement of development activities, will rely on the final baseline report covering the two years of environmental baseline data collection. The material in this section is organized by subject programs, consistent with the approved baseline data gathering programs. For a description of the individual Baseline Programs, see Volume II of the DDP. Detailed information and data for each of the Baseline Programs can be found in the Quarterly Data Reports, Summary Reports, and the Annual Summary and Trends Report filed with the Area Oil Shale Supervisor. It should be emphasized that all of the proposed Monitoring Programs are subject to periodic review and modification with the approval of the Area Oil Shale Supervisor. In accordance with the Stipulations, all monitoring results will be included in an annual progress report to the Area Oil Shale Supervisor. It is essential that the Monitoring Program be dynamic and have sufficient flexibility to allow incorporation of new techniques as the program progresses, and to eliminate superfluous data collection methods if such methods become identified during conduct of the Monitoring Program. The annual progress report provides a mechanism for achieving this objective.

B. Soils Survey and Productivity Assessment

Baseline Programs include a soils survey and productivity assessment for all proposed areas of disturbance. Maps and tables have been prepared illustrating various soils and soil layers by type, depth, strike, dip, slope, solar exposure, vegetative cover, and erodibility. Soil analyses have also included determination of chemical, physical, and structural engineering properties necessary for feasibility evaluations of various proposed construction sites. These studies are of a non-continuing nature and have not been duplicated during the second year of baseline data collection. A description of the first year's Baseline Program and results is found in Section XII of the DDP. Substantial additional engineering data will be required in the process of preparing definitive engineering designs for the mine and surface facilities. This data will be included in reports to the Area Oil Shale Supervisor.

In order to provide documentation of any long term environmental effect upon soils, land forms, and vegetative patterns, the Lessee proposes to obtain aerial photos of the Tract and surrounding areas upon completion of plant construction and at five-year intervals thereafter, until operations have been terminated and disturbed areas have been reclaimed. These photos will be compared with aerial photos taken when the Lease was obtained and photos taken during the baseline period. All visible changes will be noted and significant changes will be reported to the Area Oil Shale Supervisor.

C. Hydrological Monitoring

1. Introduction and Scope

There are two distinct aspects to monitoring the effects of oil shale development upon water resources. The first is water quality and the second is water quantity. Quality and quantity are, of course interrelated to a certain extent, and may have synergistic effects in the biological sphere. However, from the practical standpoint of monitoring technology, it is useful to separate the two aspects in initially determining monitoring requirements; then some readjustments can be made for the sake of efficiency when combining the elements into a complete Monitoring Program.

Monitoring water resources is often thought of as merely the observation of water quality by sampling streams and wells. However, the purpose of an ideal Monitoring Program is not merely to document environmental changes if and when they occur, but to provide a framework for predicting impacts related to such changes before they occur, to provide the data necessary for such predictions, and to determine the effectiveness of mitigating procedures. At the same time, more prosaic objectives of documenting compliance with legal standards for discharge, etc. must be satisfied. An effective Monitoring Program must take into account the geology and hydrology of the specific site, as well as the characteristics of the impact-producing development being monitored. The following sections will discuss the rationale for choosing monitoring sites, monitoring parameters and monitoring frequency. An ultimate goal of the complete development Monitoring Program is to observe or calculate effects in the biological realm due to any changes in water resource properties. The hydrological program is intended to provide quality and quantity data which will be useful for this purpose as well as for the more usual water resource analyses, including the determination of effects on water rights.

In the following discussion an attempt is made to use terminology consistent with that presented by McKee & Wolf (Water Quality Criteria, California State Water Quality Control Board, Publication 3-A, 1963):

degradation -- some change in water quality but not significant
pollution -- a change which impairs public use of the water
contamination -- a change which presents a public health problem

2. Water Quality Monitoring

a. Surface Water

Changes in water quality or the modification of flow in any part of the hydrological sphere will ultimately have an effect on the quality of surface waters. Thus surface water quality is linked to groundwater quality. A properly designed Monitoring Program, however, will detect those effects propagating through the groundwater system long before surface effects are seen. The discussion in this section will therefore be devoted only to those effects which will appear directly in the surface waters. Degradation of surface streams is most commonly thought of as arising from point source discharges; for example, sewer outfalls, cooling system discharges, etc. In these cases, monitoring of the source is effective. For the C-b Project, no direct discharges are planned. The Monitoring Program is therefore designed to detect 1) unplanned point discharges, such as spills or leaks from trucks or pipelines, and 2) pollution from non-point discharges. Accidental spills would likely cause intensive short-term pollution and not be detected in the stream by periodic routine sampling (but might be detected by continuous monitoring). Such spills, if they should happen, would be reported and special samples would be taken as necessary. Small leaks, however, could go undetected until the effects were seen in the regular water samples. The major emphasis in surface water monitoring will be on non-point source pollution. General sources of this type include: 1) increased erosion rates and stream sediment loads due to construction activities, 2) runoff from process plant and paved areas, 3) runoff carrying solids resulting from fallout of air-borne particulate emissions, 4) seepage or runoff from piled solids, and 5) infiltration into the groundwater system from reservoirs, ponds, or injection wells.

The location of monitoring stations for surface water quality is a relatively straightforward procedure when only a small drainage area is involved. Sampling stations on each tributary of significance will make it possible to quickly pinpoint the source of any changes detected in the mainstream. If larger drainage areas are involved, then a rationale must be developed for placing the monitoring stations in specific locations. For the C-b Tract, however, the surface hydrology is defined rather simply in terms of the mainstem Piceance Creek and its two perennial tributaries, Willow Creek and Stewart Gulch. These three stream elements completely encompass the surface drainage from the Tract. The four major gauging stations which presently define upstream and downstream Piceance plus the two tributaries will therefore be retained as part of the permanent monitoring system. None of the ephemeral streams presently being monitored have shown significant flows during the two-year baseline period. Nevertheless, monitoring of these stream channels should continue. Some changes in station locations may be desirable. Sampling of springs and seeps for water quality will also be continued. Such samples would be useful in determining the source of any variations in surface water quality.

Selection of water quality parameters to be monitored should be based on an analysis of possible pollutants or quality changes and should focus on specific constituents chosen because of their hazardous character, persistence, concentration, ease of identification, or other pertinent characteristics. It is felt that the major probability for direct surface water degradation is increased erosion and sediment loads resulting from construction activities. Thus special attention will be given to maintaining sediment records at all stations. In addition to suspended sediment, total dissolved solids and turbidity are important parameters. These three measurements are sufficient to record a major change in the solids loading of a stream because of increased erosion or due to runoff from piled solids. To determine the nature and source of the solids and their effect on stream biology, such standard measures as temperature, dissolved oxygen, pH, hardness, alkalinity, and major ion concentrations should also be determined on a routine basis.

Detection of spills and leaks of oil and other organic materials would be accomplished by normal analyses for oil and grease, and for dissolved and suspended organic carbon. Pollution via runoff from paved areas would also show up in these analyses. Fractionation of the dissolved organic carbon can be used to identify classes or origins of pollutants.

Analyses for trace elements should be designed in accordance with possible sources which can be defined. From examination of the geochemical and hydrological characteristics of the C-b resource, it is apparent that the elements fluorine and arsenic are of special significance. Fluoride is present in high concentrations in all the deep aquifers under C-b. Thus any surface water changes resulting from mine inflow water reaching the surface via leakage from well reinjection systems, holding reservoirs, etc., will be immediately apparent as an increase in fluoride levels. Fluoride in water is normally conservative, that is it does not change in concentration readily by natural processes such as sorption and chemical reactions. There is such a strong contrast between surface and deep aquifer waters with regard to this element that no other identification of the source of change would be necessary in most cases.

Arsenic must be removed from the crude shale oil prior to hydrotreating. To insure that no environmental pollution occurs as a result of this step, monitoring for arsenic will be conducted routinely. Arsenic could be emitted to the atmosphere via process stacks,and air quality regulations will require stack monitoring as the primary means of regulating these emissions. Arsenic in surface waters could result from secondary sources via fallout of atmospheric emissions. Unexpected leaching from the waste disposal pile could also result in increased arsenic levels. Other trace elements of interest besides fluorine and arsenic may be defined later.

Another category of trace quantity contaminants which appears to be of concern is polycyclic organic matter (POM). These materials, some of which are known to be carcinogenic, can be found in trace quantities in both raw and processed shale. Continued surveillance of surface waters will be conducted to detect possible pollution from wind-blown dust off either the raw shale or processed shale piles, from percolation and seepage, or from process units. Major changes will be picked up by the organic carbon fractionation procedure.

Many measures of surface water quality which would be standard in other circumstances, such as pesticide and herbicide levels and coliform counts, will have little relevancy for monitoring the C-b Project. Agreement on details of the analytical schedule will be worked out with the Area Oil Shale Supervisor at the end of the two-year Baseline Program.

b. Subsurface Water

(1) Shallow Aquifers

Degradation of the groundwater system in the shallow alluvial aquifers would eventually lead to surface water effects. However, in order to detect any changes in the shortest possible time, a series of alluvial monitoring wells near potential sources will be utilized. If surface water degradation is detected, the inspection of groundwater records may be valuable in pinpointing the source. Classic examples of groundwater pollution have resulted from such things as reservoir seepage, acid mine drainage, and waste injection wells. The geochemical characteristics of the C-b mining zone do not suggest that acid drainage could form in the mine. Even if it could, the mine will be far below the alluvial aquifer system, so that no drainage from the mine could result. Thus contamination of the shallow aquifers by mine water could only occur via mine water pumped to the surface and subsequently lost from a reservoir or injection well system. This would be one of two major possibilities for directly affecting the shallow aquifer system without first going through the surface water or deep aquifer systems. The second possibility is via percolation through and seepage from the shale piles. A potential for pollution of the shallow aquifer by reinjection of mine inflow water could result from 1) escape through the well bore because of casing failure from corrosion or other causes, 2) vertical escape outside the casing as a result of poor cementing, and 3) vertical escape through leaky aquitards caused by over-pressuring and fracturing the formation. Pollution from piled material could result if rainwater or snowmelt on the piles would infiltrate downward to the alluvial or shallow aquifer zone, then move laterally.

Because of the longer time scale involved in groundwater movements, (weeks or months may be required to move relatively short distances), the location of monitoring sites is much more critical than for surface water in order to detect pollution before a significant buildup occurs in the system. Site selection must be based on a general knowledge of the area hydrology as well as on an analysis of the possible pollution sources. Haphazard location of monitoring wells is certain to result in excessive costs and inadequate coverage. To provide general area coverage, the present network of alluvial wells will be maintained. Because the general hydraulic gradient in the area slopes to the north, unless other local conditions are controlling, monitor wells should be placed to the north of possible pollution sources. Within local valleys, of course, wells should be placed downstream. Determining the number of wells required is not as simple as determining the number of stream gauging stations. Because of its small lateral dimensions, a stream may be considered well-mixed, so that only a single sampling point is needed. Although an alluvial aquifer may be thought of as an underground river, it is far from well-mixed, and samples may be necessary at more than one point along a line perpendicular to the direction of flow. The further downstream the wells are placed from a suspected source, the fewer wells would be required. However, greater downstream distances imply longer time intervals before pollution could be detected. As a general guideline, it is expected that one shallow monitoring well will be placed within 100 ft. down-gradient of each reinjection well. Monitoring wells will also be placed a short distance downstream from each reservoir, raw shale pile, and spent shale pile. These locations should be as near as possible to the center of groundwater drainage pattern and should be no farther downstream than the intersection with the next larger tributary branch. For wide sources more than one well should be planned. Well construction should be such as to allow sampling from different depths within the saturated interval.

Selection of chemical parameters to monitor should be based upon hydrological and geochemical considerations as well as the nature of the potential pollution. The same general considerations will apply as for surface water. Sediment, of course, will not be a factor in ground water.

(2) Deep Aquifers

In many mines, degradation of aquifers adjacent to the mine can result from the reactions between air, water, and minerals at surfaces exposed to air by the mining process. Acid mine drainage from coal mines is a well-known example. In most cases the coal seam is saturated prior to mining. After the groundwater table has been lowered, the iron pyrite that was previously covered by water is exposed to oxygen in the air and is oxidized. The iron, sulfate, and acid formed in this process become soluble and are taken into solution by water percolating through the mine. The acid water then enters the mine workings and percolates through the floor and into the groundwater system. Similar effects may be possible with other minerals even where pyrite is absent.

The hydraulic gradients in the deep aquifers near the Mahogany zone on Tract C-b are such that flow will be up into the mine through the floor and down through the roof rather than away from the mine. If the mine inflow water is reinjected, however, any acidic or mineralized water formed in the mine would become mixed with the aquifer system. This is the only expected route of entry for pollutants into the deep aquifers. Indirect degradation of the deep aquifers could result due to changed flow patterns induced by mine dewatering. Reduction of pressure in the mining zone could result in upward flow of saline water from deeper underlying zones. Upon reinjection, this water would become mixed with the better quality water in the reinjection interval above the mining zone. This upward flow of saline water might be accelerated if the mine inflow water were injected into a deeper interval below the saline zone instead of the interval above the mine. The stratified aquifer-aquitard system present would tend to restrict such effects. In any case it would appear that the only significant point of entry for contaminants into the deep aquifers would be through reinjection wells. Since recharge of these aquifers from the surface is not believed to occur in the C-b area, surface pollutants would be confined to the shallow aquifer system. If massive unanticipated changes occur in the hydrological regime as a result of dewatering efforts, then this assumption may become invalid. Continued monitoring of water levels and mathematical simulation of the aquifer system will reveal such a change if it occurs.

If reinjection wells are the only mode of entry for pollutants, then it may be necessary only to monitor the quality of the reinjection stream to predict future conditions in the upper aquifer. The mine inflow stream will be the best measure of present conditions. No water quality observation wells would be needed. However, to provide continuity of observation for unforseen effects, (such as slow geochemical changes resulting from exposure of mine water to air) a network of deep observation wells surrounding the Tract will be maintained. These will include SG-1, SG-8, SG-17, SG-18, SG-19, SG-20, and SG-21.

The primary variable of interest with respect to deep water quality is salinity or total dissolved solids. This quantity is reflected in measurements of specific conductance. Periodic conductivity logs might be especially meaningful in those wells having long sections open to the formation. Significant changes in conductivity could flag the necessit" for additional tests. Mine inflow water and injection water will be analyzed regularly for such things as major ions, pH, and dissolved metals to determine whether acid mine drainage or similar phenomena are affecting the water.

3. Water Quantity Monitoring

Flow rates in surface springs and streams, water levels in alluvial aquifers and water levels and regional flows in the deep aquifers will all be affected by mine dewatering activities. The ultimate goal of collecting these data is to produce a mathematical model capable of accurately simulating the total hydrological regime surrounding Tract C-b. This model can then be used to calculate long-term effects and the results of such things as reinjection and mine abandonment. Since flow rates and water levels provide basic hydrologic information and are relatively easy and inexpensive to measure, all water monitoring sites established for any reason will include provision for such measurements. In addition, water levels will continue to be recorded in those presently existing wells which will not be used as water quality wells, until such time as the wells are abandoned because of mine advancement.

4. Baseline Values

Water quality and quantity measurements collected during the environmental baseline monitoring period have served to 1) indicate which parameters are important for further monitoring, 2) establish reference levels for measuring changes, and 3) influence development plans and procedures. As an example of the last item, the measurement of universally high fluoride levels in the deep aquifers led to the conclusion that direct discharge of mine inflow waters would be unacceptable, even though the level of total dissolved solids was less than had been expected. Comparison with the low fluoride levels in the springs then led to the hypothesis that the springs were not hydraulically connected to the deep aquifers. This in turn led to the suggestion that the mining zone could be dewatered and the water reinjected into the upper aquifer without having a major effect on the spring flows.

The Baseline Program was designed to cover all parameters of possible importance without knowing in advance what the values of those parameters might be. For instance, water quality monitoring was instituted on ephemeral streams without knowing what the flows might be. Since no significant flow has been observed on most of those streams during the baseline period, it is obvious that more extensive water quality monitoring is not justified. On the other hand, the Baseline Program has revealed certain deficiencies in earlier concepts of the Tract hydrology and a need for additional data in some areas. An example of this is the two-aquifer concept surrounding the mining zone. It was originally assumed that there were essentially two homogeneous deep aquifers separated by the Mahogany zone, and observation wells were completed in accordance with this concept. It is now known that the geology and hydrology is much more complex, with highly stratified aquifers and aquitards. Changes in the observation well configuration will be based on this new and more detailed information.

5. Monitoring Network

Although the monitoring network will be conceptually the same as that used during the baseline period, a number of changes will be made, with contractions in some areas and expansions in others. Contractions will be made in the monitoring of ephemeral surface streams and expansions in the number of shallow or alluvial aquifer monitoring wells. A summary of the various components of the monitoring network follows.

Figure VI C-1 is a map of the Tract showing the location of the principal surface facilities which will be constructed after approval of the DDP, as well as the location of surface water monitoring stations which would be included in the Monitoring Program. The Monitoring Program will utilize the existing stations which are included in the Baseline Program, with some stations deleted.

