REGIONAL OIL SHALE STUDY

ENVIRONMENTAL IMPACT ASSESSMENT

Of

OIL SHALE DEVELOPMENT

ON SURFACE RUNOFF

PICEANCE CREEK BASIN

RIO BLANCO and GARFIELD COUNTIES, COLORADO

Prepared For

The State of Colorado

by

James R. Meiman, Ph.D.

1974

THORNE ECOLOGICAL INSTITUTE

2305 CANYON BLVD.
BOULDER, COLORADO 80302
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Synopsis

Surface runoff was chosen as the hydrologic component for concentrated evaluation as part of the ecologic inventory and impact studies within the larger Regional Oil Shale Studies. Surface runoff was chosen because from an ecological viewpoint, it is associated with soil erosion, plant water supply, delivery of pollutants to the aquatic system, flooding, channel configuration, and sedimentation.

Based on field study including 39 one-hour infiltration runs, it appears that soils in the vicinity of the Ca and Cb lease sites have relatively high infiltration rates (5 to 10 cm per hr.) and these rates may diminish to about 2 cm per hr. with moderate disturbance. Severe compaction would be expected to reduce infiltration even further. Thus, the major problem of surface runoff increase would be from those areas that are paved or otherwise covered, especially those areas covered by processed shale. The processed shale and paved areas are of special concern because of the higher probability that runoff from these areas could be polluted.

Long-range concerns with the development of a full-scale oil shale industry are greatest in relation to the potential for delivery of pollutants by surface runoff to the aquatic system. Localized areas of erosion could develop if surface drainage from impacted areas is not properly disposed. Changes in snow drift accumulation at higher elevations by changes in landform or vegetation could cause localized problems of runoff, erosion, and stream pollution. Excessive engineer-
ing of storm runoff to prevent infiltration into the alluvial bottomlands could result in increased storm runoff peaks and decreased ground water recharge.

I. Introduction

The hydrologic system is a complex interaction of precipitation, infiltration, soil water movement, evaporation from the surfaces of soil and water, transpiration from plants, movement into and out of the geologic strata beneath the soil mantle, and flow of water in streams and channels. Each of these processes is in itself a complicated phenomenon. For example, precipitation may be in the form of rain or snow. Rain has inherent characteristics of amount, intensity and duration which interact with topography. Snow, in addition to these characteristics is also subject to redistribution by wind and is acted upon by solar radiation and temperature to produce meltwater. Water may leave a given site by surface runoff, near-surface flow in the soil mantle, or deep seepage into the groundwater system. Water that runs off from on site may infiltrate at another site and vice versa.

All of the above processes are important in relation to the natural environment and man's impact thereon. In the framework of the Regional Oil Shale Studies, surface runoff generated on site was selected as the process most directly related to ecological concerns of the environmental impact part of the Regional Oil Shale Studies. Water supply and disposal is the charge of the Regional Development study by another group. The water requirements for revegetation are the responsibility of the Colorado State University study group. The
overall hydrologic system with special emphasis on groundwater is being studied by the U.S. Geological Survey. All of these studies are interrelated; communication and exchange of data have been important features of the Regional Oil Shale Studies.

Surface runoff as used in this report refers to that water running on or near the surface of the land that usually reaches a stream rapidly compared to "base flow" or "groundwater flow". Synonyms include "direct runoff", "direct surface runoff", and "storm runoff".

On-site surface runoff is important from an ecological viewpoint because it is the flow that is associated with soil erosion and loss of water from the site that otherwise could be used by vegetation. Surface runoff is particularly critical in assessing potential for delivery of pollutants to streams and the resultant impact on the aquatic ecosystem. To the extent that surface runoff reaches streams, it is important in flooding, channel configuration, and sedimentation.

II. Inventory and Analysis

The general survey of existing information was carried out in Part I, Phase I and is published in the Thorne Report, Chapter V. Additional studies on infiltration were carried out during the summer of 1973 and will be published as a Thorne Technical Report. Only the summary (Table 1) and the general conclusions are included here.

---


During the summer of 1973 each lease site (Ca and Cb) was examined thoroughly in the company of the Thorne geologist and soil scientist. Most of the effort was concentrated on the lease sites and proposed Douglas Creek disposal area, although further reconnaissance of the entire Colorado oil shale area was also included. Infiltration was measured on processed shale at both the Colony Development Operations disposal site and at Anvil Points.

