DEPARTMENT OF THE AIR FORCE
HEADQUARTERS OGDEN AIR LOGISTICS CENTER (AFMC)
HILL AIR FORCE BASE, UTAH

February 14, 1995

OO-ALC/EM
7276 Wardleigh Road
Hill AFB, UT 84056

Mr. Floyd Baham
Davis and Weber Counties Canal Company
138 West 1300 North
Sunset, UT 84015

Dear Mr. Baham:

I would like to provide to you a summary of the findings of the engineering evaluation of the impact base activities may have upon the Davis-Weber Canal. Hill Air Force Base Environmental Management engineers evaluated the problem and also conducted an initial records search which included; State of Utah Department of Natural Resources studies, Weber Basin Conservancy District records, consulting engineers' reports and our own records. Although our engineers' calculations indicated that it is unlikely that the base has an impact upon the slope adjacent to the canal, EM contracted with Dr. Gary Merkley and the Irrigation Engineering Department at Utah State University to evaluate the problem.

Dr. Merkley's results from the analysis on turf consumptive use on the Hill Air Force Base golf course and the shallow ground water depths from six observation wells (located between the golf course and canal) from the April 1993 to August 1994 record, indicates that irrigation of the golf course probably does not significantly impact the movement of groundwater. He concluded that "Current levels of over-irrigation on the golf course are such that deep percolation from the golf course is not a factor in the sloughing of the Davis-Weber Canal. It is highly probable that the sloughing of the canal is caused by other factors, and not by irrigation of the golf course."

Dr. Merkley also modeled the amount of flooding which would occur if the canal were to be breached due to a landslide in the area directly north of the golf course. Dr. Merkley concluded that "From the hydraulic modeling results on the Davis-Weber Canal for complete blockage under full-flow conditions, it can be argued that flooding from a canal breach would not be a threat to human life. Property damage would be expected due to erosion, especially in the steep slope below the canal, and in some of the fields beyond. However, the flow depth at the elementary school, some 1400 ft from the canal, would probably be less than 3 inches. The flood water may not even cross the school grounds at all, especially if the breach were to occur in the canal at a location further east or further west from the school's position." He also evaluated the extreme conditions of full canal flow within a 50-ft wide path and calculated the theoretical flow depth at the school would be less than 1.2 ft.

In two other engineering evaluations (Tabs 1 & 2 of the attached report) which are independent of each other and the work done by Dr. Merkley at the university, CH2M-Hill Engineering and Montgomery-Watson Engineering both came to the conclusion that slope instability problems are most likely the result of the canal construction cutting through the toe of the slope.

Montgomery-Watson went on to indicate that based on hillside mapping, historical aerial photograph review, and inclinometer measurement, the majority of hillside movement occurred as a result of the construction of the Davis-Weber Canal. The canal cut through the toe of the slope, which oversteepened the hillside and resulted in slumps. Most of the slumping is within highly active surficial landslides located just above and adjacent to the canal. With landslide depths ranging from 5 to 15 feet below ground surface. They also looked at the possibility of deep seated instability and found that data from an inclinometer placed in 1990 at Operable Unit 1 (North of the golf course) indicates there is currently no deep movement.

It should be noted that environmental remediation efforts at Operable Unit 1 have since 1984, removed approximately 15 million gallons of groundwater annually from the north side of the base. There are future plans to increase groundwater extraction and treatment efforts which should in turn further remove water from the area. These efforts not only will help the environment but should improve slope stability.

Your patience in this matter is appreciated. If additional information is required or if we can be further help to you, please feel free to contact myself or Dr. Dan Adkins at 777-8790.

Sincerely

James R. Van Orman

JAMES R. VAN ORMAN
Director Environmental Management

Attachment: USU Report

May 29, 1984

James J. Brophy, Vice President for Research
President's Office
304 Park Building
University of Utah
Salt Lake City UT 84108

Dear Mr. Brophy:

I am writing you at this time to state how privileged I believe I am and, indeed, the State of Utah is, in having the cooperation of Professor Kim McCarter, Dept. of Mining Engineering, in our landslide monitoring. His contribution to our geologic hazard instrumentation program has been quite significant. You may not have been aware that the instrument packages that have been monitoring landslides in Weber, Davis and Salt Lake Counties are entirely successful and in the case of the latter two have provided warnings of impending debris flow events.

I believe this to be a fine example of town and gown cooperation.

I might add that though his efforts during recent emergency situations may have occasionally encroached upon classroom or laboratory sessions, Dr. Mc Carter clearly places student interaction top on his list of priorities as I have witnessed on the occassions while in his office.

Sincerely yours,

Bruce N. Kaliser, Chief
Geologic Hazard Section

BNK/rd

Encl.: report

A Partial Analysis of Water Use on Hill Air Force Base and the Effects of Runoff on the Davis-Weber Canal

IPA Agreement between

Environmental Management Directorate
Hill Air Force Base, Ogden, Utah

and

Gary P. Merkley
Biological and Irrigation Engineering Department
Utah State University
Logan, Utah 84322-4105

October 1994

Summary

The scope of work of this IPA was to investigate the possibility of over-irrigation on the golf course at Hill Air Force Base (HAFB), and its effect on degradation of the Davis-Weber Canal through seepage down the steep slope upon which the canal is located. A related issue dealt with the hydraulic consequences of a sudden (hypothetical) canal blockage due to a landslide, possibly caused by seepage and sloughing, and possible impact on an elementary school located 1,400 ft downhill from the canal.

The extent of over-irrigation on the HAFB golf course was analyzed using historical weather data from three sites near HAFB, reported water deliveries to the golf course by the Weber Basin Water Conservancy District, and other available data. It was found that water applications on the golf course are typical of other golf courses in the general area, but that some excess water is often applied and that a portion of this excess probably infiltrates to the shallow groundwater table. Historical data from several observation wells were also analyzed, showing groundwater movement from the vicinity of the HAFB golf course toward the Davis-Weber Canal. However, insufficient data were available to determine the extent to which over-irrigation of the golf course might contribute to seepage above the canal, and to sloughing of the canal banks. But groundwater levels appear to be fairly static from month to month year-round, indicating that the golf course irrigation by itself probably does not contribute significantly to the groundwater movement. Furthermore, some groundwater movement is undoubtedly due to the natural hydrology of the area.

An unsteady hydraulic simulation of the Davis-Weber Canal was performed using a computer model. The simulation was designed to investigate the consequences of a sudden and complete blockage of the canal under full-flow conditions. All calculations were based on what were considered to be worst-case (extreme) conditions. It was found that the full canal flow would arrive at the school in a minimum time of about 30 minutes, with a flow depth of less than 1.2 ft. However, this depth would probably be much smaller due to soil infiltration and spreading of the water over the surface. If the depth were anywhere near 1.2 ft, the flow would necessarily be contained in a channel of less than 50-ft width, which is unlikely to happen. A more realistic estimate of the flow width would be 500 ft, corresponding to a maximum flow depth of approximately 3 inches.

Introduction and Background

The Davis-Weber canal was built in 1882 using horse-drawn machinery and manual labor. Concrete lining of some reaches of the canal began in about 1910, but even now the canal is only partially lined. New concrete lining was placed in a 1000-ft section of the canal north of the HAFB runway in 1993-94 to ameliorate groundwater contamination risks from point-source pollutants on the base. The upstream end of the canal runs roughly northeast along a steep embankment just north of the HAFB perimeter. Some surface and subsurface drainage enters the canal each year. The canal company has experienced problems over the years with deterioration of the canal lining and sloughing of the lined and unlined canal banks. The deterioration and sloughing is most prominent on the uphill side of the canal. Some of this deterioration has been attributed to natural freeze-thaw processes in the soil adjacent to the lining, and some parties have claimed that runoff from HAFB contributes to the problem. There is little doubt that some sections of the canal are affected by the subsurface flow in the embankment where the canal is located, but it is not clear how much of this flow is from the natural hydrology of the area, and how much is from the impact of HAFB and other activities. The canal has apparently suffered from these flows since the 1880s when it was first constructed, before significant development of the uphill areas.

The geology of the bench areas at HAFB is characterized by an unconfined perched aquifer over a relatively impervious clay layer, with an underlying confined aquifer. Natural runoff from the mountains to the east tends to move through the aquifers in a westerly direction. However, some of the flow seeps out through the steep slope to the north of the base where the upstream reaches of the Davis-Weber canal are located. In general, this seepage tends to move toward the west, ultimately discharged to the valley lowlands and the Great Salt Lake.

The HAFB golf course covers an area of 156 acres in Operable Unit 1 (OU1), located on the north side of the base and uphill from the Davis-Weber Canal. Irrigation water for the golf course is purchased from the Weber Basin Water Conservancy District, with an annual contract amount of 640 acre-ft for the golf course alone. However, much less than the contract amount is used for irrigation of the golf course. Weber Basin does not supply water year-round for the golf course; therefore, HAFB uses groundwater wells on the base to supply irrigation water, as needed, from October 15 to April 15 each year. Irrigation is by sprinkler, and occurs mostly during the nighttime, according to the HAFB golf course superintendent, Greg Gilmore (1994).

Downhill from the Davis-Weber Canal is the Bambrough Canal, smaller in size and roughly paralleling the Davis-Weber Canal in the area north of OU1.

North of the Bambrough Canal the terrain flattens considerably, up to and beyond South Weber Drive. An elementary school is located approximately 1,400 ft north of the Davis-Weber Canal, a few hundred feet east of where the HAFB golf course begins. Irrigated fields cover most of the area immediately north of Bambrough Canal, and resiaential areas also exist in the vicinity of South Weber Drive. Figure 1 illustrates some of the features in this area.

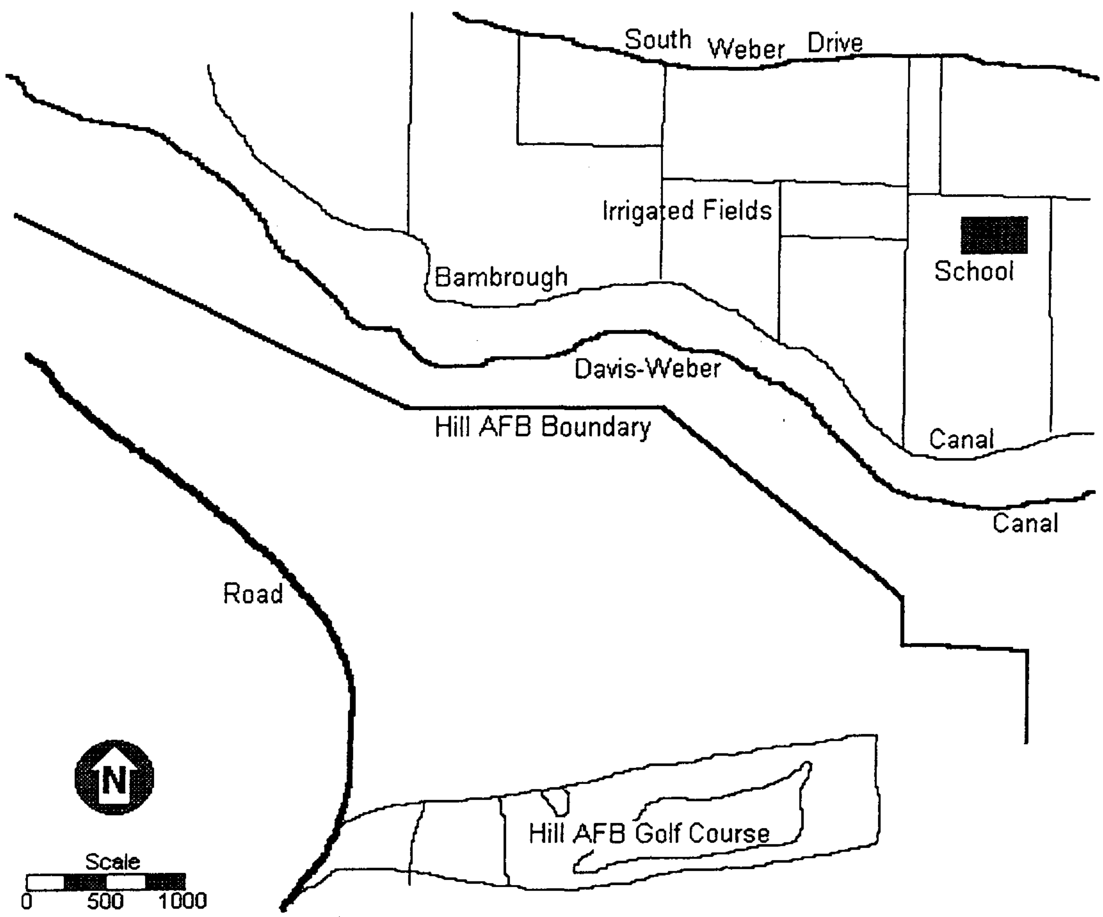


Figure 1. Plan View of the Hill AFB Golf Course and Davis-Weber Canal.

Consumptive Use for Turf

Data from weather stations in Riverdale, Farmington, and the Salt Lake City International Airport were obtained to estimate representative long-term averages of turf water requirements for the HAFB golf course. The data for turf are available from March through October, even though turf may not have significant transpiration during the early Spring and late Autumn every year. The 30-year data for the three sites are presented below in Table 1. Note that the net irrigation requirement is calculated by subtracting 80% of the measured precipitation for each month. In the absence of detailed site-specific data it is customary to assume that 80% of measured rainfall is "effective" (i.e. enters the turf root zone and is available for extraction by roots).

Table 1. Gross and Net Turf Water Requirements from 30-Year Averages from Three Sites in Northern Utah.

Month	Gross Turf Requirement (inches)			Net Turf Requirement[1] (inches)		
	Riverdale	Farmington	SLC	Riverdale	Farmington	SLC
March	0.50	0.26	0.31	0	0	0
April	2.19	1.98	1.89	0.25	0	0.20
May	3.17	3.46	3.39	1.82	1.29	1.95
June	4.91	4.60	4.64	3.82	3.42	3.90
July	5.29	5.17	5.39	4.67	4.51	4.74
August	4.50	4.36	4.53	3.74	3.57	3.85
September	2.75	2.79	2.72	1.45	1.47	1.70
October	1.49	1.09	1.38	0	0	0.23
Totals:	24.8	23.71	24.25	15.75	14.26	16.57

[1] Net requirement is calculated by subtracting 80% of the gross precipitation.

Standard deviations for precipitation (annual) at the above three sites vary from 4.2 inches to 19.97 inches, and the standard deviation of gross turf water requirements vary from1.36 to 1.43. Thus, the gross requirement does not tend to deviate greatly from one year to the next, but due to variations in precipitation the net requirements can fluctuate substantially. The annual totals for the three sites are very similar. Salt Lake City has the highest average annual requirement, but this is expected because the weather data was taken from the international airport, not an agricultural area.

Taking the "worst case" in terms of excess irrigation water applied, the average Farmington data shows a net of 14.26 inches per turf season (March through October, approximately), or 1.19 ft. The golf course on Hill Air Force Base is 156 acres, and (156 acres x 14.26 inches per year)/12 = 185 acre-ft per year. According to the Weber Basin Water Conservancy District (Anderson 1994), 365 acre-ft of water was delivered to the HAFB golf course during the period April 15 to October 15, 1993. This amounts to 2.34 ft of application over the entire area of the golf course during the irrigation season. Data from five golf course sites in the Salt Lake and Davis counties from 1991-93 indicate an average application depth of 2.67 per year, with a high of 4.46 and a low of 1.88 (State of Utah 1994). Therefore, the seasonal value of 2.34 ft for the HAFB golf course seems reasonable for the geographical area.

Taking 1993 as a typical year in terms of water application on the golf course, an excess of 365-185 = 180 acre-ft was applied. For the 156 acres of the golf course, this is equivalent to a depth of 1.15 ft (13.8 inches) of excess application over the turf growing season (April through October). This is in contrast with figures of 9.5 inches (Adkins 1994) and 8.5 inches (Montgomery-Watson 1989). However, the calculations by Adkins and Montgomery-Watson apparently considered some retention of excess water by the soil under the golf course. Direct evaporation and wind drift of the sprinkler-applied water can be conservatively estimated at 20% of the gross application, even though much of the irrigation occurs at night. Thus, perhaps only 0.80 x 1.15 ft = 0.92 ft (11.0 inches) are actually infiltrating below the turf root zone as deep percolation. This value would be the total for the entire irrigation season.

In 1991 and 1992 more water was delivered to the HAFB golf course during the April 15 to October 15 period (see Table 2). This may have been due to warmer weather and or less rainfall. At any rate, taking the 1991 delivery volume, the excess application would be 537-185 = 352 acre-ft. Following the same calculation as in the previous paragraph, this translates to 21.7 inches of deep percolation for the entire irrigation season. However, the actual amount of excess application could be much less if the weather conditions were such that turf ET was higher than normal for that year.

Table 2. Volume of Water Delivered to Hill AFB Golf Course from 1991 to 1993 (from Anderson 1994).

Year	Delivery (acre-ft)
1991	537
1992	499
1993	365

A soil water balance could be studied if more data were available, particularly the temporal distribution of irrigation applications. However, it may be reasonably assumed that the soil on the golf course is at or above field capacity (retentive capacity) during the early Spring, which is when turf begins to transpire significant amounts of water. Thus, even without irrigation in the early Spring, the grass can take existing water from the soil.

The golf course appeared to be well-watered when viewed from an airplane in early August, 1994, and no dry spots were visible on the turf. This indicates some over-watering, because there are certainly nonuniformities in the application of water. Thus, if the exact water requirement were applied over the whole golf course, some areas would be dry due to a lack of application uniformity. It is normal for sprinklers to operate with less than 100% uniformity of coverage, but the sprinklers used on the HAFB golf course are not in the best condition (according to Greg Gilmore, the irrigation system is being incrementally renovated, with new pipe lines and a sprinkler automation system being installed), nor are they of the best design. Golf course personnel have conducted informal "catch-can" tests to determine uniformity, but the results were not formally recorded, nor were they mathematically analyzed. Greg Gilmore acknowledged that the uniformity is "not too good". Thus, this substantiates the above analysis, using weather data and turf consumptive use values, which showed the likelihood of some excess application.

Groundwater Movement

Data were obtained from James M. Montgomery (1994) showing groundwater elevations in several dozen observation wells north of the HAFB golf course and in the areas near the Davis-Weber Canal. The data consists of monthly readings from the wells for the period from April 1993 to August 1994. Six of the well sites lying approximately on a straight north-south line were chosen to graph the elevation profiles during this period of time. From south to north, the sites are U1-025, U1-106, U1-127, U1-087, U1-091, and U1-090. U1-025 is near the north edge of the golf course, and U1-90 is near the downstream bank of the Davis-Weber Canal, north of the golf course (refer to Figure 2 for approximate locations of the wells). Figure 3 shows the profiles for six different months during the period. Table 3 gives the numerical values, which are elevations referenced to mean sea level. If the values in Table 3 were subtracted from the ground surface elevations at the respective observation well sites, the result would be the depth to the phreatic surface, which is essentially the top of the shallow aquifer.

Table 3. **Groundwater Elevations at Six Sites from the Hill AFB Golf Course to the Davis-Weber Canal from April 1993 to August 1994.**

Site ID	Location (ft)	Apr 93	Jul 93	Oct 93	Jan 94	Apr 94	Jul 94
U1-025	0	4786.84	4785.80	4784.59	4784.48	4785.19	4783.54
U1-106	621	4773.48	4773.40	4772.50	4771.98	4772.31	4772.05
U1-127	884	4771.06	4770.62	4770.15	4769.87	4769.01	4769.96
U1-087	1179	4746.39	4746.16	4746.00	4746.00	4746.31	4745.96
U1-091	1316	4680.27	4681.40	4681.22	4681.38	4682.14	4681.81
U1-090	1832	4484.55	4485.33	4484.84	4483.15	4483.40	4486.67

Note: Data is from James M. Montgomery, Consulting Engineers (1994).

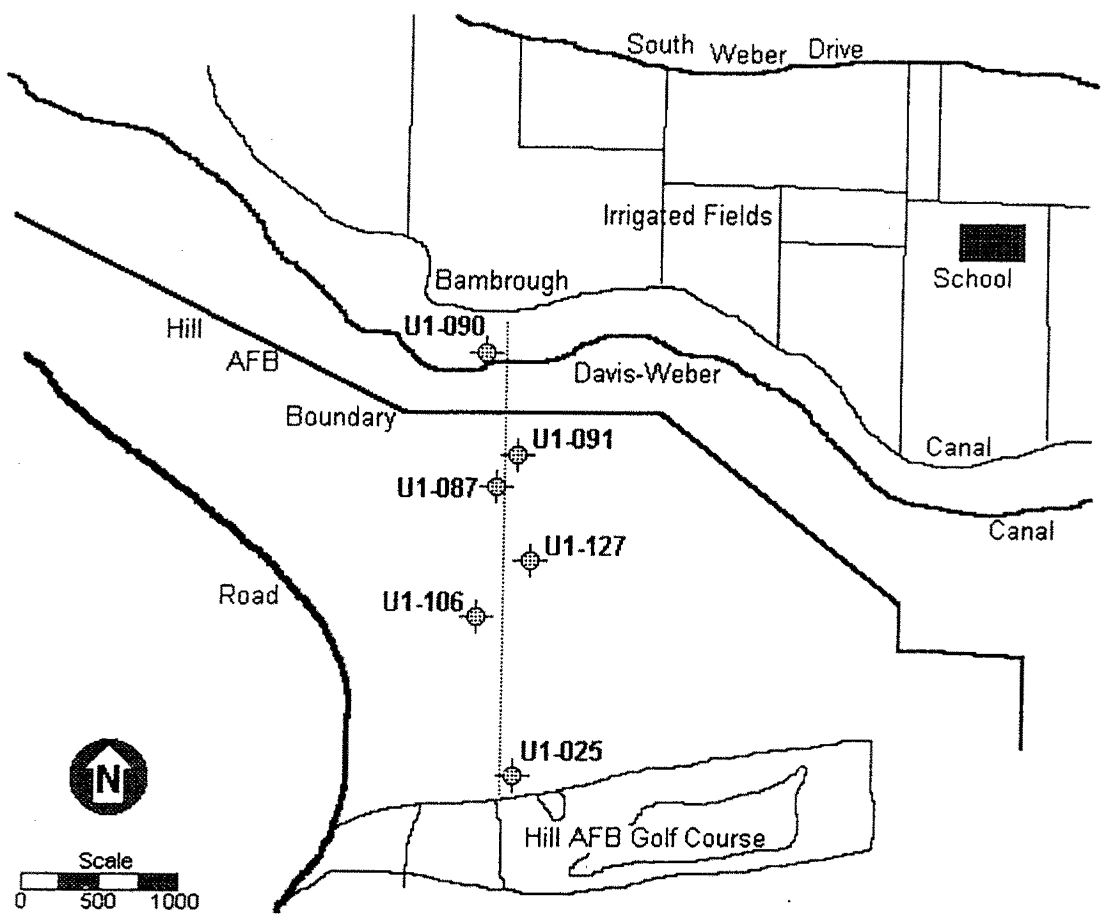


Figure 2. Approximate Locations of Selected Observation Wells North of the HAFB Golf Course.

It can be seen from Figure 3 that the profile does not change significantly with time over the study period; however, the spatial variation in groundwater elevation shows a marked decrease from the HAFB golf course to the Davis-Weber Canal. The profile has a steep drop in the area above the Davis-Weber Canal, which also has a steep ground surface slope. Nevertheless, these data show that there is some groundwater movement northward off HAFB and down the slope upon which the Davis-Weber Canal was constructed.

The irrigation of the golf course probably does not contribute significantly to this groundwater movement because of the static nature of the groundwater profile. If the golf course irrigation were to cause significant recharge to the shallow groundwater in this area, one would expect to see an increase in groundwater elevations during the period from about June to August when most irrigation water is applied. However, such an increase is not manifested in the data. Some of this movement may be due to other activities on the base, and some is probably due to natural groundwater flow in the area.

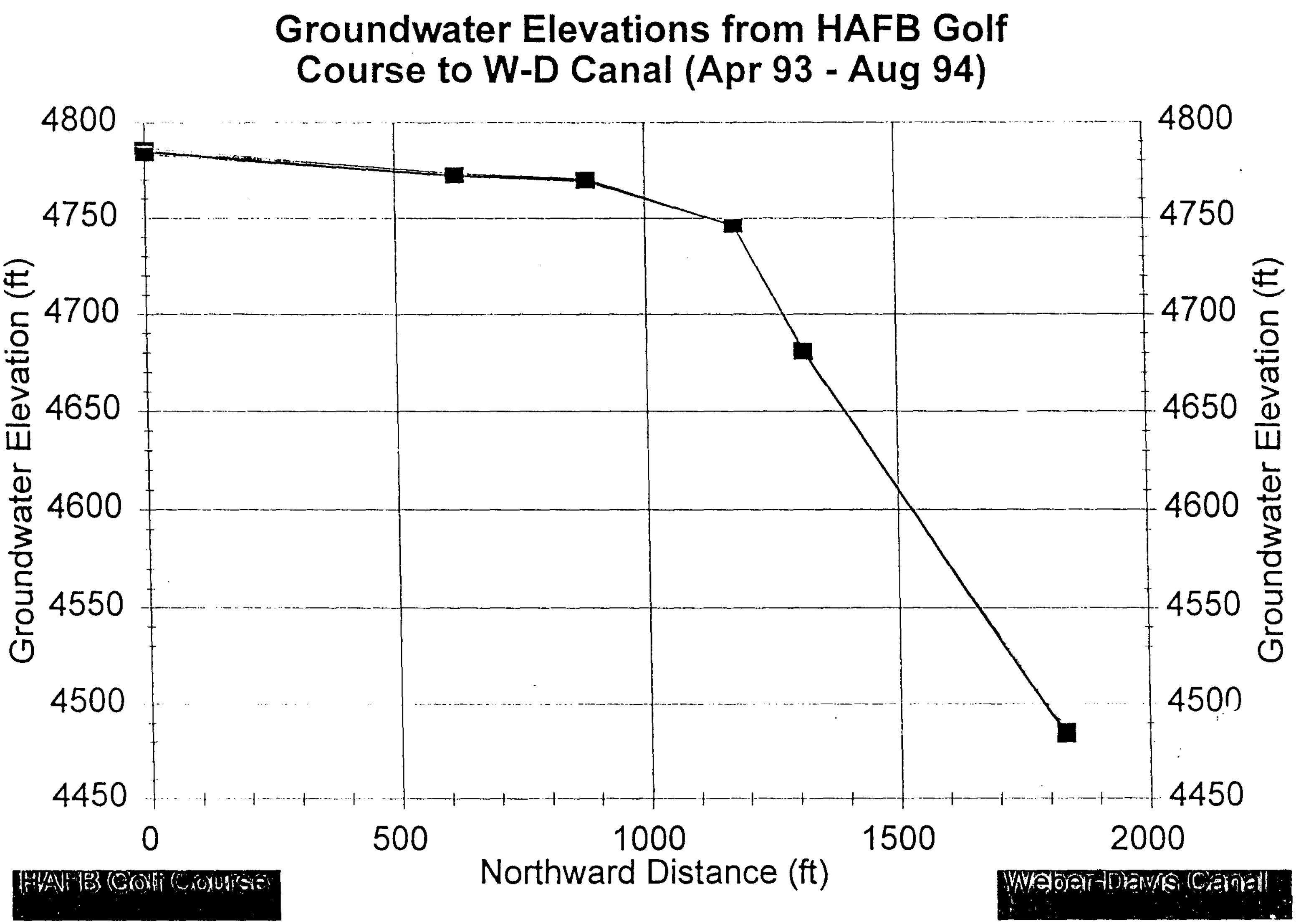


Figure 3. Groundwater Elevations at Six Sites from the Hill AFB Golf Course to the Davis-Weber Canal from April 1993 to August 1994 (data from Montgomery 1994).

Canal Safety Issues

An elementary school is located approximately 1,400 ft downhill from the Davis-Weber Canal, north of OU1 and the HAFB golf course. The Davis-Weber Counties Canal Company has expressed concern over the safety of the school's occupants in the event of a canal breach uphill from the school. A breach could be caused by a landslide, blocking the canal and causing it to overflow in the downhill direction.

The current study did not involve any field measurements, and some of the values taken for the canal hydraulic analysis are only estimates. The canal cross section was taken to have a bed width of 22.0 ft, with a maximum depth of 3.0 ft and a side slope of 1:1 (Adkins 1994). These values are for a recently lined section, and are consistent with those supplied by the manager of the Davis-Weber Counties Canal Company, Floyd Baham (1994). The bed slope of the canal was taken to be 1 ft drop in 1600 ft (0.000625 ft/ft) based on an estimate provided by Floyd Baham (1994). Assuming a Manning roughness value of 0.017, the channel capacity of the canal on the north end of HAFB is on the order of 300 cfs, which agrees with the value reported by Jones & Associates (1989) and the Utah Department of Water Resources (1987).

A canal length of 4 miles was assumed, representing the distance between the beginning of the canal at the river diversion to the approximate location of the school. Actually, a distance of 2 miles or more would give the same results in terms of a total canal blockage -- this is because the slope of the canal is relatively high. The net seepage loss from the canal was reported to be 17.0 cfs (Department of Water Resources 1987), which can be converted to an equivalent 169 mm/day (for input to the hydraulic model) by dividing by the total canal length of 88,320 ft, and by the full-flow wetted perimeter of 29.92 ft. This value for the wetted perimeter in a trapezoidal section is for a flow depth of 2.8 ft (using the cross-section values given above).

The Davis-Weber Canal is approximately 200 ft lower in elevation than the area on HAFB between the north boundary and the golf course. There is another 80 ft of elevation drop from the Davis-Weber Canal to the south end of the irrigated fields, which border the Bambrough Canal (see Figure 1). The slope of the irrigated fields is estimated (using detailed topographical maps) to be not more than 2%.

Simulation results from the ***CanalMan*** hydraulic model (Merkley 1994) are given in Table 4 and Figures 4, 5 and 6 (the spike in the curve at about 11 minutes elapsed time in Figure 5 is due to a temporary numerical instability in the simulation, and would not be expected to occur in the real canal). The simulation began with a steady-state condition and 290 cfs inflow. The steady-state outflow (at 4 miles distance) is 286 cfs, which takes into account the seepage loss at 169 mm/day. After ten minutes of simulation time, the downstream flow was suddenly and completely blocked, causing the water level to rapidly rise. Water then spilled over the north canal bank in the simulation, essentially stabilizing about 25 minutes after the time of blockage. At this time the water depth stopped rising upstream of the blockage, and the full canal flow was spilling over the bank (see Figures 4, 5 and 6). The simulated spill took place over a maximum width of 100 ft at the blockage location. No significant erosion of the bank was considered. Thus, if the bank were to erode in the first few minutes of a blockage, the time to reach full discharge over the bank would be less than 25 minutes.