Sorghum Gulch, the site of the processed-shale pile and containment dam, will be monitored by existing station #09306036. The upstream Sorghum Gulch station, #09306033 will be removed, as it is in the area to be covered by the spent shale pile.

Cottonwood Gulch, which will drain storm runoff from surface facilities, ore storage piles, roads and other construction areas, will be monitored by station #09306039. Station #09306042 in the unnamed gulch west of Cottonwood will monitor the effects of road construction in that area.

These three gulches are dry gulches containing only intermittent water resulting from snow and storm runoff. Pollution of this water will be avoided or reduced by the policies included in the Oil and Hazardous Materials Spill Contingency Plan and the Erosion Control and Rehabilitation Plan (see Section V. L. and V. K., respectively), by the catchment dams in Sorghum Gulch, and by treatment facilities.

It is now known that Stewart Gulch and Willow Creek will not be affected by major construction and operation activities. However, these tributaries will continue to be monitored by station #09306028, #09306022, and #09306058. Stations #09306025 in upper West Fork Stewart and #09306015 in Middle Fork Stewart will be abandoned.

Piceance Creek will be monitored by existing stations #09306007 and #09306061 upstream and downstream of Tract C-b, respectively.

Existing station #09306052 at the mouth of Scandard Gulch will be used under all circumstances. Scandard Gulch is a potential location for a storage reservoir which may be used if mine dewatering flows require significant storage. Station #09306050 located near the southern tract boundary on Scandard Gulch will be left in place and used only if major operational activity takes place in the gulch.

Each of the foregoing stations will be operated continuously during the development and construction stages of activity. After plant operations have been in effect for some time and monitoring conditions are stable, the use of monitoring stations on Scandard and Stewart Gulches and Willow

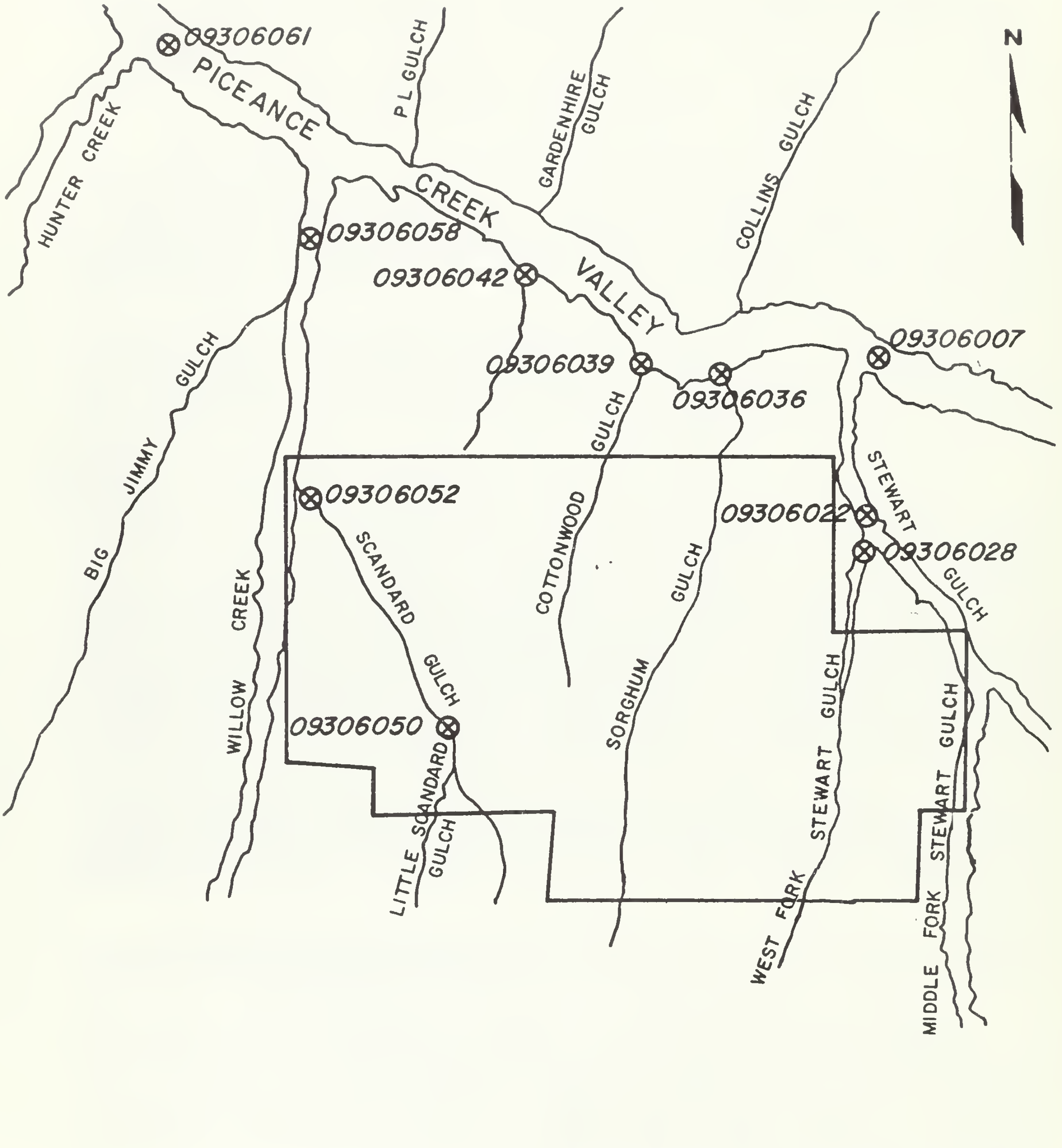


Figure VI C-1 TRACT C-b SURFACE WATER GAUGING STATIONS

Creek may be discontinued or they may be sampled on a less frequent schedule. Sampling parameters and schedules for other stations will be reviewed and modified as appropriate after approval by the Area Oil Shale Supervisor.

In summary, the following stations will be incorporated into the surface water monitoring program:

USGS No.	Station Location	Comment
09306007	Piceance Creek below Rio Blanco	operate during life of project
09306061	Piceance Creek at Hunter Creek	operate during life of project
09306042	Unnamed Gulch west of Cottonwood Gulch	used to monitor road construction activities
09306036	Sorghum Gulch at mouth	operate during life of project
09306039	Cottonwood Gulch at mouth	operate during life of project
09306022	Stewart Gulch	consider removal or reduction if data are stable after period of commercial operations
09306028	West Fork Stewart	consider removal or reduction if data are stable after period of commercial operations
09306052	Scandard Gulch at mouth	consider removal or reduction if data are stable after period of commercial operations
09306058	Willow Creek	consider removal or reduction if data are stable after period of commercial operations
09306050	Scandard Gulch upstream	use only if dam is constructed in Scandard Gulch

During development and construction, the monitoring stations will be sampled according to the schedule and parameters listed in Table VI C-1. As indicated above, both schedules and parameters will be reviewed for possible modification after the plant has been in stable operation for a period of time.

In addition to the laboratory analyses listed above, continuous measurements of temperature and specific conductance will be made at all stations. At the four major stations pH and dissolved oxygen will also be measured continuously and turbidity will be recorded continuously at the two Piceance Creek stations.

The deep well Monitoring Program is designed to monitor the following three major bedrock aquifer units:

- the Uinta aquifer, which includes the Uinta formation and the Parachute Creek section above the top of the Four Senators zone

- the Upper Parachute Creek aquifer, which encompasses the interval between the Four Senators zone and the top of the Mahogany zone

Table VI C-1 SURFACE WATER ANALYTICAL PROGRAM

A. Data to be Collected Monthly

1. Alkalinity
2. Ammonia
3. Boron
4. Calcium
5. Fluoride
6. Iron
7. Magnesium
8. Potassium
9. Silica
10. Sodium
11. Bicarbonate
12. Carbonate
13. Chloride
14. Total dissolved solids
15. Kjeldahl nitrogen
16. Nitrate & nitrite
17. Arsenic
18. Manganese
19. Phosphate
20. Dissolved organic carbon
21. Suspended organic carbon
22. Sulfate
23. Sediment
24. Precipitation

B. Data to be Collected Quarterly from Major Stations

1. Aluminum
2. Bromine
3. Barium
4. Cadmium
5. Copper
6. Chromium
7. Oil & grease
8. Lead
9. Lithium
10. Mercury
11. Molybdenum
12. Selenium
13. Sulfide
14. Zinc
15. Cyanide
16. Strontium
17. Fecal coliform
18. Fecal streptococcus
19. Total coliform
20. COD
21. BOD
22. Phenols
23. Complete element scan
24. Gross alpha radiation. If greater than 4 pcl, then analyze for radium 226 and natural uranium.
25. Gross beta radiation. If greater than 100 pcl, then analyze for strontium 90 and cesium 137.

C. Data to be Collected Twice Yearly

1. MBAS (Methylene Blue Active Substance)
2. Sediment pesticides
3. Sediment herbicides
4. Organic fractionation into:
    a. hydrophobic acids, bases & neutrals
    b. hydrophilic acids, bases & neutrals

- the Lower Parachute Creek aquifer, which includes the interval from the base of the Mahogany zone to the top of the unleached zone

The Monitoring Program will use most of the present wells on the Tract. In general, modifications will be made in the shallow tubing strings so that the sections above and below the Four Senators zone can be monitored separately. Lower tubing strings will not be altered significantly. Any new wells will be evaluated for possible inclusion in the Monitoring Program.

In addition, as a part of the extended program, all present alluvial wells, except Well A-13, will continue to be monitored as in the past. Well A-13 will be in the processed-shale disposal area. It will be used to monitor conditions below the shale pile by extending the casing upward as the waste pile grows. Following is a listing of the wells that will be recompleted as part of the development monitoring program, and the type of recompletion presently contemplated.

- wells SG-19, TG-71-1, TG-71-2, SG-1, and CB-2B will be recompleted so the Uinta aquifer can be monitored as a separate unit

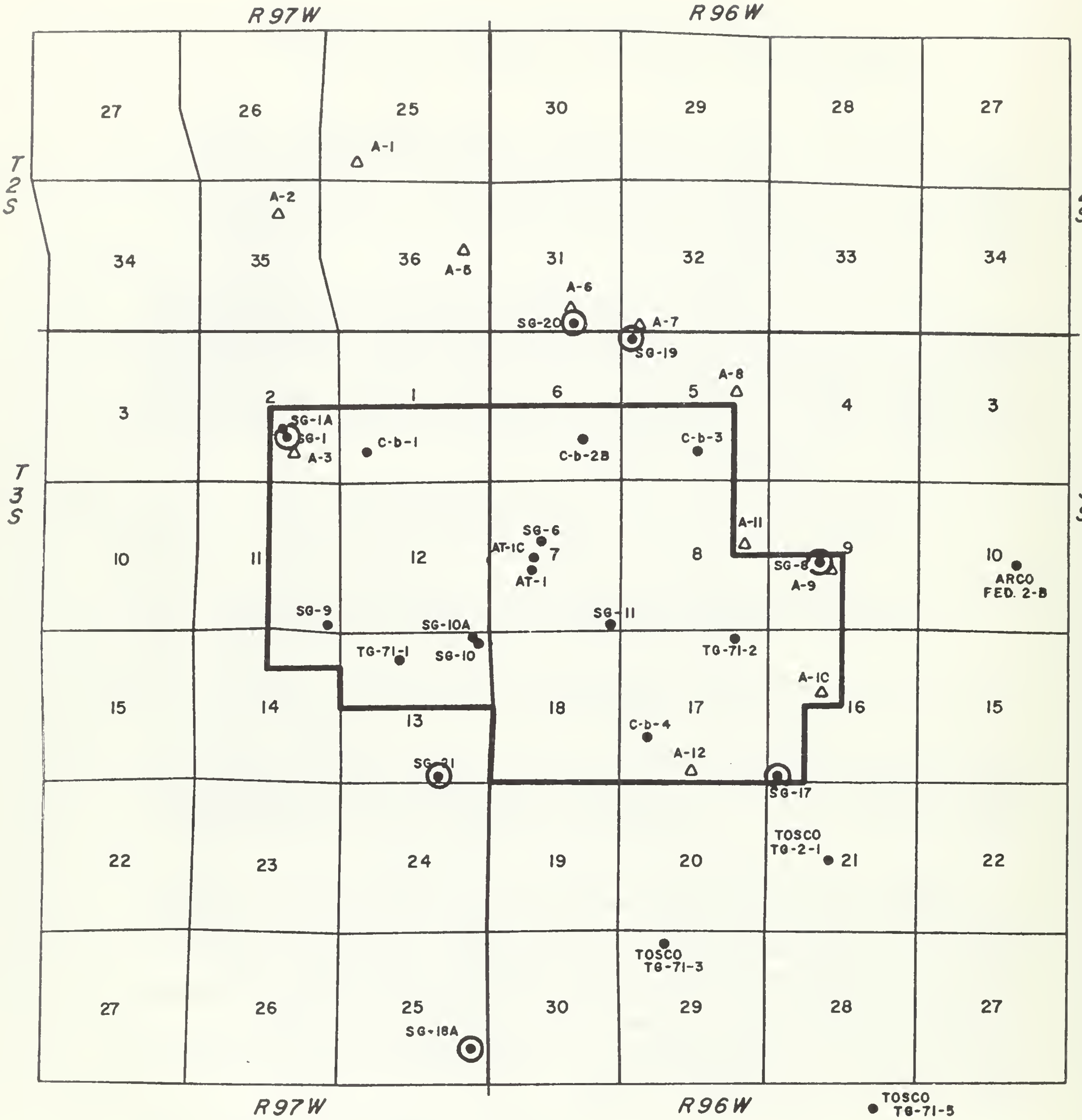
- wells SG-18A, SG-20, and SG-21 will be reworked so that the Uinta and Upper Parachute Creek aquifers are mutually isolated and can be monitored separately in the same hole

- well SG-1A will be recompleted so that the Upper Parachute Creek aquifer can be monitored as a separate unit

Figure VI C-2 shows the locations of existing wells which will be used in the initial phase of the mine development monitoring program. Water level observations will be continued in all these wells. Sampling and chemical analyses will be performed only for those wells noted earlier.

Depending upon the results of Phase I shaft-sinking program, it may be necessary to recomplete those wells in the area that would be open to both the Uinta and Upper Parachute Creek aquifers. The purpose of this would be to prevent water from the Uinta aquifer from moving through the well bore down-hole and into the Upper Parachute Creek aquifer, and eventually into the mine. It also may be necessary to add Uinta formation and upper zone Parachute Creek monitoring wells as the mine-front advances in order to record changes in water levels and predict potential changes in water inflow into the mine. Some of these wells would most likely be drilled from within the mine.

Initially, monitoring samples from both alluvial wells and deep wells will be taken on the same schedule used in the second-year Baseline Program. As more information and a better understanding of the nature of the aquifers are obtained, the program will be reevaluated and modified as appropriate. The frequency of sampling and the number of constituents monitored may be increased or decreased with the approval of the Area Oil Shale Supervisor.



LEGEND

△ ALLUVIAL WELLS

● OTHERS

⊙ SAMPLING WELL

Table VI C-2 GROUND WATER MONITORING WELLS

6. Waste Pile and Impoundment Monitoring

The physical stability of the worked-out mine and the spent shale pile will determine the degree of impact on hydrological parameters. Continuous monitoring of these components is advisable in order to anticipate adverse impacts and take corrective action if possible. Moisture levels in the spent shale pile will be determined periodically by neutron log analysis. Pipes will be placed at several locations and extended upward as the waste pile grows. A neutron probe lowered into the pipe can then be used for determination of moisture profiles. In this way it can be ascertained whether moisture movement through the pile is occurring.

Any leachate resulting from precipitation percolating through the toe or edges of the pile will be quantified by means of a water gauging station and/or water level measurements in the catchment reservoir. Samples of any leachate will be analyzed for chemical quality. Siltation rates in all impoundments will be determined on an annual basis.

7. Frequency of Monitoring

Under natural conditions the quality of both surface and ground water will change slowly but perceptibly with time. Rates of change are related to rates of flow, which are determined by hydro-geologic considerations. Some groundwater basins unaffected by man show annual fluctuations in quality produced by seasonal variations in precipitation, aquifer recharge, water table levels, and discharge rates. The influence of man and industrial development is usually marked as an increase in the amplitude of annual changes in quality along with a progressive decrease in average quality. The desirable frequency for monitoring water quality depends upon its sensitivity to natural and man-made influences and upon the pace of industrial development. Where effluents are being discharged directly and are subject to rapid changes in composition, continuous or daily or weekly sampling would be appropriate. To characterize changes in near-surface aquifers, a bimonthly or quarterly frequency should be adequate. Monitoring of deep aquifers in the region of maximum influence should be done semi-annually while outlying wells can be checked annually. Monitoring near or downstream from a known potential pollution source might require a frequency on the order of semi-monthly, monthly or bimonthly. Wherever and whenever a pollution hazard develops, such as a toxic constituent in the ground water within a discharge area, the frequency of monitoring must be increased in accordance with the importance or seriousness of the situation.