Based on these limited studies and field observations made while they were conducted, some inferences about surface runoff and the impact of an oil shale industry thereon can be made. Generally it appears that the soil-covered ridges and bottomlands have relatively high infiltration rates ranging from 5 to 10 cm per hour for durations of approximately one hour. Thus the major part of on-site surface runoff comes from the rock outcrops and very shallow rockland soils on the steeper slopes. Alluvial bottoms are runoff acceptors (infiltrators), rather than runoff producers in most instances.

Disturbance of natural conditions by bulldozing or otherwise removing the protective covering of vegetation and litter appears to reduce the infiltration rate for one hour from 5 to 10 cm to about 2 cm per hour per hour. Lower rates would be expected with excessive compaction. Thus the soils, because of their coarse texture, appear to maintain a relatively high infiltration rate, even when disturbed, although much reduced from the undisturbed condition.

Infiltration runs on bare spent shale indicate that rates of 3 to 4 cm per hour may be expected on mixtures of coarse and fine materials
such as exist on the old Anvil Points disposal pile. Infiltration rates on the very fine TOSCO processed shale are closely related to the treatment it receives after deposition. Shale allowed to dry and become powdery and salty without any surface protection was found to have very low infiltration (none after 10 to 15 min. of rainfall application). On the other hand, if this processed shale were kept moist and/or mulched, then rates of 2.0 to 2.5 cm per hour for a one-hour duration were found. Highest rates on this material were found where living vegetation occurred (3.4 cm per hour).

It should be reemphasized that all these inferences are based on 39 one-hour infiltration runs made with the USGS rainfall-simulator during the summer of 1973. Unusually high application rates of from 8 to 12+ cm per hour (3 to 5+ in.) were used to accentuate the effects of surface control on infiltration during short-duration intense storms. Larger plot studies would give needed additional interpretive information.
Table 1. Summary of Infiltration Runs

<table>
<thead>
<tr>
<th>Run</th>
<th>Soil</th>
<th>Vegetation</th>
<th>Ground Cover</th>
<th>Soil Moisture</th>
<th>Infiltration Rate cm/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Loam (calcareous)</td>
<td>Peppergrass</td>
<td>100%</td>
<td>Moist</td>
<td>9.7</td>
</tr>
<tr>
<td>27</td>
<td>&quot;</td>
<td>&quot;</td>
<td>100%</td>
<td>Moist</td>
<td>6.5</td>
</tr>
<tr>
<td>26</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Scraped bare</td>
<td>Moist</td>
<td>2.3</td>
</tr>
<tr>
<td>4</td>
<td>Loamy sand</td>
<td>Rabbitbrush and grasses</td>
<td>50%</td>
<td>Dry</td>
<td>8.4</td>
</tr>
<tr>
<td>5</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Rabbitbrush and grasses</td>
<td>Scraped bare</td>
<td>Dry</td>
</tr>
<tr>
<td>14</td>
<td>Loam (calcareous)</td>
<td>Rabbitbrush and wild rye</td>
<td>100%</td>
<td>Dry</td>
<td>7.0</td>
</tr>
<tr>
<td>13</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Rabbitbrush and wild rye</td>
<td>50%</td>
<td>Dry</td>
</tr>
<tr>
<td>12</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Rabbitbrush and wild rye</td>
<td>0%</td>
<td>Moist</td>
</tr>
</tbody>
</table>
Table 1, cont.

<table>
<thead>
<tr>
<th>Run</th>
<th>Soil</th>
<th>Ground Cover</th>
<th>Soil Moisture</th>
<th>Infiltration Rate cm/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Sandy loam</td>
<td>100% Sagebrush litter</td>
<td>Dry</td>
<td>12.5</td>
</tr>
<tr>
<td>3</td>
<td>&quot; &quot;</td>
<td>70% Grass and litter</td>
<td>Dry</td>
<td>10.9</td>
</tr>
<tr>
<td>1</td>
<td>&quot; &quot;</td>
<td>10% Grass</td>
<td>Dry</td>
<td>2.9</td>
</tr>
<tr>
<td>7</td>
<td>&quot; &quot;</td>
<td>0%</td>
<td>Dry</td>
<td>2.8</td>
</tr>
<tr>
<td>18</td>
<td>&quot; &quot;</td>
<td>0%</td>
<td>Moist</td>
<td>1.3</td>
</tr>
<tr>
<td>22</td>
<td>Sandy loam</td>
<td>70% Western wheatgrass</td>
<td>Moist</td>
<td>2.9</td>
</tr>
<tr>
<td>24</td>
<td>&quot; &quot;</td>
<td>0%</td>
<td>Moist</td>
<td>2.9</td>
</tr>
<tr>
<td>30</td>
<td>Clay loam</td>
<td>20% Forbs</td>
<td>Bulldozed area on Mesa Verde formation. Very shallow soil. Dry soil.</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Table 1, cont.