The spill from the canal at the point of blockage would, of course, move downhill. Some of the water would be intercepted by the Bambrough canal, and some would flow along drainage ditches between the irrigated fields below. Nevertheless, the full-flow capacity of the Davis-Weber Canal would also cause some flooding of the fields and beyond. The velocity of the flow would slow down considerably as it spreads out over the relatively flat irrigated areas. Also, some of the flow would initially infiltrate into the soil, but for the following calculations it is assumed that the full 286 cfs continues over the fields.

Using a conservative (small) flow width of 50 ft, and assuming a 2% slope towards the school, the flow depth would be in the neighborhood of 1.2 ft. This can be determined by applying the Manning equation (Henderson 1966) with a roughness value of 0.050. This depth would decrease in the downstream direction as the flow spreads out and more water infiltrates into the soil. However, the flow velocity at 50 ft wide, 1.2 ft depth, and 286 cfs would be 4.8 ft/s, arriving at the school no sooner than 1400 ft ÷ (4.8 ft/s x 60 s/min) = 4.9 min. Thus, the full flow of the canal breach would not arrive at the school before about 25 + 4.9 ≈ 30 min, and the depth of water at the school would be less than 1.2 ft. Being worst-case conditions (full canal flow and complete blockage), the time to arrive at the school would likely be more than 30 min.

Taking a more realistic flow width of 500 ft over the fields, the depth would be approximately 0.30 ft (3.6 inches). Due to soil infiltration and some interception of the flow by the Bambrough Canal and other open ditches in the fields, the actual depth may be closer to 1 inch when arriving at the school. Also, at the assumed flow width of 500 ft, not all of the school grounds would be affected.

Table 4. Hydraulic Modeling Results for a Simulated Total Blockage of the Davis-Weber Canal North of the HAFB Golf Course.

Reach Name: Davis-Weber Canal

Elapsed Time	US Flow (cfs)	DS Flow (cfs)	Loss (cfs)	US Depth (ft)	DS Depth (ft)	Stability Index	Reach Mode	Reach Status
00:00:00	290.000	285.893	4.107	2.946	2.944	0.0020	Inactive	Normal
00:00:01	290.000	285.893	4.107	2.946	2.944	0.0000	Inactive	Normal
00:00:02	290.000	285.893	4.107	2.946	2.944	0.0000	Inactive	Normal
00:00:03	290.000	285.893	4.107	2.946	2.944	0.0000	Inactive	Normal
00:00:04	290.000	285.893	4.107	2.946	2.944	0.0000	Inactive	Normal
00:00:05	290.000	285.893	4.107	2.946	2.944	0.0000	Inactive	Normal
00:00:06	290.000	285.893	4.107	2.946	2.944	0.0000	Inactive	Normal
00:00:07	290.000	285.893	4.107	2.946	2.944	0.0000	Inactive	Normal
00:00:08	290.000	285.893	4.107	2.946	2.944	0.0000	Inactive	Normal
00:00:09	290.000	285.893	4.107	2.946	2.944	0.0000	Inactive	Normal
00:00:10	290.000	0.000	4.111	2.946	3.907	0.0000	Inactive	Normal
00:00:11	290.000	0.000	4.117	2.946	4.058	0.4140	Inactive	Normal
00:00:12	290.000	0.000	4.122	2.946	4.037	0.1945	Inactive	Normal
00:00:13	290.000	0.000	4.126	2.946	4.075	0.2488	Inactive	Normal
00:00:14	290.000	0.000	4.130	2.946	4.180	0.2222	Inactive	Normal
00:00:15	290.000	0.000	4.133	2.946	4.209	0.1622	Inactive	Normal
00:00:16	290.000	0.000	4.136	2.946	4.253	0.1358	Inactive	Normal
00:00:17	290.000	0.000	4.138	2.946	4.283	0.1214	Inactive	Normal
00:00:18	290.000	0.000	4.140	2.946	4.317	0.1027	Inactive	Normal
00:00:19	290.000	0.000	4.142	2.946	4.335	0.0855	Inactive	Normal
00:00:20	290.000	0.000	4.143	2.946	4.357	0.0709	Inactive	Normal
00:00:21	290.000	0.000	4.144	2.946	4.375	0.0606	Inactive	Normal
00:00:22	290.000	0.000	4.145	2.946	4.389	0.0559	Inactive	Normal
00:00:23	290.000	0.000	4.146	2.946	4.400	0.0491	Inactive	Normal
00:00:24	290.000	0.000	4.147	2.946	4.410	0.0390	Inactive	Normal
00:00:25	290.000	0.000	4.148	2.946	4.417	0.0336	Inactive	Normal
00:00:26	290.000	0.000	4.149	2.946	4.428	0.0307	Inactive	Normal
00:00:27	290.000	0.000	4.149	2.946	4.434	0.0299	Inactive	Normal
00:00:28	290.000	0.000	4.149	2.946	4.443	0.0267	Inactive	Normal
00:00:29	290.000	0.000	4.150	2.946	4.444	0.0243	Inactive	Normal
00:00:30	290.000	0.000	4.150	2.946	4.454	0.0193	Inactive	Normal
00:00:31	290.000	0.000	4.151	2.946	4.454	0.0194	Inactive	Normal
00:00:32	290.000	0.000	4.151	2.946	4.461	0.0172	Inactive	Normal
00:00:33	290.000	0.000	4.152	2.946	4.460	0.0148	Inactive	Normal
00:00:34	290.000	0.000	4.152	2.946	4.465	0.0122	Inactive	Normal
00:00:35	290.000	0.000	4.152	2.946	4.465	0.0116	Inactive	Normal
00:00:36	290.000	0.000	4.152	2.946	4.471	0.0095	Inactive	Normal
00:00:37	290.000	0.000	4.153	2.946	4.470	0.0101	Inactive	Normal
00:00:38	290.000	0.000	4.153	2.946	4.473	0.0092	Inactive	Normal
00:00:39	290.000	0.000	4.153	2.946	4.473	0.0073	Inactive	Normal
00:00:40	290.000	0.000	4.153	2.946	4.475	0.0060	Inactive	Normal
00:00:41	290.000	0.000	4.153	2.946	4.475	0.0060	Inactive	Normal
00:00:42	290.000	0.000	4.153	2.946	4.478	0.0052	Inactive	Normal
00:00:43	290.000	0.000	4.153	2.946	4.476	0.0053	Inactive	Normal
00:00:44	290.000	0.000	4.154	2.946	4.480	0.0039	Inactive	Normal
00:00:45	290.000	0.000	4.154	2.946	4.477	0.0047	Inactive	Normal
00:00:46	290.000	0.000	4.154	2.946	4.483	0.0027	Inactive	Normal
00:00:47	290.000	0.000	4.154	2.946	4.480	0.0047	Inactive	Normal
00:00:48	290.000	0.000	4.154	2.946	4.482	0.0049	Inactive	Normal
00:00:49	290.000	0.000	4.154	2.946	4.482	0.0024	Inactive	Normal
00:00:50	290.000	0.000	4.154	2.946	4.481	0.0018	Inactive	Normal
00:00:51	290.000	0.000	4.154	2.946	4.483	0.0016	Inactive	Normal
00:00:52	290.000	0.000	4.154	2.946	4.481	0.0026	Inactive	Normal
00:00:53	290.000	0.000	4.154	2.946	4.485	0.0013	Inactive	Normal
00:00:54	290.000	0.000	4.154	2.946	4.484	0.0025	Inactive	Normal
00:00:55	290.000	0.000	4.154	2.946	4.484	0.0031	Inactive	Normal
00:00:56	290.000	0.000	4.154	2.946	4.486	0.0007	Inactive	Normal
00:00:57	290.000	0.000	4.154	2.946	4.485	0.0013	Inactive	Normal

00:00:58	290.000	0.000	4.154	2.946	4.484	0.0025	Inactive	Normal
00:00:59	290.000	0.000	4.154	2.946	4.487	0.0003	Inactive	Normal
00:01:00	290.000	0.000	4.154	2.946	4.486	0.0012	Inactive	Normal
00:01:01	290.000	0.000	4.155	2.946	4.485	0.0024	Inactive	Normal
00:01:02	290.000	0.000	4.155	2.946	4.488	-0.0001	Inactive	Normal
00:01:03	290.000	0.000	4.155	2.946	4.483	0.0009	Inactive	Normal
00:01:04	290.000	0.000	4.155	2.946	4.488	-0.0005	Inactive	Normal
00:01:05	290.000	0.000	4.155	2.946	4.482	0.0013	Inactive	Normal
00:01:06	290.000	0.000	4.155	2.946	4.486	-0.0005	Inactive	Normal
00:01:07	290.000	0.000	4.155	2.946	4.485	-0.0016	Inactive	Normal
00:01:08	290.000	0.000	4.155	2.946	4.484	0.0009	Inactive	Normal
00:01:09	290.000	0.000	4.155	2.946	4.488	0.0005	Inactive	Normal
00:01:10	290.000	0.000	4.155	2.946	4.486	0.0015	Inactive	Normal
00:01:11	290.000	0.000	4.155	2.946	4.486	0.0019	Inactive	Normal

End of Listing (Complete)

Note: The “Stability Index” is the ratio defined as $(Q_{in} - Q_{out})/(Q_{in}+Q_{out})$, where Q_{in} is the total inflow and Q_{out} is the total outflow (including seepage loss).

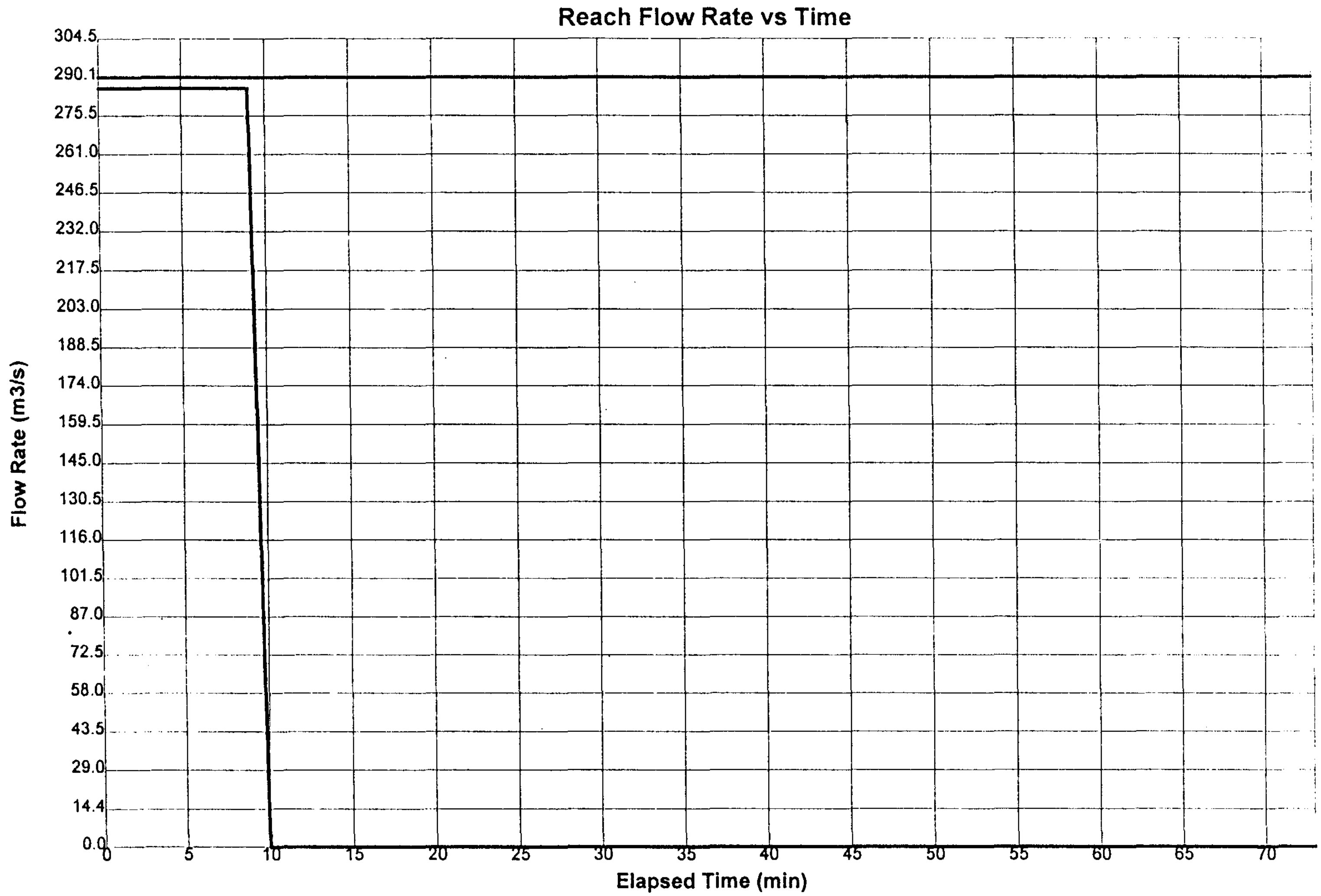


Figure 4. Reach Flow Rate vs. Time in the Simulated Davis-Weber Canal.

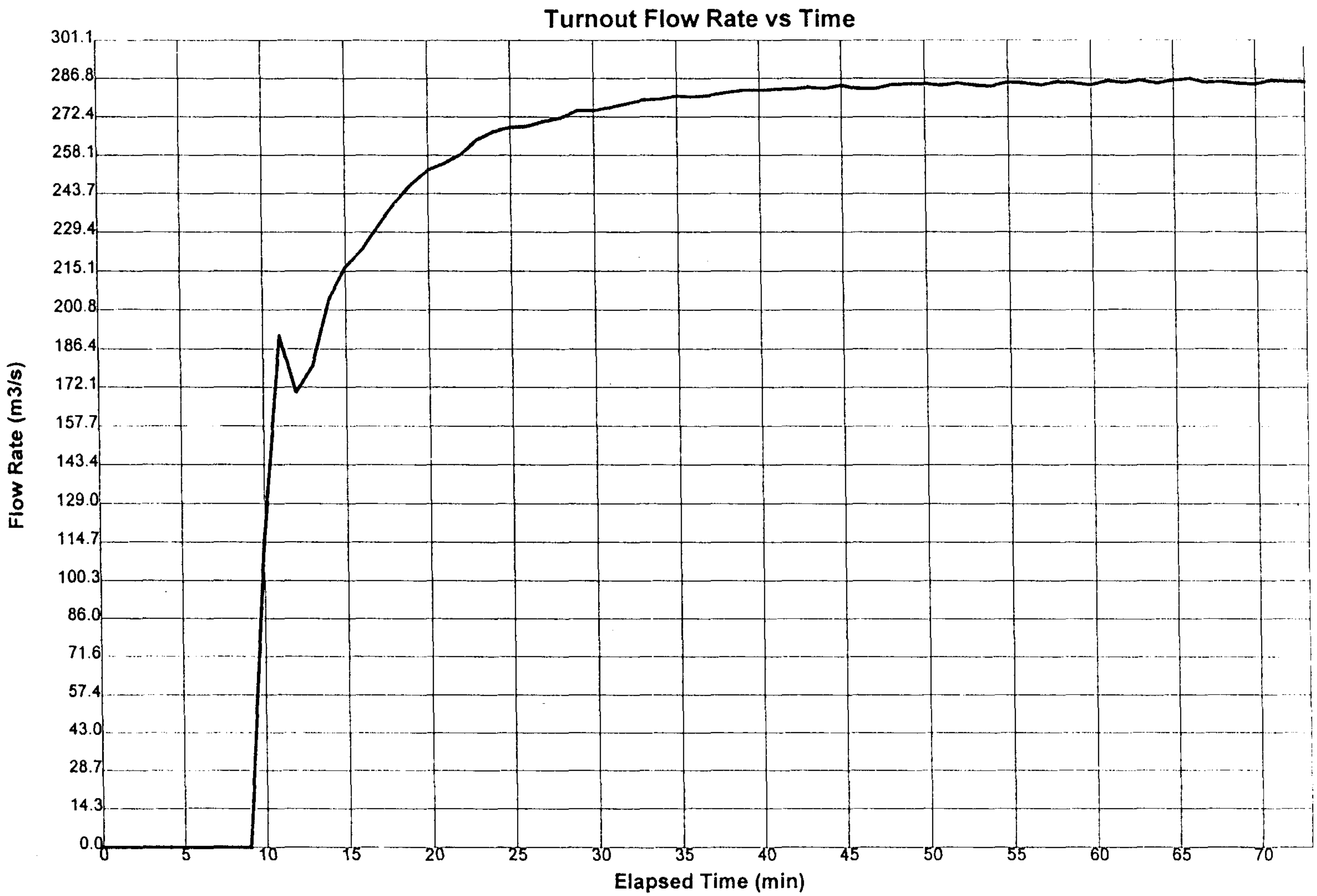


Figure 5. Spillage Flow Rate vs. Time in the Simulated Davis-Weber Canal.

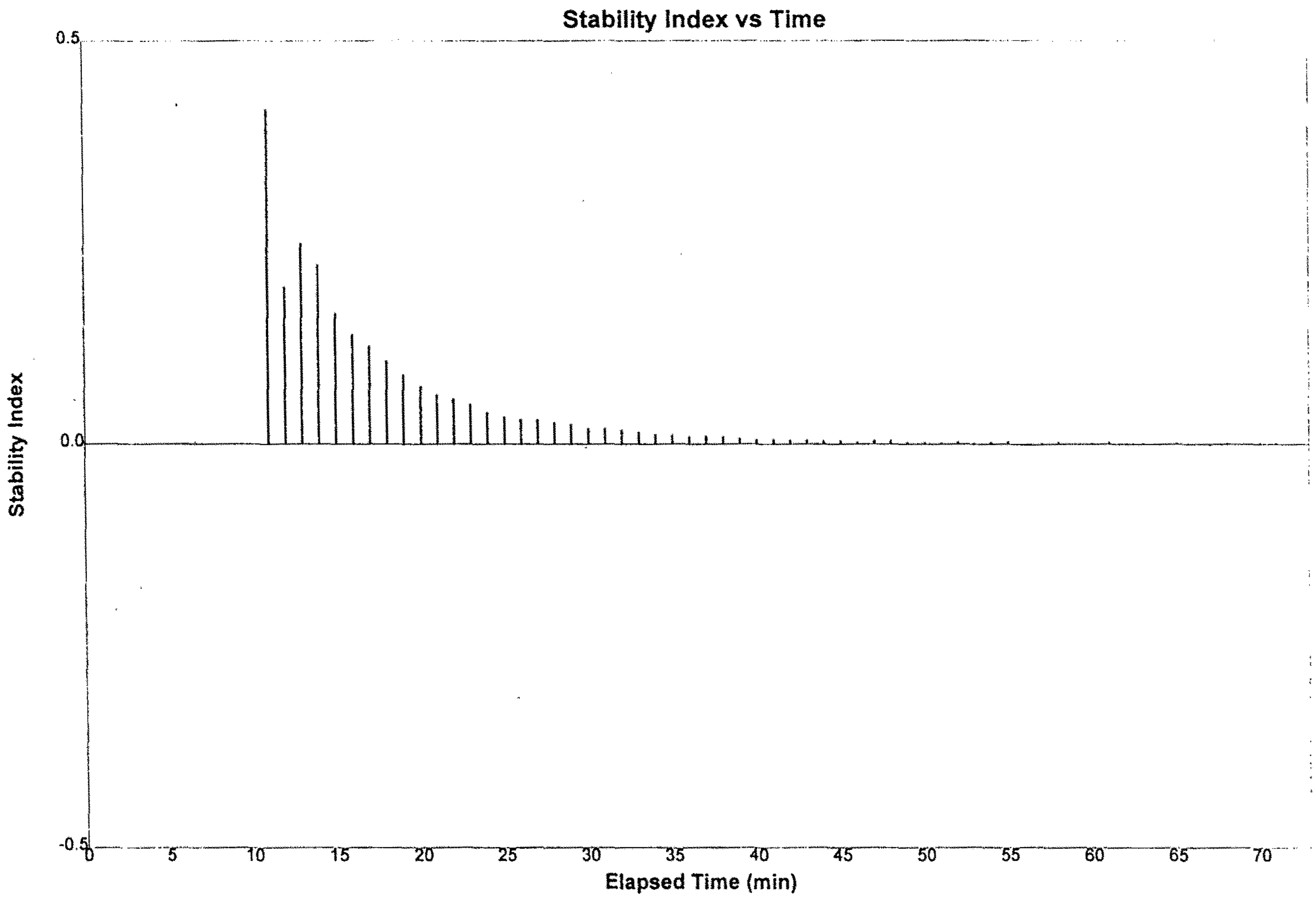


Figure 6. Hydraulic Stability in the Simulated Davis-Weber Canal.

Conclusions

Results from the analysis on turf consumptive use in the HAFB region, and from records of actual water use on the base, indicate that some over-watering occurs from April 15 to October 15 in most (if not all) years. This is substantiated by other empirical evidence from observations by the golf course superindendent and from an aerial view of the golf course in August this year. However, irrigation water applications on the golf course are within the normal practices as compared to records from other golf courses in the region. Also, shallow ground water depths from six observation wells are essentially static from the April 1993 to August 1994 continuous record, indicating that irrigation of the golf course probably does not significantly impact the movement of groundwater. Therefore, it is concluded that the current levels of over-irrigation on the golf course are such that deep percolation from the golf course is not a factor in the sloughing of the Davis-Weber Canal. It is highly probably that the sloughing of the canal is caused by other factors, and not by irrigation of the golf course. However, the study of these other factors is beyond the scope of this analysis.

From the hydraulic modeling results on the Davis-Weber Canal for complete blockage under full-flow conditions, it can be argued that flooding from a canal breach would not be a threat to human life. Property damage would be expected due to erosion, especially in the steep slope below the canal, and in some of the fields beyond. However, the flow depth at the elementary school, some 1400 ft from the canal, would probably be less than 3 inches. The flood waters may not even cross the school grounds at all, especially if the breach were to occur in the canal at a location further east or further west from the school's position. As far as the school is concerned, flooding from a canal breach would be nothing more than an inconvenience, but possibly with minor property damage. In any case, a more detailed study would be required to provide a more accurate description of the flooding from a canal breach.

References

Adkins, D.F. 1994. Statement of Work for Contract F42650-92-D0005.

Anderson, M. 1994. Personal communication.

Baham, F. 1994. Personal communication.

Canal Inflow Study, December 1989. Report prepared by Jones & Associates, consulting engineers, Ogden, Utah, for the Davis and Weber Counties Canal Company (14 pages).

Consumptive Use of Irrigated Crops in Utah, 1994. Draft final report of the Utah Dept. of Natural Resources, Division of Water Resources and Division of Water Rights, prepared under the direction of R.W. Hill at Utah State Univ.

Gilmore, G. 1994. Personal communication.

Golf Course Water Use, January 1994. Report published by the Department of Water Resources, Division of Water Rights, State of Utah.

Henderson, F.M. 1966. Open Channel Flow. MacMillan Publishing Co., Inc., New York, N.Y. (522 pages).

Merkley, G.P. 1994. User's Guide for the CanalMan Hydraulic Model, Dept. of Biological & Irrigation Engrg., Utah State Univ. Logan, UT 84322-4105.

Montgomery, J.M. 1994. Report on Groundwater Levels in Observation Wells on Hill AFB.

Seepage Studies of the Weber River and the Davis-Weber and Ogden Valley Canals, 1985, 1987. Technical Publication No. 90, Dept. of Natural Resources, State of Utah (53 pages).

Attachment A

Consumptive Use of Irrigated Crops in Utah
(selected pages from the full report)

and

State of Utah, Division of Water Rights,
data on Golf Course Water Use

CONSUMPTIVE USE OF IRRIGATED CROPS IN UTAH

FINAL REPORT

Submitted to

Utah Department of Natural Resources
Division of Water Resources
and
Division of Water Rights

A Cooperative Project
Sponsored by

Utah Department of Natural Resources
Division of Water Resources
and
Division of Water Rights

and
Utah State University
Utah Agricultural Experiment Station

Utah Agricultural Experiment Station
Project No. 796
USU Control No. 90-391

Project Director:
Robert W. Hill
Utah State University
Logan, Utah 84322-4105

RESEARCH REPORT 145

October, 1994

Table 25.(Continued) Estimated Consumptive Use for the NWS Station at RIVERDALE
From a Calibrated SCS Blaney-Criddle Equation using data from KAYSVILLE 10-26-1994
Years of Data Available; NWS: 1961-1990 KAYSVILLE: 1980-1990 Elev. 4400 ft., Lat. 41.15

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
% Day Light	6.65	6.63	8.27	8.97	10.11	10.21	10.36	9.64	8.40	7.69	6.63	6.43	100.00
Avg Temp F	27.08	32.65	40.44	48.59	57.34	66.61	75.17	73.08	63.15	51.77	39.26	28.64	50.31
Std Dev Temp	4.16	4.58	3.71	3.20	2.98	2.96	1.96	2.40	3.31	3.38	2.92	3.41	1.26
Avg Prec in.	1.51	1.57	2.16	2.43	2.36	1.36	0.78	0.95	1.63	1.86	1.73	1.62	19.97
Std Dev Prec	0.96	1.12	1.33	1.34	1.68	1.11	0.85	1.01	1.55	1.26	0.93	1.29	5.82
SCS-BC f in.	0.54	0.68	1.31	2.31	3.95	5.72	7.69	6.71	4.15	2.33	0.97	0.55	36.90
Std Dev f	0.08	0.14	0.32	0.39	0.51	0.61	0.46	0.51	0.52	0.39	0.19	0.07	1.86
ALFALFA													
Cal SCS-BC k				1.30	1.65	1.16	0.90	0.89	0.91	1.07			
Cal SCS-BC Et				2.99	6.53	6.64	6.93	6.00	3.76	2.48			35.34
Std Dev Et				0.51	0.85	0.71	0.42	0.46	0.47	0.41			1.95
Net Irr in.				1.05	4.64	5.55	6.30	5.24	2.46	0.99			26.23
PASTURE													
Cal SCS-BC k			0.32	0.97	1.08	0.98	0.79	0.77	0.76	0.84			
Cal SCS-BC Et			0.41	2.25	4.26	5.61	6.05	5.16	3.17	1.97			28.88
Std Dev Et			0.10	0.38	0.55	0.60	0.36	0.39	0.40	0.33			1.54
Net Irr in.				0.30	2.37	4.52	5.43	4.40	1.86	0.48			19.36
SP GRAIN													
Cal SCS-BC k				0.43	1.29	1.51	0.90	0.01					
Cal SCS-BC Et				0.99	5.08	8.64	6.91	0.09					21.71
Std Dev Et				0.17	0.66	0.92	0.42	0.01					1.46
Net Irr in.					3.20	7.55	6.28						17.03
CORN													
Cal SCS-BC k					0.33	0.52	0.90	1.12	1.01				
Cal SCS-BC Et					1.31	2.98	6.88	7.53	4.17				22.87
Std Dev Et					0.17	0.32	0.41	0.57	0.53				1.19
Net Irr in.						1.89	6.26	6.77	2.86				17.78
PEACHES													
Cal SCS-BC k			0.08	0.83	1.27	1.38	1.21	1.16	0.97				
Cal SCS-BC Et			0.11	1.93	5.02	7.88	9.28	7.80	4.02				36.03
Std Dev Et			0.03	0.33	0.65	0.84	0.56	0.59	0.51				1.92
Net Irr in.					3.14	6.79	8.65	7.03	2.71				28.32
ORCHARD													
Cal SCS-BC k				0.24	0.97	1.41	1.30	1.29	1.23	0.59			
Cal SCS-BC Et				0.54	3.81	8.05	10.03	8.64	5.11	1.37			37.57
Std Dev Et				0.09	0.49	0.86	0.60	0.66	0.65	0.23			1.89
Net Irr in.					1.93	6.96	9.41	7.88	3.81				29.98

All Values are 30 Year Averages. Effective Precipitation is 80 Percent of Total During Growing Season

Table 25.(Continued) Estimated Consumptive Use for the NWS Station at RIVERDALE
From a Calibrated SCS Blaney-Criddle Equation using data from KAYSVILLE 10-26-1994
Years of Data Available; NWS: 1961-1990 KAYSVILLE: 1980-1990 Elev. 4400 ft., Lat. 41.15

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
TURF													
Cal SCS-BC k			0.36	0.94	0.93	0.85	0.68	0.66	0.66	0.85			
Cal SCS-BC Et			0.47	2.17	3.67	4.84	5.21	4.44	2.73	1.98			25.52
Std Dev Et			0.12	0.37	0.47	0.51	0.31	0.34	0.34	0.33			1.36
Net Irr in.				0.22	1.78	3.75	4.59	3.68	1.43	0.49			15.94
GARDEN													
Cal SCS-BC k				0.11	0.45	0.71	0.92	0.72	0.27	0.17			
Cal SCS-BC Et				0.24	1.79	4.06	7.07	4.85	1.10	0.39			19.50
Std Dev Et				0.04	0.23	0.43	0.43	0.37	0.14	0.07			0.96
Net Irr in.						2.97	6.44	4.08					13.49
E-LAKE													
Cal SCS-BC k	1.43	2.00	1.53	1.55	1.31	1.06	0.83	0.87	0.95	1.35	1.41	1.51	
Cal SCS-BC Evap	0.77	1.36	2.01	3.58	5.16	6.07	6.38	5.81	3.93	3.15	1.36	0.84	40.43
Std Dev Evap	0.12	0.28	0.49	0.61	0.67	0.65	0.38	0.44	0.50	0.52	0.27	0.10	2.15
Net Loss in.				1.15	2.80	4.71	5.60	4.86	2.30	1.29			22.72
ET Ref													
Cal SCS-BC k	1.59	2.33	1.70	1.75	1.66	1.51	1.21	1.18	1.18	1.54	1.56	1.68	
Estimated Etr	0.86	1.58	2.23	4.04	6.54	8.64	9.31	7.94	4.87	3.60	1.51	0.93	52.04
Std Dev Et	0.13	0.32	0.55	0.69	0.85	0.92	0.56	0.60	0.61	0.60	0.29	0.11	2.71

All Values are 30 Year Averages. Effective Precipitation is 80 Percent of Total During Growing Season
Blank values (if any) of ET Ref in early and late months denotes only seasonal calibration data

Table 25.(Continued) Estimated Consumptive Use for the NWS Station at FARMINGTON/USU FL STN
From a Calibrated SCS Blaney-Criddle Equation using data from KAYSVILLE 10-26-1994
Years of Data Available; NWS: 1961-1990 KAYSVILLE: 1980-1991 Elev. 4340 ft., Lat. 41.02

