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IRRIGATION EXPERIMENTS WITH PRODUCED
WATERS FROM THE RETORTING OF OIL SHALE

MASTER

by

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SUMMARY

The research described herein was conducted by Geokinetics to qualitatively assess the tolerance of native and certain introduced species of vegetation to irrigation with produced water from the retorting of oil shale. Two separate experiments were conducted at the Kamp Kerogen field site in Uintah County, Utah. The results indicate possible effects on vegetation that a prolonged exposure to produced water would have.

The two simple experiments were initiated during the summer of 1979. It was expected that irrigation with produced water would eventually result in detrimental effects to the plants receiving it; the concentrations of boron, molybdenum, arsenic, oil and other constituents in untreated production waters are high enough to likely cause damage to plants.

In one experiment a 27 foot by 27 foot plot of native vegetation was irrigated with one inch of produced water per week for five weeks using a lawn sprinkler. Grasses and shrubs within the test plot appeared to have died; germination of annual plants was greatly inhibited.

In the other experiment, 30 container-grown seedlings ranging in height from 0.3 feet to 3.0 feet were transplanted. Six species of broadleaf, deciduous trees not native to the test site were represented by five seedlings each. All 30 trees received well water irrigation for one month, after which four trees of each species were irrigated with produced water for seven weeks.

One tree of each species continued to receive well water throughout the experiment; only two of those trees survived the summer of 1979. All six species appeared to have been adversely affected by produced water. The horse chestnut trees were the hardiest of the species planted. Most of the 30 trees, including those irrigated with well water, did not survive the winter season.

INTRODUCTION

The Geokinetics In Situ Oil Shale Project is a cooperative venture between Geokinetics Inc. and the U. S. Department of Energy. The objective is to develop an in situ process for recovering shale oil using a fire front moving in a horizontal direction. The project is being conducted at a field site (Kamp Kerogen) located 70 miles south of Vernal, Utah, on Section 2, Range 22 East, Township 14 South, Uintah County, Utah.

The process is a true in situ method for extracting oil from

oil shale. The oil shale is fractured by means of explosives placed in blastholes drilled from the surface. After a specific area has been fractured to create an in situ retort, air injection wells are drilled at one end and off-gas recovery (air-out) wells are drilled at the other. The oil shale is ignited at the air injection wells, and air is continually injected to establish and maintain a burning front. The front is moved in a horizontal direction through the fractured rock. This heats the shale, driving out the shale oil which drains to the bottom of the retort where it is recovered through oil production wells. As the burn front moves from the air-in to the air-out wells, residual coke serves as the primary fuel source to sustain the moving burn front. Combustion gases are recovered at the off-gas wells.

This retorting process requires no water, but produces water at a volume approximately equal to oil production. The oil-water emulsion is pumped out of the retort and is then separated. A representative characterization of retort water is shown in Table I.

NATIVE VEGETATION EXPERIMENT

A 27 foot by 27 foot plot was established at the location shown in Figure 1. A plot of equal dimensions with similar vegetation was established as a control plot. The control plot was located just north of the irrigated test plot. Both plots were marked with laths, survey tape and string.

One inch of produced water per week was applied to the irrigated plot using a spray-type lawn sprinkler placed in the center of the test plot. This amount of watering was recommended by ecological consultant Dr. Erik R. Olgeirson; he indicated that sagebrush and other native vegetation should tolerate irrigation with one inch of normal water per week. The quantity of water applied was monitored using a glass beaker placed in the path of the sprinkler. Produced water was applied on August 23, 1979; August 30, 1979; September 6, 1979; September 12, 1979; and September 20, 1979.

Color slides of the plots were taken prior to irrigation, during the program and at the completion of the experiment. The slides and frame records are on file at Kamp Kerogen.