<table>
<thead>
<tr>
<th>Run</th>
<th>Ground Cover</th>
<th>Remarks</th>
<th>Infiltration Rate cm/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>100% Pinyon litter</td>
<td>Dry soil</td>
<td>12.5</td>
</tr>
<tr>
<td>10</td>
<td>50% Pinyon litter</td>
<td>Dry soil</td>
<td>4.9</td>
</tr>
<tr>
<td>9</td>
<td>0% Litter 50% Coarse fragments</td>
<td>Adjacent to #10</td>
<td>3.9</td>
</tr>
<tr>
<td>19</td>
<td>5% Pinyon litter</td>
<td>No coarse fragments</td>
<td>2.1</td>
</tr>
<tr>
<td>20</td>
<td>0%</td>
<td>All juniper litter removed to expose mineral soil. Moist soil</td>
<td>2.4</td>
</tr>
<tr>
<td>21</td>
<td>0%</td>
<td>All Pinyon litter removed to expose mineral soil. Moist soil</td>
<td>8.0*</td>
</tr>
<tr>
<td>29</td>
<td>50% Pinyon litter</td>
<td>Excessive lateral spread along bedrock interface; run indicates surface control conditions only. Dry soil.</td>
<td>4.7</td>
</tr>
</tbody>
</table>

* Indicates run less than 1 hour.
Table 1, cont.

<table>
<thead>
<tr>
<th>Run</th>
<th>Site Description</th>
<th>Infiltration Rate cm/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>No vegetation or litter. 25% of surface initially covered by coarse fragments $\geq$ 1 cm; surface cover of coarse fragments increased with time. Moist.</td>
<td>4.5</td>
</tr>
<tr>
<td>16</td>
<td>No vegetation or litter; surface 90% covered by coarse fragments. Moist.</td>
<td>3.3</td>
</tr>
<tr>
<td>15</td>
<td>Complete cover by coarse fragments. Moist</td>
<td>12.6$^*$ (4.2 cm in 20 min.)</td>
</tr>
</tbody>
</table>

* Run less than 1 hour duration.
<table>
<thead>
<tr>
<th>Run</th>
<th>Site Description</th>
<th>Infiltration Rate cm/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>Compacted shale with 1 to several centimeters of loose material on surface; loose dry material scraped off to expose compact, slightly moist shale</td>
<td>2.5</td>
</tr>
<tr>
<td>37</td>
<td>Plot adjacent to #36 that has been watered for 2 years, seeded and mulched with straw; ~60% straw cover. Soil moist.</td>
<td>2.1</td>
</tr>
<tr>
<td>38</td>
<td>Untreated and undisturbed compacted shale with top 2 to 3 cm very dry and salt-crusted; some disturbance in placing funnel through top layer. Slightly moist.</td>
<td>0 after 10 min.</td>
</tr>
<tr>
<td>39</td>
<td>Same as #38</td>
<td>0 after 15 min.</td>
</tr>
</tbody>
</table>
Table 1, cont.