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
% Day Light	6.66	6.64	8.27	8.96	10.10	10.20	10.36	9.64	8.40	7.69	6.64	6.44	100.00
Avg Temp F	28.56	33.66	41.71	49.54	58.30	67.81	75.95	73.86	64.24	51.82	39.80	29.33	51.21
Std Dev Temp	3.73	3.94	3.07	3.76	2.55	3.07	1.66	2.28	2.84	2.98	2.26	3.06	1.28
Avg Prec in.	1.88	1.89	2.44	2.76	2.71	1.48	0.83	0.99	1.65	2.01	1.96	2.00	22.60
Std Dev Prec	0.84	1.03	1.45	1.47	1.50	1.33	0.74	0.98	1.65	1.15	1.15	1.43	5.77
SCS-BC f in.	0.57	0.70	1.42	2.43	4.10	5.96	7.87	6.87	4.31	2.33	1.00	0.57	38.14
Std Dev f	0.07	0.13	0.29	0.48	0.44	0.65	0.40	0.49	0.46	0.34	0.16	0.06	2.14
ALFALFA													
Cal SCS-BC k			0.19	1.31	1.33	1.19	0.86	0.82	0.86	0.83			
Cal SCS-BC Et			0.27	3.19	5.44	7.08	6.78	5.66	3.73	1.95			34.11
Std Dev Et			0.06	0.63	0.58	0.77	0.35	0.40	0.39	0.29			2.16
Net Irr in.				0.99	3.27	5.89	6.12	4.87	2.41	0.34			23.89
PASTURE													
Cal SCS-BC k			0.39	0.91	0.97	0.89	0.76	0.73	0.75	0.63			
Cal SCS-BC Et			0.56	2.22	3.98	5.29	5.95	5.03	3.22	1.47			27.71
Std Dev Et			0.11	0.44	0.43	0.58	0.30	0.36	0.34	0.22			1.67
Net Irr in.				0.01	1.81	4.11	5.29	4.24	1.89				17.35
SP GRAIN													
Cal SCS-BC k				0.47	1.26	1.37	0.74						
Cal SCS-BC Et				1.14	5.17	8.14	5.84						20.30
Std Dev Et				0.22	0.55	0.89	0.30						1.43
Net Irr in.					3.01	6.96	5.18						15.15
CORN													
Cal SCS-BC k				0.04	0.30	0.51	0.90	1.07	0.96				
Cal SCS-BC Et				0.10	1.23	3.06	7.12	7.33	4.14				22.97
Std Dev Et				0.02	0.13	0.33	0.36	0.52	0.44				1.11
Net Irr in.						1.88	6.45	6.53	2.82				17.68
PEACHES													
Cal SCS-BC k			0.08	0.74	1.15	1.25	1.16	1.11	0.95				
Cal SCS-BC Et			0.12	1.79	4.70	7.43	9.13	7.60	4.08				34.84
Std Dev Et			0.02	0.35	0.50	0.81	0.47	0.54	0.43				1.91
Net Irr in.					2.53	6.24	8.46	6.80	2.75				26.80
ORCHARD													
Cal SCS-BC k				0.32	0.97	1.32	1.26	1.23	1.18	0.43			
Cal SCS-BC Et				0.77	3.98	7.89	9.93	8.41	5.11	1.00			37.10
Std Dev Et				0.15	0.43	0.86	0.51	0.60	0.54	0.15			1.92
Net Irr in.					1.82	6.71	9.27	7.62	3.79				29.20

All Values are 30 Year Averages. Effective Precipitation is 80 Percent of Total During Growing Season

Table 25.(Continued) Estimated Consumptive Use for the NWS Station at FARMINGTON/USU FL STN
From a Calibrated SCS Blaney-Criddle Equation using data from KAYSVILLE 10-26-1994
Years of Data Available; NWS: 1961-1990 KAYSVILLE: 1980-1991 Elev. 4340 ft., Lat. 41.02

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
SWE CORN													
Cal SCS-BC k					0.26	0.54	0.99	0.68					
Cal SCS-BC Et					1.08	3.22	7.76	4.67					16.74
Std Dev Et					0.12	0.35	0.40	0.33					0.77
Net Irr in.						2.04	7.09	3.88					13.01
POTATOES													
Cal SCS-BC k					0.37	0.89	0.90	0.77	0.46				
Cal SCS-BC Et					1.51	5.29	7.08	5.28	2.00				21.15
Std Dev Et					0.16	0.58	0.36	0.37	0.21				1.04
Net Irr in.						4.10	6.42	4.48	0.67				15.67
TURF													
Cal SCS-BC k			0.51	0.86	0.84	0.77	0.65	0.63	0.64	0.62			
Cal SCS-BC Et			0.73	2.10	3.43	4.56	5.13	4.33	2.77	1.44			24.49
Std Dev Et			0.15	0.41	0.37	0.50	0.26	0.31	0.29	0.21			1.50
Net Irr in.					1.26	3.37	4.47	3.54	1.45				14.09
GARDEN													
Cal SCS-BC k				0.16	0.44	0.70	0.91	0.59	0.24	0.12			
Cal SCS-BC Et				0.39	1.79	4.18	7.20	4.08	1.03	0.29			18.96
Std Dev Et				0.08	0.19	0.46	0.37	0.29	0.11	0.04			0.95
Net Irr in.						3.00	6.54	3.29					12.82
E-LAKE													
Cal SCS-BC k	1.31	1.92	1.54	1.39	1.17	0.96	0.80	0.82	0.91	0.97	1.30	1.37	
Cal SCS-BC Evap	0.75	1.35	2.18	3.38	4.78	5.73	6.28	5.64	3.94	2.25	1.30	0.78	38.36
Std Dev Evap	0.10	0.24	0.44	0.67	0.51	0.62	0.32	0.40	0.42	0.33	0.20	0.09	2.29
Net Loss in.				0.62	2.07	4.25	5.46	4.65	2.29	0.24			19.58
ET Ref													
Cal SCS-BC k	1.45	2.14	1.71	1.56	1.49	1.37	1.16	1.13	1.15	1.12	1.45	1.52	
Estimated Etr	0.83	1.50	2.42	3.81	6.12	8.14	9.16	7.74	4.95	2.60	1.45	0.86	49.58
Std Dev Et	0.11	0.27	0.49	0.75	0.65	0.89	0.47	0.55	0.52	0.38	0.23	0.10	2.88

All Values are 30 Year Averages. Effective Precipitation is 80 Percent of Total During Growing Season
Blank values (if any) of ET Ref in early and late months denotes only seasonal calibration data

PHONE (801) 771-1677

WATER USE REPORT (in acre-feet)

WATER USER: HILL FIELD GOLF	DELIVERIES FOR MONTH OF:	APRIL -JULY 1994
CONTRACTED WATER		640
	10% LOSS	64
TOTAL WATER AVAILABLE		576
PREVIOUS BALANCE		469.05

METER STATIONS	GALLONS	ACRE-FEET	XXXXXX
JULY		127.7	XXXXXXX
			XXXXXXX
			XXXXXXX
			XXXXXXX
			XXXXXXX
			XXXXXXX
TOTAL ALL STATIONS		XXXXXX	127.7
BALANCE OF AVAILABLE WATER			341.35
TOTAL CONTRACT WATER USED TO DATE			234.65
ACCUMULATED MONTHLY OVER USE			
OTHER WATER USE OR CREDITS	XXXXXXXXXXXXXXXXXXXXXXXXXX		
PREVIOUS USE OF WATER			
PRESENT USE OF WATER			
TOTAL USE OF WATER			
TOTAL OF ALL WATER USED TO DATE			

PERCENTAGES OF CONTRACT WATER USED

% OF YEAR	% USED THIS MONTH	% USED TO DATE

State of Utah
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATER RIGHTS

Michael O. Leavitt
Governor
Ted Stewart
Executive Director
Robert L. Morgan
Division Director

1636 West North Temple, Suite 220
Salt Lake City, UT 84116-3156
801-538-7240
801-538-7467 (Fax)

Fax Cover Sheet

Date 5/25/94

Time 10:00 AM

TO: DR. DAN ADKINS

Name Hill Air force Base

Agency EMR

Fax No. 777-4306

FROM: [signature]

Name

Agency Division of Water Rights

Fax No. 801-538-7467

Number of pages transmitted including cover sheet 2

Comments:

STATE OF UTAH
NATURAL RESOURCES
Division of Water Rights

GOLF COURSE WATER USE

INTRODUCTION

The Utah Division of Water Rights, in cooperation with the U.S. Geological Survey, operates the Utah Water Use program. Due to the increasing number of golf courses built in Utah, there is a need to have good water use data in planning future water needs. The purpose of this report is to document water use rates for golf courses.

DATA COLLECTION

Data was collected by contacting golf course superintendents to identify those courses that used metered water only. These courses included Glendale and Wingpointe, metered by the Salt Lake City Corporation, West Ridge, metered by Kearns Improvement District and Jeremy Ranch, which is self-metered. Together with the metered courses, data was also collected (where reasonable estimates were provided) from courses that used partially metered water. Five courses that were not totally metered were included in the report in order to provide a greater variety of locations. Hidden Valley sources consisted of two metered wells and unmetered ditch water. Valley View sources include metered water from Weber Basin Water Conservancy District and unmetered water from Kays Creek Irrigation Company. There are numerous golf courses in the St. George area. None of these courses are totally metered; therefore, only three courses are included in the report. The three golf courses are Red Hills, South Gate and St. George, which irrigate with unmetered ditch water and a small amount of St. George City metered water. All golf courses in the study used a combination of Kentucky Blue, Annual Kentucky Blue and Rye Grass on the fairways. Bent Grass or a combination of Bent and Annual Blue Grass was used on the greens. The soil type at each course is different and varies considerably within an individual course. Thus, soil type drainage, and other related parameters may also affect water use rates.

SUMMARY

The water most accurately metered was at three golf courses located in the Salt Lake Valley, metered by municipal water suppliers. The three courses are Glendale, West Ridge and Wingpointe. At these three courses, 1992 was the highest water use year of the three years in the survey. In 1993, precipitation increased significantly, temperatures were lower than normal, and water use declined an average of 31.6 percent. The average water use for the three Salt Lake area courses during the period 1991 through 1993 was 2.76 acre-feet per acre. The three courses surveyed in the St. George area, with an average frost-free season of 216 days and an annual mean temperature of 62.3 degrees, used an estimated average of 9.8 acre-feet per acre while the Jeremy Ranch Golf Course, with an annual mean temperature of 44 degrees and approximately 105 frost-free days annually, used an average of 1.6 acre-feet per acre.

GOLF COURSE WATER USE

COURSE NAME/COUNTY	YEAR	IRRIGATED ACREAGE	WATER USED (IN ACRE-FT)	ACRE-FEET PER ACRE	ELEVATION (FEET)	MEAN ANNUAL TEMPERATURE Degrees (F)	ANNUAL PRECIPITATION (Inches)	FROST FREE Period	FROST FREE Days
Glendale (Salt Lake)	1991 1992 1993	170	370 477 321	2.18 2.80 1.89	4225	52.0[1]	17.79[1] 12.07[1] 18.87[1]	4/12 to 10/31[1]	201[1]
Wingpointe (Salt Lake)	1991 1992 1993	163[2]	492 725 524	3.00 4.46 3.23	4220	52.0[1]	17.79[1] 12.07[1] 18.87[1]	4/12 to 10/31[1]	201[1]
West Ridge (Salt Lake)	1991 1992 1993	210	548 594 396	2.61 2.83 1.88	4750	52.0[1]	17.79[1] 12.07[1] 18.87[1]	4/12 to 10/31[1]	201[1]
Jeremy Ranch (Summit)	1992 1993	129	226[6] 192[6]	1.75 1.49	6400	44.0[4]	*20.68[4] 24.80[5]	6/5 to 9/19[4]	105[4]
Hidden Valley Country Club (Salt Lake)		185	424[3]	2.29	4760	53.1[7]	*24.30[7]	5/1 to 10/14[7]	166[7]
Valley View (Davis)	1991	120	261[8]	2.18	4600	51.2[9]	*27.22[9]	5/5 to 10/10[9]	157[9]
St. George Golf Club (Washington)		180	1700[10]	9.40	2600	62.3[11]	*8.06[11]	3/29 to 11/1[11]	216[11]
South Gate (Washington)		125	1250[12]	10.0	2520	62.3[11]	*8.06[11]	3/29 to 11/1[11]	216[11]
Dixie Red Hills (Washington)		50	500[13]	10.0	2950	62.3[11]	*8.06[11]	3/29 to 11/1[11]	216[11]

* Mean annual precipitation reported.

1. Salt Lake City Airport Weather Station.
2. 125 acres of grass, 75 acres native vegetation irrigated at 50 percent the rate of grass.
3. Includes water for seven acres of ponds.
4. Park City Radio Weather Station.
5. Snyderville Weather Station.
6. Estimated using one million gallons for 90 days; 400,000 gallons for 120 days. Includes water used for three acres of ponds. Sources include two metered wells and Hill Ditch.
7. Cottonwood Weir Weather Station.
8. Sources include Weber Basin Water Conservancy District (metered) at 55% and Kays Creek Irrigation Company at 45%.
9. Farmington USU Station.
10. Estimated by pumping volume and duration. Source includes Washington Fields Canal.
11. St. George Weather Station.
12. Estimated by average water deliveries and sprinkling duration X the flow rate of the sprinkler heads in gallons per minute. Sources include Santa Clara Seep Ditch and St. George City water.
13. Estimated by average water deliveries and sprinkling duration X the flow rate of the sprinkler heads in gallons per minute. Sources include City Springs and St. George City water.

Department of Natural Resources/Division of Water Rights - January 1994

Attachment B

Excerpts from Various Documents and Reports Dealing with Slope Stability and Landsliding in and Near the Davis-Weber Canal

PREPARED FOR: Kyle Kirchner/EMR
Bob Elliott/EMR

PREPARED BY: Michal Bukovansky/CH2M HILL
Steve Brown/CH2M HILL

COPIES: Dan Adkins/EMR
Randy Underwood/CH2M HILL
Howard Saxion/CH2M HILL

DATE: December 21, 1993

SUBJECT: Active Landslide Above the Davis-Weber Canal, Hill Air Force Base, Utah

PROJECT: BOI70158.F0.04

On December 7, 1993, Steve Brown and Michal Bukovansky of CH2M HILL visited the site of the proposed remedial mitigation at Operable Unit 2 (OU2), Hill Air Force Base (HAFB), Utah. The purpose of our visit was to assess the potential stability problems of the area of the proposed OU2 mitigation; this area was identified as an area of a large, ancient landslide that appears to be inactive at present (see Addendum to the Remedial Investigation Report for Operable Unit 2, V.1, August 1993 and CH2M HILL Technical Memorandum, Landslide at OU2, Hill Air Force Base, Utah, dated December 13, 1993).

During our visit, we also briefly inspected an area of active landslides, located on the south flank of the large landslide and immediately south (upslope) of the Davis-Weber Canal. The area inspected included a short section of the slope above the canal, above a small pond located north (downslope) of the canal.

The slope above the canal has been disturbed by current (active) landsliding. There are numerous fresh cracks, bulges, slumps and other features typical of landsliding visible in the area immediately above the canal. Landsliding is recent and we assume that a majority of the movement occurred during the 1993 season. It cannot be ruled out that landsliding in this area has been occurring for a longer period of time.

Some of the sliding reportedly resulted in partial or complete filling of the canal and the sloughed material had to be removed from the canal (Personal communication with Kyle Kirchner/EMR). The construction of the canal likely contributed to the stability problems of the area as the slope was undercut by the considerable excavation required for the canal. Based on our limited observations, landsliding extends high into the slope above the canal, probably close to the HAFB boundary. A storage reservoir is located on the slope above the landslide area.

A preliminary estimate of the landslide area is about 5 acres. The depth of the slip plane is unknown. If we assume a depth of 15 feet, then the landslide volume would be on the order of 120,000 cubic yards. Mitigation of a slope stability problem of this magnitude and type is difficult. The slope above the canal is very steep and there is presently no access. Construction of an access road could result in further undercutting of the unstable slope and in further slope failures. Dewatering might be the most economic means of slope stabilization if groundwater is present close below the topographic surface, as is suspected. Any slope stability mitigation would require certain geotechnical and groundwater studies if it were to be effective and not excessively expensive.

We believe that the landslide will continue to actively move downslope, threatening the canal. Once surface cracks have formed in a landslide, they provide pathways for continued access by water, thereby building hydrostatic pressure and contributing to freeze-thaw processes.

Also, the current landsliding will tend to progress uphill towards the HAFB boundary, potentially also threatening the storage reservoir located near the top of the slope, if no mitigative measures are undertaken in the future.

SLC102/015a.WP5

CH2M HILL

TECHNICAL MEMORANDUM

PREPARED FOR: Kyle Kirchner/EMR

PREPARED BY: Michal Bukovansky/CH2M HILL
Steve Brown/CH2M HILL

COPIES: Bob Elliott/EMR
Dan Adkins/EMR
Randy Underwood/CH2M HILL
Howard Saxion/CH2M HILL

DATE: December 21, 1993

SUBJECT: Proposed Additional Geotechnical Studies to Investigate Landslide at Operable Unit 2, Hill Air Force Base, Utah

PROJECT: BOI70158.F0.04

Introduction

CH2M HILL has started the geotechnical and groundwater studies required for design of the containment system at Operable Unit 2 (OU2), Hill Air Force Base (HAFB), Utah. The geotechnical and groundwater studies include a slope stability assessment of the containment system area and of the area of potential slope stability problems between OU2 and the Weber River Valley immediately north of HAFB.

Potential slope stability problems within and beyond the OU2 area were earlier identified by Radian Corporation (Radian), but no detailed or specific studies related to the stability of the area have been performed.

On December 7, 1993, Steve Brown and Michal Bukovansky of CH2M HILL visited the site to make a preliminary assessment of the suspected slope stability problems and to propose to HAFB future studies that are considered necessary for the design of the containment system. During this 1-day site visit, the suspected landslide area was inspected and results of previous studies were reviewed. Our proposed course of action was briefly discussed with HAFB Environmental Management Directorate (EMR) personnel, Kyle Kirchner and Dan Adkins.

This Technical Memorandum summarizes the results of our visit and of our discussions with HAFB EMR personnel.

Previous Investigations and Available Documentation

A considerable amount of information on the geologic and slope stability conditions is available from the previous studies by Radian. The information includes geologic descriptions of the area, subsurface conditions evaluation based on a number of borings, and groundwater information based on groundwater monitoring wells and piezometers installed by Radian during their previous studies.

Radian also provided several schematic geologic and geotechnical profiles in the area of suspected slope stability problems and some limited interpretations of possible slope failure mechanisms. Their interpretation of potential slope stability problems is not sufficient for the final design of the OU2 containment.

Probably the most significant geologic profile is Figure 3-13, Conceptual Illustration of Groundwater System Relationships (Addendum to the Remedial Investigation Report for Operable Unit 2, V.1, August 1993). In this profile, Radian has interpreted a slump zone in the Alpine formation in the upper portion of the slope and an earthflow in the lower portion of the slope. The profile lacks the uppermost portion of the slope (the area between the HAFB boundary and Foulois Drive, which is located at HAFB terrace elevation). This profile illustrates a mechanism inconsistent with landslides in the area and probably is not representative of this landslide. Therefore, use of this profile for design is not recommended.

A topographic map (Plate 2, Operable Unit 2, Topographic Map, Hill Air Force Base, Utah, from Addendum to RI, V.2, August 1993) has been identified for use during the proposed geotechnical and groundwater studies. However, this map also lacks the topography of the same upper landslide area.

A pair of aerial stereo photographs covering the area of suspected slope stability problems was found in the files of HAFB during our visit. The aerial photographs are useful for interpretation of potential slope stability problems. The scale of these photographs is small (probably on the order of 1 inch equals 2,000 feet). It would be useful if aerial photographs in a larger scale could be found for use during the geotechnical studies.

Site Conditions

Geologic Conditions

Geologic conditions of the area have been described in a report prepared by Radian (Final Remedial Investigation Report for Operable Unit 2, V.1, July 1992). According to this report, the area is underlain by relatively soft sedimentary soils of Pleistocene age. The area between the Weber River alluvial plain and HAFB is underlain by the fine grained soils of the Alpine Formation. The Alpine Formation soils typically consist of clay, silt, and fine sand. They are horizontally bedded when in an undisturbed condition.

The Alpine Formation is overlain by the Provo Formation, which underlies most of HAFB. This formation is more coarse-grained and consists of gravel and sand. Based on the results of Radian's drilling, the Provo Formation is about 50 feet thick. The Weber River alluvial plain is underlain by thick alluvial sediments of the Holocene age

The valley slopes between the Weber River alluvial plain and the large terrace surface where HAFB has been developed are susceptible to slope stability problems. There are two reasons for this instability: the character of the Alpine Formation soils (unconsolidated, soft clayey soils), and the presence of shallow groundwater and springs on the hillside.

Slope instability in the form of large landslides was documented by geologic mapping in the past. Pashley and Wiggins describe the slope between the HAFB and the Weber River alluvium as an area of "active and inactive landsliding", (Pashley, E.F., and Wiggins, R.A., Landslides of the Northern Wasatch Front, Utah Geologic Association, Publ. No. 1, 1971) .

Based on the results of our field inspection and study of aerial photographs, we believe that this interpretation is fairly accurate. The slope between HAFB and the alluvium has been disturbed by landsliding both in the past and at present. Some landslides in the area are ancient (on the order of hundreds or thousands of years) and they appear to be stable and inactive at present. Some recent landsliding can also be documented in the area. Recent landsliding is evident by the development of large tension cracks, sliding of large blocks, etc. One recent landslide could be observed above the Davis-Weber canal, immediately south of OU2 (this landslide is briefly described in a separate technical memorandum).

Landslide Description

A large landslide that extends over the entire slope between Foulois Drive and the Weber River alluvial plain is the primary feature that may influence the proposed OU2 containment. The entire area of the proposed containment is expected to be within the area of this large landslide. We expect that this landslide is old and inactive at present. Any landslide activity would be indicated by problems with the Davis-Weber canal, which crosses the entire width of this feature, or problems with the Mountain Fuel natural gas transmission line also located in this landslide, or problems with other structures (agricultural buildings, roads) in the landslide area.

The landslide has formed on the hillside of a large terrace with top elevation of approximately 4780 feet above mean sea level (msl). The landslide is characterized by two distinct benches in the upper part: one bench (elevation about 4700 feet msl) coincides with the contamination source area, the lower bench (elevation about 4550 feet msl) includes the distinct "knoll" area. Both of these benches are probably the result of a significant drop in ground elevation due to massive landslide events. Our site inspection indicates that these benches, and, specifically, the upper bench, may have been disturbed by smaller, more localized landsliding following the occurrence of the larger landslide events.

At the bottom of the hillside a large landslide toe extends over the surface of the Weber River alluvium. Ground elevation at the toe is approximately 4450 feet msl. This large landslide toe modifies the otherwise uniform Weber River Valley as it reduces the valley width significantly at this location and is another feature indicative of the large scale earth movement at this site. A large part of the landslide toe mass has been removed in the past, probably by long-term erosive action of the Weber River.

Our preliminary evaluation indicates that this landslide is very large. The length (measured along the direction of the deformation) is approximately 3,000 feet; the width is estimated to be 2,000 feet. If we assume the average depth of the landslide deposit is about 50 feet, the volume of the landslide could be about 11 million cubic yards.

Even though these estimates are very preliminary and will need verification, they indicate the general size of this landslide. It is also evident that the size of this feature would make any conventional stabilization methods practically impossible.

As discussed earlier, we believe the landslide is several hundred to several thousand years old and inactive at present. This preliminary evaluation needs some verification. The proposed containment system will be constructed within the area of the landslide and even small deformations of the landslide could reduce the efficiency of the containment structure. It should also be noted that landslide deformations typically develop in the landslide upper portions, prior to deformation of the remaining portions of the landslide. For these reasons, we believe that a limited geotechnical and groundwater study is needed prior to the design of the OU2 containment system.

Proposed Geotechnical Studies

The proposed geotechnical and groundwater study will use, to the extent possible, the considerable amount of information collected by Radian during their investigation. The geotechnical study will also make use of existing groundwater information compiled by Radian. The groundwater conditions are the single most important factor influencing the stability of the area. Except for the proposed inclinometer installation, the recommended geotechnical and groundwater studies are therefore a compilation of the available data and information, complemented by limited field work. An assessment of the overall slope stability can only be made after these basic data are developed and the landslide conditions are understood in more detail.

The following investigation phases are recommended:

- Mapping of landslide features
- Development of a landslide profile
- Inclinometer installation
- Stability assessment

The available RI map is not suitable as it does not cover the entire landslide area and it has an unsuitable scale (1 inch equals 133 feet). It is essential that a good topographic map, covering the entire area of the landslide be available. The topographic map should be in a scale of 1 inch equals 200 feet and it should include the most recent elevation contours and other features. The new map would be used for mapping of all important landslide features.

A geologic profile should be developed for further understanding of the landslide characteristics and for the stability evaluation. The new profile will be developed along the alignment used for the original Radian conceptual profile (Figure 3-13). However, the new profile needs to be extended as a minimum to Foulois Drive which is higher up the slope. All borings completed by Radian in the vicinity of the cross-section should be plotted on this profile, together with the groundwater conditions. The profile will be used for interpretation of the landslide slip plane and other features that may be of importance for the proposed containment system design. The map and the profile will also be used for the slope stability evaluation.

Installation of at least one inclinometer is considered essential for the proposed project. The inclinometer is a device, when installed in a boring, which can detect very small slope deformations of the landslide. The inclinometer installation would detect potential deformations in the area of the proposed containment structure. We understand that an inclinometer could be installed in the near future at a location close to the proposed containment structure. This installation will provide useful information prior to the final design, particularly if the inclinometer is installed before spring 1994. It is probable that any deformation of the landslide would develop during a spring thaw and runoff period when groundwater levels are at their highest.

Our preliminary evaluation indicates that the depth of the inclinometer may need to be up to 150 feet. Drilling for the installation should use a coring method that would provide relatively undisturbed soil core recovery thereby enabling a detailed inspection of the core. Tilted bedding and a landslide slip plane could also possibly be identified using such a drilling method.

Installation of additional inclinometers should be considered in the future. Candidate locations for additional inclinometers would include locations at approximately the mid-length of the slide, just north of the Davis-Weber Canal.

The proposed geotechnical studies and inclinometer installation constitute a limited study. At the conclusion of these proposed studies, we will provide the EMR with a Technical Memorandum discussing:

- Nature of the landslide
- Drill core information
- Inclinometer data
- Potential impact to OU2 containment and other HAFB actions
- Recommendations and identification of further actions, if required.

SLC102/015a.WP5

MEMO

To: Ron Pauling April 19, 1994

From: James R. Van Orman

In the past, the Canal Company has contacted Environmental Management (EM) concerning problems of canal lining deterioration and instability of the hill side in which the canal is constructed. Neither of these problems are the results of activities at Hill Air Force Base and EM regrets it can not be of assistance to the Canal Company.

Deterioration of the canal's lining is most likely a result of freeze-thaw action in the soil immediately below the lining; i.e., localized frost heave occurring during almost a century's time. The canal system was, for the most part, constructed in the late 1800's and early 1900's. The Davis-Weber Counties' canal structure is over eighty years old and repair of the deteriorated concrete lining is long overdue. The "1989 Canal Inflow Study" conducted for the Canal Company by J. A. Jones & Associates indicates that current life expectancy of repairs or new facilities for the canal is thirty years. The 80 plus year old structure has exceeded the commonly expected design life of 30 years for similar structures and failure is most likely the result of natural weathering and expected deterioration.

Although the Davis-Weber Canal is concrete lined, visual inspection indicates that the lining is cracked and broken in many places, and conducive to movement of water through it. During operation, the canal acts as if it is an infiltration gallery leaking water into the shallow aquifer just outside the base boundary. Studies by the USGS, as well as records from environmental remediation studies have documented the effects of the leaking canal and a rise in the water table.

Portions of the canal which run along the northern boundary of Hill Air Force Base were constructed through an active landslide area. The original construction of the canal likely contributes to the stability of problems of the area as the slope was undercut by the considerable excavation required for the canal, Ref. CH2M-Hill report "Active Landslide Above Davis-Weber Canal," December 1993. A copy of this report is being forwarded to the Canal Company. Infiltration of water resulting from the natural deterioration of the canal's lining over the years tends to saturate the slope below the canal and results in additional slope stability problems.

Recent, off-base excavation by the Davis-Weber Canal Company has made sections of the hill side even more unstable. Base Civil Engineering is preparing a letter to the Canal Company to advise them of HAFB's concern. Civil Engineering has also indicated a willingness to coordinate efforts with the canal company while the canal company makes the needed corrections.

The Environmental Management Directorate is studying the infiltration of water from the canal which in places intersects off-base contaminated plumes originating from Hill Air Force Base, thus adding volume and hydraulic head to the plume. As part of a cost savings move to limit the spread of contamination and future clean up cost the Environmental Management's

Restoration Division (EMR) relined the 1,000 foot section of the canal which spans the Operable Unit 2 plume at a cost of $93,000 during the Winter of 1993-94. Over the past several years (1992-1994) EMR has been in constant contact with the canal company, however it is apparent that any deterioration of the canal is a result of the canal's age and the forces of nature. Attached is a copy of CH2M-Hill's technical memorandum titled "Active Landslide Above the Davis-Weber Canal, Hill Air Force Base, Utah. EM's POC is Dr. Dan Adkins at 777-8790.

Coordination		
Org	Name	Date
CECM-A	J. Grunwald	20 Apr
CECM	[illegible]	20
CE-1	P. McReal	20 (see note)
JAN-EA	J. Tadie	20 Apr

MEMO

April 19, 1994

To: Ron Hulling

From: James R. Van Orman

In the past, the Canal Company has contacted Environmental Management (EM) concerning problems of canal lining deterioration and instability of the hill side in which the canal is constructed. Neither of these problems are the results of activities at Hill Air Force Base and EM regrets it can not be of assistance to the Canal Comapny.

Deterioration of the canal's lining is most likely a result of freeze-thaw action in the soil immediately below the lining; i.e., localized frost heave occurring during almost a century's time. The canal system was, for the most part, constructed in the late 1800's and early 1900's. The Davis-Weber Counties' canal structure is over eighty years old and repair of the deteriorated concrete lining is long overdue. The "1989 Canal Inflow Study" conducted for the Canal Company by J. A. Jones & Associates indicates that current life expectancy of repairs or new facilities for the canal is thirty years. The 80 plus year old structure has exceeded the commonly expected design life of 30 years for similar structures and failure is most likely the result of natural weathering and expected deterioration.