8. Quality Assurance

A quality assurance program for the hydrological data will consist of several parts. Regular field inspections of operating stations and continuous monitoring instruments is necessary to assure reliable operation. Periodic calibration of field instruments is a part of this procedure.

Duplicate analyses of samples by different laboratories is the customary procedure for maintaining a check on the reliability of laboratory analyses. This will continue to be applied periodically.

All laboratory procedures will be subject to re-evaluation in the light of advances in the state of the art. As an example, if a suitable method for detecting trace concentrations of polycyclic organic matter should be developed, this parameter would be added to the analytical schedule.

Probably the most effective quality control procedure is a standard policy of reviewing all data as soon as it is available, with an eye toward past history on the same parameter.

9. Dynamic Modifications to Program

A Hydrological Monitoring Program should contain provisions for periodic review and modifications as justified by changing conditions or by additional interpretation of the record. A convenient format for this review is provided by the required annual report. Types of changes which might be suggested are, for example, more frequent analyses for specific constituents related to development activities, less frequent analyses of constituents found to be stable with time, or additional shallow monitoring wells if significant changes in water quality are observed in the alluvial aquifer. The monitoring network devised for this plan is comprehensive and versatile enough to detect any significant water quality effects. If such changes occur, however, it may be desirable to increase the monitoring coverage in the region of change. This may be desirable in order to more precisely quantify the effects, or to map the source, or to reduce the lag time when studying the effectiveness of corrective actions.

Some modifications may be suggested at the completion of the two-year Baseline Program. While it is not expected that results will be appreciably different from those obtained during the first year, there is a chance that additional data may change the picture somewhat. For example, it could be that additional water level data and a refinement of the analysis would either confirm or disprove the hypothesis of a hydraulic connection between the springs and deep aquifers. The emphasis on monitoring of the different geologic units above the mine zone might be shifted accordingly.

A second way in which completion of the two-year baseline might suggest changes in the Hydrological Monitoring Program is through the development of ecological interrelationships. This effort may suggest that certain water quality parameters are of more critical importance than is presently perceived. Additional coverage in some areas, or different analytical techniques might be required.

D. Air Quality and Meteorology

1. Introduction and Scope

The Air Quality Monitoring Program encompasses mine development

(Phase I), plant construction (Phase II), plant operations (Phase III), and post operations (Phase IV). In-mine, process, and stack emission sources, as well as ambient conditions, will be monitored. Because of the extended time period that the Monitoring Program covers and the changing development and operational phases, air quality monitoring must be regarded as dynamic. Number and location of sites, quantities sampled, sampling techniques, and sampling frequencies are subject to change with time inasmuch as it is a scientifically designed program the results of which are subject to on-going analyses and cumulative judgments.

A monitoring network overview and functions are discussed first, followed by ambient monitoring, source emissions monitoring, and data treatment and reporting.

2. Monitoring Network Overview and Functions

The functions or objectives of the air quality monitoring network are summarized on Table VI D-1. Functions designated "ALL" apply to all phases of the Monitoring Program. It is to be understood that this program attempts to address air quality impacts which are predicted before the fact and those which occur but weren't predicted. Pollution control system effectiveness is determined to assess its adequacy and provide feedback in a timely fashion. A major feature of this network is the real-time system status and cathode ray tube display provided relative to air quality at one centralized location to furnish the network overview for sound air quality management.

3. Ambient Monitoring

The proposed air quality and meteorological ambient monitoring sites are shown on Figures VI D-1 and VI D-2 for program phases. Although specific monitoring sites are proposed on these figures, it is recognized that locations of the sites are subject to change as additional data from the second year of baseline and further modeling results become available; therefore, criteria and guidelines for site selection are as important as the proposed sites themselves. Twelve such criteria for site selection are shown on Table VI D-2. Utilizing these criteria proposed monitoring sites and associated parameters are presented on Table VI D-3. Associated parameters include the following:

Meteorology (wind speed and direction, wind direction variance, temperature, relative humidity, precipitation, solar insolation, and acoustic echo)

Particulates (including trace element analysis via use of special filters or other improved techniques)

All of the above are sampled continuously except for particulates which are sampled for 24-hours every sixth day. An area-wide visibility check utilizing photographic photometry will be made annually once per program phase to establish long-term trends from the baseline, utilizing the

Table VI D-1

FUNCTIONS AND OBJECTIVES OF THE AIR QUALITY MONITORING NETWORK

Phase	Network Functions and Objectives
All	Monitor ambient environmental changes from baseline in dynamic fashion and identification of parameters of max. and min. change. Provide abiotic-variable inputs for ecosystem studies. Provide checks of compliance with all governmental regulations and with lease. Provide real-time system status and display related to air quality and meteorology at one centralized location.
Phase I - Mine Development (start 6 mo. prior to this phase)	I.1 Monitor process-related emissions (mine and ore pile). I.2 Monitor mine dust and fume control system effectiveness. I.3 Pollution and safety alerts. I.4 Provide feedback and design-insight for production mine dust and fume control system. I.5 Monitor fugitive emissions and control effectiveness. I.6 Provide area-wide visibility check.
Phase II Plant Construction	Continue functions I.1 to I.6 above. II.1 Monitor fugitive emissions to provide early control effectiveness feedback. II.2 Monitor transportation system-related effects on air quality in Piceance Creek corridor to assist in scheduling of traffic, if required.
Phase III Plant Operation	Continue I.1 to I.6; II.1, II.2. III.1 Provide pollution episode warning alert. III.2 Monitor process-related and stack emissions continuously, where possible and practicable. III.3 Provide inputs for real-time active control system for SO_2 and particulates. (tentative) III.4 Provide real-time pollutant diffusion modeling and display. III.5 Pinpoint those geographical sites containing biological indicator species most likely to be impacted by pollutant concentrations.
Phase IV - Post Operation	IV.1 Monitor fugitive emissions and control effectiveness associated with post operations.

baseline site 060, in Hunter Creek. Sampling over one season at a frequency identical to that of the baseline will be undertaken; additional seasonal sampling may be considered pending the amount of seasonal variation in visibility indicated in the baseline summary report. Also extra annual sampling will be considered for the plant operational phase. A quality assurance program will be mutually worked out with the Area Oil Shale Supervisor to assure that all sampling procedures are entirely adequate and accurate.

Baseline stations 021 and 022 in Piceance Creek are recommended to be discontinued since flow there has been demonstrated to follow the general direction of the creek-bed and can be monitored adequately by continuing operation of the heavily-instrumented station 020 through the plant operations phase. Station 020 is expected to be exposed to heavier concentrations from vehicular exhaust than 021. Station 024 with added instrumentation will continue operation at the expected on-tract point of maximum concentration for the south-southwest predominant wind direction from the plateau. The tower site and station 023, coincide with the center of the proposed plant complex, so will need to be moved to a recommended new location, designated 025 on Figure VI D-1. The trailer previously at station 022 will be moved to the present 023 site, so that data from sites 023 and 025 may be correlated in Phases I and II. Station 025 will be upwind of plant-induced emissions practically all the time and therefore may be considered to be monitoring ambient conditions. Station 026 will serve a dual role - practically all the time it will be serving as an ambient reference since predominant wind direction on the plateau is SSW; however, one potentially worst-case condition from plant-induced emissions occurs for north winds, so in this case it will monitor these downwind concentrations at their estimated maximum point.

Particulate-only stations include stations 051 and 054, downwind and upwind respectively of the processed shale pile, stations 052 and 053 to monitor ventilation dust from the two ventilation shafts, and station 055 on Collins Overlook across Piceance Creek which is an estimated point of high concentrations on high ground in proximity to the Tract.

As mentioned in Table VI D-1 in Phase III, real-time diffusion modeling results may be displayed (on request). These pollution isopleths may be overlaid on previously developed geophysical maps of indicator species (for soils, animal habitats, vegetation and aquatics) to pinpoint locations of such species exposed to the higher levels of airborne pollutants, long-term doses and short-term dose rate.

4. Source Emissions Monitoring

Applicable Federal and State of Colorado air standards must be complied with and have previously been reviewed in Section V A-2. All source emissions monitoring will be designed to be consistent with such regulations.

Principal emissions from the mine itself fall into categories of mine dust and fumes. Dust arises more-or-less continuously from the truck

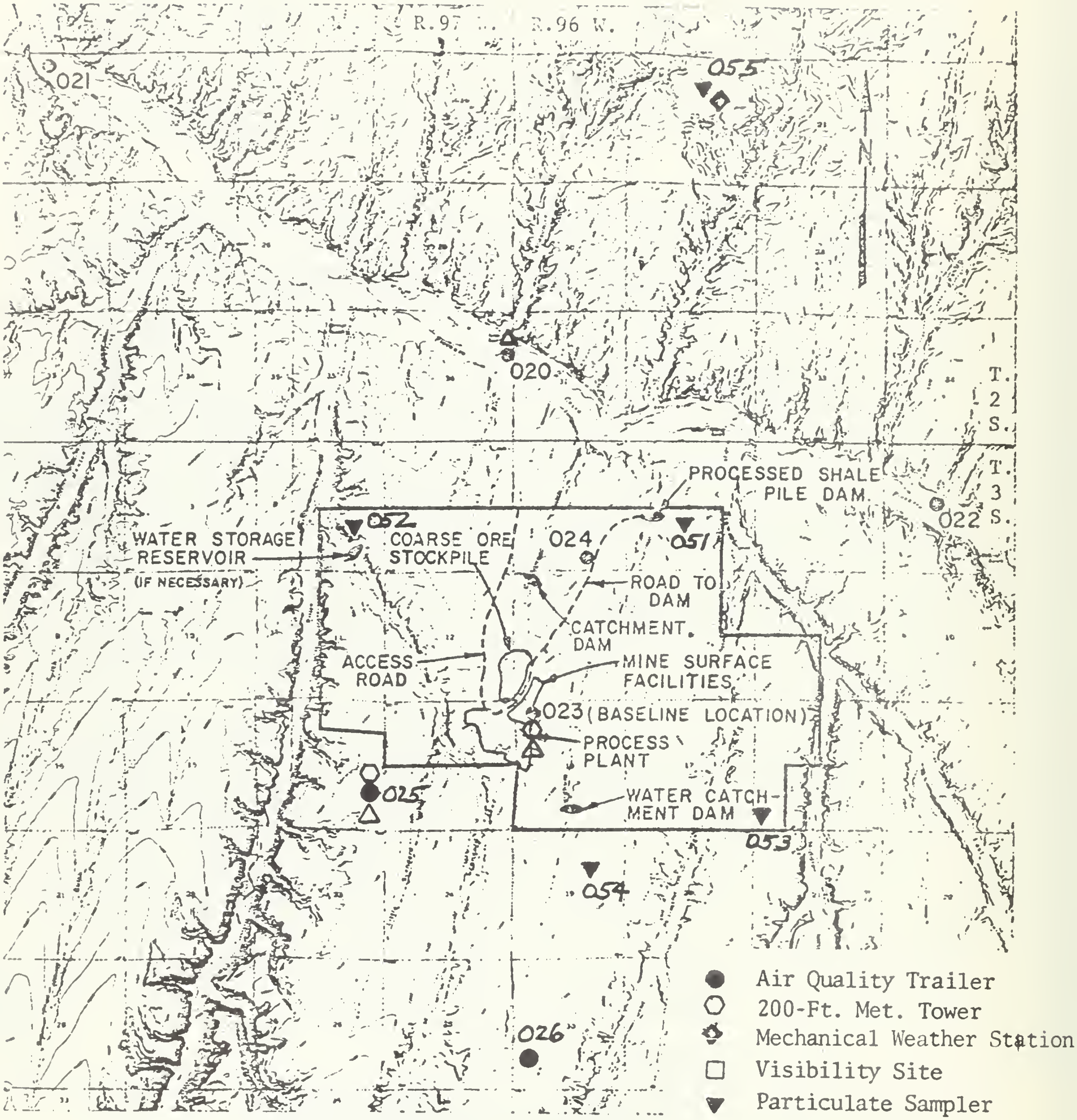
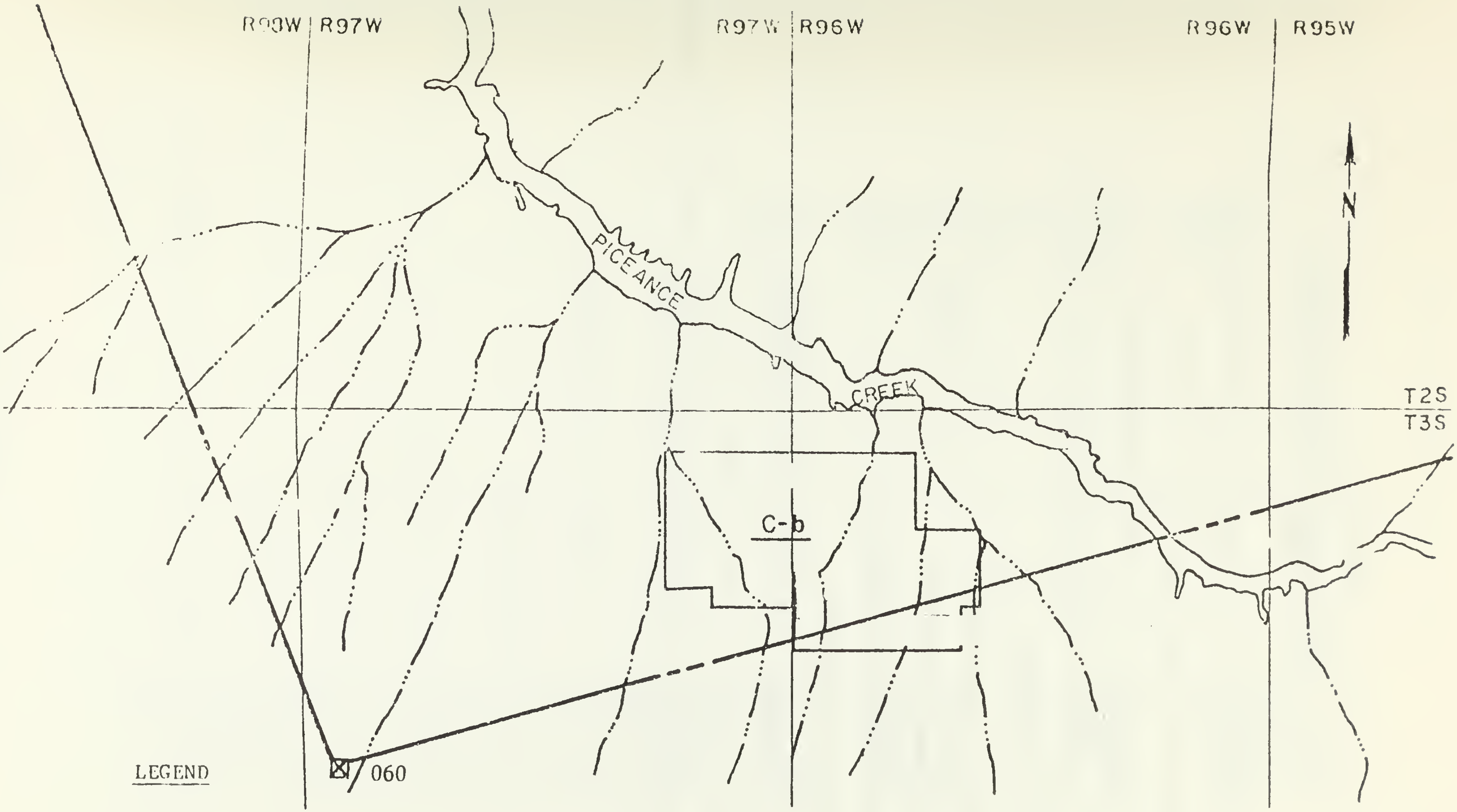


Figure VI D-1 PROPOSED AIR QUALITY MONITORING NETWORK



LEGEND

⊠ Visibility Site-Lines Show Sector Covered

Figure VI D-2 VISIBILITY SITE LOCATION

Table VI D-2

CRITERIA AND GUIDELINES FOR LOCATING MONITORS

C1. Give priority to areas of highest pollutant concentration.

C2. Give attention to any densely populated areas.

C3. Reflect the quality of the air entering the area.

C4. Reflect projected population growth areas, where applicable.

C5. Provide site security.

C6. Provide site accessibility.

C7. Provide power availability.

C8. Provide housing of the samplers.

C9. Meet legal requirements.

C10. Locate on boundary of the Tract, where applicable.

C11. Provide best "coverage" for a region.

C12. Give attention to national park, refuge wilderness "entrance" (pollution) values, where applicable.