Processed Shale - Colony 1972 Study Plots

<table>
<thead>
<tr>
<th>Run</th>
<th>Site Description</th>
<th>Infiltration Rate cm/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>50% cover by Russian wild rye or pure processed shale; remaining surface shows evidence of organic materials from hydromulch; run was made immediately after sprinkler irrigation. Wet</td>
<td>3.4</td>
</tr>
<tr>
<td>34</td>
<td>As above but on mixture of equal parts of shale and local soil parent material. Moist.</td>
<td>2.6</td>
</tr>
<tr>
<td>32</td>
<td>Processed shale without surface cover except for organic remnants of hydromulch. Moist.</td>
<td>2.4</td>
</tr>
<tr>
<td>33</td>
<td>Processed shale and local soil parent material mixture; no surface cover except organic remnants of hydromulch. Moist.</td>
<td>2.2</td>
</tr>
<tr>
<td>31</td>
<td>Same as #32. Moist</td>
<td>2.1</td>
</tr>
<tr>
<td>35</td>
<td>Bare processed shale with surface crust removed; run only 50 min. duration. Moist.</td>
<td>1.8*</td>
</tr>
<tr>
<td>40</td>
<td>Approximately 10 cm of local soil parent material over shale; no vegetation or litter; immediately after sprinkler irrigation. Wet</td>
<td>1.3</td>
</tr>
</tbody>
</table>

* Run less than 1 hour duration.
III. Evaluation of Impacts

A. Definition of Impact

The quantitative basis for impact assessment is the amount of runoff generated on-site from a 3 cm, one-hour storm (re: Part 1, Phase 1, Page V-17). High impact is runoff greater than 2 cm, moderate impact is 1 to 2 cm, and low impact is less than 1 cm of runoff per unit area. The impact is rated negative if an increase in on-site runoff occurs and positive if on-site runoff is decreased. This rating is based on runoff per unit area. Interpretation of the severity of the per unit area impact in relation to total environmental impact must include consideration of acres involved, proximity to stream, soil and landform characteristics between the site and stream channel, and pollution potential in addition to unit area runoff. Because on-site runoff may infiltrate into the soil during transport in channels or into alluvial bottom-soils along major drainages in the Piceance Basin, it should not be inferred that all on-site runoff will appear as streamflow in the major streams of the area.

B. Assessments of Impacts

The following assessment is based on information furnished by Thorne Ecological Institute (Memoranded by Hubert Burke, dated May 24, 1973), Thorne ROSS report Part 1, Phase I,\textsuperscript{1} and the infiltration studies from Part I, Phase II,\textsuperscript{2}.

\textsuperscript{1} An Environmental Reconnaissance of the Piceance Basin, 1973. Thorne Ecological Institute.

1. Ca Site, Underground Mining

a. Mine Complex

(1) Impact

<table>
<thead>
<tr>
<th>Construction</th>
<th>Operation</th>
<th>Post Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mitigation</td>
<td>High-Neg</td>
<td>High-Neg</td>
</tr>
<tr>
<td>With mitigation</td>
<td>High-Neg</td>
<td>High-Neg</td>
</tr>
</tbody>
</table>

(2) Sphere of Influence

On-site (pollution potential off-site)

(3) Environmental Costs and Gains

Surface runoff would be increased 3 cm on covered areas (15ac.) and 1 to 2 cm on remaining disturbed areas (15ac.). This increase would be particularly hazardous in transporting potential pollutants to aquatic systems.

(4) Environmental Constraints and Design Criteria

Runoff from paved areas should be disposed of safely, since this runoff has a high pollution potential, it should be diverted to a catchment basin for treatment or recycling. Nonpaved disturbed areas should be re-vegetated. Provision must be made for mitigating practices in perpetuity.
b. Ventilation System
   No significant impact

c. Plant Complex

   (1) Impact | Construction | Operation | Post Operation
           |             |           |               |
   No mitigation | High-       | High-     | High-         |
   With mitigation | High-       | Moderate- | Moderate-     |

   (2) Sphere of Influence
   On-site (pollution potential off-site)

   (3) Environmental Costs and Gains
   Assuming plant is primarily on ridge, then surface runoff from covered areas (60ac.) would be increased 3 cm and from 1 to 2 cm on remaining disturbed areas (80ac). This runoff would have a very high pollutant delivery potential to the aquatic systems.

   (4) Environmental Constraints and Design Criteria
   Because of pollution potential, all runoff from this area should be diverted to catchment basin for possible treatment or recycling to prevent pollution. Provision should be made for these protection practices in perpetuity. All non-covered but disturbed areas should be revegetated as soon after disturbance as feasible.
d. Conveyor System for Processed Shale Disposal

(1) Impact

<table>
<thead>
<tr>
<th></th>
<th>Construction</th>
<th>Operation</th>
<th>Post Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mitigation</td>
<td>Mod.-</td>
<td>Mod.-</td>
<td>Low-</td>
</tr>
<tr>
<td>With mitigation</td>
<td>Mod.-</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

(2) Sphere of Influence

On-site

(3) Environmental Costs and Gains

The moderate increase in on-site runoff would result in disturbance during construction, natural recovery would gradually reduce this effect. Because of relatively small corridor-type impact, there should be no serious off-site damage threat.