Irrigated plants began drying up and showing discoloration within three weeks after the program began. The plots were left undisturbed through the winter of 1979 and spring of 1980. Geokinetics botanist Linda Kenny examined the plots on July 16, 1980. Grasses and shrubs within the test plot appeared to be dead. Several small groups of cactus were alive but brown and shriveled in spots. Germination of annual plants within the test plot was greatly inhibited. The control plot and areas surrounding the test plot were thickly populated with cheat grass, an

annual grass. None had grown in the test plot. A few perennial grasses had sprouted in one small area in the test plot.

A small pinyon pine was located on the boundary of the test and control plots. The south side of the tree, which was in the test plot, was in the path of the produced water spray. The north side of the tree was not hit by the water. Needles on the northern side of the pinyon were all green. The needles on the south side were dead, but there was some new growth at the tips of the branches. This may indicate that produced water is most toxic to plants when it contacts the leaves.

TREE EXPERIMENT

This experiment was initiated to determine if several species of trees selected by the U. S. Forest Service (USFS) would grow at the field site if irrigated with produced water. Thirty small, container-grown trees were transplanted on July 13, 1979. The height of the seedlings ranged from 0.3 feet to 3.0 feet. Five trees each of the following six species were planted:

1. Aesculus hippocastanum (Horse Chestnut)
2. Quercus macrocarpa (Bur Oak)
3. Acer grandidentatum (Bigtooth Maple)
4. Celtis occidentalis (Common Hackberry)
5. Fraxinus amonala (Singleleaf Ash)
6. Five Hybrid Poplars:
 - NE-53: Populus masimowiczii x P. Caudina
 - NE-9: P. nigra x P. trichocarpa ("Roxbury" Poplar)
 - NE-302: P. betulifolia x P. trichocarpa
("Andover" Poplar)
 - NE-32: P. angulata x P. berolinensis
 - NE-388: P. maximowiczii x P. trichocarpa
("Androscoggin" Poplar)

The trees were watered with approximately one gallon every two weeks, as prescribed by USFS personnel. All 30 trees were watered with Kamp kerogen well water at the time of planting and through July 26, 1979. Kamp water was applied on July 13, 15, 18, 21, and 26, in quantities totaling the prescribed amount. By July 30, 1979, four trees of each species were watered with produced water and one tree of each species was watered with Kamp water. The trees were watered in this manner on July 30; August 9, 12, 18, 23, 25, and 30; and September 2, 6 and 20. No water-

ing took place after September 20, 1979. The trees were left undisturbed through winter and spring, and were examined by botanist Linda Kenny on July 16, 1980. The following observations were made regarding each of the species planted:

Aesculus hippocastanum (Horse Chestnut) - The leaves of all five trees began turning brown almost immediately after transplanting. Each plant had lost some leaves and one had lost all leaves by July 26, 1979, while all were still being irrigated with Kamp water. The Horse Chestnut trees continued to brown and lose leaves after watering with produced water began. By September 2, the four trees receiving produced water had no leaves and the tree receiving Kamp water had only one browning leaf left. At the time that watering was discontinued, it did not appear that the Horse Chestnut trees would survive. However, when the trees were evaluated in July 1980, the Horse Chestnut trees appeared healthier than the other species planted. Three of the four Horse Chestnut trees watered with produced water and the tree that received Kamp water were alive with a few small new leaves.

Quercus macrocarpa (Bur Oak) - These trees appeared to remain in good condition through July 1979, with one tree exhibiting some wilting (loss of turgidity after five days but recovering). One week after produced water irrigation began, all of the trees except one (which received produced water) began showing leaf discoloration and drying. By August 12 all of the oak trees had browning at the tips of some or all leaves. The tree receiving Kamp water had lost a few leaves and may have been affected by produced water leaking from the spigot of the plumbing system. Observations on September 2 indicated that three of the oak trees watered with produced water had browning leaves. This included the tree which had wilted earlier; the leaves had curled and then crumpled at the tips. The other oak tree irrigated with produced water had no leaves at that time. The tree watered with Kamp water showed browning at leaf edges and signs of possible windburn (which may have resulted from the leaking water contacting the leaves). When the trees were examined in July 1980, only the one that had received Kamp water appeared to have survived the winter. It had only a few small leaves at that time.