Table VI D 3

PROPOSED AIR QUALITY AND METEOROLOGICAL MONITORING SITES* AND ASSOCIATED PARAMETERS

Site Location	Parameters Measured: Baseline	Monitoring[(1)] Phase I, Mine Development	Monitoring Phase II, Plant Const.	Monitoring Phase III, Plant Ops.	Monitoring Phase IV, Post Ops.	Rationale
020	Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	→	→	→		Downwind, down valley concentrations from plant and travel corridor
021	Meteorology Particulates; SO_2, H_2S					Flow patterns follow creek, established in baseline
022	Meteorology Particulates; SO_2, H_2S					Same as 021
023	Tower Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	Meteorology Particulates; SO_2, H_2S	→			Tower & station need relocation from center of plant complex so terminate before Phase III
024	Meteorology Particulates; SO_2, H_2S	Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	→	→		Estimated point of max. concentration from plant for predominant wind direction
025[(2)]		Tower Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	→	→		New tower location; ambient conditions, Sta. 025 correlated with 023 in Phases I and II
026		Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	→	→		Estimated point of max. concentrations for N. wind direction, ambient for S. wind
051				Particulates	→	Downwind monitor for dust from processed shale pile
052		Particulates	→	→	→	Monitor ventilation dust from mine
053		Particulates	→	→	→	Same as 052
054				Particulates	→	Upwind monitor for dust from processed shale pile
055				Particulates		An estimated point of max. concentration for particulates
060	Area-wide Visibility	→	→	→	→	One annual check per phase to establish long term trends

* In-mine, process, and stack monitoring sites not shown.
(1) Monitoring start-up, six month prior to Phase I.
(2) Estimated locations (here and below) subject to mutual concurrence between Lessee and Area Oil Shale Supervisor.

loading, scaling, drilling, charging and bolting operations and intermittantly from blasting in three spikes per day. The reader is referred to Section II F-4 - Mine Development Programs, for discussions on gas sampling, air quality and ventilation. The Monitoring Program will be concerned with effectiveness of the dust suppression techniques associated with wetting of haulage roads and muck piles and water sprays at truck dumping and primary crushing operations. Mine fumes are expected to include nitrogen oxides, aldehydes, hydrocarbons and carbon monoxide from the truck diesel engines. Blasting produces NO_2 and CO. Levels of these constituents will be monitored at strategic locations in the mine and at the vent shaft early in the mining phase to see if continued monitoring at these locations is justified in the operational phase. Continuous monitoring of CO inside the exhaust portals will be accomplished and coupled to a remote alarm system for CO warning.

On one sample process train, it is anticipated that 50-100 sampling ports or stations will be installed for continuous monitoring, where feasible, subject to concurrence of Lessee and Area Oil Shale Supervisor.

It is recognized that a permit to construct the oil shale facility is required from the Air Pollution Control Division of the State of Colorado Board of Health, approximately 18 months prior to the start of such construction (our Phase II) and that a new source performance review is to be conducted by the EPA for compliance with potential new source performance standards for the oil industry. This review includes new source performance tests which are required within 60 days after achieving maximum production rate but no later than 180 days after initial plant start-up. EPA reference methods will be utilized during the source performance tests. Such review also requires demonstration that adequate air pollution source control system devices have been installed and are adequately monitored. The existing new performance standards for fossil-fuel fired steam generating plants require, under certain circumstances, continuous emissions monitoring for opacity with regard to particulates and continuous monitoring for sulfur dioxide, nitrogen oxides, and either oxygen or carbon dioxide. Existing new performance standards for petroleum refineries require continuous opacity monitoring for particulates, continuous monitoring for sulfur dioxide, and monitoring for carbon monoxide. It is expected that the potential new source performance standards for oil shale will require continuous monitoring of all stacks, typified by a combination of all of the above constituents, and possibly for total hydrocarbons.

As previously mentioned in Table VI D-1, major objectives of emissions monitoring are to insure compliance with standards, to monitor control system effectiveness, and to provide suitable real-time displays and warning-alerts at one centralized location, and to (tentatively) provide inputs for active control of SO_2 and particulates.

It is to be noted that particulate samplers shown on Figure VI D-1 and Table VI D-3 will also serve as fugitive emissions monitors. It is expected that several discrete tests on the processed shale pile be conducted to assess control effectiveness of the shale moisturizing technique early in the operational phase. Additional tests may be required (in consultation with AOSS) relative to trace element, hydrogen sulfide, total hydrocarbons, and ammonia emissions from the spent shale pile.

It is recognized the carcinogens may be a problem in the operational phase emissions. Further research is required to identify the need for their monitoring.

5. Data Treatment and Reporting

Air quality data (except particulates) and meteorological data are obtained continuously during the baseline period. Five-minute samples are averaged to obtain 1-hour, 3-hour, 24-hour, monthly, and annual averages for comparison with standards requiring specified averaging times. Ambient monitoring will continue to report data for these averaging periods. As a minimum, 5-minute values will be part of the real-time display.

Emissions monitoring sampling will comply with regulations. It is expressly noted that reports to the EPA are presently required within 60 days for any 3-hour periods for which SO_2 or NO_x exceed the new source performance standards for fossil-fueled steam generating plants and any 6-hour period for which SO_2 standards are exceeded for petroleum refineries. It is expected similar reports will be required for the oil shale industry.

Meteorological data will be available along with an air pollution diffusion model in the operational phase to predict ground level pollution isopleths, useful for potential pollution episode conditions.

An Annual Report will be prepared each year throughout the Monitoring Program, containing all aspects of the Air Quality and Meteorological Monitoring Program. It will address program objectives and functions as stated herein and analyses related thereto.

E. Biological Monitoring

1. Introduction and Scope

Objectives: The principal aim of the biological monitoring program is the continued evaluation of conditions in Tract C-b systems. This effort is concerned with the identification of changes in system parameters, the identification of causes for change, and the mitigation of such effects where appropriate. The individual studies will focus on the collection of data on important biotic and abiotic parameters elucidated through analysis of baseline data. The systems approach used will be based on testing of hypotheses generated for each parameter selected.

Rationale: The selection of key parameters shown to be important through analysis of baseline data will allow critical focus on areas of the Tract C-b system which are important to system function. The hypothesis testing approach more affectively assures that significant changes will be detected through proper and appropriately rigorous analytical data comparisons.

Hypotheses: The general hypotheses to be tested are null hypotheses, as follows. Specific hypotheses are also given for each parameter to be studied.

Pre-operation Phase:

H_o: No differences among treatment and control sites under natural conditions

H_o: No difference between years at any given site under natural conditions

H_o: No difference between treatment sites, or between control sites in any given year under natural conditions

Construction Phase:

H_o: No difference between baseline and construction conditions at any given site as a result of construction operations

H_o: No correlation between site-to-site differences in community structure and emission gradients established by air quality samples

Plant Operation Phase:

H_o: No change in measured preoperational differences established between treatment and control sites as a result of retort plant operations

H_o: No difference between baseline and operational conditions at any given site as a result of retort plant operations

H_o: No correlation between site-to-site differences in community structure and emission gradients established by air quality samples.

Experimental Design: The biological monitoring program will be initiated in phases which will correspond to the level of development intensity (see hypotheses section). The basic design of the program is the study of control (non-affected) sites and treatment (potentially affected) sites. Parameters studied will be selected for their relative importance to the system and will be subjected to statistical testing when possible. The program outlined here is subject to change upon final interpretation of baseline data in order to allow appropriate changes which might be indicated due to a greater understanding of species importance and ecological interrelationships on Tract C-b. There are two major parts of the biological program: 1) long-term monitoring studies which will continue to collect data on important parts of the Tract C-b system, and 2) system dependent monitoring studies which will examine specific problem areas which may arise as a result of oil shale development. Long-term monitoring will address itself to the evaluation of changes from baseline conditions in order to determine their significance and assign causes. System dependent monitoring will provide a more detailed inspection of functional alterations in individuals and larger system components and attempt to determine the significance of the alterations as well as their potential causes. System dependent monitoring will also be further developed in the event that currently unforseen impacts or alterations arise. While some methods for testing in the system development phase are presented herein, actual methods to be selected will depend on the latest acceptable methods available at the time a system dependent monitoring phase is required. The parameters chosen for use in the monitoring program have been selected for their ability to show significant changes in the Tract C-b system. Parameters are both quantitative and qualitative, although emphasis has been placed on the selection of quantitative parameters because they lend themselves to statistical comparisons.

Methods: Parameters have been selected by placing importance values on them through the use of a matrix, (Table VI E-1). The importance valuations are based on ecological, economic, and political factors, as well as testability of the parameter in a statistical sense. The sampling intensity assigned to each parameter is determined by evaluating its variability. A highly variable parameter requires a more intensive sampling effort than a more stable parameter. So-called non-dynamic parameters are sampled only intensively enough to detect changes.

Sampling locations have been determined by their proximity to development activities (Figure VI E-1). Control sites have been established in areas which are not expected to be affected either directly (construction) or indirectly (pollution) by development activities. Treatment sites have been established in areas which are adjacent to either construction/operation sites and which will be subjected to the effects of construction and plant emissions.

Specific experimental design and methods are discussed below for each monitoring parameter. A summary of the long-term monitoring program is given in Table VI E-2.

Data Treatment: Wherever possible data collected from the monitoring program will be subjected to statistical comparisons. Statistical comparisons to be used are indicated under the discussion for each parameter selected.

2. Fauna

a. Big Game - Long-term Monitoring

Objectives: Big game refers primarily to mule deer, since they are the only large mammal in the C-b study area. Monitoring of mule deer will show the significance of Tract C-b to their survival. This will be accomplished through the following parameters: 1) shrub production/utilization, 2) deer-days use, 3) meadow distributions 4) mortality, and 5) age-class. Intensive studies of mule deer are justified since deer are 1) a major herbivore of ecological importance, and 2) a game species of economic importance. In addition, they are vulnerable to impact from development activities, road kill, and increased hunting pressure. Study transects and sample sizes are based on adequate samples obtained during baseline.

Table VI E-1 SUITABILITY OF STATISTICAL COMPARISON

Importance Value (Ecological, Economical, Political)	High 1.	Med. 2.	Low 3.	Not Suitable 4.
	A-1	A-2	A-3	A-4
	B-1	B-2	B-3	B-4
	C-1	C-2	C-3	C-4
	D-1	D-2	D-3	D-4

Codes	Comments
A-1, 2, B-1, 2	Important to very important population parameters and can use sophisticated statistical methods - T-test, analysis of variance, co-variance, multi=variate, multiple regression, etc.
A-3, B-3	Important to very important but data is of nature (count, ranked, or observed) suitable only for non-parametric statistics such as Chi Square.
A-4, B-4	Important to very important, but not suitable for statistical analysis - use best professional judgement. Observation data and interpretation by expert.
C-1, 2	Of low importance - use low cost routine statistics analysis if desired or disregard.
C-3	Low importance - use Chi Square or disregard.
C-4, D-4, 4	Of no importance - disregard.

TABLE VI E-2 LONG-TERM MONITORING PARAMETER FOR BIOLOGICAL MONITORING PROGRAM

Parameter	Sampling Period and/or Intensity
Fauna: Big Game-	
Srub Production/Utilization	Twice per year in chained pinyon-juniper rangelands and pinyon-juniper woodlands
Deer Days Use	Twice per year, as above
Deer Migration	Mid-September through Mid-May along roadway between Rio Blanco and Little Hills
Deer Mortality	Once each year in spring in lateral draws and bottomland sagebrush
Deer Age-Class Composition	Twice each year in fall and spring in meadows adjacent to Piceance Creek
Medium-Sized Mammals-	
Coyote Abundance	Once per year along 15 miles of road south of Tract C-b
Lagomorph Abundance	Twice per year in chained pinyon-juniper rangelands and pinyon-juniper woodlands
Small Mammals:	
Population Densities, Reproductive Condition, Biomass, and Foodhabits	Twice per year in early and late summer in pinyon-juniper rangelands, pinyon-juniper woodlands and bottomalnd hay meadows
Avifauna-	
Songbird Population Densities, Relative Abundance, and Species Composition	Once each year in pinyon-juniper rangelands and pinyon-juniper woodlands
Mourning Dove Densities and Relative Abundance	Once each year in pinyon-juniper rangelands and pinyon-juniper woodlands
Raptor Census, Nesting Sites	Once each year during the appropriate breeding season along a transect established from Tract C-b eastward
Aquatic Ecology:	
Fish Populations	Quarterly in aquatic habitats in the vicinity of Tract C-b
Benthos	Quarterly, as above
Periphyton	Quarterly, as above
Water Quality	Quarterly, as above
Terrestrial Vegetation:	
Community Structure and Composition	Three year rotational sampling in each of the six extensive study plots established in the four major vegetation types
Herbaceous Productivity	Three times each year in six locations established in the four major vegetation types
Sublethal Biochemistry	Three times each year during May, July, and September in the extensive study plots
General Vegetation Condition (Photogrammetry)	Every three to five years over the Tract and the one-mile surrounding study area
Plant-Soil Water Relations	Each month during the growing season (plant) Each month during the year (soil)
Revegetation:	
Community Structure and Composition	Once each year during mid-June at each disturbed site or processed shale disposal study site
Herbaceous Productivity	Once each year during peak season at each disturbed site or processed shale disposal study site

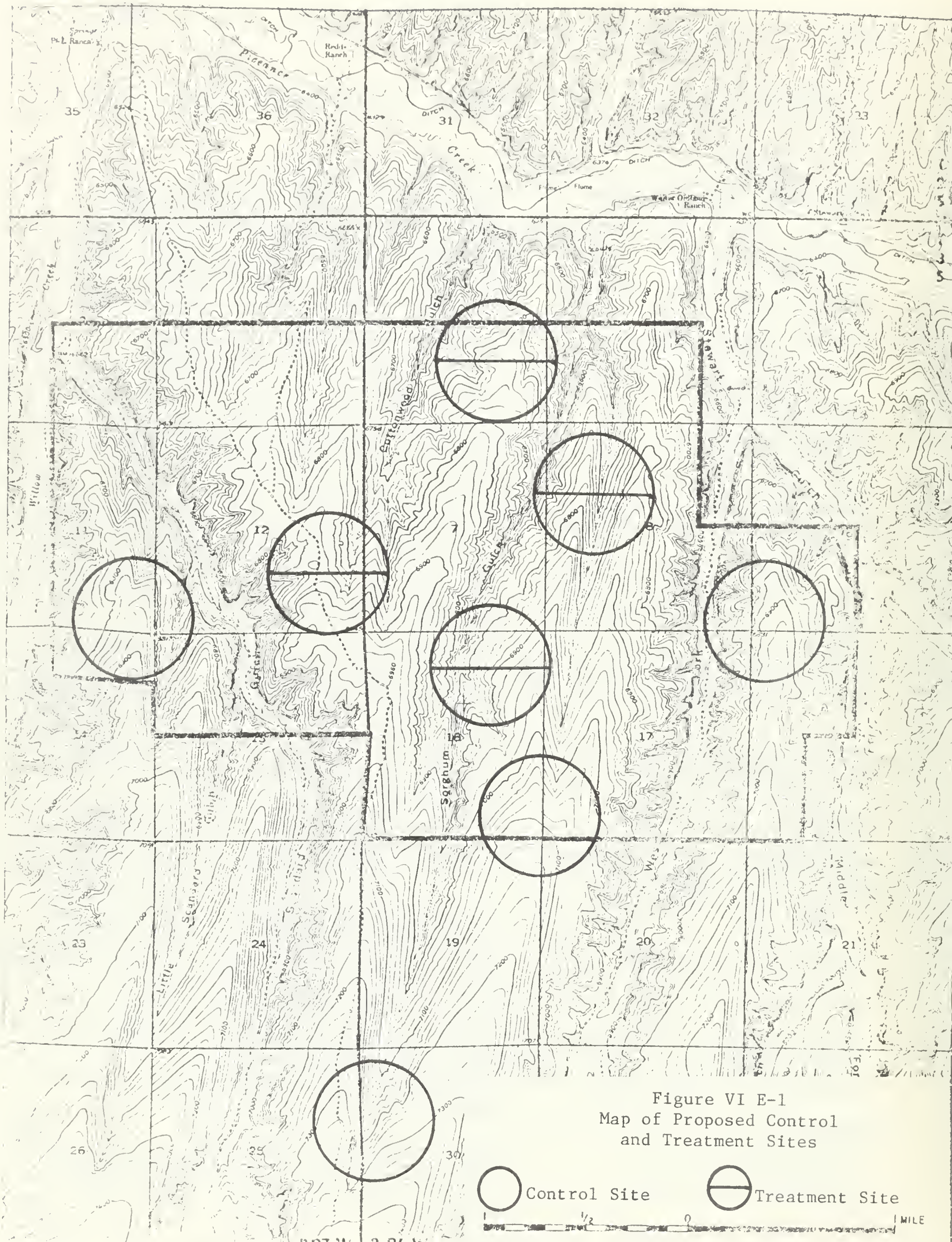


Figure VI E-1
Map of Proposed Control
and Treatment Sites

Parameter 1 - Shrub production/utilization

Rationale: This parameter is designed to evaluate browse available to deer and actual quantities consumed. Productivity of browse species may change from year to year due to climatic variation, and quantity expressed as biomass may be altered by development.