(4) Environmental Constraints and Design Criteria

Disturbed areas should be revegetated as soon as possible. Where line traverses steep slopes, waterbar drainage structures should be installed. Vehicular traffic along line should be minimized. Provision should be made for recycling water if slurry system is used. Provision should also be made for safe temporary disposal if line breakage occurs.
e. Processed Shale Disposal - Douglas Creek

(1) Impact | Construction | Operation | Post Operation
---|---|---|---
No mitigation | None | High- | High-
With mitigation | None | Moderate- | Low-

(2) Sphere of Influence
On-site and Douglas Creek

(3) Environmental Costs and Gains
Surface runoff could be increased up to 3 cm on approximately 2400 acres. Without adequate design of disposal pile, mudflows could occur across Douglas Pass Road and into Douglas Creek. With mitigation, a relatively small part of the total acreage would be exposed each year and, with revegetation, the runoff increase potential would diminish to less than 1 cm after 2 to 5 years, depending on success of revegetation.

(4) Environmental Constraints and Design Criteria
The major requirements are for protection of the disposal area from runoff from the watershed above and design of a drainage system to safely dispose of runoff from the pile itself. Runoff from the watershed above the disposal area should be diverted to a floodwater retarding structure located immediately above the disposal area and safely disposed. Runoff from the disposal area could be recycled
(4) **Environmental Constraints and Design Criteria** (cont.)
during the operation period or could be safely delivered by a terrace and diversion system to a catchment basin below the disposal area. A critical consideration of utmost importance is the provision for both floodwater-retarding structures and drainage-plus-catchment system after the operations cease. This requirement is perpetual.

f. **Processed Shale 60% in Mine and 40% in Douglas Creek Watershed**

<table>
<thead>
<tr>
<th>(1) Impact</th>
<th>Construction</th>
<th>Operation</th>
<th>Post Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mitigation</td>
<td>None</td>
<td>High-</td>
<td>High-</td>
</tr>
<tr>
<td>With mitigation</td>
<td>None</td>
<td>Moderate-</td>
<td>Low-</td>
</tr>
</tbody>
</table>

(2) **Sphere of Influence**
On-site and Douglas Creek

(3) **Environmental Costs and Gains**
This alternative would reduce the area disturbed in Douglas Creek from 2400 acres to around 1000 acres and thus is preferred to complete disposal in Douglas Creek area. Surface runoff could be increased up to 3 cm. Without adequate design of disposal pile, mudflows could occur across Douglas Pass Road and into Douglas Creek. With mitigation, a relatively small part of the total acreage would be exposed each year and, with revegetation, the runoff increase potential would diminish to less than 1 cm after 2 to 5 years, depending on success of revegetation.
(4) Environmental Constraints and Design Criteria
Mitigation requirements are the same as outlined in section 1-e-(4).

g. Water Gulch Disposal Site for Processed Shale

(1) Impact  Construction  Operation  Post Operation
No mitigation  None  High-  High-
With mitigation  None  Moderate-  Low-

(2) Sphere of Influence
On-site, Corral Gulch, possibly Yellow Creek

(3) Environmental Costs and Gains
This alternative has the advantage of a reduced problem from runoff from the watershed above the processed shale as compared to Douglas Creek disposal. Also, higher effective precipitation, particularly in the form of snow, may aid revegetation.

(4) Environmental Constraints and Design Criteria
Mitigation requirements are the same as outlined in section 1-e-(4).

h. Boxelder Gulch Disposal Site for Processed Shale

(1) Impact  Construction  Operation  Post Operation
No mitigation  None  High-  High-
With mitigation  None  Moderate-  Low-

(2) Sphere of Influence
On-site and Boxelder Gulch, possibly Yellow Creek.
(3) **Environmental Costs and Gains**

Boxelder Gulch is less desirable than Water Gulch because of the larger drainage area and potential runoff from areas above the pile.