Although the Davis-Weber Canal is concrete lined, visual inspection indicates that the lining is cracked and broken in many places, and conducive to movement of water through it. During operation, the canal acts as if it is an infiltration gallery leaking water into the shallow aquifer just outside the base boundary. Studies by the USGS, as well as records from environmental remediation studies have documented the effects of the leaking canal and a rise in the water table.

Portions of the canal which run along the northern boundary of Hill Air Force Base were constructed through an active landslide area. The original construction of the canal likely contributes to the stability of problems of the area as the slope was undercut by the considerable excavation required for the canal, Ref. CH2M-Hill report "Active Landslide Above Davis-Weber Canal," December 1993. A copy of this report is being forwarded to the Canal Company. Infiltration of water resulting from the natural deterioration of the canal's lining over the years tends to saturate the slope below the canal and results in additional slope stability problems.

The Environmental Management Directorate is studying the infiltration of water from the canal which in places intersects off-base contaminated plumes originating from Hill Air Force Base, thus adding volume and hydraulic head to the plume. As part of a cost savings move to limit the spread of contamination and future clean up cost the Environmental Management's Restoration Division (EMR) relined the 1,000 section of the canal which spans the Operable Unit 2 plume at a cost of $93,000 during the Winter of 1993-94. Over the past several years (1992-1994) EMR has been in constant contact with the canal company, however it is apparent that any deterioration of the canal is a result of the canal's age and the forces of nature. Attached is a a copy of CH2M-Hill's technical memoradum titled "Active Landslide Above the Davis-Weber Canal, Hill Air Force Base, Utah. EM's POC is Dr. Dan Adkins at 777-8790.

Note: Recommend we add info on recent off-base excavation by Davis Weber which has made the hill even more unstable. CE is preparing [illegible]

JAMES V. HANSEN
1ST DISTRICT, UTAH

COMMITTEES:
ARMED SERVICES
NATURAL RESOURCES
SELECT COMMITTEE ON INTELLIGENCE

WASHINGTON OFFICE:
ROOM 2466
RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-4401
[illegible]

Congress of the United States
House of Representatives
Washington, DC 20515-4401

DISTRICT OFFICES:
1017 FEDERAL BUILDING
324 25TH STREET
OGDEN, UT 84401
[illegible]

435 EAST TABERNACLE
SUITE 301
ST. GEORGE, UT 84770
[illegible]

EM BobV. (19)

FAX MESSAGE
(This page only)

Bob, Per our discussion. Please ~~keep me~~ updated on this. Ron 4/18/94

TO: RON PAULING
FROM: STEVE PETERSEN
DATE: APRIL 19, 1994
RE: MEETING WITH WEBER RIVER WATER USERS

AS WE DISCUSSED TODAY, THE WEBER RIVER WATER USER'S ASSOCIATION AND WEBER-DAVIS CANAL ASSOCIATION, HAVE REQUESTED A MEETING WITH HILL AFB REPRESENTATIVES TO RESOLVE ISSUES OF GROUND WATER DAMAGE.

THEIR REPRESENTATIVE:

FLOYD BAYHAM (801) 774-6373

EMR — please, Prepare respon by COB 20 Apr. Coord w JA an CE. BobV (18)

FLOYD INDICATES THAT THEY FIRST RAISED THIS ISSUE WITH THE BASE OVER TWO YEARS AGO.... AND HAVE HAD NO DIALOGUE OR MEETINGS SINCE THEN. AT THE LAST MEETING, MR. BAYHAM INDICATES THAT HILL TOOK THE POSITION THAT THEY WOULD NOT TAKE ANY RESPONSIBILITY WHATSOEVER FOR GROUND WATER PROBLEMS (ONLY POLLUTION).

HERE ARE THE HILL AFB CONTACTS THAT HE HAD WORKED WITH:

ENVIRONMENTAL:
PAUL BETZ
DAN ATKINS

BASE ENGINEERING:
JOHN GROSNCKO (spelling?) CE

PLEASE LET ME KNOW IF YOU NEED ANY MORE INFORMATION.

THANKS FOR YOUR HELP!

Ogden Air Logistics Center
Executive Assistant
Mr H. Ronald Pauling

7981 Georgia St, Hill Air Force Base, Utah 84056-5824
FAX Number: DSN 458-4640 / Commercial (801) 777-4640
Voice Number: DSN 458-5111 / Commercial (801) 777-5111

To: Mr Van Orman **Date:** 18 Apr
Subject: Note from Congressman Hansen
Remarks:
Number of Pages (Including Coversheet): 2
Administrative Assistant: Sgt Hall

PREPARED FOR: Kyle Kirchner/EMR
Bob Elliott/EMR

PREPARED BY: Michal Bukovansky/CH2M HILL
Steve Brown/CH2M HILL

COPIES: Dan Adkins/EMR
Randy Underwood/CH2M HILL
Howard Saxion/CH2M HILL

DATE: December 21, 1993

SUBJECT: Active Landslide Above the Davis-Weber Canal, Hill Air Force Base, Utah

PROJECT: BOI70158.F0.04

On December 7, 1993, Steve Brown and Michal Bukovansky of CH2M HILL visited the site of the proposed remedial mitigation at Operable Unit 2 (OU2), Hill Air Force Base (HAFB), Utah. The purpose of our visit was to assess the potential stability problems of the area of the proposed OU2 mitigation; this area was identified as an area of a large, ancient landslide that appears to be inactive at present (see Addendum to the Remedial Investigation Report for Operable Unit 2, V.1, August 1993 and CH2M HILL Technical Memorandum, Landslide at OU2, Hill Air Force Base, Utah, dated December 13, 1993).

During our visit, we also briefly inspected an area of active landslides, located on the south flank of the large landslide and immediately south (upslope) of the Davis-Weber Canal. The area inspected included a short section of the slope above the canal, above a small pond located north (downslope) of the canal.

The slope above the canal has been disturbed by current (active) landsliding. There are numerous fresh cracks, bulges, slumps and other features typical of landsliding visible in the area immediately above the canal. Landsliding is recent and we assume that a majority of the movement occurred during the 1993 season. It cannot be ruled out that landsliding in this area has been occurring for a longer period of time.

Some of the sliding reportedly resulted in partial or complete filling of the canal and the sloughed material had to be removed from the canal (Personal communication with Kyle Kirchner/EMR). The construction of the canal likely contributed to the stability problems of the area as the slope was undercut by the considerable excavation required for the canal. Based on our limited observations, landsliding extends high into the slope above the canal, probably close to the HAFB boundary. A storage reservoir is located on the slope above the landslide area.

A preliminary estimate of the landslide area is about 5 acres. The depth of the slip plane is unknown. If we assume a depth of 15 feet, then the landslide volume would be on the order of 120,000 cubic yards. Mitigation of a slope stability problem of this magnitude and type is difficult. The slope above the canal is very steep and there is presently no access. Construction of an access road could result in further undercutting of the unstable slope and in further slope failures. Dewatering might be the most economic means of slope stabilization if groundwater is present close below the topographic surface, as is suspected. Any slope stability mitigation would require certain geotechnical and groundwater studies if it were to be effective and not excessively expensive.

We believe that the landslide will continue to actively move downslope, threatening the canal. Once surface cracks have formed in a landslide, they provide pathways for continued access by water, thereby building hydrostatic pressure and contributing to freeze-thaw processes.

Also, the current landsliding will tend to progress uphill towards the HAFB boundary, potentially also threatening the storage reservoir located near the top of the slope, if no mitigative measures are undertaken in the future.

SLC102/015a.WP5

CH2M HILL

TECHNICAL MEMORANDUM

PREPARED FOR: Kyle Kirchner/EMR

PREPARED BY: Michal Bukovansky/CH2M HILL
Steve Brown/CH2M HILL

COPIES: Bob Elliott/EMR
Dan Adkins/EMR
Randy Underwood/CH2M HILL
Howard Saxion/CH2M HILL

DATE: December 21, 1993

SUBJECT: Proposed Additional Geotechnical Studies to Investigate Landslide at Operable Unit 2, Hill Air Force Base, Utah

PROJECT: BOI70158.F0.04

Introduction

CH2M HILL has started the geotechnical and groundwater studies required for design of the containment system at Operable Unit 2 (OU2), Hill Air Force Base (HAFB), Utah. The geotechnical and groundwater studies include a slope stability assessment of the containment system area and of the area of potential slope stability problems between OU2 and the Weber River Valley immediately north of HAFB.

Potential slope stability problems within and beyond the OU2 area were earlier identified by Radian Corporation (Radian), but no detailed or specific studies related to the stability of the area have been performed.

On December 7, 1993, Steve Brown and Michal Bukovansky of CH2M HILL visited the site to make a preliminary assessment of the suspected slope stability problems and to propose to HAFB future studies that are considered necessary for the design of the containment system. During this 1-day site visit, the suspected landslide area was inspected and results of previous studies were reviewed. Our proposed course of action was briefly discussed with HAFB Environmental Management Directorate (EMR) personnel, Kyle Kirchner and Dan Adkins.

This Technical Memorandum summarizes the results of our visit and of our discussions with HAFB EMR personnel.

Previous Investigations and Available Documentation

A considerable amount of information on the geologic and slope stability conditions is available from the previous studies by Radian. The information includes geologic descriptions of the area, subsurface conditions evaluation based on a number of borings, and groundwater information based on groundwater monitoring wells and piezometers installed by Radian during their previous studies.

Radian also provided several schematic geologic and geotechnical profiles in the area of suspected slope stability problems and some limited interpretations of possible slope failure mechanisms. Their interpretation of potential slope stability problems is not sufficient for the final design of the OU2 containment.

Probably the most significant geologic profile is Figure 3-13, Conceptual Illustration of Groundwater System Relationships (Addendum to the Remedial Investigation Report for Operable Unit 2, V.1, August 1993). In this profile, Radian has interpreted a slump zone in the Alpine formation in the upper portion of the slope and an earthflow in the lower portion of the slope. The profile lacks the uppermost portion of the slope (the area between the HAFB boundary and Foulois Drive, which is located at HAFB terrace elevation). This profile illustrates a mechanism inconsistent with landslides in the area and probably is not representative of this landslide. Therefore, use of this profile for design is not recommended.

A topographic map (Plate 2, Operable Unit 2, Topographic Map, Hill Air Force Base, Utah, from Addendum to RI, V.2, August 1993) has been identified for use during the proposed geotechnical and groundwater studies. However, this map also lacks the topography of the same upper landslide area.

A pair of aerial stereo photographs covering the area of suspected slope stability problems was found in the files of HAFB during our visit. The aerial photographs are useful for interpretation of potential slope stability problems. The scale of these photographs is small (probably on the order of 1 inch equals 2,000 feet). It would be useful if aerial photographs in a larger scale could be found for use during the geotechnical studies.

Site Conditions

Geologic Conditions

Geologic conditions of the area have been described in a report prepared by Radian (Final Remedial Investigation Report for Operable Unit 2, V.1, July 1992). According to this report, the area is underlain by relatively soft sedimentary soils of Pleistocene age. The area between the Weber River alluvial plain and HAFB is underlain by the fine grained soils of the Alpine Formation. The Alpine Formation soils typically consist of clay, silt, and fine sand. They are horizontally bedded when in an undisturbed condition.

The Alpine Formation is overlain by the Provo Formation, which underlies most of HAFB. This formation is more coarse-grained and consists of gravel and sand. Based on the results of Radian's drilling, the Provo Formation is about 50 feet thick. The Weber River alluvial plain is underlain by thick alluvial sediments of the Holocene age.

The valley slopes between the Weber River alluvial plain and the large terrace surface where HAFB has been developed are susceptible to slope stability problems. There are two reasons for this instability: the character of the Alpine Formation soils (unconsolidated, soft clayey soils), and the presence of shallow groundwater and springs on the hillside.

Slope instability in the form of large landslides was documented by geologic mapping in the past. Pashley and Wiggins describe the slope between the HAFB and the Weber River alluvium as an area of "active and inactive landsliding", (Pashley, E.F., and Wiggins, R.A., Landslides of the Northern Wasatch Front, Utah Geologic Association, Publ. No. 1, 1971).

Based on the results of our field inspection and study of aerial photographs, we believe that this interpretation is fairly accurate. The slope between HAFB and the alluvium has been disturbed by landsliding both in the past and at present. Some landslides in the area are ancient (on the order of hundreds or thousands of years) and they appear to be stable and inactive at present. Some recent landsliding can also be documented in the area. Recent landsliding is evident by the development of large tension cracks, sliding of large blocks, etc. One recent landslide could be observed above the Davis-Weber canal, immediately south of OU2 (this landslide is briefly described in a separate technical memorandum).

Landslide Description

A large landslide that extends over the entire slope between Foulois Drive and the Weber River alluvial plain is the primary feature that may influence the proposed OU2 containment. The entire area of the proposed containment is expected to be within the area of this large landslide. We expect that this landslide is old and inactive at present. Any landslide activity would be indicated by problems with the Davis-Weber canal, which crosses the entire width of this feature, or problems with the Mountain Fuel natural gas transmission line also located in this landslide, or problems with other structures (agricultural buildings, roads) in the landslide area.

The landslide has formed on the hillside of a large terrace with top elevation of approximately 4780 feet above mean sea level (msl). The landslide is characterized by two distinct benches in the upper part: one bench (elevation about 4700 feet msl) coincides with the contamination source area, the lower bench (elevation about 4550 feet msl) includes the distinct "knoll" area. Both of these benches are probably the result of a significant drop in ground elevation due to massive landslide events. Our site inspection indicates that these benches, and, specifically, the upper bench, may have been disturbed by smaller, more localized landsliding following the occurrence of the larger landslide events.

At the bottom of the hillside a large landslide toe extends over the surface of the Weber River alluvium. Ground elevation at the toe is approximately 4450 feet msl. This large landslide toe modifies the otherwise uniform Weber River Valley as it reduces the valley width significantly at this location and is another feature indicative of the large scale earth movement at this site. A large part of the landslide toe mass has been removed in the past, probably by long-term erosive action of the Weber River.

Our preliminary evaluation indicates that this landslide is very large. The length (measured along the direction of the deformation) is approximately 3,000 feet; the width is estimated to be 2,000 feet. If we assume the average depth of the landslide deposit is about 50 feet, the volume of the landslide could be about 11 million cubic yards.

Even though these estimates are very preliminary and will need verification, they indicate the general size of this landslide. It is also evident that the size of this feature would make any conventional stabilization methods practically impossible.

As discussed earlier, we believe the landslide is several hundred to several thousand years old and inactive at present. This preliminary evaluation needs some verification. The proposed containment system will be constructed within the area of the landslide and even small deformations of the landslide could reduce the efficiency of the containment structure. It should also be noted that landslide deformations typically develop in the landslide upper portions, prior to deformation of the remaining portions of the landslide. For these reasons, we believe that a limited geotechnical and groundwater study is needed prior to the design of the QU2 containment system.

Proposed Geotechnical Studies

The proposed geotechnical and groundwater study will use, to the extent possible, the considerable amount of information collected by Radian during their investigation. The geotechnical study will also make use of existing groundwater information compiled by Radian. The groundwater conditions are the single most important factor influencing the stability of the area. Except for the proposed inclinometer installation, the recommended geotechnical and groundwater studies are therefore a compilation of the available data and information, complemented by limited field work. An assessment of the overall slope stability can only be made after these basic data are developed and the landslide conditions are understood in more detail.

The following investigation phases are recommended:

- Mapping of landslide features
- Development of a landslide profile
- Inclinometer installation
- Stability assessment

The available RI map is not suitable as it does not cover the entire landslide area and it has an unsuitable scale (1 inch equals 133 feet). It is essential that a good topographic map, covering the entire area of the landslide be available. The topographic map should be in a scale of 1 inch equals 200 feet and it should include the most recent elevation contours and other features. The new map would be used for mapping of all important landslide features.

A geologic profile should be developed for further understanding of the landslide characteristics and for the stability evaluation. The new profile will be developed along the alignment used for the original Radian conceptual profile (Figure 3-13). However, the new profile needs to be extended as a minimum to Foulois Drive which is higher up the slope. All borings completed by Radian in the vicinity of the cross-section should be plotted on this profile, together with the groundwater conditions. The profile will be used for interpretation of the landslide slip plane and other features that may be of importance for the proposed containment system design. The map and the profile will also be used for the slope stability evaluation.

Installation of at least one inclinometer is considered essential for the proposed project The inclinometer is a device, when installed in a boring, which can detect very small slope deformations of the landslide. The inclinometer installation would detect potential deformations in the area of the proposed containment structure. We understand that an inclinometer could be installed in the near future at a location close to the proposed containment structure. This installation will provide useful information prior to the final design, particularly if the inclinometer is installed before spring 1994. It is probable that any deformation of the landslide would develop during a spring thaw and runoff period when groundwater levels are at their highest.

Our preliminary evaluation indicates that the depth of the inclinometer may need to be up to 150 feet. Drilling for the installation should use a coring method that would provide relatively undisturbed soil core recovery thereby enabling a detailed inspection of the core. Tilted bedding and a landslide slip plane could also possibly be identified using such a drilling method.

Installation of additional inclinometers should be considered in the future. Candidate locations for additional inclinometers would include locations at approximately the mid-length of the slide, just north of the Davis-Weber Canal.

The proposed geotechnical studies and inclinometer installation constitute a limited study. At the conclusion of these proposed studies, we will provide the EMR with a Technical Memorandum discussing:

- Nature of the landslide
- Drill core information
- Inclinometer data
- Potential impact to OU2 containment and other HAFB actions
- Recommendations and identification of further actions, if required.

SLC102/015a.WPS

elevation of 4,750 feet and runs east and then north. The channel west of the CDPs is incised to an elevation of at least 4,764 feet and could be responsible for the transport of contaminants to this area from the CDPs. This clay unit is believed to be approximately 195 feet thick based on the drilling logs from soil borings U1-748 and U1-787 and monitoring well U1-090, and contains occasional sand and silt interbeds and frequent stringers of fine-grained sand that are less than 3 cm (1 inch) in thickness. At the north end of OU 1 in soil boring U1-748, the silty clay layer was observed from the ground surface to its total depth of 136 feet. In Monitoring Well U1-088, north of CDP 1, clay was observed from a depth of 30 feet to 80 feet bgs (the bottom of the boring). At the west end of OU 1, Monitoring Well U1-117 was installed to a depth of 59 feet and silty clay was encountered from 38 feet to the bottom of the boring. Along the northeast margin of LF 4, soil borings U1-783, U1-784, and U1-785 were drilled to depths of 82, 89, and 94 feet, respectively; silty clay was encountered from depths of 26, 26, and 52 feet, respectively, to the bottoms of these boreholes.

4.2.2.4. Geotechnical tests were performed on soil samples collected during the Hydrogeologic Investigation, including tests: ASTM D3080 for direct shear strength; ASTM 152-H for particle size analysis (sieve test); and ASTM D3080 for particle size analysis (hydrometer test). These data were used to confirm the field lithologies and to evaluate the engineering properties of site materials. All grain-size analyses substantiate the field call outs. The results of these analyses are presented in Appendix G. The boring logs have a broader range of soil types due to the heterogeneous, interbedded nature of site materials. The geotechnical grain-size determinations are limited to soil from a specific depth and are identified as a single soil type.

4.2.3. Slope Stability

4.2.3.1. During this investigation, the hillside on the north side of OU 1 was mapped to evaluate slope stability and whether slump scarps on the hillside may be preferential flow paths for contaminant migration. In addition, the inclinometer installed in the hillside in 1990 as part of the RI, was measured in 1990 and 1991 and has been measured on a quarterly basis since April 1993 to evaluate slope stability. These data in conjunction with previous inclinometer data collected for the *Draft Final Slope Stability Study Report for Operable Unit 1* (JMM, 1992f) and the RI, were used to evaluate slope stability. This section presents the results of this landslide mapping and slope inclinometer monitoring. The objectives of the hillside mapping were to identify landslides and to document surficial geology and landslides on topographic maps at a scale of one inch equals 100 feet. The slope was mapped in July, 1994. Slope stability was evaluated using historical aerial photographs and slope inclinometer data. The results of this portion of the investigation are presented on the surficial Geologic Maps (Plates 1 and 2), with geologic cross sections A-A' and B-B'.

4.2.3.2. Surficial Slope Instability. There are numerous landslides throughout the project area. Most of these are relatively small, highly active surficial landslides located just above and adjacent to the Davis-Weber Canal (see Plates 1 and 2). These slides appear to have been caused by oversteepening of the slope during construction of the canal. The largest slides are in areas where large amounts of materials needed to be removed to construct the canal. There is a series of highly complex smaller slides within the larger slide masses. Many landslides have slid into the canal. Landslide depths are anticipated to be approximately 5 to 15 feet below the existing ground surface with the larger slides possibly as deep as 25 feet. Subsurface data are not available to confirm landslide depths.

4.2.3.3. Deep-Seated Slope Instability. Portions of the west side of the subject area have been included as part of the South Weber Landslide Complex (Pashley and Wiggins, 1971). The South Weber Landslide Complex is a series of large, deep-seated landslides along the steep Weber River Valley escarpment (see Plates 1 and 2). The complex, as mapped by Pashley and Wiggins (1971), extends from the west side of OU 1 to OU 2 and OU 4. The larger slides in this complex appear to be inactive as indicated by the lack of recent backscarps and the numerous well-developed drainage channels within the postulated landslide masses. These masses also may be a series of terrace surfaces formed during the downcutting of the Weber River. There has been very limited subsurface exploration to evaluate whether these features represent landslides or a terrace surface. Features of this type were identified in the western portion of the subject area and are shown on Plate 1 as Qlso.

4.2.3.4. Aerial Photograph Analysis. Analysis of historical aerial photographs of the slide masses show little change in the major slide complexes from 1952 to the present. Most of the slide activity apparently took place between construction of the canal in the early 1900's and 1952. However, a majority of the slide activity occurred immediately after construction of the canal. There has been considerable activity in the small slides within the large slide masses since 1952, but most of these active slides are small and difficult to identify on the aerial photos. Consequently, a separate map that compares the older slides to the present small slides could not be drawn. A list of aerial photographs used for this investigation is included in Table 4-2 .

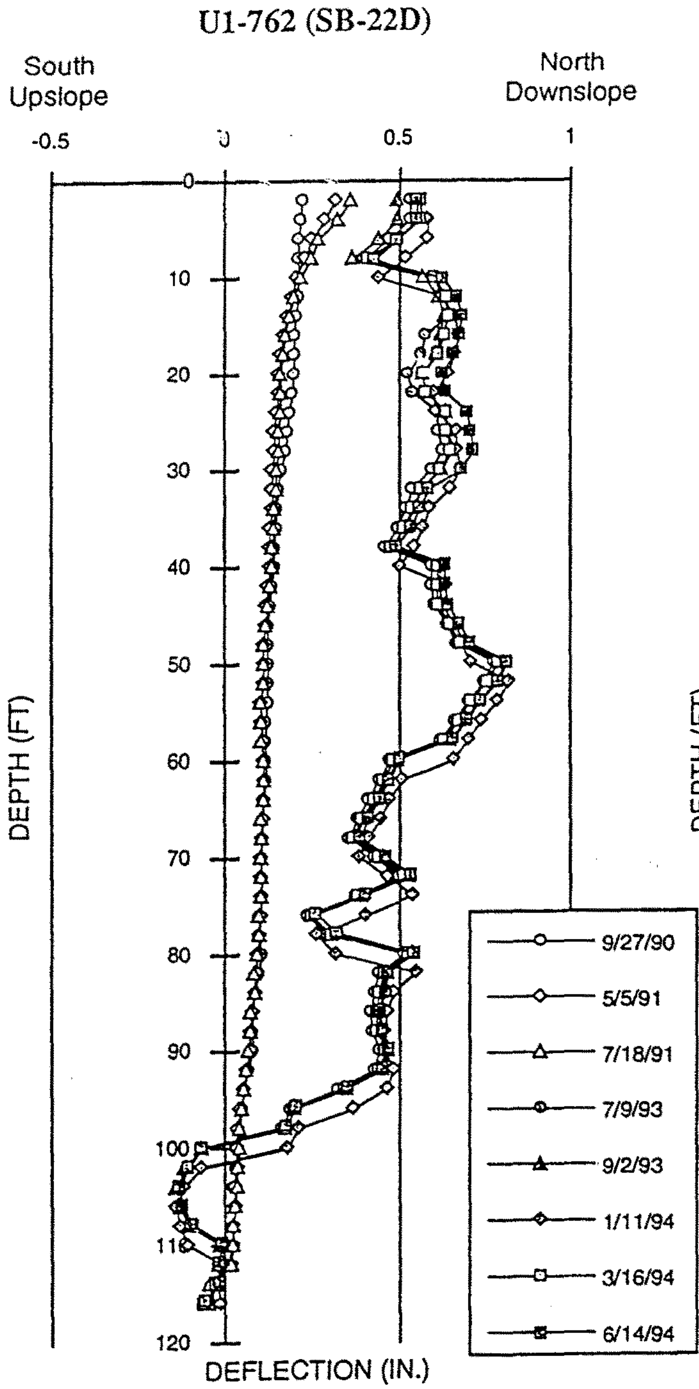
4.2.3.5. Slope Inclinometer Monitoring. In the summer of 1990, a slope inclinometer (U1-748) was installed downslope of FTA 2 to monitor long-term slope stability (see Figure 4-2). The inclinometer was monitored from September 1990 to July 1991, and from July 1993 to present. The inclinometer currently is monitored quarterly. Figure 4-8 graphically represents the amount of downslope movement relative to the baseline reading taken in the Summer of 1990. The inclinometer was not read in the cross-slope direction during the 1990-1991 monitoring period, so the July 1993 reading is considered the baseline reading in this direction. Figure 4-8 shows the plots from 1990-1991 and 1993-1994 to be similar showing no slope movement. The difference between the 1990-1991 and 1993-1994 monitoring may be the result of the difference between equipment and/or operators. These data show no deep-seated or shallow slope instability at this location.

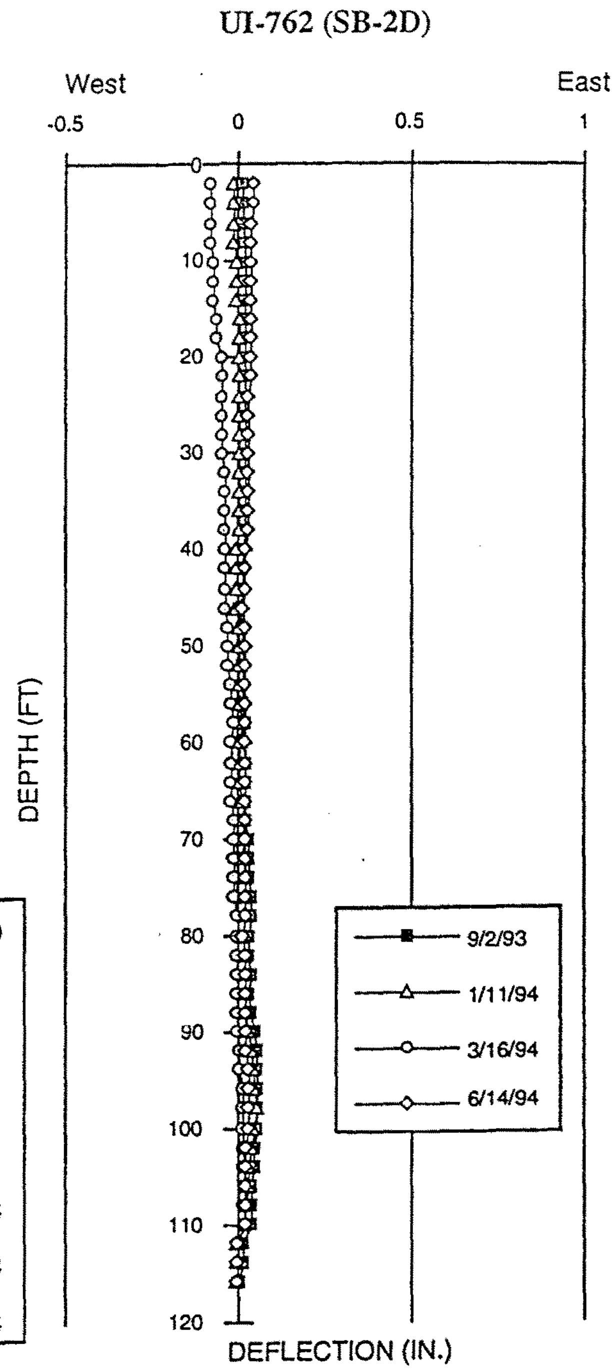
4.2.3.6. Based on the hillside mapping, historical aerial photograph review, and inclinometer measurements, the majority of hillside movement occurred when the Davis-Weber Canal was constructed. The canal cut through the toe of the slope, which oversteepened the hillside and resulted in slumps. As discussed above, the majority of these slumps are located at or just above the canal. There is no evidence of slump activity further upslope or further downslope of the canal downgradient of LFs 3 and 4 (see Plates 1 and 2).

4.2.4. Spring and Seep Descriptions

4.2.4.1. The following section briefly describes springs and seeps at OU 1, including a physical description, associated structures (i.e., fences and spring boxes), flow rates, and probable sub-surface conditions responsible for the existence of the spring/seep. These descriptions include all seeps and springs located to date.

4.2.4.2. U1-301. Spring U1-301 is located between the Base boundary and the Davis-Weber Canal northeast of the eastern portion of OU 1 (see Figure 4-9). The spring currently is fenced with barbed-wire. The spring flows at rates up to 1.5 gallons per minute (gpm). Flow from the spring exits the barbed-wire fenced area in the northwest corner and flows downslope approximately 30 to 40 feet before all the water infiltrates





PROJECT NO. 2208.0713

INCLINOMETER MONITORING RESULTS
INCLINOMETER U1-762

into the soil or evaporates. Subsurface conditions responsible for flow currently are unknown, but may result from a sand and gravel deposit intersecting the slope face.

4.2.4.3. U1-302. Seep U1-302 is located just upslope of the Davis Weber Canal northeast of the eastern portion of OU 1 (see Figure 4-9). The seep is located in a small drainage channel and only flows in the early spring at rates less than 0.5 gpm. This seep is the result of a relatively impermeable layer within the drainage area that forces ground water to the surface during wet periods.

4.2.4.4. U1-303 and U1-304. Springs U1-303 and U1-304 are adjacent to the Base boundary north of Landfill 4 (see Figure 4-9). Both springs are surrounded by a barbed-wire fence and the water is collected before it reaches the ground surface. The collection system pumps the water to the Hill AFB IWTP. Water from the springs is not visible on the ground surface. Both springs are located at the contact between more permeable soils and less permeable soils. Clays are most likely forcing water flowing within sands and gravels to the ground surface along the contact.