Hypothesis:

H_o: No difference between weights of forage consumed a) between chained pinyon-juniper rangeland vs. pinyon-juniper woodland, and b) over time.

Experimental Design: Sampling will be done in two habitat types, chained pinyon-juniper rangeland and pinyon-juniper woodland, since these represent most of the Tract C-b habitat. There will be two sample times, in the spring to assess production and in the fall to measure utilization.

Methods: Methods will consist of clipping new shoots in the fall. This will be followed by clipping the remainder of the new shoot growth in the spring, subsequent to winter browsing by deer. Six transects of 20 plots each will be placed in the chained rangeland and in the pinyon-juniper woodland, with locations near development areas and at control sites. A double sampling technique will be employed if the above method does not provide an adequate sample.

Data Treatment: Results will likely be amenable to parametric statistical treatment (eg. t-test); if not, parametric tests are available (eg. Mann-Whitney, Zar, 1974). The level of resolution for rejection of the null hypothesis will be: standard error within 25% of the mean, 90% of the time.

Parameter 2 - Deer-days use

Rationale: The importance of the Tract C-b area to deer can be evaluated by an estimate of deer-days use, measured by pellet-group counts.

Hypothesis:

H_o: No difference in deer days use a) between chained pinyon-juniper rangeland vs. pinyon-juniper woodland and b) over time.

Experimental Design: Sampling would occur along the same twelve transects used above and at the same times, spring and fall. Twenty plots in each transect have proved to provide an adequate sample. Additionally, transects will be placed to the east and west of the Tract to detect shifts in distribution due to development-related activities.

Methods: Deer pellet-groups will be counted in the permanent plots. These plots will be raked free of pellets in the fall and pellet groups counted in the spring.

Data Treatment: The same treatment will be used for this parameter as for parameter 1, with the same level of confidence.

Parameter 3 - Meadow distributions and migration times

Rationale: This study will show distribution of deer along the Piceance Creek meadows and will indicate their times of migration. Changes in distributional patterns may account for displacement due to disturbance.

Hypothesis:

H_o: No differences in meadow distributions compared to baseline studies

Experimental Design: Sampling will occur each year beginning in mid-September and ending in mid-May. The sample area is the 36-mile stretch of road between Rio Blanco and Little Hills. Times of migration will be based on the occurrence and disappearance of deer in the meadows. Road-killed deer will also be recorded and tabulated for one-mile intervals.

Methods: Deer will be counted from a vehicle during evenings and recorded per one-mile interval.

Data Treatment: Non-parametric procedures would be used to compare changes in observed distributions.

Parameter 4 - Deer mortality

Rationale: This parameter will indicate changes in the relative magnitude of deer mortailty and various causes of death. Baseline studies have shown winter kills to be largely restricted to two habitat types, lateral draws and bottomland sagebrush.

Hypothesis:

H_o: No difference in deer mortality on a year-to-year basis.

Experimental Design: Sampling will be done once each year, in spring, and will be done in two habitats, lateral draws and bottomland sagebrush adjacent to agricultural meadows.

Methods: Deer carcasses, representing winter kill of the current winter, will be counted in permanent plots. Carcasses will be separated as fawns and adults. An estimate of the number of deer killed by hunters will be obtained by hunter interview. Deer mandibles will be collected for future analysis for fluorosis.

Data Treatment: Non-parametric tests will be used, such as a log-likelihood G test (Zar, 1974).

Parameter 5 - Age-class composition

Rationale: Composition of the deer herd enables evaluation of the magnitude of fawn mortality that has occurred during spring and summer while deer were on summer range. Estimates taken in spring permit evaluation of fawn mortality that had occurred while deer are on winter range in the

C-b area.

Hypothesis:

H_o: No difference in age class composition on a year-to-year basis.

Experimental Design: Sampling would occur in fall and in spring. Locations of sampling would lie in meadows immediately north of the Tract.

Methods: Deer are observed and recorded as numbers of fawns to adults. Sex ratio estimates will also be obtained.

Data Treatment: Non-parametric statistics.

b. Big Game - System Dependent Monitoring

Objectives: The objective is to identify cause and effect in observed changes in mule deer parameters. If deviation from baseline deer mortality is detected, further investigation would be warranted.

Parameter 1 - Necropsy of deer carcasses

Rationale: Necropsy of deer carcasses would be justified if toxins are identified in plant tissues that could be transferred to deer. If fluorosis is suspected, deer bones could be examined.

Hypothesis:

H_o: No significant levels of toxic substances in deer carcasses.

Experimental Design: Collect deer carcasses from lateral draws and bottomland sagebrush sites.

Methods: Mule deer tissue and bones will be analyzed by standard laboratory methods for evidence of high concentrations of toxic substances, such as fluoride.

Data Treatment: Data would be analyzed and compared with known tissue levels of toxic substances identified.

c. Medium-sized Mammals - Long-term Monitoring

Objectives: The medium-sized mammals to be treated here are the two most significant to Tract C-b, coyotes and lagomorphs (cottontails and jackrabbits). Monitoring these animal groups will show important cycles and trends, which will contribute to the understanding of predators and prey species in the Tract C-b ecosystem.

Parameter 1 - Coyote abundance

Rationale: Coyotes are a major predator on Tract and, therefore, of significance ecologically. They are of political and economic interest to the public, with strongly negative and positive supporters.

Hypothesis:

H_o: No difference in relative abundance of coyotes from year to year.

Experimental Design: Sampling will be done each year in September along a 15-mile length of road to the south of Tract C-b.

Methods: Scent-post survey (Linhart and Knowlton, 1975) is an accepted method currently used by the U. S. Fish and Wildlife Service.

Data Treatment: Non-parametric tests will be used to show comparisons of indices of abundance between years. Tract C-b data can be compared to other data (using 20 lines) elsewhere in Colorado and throughout 17 western states.

Parameter 2 - Lagomorph abundance

Rationale: Cottontails and jackrabbits provide an important prey base for raptorial birds and coyotes. The cottontail is classified as a game species, but presently it is of little economic value in the vicinity of Tract C-b, however, at some future date its status could change.

Hypothesis:

H_o: No difference in lagomorph abundance a) between chained pinyon-juniper rangeland vs. pinyon-juniper woodland and b) over time.

Experimental Design: Sampling would occur concurrently and along the same transects that are used for deer pellet counts. Number of plots sampled will be adjusted to provide an adequate sample size.

Methods: Pellets will be cleaned from plots in the fall and recorded as present or absent from plots in spring. Data is in pellets/area over time.

Data Treatment: Non-parametric tests will be used, such as the log-likelihood G test.

d. Medium-sized Mammals - System Dependent Monitoring

Objectives: In the event a suspected impact is identified, as determined by rejection of the null hypothesis, change from baseline conditions or some suspected impact, additional monitoring would identify seriousness of impact. Selected histological investigations can provide supportive information for assessing air pollution stress to vertebrate population. The desert cottontail is an appropriate species to select for experimentation, because of their local occurrence and importance as a prey species.

Rationale: Histology of organs could be implemented to determine effects of accumulation of particulate matter, gaseous emissions and trace elements. If stress is created in the animals by these pollutants, two studies may be used to measure response to stress: the immune response and the general adaptation syndrome (GAS). The ratio of blood cell types would indicate a change in the immune system as a whole. Also, examination of spleen and peripheral lymph nodes, which function in the immune response of an animal, will reveal changes in activity level, hence degree of stress experienced by the animal.

Hypothesis:

H_o: No significant response to stress as the result of pollutant emissions.

Experimental Design: Cottontails will be collected at each of four primary monitoring and control sites during May, July and September.

Methods: At least 20 live trappings would be made, about three individuals per site. Ten cc of blood is collected from an ear vein. A tatooed ear would identify the individual if recaptured. All animals would be released after examination.

Stress, as reflected in blood cell differentials, would be expressed as the ratio of numbers of lymphocytes (PMN) to the total number of cells.

Data Treatment: If baseline data indicate a PMN total cell ratio of 5:100 and that increases to 25:100, the relative percent increase would be 500%, a pathological change resulting from "x" degrees of stress.

e. Small Mammals - Long-term Monitoring

Objectives: Small mammals are both a prey base for predators and a major primary consumer. Monitoring changes in selected small mammal parameters will therefore aid in assessing the effects of pollutants which may become concentrated in primary producers and should also reflect the effects of man-induced disturbance or pollutants before populations of larger animals are greatly affected. Parameters to be monitored include those which have been measured in baseline studies and can be compared to baseline information or between treatment and control sites by statistically valid methods.

Parameter 1 - Small mammal population densities, reproductive condition, biomass, and food habits.

Rationale: Changes in small mammal densities, species composition and food habits will reflect gross environmental perturbations while changes in biomass of populations and reproductive condition may indicate environmental perturbation or pollutants present at low levels.

Hypotheses:

H_o: No significant difference in population densities, reproductive conditions, species composition, or food habits at a given location in year one and in year x of the monitoring program.

H_o: No significant difference between treatment sites and control sites in a given year for small mammal population densities, reproductive condition, species composition, or food habits.

Experimental Design: To adequately measure small mammal parameters, sampling should be conducted during June and August for each year. This sampling frequency will insure that small mammal populations are assessed at the beginning and termination of their most active season, which represents periods of peak reproductive activity and maximum densities.

Monitoring small mammal densities, reproductive conditions, biomass, food habits and species composition will be carried out in control areas not expected to be affected by oil shale development, in areas which will be influenced by retort emissions, and in areas being disturbed by Tract activities. These sites will be chosen from four control sites and four sites which are exposed to retort emissions. (Figure VI E-1). Sites will be chosen to represent chained pinyon-juniper, pinyon-juniper, and bottomland hay meadows, which are three major habitats in the Tract C-b study area and support significant small mammal populations. Control sites will provide information on natural variations, such as large scale annual fluctuations in small mammal densities, that occurs regardless of man-induced effects. Such information can be used to correct monitoring data at the monitoring sites for these natural variations.

Methods: Small mammal density estimates will be obtained by live trapping and mark-release methods which were utilized during baseline studies. A sampling effort of five to seven consecutive days would be conducted, using 100 traps per grid.

Animals which are captured in live traps will be weighed and checked for reproduction conditions. Food habits will be studied by snare trapping and stomach analysis at locations adjacent to live trapping grids.

Data Treatment: Statistical tests which will be utilized to compare control plot data against experimental plots, i.e., plots expected to be affected by shale oil development, include:

Population Density	-	Chi square
Species Composition	-	Shannon-Weiner Species Diversity Indices
Reproductive Condition	-	Chi square
Biomass	-	One way analysis of variance
Food Habits	-	Difference and Proportions Dixon and Wassey (1969)

Statistical tests which will be utilized to compare sets of data between year one and year x at a given site are the same as above.

Statistical tests which will be utilized to compare data sets among years and between sites include:

Biomass	-	Two way analysis of variance
Density	-	Same as above
Reproductive Condition	-	G Test - Sokal and Rohlf (1969)
Food Habits	-	Same as above
Species Composition	-	Same as above

f. Small Mammals - System Dependent Monitoring

Objectives: If significant differences are observed for biomass densities, species composition, or reproductive condition between control grids and grids within the influence of retort emissions, selected system dependent variables will be investigated. In addition, if it is established that contaminants have become concentrated in primary producers at a significant level (to be determined in vegetation investigations) the selected system dependent variables will be investigated.

Parameter 1 - General adaptation syndrome

Rationale: System dependent variables for small mammals that will be studied are described as the General Adaptation Syndrome (GAS). The GAS is the physiologic response system designed to aid the animal in reacting quickly in emergency situations. If animal populations are stressed as a result of air pollution or increased human disturbance associated with plant or retorting operation, the GAS will be triggered and will produce specific physiological changes that will act as indicators of environmental impact. Specific changes include altered histology of the adrenals and lymph tissue, increases in adrenal gland weight, and slightly changed blood chemistry.

Hypotheses:

H_o: No significant difference in physiological responses related to the GAS between control plots and treatment plots.

H_o: No significant difference in physiological responses related to the GAS between year one and year x at a given site.

Experimental Design: At each monitoring site, five individuals would be collected during May, July, and September. Methodology presented by McArn, et al. (1974) indicates that this sampling intensity will be sufficient to identify man-induced responses to measured parameters.

Design: At each monitoring site, five individuals would be collected during May, July, and September. Methodology presented by McArn, et al. (1974) indicates that this sampling intensity will be sufficient to identify man-induced responses to measured parameters.

Deer mice, least chipmunks, and voles are important prey for numerous predators, abundant and widely distributed on Tract C-b. For these reasons, they are considered key species and will be utilized in studies of the GAS and system dependent variables.

Methods: In the field, adrenal glands, spleen, and a few peripheral lymph nodes would be collected, placed in isotonic solution and transported to the laboratory. In the lab, all organs would be weighed on a Mettler balance, preserved in 10% formalin, and transported to a diagnostic laboratory for sectioning, staining, and examination by a qualified histopathologist. The histopathologist would rate the histological status of each organ examined on the following scale: 1) very hyperactive or hypertrophic, 2) moderate hypertrophy or hyperactivity, 3) slight hypertrophy or hyperactivity, 4) suspicious hypertrophy or hyperactivity, 5) normal tissue, 6) hypotrophic or hypoactive tissue.

Data Treatment: Differences between observed and expected physiological parameters associated with the GAS will be evaluated by use of the chi-square or other non-parametric procedure.

g. Avifauna - Long-term Monitoring

Objectives: To detect changes in avifauna populations at the population level. Analysis of data from regular monitoring procedures will form the basis for initiating system dependent monitoring programs.

Parameter 1 - Songbird-like population density, relative abundance, species composition (as evaluated by species diversity indices).

Rationale: Two levels of monitoring activities would detect changes in avifauna. The first level of study is focused on communities or populations of birds. It is anticipated that some effects of habitat disturbance and increased human activity associated with development of Tract C-b will occur at the population densities and relative abundance of the more prominent species that can be tracked over time. Also, certain species may be more amenable to man-made impacts while others are not. This might be noted in a change in species composition within a community, as reflected by indices of species diversity.

Hypotheses:

H_o: No difference between population density, relative abundance, and species composition in year one, and population density, relative abundance and species composition in year x of monitoring, at a given plot.

H_o: No difference between population density, relative abundance, and species composition at control plots, and population density, relative abundance and species composition at treatment monitoring plots during year x of monitoring.

Experimental Design: Control plots in areas not expected to be affected by oil shale development, treatment plots which will be influenced by retort emissions, and treatment plots adjacent to areas being disturbed by Tract construction will be monitored. As presently conceived there will be six primary treatment monitoring plots, each of which is exposed to a different level of retort plant emissions; four treatment plots immediately contiguous with construction activities; and four control plots in nonaffected areas. Control plots will provide information on the natural variation that occurs regardless of man-induced effects. Such information can be used to correct monitoring data at the primary site for these natural variations.

To reduce natural variability between plots and thus improve the sensitivity of the proposed program, half the plots will be established in pinyon-juniper vegetation exhibiting a shrub understory, and half will be located in the chained pinyon-juniper rangeland vegetation type. These are the predominant vegetative types found in the Tract C-b study area.

Data collected during the inventory/baseline phase of the C-b Shale Oil Project constitute a strong justification for limiting the bulk of avian monitoring to the breeding season. Section V E 2b (Efficacy of General Data) of the Annual Summary and Trends Report indicates reasons why monitoring in the Piceance Basin during the winter and migration periods would require extraordinary efforts and still would generally lead to data of questionable utility. Thus, for a majority of birds, monitoring will be confined to the first two weeks in June of each year, at each of the control and treatment plots. To provide necessary census replication for statistical analysis, censuses will be conducted in quadruplicate at each of the plots.

Methods: Species and population size will be determined by the strip transect method, adjusting observed numbers by the procedures being employed in the inventory/baseline program. Censuses will be conducted during periods of peak daily activities, generally within 3.5 hours of sunrise and sunset. Specific procedures used in this technique have appeared in past reports.

Data Treatment: After three years of monitoring, statistical analyses of variance will be applied to replicated census data from each of the plots to estimate variation within, as well as between, sampling plots, and to determine if census replication can be decreased. Null hypothesis will be tested annually. Each null hypothesis will be rejected if the standard error of the mean does not fall within 25% of the mean, with 80% confidence limits.

Parameter 2 - Effectiveness of the strip transect technique.

Rationale: During the first 18 months of the inventory/baseline program, certain difficulties were perceived in application of the strip-transect procedures to the Tract C-b study area because of variable habitats, linearly arranged habitat units, and other factors. During the first year, a number of modifications were made to fine-tune the field and laboratory methodologies to the area. The strip-transect method was originally chosen over plot map procedures because of its markedly increased efficiency. Although we believe the modified strip transect approach being used at the present time has corrected the problems we discovered during earlier analyses, specific comparisons of the two methodologies at selected pinyon-juniper sites will be made early in the monitoring program.

Hypothesis:

H_0: No difference between population estimates obtained by strip transect method and spot-mapping method occurs at control plots in year x of monitoring.