(4) **Environmental Constraints and Design Criteria**

Mitigation requirements are the same as outlined in section 1-e-(4).

i. **Water Diversion Systems**

<table>
<thead>
<tr>
<th>Impact</th>
<th>Construction</th>
<th>Operation</th>
<th>Post Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mitigation</td>
<td>High-</td>
<td>Moderate+</td>
<td>Moderate+</td>
</tr>
<tr>
<td>With mitigation</td>
<td>--------------</td>
<td>N/A</td>
<td>--------------</td>
</tr>
</tbody>
</table>

(2) **Sphere of Influence**

On-site and Douglas Creek or Corral Gulch

(3) **Environmental Costs and Gains**

During construction there is a potential increase from the disturbed area of up to 3 cm. This would be a hazard for a relatively brief time. After construction there would be a reduction in peak flood flows by the floodwater retarding structure. These structures are required mitigating actions for runoff control and thus a "with mitigation" rating is not applicable.

(4) **Environmental Constraints and Design Criteria**

An essential feature of these structures is that they be designed for and provision made for perpetual operation and maintenance. Clogging by debris could be a serious problem on the Douglas Creek area where timber is present. Provisions should be incorporated in the water control system design to prevent clogging and overtopping of structures.
j. Water Catchment Systems

(1) **Impact**

<table>
<thead>
<tr>
<th></th>
<th>Construction</th>
<th>Operation</th>
<th>Post Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mitigation</td>
<td>High-</td>
<td>Moderate+</td>
<td>Moderate+</td>
</tr>
<tr>
<td>With mitigation</td>
<td>--------------</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

(2) **Sphere of Influence**

On-site and Douglas Creek or Corral Gulch

(3) **Environmental Costs and Gains**

During construction surface runoff could be increased from the disturbed areas by as much as 3 cm. After construction the structures would reduce peak runoff from the areas not controlled by the floodwater retarding and diversion structures. Failure of these structures poses a perpetual threat of environmental damage by mudflows and polluted water. The Douglas Creek location has a decided advantage in this regard because the amount of runoff is relatively small.

(4) **Environmental Constraints and Design Criteria**

These structures should be designed to store the maximum expected runoff from the disposal area. Although emergency spillways would have to be incorporated in the design, any spill from these structures would be polluted water. Recycling of water would be an integral part of the system if slurry transport is used. Without slurry transport, it may be possible to design large enough storage capacity to depend on evaporation to deplete stored runoff. Provision should be made for large amounts of sedimentation. Provisions would have to be made for perpetual control of runoff from the disposal areas.
k. Support Systems - Utility Corridors and Roads

(1) Impact Construction Operation Post Operation
No mitigation High- Moderate- Low-
With mitigation High- None None

(2) Sphere of Influence
On-site

(3) Environmental Costs and Gains
Considered in total, an increase of up to 3 cm of runoff could occur on several hundred acres. This impact is diffused over large areas and therefore affects only the disturbed site. The potential impact is most severe for a relatively brief period during construction.

(4) Environmental Constraints and Design Criteria
Potential impacts can be minimized by rapid revegetation and drainage control by waterbars to prevent concentration of water on disturbed areas. In the case of roads, sound engineering drainage practices should be followed with special attention given to the safe disposal of collected water.

2. Ca Site, Surface Mining

a. The Open Pit

(1) Impact Construction Operation Post Operation
No mitigation Moderate+ Moderate+ Moderate+
With mitigation N/A

------------------
(2) Sphere of Influence
On-site, Corral Gulch

(3) Environmental Costs and Gains
The open pit will have a major influence on the hydrologic regime of Corral Gulch by its influence on surface-sub-surface water relationships. In addition, runoff from the disturbed area itself would be increased from 1 to 3 cm, but it would be trapped in the pit and thus would reduce peak storm runoff. Similarly the interception of sub-surface waters, that during a peak storm runoff event could contribute to peak flow, would reduce peak runoff in Corral Gulch. The greatest environmental hazard resulting from this operation relates to disposal of water intercepted during the operational period. Assuming this water can be used in the operation, then no serious problems relevant to increased surface runoff are anticipated. Requirements for diversion of water from adjacent areas away from the pit are discussed in section 2g.

b. Plant Complex

(1) Impact

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<tr>
<th>Impact</th>
<th>Construction</th>
<th>Operation</th>
<th>Post Operation</th>
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</thead>
<tbody>
<tr>
<td>No mitigation</td>
<td>High-</td>
<td>High-</td>
<td>High-</td>
</tr>
<tr>
<td>With mitigation</td>
<td>High-</td>
<td>Moderate-</td>
<td>Moderate-</td>
</tr>
</tbody>
</table>

(2) Sphere of Influence
On-site, (pollution potential off-site)
(3) Environmental Costs and Gains

The increase of up to 3 cm of runoff on approximately one-half of the 200 acres involved is possible. An increase of 1 to 2 cm could occur on the remaining area. These assumptions are based on the plant being located on a ridge site with little runoff under natural conditions. Runoff from the impacted areas would have a very high pollution potential for aquatic systems.