4.2.4.5. U1-305. Seep U1-305 is located between the Base boundary and the Davis-Weber Canal downslope of the middle of OU 1 (see Figure 4-9). The seep currently is fenced with barbed-wire. The seep is seasonal, flowing only during wet periods. Subsurface conditions responsible for flow are currently unknown, but may result from a sand and gravel deposit intersecting the slope face.

4.2.4.6. U1-306. Spring U1-306 is located adjacent to and slightly above the Davis-Weber Canal downslope of the western area of OU 1 (see Figure 4-9). The spring flows at rates up to 1.5 gpm and discharges into the canal. Subsurface conditions responsible for flow currently are unknown, but may be the result of surficial landslide debris forcing ground water to the surface.

4.2.4.7. U1-307. Seep U1-307 is located off-Base adjacent to the Base perimeter fence, downslope of the western portion of OU 1 (see Figure 4-9). The seep is at the head of a small, steep drainage channel below an on-Base drainage basin. Low permeability clay layers probably force ground water within the drainage basin to the surface at the seep or a break in the drainline draining the area above U1-307. An on-Base collection system recently was installed above the seep within the drainage basin to capture this flow.

4.2.4.8. U1-308. Seep U1-308 is located off-Base between the Base boundary and the Davis-Weber Canal downslope from the western portion of OU 1 (see Figure 4-9). The seep flows into a shallow drainage channel surrounded by trees. The seep is seasonal, with flows of up to 1 gpm common in the spring. Flow generally stops in late summer and early fall. Subsurface conditions responsible for flow currently are unknown, but may result from a sand and gravel deposit intersecting the slope face.

4.2.4.9. U1-309. Spring U1-309 emanates from a pipe located north of South Weber Drive near the main canal access road (see Figure 4-9). The pipe penetrates the slope that separates two terrace surfaces of the Weber River Flood plain. The purpose of the pipe is unknown, but probably is used to dewater the agricultural fields on the terrace surface above. The spring has a flow rates of 15 to 30 gpm.

4.2.4.10. U1-310. Spring U1-310 is located approximately 400 feet east of spring U1-309 and also flows from the slope separating two terrace surfaces (see Figure 4-9). The spring is a reflection of the ground-water elevation in the upper terrace surface. The spring has a flow rate that has been observed to range from 2 to 20 gpm.

4.2.4.11. U1-311 and U1-312. Both springs are located within the Davis-Weber Canal bottom and can be observed only during periods when the canal is dry (see Figure 4-9). Only a limited number of observations have been made on these springs to date. The springs probably result from excess head pressures built up during periods when the canal is in operation.

4.2.4.12. U1-313. Seep U1-313 is located off-Base near the northeastern corner of LF 4 at the head of a small drainage channel (see Figure 4-9). The seep normally is dry with the exception of after the early spring snow melt. The seep does not appear to be related to any ground-water source.

4.2.4.13. U1-314 and U1-316. Seeps U1-314 and U1-316 flow from the slope separating two terrace surfaces north of South Weber Drive (see Figure 4-9). Both flows are intermittent and normally less than 5 gpm. The causes of these seeps are similar to U1-309 and U1-310.

4.2.4.14. U1-315. Spring U1-315 is located below the canal, downslope from the western edge of OU 1 (see Figure 4-9). A spring box that has been constructed at the source does not appear to be in current use. Water currently is discharging from the spring box overflow port at a rate of approximately 1 gpm and flows into the Bambrough Canal approximately 250 feet downslope of the spring. Subsurface conditions responsible for flow are currently unknown, but may result from a sand and gravel channel deposit intersecting the slope face and/or the Davis-Weber Canal.

4.2.4.15. U1-317. Seep U1-317 is located between the Base boundary and the Davis-Weber Canal, downslope from the eastern portion of OU 1 and downslope from U1-303 (see Figure 4-9). Corrugated PVC pipe originating from U1-303 was found on the surface near the seep. The spring is seasonal, and flows only during wet periods. Subsurface conditions responsible for flow are currently unknown, but may result from a sand and gravel deposit intersecting the slope face.

4.2.4.16. U1-318. Spring U1-318 is approximately 200 feet east of U1-304 at the same elevation (see Figure 4-9). This spring flows at rates up to 1 gpm. The spring flows from the contact between more permeable and less permeable soils; clays force water flowing within sand and gravel to the surface along the contact.

4.2.4.17. U1-319. Spring U1-319 is downslope of OU 1 below the Davis-Weber Canal (see Figure 4-9). This spring was identified during this investigation. Current flow is approximately 1 to 2 gpm. The spring probably results as water from the Davis-Weber canal, flowing along the canal-fill/native-soil contact, discharges near the toe of the slope. Flows will likely decrease when the canal is shut down for the winter. The spring flows into the Bambrough Canal. This spring will be included in the on-going monthly flow-rate evaluation.

4.2.4.18. U1-320. Seep U1-320 consists of a corrugated PVC pipe that collects water from spring U1-303 and seep U1-317 (see Figure 4-9). The pipe is downslope of U1-303 and U1-317 and discharges to the Davis-Weber canal. The seep was identified during this investigation but was not flowing. This seep will be included in the on-going monthly flow rate evaluation.

4.2.5. Drain Line Investigation

4.2.5.1. Information from the Soil Conservation Service (SCS) in Logan. Utah, indicated that drain lines had been installed in the hillside adjoining OU 1 in the 1950's by Sumner G. Margetts and Company (Sumner Margetts) to help stabilize the slope. Sumner Margetts was contacted and they indicated that these records were available in the Sumner Margetts archive collection at the University of Utah Special Collections Department. The following information was obtained from a review of the records. During the early 1950's, Sumner Margetts was hired by the Weber Davis Canal Company to install several vitreous clay tile field drains along the north and north-east hillside downslope from Hill AFB (specifically OU 1). The purpose of these drain lines was to drain water from three to four ponds that apparently existed at the top of the hillside and to aid in stabilizing the underlying slope. The approximate location of these drain lines were identified and are shown on Figure 4-9.

4.2.5.2. In July 1994, Sumner Margetts surveyed the approximate locations of the tile drain inlets at OU 1. Six points were surveyed using old map locations (see Figure 4-9), but no inlets were found. Hill AFB recently intersected the drain line downslope of the western portion of OU 1 during installation of a collection gallery at the source of spring U1-307, along the fence line approximately 170 ft northwest of monitoring well U1-104. Tile drain was also found downslope of this location. Any influent from this drain line now is released to the collection gallery at U1-307 and piped on-Base where it is sent to the IWTP for treatment. Because this drain line is located within the off-Base DCE contaminant plume, it may have been a primary pathway for contaminant migration. However, this can not be confirmed until the entire drain line has been located, including origination and end points.

4.2.5.3. Broken concrete drain pipe also is found at spring U1-305. This pipe has been traced down the slope and apparently runs underneath the canal and drains into the fields north of the canal. To map the extent of this drain system and the exact locations of inlets and outlets will require further investigation.

4.3 HYDROGEOLOGY

4.3.1. Hydrogeologic Cross Section

4.3.1.1. In response to the SWLC comments regarding uncertainties associated with the hydrogeology of OU 1 and the adjacent Weber River Valley, a cross section was prepared to depict the hydrogeology of these sites. This cross section, which is included as Figure 4-10, incorporates hydrogeologic data collected during the Hydrogeologic Investigation and lithologic data collected for the RI and RI Addendum.

OU 1 SPRING AND SEEP ESTIMATED FLOW RATE SUMMARY APRIL 1993 THROUGH AUGUST 1994

Site ID	*Apr-93*	*May-93*	*Jun-93*	*Jul-93*	*Aug-93*	*Sep-93*	*Oct-93*	*Nov-93*	*Dec-93*	*Jan-94*
U1-301	0.80	0.50	0.10	0.32	0.63	0.32	1.30	1.60	1.20	1.0
U1-302	0.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U1-305	0.40	0.25	0.09	0.00	0.00	0.00	0.03	0.30	0.03	0.50
U1-306	0.60	0.50	0.00	0.00	0.05	0.32	1.50	2.60	1.27	0.50
U1-307	0.80	4.00	3.50	0.68	0.79	0.79	1.70	1.60	0.00	0.50
U1-308	0.10	0.13	0.16	0.26	0.32	0.26	0.40	1.30	0.37	1.00
U1-309	6.0-8.0	15.00	14.00	14.00	20.00	30.00	40.00	30.00	30.00	30.00
U1-310	5.0-6.0	20.00	15.00	8.00	10.00	6.00	9.00	2.00	6.50	5.00
U1-313	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Dry
U1-314	Not Meas.	No flow, ponded	0.30	0.52	0.00	9.00	0.00	0.00	0.00	Dry
U1-315	Not Meas.	0.13	Dry	0.32	0.00	0.00	0.00	0.00	0.00	Dry
U1-316	Not Meas.	Not Meas.	Not Meas.	Not Meas.	3.50	4.44	2.60	1.60	2.30	3.00
U1-317	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	0.00	0.00	0.00	0.00	Dry
U1-318	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	1.59	9.00	0.50	1.50	1.00
U1-319	Seep	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.
U1-320	Seep	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.

OU 1 SPRING AND SEEP ESTIMATED FLOW RATE SUMMARY APRIL 1993 THROUGH AUGUST 1994

Site ID	*Feb-94*	*Mar-94*	*Apr-94*	*May-94*	*Jun-94*	*Jul-94*	*Aug-94*
U1-301	1.00	1.50	1.5	0.75	7.9	0.8	4.0
U1-302	0.25	0.25	0.0	Dry	0.0	0.0	0.0
U1-305	1.25	0.50	0.75	1.00	0.0	0.0	0.0
U1-306	1.00	1.50	1.5	0.25	1.0	0.3	0.2
U1-307	0.50	0.33	Dry	Dry	0.0	0.0	0.0
U1-308	1.00	1.00	1.0	Wet, no flow	0.1	0.0	0.0
U1-309	32.00	30.00	25.0	30.00	24.0	30.0	45.0
U1-310	5.00	10.00	2.0	7.00	12.0	20.0	25.0
U1-313	0.00	Dry	Dry	Dry	0.0	0.0	0.0
U1-314	0.00	Dry	Dry	Dry	0.0	0.5	0.6
U1-315	Moist	Gone	Gone	0.00	0.0	0.8	2.1
U1-316	4.00	2.00	1.5	3.00	2.9	3.0	12.7
U1-317	Moist	Dry	0.0	Dry	0.0	0.0	0.0
U1-318	0.50	1.00	2.0	0.50	0.0	0.3	6.7
U1-319	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	1.5	0.2
U1-320	Not Meas.	Not Meas.	Not Meas.	Not Meas.	Not Meas.	0.0	0.0

Hill Air Force Base, Utah

Final

Decision Document for Site OT14 - Golf Course

May 1991

Environmental Management Directorate

Ogden Air Logistics Center
Hill AFB, Utah

U. S. AIR FORCE
INSTALLATION RESTORATION PROGRAM
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
HILL AFB, UTAH

DECISION PAPER
Site OT14 - Golf Course

No Further Response Action Planned

May, 1991

Prepared by

Captain Edward Heyse

Ogden Air Logistic Center
Directorate of Environmental Management
Hill AFB, Utah 84056

TABLE OF CONTENTS

1.0 INSTALLATION: Hill Air Force Base, Utah

2.0 SITE IDENTIFICATION:

2.1 Site Name: Site OT14 - Golf Course.

2.2 Location: OT14 is located on base along the eastern boundary of Hill AFB. See Figure 1.

2.3 Setting: The site is situated on a delta formation formed during the Pleistocene age associated with the Weber River flowing into Lake Bonneville. This ancient delta plays a major role in the site setting.

2.3.1 Topography: When the lake level dropped to become the current Great Salt Lake, the Weber River eroded its own delta. Hill AFB is located on the top of the ancient delta to the south of the Weber River. The land surface elevation at OT14 is 10 to 110 feet above the surrounding base property.

2.3.2 Geography: OT14 is located in a relatively deserted area of the base. A group of Installation Restoration Program sites known as Operable Unit 1 is located north of the site. The base runway clear zone lies to the west, and base housing (Area C) is located to the south of the site. OT14 is located on base along the eastern boundary of the base. The off-base property is used for agricultural purposes, primarily raising forage crops such as alfalfa and hay. The Davis county landfill is approximately one-half mile east of the site.

2.3.3 Geology: The delta also plays a major role in the geological and hydrogeological setting. The deltaic sediments alternate between fine and coarse materials which were eroded from the Wasatch Mountains. Hill AFB sits on top of the delta formation which rises 300 feet above the valley floor where the Weber River cuts through on its way to the Great Salt Lake. The Delta aquifer from which the communities and Hill AFB get their potable water lies 600 feet beneath the valley floor. The perched aquifers lie 20 to 100 feet beneath the surface at Hill AFB. Clay layers from 200 to 400 feet thick separate the contaminated shallow aquifer from the deeper Delta aquifer. There is no evidence of a hydraulic connection between the shallow and deeper aquifers beneath Hill AFB, but the on-going Remedial Investigations are exploring this issue. Recharge to the Delta aquifer comes mainly from the Wasatch mountains to the east of the base. Recharge to the perched upper aquifers comes from seasonal snow packs and infiltration from rain events and irrigation. Since OT14 is a golf course, irrigation during the summer months is a significant source of recharge for the shallow aquifer. Details on site geology can be found in the documents listed in section 3.2.

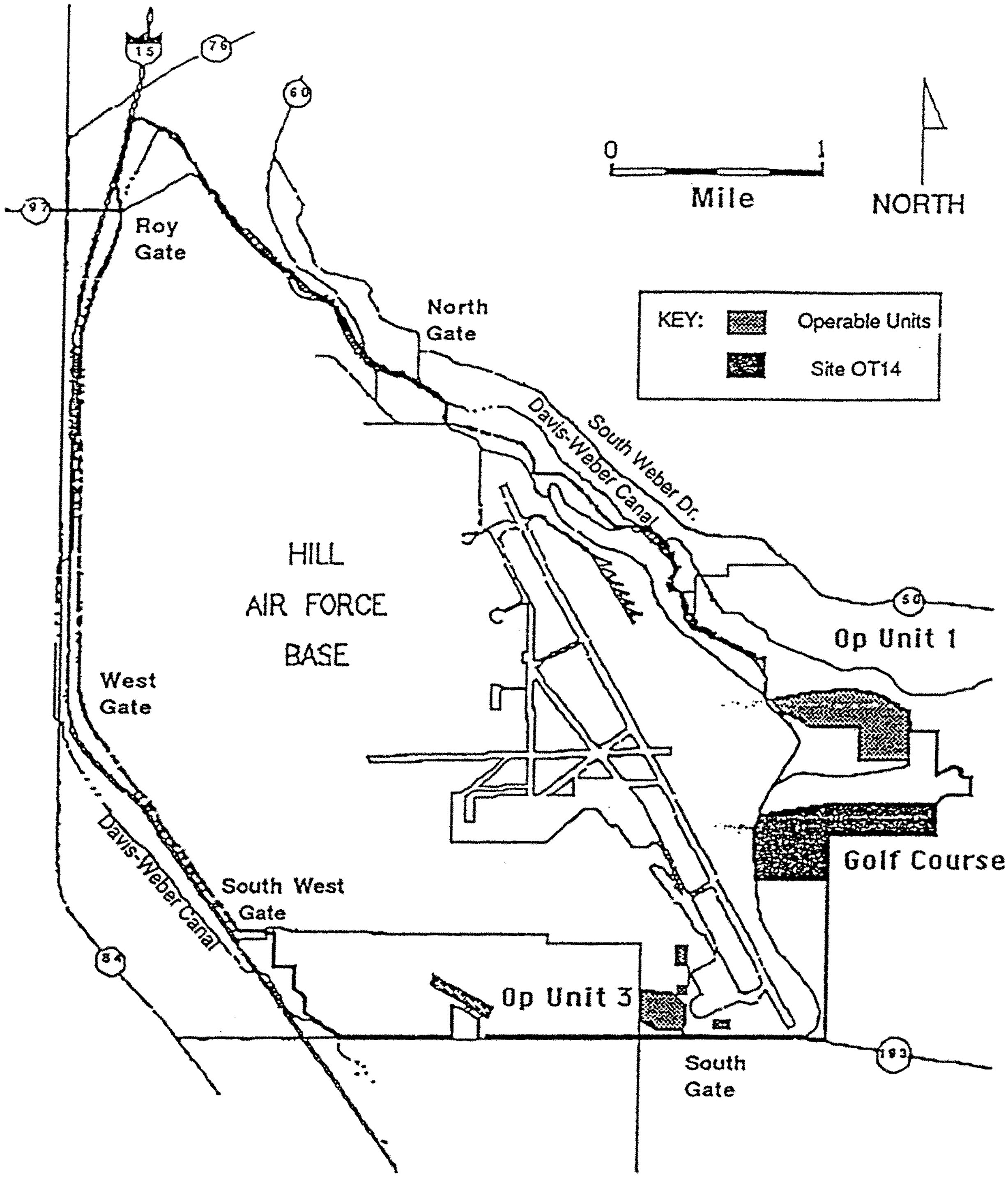


Figure 1. Location of Golf Course, Site OT14

3.0 BACKGROUND:

3.1 Nature of Site: This site was developed in 1960 as the base golf course. There is no record of hazardous wastes ever having been disposed of at this site.

3.2 Investigation History: The golf course, site OT14, was studied in two IRP investigations. The site was studied only to determine what effect its irrigation had on shallow groundwater recharge. Information on OT14 has been published in the following reports:

- Hill AFB, Utah, Installation Restoration Program, Phase IIB-IRP Survey, September 1984, by Radian Corporation.

- Installation Restoration Program, Phase II-Confirmation/ Quantification, Stage 2, Hill AFB, Utah, July 1988, by Radian Corporation.

The site is no longer under investigation. However, the groundwater flow for the entire base was evaluated in the following technical memorandum:

- Mathematical Model of Groundwater Flow and Contaminant Transport, December 1989, by J. M. Montgomery Consulting Engineers Inc. 643

3.3 Investigation Results: The effects of increased recharge by irrigation were evaluated by the Hydrologic Evaluation of Landfill Performance (HELP) model, by installing piezometers to determine hydraulic gradients, and by modeling groundwater flow for the entire base. The effect of irrigation on groundwater recharge is somewhat mitigated because irrigation occurs during the warmer months when evapotranspiration is higher. Even so, the HELP model estimates that percolation at the golf course below five feet increases from 4 inches per year to 12.5 inches per year as a result of the irrigation. The field investigations determined that some groundwater from the golf course flowed north toward Operable Unit 1. Other groundwater flowed west, and the model results indicate that this water could turn south and impact Operable Unit 3. The impact of increased groundwater flow through Operable Unit 1 has been mitigated since 1984 with the construction of a slurry wall between the golf course and Operable Unit 1.

The Phase II Stage 2 study also qualitatively evaluated the impact of herbicides, fungicides, and insecticides used at the golf course, and determined that there was no excessive use of these chemicals.

3.4 Findings and Recommendations: The Phase II Stage 2 recommended evaluation of the effects of golf course irrigation on groundwater flow for Operable Units 1 and 2. This was accomplished with the Mathematical Model for Groundwater Flow and Contaminant

Transport. Effects of all recharge and groundwater flow will be evaluated for each operable unit in the Remedial Investigation (RI) reports, and any corrective actions will be discussed in the Feasibility Study (FS) reports.

3.5 Concerns for Human Health and Environment: This site poses no direct risk to human health or the environment. Irrigation does increase groundwater flow which could increase contaminant transport from Operable Units 1 and 3. The effects of contaminant transport from these operable units, and alternatives for dealing with any problems will be evaluated in the RI and FS reports for those units.

3.6 Regulatory Coordination: The reports described in section 3.2 have been submitted to the Environmental Protection Agency and the Utah Department of Health for review.

4.0 ALTERNATIVES EVALUATED:

Only one alternative was evaluated; no further response action. Site OT14, the Hill AFB Golf Course, has no record of ever being used as a disposal site. It was investigated to determine the influence of its irrigation on groundwater flow at the known disposal sites at Operable Units 1 and 3. This has been accomplished. The effects of recharge and groundwater flow from all sources (not just the golf course) will be evaluated individually for each operable unit. There is no further action required for Site OT14, and no further need to track the golf course as an IRP site.

5.0 CONCLUSIONS:

No further response action is required at Site OT14 (Golf Course). The golf course will no longer be tracked as an IRP site. Effects of recharge from all sources will be addressed in the RI/FS reports for each operable unit.

6.0 SIGNATURE:

John C. Griffith

Signature
Vice Commander
Ogden Air Logistics Center

21 May 91

Date

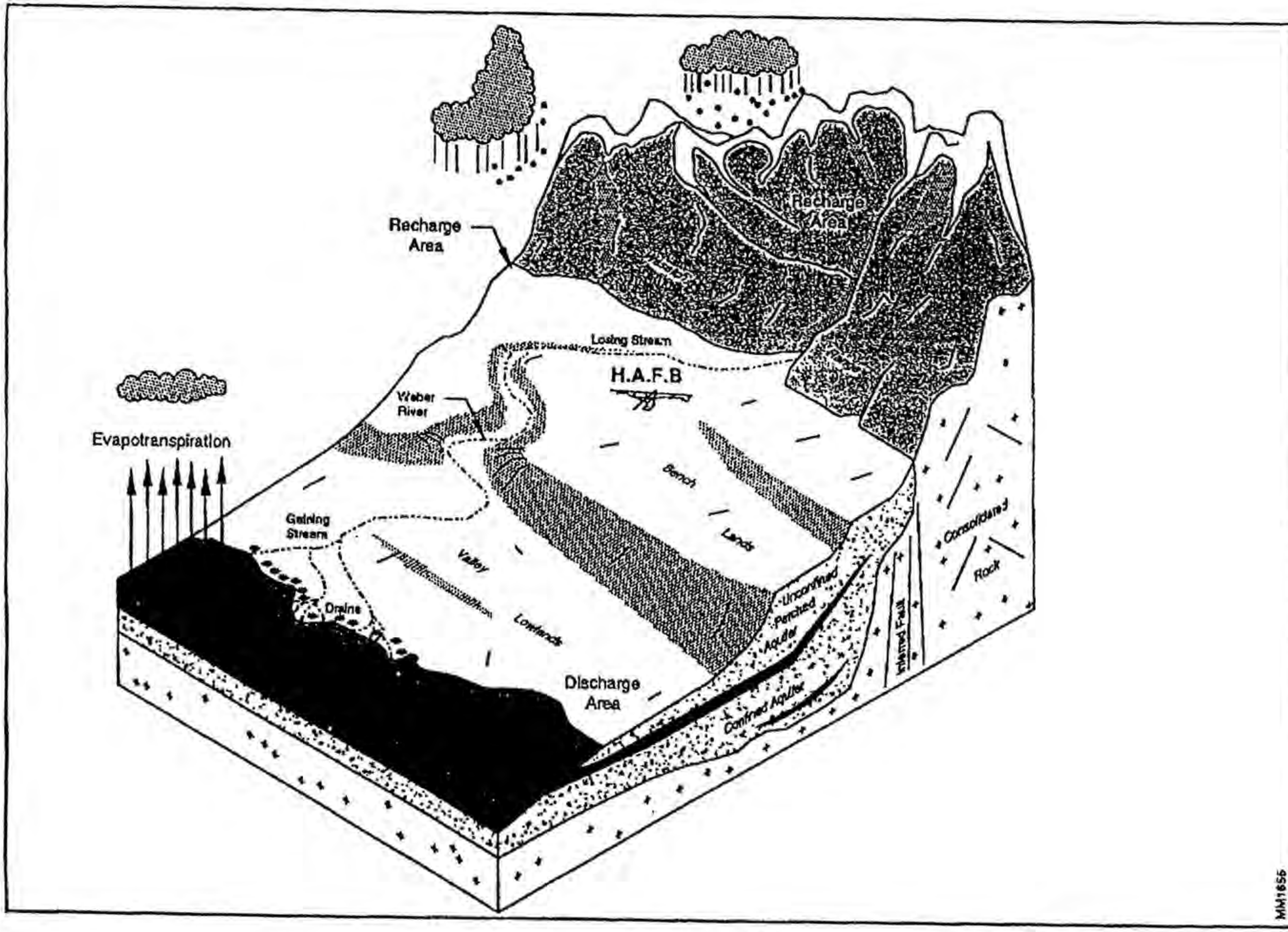


Figure 1-7. Conceptual Model of Groundwater Conditions in the Hill AFB Area

Attachment C

Data from Various Sources on Seepage and Groundwater Movement in the Vicinity of the Davis-Weber Canal

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

Technical Publication No. 90

SEEPAGE STUDIES OF THE WEBER RIVER AND THE DAVIS-WEBER AND OGDEN VALLEY CANALS, DAVIS AND WEBER COUNTIES, UTAH, 1985

by

L. R. Herbert, R. W. Cruff, D. W. Clark, and Charles Avery

Prepared by the
United States Geological Survey
in cooperation with the
Utah Department of Natural Resources
Division of Water Rights

1987

CONTENTS

ILLUSTRATIONS

TABLES

CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units, conversion factors for inch-pound units used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
Cubic foot per second	0.02832	Cubic meter per second
Cubic foot per second per mile	0.01760	Cubic meter per second per kilometer
Foot	0.3048	Meter
Mile	1.609	Kilometer

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 1.8\ (°C) + 32$$

SEEPAGE STUDIES OF THE WEBER RIVER AND THE DAVIS-WEBER AND OGDEN VALLEY CANALS, DAVIS AND WEBER COUNTIES, UTAH, 1985

by L. R. Herbert, R. W. Cruff, D. W. Clark, and Charles Avery

U.S. GEOLOGICAL SURVEY

ABSTRACT

Studies of selected reaches of the Weber River, Davis-Weber Canal, and the Ogden Valley Canal in Davis and Weber Counties, Utah, were made to determine gains or losses of flow in those reaches. Three to five sets of seepage measurements were made on the river and each canal during 1985. Adjustments for fluctuations in flow were made from information obtained from water-stage recorders operated at selected locations during the time of each set of seepage measurements. The studies indicated a loss of 20.0 cubic feet per second in the upstream reach of the Weber River and a gain of 17.0 cubic feet per second in the downstream reaches or a net loss of 3.0 cubic feet per second. Study results also indicated a net loss of 17.0 cubic feet per second in the Davis-Weber Canal and a net loss of 4.0 cubic feet per second in the Ogden Valley Canal.

INTRODUCTION

This report presents the results of a seepage study of selected reaches of the Weber River and the Davis-Weber and Ogden Valley Canals in Davis and Weber Counties, Utah. This study (seventh of a series) is part of the statewide water-resources program conducted by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights. Information on gains or losses of river and canal flow is needed by water managers for reallocating irrigation water.

The study includes 8.8 miles of the Weber River (fig. 1), 16.7 miles of the Davis-Weber Canal (fig. 2), and 8.8 miles of the Ogden Valley Canal (fig. 3). Water is diverted to the Davis-Weber Canal from the Weber River (fig. 2) and to the Ogden Valley Canal from the South Fork Ogden River near where the river enters the Ogden Valley (fig. 3). The diverted water is primarily used for irrigation.

METHODS OF INVESTIGATION

A reconnaissance of the canals was conducted in the spring of 1985 and a reconnaissance of the river was conducted in the summer of 1985. The sections of the canals and river selected for the study were examined for: (1) The locations of controls, turn outs or other diversion structures, and for bridges; (2) the general condition of the canals (for example, whether they recently had been cleaned or other maintenance had been performed); and (3) the location of areas of natural runoff and irrigation-return flow to the canals and river.

Using information gained from the reconnaissance, the selected sections of the canals and river were divided into reaches, and measuring sites were selected within each reach. Water-stage recorders were operated at selected sites, mainly at the start and the end of each reach. Because of the depth of the Davis-Weber Canal, in some reaches it was necessary to locate measuring sites at existing bridges or to construct bridges or cableways from which to make measurements.

Four sets of measurements were made at nine sites along the Weber River during 1985--on October 21, 25, 28, and 30. Five sets of measurements were made at 23 sites along the Davis-Weber Canal during 1985--on May 23, June 18, July 17, August 21, and September 17. Four sets of measurements were made at seven sites and three sets were made at six additional (downstream) sites along the Ogden Valley Canal in 1985--on June 13, July 15, August 14, and September 4. Sites where a measurement (or estimate) was made at least once are shown in figures 1-3.

The measurements of flow or discharge were made using standard methods of the U.S. Geological Survey (Buchanan and Somers, 1969). Each person making measurements was assigned a reach in which the required number of measurements could be completed in a day. In each reach, measurements were made at all selected measuring sites, including both ends of the reach, all turnouts, and all inflow points. For each main-channel measurement, the date, time, discharge, temperature, and specific conductance of the water are shown in tables 2-4 at the back of the report. For turnouts and return flow sites the date, time, and discharge also are shown in tables 2-4.

The numbers used in figures 1-3 (for example, T2 or R2) were assigned in a downstream order to those turnouts and inflow points that had flow during at least one set of measurements. Continuous water-stage records were obtained for each reach and are shown in figures 4-6.

PROCEDURES USED IN COMPUTING GAINS AND LOSSES

The gains and losses computed from the seepage measurements for reaches of the river and canals are shown in table 1. The procedures used to obtain these results are described in the following pages.

A computation was made of the flow that would be expected at each river and canal measuring site, assuming no gain or loss. Beginning with the flow at the head of each reach and proceeding in a downstream sequence, all turnout flows were subtracted and all inflows were added. The computed flow at each site then was adjusted for fluctuations in flow that originated upstream from the reach being analyzed. Information required to make this adjustment is the change in flow with time at the upstream end of the reach, the measurement times at the upstream end of the reach and at the downstream measuring site, and the traveltime (interval of time) required for passage of water from the upstream end of the reach to the downstream site.

Table 1.—Indicated gains or losses determined from seepage measurements for reaches of the river and canals

Reach	Length (feet)	Graphic average (from figures 7-9) gain (+) loss (-) (cubic feet per second)	Graphic average (from figures 7-9) gain (+) loss (-) (cubic feet per second per mile)
	Weber River		
WR1 - WR3	7,250	-20	-14.6
WR3 - WR5	10,610	0	0
WR5 - WR7	10,850	+9	+4.4
WR7 - WR9	17,530	+8	+2.4
Total	46,240	-3	
	Davis-Weber Canal		
DW1 - DW4	8,940	0	0
DW4 - DW6	7,980	-8	-5.3
DW6 - DW8	10,360	0	0
DW8 - DW10	8,290	-6	-3.8
DW10 - DW12	10,190	0	0
DW12 - DW15	17,950	0	0
DW15 - DW18	13,710	0	0
DW19 - DW20	6,650	-2	-1.6
DW20A- DW21	4,250	-1	-1.2
Total	88,320	-17	
	Ogden Valley Canal		
OV1 - OV4	12,240	0	0
OV4 - OV7	11,010	-3.5	-1.7
OV7 - OV10	11,230	-1.5	-0.7
OV10 - OV13	11,850	+1.0	+0.4
Total	46,330	-4.0	

The change in flow with time at the upstream end of each reach was determined from the recorded gage height and the discharge measurement at the upstream end of each reach. The time that each measurement was made is given in tables 2-4, and the traveltime between the upstream end of the reach and the downstream measuring site was based on the stage recorded at or near the ends of each reach.