Experimental Design: Control sites monitored using strip transect technique will be monitored by spot-mapping at the same time and frequency for the first three years of monitoring. If the null hypothesis is not rejected the strip transect technique will be considered a valid estimate of avian population densities and the spot-mapping technique will be discontinued. Should these comparisons indicate disparate census results, spot mapping procedures would be instituted for long-term monitoring if the extent of differences is such that the additional costs of the less efficient spot mapping procedure could be justified.

Methods: A standard spot mapping technique will be used, (1944) along with the strip transect method described in the inventory/baseline program. Both census techniques will be conducted during periods of peak daily activities, generally within 3.5 hours of sunrise and sunset.

Data Treatment: A statistical analysis of variance and standard errors will be applied to replicated census data for principal species from each of the control sites to estimate variation within the strip transects and the spot-mapping plots, as well as variation between the spot-mapping plots and strip transects.

The null hypothesis will be rejected if the tests do not meet 80% confidence limits with a standard error of 25% of the mean.

Parameter 3 - Upland gamebirds - mourning dove population densities and relative abundance.

Rationale: Field observations during the first year's data accumulation program indicate that sage grouse and blue grouse populations are so sparse on and near the Tract that no reasonable Monitoring Program can be designed to determine changes over time; thus, a Monitoring Program is not warranted. The mourning dove is the only upland gamebird present in sufficient numbers to be monitored. Due to the political and economic importance of upland gamebirds, the monitoring program related to the mourning dove is discussed separately here.

Hypotheses:

H_0: No difference between mourning dove population density and relative abundance in year one and mourning dove population density and relative abundance in year x of monitoring.

H_o: No difference between mourning dove population density and relative abundance at control plots and mourning dove population density and relative abundance at treatment plots during year x of monitoring.

Experimental Design: Identical to the presentation of the Experimental Design section for the songbird-like population parameter.

Methods: Identical to the presentation of the Methodology section for the songbird-like population parameter.

Data Treatment: Identical to the presentation of the data treatment of the density estimates and relative abundance indices for the songbird-like population parameter.

Parameter 4 - Raptor activity on Tract is important to monitor on a continuing basis because of importance of raptors in the food chain, their apparent vulnerability to man's activities, their political value as threatened or endangered species, and their aesthetic appeal.

Hypothesis:

H_o: No drastic change in raptor utilization of Tract C-b area is observed during monitoring program.

Experimental Design: Trends in utilization of Tract C-b and immediately contiguous habitats by raptors will be established each breeding season by determining the percent of known nest sites which are occupied by nesting pairs and comparing with data obtained during the baseline period and with data obtained on raptor nests located outside the sphere of development influence. Nest occupancy checks will be made during mid-March (great horned owls), late-April (red-tailed hawks, eagles), and early June (accipiters, American kestrels, harriers). During the early-March and early-June checks, the relative abundance of winter and summer resident raptors hunting over the Tract and in the control area chosen for the next occupancy studies will be monitored.

The census route will be a linear route beginning on Tract and leading east along Piceance Creek. This route was chosen in an attempt to sample an area having fairly homogenous habitats and topographical features. The meadow habitat along Piceance Creek represents an important winter and summer hunting area for raptors and it will constitute the major portion of the census route. This census route was also established as a method to generate data on impact trends of some raptor species along a distance gradient away from Tract activities. This technique may be particularly useful for those species such as the American kestrel that have small territories and are present in large enough numbers to provide detectable trends. Measurements of raptors in areas of the Tract is also important because many of the species that utilize the Tract area are wide-ranging species (e.g., golden eagles, red-tailed hawks) and individuals that utilize the Tract may not be sampled if a limited portion of their range is sampled.

The route census in the control plot will also be linear, and will traverse an area similar to the area traversed by the Tract route.

Methods: All nests located during baseline studies on Tract C-b and new nests located on Tract C-b and the control plot subsequent to initiation of monitoring will be checked annually for occupancy.

The relative abundance of winter and summer resident raptors hunting over the Tract and in the control area will be determined by travelling a standardized road census. The census route will be driven on three consecutive mornings, and all raptors observed will be recorded as to location, species, and sex and age, as possible.

Data Treatment:

Nest Occupancy - Professional judgement and possibly a non-parametric proportion test will be used to analyze nest occupancy data.

Road counts - Plotting techniques and professional judgement will be used to determine trends of distance from the Tract and numbers of individuals of a given species observed. Professional judgement and possibly a non-parametric technique will be used in analysis of road count data between the control route and Tract route.

h. Avifauna - System dependent monitoring

Objectives: When the null hypothesis is rejected, a change in the avian community is inferred. If the cause of change could be correlated with development activities, rather than with natural fluctuation through one of the statistical methods described for Parameter 1, system-dependent evaluation tactics will be invoked.

Parameter 1 - Avian metabolic parameters - histology of organisms and response to stress.

Rationale: Subsequent to retorting startup, if a population null hypothesis is rejected, or if emissions concentrations exceed values indicated in the literature as being harmful to individual birds, a more thorough investigation of the avian community will be undertaken.

Data obtained during a System-dependent Monitoring Plan would provide a clearer understanding of oil shale development impacts, particularly those associated with air pollutants on local bird populations, and would facilitate the development and evaluation of appropriate mitigative measures. Initiation of these programs would be contingent on identification of a suspected impact, as determined by a significant ($p=0.20$) change from baseline conditions.

The effects of retort plant emissions may be much more subtle than are impacts caused by gross modifications of habitat, and may require monitoring procedures which differ markedly from those aimed at the "cruder" state variables such as population density and species composition. Relatively long-term chronic pollution challenge could ultimately foster complex changes in ecosystem dynamics. Impending changes at the populational or ecosystem levels might originate as cellular perturbations in individuals; thus, the contemplated system-dependent component of the monitoring program centers on histopathological analyses.

Although the exact mechanisms by which air pollutants affect birds is not entirely clear, a variety of effects (e.g., changes in organ activity, altered blood cell composition, and blocked respiratory exchange) may result from SO_2, CO, NO_x particulates, and other airborne emissions blowdown. These alterations in physiology of the individuals that comprise a population may be reflected in altered survival and reproductive rates and ultimately in reduced population levels. Selected histological investigations can thus provide supportive information for assessing air pollution stress.

The literature defines several metabolic parameters as good indicators of air pollution stress. These include the histology of selected organs and the response to stress (e.g., the immune response and weight and histology of adrenal glands and associated lymph tissue). Two parameters could be studied here as follows:

(1) Histology of Organs

A potential result of serious air pollution is the accumulation of particulate matter, gaseous emissions, and trace elements in vital organs of the body. There has been considerable recent research in the histopathological changes in lung tissue of birds resulting from air pollutant challenge. These studies document two effects which can be directly attributed to SO_2, NO_x, CO, and/or particulate air pollution: 1) histological changes in respiratory tissue, and 2) abnormal infiltration and accumulation of defensive cells such as macrophages and lymphocytes in the alveoli of the lung.

(2) Histological Changes in Respiratory Tissue

Changes in respiratory system histology in response to SO_2 and particulate pollutants have been documented.

A thickening of long air-block barriers at the alveolar level, lung tissue inflammation and proliferation, and suppressed cilia activity are measurable changes. A major conclusion of studies performed to date is that birds as a group serve as excellent indicators of air pollution stress.

(3) Infiltration of Macrophages and Lymphocytes

McArn, et al (1974), elucidated the changes in lung histopathology of English sparrows in the polluted Davis-Sacramento, California area. They found an abundance of black granules inside the many macrophages present at the alveolar level in the lung. Local infiltrations of lymphocytes were also observed in the same general area. Lung tissue from control birds taken from an unpolluted coastal area near Bodega Bay, California, revealed only occasional macrophages and no lymphocytic infiltrations. It appears that heavy particulate air pollution in conjunction with SO_2 suppression of normal ciliary and mucociliary action, caused the secondary body defense cells (macrophages and lymphocytes) to infiltrate the lungs and remove the foreign particulates, those that have been engulfed by the macrophage. Suppression of mucociliary and ciliary action would tend to increase lung susceptibility to particulate invasions as the cilia fulfill an important "sweeping" action to clean nasal pathways of foreign material and to secrete mucous to entrap particulate matter and aid in its disposal. In short, changes in lung histology have been found to be an effective monitoring tool for detecting the presence of particulate pollution.

(4) Response to Stress

This section deals with those systems that react predictably to stress. These systems comprise the secondary defense to SO_2, NO_x, CO, particulate matter, and other pollutants. Included in this group of systems that allow an animal to cope with stress and in doing so, leave a stress signature, are the immune response and the general adaptation syndrome (GAS). These systems can be monitored with relative ease and provide a sensitive indicator for external stresses, as described by Siegel.

(5) The Immune Response

The purpose of this system is to identify, intercept, and destroy any invading foreign particles such as viruses, bacteria, dust, or inorganic elements. It is possible to detect changes in the activity level of this system and therefore, the degree of stress, by monitoring the relative number of defensive blood cell types (i.e., macrophages and lymphocytes). A change in the work load of the immune system as a whole will immediately be reflected in the blood cell differential (the ratio of blood cell types). Also, histologic examination of discreet organs involved in the immune response (e.g., spleen and peripheral lymph nodes), will reveal changes in the activity level of those organs and therefore the degree of stress experienced by the animal before suppression of the immune response (e.g., the death of the animal) can be reflected on the population level.

(6) The General Adaptation Syndrome (GAS)

The GAS is the physiologic response system designed to aid the animal in reacting quickly in emergency situations. Since its initial description, investigators have identified the biochemical, physiological, and pathological changes produced by stress. If animal populations are stressed as a result of air pollution or increased human activity associated with plant or retorting operations, the GAS will be triggered and will produce specific physiological changes that will act as indicators of environmental impact. Specific changes include altered histology and the adrenals and lymph tissue, increases in adrenal gland weight, and slightly changed blood chemistry. All of the effects are reflected in the blood chemistry and adrenal weight of the individual long after cessation of the causative stress.

Either the Immune Response or the General Adaptation Syndrome would be measured in the event that system-dependent monitoring of birds becomes necessary. The specific choice will depend upon the state-of-art at the future decision point.

Hypothesis:

H_o: No difference between the histopathological condition of individuals of indicator species A collected at control plots and the histopathological condition of individuals of indicator species A at treatment plots during year x of monitoring.

Experimental Design: At each monitoring and control plot, five individuals of the indicator species associated with the appropriate habitat type would be collected during May, July, and September. Methodology presented by McArn, et al (1974) indicates that this sampling intensity will be sufficient to identify man-induced responses to measured parameters.

The avian indicator species selected for consideration at the pinyon-juniper woodland plots are the mountain chickadee and house finch. One or both of these species could be analyzed. These species were chosen primarily due to their status as abundant, year-round permanent residents of the pinyon-juniper woodlands on Tract C-b. The degree of resolution of oil shale-related impacts is dependent on minimizing the input of off-Tract impacts on an indicator species. This is facilitated by selecting as indicator species those that are permanent residents of the Tract, when possible.

Another criterion used in the selection of the mountain chickadee and house finch is the positions of these species in the trophic structure of Tract C-b is terrestrial ecosystem. The avian primary consumer level is represented by the house finch, a species that is by and large an herbivore, and the secondary consumer level is represented by the mountain chickadee, an insectivore.

The criteria of residency used in selection of the pinyon-juniper woodland indicator species is not applicable to the selection of indicator species at the chained pinyon-juniper rangeland sites. Because of harsh winter conditions, few individuals inhabit the chained pinyon-juniper rangeland through the year. The important avian users of this habitat are all summer residents; therefore, summer residents, the green-tailed towhee and Brewer's sparrow, were chosen as indicator species for purposes of monitoring. Although due to their migratory status, resolution of oil-shale related impacts on these avian species cannot be determined as accurately as for the pinyon-juniper woodland indicator species, the chained rangeland is a dominant habitat on Tract and any changes within the avian community in this habitat need to be identified to as fine a degree of resolution as possible.

Methods: After collection of an individual the lungs would be removed and placed in a 10 percent formalin preservative for shipment to a diagnostic laboratory for histological sectioning, staining, and examination by a qualified histopathologist. Stress of particulate matter inhalation would be expressed as the number of granule-laden macrophages per 10 tertiary bronchi. The degree of stress would be expressed as the relative percent increase (RPI) in the number of macrophages. For example, if the number of granule-laden macrophages per 10 tertiary bronchi is 10 in baseline determination and it increases to 50 per 10 tertiary bronchi, the RPI would be 500%.

Takemoto, et al (1974) defined a classification as to degree of epithelial cell proliferation in the lung, which included five classes: 1) heavy fibrous proliferation (partly from granulation), 2) moderate proliferation, 3) slight proliferation, 4) suspicisous proliferation, and 5) no proliferation. Takemoto considered lungs in classes 1) and 2) as being indicative of relatively bad pollution. The same rating system would be employed here.

In the field, adrenal glands, spleen, and a few peripheral lymph nodes would be collected, placed in an isotonic solution, and transported in the laboratory. In the laboratory, all organs would be weighed on a Mettler balance, then preserved in 10 percent formalin, and transported to a diagnostic laboratory for sectioning, staining, and examination by a qualified histopathologist. The histopathologist would rate the histological status of each organ examined on the following scale: 1) very hyperactive or hypertrophic, 2) moderate hypertrophy or hyperactivity, 3) slight hypertrophy or hyperactivity, 4) suspicious hypertrophy or hyperactivity, 5) normal tissue or 6) hypotrophic or hypoactive tissue.

Data Treatment: An appropriate non-parametric analysis of variance technique will be used in analyzing the data collected within a year at control plots and experimental sites. This technique will be applied separately to data collected on the stress of particulate matter, degree of epithelial cell proliferation in the lung, histopathological status of the adrenal glands, the spleen, and the peripheral lymph nodes.

3. Aquatic Ecology

a. Aquatic Ecology - Long-term monitoring

Objectives: The aspects of the aquatic program to be continued through the Monitoring Program are: fish, benthos, periphyton, and water quality. Although there are no continually-flowing streams on the Tract, aquatic ecosystems could be secondarily affected by mining and development on Tract. Fish, benthos, and periphyton could be "indicators" of a significant change in stream characteristics downstream from oil shale development. The specific changes should be apparent in water quality parameters. Statistical comparisons to baseline data would show alterations of baseline conditions and indicate, through correlation coefficients, the severity of the impact so that timely corrections of detrimental conditions could be made.

Aquatic monitoring would be conducted on a quarterly basis, sampling all parameters concurrently during established quarterly sampling times.

Parameter 1 - Fish

Rationale: Fish will be examined during monitoring because of their importance as the top level of the food chain and because of the interest in game fish in the streams.

Hypothesis:

H_O: No difference between fish populations during development and the baseline period due to mine operations.

Experimental Design:

The number of sampling stations will be reduced from the baseline studies. Sampling periods will be scheduled to include the brook trout, spawning period (October-November) and mountain sucker and speckled dace spawning (May-July). Although the mountain sucker is not a game fish, its occurrence in Piceance Basin is unique in Colorado. Sampling in January will examine the over-wintering conditions. Spring sampling will occur during the peak run-off period. It is possible that the number of sampling periods could be reduced after the first two to five years of monitoring, perhaps to two per year. System state variables to be measured are: condition factor, growth, reproduction, and age and year class structure. Tagging studies would continue to examine migration and growth.

Natural fluctuations occur in various fish year classes. Species live for four or five years or longer in the Tract C-b vicinity. Analysis of long-term trends (three to four years) in the Monitoring Program, condition factor, and age and year class structure of the population should enable a determination of any changes caused by mining activities. These would be correlated with water quality data and the other aspects of the Aquatic Monitoring Program.

Methods: The present electrofishing methods for fish collections would continue with the same basic information being gathered as during baseline studies: estimates of population size, length, weight, age, condition, and reproductive condition.

Data Treatment: Statistical analyses used to examine any possible changes in the fish population in the Tract vicinity could include some nonparametric procedures and chi-square tests along with analysis of variance and correlation.

Parameter 2 - Benthos

Rationale: The benthic species are important as grazers in the stream community as well as providing food for carnivorous species. They are significant indicators of changes in the aquatic habitat. There are a number of organisms indicative of good or poor water quality conditions and qualitative data will give some indication of changes in water quality.

Hypothesis:

H_o: No change or degradation in benthic communities during mine development as compared with baseline conditions.

Experimental Design: Year to year comparisons will be made to determine significant fluctuations. Benthic invertebrates have a short life cycle and undergo seasonal fluctuations with generally reduced levels in winter. Analysis of species diversity and abundance will be coupled with qualitative data. Viewed with regard to the long-term fluctuations and seasonal changes in benthos determined during the baseline and Monitoring Programs this approach will enable detection of any degradation in the benthic community caused by mining activities. These changes would primarily be caused by changes in water quality and aquatic habitat data collected for these programs.

Methods: The method used in the baseline studies will be continued during the Monitoring Program. The surber sampler will be used to make benthic collections at the same stations sampled for fish species. Sampling will be done concurrently with fish collections in January, March, July, and October.