Acer grandidentatum (Bigtooth Maple) - All five maples did quite well through July 1979. By August 9, two of the trees receiving produced water showed browning at the tips of some leaves. On August 12, all five maples showed browning on some leaves. Observations on September 2 noted that all leaves were brown on three of the maples receiving produced water; the other tree receiving produced water showed leaves slightly brown at the tips. The maple receiving Kamp water looked healthy with deep green leaves in September 1979. None of the maples had any live

leaves or showed any signs of new growth when examined in July 1980. Apparently none survived the winter.

Celtis occidentalis (Common Hackberry) - Within two days after transplanting, two trees had lost some leaves and another showed some browning of leaves. By the fifth day, all of the hackberries had dry leaves with another tree also showing browning of leaves. On August 9, it was noted that two of the trees receiving produced water had brittle leaves; the other three trees showed some browning at the tips of leaves. On August 12, the two trees with brittle leaves showed a slight browning at tips of leaves. Observations on September 2 noted that trees receiving produced water had browning, yellowish leaves that were brittle or very brittle. The tree receiving Kamp water had no leaves. None of the hackberry trees appeared to have survived the winter when observed in July 1980.

Fraxinus amonala (Singleleaf Ash) - Although two of these trees lost some leaves on top shortly after transplanting, the ash trees appeared to be in good condition through July. One week after being watered with produced water, one tree was turning brown at the tips of leaves and two other trees had brittle leaves. On August 12, leaves on the two trees with brittle leaves were curling and the other two trees receiving produced water had some leaves turning brown at the tips. The tree receiving Kamp water showed slight browning of some leaves. In September 1979, none of the trees receiving produced water had any live leaves; one tree had lost all leaves. The tree receiving Kamp water looked healthy in September 1979, none of the trees receiving produced water had any live leaves; one tree had lost all leaves. The tree receiving Kamp water looked healthy in September 1979 and had deep green leaves. None of the ash trees appeared to be alive when examined in July 1980.

The five hybrid poplars are referred to here by the designations preceding the scientific descriptions listed above. Poplars NE-53, NE-9, NEW-302 and NE-32 were irrigated with produced water; NE-388 received Kamp water.

NE-32 showed some signs of browning two days after being transplanted and NE-53 showed some yellowing five days after transplanting. Generally, however, all five poplars were in good condition when irrigation with produced water began. On August 9, the poplar trees were still in fair condition, with browning at the tips of some leaves on all five plants. Observations made in September 1979 indicated the following: NE-53 had some new growth with most of the new leaves turning black at the tips. All of the original leaves had fallen off. All leaves on NE-9 were very brittle; there appeared to have been some new growth which was brittle and blackened. The original leaves on NE-302 were almost totally brown while new growth was slightly black at tips of leaves. The original leaves on NE-32 were brown, but

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there were some healthy-looking new leaves as well as some new leaves with black tips. NE-388, which received Kamp water, looked healthy and had some new growth. On September 20, 1979, when the trees were watered for the last time, the leaves on NE-388 had begun to dry out. None of the poplars showed evidence of being alive when examined in July 1980.

TABLE I

STATISTICAL CHARACTERIZATION OF RETORT WATER

(All Concentrations Expressed as mg/l,
Unless Otherwise Noted)