As an example, assume that the measurement at the upstream end of the reach was 200 cubic feet per second at 0800 hours, the measurement at the downstream measuring site was made at 1000 hours, the traveltime between the two sites is 1 hour, and the discharge at the upstream end of the reach was decreasing at the rate of 5 cubic feet per second each hour. To make the adjustment, the traveltime is subtracted from the time of the downstream measurement to give a comparable time for flow at the upstream end of the reach. From the gage-height records and the measurements available for the upstream end of the reach, the flow at 0900 hours at the upstream end of the reach was calculated at 195 cubic feet per second, or an adjustment of 5 cubic feet per second. This adjustment was then applied to the computed value of the downstream measuring site. The computed value then was subtracted from the measured value to determine the amount of gain or loss between the upstream end of the reach and the downstream measuring site. The amount of gain or loss then was plotted as a function of distance downstream from the upstream end of the reach. This was done for each main river or canal measuring site for each set of measurements.

In some instances, depending on the rate of gain or loss or the scatter of plotted points, the river or canals were segmented into shorter reaches. The data for each of the newly defined reaches were then plotted in figures 7-9 with the gain or loss at each main river or canal measuring site plotted as a function of distance from the upstream end of the reach. A straight line was fitted, based on the plotted points for each reach, and the amount and rate per mile of gain or loss for the reach were determined from this line. The amount and rate of gain or loss by reach are shown in table 1.

Within a given reach, the amount of gain or loss varied in each set of seepage measurements and among the several sets of measurements. This variation is shown by the scatter of the plotted points in figures 7-9. The scatter is attributed to one or more of the following: (1) Poor measuring conditions, (2) changes in the rate of seepage from or to the river or canal, (3) changes in the rate of return flow to the river or canal, (4) the inability to adjust completely for fluctuation in the amount of flow within a given reach, and (5) the possibility that a water user changed the flow in his turnouts or return flows during the time of the measurements.

Weber River

Four sets of seepage measurements at nine sites were made on the Weber River (see fig. 1 and table 2). Seepage from the Weber River in this area is considered to be a major source of recharge to the ground-water reservoir (Feth and others, 1966, p. 39). Losses were indicated in the upstream reach of the study, whereas the downstream reach indicated gains. The river had a net loss of 3 cubic feet per second with a loss of 20 cubic feet per second in the upstream reach and a gain of 17 cubic feet per second in the downstream reach. The following is a brief description of each reach studied and the calculated changes (see fig. 7 and table 1).

Reach WR1-WR3.--Site WR1 is a temporary gage where a water-stage recorder was operated to monitor changes in stage of the river; it is 0.1 mile downstream from the Davis-Weber Canal diversion. Site WR3 is at the intersection of the river and U.S. Highway 89. In this reach the river is underlain by coarse permeable gravel several hundred feet thick (Feth and others, 1966, p. 41). The measurements in this reach had some scatter, and they indicate a net loss of 20 cubic feet per second or about 14.6 cubic feet per second per mile. Losses in this reach are assumed to percolate downward and enter the principal ground-water reservoir.

Reach WR3-WR5.--Site WR5 is a temporary gage where a water-stage recorder was operated to monitor changes in stage of the river about 2.0 miles downstream from U.S. Highway 89 or site WR3. This probably is a transition reach between the losing and gaining reaches of the river. The measurements in reach WR3-WR5 had considerable scatter. In looking at the measurements, one might think that there is a gain between WR3 and WR4, with a similar loss between WR4 and WR5. The authors do not know of any logical reason why this would occur, thus, it was decided to interpret the results as indicating no change between WR3 and WR5.

Reach WR5-WR7.--Site WR7 is about 2.0 miles downstream from WR5. The measurements in this reach had some scatter, and they indicated a net gain of 9.0 cubic feet per second or 4.4 cubic feet per second per mile. In the floodplain of this reach there is evidence of perched ground water which probably also underlies the river (Feth and others, 1966, p. 41). The source of the gain in flow probably is the perched ground water.

Reach WR7-WR9.--Site WR9 is a temporary gage where a water-stage recorder was operated to monitor changes in stage of the river, 0.1 mile upstream from the intersection of the river and U.S. Highway 91 at Riverdale, Utah. The measurements in this reach had some scatter, and they indicate a net gain of 8 cubic feet per second or 2.4 cubic feet per second per mile. The gains measured in this reach also are assumed to be from water moving into the river from the perched ground water.

Davis-Weber Canal

Five sets of seepage measurements at 23 sites were made on the Davis-Weber Canal (table 3, fig. 2). The canal has been in operation for many years and the concrete lining in many places is cracked and in poor condition. Most of the canal system is within the ground-water recharge area (Feth and others, 1966, p. 41); this is underlain by permeable sediments where water can percolate downward toward the aquifers without impediment from fine-grained layers. Therefore, most losses from the canal are considered to be recharge to the principal ground-water reservoir. Losses were indicated in four of the reaches mainly near the upstream and downstream end of the canal, whereas the remainder of the reaches had no indicated gain or loss. The maximum loss in a reach was 8.0 cubic feet per second, and the net loss for the canal was 17 cubic feet per second. The location and amount of the losses may be caused in part by the extent of degradation on the canal rather than the type of sediments beneath the canal. The following is a brief description of each reach studied and the calculated changes (see fig. 8 and table 1).

Reach DW1-DW4.—Site DW1 is the Davis-Weber Canal gage near the diversion point of the canal. A water-stage recorder operated by the water users was used to monitor changes in stage at this site. Site DW4 is a temporary gage on the canal where a water-stage recorder was operated to monitor changes of stage; the gage is at the intersection of the canal and U.S. Highway 89. The measurements had considerable scatter and indicated no net gain or loss in flow.

Reach DW4-DW6.--Site DW6 is 1.5 miles downstream from DW4 at a bridge across the canal. The measurements in this reach had some scatter, and they indicated a net loss of about 8.0 cubic feet per second or 5.3 cubic feet per second per mile. All losses in this reach are assumed to be recharge to the underlying water-table aquifer.

Reach DW6-DW8.—Site DW8 is a temporary gage on the canal where a water-stage recorder was operated to monitor changes in stage, about 2.0 miles downstream from DW6 and at a farm bridge. The measurements in this reach had little scatter, and indicated no gain or loss in flow.

Reach DW8-DW10.—Site DW10 is about 1.6 miles downstream from DW8 and at a bridge across the canal. The measurements in this reach had some scatter, and they indicated a net loss of 6.0 cubic feet per second or 3.8 cubic feet per second per mile. It is assumed that a large percent of the losses in this reach percolates to the ground-water reservoir.

Reach DW10-DW12.--Site DW12 is a temporary gage on the canal where a water-stage recorder was operated to monitor changes in stage; it is about 1.9 miles downstream from DW10 at a bridge across the canal. The measurements in this reach had considerable scatter and indicated no net gain or loss in flow. Although the measurements indicate that the reach has some losses they also indicate that there are gains in this reach, most probably from seepage from the hillside above the canal's left bank. There may actually be losses to the ground-water reservoir in this reach, but no specific amount was identified.

Reach DW12-DW15.--Site DW15 is a temporary gage on the canal where a water-stage recorder was operated to monitor changes in stage, about 3.4 miles downstream from DW12 and at the intersection of the canal and State Road 84 in Sunset, Utah. The measurements in this reach had considerable scatter and indicated no gain or loss in flow.

Reach DW15-DW18.--Site DW18 is about 2.6 miles downstream from DW15 and upstream from a large diversion in Clearfield. The measurements in this reach had some scatter and indicate no gain or loss in flow.

Reach DW19-DW20.--Site DW19 is downstream from a large diversion near Site DW18. Site DW20 is a temporary gage on the canal where a water-stage recorder was operated to monitor changes in stage; it is about 1.3 miles downstream from DW19 and upstream from a large diversion. Measurements in this reach had little scatter and indicated a net loss of 2.0 cubic feet per second or 1.6 cubic feet per second per mile. Because fine-grained material underlie this area, it is assumed that only about half of these canal losses reach the principal ground-water reservoir as recharge.

Reach DW20A-DW21.--Site DW20A is downstream from the large diversion near DW20. Site DW21 is about 0.8 miles downstream from DW20A and on the upstream side of State Road 232. The measurements had little scatter and indicate a net loss of 1.0 cubic foot per second or 1.2 cubic feet per second per mile. This reach is considered to be outside of the recharge area, and the losses probably do not reach the ground-water reservoir.

Ogden Valley Canal

Four sets of seepage measurements at the seven upstream sites and three sets of seepage measurements at six additional sites in the downstream section of the canal were made on the Ogden Valley Canal (table 1, fig. 3). Although the canal is lined with a clay liner, losses were indicated in the middle reaches. The upstream reach, however, had no gain or loss, and the downstream reach had a gain of 1.0 cubic foot per second. The net loss for the full length of the canal studied was 4.0 cubic feet per second. Clay and other fine-grained deposits with local veneers of coarser material underlie the canal. The following is a brief description of each reach studied and the calculated changes (see fig. 9 and table 1).

Reach OV1-OV4.--Site OV1 is a temporary gage near the diversion point of the canal where a water-stage recorder was operated to monitor changes in stage. Site OV4 is 2.3 miles downstream from OV1. The measurements in this reach had little scatter and indicated no gain or loss in flow, although the canal crosses over a gravel deposit. Apparently the clay liner was still effective between OV1 and OV4 during this study.

Reach OV4-OV7.--Site OV7 is a temporary gage near the left bank of the Middle Fork Ogden River and 2.1 miles downstream from OV4, where a water-stage recorder was operated to monitor change in stage and flow. The measurements in this reach had little scatter and indicate a net loss of 3.5 cubic feet per second or 1.7 cubic feet per second per mile. The losses probably are caused by deterioration of the clay liner in areas of coarser underlying materials.

Measurements made July 15 and September 4 at site OV7 were not used because they were affected by changes in upstream diversion rates to a storage reservoir.

Reach OV7-OV10.--Site OV10 is 2.1 miles downstream from OV7. The measurements in this reach had little scatter and indicate a net loss of 1.5 cubic feet per second or 0.7 cubic foot per second per mile. The losses probably were caused by leakage through the clay liner to the coarser deposits underlying this reach.

Reach OV10-OV13.--Site OV13 is the water users gage north of Eden, Utah, where a water-stage recorder was operated to monitor changes in stage. Site OV13 is 2.2 miles downstream from OV10. The measurements in this reach had little scatter and indicate a net gain of 1.0 cubic foot per second or 0.4 cubic foot per second per mile. The gains probably are caused by discharge of unconfined ground water to this reach.

SUMMARY

The upstream reach of the Weber River had a loss in flow, whereas the downstream reaches gained in flow. The loss in the upstream reach is assumed to be recharge to the principal ground-water reservoir in the area. Gains in the downstream reaches probably result from movement of ground-water from the adjacent perched zones to the river. Many of the study reaches of the Davis-Weber Canal did not have gains or losses, although some reaches near the upstream and the downstream ends of the canal had substantial losses, most of which are assumed to infiltrate downward to the ground-water reservoir. Study reaches of the Ogden Valley Canal had losses in the middle reaches, where the canal's clay lining may have deteriorated; whereas the upstream reach had no gain or loss, and the downstream reach gained flow from the unconfined ground water.

REFERENCES CITED

Buchanan, T. J. and Somers, W. P., 1969, Discharge measurements at gaging stations, U.S. Geological Survey TWRI, Book 3, Chapter A8, 66 p.

Feth, J. H., Barker, D. A., Moore, L. G., Brown, R. J., and Veirs, C. E., 1966, Lake Bonneville: Geology and hydrology of the Weber Delta district, including Ogden, Utah: U.S. Geological Survey Professional Paper 518.

TABLE 4.3.13-1. SUMMARY OF GROUNDWATER AND QC ANALYSES AT HERBICIDE ORANGE TEST PLOTS

			Well Number/Sampling Round								QC Samples			
			HOT-1		HOT-2		HOT-1R		HOT-2R		Bailer Wash		Field Blk.	
Parameter	Detection Units	Limit	I[a]	II[b]	I[a]	II[b]	I[a]	II[b]	I[a]	II[b]	HEW-1[a]	HWB-4[b]	HFB-G1	HFB-6[4]
Herbicides														
2,4-D	ug/L	0.50	ND	ND	ND	ND	ND	NA	NA	ND	ND	ND	ND	ND
2,4,5-T	ug/L	0.10	ND	ND	ND	ND	ND	NA	NA	ND	ND	ND	ND	ND
2,3,7,8-TCDD	ug/L	2.0	ND	ND	ND	ND	ND	NA	NA	ND	ND	ND	ND	ND

No 2,4-D 2,4,5-T or TCDD was detected in any soil or water samples

[a]I - Samples collected 6/10/86.
[b]II - Samples collected 8/20/86.

ND - Not detected above method detection limits.
NA - Not analyzed.

half-life of 12 years, decomposition over 16 years cannot account for its complete absence. In all likelihood the remainder has been removed by wind transport.

4.3.14 Site 14, Golf Course (Radian)

Construction of the golf course began in 1960. The golf course itself is not a waste disposal area. The site, which is equipped with an irrigation system, was investigated to determine whether or not a hydraulic connection exists between the golf course and the topographically lower waste disposal areas of Landfill 4, Landfill 3, and Chemical Disposal Pits 1 and 2. During the Phase II Stage 1 investigation, well GC-1 was installed on the golf course and was sampled for analytical comparison to samples from previously existing wells 80-19 and W-13 which are located just north of the golf course. Results from these analyses, though inconclusive, suggested that the water in the golf course area is not significantly different chemically from groundwater to the north but no gradual transition in water chemistry was observed.

4.3.14.1 Results of Investigation

IRP Phase II Stage 2 activites at the golf course consisted of a data review; installation of test wells GC-2, GC-3, and GC-4; analysis of the water balance of the golf course area; eleven water level measurements of the golf course wells and Berman Pond wells to determine the nature of groundwater recharge to verify the water balance and to identify flow directions associated with irrigation at the golf course; and collection and analysis of groundwater samples. Groundwater samples were analyzed in the field for temperature and conductivity and in the laboratory for major anions and cations. Figure 4.3.14-1 shows the locations of wells associated with this site.

Results of these activities and descriptions of the site geology and occurrence of groundwater follow.

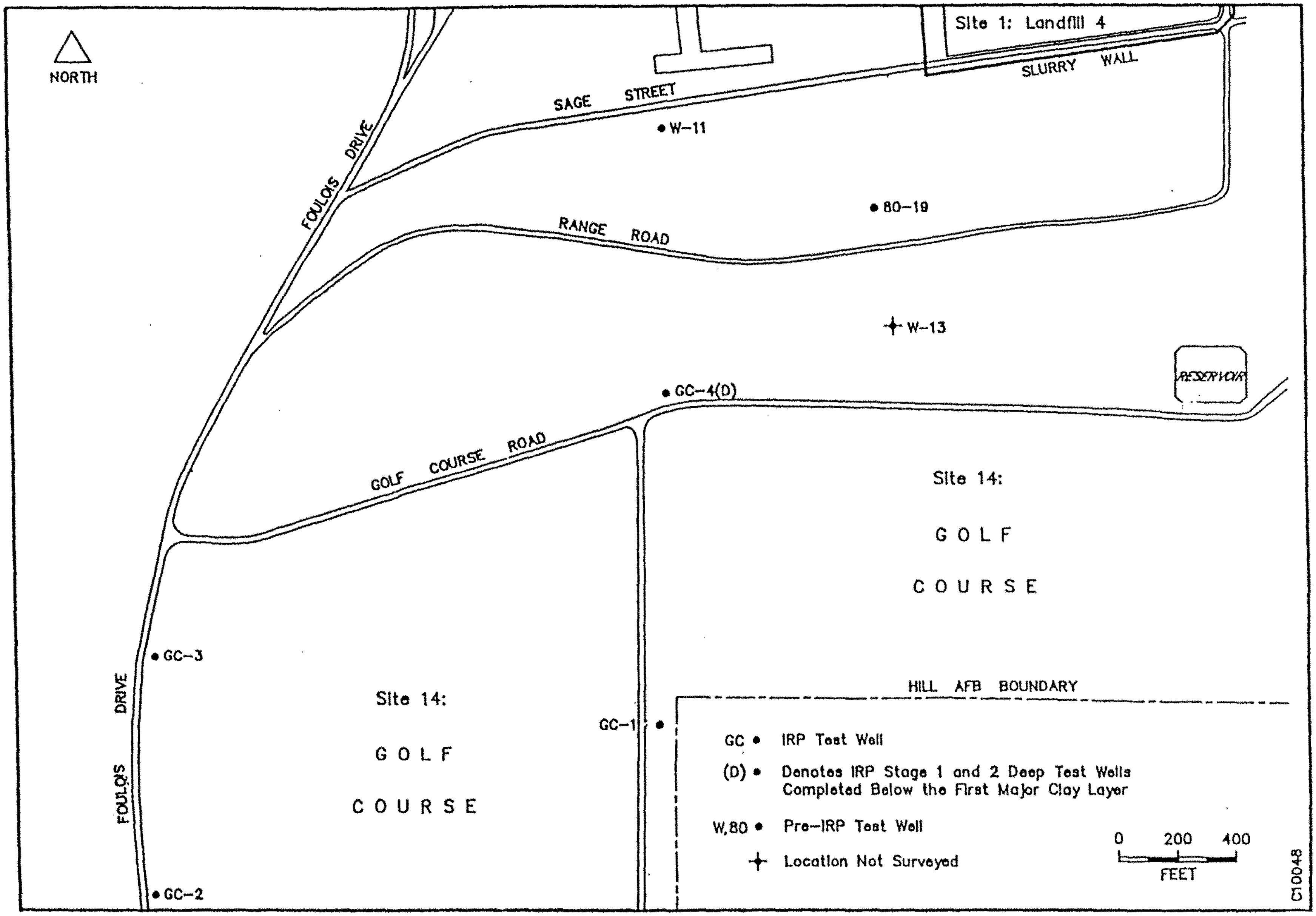


Figure 4.3.14-1. Locations of Test Wells, Site 14, Golf Course, Hill AFB, Utah

4.3.14.1.1 Data Review

A data review (including irrigation practices and septic system information) for the base golf course was performed to gather information necessary for conducting a water balance. Pesticide use was documented and reviewed to assess potential groundwater impacts. The water balance analysis is presented in Section 4.3.14.1.2. Golf course herbicide application is discussed in the following paragraphs.

Golf Course Pesticide Application

A data review was conducted on the application of pesticides at the golf course. This qualitative investigation of the use of pesticides was used to determine if there was a potential for irrigation or precipitation water to carry excess pesticides downward to the groundwater. The data review was conducted with personnel from the Base Entomology Section, who are responsible for the application of the pesticides at the golf course. The area treated for entomological control is about 180 acres, mainly the fairways, greens and roughs. Weed control spraying is mainly during the June, July and August golfing season. Large areas are treated with a boom sprayer while for smaller areas a hand sprayer is used.

Types of pesticides used at the golf course include herbicides, fungicides, and insecticides. Specific products are 2,4-D, Round Up, Terraneb, and Sevin. No ground sterilants are used. The following is a summary of the use of these chemicals and their function at the golf course.

Herbicide 2,4 D: The herbicide 2,4-D is used for broad leaf weed control. The areas of application are the fairways and in the roughs. It is generally applied once per year after the rainy season so that it does not wash away. The chemical is used according to the manufacturer's instructions. It is diluted at 1 part per 100 parts water and lightly sprayed on the target areas. This equates to an application rate of about 1 quart/acre. In 1986 about 25 gallons of the 2,4 D were used over an area of about 100 acres.

Round Up: Round Up is a phytotoxic herbicide used for limited control along the fences of the golf course. About two gallons of this contact herbicide are used per year.

Terraneb: Terraneb is a powdered turf fungicide applied to the greens at the golf course. Application occurs once or twice a year as needed. It is applied as late as possible, around October before cold temperatures begin. Once cold temperatures begin, snow mold, a fungus, can grow and adversly affect the carpet grass of the greens. In 1986 approximately six pounds of the fungicide in about 330 gallons of water were applied.

Sevin and Dursban: Two chemicals are used for control of cut worms which attack the greens. These are Sevin and Dursban. These insecticides are rotated in usage and generally applied once or twice a year as needed. In the past Diazanon was also applied but is no longer used.

The results of this data review indicate that there appears to be no excess use of the various chemicals at the golf course. The personnel interviewed demonstrated an awareness of the proper application of these chemicals. Also, if an excess amount of the chemicals were inadvertently used, the vegetation quickly shows chemical stress or dies. This provides rapid indication to the entomology section of an inadvertent overuse. Since the chemicals appear to be safely handled and the applications are minimal, little environmental impact is probable. Some chemicals could be transported downward from precipitation or irrigation but the opportunity for this happening appears minimal since they are applied once or twice a year during low water cycles.

4.3.14.1.2 Water Balance Analysis

Radian reviewed the available precipitation data and irrigation watering practices at the golf course in order to perform a water balance of the area. The purpose of the water balance study was to identify the amount of water from precipitation and irrigation which has the potential to recharge the local groundwater. If the recharge were substantial, it could affect the waste sites to the north and/or the effectiveness of the slurry trench wall. For instance, excess recharge could cause static water levels to rise on the upgradient side of the slurry trench wall. The resulting pressure can stress the slurry trench wall, or if the wall was not effective, water levels downgradient could rise and intrude into the old waste sites. The following topics are discussed in this subsection: 1) background, 2) water budget determination, and 3) results and significance of findings.

Background

In 1983 during the IRP stage 1 activities, the golf course area was added to the investigation. This was to determine the potential for groundwater recharge to the waste disposal sites (Chemical Disposal Pits 1 and 2, and Landfill 3) from irrigation and precipitation. Test well GC-1 was emplaced to characterize the local groundwater system. The limited data collected suggested that recharge could occur to the shallow aquifer under the waste sites. Additional investigations were needed to confirm the Stage 1 results. Therefore, during the Stage 2 activities a water balance of the golf course area was conducted to determine if irrigation practices could contribute to the groundwater below the golf course.

Water Budget Determination

The water budget was calculated with the U.S. Army Corps of Engineers Waterways Experiment Station's model: Hydrologic Evaluation of Landfill Performance (HELP). This model has been adapted for IBM PC use. The HELP model was used because it was readily available, cost efficient, and easy to use. An additional benefit is it provided access to data bases that could provide a range of climates and soil types. Further, it is a U.S. Army Corps of Engineers model developed and tested for the EPA.

HELP is a hydrologic model that computes water movement across, into, through and out of landfills. It also accounts for the water balance at the surface for a variety of soils and vegetation methods. The model uses weather information either manually input or from a HELP default data base. Other physical parameters are used which describe the slope, vegetative cover and surface soil type to compute daily seepage and runoff. Runoff was computed using the Soil Conservation Services (SCS) runoff curve number method. Percolation was determined by Darcy's Law for saturated flow with modifications for unsaturated conditions. Evapotranspiration was determined by a modified Penman method. Even though this program was developed for landfill applications, it can also be used for determining the infiltration and percolation at the golf course area. The model was applied to the golf course by using one soil layer with no underlying waste or barrier layers. HELP assumes the soil layer is at field capacity initially and the entire soil layer is homogeneous.

Precipitation and irrigation data were supplied by Hill AFB for the time period 1980 through 1986. This was considered a reasonable time period sufficient to determine a water budget for the golf course. A silty-clay loam was used for the soil data input. This soil type best describes the materials underlying the golf course, according to IRP field investigations conducted and a U.S. Department of Agriculture Soil Survey of the Davis-Weber Area (1960).

The soils underlying the golf course were defined in the model as a five-foot vertical percolation layer. A depth of five feet was chosen because if there were no percolation of water below five feet, then the groundwater would not be affected. No evapotranspiration should take place below about five feet because of the shallow root system of the golf course grasses.

The principal assumptions used for the golf course to calculate the water budget are summarized in Table 4.3.14-1. The details of other model data, specific assumptions and methodology are provided in Appendix H. The following summarizes the results of the water budget analysis.

TABLE 4.3.14-1. SUMMARY OF HELP MODEL SOIL DATA ASSUMPTIONS

Vegetative Cover:	Excellent grass[a]
Layer Type:	Vertical percolation layer[a]
Soil Type:	Silty clay loam[a]
Soil Thickness:	60 inches (5 feet)[a]
Evaporation Coefficient:	4.2 mm/day (0.5)[b]
Porosity:	0.5880 vol/vol[b]
Field Capacity:	0.5040 vol/vol[b]
Wilting Point	0.3550 vol/vol[b]
Effective Hydraulic Conductivity:	0.2049998 in/hr[b]

[a]Data input manually.
[b]Default data from HELP's data base.

Water Budget Results and Significance of Findings

Infiltration rates were calculated for the golf course area using precipitation (rain and snow) only and precipitation plus irrigation. These data were used because they represent general conditions likely to be encountered at the golf course. Tables 4.3.14-2 and 4.3.14-3 summarize these results. The average annual percolation using only precipitation data was 45 acre-feet or 3.9 inches, while the average percolation using precipitation and irrigation data was 144 acre-feet or 12.5 inches. These values are the net infiltration which would percolate downward to a depth of five feet below the land surface under non-irrigated and irrigated conditions respectively. In a study by the University of Kentucky evaluating the performance of the HELP model, percent errors for determining infiltration, runoff and drainage were in the range of -54 to +8 percent. Applying these percentages to the model results, the values could range from a low of 1.8 inches to a high of 13.5 inches of infiltration which equates to 20.7 to 155.5 acre-feet respectively.

These qualitative values indicate that surplus water would percolate below the assumed five foot layer under both non-irrigated and irrigated conditions. The significance is that any surplus water throughout the year is likely to recharge groundwater systems, provided that the underlying formations are hydraulically connected. A hydraulic connection was verified from a groundwater level analysis discussed in Section 4.3.14.1.4. Based upon the present data vertical connections appears to be variable between the golf course and the waste sites to the north. This is evidenced by the thick dry clays of over forty feet in thickness encountered at test wells GC-1 and GC-4. However, there likely exists silt and sand lenses between these wells that could permit downward recharge. This appears to be the case at test wells GC-2 and GC-3 to the west. At these locations interlayered clay, silt and sands were found in the wells. Also, periodic surface water has been observed in this area along Foulois Drive indicating that a portion of the irrigation water is rejected as recharge and does not infiltrate. This excess irrigation water flows overland and ponds in low areas until it either infiltrates or evaporates.

TABLE 4.3.14-2. HELP MODEL OUTPUT SUMMARY FOR PRECIPITATION ONLY: AVERAGE ANNUAL TOTALS FOR 1980 THROUGH 1986

	Inches	Cubic Feet	Percent
Precipitation	24.67	12,334,838	100.00
Runoff	0.148	73,760	0.60
Evapotranspiration	20.724	10,362,021	84.01
Percolation Below 5 Feet	3.9488	1,974,416	16.01

TABLE 4.3.14-3. HELP MODEL OUTPUT SUMMARY FOR PRECIPITATION PLUS IRRIGATION: AVERAGE ANNUAL TOTALS FOR 1980 THROUGH 1986

	Inches	Cubic Feet	Percent
Precipitation and Irrigation	66.85	33,425,760	100.00
Runoff	0.574	287,090	0.86
Evapotranspiration	53.675[a]	26,837,328	80.29
Percolation Below 5 Feet	12.5423	6,271,138	18.76

[a]Evapotranspiration potential increases because of irrigation during warmer times of the year.

4.3.14.1.3 <u>Geologic Features</u>

Two test well borings were drilled west of the golf course, GC-2 and GC-3, to a depth of 56.5 and 24.5 feet, respectively. A third well boring, GC-4, was drilled north of the golf course in a topographically higher area. Appendix G contains corresponding lithologic logs for these test well borings.

The uppermost soils at the site in the vicinity of GC-2 and GC-3 consist of varying combinations of sand, silt and clay. A zone of saturated fine- to medium-grained silty sand, 2 to 5 feet in thickness, was encountered in both of these borings at depths of 13 and 20 feet. An additional saturated unit comprised of clayey sand was recorded at a depth of 55 feet in well boring GC-2.

The lithologic units logged for well borings GC-2 and GC-3 are not correlative with those encountered in GC-4. A clay unit persisted from ground surface to the total depth of the boring (97 feet) with thin interbeds of clayey silt and silty sand. Saturation was noted at 93 feet.

4.3.14.1.4 <u>Occurrence of Groundwater</u>

<u>Groundwater Levels</u>

Eleven water level measurements were collected at the four golf course wells (GC-1,2,3 and 4), the two adjacent test wells (80-19 and W-11), and the two Berman Pond wells (BPM-1 and -2) over the period 14 August 1986 to 13 March 1987. Originally, test well W-13 was to be measured, but it could not be located during the Stage 2 activities. The area at W-13 was covered with discarded inert materials and W-13 was destroyed. Test well W-11 was the next closest well for obtaining the desired data. Therefore, test well W-11 was substituted for W-13. The measurements at these wells were used to determine the nature of groundwater recharge, to verify the water balance and to identify flow directions associated with irrigation at the golf course.

Measurements began in August after all the test wells were completed and developed. Therefore, the data begins late in the irrigation season usually ending in September. The data continue through the winter and spring precipitation seasons. Trends in the data can still be observed because static water level changes reflect any overall infiltration at the golf course. The intent of these measurements was to document infiltration that recharges the groundwater under the golf course. Figure 4.3.14-2 is a hydrograph showing the changes in water level elevation over time. Table 4.3.14-4 lists the water level elevations used to generate the hydrograph.

Static water levels at the golf course are shown in Figures 4.3.14-3 and 4.3.14-4. These figures represent measurements made 19 September, 1986, and 27 January 1987, which represent irrigation and non-irrigation periods, respectively. Analysis of the water level contours show groundwater flow directions to the west and north. Groundwater flow is perpendicular to the water level contour of equipotential lines. The westerly flow is baseward while the northerly flow is towards the slurry trench wall and waste site areas. These data confirm that groundwater underflow occurs at the golf course. Static water level contours were estimated in the area bounded by GC-4, Golf Course Road, Foulois Drive, and Range Road. No well data were available in this area. Therefore, the contours are based upon known hydrogeologic conditions of the study sites.