Data Treatment: Statistical analyses for benthic studies could include diversity indices, and T-test, analysis of variance within and between stations along with correlation and some non-parametric tests used in an effort to pinpoint sources of impact.

Parameter 3 - Periphyton

Rationale: The periphyton communities are the major primary producers in the streams. They provide a major food source for benthic organisms and some fish species. They can respond very quickly to changes in water quality, and as such can be an important parameter for early detection of habitat degradation.

Hypothesis:

H_o: No change in periphyton communities during mine development and operation compared to baseline data.

Experimental Design: Productivity estimates for periphyton and qualitative analysis will enable species diversity analysis. These analyses, together with detection of presence or absence of organisms, which are pollution-indicative or good quality water-indicative, should be adequate to assess any impacts on periphyton communities as a result of oil shale development.

Methods: Continued use of artificial substrates for periphyton collections will be made for monitoring. Samples will be collected in conjunction with other sampling (January, March, July, and October). Optimum exposure time for artificial substrates is four to six weeks. This would require placement of substrates in the streams one month prior to regular sampling each quarter.

Data Treatment: Statistical analyses that can be made in examining productivity during monitoring versus baseline conditions could include analysis of variance or co-variance, correlation, diversity indices as well as some non-parametric tests.

Parameter 4 - Water quality

Rationale: Correlations can be made between water quality parameters and observed changes in aquatic organisms. Some sampling of the lake stations and springs and seeps may be justified, but are not included in this Monitoring Program. Alteration of ground water availability and water quality affecting lake stations and/or springs or seeps could necessitate examination of these habitats. Turbidity increases resulting from erosion or run-off from mine development can be an important factor for aquatic organisms.

Hypothesis:

H_o: No change in water quality among years at any given site.

Experimental Design: Continuous data from U.S.G.S. gauging stations will be used for water quality parameters during the Monitoring Program. This assumes that the existing stations will continue operation. U.S.G.S. gauging stations on Piceance Creek (09306007, 09306061), Stewart Creek (09306022), and Willow Creek (09306058) will be adequate to monitor conditions in the Tract vicinity.

Sediment grain size analysis will be made during the monitoring studies to detect increased siltation levels resulting from Tract operations.

Methods: Collections will be made of sediment samples at quarterly sampling periods along with other studies.

Data Treatment: Analysis can be made with sediment analyses conducted during the baseline studies using analysis of variance and correlation to detect significant changes in sedimentation due to plant construction and operation.

b. Aquatic Ecology - System Dependent Monitoring

Objectives: Should significant changes in the system be detected or a given level of a pollutant be reached, more detailed monitoring may be warranted. Various methods could be used.

Parameter 1 - Bioassay of pollutants

Rationale: Bioassay methods can be an aid to forecasting the effects upon aquatic ecosystems caused by various physical and chemical pollutants. Much work has been conducted on lethal conditions. More recently the trend has been toward sublethal effects. Often these are manifest over a much longer time period (weeks, months, or years) than lethal effects (24, 48, 72, or 96 hours). Sublethal effects can be as important in altering the ecosystem as acute mortality. The subtle effects of certain low levels of pollutants may make studies over the entire life span of an individual or even over several generations necessary. Some processes which may be altered by sublethal stress could include: development, growth, feeding, biochemical processes, reproduction, and respiration.

Hypotheses:

H_o: No difference in pollutant levels at control or treatment sites from baseline conditions.

H_o: No change in pollutant levels at control sites vs. treatment sites among years.

Experimental Design: Bioassay methods can be used during the monitoring period to permit detection of responses to possible pollutants at stress levels. Both laboratory and stream tests could be used. However, the ultimate proof that streams are adequately protected can be assured only be periodic examination of the natural communities of aquatic life in the streams.

Methods: Several methods might be used in system-dependent monitoring studies. The methods will be selected near the commencement of system-dependent monitoring to utilize the accepted methodology available at that time. Possible studies could include:

Biochemistry: Changes in enzyme concentrations due to stress, urine excretion, etc.

Histopathology: Analysis of gill capillaries, and changes in various tissues due to exposure to pollutants.

Hemotology: Blood cell count (hemoglobin erythrocyte, lymphocyte) and analysis has been conducted on fish to show physiological effects caused by pollutants.

Respiration: Changes in respiratory rate and oxygen consumption can be an indicator of sublethal stress. Some workers feel the activity of the fish must also be examined during these studies.

Behavior: Avoidance behavior and equilibrium loss have been studied. Quantitative data from which to base predictions is lacking in some of these approaches.

Growth: Growth is not always the most sensitive of sublethal effects. In some cases it may be stimulated, in others reduced. It is important, however, in assessing fish populations.

Reproduction: The early life history stages are often the most sensitive to stress. This is frequently where the first signs of stress will become evident. Gamete, embryo and fry stages of development are the most sensitive. Delays in attainment of sexual maturity, changes in fecundity and other reproductive studies could be used for comparison with baseline data.

Bioassay methods can be used during the monitoring period to permit detection of responses to possible pollutants at stress levels. Both laboratory and stream tests could be used. However, the ultimate proof that streams are adequately protected can be assured only by periodic examination of the natural communities of aquatic life in the streams.

4. Terrestrial Vegetation

a. Terrestrial Vegetation - Long-term monitoring

Objectives: The vegetation program presented below has been designed to detect any changes in vegetation as a result of oil shale operations at the individual plant level as well as at the community level. Early detection of any changes requires monitoring community structure, biochemistry of individuals and productivity of herbaceous cover. Analysis of data from these regular monitoring studies would form the basis for initiating a system dependent monitoring program. In the event changes are detected, a contingency sampling procedure would be activated. The vegetation monitoring program would investigate the following parameters as indicators of vegetation disturbance.

Parameter 1 - Community structural and compositional studies

Rationale: These studies are designed to detect changes in the structural and compositional characteristics of the major plant communities. It will be important to determine: whether certain species increase or decrease in abundance, and whether new species appear or are lost from the existing stem. Examination of changes in shrub density or tree growth rates would also enable evaluation of influences relating to shale oil development.

Hypothesis:

H_o: No changes in herb frequency, total herb cover, shrub frequency, shrub density, tree canopy cover, or tree growth rate over time.

Experimental Design: The six permanent intensive study plots established during the baseline period will be utilized to monitor structural parameters in the four major vegetation types occurring on the Tract (i.e., chained pinyon-juniper rangeland, pinyon-juniper woodland, upland sagebrush, and bottomland sagebrush). The intensive study plots were established on sites (treatment sites) which will allow comparison of possible pollutant effects with control sites.

Sampling in the permanent study sites will be carried out on a three-year rotational basis; each plot will be sampled every three years. During the first year of monitoring the chained pinyon-juniper control and monitoring sites will be sampled; during the second year the two pinyon-juniper woodland sites will be sampled; and the sagebrush sites sampled in the third year.

Methods: These parameters would be monitored by repeated sampling of permanently located herb quadrats and line transects, and by repeated measurement of marked trees at permanently located study sites.

Sampling will employ the same methods used during baseline investigations. Shrub frequency, density, and cover will be measured using 20 4x10 m belt transects (Lindsey 1955) per plot. Herb frequency and cover will be measured using 25 $1m^2$ (one centare) quadrats per plot; cover by litter, soil, rock, lichens, mosses, and woody seedlings will also be measured in these quadrats. Sampling of trees in the woodland sites will include canopy cover by vertical projection (dizzy stick method); and diameter at breast height will be recorded on permanently marked trees in the woodland plots.

Data Treatment: Data will be analyzed using either a paired T-test (Sokal and Rolf 1969) or an appropriate non-parametric test such as a paired sign test (Li 1964).

Parameter 2 - herbaceous productivity

Rationale: Since the herbaceous production forms the food base at least in part for the primary consumers of the site, it is important to monitor yearly production levels and also to evaluate whether the production of shale oil will alter the productivity of the herbaceous layer.

Hypothesis: Several hypotheses regarding the productivity of perennial grasses (excluding *Agropyron smithii* which will be tested separately), annual grasses (excluding *Bromus tectorum* which will be tested separately), perennial forbs, annual forbs, and half shrubs will be tested relative to differences in production during different years, at different sites, and under different treatments resulting from the production of shale oil (e.g. downwind effects of processing pollutants).

H_o: No differences in productivity exist relative to sites, years, and treatments. (Possible differences related to those factors will be tested separately.)

Experimental Design: During the monitoring period six locations (permanent study sites which have been used during the baseline studies) will be used to evaluate herbaceous production. At each site an area 50 meters on a side will be fenced with three-strand barbed wire prior to the onset of growth in the spring. Clipping will be conducted three times during the growing season. At each date ten 1 m^2 plots will be clipped and separated into the following fractions: *Agropyron smithii*, *Bromus tectorum*, perennial grasses (except for *Agropyron smithii*), perennial forbs, annual forbs, and half shrubs. Additionally, ocular estimates of standing crop will be made in the clipped plots as well as in 90 other 1 m^2 quadrats. Clippings and ocular estimates will also be made in adjacent unfenced areas in order to estimate the degree of utilization of herbaceous components during the growing season. Fences will be removed at the end of the growing season and will be re-established in a slightly different location (but still in the same general area) the following spring. During the operational phase of development it will be necessary to establish more study sites including new control plots and replicates of existing plots in order to separate operational influences from other changes.

Methods: Herbaceous productivity will be studied using a harvest method utilizing a double sampling approach (Wilm 1944).

Data Treatment: Hypotheses will be tested using an F-test either on paired plot evaluations or through analysis of variance.

Parameter 3 - sublethal biochemical parameter studies

Rationale: The accumulation of pollutants in plant tissues is expected to be one of the first notable changes in vegetation as a result of the project operation. The concentration of these pollutants may be highest near the point source and will diminish to varying degrees (according to prevailing wind directions) as the distance from the point source increases.

The study of sublethal biochemical parameters is designed with the purpose of detecting early changes in the concentration of potentially harmful substances which may in time adversely affect primary productivity. As such this program constitutes one of the most important monitoring studies.

Hypothesis:

H_o: No differences in concentration of SO_2, NO_x, fluoride, chloride, copper, zinc, cadmium, or mercury have occurred in leaves, seeds, and stems of selected plant species as a result of shale oil development. These would be separately tested hypotheses made on samples collected at various locations.

Experimental Design: Plant tissues from the species listed in Table VI E-2 will be analyzed each year, for anticipated pollutants: sulphur dioxide, oxides of nitrogen, fluoride, chloride, copper, zinc, cadmium, and mercury.

Samples will be collected during May, July, and September of each year at various locations -- including the permanent study plots. Sites will be located along prevailing winds at various distances from point sources of pollution and in control areas. Actual site locations will be determined based on air-flow and meteorological studies which are currently being analyzed.

Table VI E- 3 SPECIES TO BE USED IN STUDIES OF PLANT TISSUE BIOCHEMISTRY

Trees

Pinus edulis -- leaves and seeds
Juniperus osteosperma -- leaves and seeds

Shrubs

Artemisia tridentata -- leaves
Purshia tridentata -- leaves and current years growth
Cercocarpus montanus -- leaves and current years growth
Amelanchier spp. -- leaves and current years growth
Symphoricarpos oreophilus -- leaves

Herbs

Agropyron smithii
Oryzopsis hymenoides
Bromus tectorum
Crepis accuminatus

Lichens

Methods: Appropriate analytical methods for determination of the concentration of the above mentioned substances will be used.

Data Treatment: Hypotheses will be tested using an F-test in conjunction with an analysis of variance. Sample collections will be made so that these tests can be applied to the data.

Parameter 4 - general vegetation condition studies

Rationale: Since most of the other monitoring programs are site specific or aimed at individual species, it is beneficial to implement a program which will allow for a complete overview of the Tract vegetation.

Hypothesis:

H_o: No specific hypothesis is to be tested statistically as part of this program. The purpose of the program is to evaluate the overall condition of the vegetation at a more general level than the other monitoring programs.

Experimental Design: Flights will be made every three to five years. The actual time of the flights will be determined by the stage and/or intensity of development throughout the life of the project. Aerial photographs will be used to monitor the physical changes which occur as the result of development and to detect any physiological stress which might occur.

Methods: General vegetation condition will be monitored through the use of aerial photogrammetry including color infrared and color film taken by fixed wing aircraft.

Data Treatment: The photographs from the air photo surveys will be examined for any anomalous vegetation patterns compared to those which occur on the photographs taken during the baseline data collection period.

Parameter 5 - plant-soil water relations

Rationale: The relationship between soil moisture and plants is critical in understanding vegetation dynamics and the relationship of vegetation to abiotic factors. Continued sampling of this parameter will increase the data record and aid in ellucidating possible trends and naturally occurring cycles.

Hypotheses:

H_o: No difference in soil moisture trends (plant tissue moisture content) among years at any given site

H_o: No difference in soil moisture trends (plant tissue moisture content) at control plots and treatment plots during any given year.

Experimental Design: Moisture content of leaf tissues and soils will be measured at thirteen sites using thermocouple psychrometry. The sites used will be those at which microenvironmental spot check data was collected during the baseline period (these include the six permanent vegetation study sites and seven additional sites located in each of the nine vegetation types on Tract C-b). Herbaceous and shrubby species will be measured at each site. Species sampled include big sagebrush, bitterbrush, pinyon pine, mountain mahogany, western wheatgrass, and cheatgrass. Soil moisture will be measured each month during the year, whereas plant tissue moisture content will be measured monthly during the growing season (April through September).

Methods: Five individuals of each species will be measured at each site. The number of leaves sampled per individual will be field determined; the number of leaves sampled will be increased until the standard error of the mean is within 20 percent of the mean 90% of the time. Soil moisture will be measured at three depths at each site. Although actual depth may vary in site conditions, planned depths are 20, 40, and 60 cm.

Data Treatment: Soil moisture and plant tissue moisture content data will be subjected to statistical analyses in order to compare species at different sites, species at any given site over time; soil moisture differences at different sites and any given site over time; the possible correlations between soil moisture and plant moisture content. Analysis of variance procedures will be used to test these data.

b. Terrestrial Vegetation - System Dependent Monitoring Program

Objectives: The objective of this program is to determine the nature and cause of observed vegetation changes at the individual and community levels.

Parameter 1 - Carbon Dioxide uptake studies

Rationale: The rate of carbon dioxide uptake by plants constitutes the basis of photosynthesis and primary production. The herbaceous productivity studies provide an indirect means of estimating the net amount of photosynthate produced as an end product of photosynthetic reactions. Being based on weight estimate methods, these studies will provide evidence for productivity changes only after some toxic substances have blocked (if they indeed reach significantly high enough levels) or impeded carbon dioxide uptake. Direct observations of carbon dioxide uptake rates would provide an estimate of the degree to which photosynthesis has been reduced in the presence of toxic air pollutants. Since these studies, based on infrared gas analysis are extremely expensive, they will be initiated only when the data collected as part of the sublethal biochemical parameter studies demonstrate that toxic levels of pollutants in plant tissues are being approached. These toxic levels would be assessed on the basis of published information regarding the tolerances of the species being studied (Table VI E-2) or on the basis of species similar to those being studied.

Hypothesis:

H_0: No significant alteration in the rate of carbon dioxide uptake in the species listed in Table VI E-2 of this report at any given site among years.

Experimental Design: The study will be conducted with the species listed in Table 1 and will utilize the same field sampling locations as those established for the sublethal biochemical parameter studies. Finalization of the actual field design would be prepared at such time that this program would need to be implemented.

Methods: Carbon dioxide uptake would be measured using infrared gas analysis procedures. Refer to Chapman (1976) for general descriptions of gas analyzation approaches.

in Table 1 and will utilize the same field sampling locations as those established for the sublethal biochemical parameter studies. Finalization of the actual field design would be prepared at such time that this program would need to be implemented.

Methods: Carbon dioxide uptake would be measured using infrared gas analysis procedures. Refer to Chapman (1976) for general descriptions of gas analyzation approaches.

Data Treatment: Hypotheses would be tested using an F-test as part of an analysis of variance. Finalization of experimental design would be such that an analysis of variance could be used for data treatment.

Parameter 2 - Decomposition studies

Rationale: The decomposition studies allow for evaluation of processes involving microbial activity as well as geo-chemical cycling in and just below the soil surface. These studies constitute the only measure of biological activity of the decomposer organisms. Studies on decomposition will be initiated during the monitoring period in the event of a detected buildup of toxic substances in plant tissues.

Hypothesis:

H_o: No differences in decomposition rates have occurred among years at any given site.

Experimental Design: The experimental design for this study would be the same as that used during the baseline studies with the exception that additional locations near point source emissions would also be included as study sites.

Methods: Decomposition rates would be evaluated by repeated weighing of plant tissue and cellulose standard samples contained in nylon mesh bags (refer to Chapman 1976).

Data Treatment: Data from these studies would be tested using a paired t-test or a non-parametric test such as a paired sign test.