(4) Because of pollution potential, all runoff from this area should be diverted to catchment basin for possible treatment or recycling to prevent pollution. Provision should be made for these protection practices in perpetuity. All non-covered but disturbed areas should be revegetated as soon after disturbance as feasible.

c. Overburden Disposal - Water Gulch

(1) Impact

<table>
<thead>
<tr>
<th>Construction</th>
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<th>Post Operation</th>
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<tbody>
<tr>
<td>No mitigation</td>
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<tr>
<td>With mitigation</td>
<td>Low-</td>
<td>Low-</td>
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<tr>
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(2) Sphere of Influence

Corral Gulch

(3) Environmental Costs and Gains

It is not expected that runoff would be greatly increased from the approximately 1000 acres on which the overburden is placed. Indications are that this material would maintain a relatively high infiltration rate. That part of the area to be covered that consists of steep slopes and rock outcrop already has a high natural runoff production. Some
pollution potential may develop from seepage water over a long period of time.

(4) Environmental Constraints and Design Criteria
The major mitigation effort should be to encourage re-vegetation. A catchment basin below and water diversion above the overburden material should be installed.

d. Overburden Disposal - Dry Fork
The same on-site ratings apply as were described on Water Gulch. The major advantage for this location over Water Gulch is the smaller drainage area and lower runoff to be controlled.

e. Lean Shale Deposit

(1) Impact
<table>
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<th>Construction</th>
<th>Operation</th>
<th>Post Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No mitigation</td>
<td>Moderate-</td>
<td>Moderate-</td>
</tr>
<tr>
<td>With mitigation</td>
<td>Moderate-</td>
<td>Moderate-</td>
</tr>
</tbody>
</table>

(2) Sphere of Influence
Local drainage in which placed.

(3) Environmental Costs and Gains
Runoff could be increased around 1 cm on the several hundred acres involved.

(4) Environmental Constraints and Design Criteria
Because of temporary nature of storage, mitigation is restricted, but attempts should be made to encourage vegetation. Surface water should be diverted from and drainage water collected from the deposit.
f. **Processed Shale Disposal**
   The same impact ratings and control requirements pertain as described in sections 1-d, e, and g. A major advantage would accrue if processed shale could be returned to pit after 16 years as indicated; only 900 acres offsite would be impacted as compared with 2200 acres if shale were not returned to pit.

g. **Water Diversion Systems**
   Same evaluation and recommendations as given in section 1-i. A new consideration is introduced with pit mining in that subsurface waters may be encountered. Such intercepted water, if not used, should be safely diverted to natural channels. Depending on the amounts encountered during operations, post-operation plans for safe disposal of such water should be envisioned and arrangements established for their implementation.

h. **Water Catchment Systems**
   See section 1-j.

i. **Support Systems**
   See section 1-i.

3. Cb Site, Underground Mining
   The on-site unit area impacts for the various engineering activities for this site would be nearly identical to those described in section 1 for site Ca. The mitigation requirements are the same.
The major differences in this site compared to Site Ca with respect to surface runoff are the larger drainage areas above proposed disposal sites and the proximity of the site to Piceance Creek. Although the requirements for mitigation involve the same approaches, the larger watershed areas above the Stewart Gulch and Scandard Gulch disposal sites would require larger diversion, floodwater retention, and catchment basins. Furthermore, because of the potentially larger volumes of water involved, the potential damage from failure is increased.

The proximity of this site to Piceance Creek increases the risk of damage to the aquatic environment. At Site Ca there is a long buffer stretch (~20 miles) of Yellow Creek before polluted peak runoff would reach the White River. By contract, disposal in Stewart Gulch would place a major potential pollution source within one mile of Piceance Creek.
C. Interactions Within the Ecosystem that Influence Impact on Surface Runoff

The major ecosystem components that influence surface runoff from a site are precipitation, geology, soil, and vegetation. Because of their influence on snow, both air-flow and temperature may be important in generation of runoff from snowmelt. The effects of insects, invertebrates, and mammals are indirect because they may influence either soil or vegetation and thereby influence surface runoff.