Further analysis indicates that recharge occurred during the golf course irrigation activities. Recharge can also be from private farmland located next to the golf course. The contribution from the farmland is unknown. No well data are available to the east of the golf course and the recharge potential is unknown. Recharge occurred mainly in the vicinity and west of test well GC-1. This is indicated by an eastward shifting of the water level contours such as the 4800 water level line after the irrigation season. The eastward shifting of the contours is an indication of declining recharge. On the other hand, less shifting of the contours occurred in the vicinity of GC-4. This can represent less recharge and/or changes in formation permeability characteristics. Variations in recharge were confirmed at

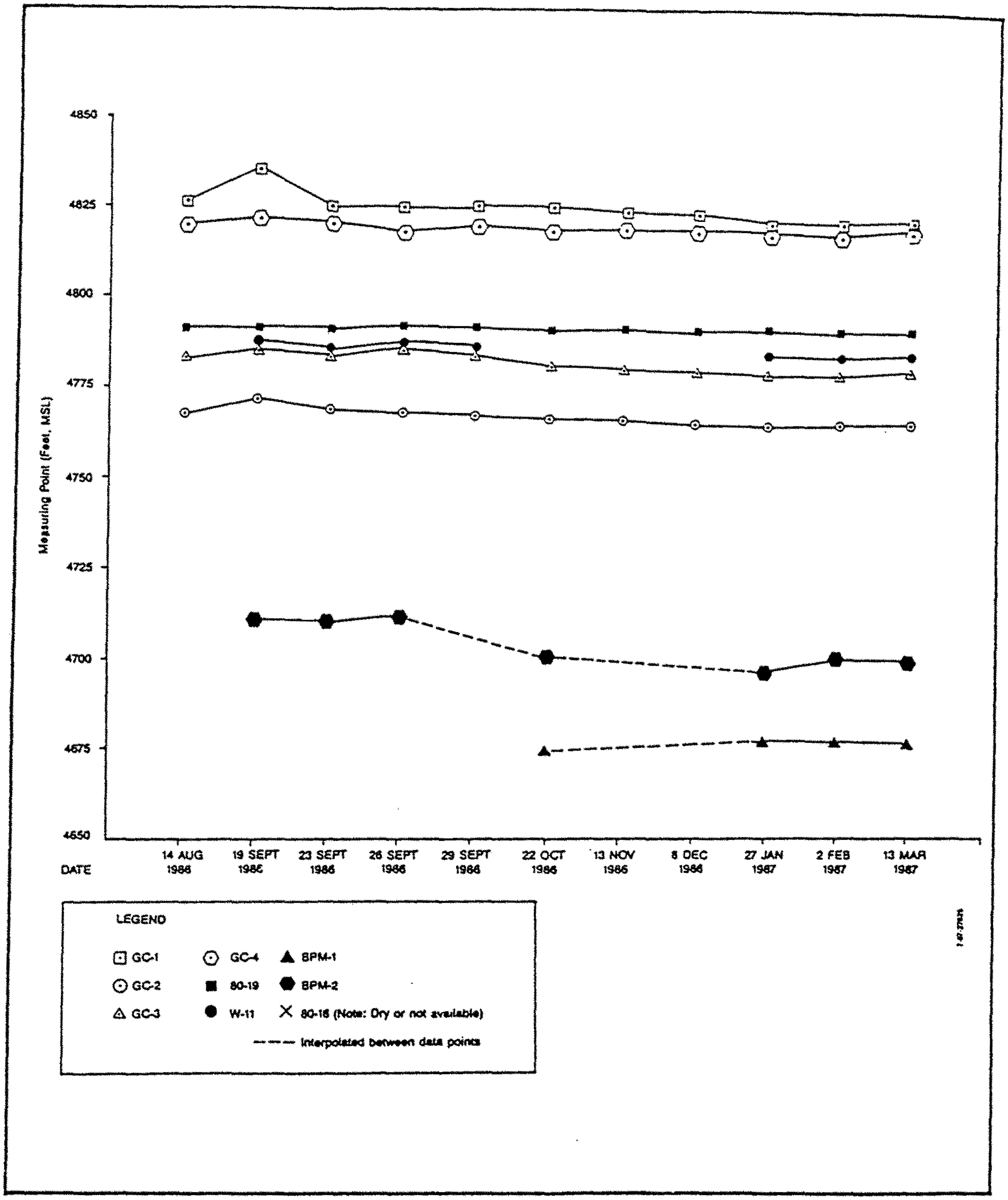


Figure 4.3.14-2. Test Well Water Level Hydrographs, Site 14 Golf Course, Hill AFB, Utah

TABLE 4.3.14-4. WATER LEVEL ELEVATIONS (FT, MSL), SITE 14, GOLF COURSE, HILL AFB, UTAH

Date	GC-1	Static Water Level Elevations							
		GC-2	GC-3	GC-4	80-18	80-19	W-11	BPM-1	BPM-2
14 Aug 1986	4826.81	4768.33	4784.64	4820.17	Dry	4792.96	NA	NA	NA
19 Sep 1986	4835.62	4773.06	4785.82	4822.01	NA	4792.54	4787.56	NA	4711.35
23 Sep 1986	4825.34	4769.34	4784.14	4820.79	NA	4792.43	4786.21	NA	4711.19
26 Sep 1986	4825.41	4769.62	4785.92	4818.73	NA	4793.28	4788.04	NA	4713.17
29 Sep 1986	4825.81	4768.37	4784.25	4820.07	NA	4793.07	4786.23	NA	NA
22 Oct 1986	4825.65	4768.31	4782.77	4819.92	NA	4792.38	NA	4676.37	4703.07
13 Nov 1986	4824.73	4767.51	4781.80	4819.60	NA	4792.32	NA	NA	NA
8 Dec 1986	4823.82	4767.03	4780.82	4819.36	NA	4792.25	NA	NA	NA
27 Jan 1987	4822.78	4766.01	4779.07	4819.08	Dry	4792.19	4785.01	4678.89	4697.61
2 Feb 1987	4822.96	4765.80	4779.16	4818.97	Dry	4792.38	4784.94	4678.77	4702.31
13 Mar 1987	4823.03	4766.32	4780.12	4819.49	Dry	4792.40	4785.23	4678.73	4701.73

NA - Not Available.

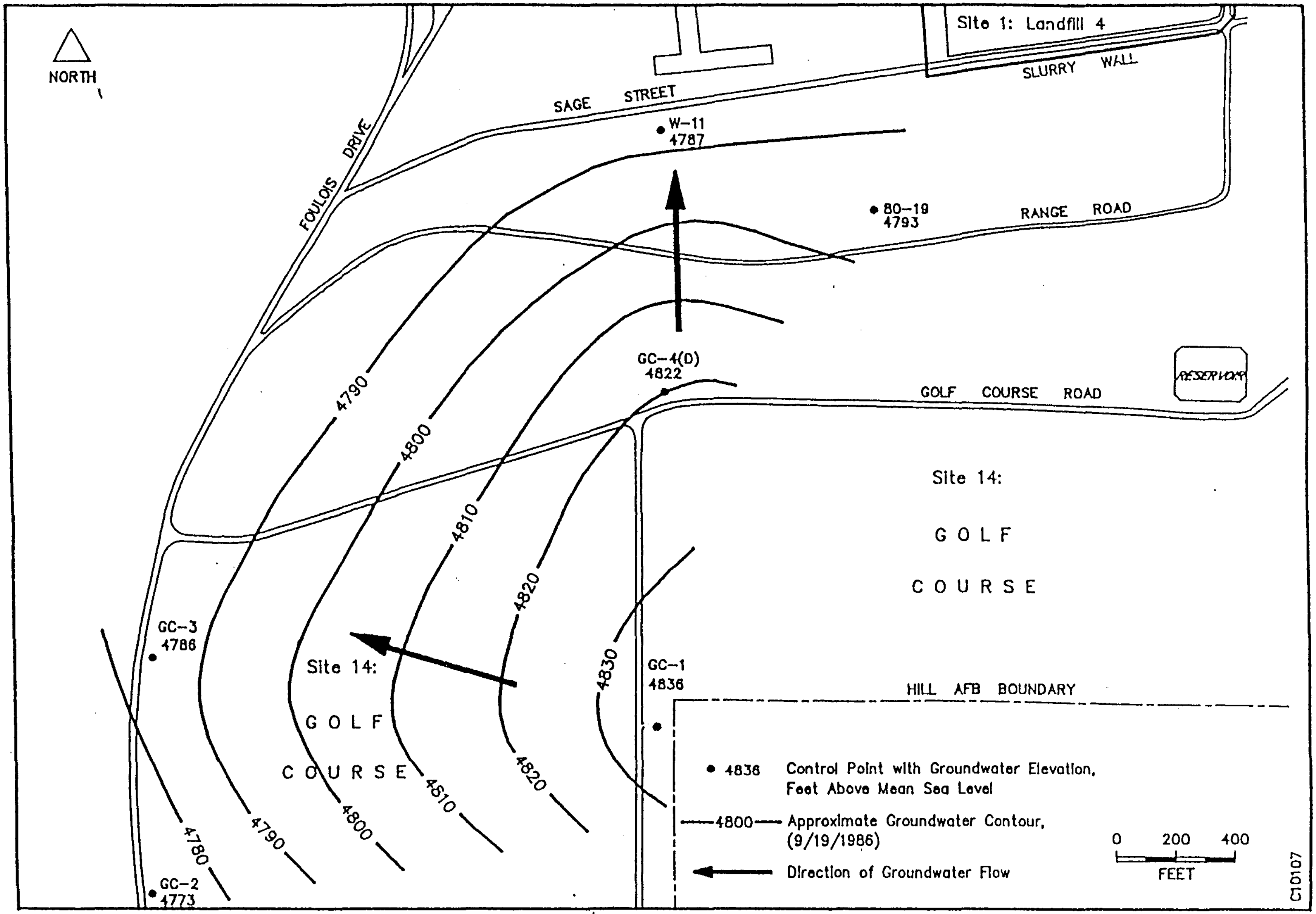


Figure 4.3.14-3. Water Level Contour Map During Irrigation Season (9-19-86), Site 14, Golf Course, Hill AFB, Utah

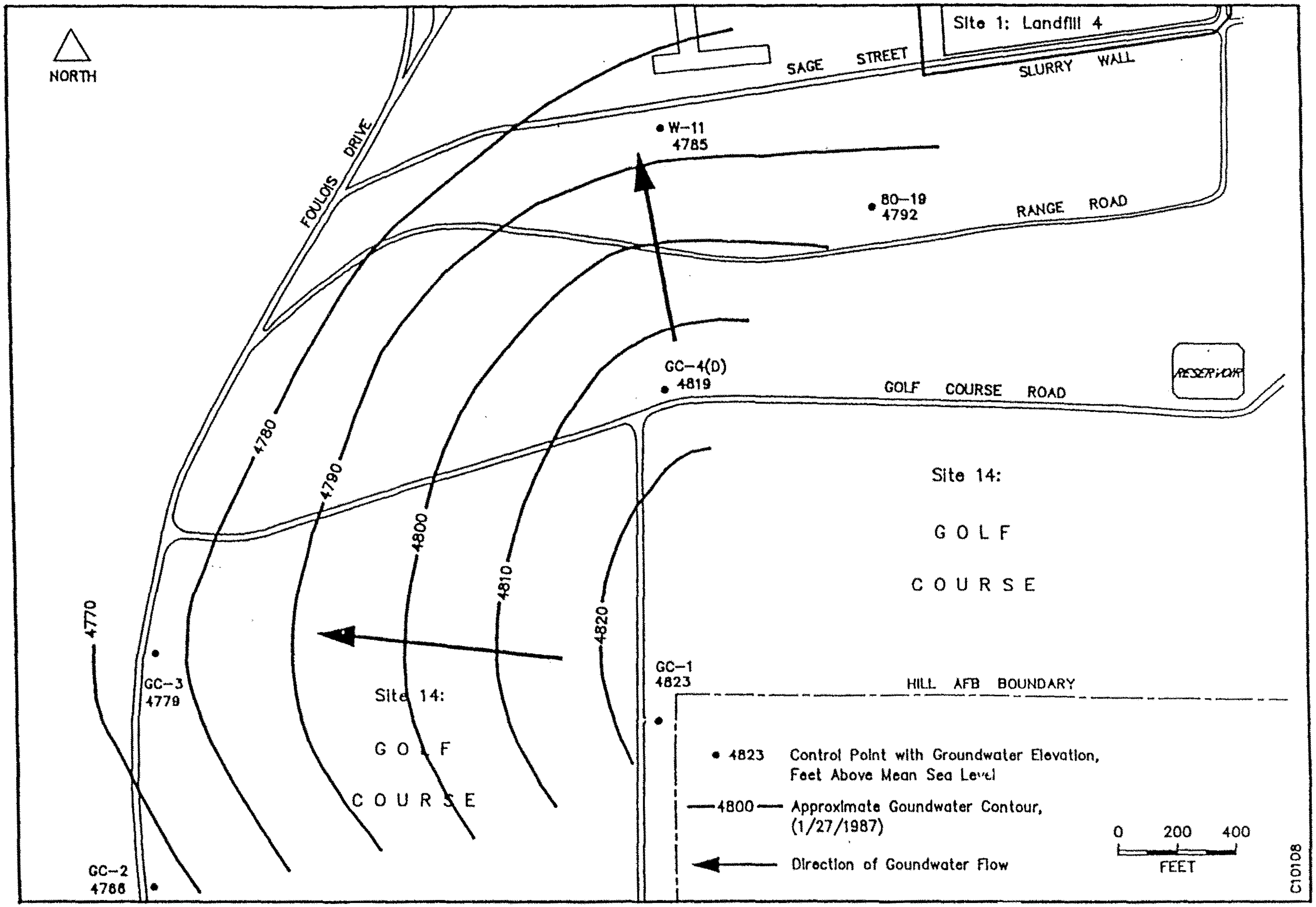


Figure 4.3.14-4. Water Level Contour Map During Period of No Irrigation Application, Site 14, Golf Course, Hill AFB, Utah

test well GC-1 which had about a ten-foot decline in the static water levels, while at GC-4 it was about a three-foot change. The contrast in water level changes between the wells again results from differing recharge characteristics throughout the golf course.

To determine the groundwater relationship between the golf course and the waste site areas, the static water levels were plotted for both areas. The results are shown on Plate 8. The results show the nature of the groundwater flow conditions between these areas. Again the static water level contours show groundwater underflow westward and northward from the golf course. These flows are similar to the previous two static water level figures discussed. This demonstrates that a hydrogeologic connection exists between these areas. A comparison of the water chemistry for the golf course and Berman Pond wells is presented on trilinear diagrams of common cations and anions in Figures 4.3.14-5 and 4.3.14-6. The plot of common cations and anions shows that Wells GC-1, 2, 3, W-11 and 80-19 all contain bicarbonate type water. The water from Wells BPM-2 and GC-4 are a chloride type water. This suggests that the chemistry of water from deep wells BPM-2 and GC-4 is different from the other, shallow wells.

The findings from the static water level analysis supports the water balance analysis previously discussed. The water balance results indicated that surplus precipitation and irrigation water is available for infiltration, and verified during the static water level analysis.

Groundwater Formation Characteristics

To determine the hydraulic characteristics of the sediments beneath the golf course, Radian conducted a slug test in test well GC-4. This well is screened in a confined zone of silty sand and clays representative of the shallow water bearing zones at the golf course. The slug test method generates estimates of the in situ hydraulic conductivity of the site. The estimated hydraulic conductivity values, although limited by the heterogeneity of

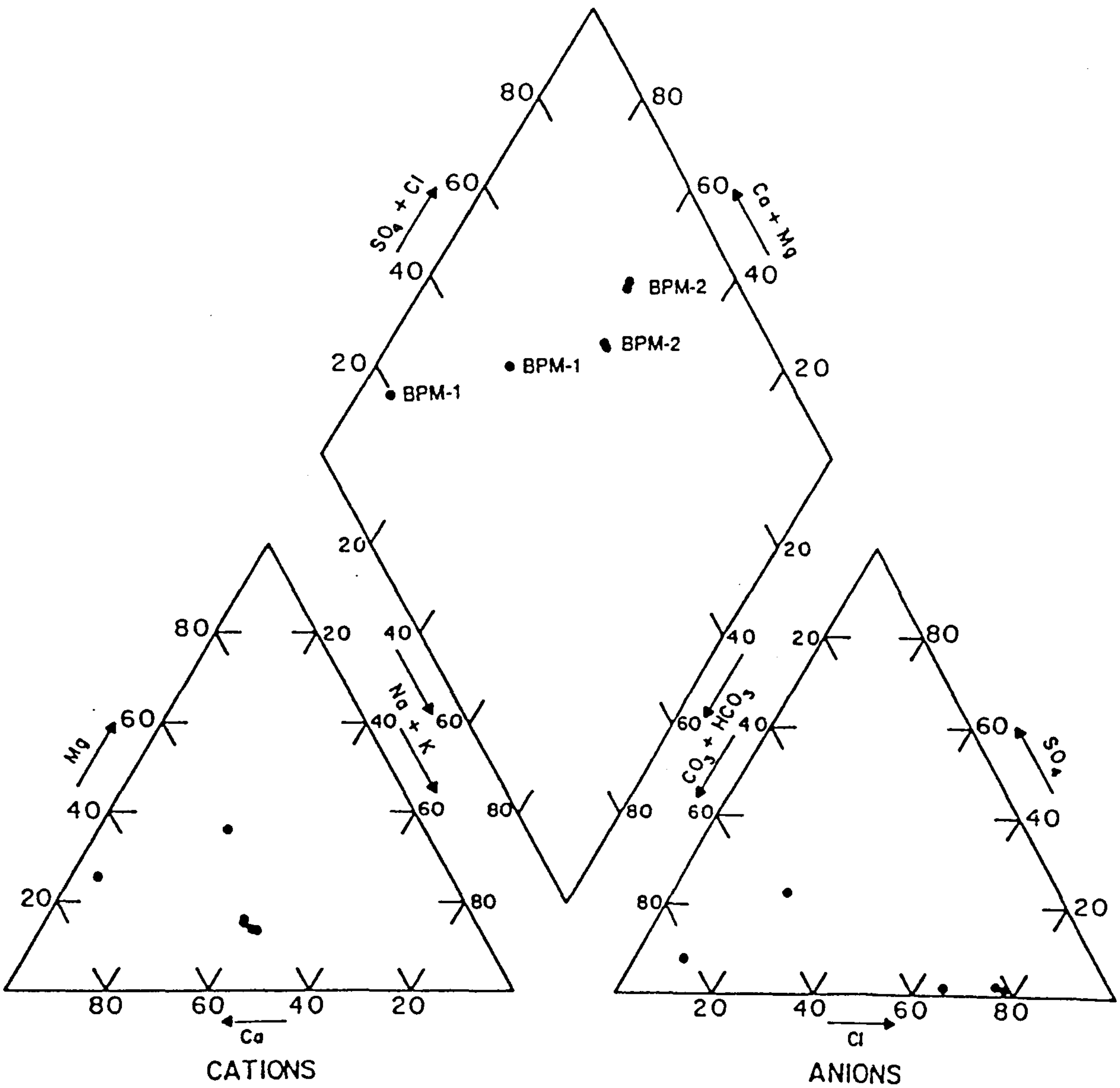


Figure 4.3.14-5. Trilinear Plot of Common Cations and Anions, Site 5, Berman Pond, Hill AFB, Utah

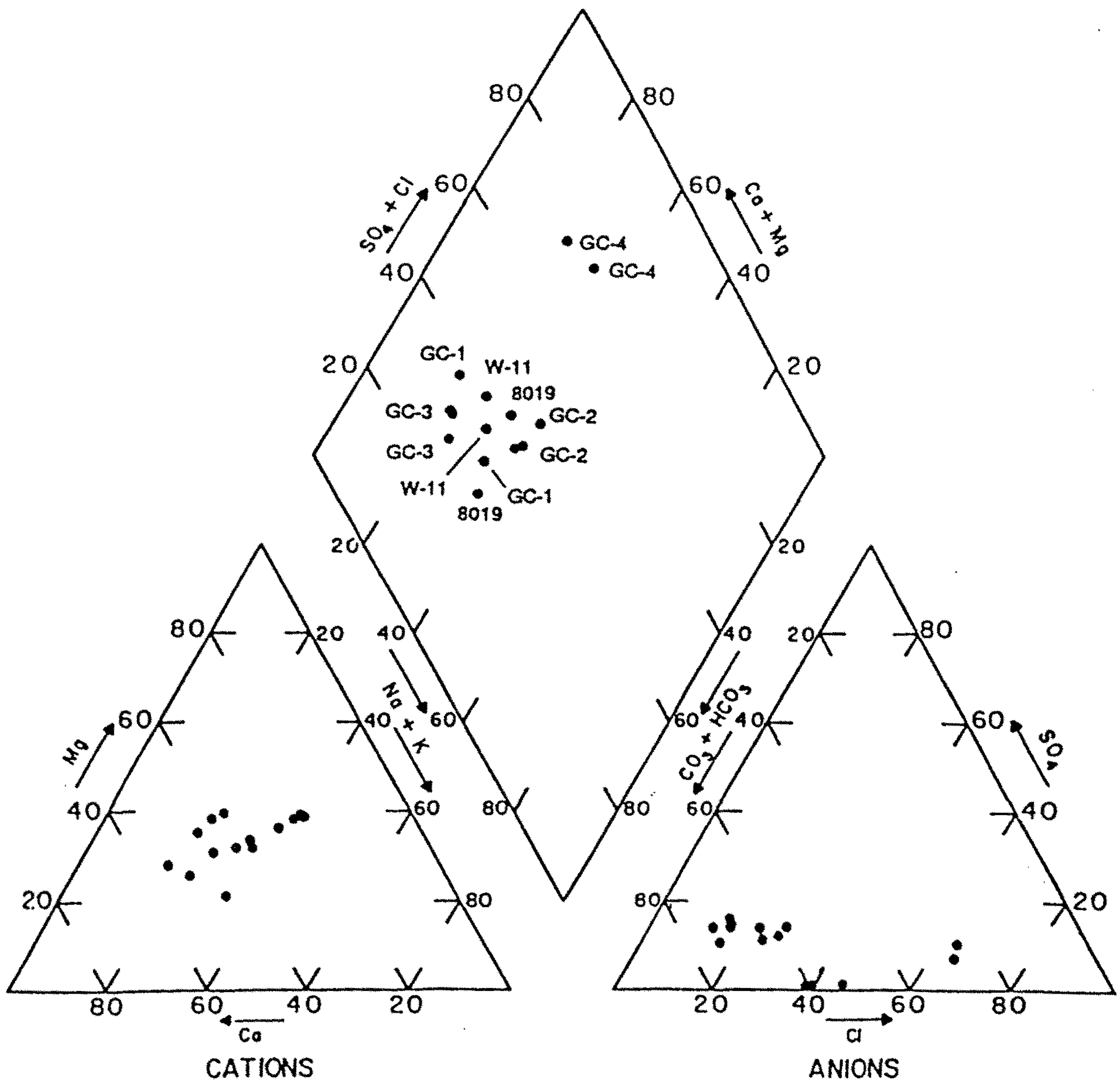


Figure 4.3.14-6. Trilinear Plot of Common Cations and Anions, Site 14, Golf Course, Hill AFB, Utah

the formation and a partially penetrating well, are representative of the expected range of permeability values for silty sands. The calculated hydraulic conductivity ranges from 0.31 to 0.54 gallons per day per square foot (gpd/ft^2). A calculated value for storativity of 0.005 suggests a confined aquifer and compares well with the confined nature of the saturated zone encountered during drilling and well installation. The calculated values for hydraulic conductivity and storativity are accurate within an order of magnitude and are useful as generalized indicators of the hydraulic nature of the golf course sediments. A complete discussion of slug test methodology and all field data and calculations are included in Appendix H.

4.3.14.1.5 Groundwater Quality

Two rounds of groundwater samples were collected from test wells GC-1, -2, -3, -4, 80-19, and W-11. Samples were analyzed for major anions and cations by EPA Methods 200.7, 310.1, and 300.0. Results of groundwater sample analyses are shown in Table 4.3.14-5. Complete analytical reports for these analyses appear in Appendix C.

To evaluate the degree of groundwater contamination, analytical results from IRP Phase II Stage 2 sampling were compared to federal standards and guidelines. Table 4.3.14-6 summarizes this comparison.

4.3.14.2 Significance of Findings

A discussion of the significance of the analytical results obtained for groundwater samples collected in the Phase II Stage 2 effort follows.

4.3.14.2.1 Significance of Inorganic Parameters in Groundwater

Analysis of groundwater samples from golf course wells revealed levels of iron exceeding federal MCLs at all site test wells. Concentrations

TABLE 4.3.14-5. RESULTS OF GROUNDWATER SAMPLE ANALYSES, SITE 14, GOLF COURSE, HILL AFB, UTAH

Analytical Parameter	Method Detection Limit	Monitor Well Sampling Round: GC-1 I	GC-1 II	GC-2 I	GC-2 I D	GC-2 II	GC-3 I	GC-3 II	GC-3 II D
Major Anions & Cations (mg/L)									
Sodium	0.08	130	120	130	130	210	59	58	62[a]
Calcium	0.06	340	110	71	63	55	81	110	100[a]
Bicarbonate	1	360	360	410	410	380	400	400	410
Magnesium	0.1	110	62	71	70	63	53	54	59[a]
Iron	0.03	470	90	17	12	7.3	9.5	10	16[a]
Fluoride	0.1	1.0	1.2	0.7	0.7	0.9	1.0	0.7	0.7
Chloride	1	72	46	150	160	190	41	54	56
Sulfate	1	64	69	5[b]	5[b]	8	62	65	68

Analytical Parameter	Method Detection Limit	GC-4 I	GC-4 II	GC 80-19 I	GC 80-19 II	W-11 I	W-11 II
Major Anions & Cations (mg/L)							
Sodium	0.08	64	170	180	100	85	89
Calcium	0.06	120	160	120	120	95	130
Bicarbonate	1	360	330	360	400	400	390
Magnesium	0.1	38	96	98	35	49	57
Iron	0.03	17	38	6.1	3.5	9.4	28
Fluoride	0.1	ND	1.4	1.0	0.8	1.0	0.8
Chloride	1	500	490	45	110	86	100
Sulfate	1	76	110	43	79	58	64

[a]Spike recovery not within acceptable limits. Indicates interference.
[b]Value less than 5 times detection limit.

I - Sampled 3 October 1986.

TABLE 4.3.14-6. PARAMETERS EXCEEDING WATER QUALITY CRITERIA, GROUNDWATER SAMPLING LOCATIONS, SITE 14, GOLF COURSE, HILL AFB, UTAH

		Sampling Location Sampling Round													
Parameter	Criteria	GC-1 I	GC-1 II	GC-2 I	GC-2 I D	GC-2 II	GC-3 I	GC-3 II	GC-3 II D	GC-4 I	GC-4 II	30-19 I	80-19 II	W-11 I	W-11 II
INORGANIC PARAMETERS															
Iron mg/L	0.3 mg/L	470	90	17	12	7.3	8.5	10	16[a]	17	38	6.1	3.5	9.4	28
Fluoride mg/L	b										1.4				
Chloride mg/L	250 mg/L									500	490				

[a]Spike recoevry not within acceptable limits. Indicates interferent.
bMCL ranges from 1.4 mg/L to 4.0 mg/L, depending on temprеature.

I = Sampled 3 October 1986.
II = Sampled 7 November 1986 - 10 November 1986.

of iron ranged from 7.3 mg/L at GC-2 (Round II) to 470 mg/L at GC-1 (Round I). Fluoride and chloride were detected equal to or in excess of federal criteria only at GC-4. These levels of inorganic parameters are within the normal ranges measured for groundwater at Hill AFB during previous investigations. The concentration levels for fluoride range from 0.7 mg/L in Well GC-2 to 1.4 mg/L at Well GC-4. The highest level for fluoride is equal to the MCL for fluoride. Chloride concentrations ranged from a low of 41 mg/L at Well GC-3 to a high of 500 mg/L at Well GC-4. The MCL of 250 mg/L was exceeded only at GC-4. The presence of these inorganic parameters may also represent the quality of the irrigation water used at the golf course.

4.3.15 Site 15: Refueling Area JP-4 Spill (Building 914) (SAIC)

In January 1985, a major JP-4 fuel spill resulted when an automatic fill system failed at a truck fill stand (Building 914). This resulted in approximately 27,000 gallons of JP-4 fuel being released on the unpaved area around the tanks. Clean-up effort resulted in the recovery of about 1000 gallons of fuel with the remaining portion infiltrating into the soil. An investigation conducted in December 1985, delineated the areas of soil having greater than and less than 1 percent fuel in the soil (RGB, 1985). This investigation only dealt with surface and soil contamination to a depth of approximately 40 feet below land surface. No information was obtained on the quality of the groundwater beneath the site.

The purpose of the Phase II Stage 2 investigation was to evaluate the current contaminant level in the soil and aquifer media and determine if contamination had reached the water table. Initial efforts included geophysical investigations, electromagnetic surveys (both vertical and horizontal dipole modes), seismic surveys, and a resistivity profile. Next, a soil vapor investigation was conducted. Samples were analyzed for methane, toluene, and total hydrocarbons. Using the information obtained from the geophysical and soil vapor investigation, three soil borings were located and drilled. Also, based on the two initial investigations and photoionization detection readings, soil samples were collected and analyzed for fuel hydrocarbons. One of the borings was completed as a monitoring well. Locations of the geophysical surveys, soil gas sampling points, soil borings, and monitoring well are shown in Figure 4.3.15-1.

4.3.15.1 Results of Investigation

Topography of the site is a reflection of the grading activities associated with the construction of the refueling station. The area is essentially flat with minor slopes constructed for drainage of surface water. The area is fenced and access is controlled. An asphalt loading/parking area is located just to the south of the spill area.

The seismic investigation indicated the water table to be approximately 43 feet below land surface (BLS) and dipping slightly to the southwest. A resistivity measurement at a single location, although showing some interference from cultural features, indicated the water table to be approximately 46 feet BLS. This showed good agreement with the seismic investigation. The electromagnetic (EM) readings obtained from the vertical dipole mode showed an area of zero conductivity. Since fuel, as a non-polar liquid, should show zero conductivity this may be attributed to the presence of high concentration of fuel in the soil at depth. The EM readings in the horizontal mode showed a relatively uniform geologic condition within the 25 feet of penetration. The detailed geophysical report is included in Appendix M.