Parameter 3 - Morphological change studies

Rationale: Considerable research has been done on the effects of air pollution on vegetation. These studies have found that various pollutants may accumulate in plants and result in a variety of changes which can often be documented by observation. These changes often take the form of leaf necrosis (partial or complete death of the leaf), chlorosis (yellowing of leaves), or destruction of reproductive organs (buds, flowers, seeds). The type of damage is often characteristic for the various pollutants and can generally be distinguished from other damages such as from insects.

These damages could be detected and monitored by analyzing the leaves and reproductive parts of key taxa in sample sites radiating from the pollution point source.

Data Treatment: Hypotheses would be tested using an F-test as part of an analysis of variance. Finalization of experimental design would be such that an analysis of variance could be used for data treatment.

Parameter 2 - Decomposition studies

Rationale: The decomposition studies allow for evaluation of processes involving microbial activity as well as geo-chemical cycling in and just below the soil surface. These studies constitute the only measure of biological activity of the decomposer organisms. Studies on decomposition will be initiated during the monitoring period in the event of a detected buildup of toxic substances in plant tissues.

Hypothesis:

H_o: No differences in decomposition rates have occurred among years at any given site.

Experimental Design: The experimental design for this study would be the same as that used during the baseline studies with the exception that additional locations near point source emissions would also be included as study sites.

Methods: Decomposition rates would be evaluated by repeated weighing of plant tissue and cellulose standard samples contained in nylon mesh bags (refer to Chapman 1976).

Data Treatment: Data from these studies would be tested using a paired t-test or a non-parametric test such as a paired sign test.

Parameter 3 - Morphological change studies

Rationale: Considerable research has been done on the effects of air pollution on vegetation. These studies have found that various pollutants may accumulate in plants and result in a variety of changes which can often be documented by observation. These changes often take the form of leaf necrosis (partial or complete death of the leaf), chlorosis (yellowing of leaves), or destruction of reproductive organs (buds, flowers, seeds). The type of damage is often characteristic for the various pollutants and can generally be distinguished from other damages such as from insects.

These damages could be detected and monitored by analyzing the leaves and reproductive parts of key taxa in sample sites radiating from the pollution point source.

Hypothesis:

H_o: No changes in the leaf morphology or reproductive organs has occurred as a result of shale oil development.

Experimental Design: During periods of high level concentrations of pollutants (such as sulfur dioxide and nitrous gases) samples of plant leaf tissue will be collected for microscopic analysis of tissue structure. Samples will be collected from the following species: pinyon-pine, mountain mahogany, bitterbrush, big sagebrush, and western wheatgrass.

Methods: Samples will be prepared using standard laboratory techniques and analyzed microscopically for anatomical condition following literature-derived guidelines.

Data Treatment: Analysis of tissue damage will be subjectively determined following known symptoms and evidences of anatomical change.

5. Revegetation

Objectives: Revegetation monitoring will be conducted on sites which have undergone surface disturbance and on processed shale disposal sites. Monitoring techniques will be aimed at assessing the progress of re-established vegetation through determination of cover and productivity of species groups and entire sites. Parameters to be studied on disturbed sites include species frequency and cover for forbs, grasses, and shrub seedlings; cover by litter, soil, rock, mosses, and lichens; and herbaceous standing crop for annual and perennial grasses and forbs. Processed shale monitoring parameters will include compositional and standing crop measurements as above with the addition of plant tissue analysis to be performed on key species of herbs and shrubs.

a. Disturbed Sites

Parameter 1 - Vegetation structure and composition

Rationale: Vegetation structure and composition on revegetated disturbed sites will be monitored in order to evaluate the general success obtained in re-establishing vegetation on these sites. Specific attention will be given to the changes in species presence and cover over time.

Hypotheses:

H_o: No change in species frequency among years at any given site

H_o: No change in species cover among years at any given site.

Experimental Design: Each disturbed site will be sampled once each year during mid-June. Sampling will include determination of species frequency; % cover by species; and % cover by litter, soil, rock, mosses, and lichens. Herbaceous species and shrubs less than 0.25 M in height will be sampled.

Methods: Ten 1-centare quadrats will be permanently located at each disturbed site. Species frequency will be noted by presence. Percent cover of species, litter, soil, rock, mosses, and lichens will be estimated.

Data Treatment: Frequency and cover data will be analyzed using non-parametric methods, such as a paired sign test or paired t-test. Data will be evaluated for differences between years at any given site. Sites will also be compared in a subjective manner for differences in any given year or between years.

Parameter 2 - Herbaceous standing crop

Rationale: Herbaceous standing crop on disturbed sites will be measured in order to determine successive changes in this parameter over time and to evaluate the productivity of these sites.

Hypotheses:

H_o: No change in standing crop among years at any given site

H_o: No difference in standing crop in any given year between sites

H_o: No difference in standing crop among years between sites.

Experimental Design: Each disturbed site will be sampled once each year during peak season (late June-early July). Sampling will include clipping of the following herbaceous fractions: perennial forbs and grasses; annual forbs and grasses.

Methods: Five 1-square meter plots will be located in each disturbed site and clipped at ground level. Clipped fractions will be separated according to the fractions described above. In addition to the clipped plots, 50 1-square meter plots (including the 5 clip plots) will be estimated by the ocular method at each site. This method constitutes the double sampling technique. Fractions will be bagged and weighed separately to determine standing crop expressed in kg per hectare for the individual fractions and the total clipped sample. The combined data from clipped and ocular data will be used to generate a regression line in order to adjust the ocular estimates (Wilm 1944).

Data Treatment: Standing crop data will be subjected to analysis of variance techniques in order to determine the significance of year to year changes in any given site or between sites, and to determine the differences in sites during any given year.

b. Processed Shale Disposal Sites

Parameter 1 - Vegetation structure and composition

Rationale: Vegetation structure and composition on revegetated processed shale will be measured in order to evaluate the general success obtained in re-establishing vegetation on processed shale. Specific attention will be given to the changes in species presence and cover over time.

Hypotheses:

H_o: No change in species frequency among year at any given site

H_o: No change in species cover among years at any given site.

Experimental Design: Each processed shale plot will be sampled once each year during mid-June. Sampling will include determination of species frequency; percent cover by species; and percent cover by litter, soil, rock, mosses, and lichens. Herbaceous species and shrubs less than 0.25 M in height will be sampled. Plots will be located according to explosure and slope characteristics.

Methods: Up to 20 1-centare quadrats will be permanently located at each processed shale plot. Species frequency will be noted by presence or absence. Percent cover of species, litter, soil, rock, mosses, and lichens will be estimated.

Data Treatment: Frequency and cover data will be analyzed using non-parametric methods, such as a paired sign test or paired t-test. Data will be evaluated for differences between years at any given site. Sites will also be compared subjectively for differences in any given year or between years.

Parameter 2 - Herbaceous standing crop

Rationale: Herbaceous standing crop on processed shale disposal sites will be measured in order to determine successive changes in this parameter over time and in order to evaluate the productivity of these sites.

Hypotheses:

H_o: No change in standing crop among years at any given site

H_o: No difference in standing crop in any given year between sites

H_o: No difference in standing crop among years between sites.

Experimental Design: Each site will be sampled once each year during peak season (late June-early July). Sampling will include clipping of a number of herbaceous fractions, including perennial forbs and grasses, and annual forbs and grasses.

Methods: Five 1-square meter plots will be located in each processed shale sampling site. Each plot will be clipped at ground level and separated according to the four fractions mentioned above. In addition to the clipped plots, 50 1-square meter plots (including the five clip plots) will be used to estimate standing crop using an ocular method. Clipped fractions will be bagged and weighed separately; results will be expressed in kilograms per hectare for the individual fractions and for the total site. Data obtained from clipping and ocular estimate will be subjected to regression analysis in order to adjust the ocular estimates.

Data Treatment: Herbaceous standing crop data will be subjected to analysis of variance procedures in order to determine the significance of year to year changes in any given site or between sites, and to determine the potential differences between sites in any given year.

Parameter 3 - Chemical analysis of plant tissues

Rationale: Potential uptake by plants of toxic materials present in processed shale would have a direct effect on both plant vigor and ingestion by herbivores. Monitoring of the levels of these substances in plant tissue is a provision for implementing mitigation measures.

Hypothesis:

H_o: No change in plant tissue levels of toxic substances present in processed shale among years.

Experimental Design: During herbaceous productivity clipping samples will be taken from each clip site and bagged for laboratory analysis. Analysis will include the following: boron, electrical conductivity - total salts, sulfate, magnesium, and cadmium.

Methods: Analysis will be accomplished by standard laboratory methods.

Data Treatment: Data will be statistically compared for significance of change using analysis of variance, as well as being directly compared against known levels of these substances relating to their toxic effects.

F. Noise

1. Introduction and Scope

Noise levels will be monitored during all phases of oil shale development to meet Federal and State standards for noise impact.

The hearing of industrial workers is protected under regulations of both the U. S. Mine Enforcement Safety Administration (MESA) and the Occupational Safety and Health Administration (OSHA). Regulations pertain not only to noise intensity level but to noise exposure, i.e. the product of intensity and time sometimes called "dose". Noise control and hearing conservation programs will be conducted in this regard, as required. These measurements will be made on the surface and in the mine as required by regulations pertaining to occupational noise exposure.

2. Objectives

Noise level monitoring is designed with the following objectives:

a. Perform environmental monitoring of surface noise levels at selected tract boundary locations and at the estimated point of peak intensity on the Tract;

b. Demonstrate compliance with all regulations pertaining to occupational noise exposure on the surface and in the mine;

c. Demonstrate continuing compliance with applicable noise pollution standards. Such standards are specifically delineated in Tables V-9 to V-12 in the Noise Control Section of the DDP.

3. Experimental Design

Surface noise levels will be monitored in each of the four development phases. Colorado law specifically requires demonstration of compliance within 25 feet of property lines during construction phases of industrial developments.

One of the environmental monitoring stations will be located near the principal deer migration route identified in the baseline so that potential effects of noise on utilization of this route by deer can be studied.

Tentative site selections for the surface environmental noise program include the following stations from the baseline program (Figure VI F-1):

Stations 10, 11, 12 present locations

Station 13 moved to new principal access road at the Tract northern boundary

Station 5 moved directly south to the boundary

Station 6 moved north to the boundary at the peak (non-vehicular) intensity location on the northern Tract boundary

Station 15 one new station at (or near) the peak intensity location on Tract

Station 16 one new station on the principal deer migration route near the northern Tract boundary.

Stations 6, 11, 12, and 13 will be continuous monitors operating during the first three development phases; they revert to intermittent operation during the post-operations phase. Stations 5, 10, 15, and 16 are operated one month per quarter for four quarters at least once per operational phase as a "roving" instrument operating continuously for 15 minutes out of each hour for two shifts every sixth day. (Station 5 at 1 a.m., Station 10 at 2 a.m., Station 15 at 3 a.m., Station 16 at 4 a.m., Station 5 at 5 a.m., etc.)

4. Methods

Standard dosimeters will be used for noise exposure measurements according to MESA and OSHA standards.

The surface environmental noise program will utilize A-weighting noise intensity meters coupled with suitable recorders at both fixed and moveable locations.

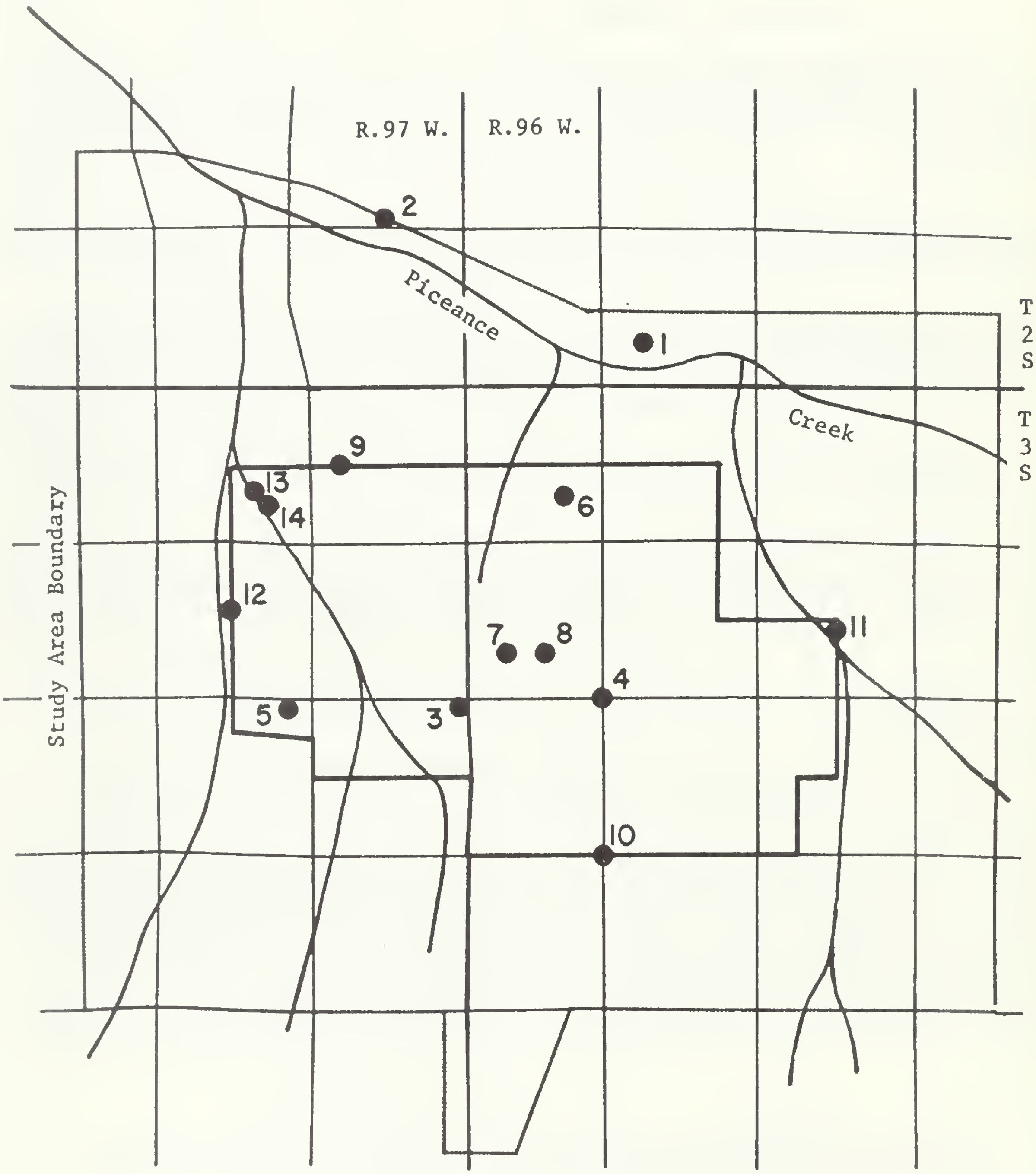


Figure VI F-1 TRACT C-B BASELINE NOISE LEVEL MEASUREMENT NETWORK

5. Data Treatment and Reporting

Noise intensity levels will be reported as hourly peaks, daily peaks, monthly peaks, and (in the case of continuous measurements) integrated averages. Comparisons will be made with baseline noise levels.

Noise data will be reported in the Annual Reports generated during the monitoring program.

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Table VI D-3

PROPOSED AIR QUALITY AND METEOROLOGICAL MONITORING SITES* AND ASSOCIATED PARAMETERS

Site Location	Parameters Measured: Baseline	Monitoring[1] Phase I, Mine Development	Monitoring Phase II, Plant Const.	Monitoring Phase III, Plant Ops.	Monitoring Phase IV, Post Ops.	Rationale
020	Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	→	→	→		Downwind, down valley concentrations from plant and travel corridor
021	Meteorology Particulates; SO_2, H_2S					Flow patterns follow creek, established in baseline
022	Meteorology Particulates; SO_2, H_2S					Same as 021
023	Tower Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	Meteorology Particulates; SO_2, H_2S	→			Tower & station need relocation from center of plant complex so terminate before Phase III
024	Meteorology Particulates; SO_2, H_2S	Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	→	→		Estimated point of max. concentration from plant for predominant wind direction
025[2]		Tower Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	→	→		New tower location; ambient conditions, Sta. 025 correlated with 023 in Phases I and II
026		Meteorology Particulates; SO_2, H_2S, NO_X, THC, CO, O_3, CH_4	→	→		Estimated point of max. concentrations for N. wind direction, ambient for S. wind
051				Particulates	→	Downwind monitor for dust from processed shale pile
052		Particulates	→	→	→	Monitor ventilation dust from mine
053		Particulates	→	→	→	Same as 052
054				Particulates	→	Upwind monitor for dust from processed shale pile
055				Particulates		An estimated point of max. concentration for particulates
060	Area-wide Visibility	→	→	→	→	One annual check per phase to establish long term trends

* In-mine, process, and stack monitoring sites not shown.
(1) Monitoring start-up, six month prior to Phase I.
(2) Estimated locations (here and below) subject to mutual concurrence between Lessee and Area Oil Shale Supervisor.