Changes in geologic landform can influence surface runoff because steepness, orientation, and length of slope are all directly related to runoff. Indirectly, the influence of geology on soils, especially soil depth and permeability, can bring about an impact on surface runoff.

Any change in soil permeability or water-holding capacity can induce marked changes in surface runoff. Soil material displacement and compaction are the most likely impacts that could occur. Soil permeability was the basis used to evaluate environmental impact on surface runoff in this study.

Vegetation as it interacts with precipitation and soil is the other major determinant of surface runoff on many sites. The amount, type, and distribution of vegetation are key parameters. Any change in these parameters with their resultant influence on canopy, litter, and roots, may result in changes in runoff.

Changes in air flow patterns may have an indirect effect on runoff because of influence on soil water depletion (evapotranspiration) and on snow distribution. Particularly relevant to the higher elevations within the oil shale region would be changes in snow distribution around
facilities and on the processed shale disposal areas. In these areas the potential of runoff as a carrier of pollutants would be of special concern.

Temperature may also influence runoff indirectly by its effect on soil water depletion as well as on snow. Higher temperatures (or greater air flows) increase potential loss of water from the soil and thereby increase the potential for storage of precipitation in the soil. Temperature is a key factor in regulating snowmelt and therefore any change in temperature on a local basis may influence snowmelt runoff.
IV. Assessment of the Environmental Impact of a Mature Oil Shale Industry on Surface Runoff

The major water problems associated with the long-range development of a mature industry are likely to be those of water supply and disposal of water from dewatered mine areas. These problems are within the scope of other component studies of the Regional Oil Shale Studies. A review of the hydrology physical impacts that emphasizes these problems may be found in the 1973 report by the Institute of Ecology. Emphasis in this report has been on surface runoff as related to other ecological factors.

The results of the infiltration studies suggest that, unless the soil is compacted, large increases in surface runoff from disturbed areas in the vicinity of the Ca and Cb lease sites would not be expected. However, as a full scale industry develops, there will be other soil types involved and there will be an increasing part of the total watershed subject to severe compaction and paving from roads and developed areas along with areas covered by processed shale. The greatest long-range threat is not so much from the increased runoff, but rather from the fact that such runoff water has a much greater chance of delivering pollutants from these areas to the aquatic system.

The relation between surface and subsurface waters is another long-range, full-development concern. It appears from field observations that the alluvial bottoms are important infiltrators of the occasional storm runoff from surrounding steep, rocky, and shallow-soil lands. If

large amounts of such storm runoff are engineered directly into streams without opportunity to recharge the alluvial soils, then storm flow peaks will be increased and ground water recharge will be decreased.

The long-range impact of development on rainfall intensity, frequency, and duration is beyond the scope of this component report but, to the extent that changes could occur, these changes would influence the surface runoff produced.
The processed shale disposal areas are of particular concern because of the additive effect of the areas with development and because of the high potential for pollution. Infiltration studies indicate that bare processed shale may be highly impermeable and serious runoff problems, especially from the faces of disposal piles, could develop. This is a potential long-range problem and contingency plans for such problems should be developed.

In the upper elevations of the oil shale area, snow is an important environmental factor. Any reshaping of the land or changes in vegetation can influence the distribution of snow drifts on the watershed. These changes can have important consequences on the release of meltwater and production of runoff. This is an especially critical concern in relation to snow drifting on and in the vicinity of processed shale disposal areas.

Land use changes over time can influence the type, density and distribution of vegetation, thereby influencing surface runoff by the effect on soil moisture condition. Subtle changes over time may result from changes in grazing by domestic or wild animals. Heavy recreation use especially be cross country vehicles could cause intense local problems of runoff and erosion.

Secondary developments such as new towns, railway yards and parking areas will create new problems for surface runoff and stream pollution control.
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19 - 35 mm slides

Old location:
"Environmental impact assessment of oil shale development on surface runoff, Piceance Creek..." (Box 2)

New location:
Box 6 - "Ross oil shale, snow"

Name of processor: Clarissa J. Trapp

Date: 06/27/2012