Parameter	Mean	Deviation	Variance	High	Low
Alkalinity as CaCO ₃	17,836.36	4,373.39	17,387,768	30,300	15,000
Hardness as CaCO ₃	153.72	85.75	6,684.20	303	28
pH units	8.56	0.34	0.10	9.08	8.14
Conductivity $\mu\text{ohms}/\text{cm}^{-1}$	34,035.91	10,968.05	109,362,003	64,800	24,600
COD	3,682.36	650.57	384,764	4,420	2,000
Ammonia as NH ₃ -N	1,270.68	779.52	552,415	2,400	65.2
Bicarbonate as HCO ₃	17,174.91	7,152.98	46,513.803	36,996	11,346
Carbonate as CO ₃	2,825.45	1,567.70	2,234,261	4,560	0
Chloride as Cl	3,016.36	4,292.25	16,748,550	15,000	800
Cyanide as CN	13.31	9.55	82.89	25.3	0.94
Nitrate as NO ₃ -N	34.16	28.15	720.25	76	2.5
Nitrite as NO ₂ -N	1.33	1.13	1.17	3.6	0.18
Phenol	11.56	11.84	127.50	26.48	00.10
Phosphate-Total	2.1	1.22	1.34	3.82	0.50
Phosphate-Ortho	1.07	0.80	0.58	2.26	0.02
Sulfate as SO ₄	609.09	361.71	118,942	1,020	184
Sulfide as S	447.36	280.72	71,641.55	816	34.8
Oil & Grease	103	202.00	37,095.68	697.8	7.9
Surfactants as MBAS	23.20	34.39	1,075.35	110	0
Total Dissolved Solids	22,144.64	7,133.03	46,254,620	23,500	16,052
Gross Alpha ± 3.5 pCi $\cdot \text{l}^{-1}$	8.29	4.21	16.13	14	3.8
Gross Beta ± 5.0 pCi $\cdot \text{l}^{-1}$	26.45	6.74	41.34	38	21
Antimony as Sb	0.011	0.003	0.000006	0.015	0.008
Arsenic as As	2.55	3.92	13.96	13.485	0.21
Barium as Ba	0.54	0.18	0.03	0.82	0.30
Beryllium as Be	0.009	0.006	0.00003	0.016	0
Bismuth as Bi	0.059	0.017	0.0002	0.088	0.046
Bromide as Br	0.18	0.10	0.01	0.4	0.1
Boron as B	60.55	67.63	4,157.52	175	0.51
Cadmium as Cd	0.084	0.088	0.007	0.2	0.001
Calcium as Ca	32.58	33.25	1,005.19	101.7	0.12
Chromium as Cr	0.078	0.039	0.001	0.144	0.046
Cobalt as Co	0.56	0.30	0.08	1.272	0.246
Copper as Cu	0.209	0.167	0.025	0.504	0.026
Fluoride as F	35.15	6.47	38.10	44.3	25.0
Germanium as Ge	0.044	0.096	0.008	0.28	0
Iron as Fe	13.99	25.46	589.10	88.20	1.54
Lead as Pb	0.642	0.924	0.776	2.24	0.015
Lithium as Li	0.179	0.117	0.012	0.378	0.070
Magnesium as Mg	17.49	7.75	54.56	26.4	6.86
Manganese as Mn	0.937	1.876	3.20	4.74	0.038
Mercury as Hg $\mu\text{g} \cdot \text{l}^{-1}$	3.78	11.35	117.18	38	0
Molybdenum as Mo	11.91	8.74	69.49	24.4	2.05
Nickel as Ni	1.62	2.06	3.85	5.21	0.067
Potassium as K	121.43	21.16	407.10	147.8	99.2
Selenium as Se	0.215	0.470	0.20	1.238	0
Silica as SiO ₂	17.95	4.15	15.65	25	13.5
Silver as Ag	0.135	0.123	0.014	0.316	0.004
Sodium as Na	9,392	2,951.0	7,916,720	17,800	7,281
Strontium as Sr	0.002	0.003	0.000008	0.007	0
Tin as Sn	0.168	0.454	0.187	1.5	0
Vanadium as V	0.43	0.25	0.056	0.82	0.12
Zinc as Zn	0.095	0.067	0.004	0.242	0.03

FIGURE 1

NATIVE VEGETATION IRRIGATION
EXPERIMENT LOCATION

NE 1/4, SECTION 2, T14S, R22E, UINTAH COUNTY, UTAH

0 500' 1000'
SCALE

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KG

9/19/79