The soil gas investigation consisted of eleven points (Figure 4.3.15-1). Of the eleven points, two were located within the area that has shown fuel content of greater than 1 percent by a previous investigation (RGB, 1985). Of the remaining 9 points, 6 were located in the area that the previous report had shown less than 1 percent fuel. The remaining 3 points were located outside the area that had been indicated to have been contaminated.

OU 1 GROUND-WATER ELEVATION SUMMARY APRIL 1993 THROUGH AUGUST 1994

Site ID	*Apr-93*	*May-93*	*Jun-93*	*Jul-93*	*Aug-93*	*Sep-93*	*Oct-93*	*Nov-93*	*Dec-93*
U1-4	4774.85	4775.69	4775.98	4775.77	4775.38	4774.97	4774.65	4774.17	4773.88
U1-6	4780.31	4780.42	4780.23	4779.90	4779.50	4779.20	4779.00	4778.75	4778.71
U1-8	4782.11	4782.20	4781.83	4781.43	4781.15	4780.87	4780.67	4780.46	4780.49
U1-21	4795.39	4795.06	4794.77	4794.41	4793.06	4793.87	4793.87	4794.04	4793.98
U1-23	4788.53	4788.35	4788.15	4787.21	4787.45	4787.20	4786.97	4786.80	4786.75
U1-25	4786.84	4786.86	4786.39	4785.80	4785.21	4784.77	4784.59	4784.84	4784.74
U1-27	4788.06	4787.87	4787.41	4786.66	4785.84	4785.23	4784.98	4785.22	4785.17
U1-30	4792.70	4792.48	4792.47	4792.15	4791.93	4791.88	4791.94	4792.65	4792.22
U1-33	4776.08	4775.30	4776.11	4775.83	4775.43	4777.53	4774.78	4774.55	4774.49
U1-41	4775.08	4776.11	4776.21	4775.77	4775.13	4774.30	4773.72	4773.06	4772.78
U1-42	4770.11	4770.99	4771.60	4771.68	4771.35	4771.06	4770.76	4770.41	4770.13
U1-43	4762.89	4763.28	4763.67	4763.85	4763.69	4763.55	4763.44	4763.28	4763.81
U1-45	4786.57	4786.68	4786.20	4785.63	4784.98	4784.55	4784.38	4784.63	4784.50
U1-46	4787.70	4787.61	4787.18	4786.55	4785.94	4785.53	4785.35	4785.82	4785.61
U1-49	4792.89	4792.50	4792.13	4791.63	4791.14	4790.84	4790.75	4791.29	4790.99
U1-51	4791.12	4790.94	4790.69	4790.35	4789.99	4789.74	4789.62	4789.83	4789.68
U1-52	4792.88	4792.58	4792.28	4792.01	4791.65	4791.51	4791.53	4791.57	4791.43
U1-53	4787.72	4787.54	4787.12	4786.37	4785.73	4785.13	4785.17	4784.87	4784.87
U1-54	4788.20	4787.98	4787.76	4787.48	4787.12	4786.82	4786.61	4786.47	4786.44
U1-55	4791.26	4790.89	4790.64	4790.23	4789.78	4789.60	4789.66	4789.70	4789.69
U1-56	4790.30	4789.93	4789.63	4789.23	4788.72	4788.51	4788.60	4788.63	4788.70
U1-57	4781.99	4781.89	4781.67	4781.35	4780.93	4780.66	4780.51	4780.30	4780.27
U1-58	4783.75	4783.66	4783.42	4783.14	4782.71	4782.47	4782.31	4782.19	4782.18
U1-59	4783.42	4782.90	4782.80	4782.27	4781.64	4781.37	4780.88	4780.94	4781.06
U1-60	4784.19	4783.72	4783.36	DRY	Dry	DRY	DRY	Dry	Dry
U1-61	4779.80	4779.73	4779.38	4779.08	4778.62	4778.39	4778.21	4778.06	4778.10
U1-62	4775.08	4775.47	4775.74	4775.63	4775.21	4774.57	4774.29	4773.88	4773.54
U1-63	4763.72	4764.10	4764.65	4764.85	4764.64	4764.49	4764.35	4763.95	4763.77
U1-64	4777.28	4777.01	4777.96	4777.40	4776.68	4775.85	4775.16	4774.38	4773.92
U1-65	4769.87	4771.54	4772.00	4771.74	4771.29	4770.71	4770.25	4769.62	4769.20
U1-66	4775.77	4776.62	4776.57	4776.20	4775.68	4775.09	4774.68	4774.20	4773.83
U1-67	4773.26	4773.74	4773.59	4773.43	4773.02	4772.71	4772.52	4772.05	4771.96
U1-68	4775.68	4776.56	4776.56	4776.27	4775.75	4775.21	4774.86	4774.41	4774.15
U1-69	4774.26	4774.15	4775.23	4775.01	4774.50	4773.96	4773.60	4773.28	4772.74
U1-70	4774.57	4775.46	4775.32	4775.07	4774.61	4774.11	4773.83	4773.35	4773.22
U1-71	4772.78	4773.05	4772.87	4773.08	4772.77	4772.45	4772.40	4771.82	4771.83
U1-72	4773.83	4774.54	4774.57	4774.40	4774.14	4773.83	4773.55	4773.18	4772.99
U1-73	4771.21	4772.64	4773.11	4773.11	4772.81	4772.40	4772.01	4771.55	4771.27
U1-74	4774.85	4774.62	4773.75	4774.54	4774.24	4773.87	4773.55	4773.23	4772.95
U1-75	4747.44	4746.82	4746.45	4745.81	4744.92	4744.56	4745.54	4745.86	4746.19
U1-76	4771.80	4771.83	4771.82	4771.81	4771.73	4771.73	4771.70	4771.68	Dry
U1-77	Dry	Dry	Dry	4771.79	Dry	DRY	DRY	Dry	Dry
U1-78	4736.44	4736.49	4736.80	4736.81	4736.44	4736.19	4735.96	4735.69	4735.53
U1-79	4716.45	4716.84	4715.47	4713.95	4712.79	4712.23	4712.73	4712.94	4712.81

OU 1 GROUND-WATER ELEVATION SUMMARY APRIL 1993 THROUGH AUGUST 1994

Site ID	*Apr-93*	*May-93*	*Jun-93*	*Jul-93*	*Aug-93*	*Sep-93*	*Oct-93*	*Nov-93*	*Dec-93*
U1-80	4784.56	4784.82	4784.35	4783.68	4782.99	4782.57	4782.28	4782.05	4782.02
U1-81	4780.41	4780.25	4780.17	4779.96	4779.73	4779.53	4779.34	4779.17	4779.13
U1-82	4746.50	4745.99	4745.71	4745.19	4744.39	4744.73	4745.40	4745.71	4745.67
U1-84	4728.38	4727.78	4727.40	4726.77	4726.03	4725.79	4725.90	4725.79	4725.98
U1-85	4764.41	4763.81	4763.63	4763.42	4762.22	4763.28	4763.86	4763.80	4763.58
U1-86	4735.59	4735.34	4735.04	4734.58	4734.02	4733.94	4734.43	4734.66	4734.82
U1-87	4746.39	4746.30	4746.24	4746.16	4746.01	4745.98	4746.00	4745.93	4746.00
U1-88	4762.87	4763.25	4763.23	4759.71	4762.73	4762.54	4762.57	4762.44	4762.19
U1-89	4769.58	4770.88	4771.41	4771.00	4770.70	4770.24	4769.82	4769.23	4768.87
U1-90	4484.55	4591.79	4485.13	4485.33	4485.67	4485.43	4484.84	4483.89	4483.56
U1-91	4680.27	4681.29	4681.44	4681.40	4681.32	4681.21	4681.22	4681.28	4681.09
U1-92	4770.04	4770.10	4770.08	4769.91	4769.76	4769.51	4769.51	4769.61	4769.22
U1-93	4786.95	Dry	Dry	DRY	Dry	DRY	DRY	Dry	4784.31
U1-94	4454.37	4454.59	4454.97	4455.67	4458.08	4462.88	4461.38	4459.87	4458.37
U1-95	4458.91	4458.71	4458.62	4466.88	4471.52	4471.20	4469.88	4467.79	4466.18
U1-96	4453.21	4453.52	4453.73	4453.92	4454.31	4454.22	4454.66	4453.30	4453.33
U1-97	4480.76	4480.67	4481.45	4481.70	4483.15	4482.19	4480.80	4479.76	4480.10
U1-98	4478.15	4477.46	4478.40	4478.29	4478.66	4478.31	4477.95	4476.91	4476.45
U1-99	4461.77	4461.88	4461.99	4462.07	4461.83	4461.57	4462.23	4462.04	4461.94
U1-100	4780.47	4780.36	4780.24	4780.08	4779.86	4779.77	4779.65	4779.50	4779.43
U1-101	4773.33	4773.20	4772.96	4772.65	4772.27	4771.92	4771.71	4771.41	4771.26
U1-102	4774.69	4774.10	4774.07	4774.04	4773.78	4773.54	4773.80	4773.49	4773.60
U1-103	4769.37	4768.13	4768.65	4768.50	4768.13	4767.79	4767.53	4767.13	4766.89
U1-104	4714.02	4713.56	4712.96	4712.66	4712.12	4712.05	4712.05	4711.96	4711.79
U1-105	4482.00	4480.75	4483.82	4483.64	4483.58	4483.64	4481.70	4480.34	4479.75
U1-106	4773.48	4773.80	4773.68	4773.40	4773.04	4772.67	4772.50	4772.21	4772.16
U1-107	4776.14	4776.35	4776.17	4775.89	4775.47	4775.17	4774.94	4774.69	4774.75
U1-108	4482.64	4481.84	4484.81	4485.12	4485.03	4483.54	4482.39	4481.26	4480.44
U1-109	4478.20	4478.02	4480.02	4480.22	4482.64	4481.04	4479.26	4478.41	4478.01
U1-110	4477.99	4477.90	4478.35	4479.06	4480.58	4479.82	4478.39	4477.02	4476.42
U1-111	4478.56	4478.47	4478.64	4479.44	4480.37	4479.73	4478.56	4477.28	4476.68
U1-112	4471.03	4470.96	4470.81	4471.00	4470.99	4470.98	4470.97	4470.50	4470.29
U1-113	4444.11	4444.17	4445.03	4445.70	4444.95	4444.79	4444.56	4443.41	4442.79
U1-114									4776.76
U1-115									4764.58
U1-116									4763.06
U1-117									4742.81
U1-118									
U1-119									4769.75
U1-120									4756.30
U1-121									4771.32
U1-122									4746.27
U1-123									4766.34
U1-124									4757.01
U1-125									4778.57

OU 1 GROUND-WATER ELEVATION SUMMARY APRIL 1993 THROUGH AUGUST 1994

Site ID	*Apr-93*	*May-93*	*Jun-93*	*Jul-93*	*Aug-93*	*Sep-93*	*Oct-93*	*Nov-93*	*Dec-93*
U1-126									
U1-127	4771.06	4770.76	4770.59	4770.62	4770.31	4770.22	4770.15	4770.03	4769.96
U1-128	4773.22	4773.50	4773.37	4773.51	4773.24	4772.98	4772.83	4772.31	4772.23
U1-129	4774.46	4775.21	4774.30	4775.01	4774.84	4774.46	4774.17	4773.72	4773.41
U1-130	4774.24	4775.16	4775.18	4774.97	4774.54	4773.91	4773.66	4773.30	4772.97
U1-131	4774.56	4775.15	4775.20	4774.98	4774.59	4773.96	4773.69	4773.25	4772.94
U1-132	4775.07	4775.94	4775.72	4775.27	4774.87	4774.38	4774.16	4773.74	4773.55
U1-133	4774.83	4775.53	4775.45	4775.13	4774.56	4774.06	4773.63	4773.28	4772.90
U1-134	4775.06	4775.85	4775.63	4775.21	4774.79	4774.28	4774.22	4773.83	4773.70
U1-644									4770.20
U1-645									4767.97
U1-646									Not Measured
U1-647									4747.83
U1-648									4767.94
U1-649									4770.04
U1-135									
U1-136									
U1-137									
U1-145									
U1-146									
U1-147									
U1-148									
U1-149									
U1-150									

OU 1 GROUND-WATER ELEVATION SUMMARY APRIL 1993 THROUGH AUGUST 1994

Site ID	*Jan-94*	*Feb-94*	*Mar-94*	*Apr-94*	*May-94*	*Jun-94*	*Jul-94*	*Aug-94*
U1-4	4773.33	4773.20	4773.22	4773.41	4773.56	4773.76	4773.61	4800.67
U1-6	4778.52	4778.64	4778.84	4778.95	4778.99	4778.92	4778.74	4802.26
U1-8	4780.30	4780.32	4780.47	4780.60	4780.73	4780.65	4780.50	4801.45
U1-21	4793.94	4794.07	4794.43	4794.44	4793.00	4792.85	4792.73	4810.89
U1-23	4786.55	4786.73	4786.72	4786.86	4786.92	4786.85	4786.68	4812.46
U1-25	4784.48	4784.90	4785.03	4785.19	4785.05	4784.78	4783.54	4802.24
U1-27	4784.81	4785.18	4785.49	4785.74	4806.21	4785.25	4785.00	4803.16
U1-30	4792.05	4792.25	4792.35	4792.28	4790.35	4790.20	4790.76	4806.67
U1-33	4774.28	4774.25	4774.37	4774.43	4774.48	4774.36	4774.30	4802.63
U1-41	4772.43	4772.22	4772.22	4772.44	4772.67	4772.78	4772.58	4797.18
U1-42	4769.72	4769.59	4769.39	4769.25	4769.14	4769.05	4768.98	4798.61
U1-43	4763.47	4763.49	4763.36	4763.21	4762.88	4762.70	4762.58	4797.51
U1-45	4784.16	4784.29	4784.55	4784.67	4784.60	4784.39	4784.24	4802.80
U1-46	4785.27	4787.03	4787.48	4787.55	4787.47	4787.56	4787.03	4802.80
U1-49	4790.84	4790.97	4791.51	4791.62	4791.36	4791.09	4790.02	4808.92
U1-51	4789.51	4789.57	4789.85	4789.96	4789.83	4789.68	4789.58	4809.39
U1-52	4791.57	4791.69	4791.98	4791.97	4791.77	4791.54	4791.37	4809.63
U1-53	4784.68	4784.99	4785.57	4785.79	4785.45	4785.12	4784.86	4805.23
U1-54	4786.22	4786.19	4786.25	4786.45	4786.53	4786.52	4786.41	4805.19
U1-55	4789.61	4789.77	4790.11	4790.05	4789.91	4789.60	4788.37	4810.36
U1-56	4788.73	4788.90	4789.25	4789.20	4788.88	4788.45	4788.23	4810.78
U1-57	4780.11	4780.16	4780.24	4780.34	4780.33	4780.22	4780.11	4805.80
U1-58	4782.01	4782.08	4782.17	4782.26	4782.23	4782.10	4781.98	4807.87
U1-59	4780.99	4781.12	4781.40	4781.46	4781.29	4781.04	4780.85	4807.24
U1-60	Dry	Dry	Dry	Silted In	Dry	Silted In	4808.85	4807.20
U1-61	4777.95	4778.08	4778.24	4778.34	4778.23	4778.07	4777.95	4804.25
U1-62	4773.12	4773.04	4772.93	4772.99	4773.00	4773.05	4772.96	4797.78
U1-63	4763.34	4763.41	4763.29	4763.15	4762.85	4762.52	4762.35	4794.20
U1-64	4773.51	4773.36	4773.48	4773.94	4774.18	4774.20	4773.75	4798.40
U1-65	4768.74	4768.47	4768.39	4768.31	4768.22	4768.24	4768.19	4795.94
U1-66	4773.38	4773.33	4773.91	4774.29	4774.39	4774.40	4773.82	4800.82
U1-67	4771.81	4771.94	4771.82	4772.09	4772.13	4772.09	4771.67	4794.16
U1-68	4773.85	4773.70	4773.97	4774.23	4774.36	4774.42	4774.07	4800.58
U1-69	4772.33	4772.10	4772.12	4772.50	4772.69	4772.85	4772.52	4799.84
U1-70	4773.02	4773.17	4773.21	4773.44	4773.45	4773.46	4772.37	4793.97
U1-71	4771.71	4772.03	Dry	Dry	4771.59	4771.47	4771.31	4791.94
U1-72	4772.85	4772.78	4772.81	4772.93	4773.03	4773.06	4772.95	4795.80
U1-73	4770.80	4770.64	4770.39	4770.25	4770.04	4769.90	4769.83	4799.23
U1-74	4772.65	4772.47	4772.39	4772.50	4772.70	4772.81	4772.66	4799.55
U1-75	4746.25	4746.47	4746.84	4746.75	4745.78	4744.73	4743.69	4778.70
U1-76	Dry	Dry	Dry	Dry	Dry	Dry	Dry	4794.70
U1-77	Dry	Dry	Dry	Dry	Dry	Dry	Dry	4795.53
U1-78	4735.31	4735.35	4735.79	4735.88	4736.61	4733.53	4733.23	4759.06
U1-79	4712.39	4712.78	4713.46	4713.71	4712.80	4711.10	Wasp Nest	4726.05

OU 1 GROUND-WATER ELEVATION SUMMARY APRIL 1993 THROUGH AUGUST 1994

Site ID	*Jan-94*	*Feb-94*	*Mar-94*	*Apr-94*	*May-94*	*Jun-94*	*Jul-94*	*Aug-94*
U1-80	Dry	4781.84	4781.81	4781.85	4781.93	4782.18	4781.91	4801.10
U1-81	4778.93	4778.94	4778.88	4778.90	4778.94	4778.98	4778.98	4801.73
U1-82	4745.75	4745.98	4746.30	4746.21	4745.58	4744.48	4743.62	4779.23
U1-84	4725.89	4726.01	4727.19	4727.59	4726.63	4725.71	4725.00	4742.09
U1-85	4763.51	4763.61	4764.59	4764.37	4763.64	4761.26	4758.94	4776.71
U1-86	4734.79	4734.93	4735.17	4734.32	4734.64	4731.89	4733.03	4757.76
U1-87	4746.00	4746.18	4746.41	4746.31	4746.14	4746.11	4745.96	4780.28
U1-88	4762.28	4762.45	4762.47	4762.52	4762.39	4762.20	4762.15	4800.04
U1-89	4768.37	4768.27	4768.10	4768.02	4768.08	4768.13	4768.11	4794.03
U1-90	4483.15	4483.13	4483.40	4483.40	4484.22	4486.32	4486.67	4589.89
U1-91	4681.38	4681.60	4681.56	4682.14	4681.99	4681.96	4681.81	4735.94
U1-92	4769.11	4769.25	4769.79	4769.71	4769.34	4769.01	4768.09	4780.81
U1-93	4783.59	4783.73	4784.21	4784.24	4783.87	4783.49	4783.22	4810.78
U1-94	4457.57	4456.24	4455.53	4455.20	4454.42	4454.39	4454.89	4511.70
U1-95	4464.12	4462.76	4461.26	4461.14	4458.71	4459.16	4460.80	4499.13
U1-96	4453.28	4453.19	4453.20	4453.30	4453.22	4453.44	4453.84	4493.49
U1-97	Dry	Dry	Dry	4480.09	4481.11	4483.45	4483.95	4493.37
U1-98	4476.26	4477.76	4477.61	4477.09	4478.30	4479.98	4479.23	4482.29
U1-99	4461.82	4463.06	4462.15	4461.62	4461.52	4461.82	4461.73	4467.84
U1-100	4779.25	4779.25	4779.39	4779.51	4779.54	4779.51	4779.41	4803.45
U1-101	4771.17	4771.34	4771.44	4771.54	4771.43	4771.25	4771.08	4798.95
U1-102	4773.91	4773.98	4774.42	4774.14	4773.67	4773.81	4773.64	4779.04
U1-103	4766.43	4766.23	4766.12	4766.16	4766.18	4766.22	4766.20	4793.18
U1-104	4711.51	4711.45	4711.76	4711.81	4711.60	4711.35	4710.20	4731.71
U1-105	4479.47	4480.48	4480.93	4480.39	4483.19	4486.66	4484.52	4508.63
U1-106	4771.98	4772.14	4771.93	4772.31	4772.25	4772.18	4772.05	4791.66
U1-107	4774.43	4774.41	4774.48	4774.59	4774.60	4774.51	4774.40	4804.01
U1-108	4480.34	4481.12	4481.54	4481.17	4484.11	4487.55	4485.59	4498.42
U1-109	4477.76	4478.11	4475.20	4474.27	4474.02	4479.50	4482.31	4493.45
U1-110	4476.09	4476.68	4477.07	4476.98	4477.23	4479.72	4480.41	4490.82
U1-111	4476.36	4477.10	4477.73	4477.63	4476.77	4479.25	4479.63	4485.75
U1-112	4470.18	4471.34	4470.95	4470.53	4470.70	4471.40	4471.36	4476.39
U1-113	4442.45	4443.04	4443.21	4443.17	4443.48	4444.10	4444.60	4476.39
U1-114	4776.52	4776.53	4776.81	4776.96	4777.04	4776.81	4776.67	4794.99
U1-115	4764.01	4763.81	4763.54	4763.47	4763.55	4763.64	4763.65	4789.46
U1-116	4762.77	4762.69	4762.35	4762.20	4762.19	4762.33	4762.28	4787.00
U1-117	4743.30	4742.88	4742.69	4743.57	4743.45	4743.20	4742.96	4784.47
U1-118				0.00	0.00	Not Installed	Not Installed	0.00
U1-119	4770.19	4770.24	4770.52	4770.45	4770.13	4770.00	4769.62	4804.90
U1-120	4756.00	4757.03	4757.31	4757.29	4756.95	4756.33	4755.53	4804.71
U1-121	4771.03	4771.11	4771.25	4771.34	4771.31	4771.13	4770.96	4803.01
U1-122	4746.69	4747.33	4747.50	4747.37	4746.92	4746.29	4745.31	4803.03
U1-123	4766.71	4766.87	4767.01	4766.83	4766.54	4766.25	4766.08	4788.65
U1-124	4757.48	4757.58	4758.09	4757.70	4757.62	4755.57	4754.42	4777.39
U1-125	4778.35	4778.54	4778.89	4778.84	4778.40	4777.95	4777.60	4804.31

OU 1 GROUND-WATER ELEVATION SUMMARY APRIL 1993 THROUGH AUGUST 1994

Site ID	*Jan-94*	*Feb-94*	*Mar-94*	*Apr-94*	*May-94*	*Jun-94*	*Jul-94*	*Aug-94*
U1-126				0.00	0.00	Not Installed	Not Installed	0.00
U1-127	4769.87	4769.88	4769.92	4769.01	4770.00	4769.98	4769.96	4781.71
U1-128	4772.07	4772.47	4772.24	4772.35	4772.39	4772.31	4771.92	4793.01
U1-129	4773.25	4772.99	4772.90	4773.32	4773.41	4773.56	4773.36	4796.66
U1-130	4772.62	4772.50	4772.55	4772.85	4773.06	4773.14	4772.81	4799.69
U1-131	4772.56	4772.39	4772.36	4772.59	4801.93	Destroyed	Destroyed	4799.98
U1-132	4773.33	4773.34	4773.48	4773.85	4773.93	4773.93	4773.66	4797.50
U1-133	4772.78	4772.83	4773.12	4773.36	4773.36	4773.22	4772.73	4795.19
U1-134	4773.36	4773.37	4773.50	4773.77	4773.82	4773.85	4773.57	4797.50
U1-644	4769.63	4769.36	4769.15	4769.25	4769.50	4769.57	4769.52	4794.40
U1-645	4767.52	4767.32	4767.07	4767.07	4767.23	4767.30	4767.29	4790.36
U1-646	4767.40	4767.14	4766.80	4766.65	4766.67	4766.78	4766.78	4789.31
U1-647	4747.46	4747.12	4747.54	4747.71	4747.51	4747.36	4747.24	4785.24
U1-648	4767.52	4767.32	4767.09	4767.01	4767.07	4767.12	4767.13	4793.80
U1-649	4769.53	4769.33	4769.10	4769.15	4769.33	4769.46	4769.40	4794.44
U1-135								
U1-136								
U1-137								
U1-145								
U1-146								
U1-147								
U1-148								
U1-149								
U1-150								

Attachment D

Miscellaneous Communications by HAFB and the Davis-Weber Canal Company

and

Other Data and Previous Calculations Related to Groundwater Movement and Irrigation of the HAFB Golf Course in OU 1

May 31, 1994

To: Bob Van Orman

From: Dan Adkins

Summary of Rough Calculations of the Additional Affect HAFB has on Slope Above Canal.

Golf Coarse

Accounting for soil field capacity, precipitation, and evapotransporation over the golf coarse, 9.52 inches of excess water is added over the 180 day growing season.

The rise in water table was looked at, which in turn could cause additional head, in turn higher pore pressure, lower friction angle and lower shear in the slope's soil.

Assuming all golf coarse flow goes towards the slope (which it does not). Assuming uniform inflow over time 9.52"/180 days = .053"/day = .0044'/day. Assuming area of min slope is point of slowest flow rate and hence if any rise occurs it is here (worse case).

The ability of the soil to transport water is much greater than the additional recharge from irrigation. Therefore it is conservative to assume under a continuous steady state condition of recharge that max increase in water table is equal to input depth.

Therefore NO SIGNIFICANT IMPACT ON SLOPE.

Additionally it should be noted that Kevin Bourne is currently budgeting for a project to completely capture flow from the OU1 area and pump it to the IWTP. This is expected in 1995. Currently 15 million gallons are removed from OU1 and pumped to the IWTP.

OU2 & OU4

No major facilities and no on base irrigation occurs near these areas, additionally data for evaporation is nearly twice the rate of annual rain fall. Therefore activities of HAFB have no additional impact upon the slope.

Additionally horizontal wells have locally lowered the water table at OU4 by upto 15', Ref. Shane Hirchi.

The canal was constructed along a slope which is in an active landslide complex. As mentioned by CH2M-Hill's report "Active Landslide Above Davis-Weber Canal", December 1993, the canal likely contributes to the stability problems of the area as the slope was undercut by the considerable excavation required to construct the canal. As indicate in the January 1989, Air Base Commander Col. McCoin's response to Congressional Inquiry - Floyd Baham, Davis and Weber Counties Canal Company, and addressed to the IG the canal intercepts natural drainage channels rendering them useless as discharge points for storm runoff. This blockage of natural drainage probably adds to the problems.

<u>Golf Coarse Calculations</u>

Ref: Base CE

The base uses 476 ac-ft of water on the 156 acre golf course which equals 3.05 ft. of water applied.

Ref: "Golf Course Water Use Study Utah Dept. Natural Resources"

3.05 is within normal range for golf coarses in Utah.

Ref: "USU Irrigation Engineering Extension Service"

Etr seasonal for Kaysville = 32.5" for Alfalfa
Eto = 1.2 Etr for clipped grass
Evapotranspiration for clipped grass is 27.08 in.

3.05' (12") - 27.08" = 9.52 inches of excess water above ET is applied over entire season to golf course, i.e., which might infiltrate.

Ref: "Hill AFB OU6 RI Report May 1994"

Annual precipitation averaged over 1982-1993 is 25.3 in.
Seasonal precipitation averaged over 1982-1993 is 10.75"

Ref: Hargreaves unpublished book, & Book Irrigation Principals and Practices, & California Dept. of Water Resources, & Utah Dept. of Water Resources.

Defining field capacity as the amount of water the soil will hold against the force of gravity and using one of the more shallow depths to water table on the golf course.

For a moderately coarse sandy loam Avg. FC = 23%

Ref: Montgomery Watson Well Data.

GC-2M depth to water table 22.7 ft. Elev. 4753 Elev. (South Well) GC-3F 13.5 ft. Elev. (North Well). <u>Note:</u> Well data indicates flow in southern direction away from OU1.

Using shallower depth to water table (conservative)

13.5' soil (.23) = 3.11' = 37.26" of water stored in vadose zone.
37.26" is greater than 25.3" of annual precipitation

Therefore for worse case assume precipitation equilibrates field capacity.

Therefore maximum amount of irrigation water reaching water table is 9.52" over entire season. This confirms the modeling done in 1989 by Montgomery-Watson which indicates 8.5 in. are added by irrigation. Additionally, well data and A&E modeling indicates much of the shallow aquifer flows south west away from the golf course. However assuming all flow is northward.

Irrigation season April 15 to Oct 15, approx. 180 days and application is uniform over entire season .053 in/day per unit area is added to golf course. Horizontal hydraulic conductivity geometric average is 3 fpd. Assuming min. slope is where slowest flow rate will occur and therefore mounding if any. i = .051. Q = KiA = K(hl/L)A   A=1

Therefore ability of aquifer to allow outflow is much greater than additional inflow due to irrigation and it is conservative to assume continuous steady state condition will result in a maximum increase in water table equal to inflow depth. Therefore .053 in increase in water table, if one assumes a wall of water all at once then 9.52 in. There is probably no significant impact on hydraulic head and therefore pore pressure on the slope due to irrigation at the golf course, i.e., slope stability

In addition to this the OU1 drainage system currently removes 15 million gallons annually from the shallow aquifer. Kevin Borne indicates that he is budgeting for a 1995 project which should completely capture shallow ground water flow in OU1. If golf coarse irrigation is a problem to the canal it should be taken care of by this project. Additionally, average precipitation is nearly half the rate of evaporation in the area and there should not be a problem in the OU2 & OU4 area due to this.

Slope stability problems under OU2 and OU4, the canal company indicates that infiltration due to the base construction has changed storm runoff and infiltration is the problem. The rate of precipitation is approximate 50% the rate of evaporation.

However, it should be noted that much of the recharge to the aquifer results from the mountains East of Hill acting as a groundwater recharge basin, Ref. OU5 RI Feb. 1994.

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS OGDEN AIR LOGISTICS CENTER (AFMC)
HILL AIR FORCE BASE, UTAH

August 8, 1994

OO-ALC/EM
7276 Wardleigh Road
Hill AFB, UT 84056

Mr. Floyd Baham
Davis and Weber Counties Canal Company
138 West 1300 North
Sunset, UT 84015

Dear Mr. Baham:

I would like to provide to you an update of the Environmental Management Hill AFB's (EM) evaluation of the impact base activities may have upon the Davis-Weber Canal. EM engineers have conducted an initial records search which includes; State of Utah Department of Natural Resources studies, Weber Basin Conservancy District records and our own records. Although our engineers' calculations indicate that it is unlikely that the base has an impact upon the canal, EM has contracted with Dr. Gary Merkley and the Irrigation Engineering Department at Utah State University to evaluate the problem.

Dr. Merkley's experience includes canal/irrigation studies and designs for projects in the US as well as Egypt, Thailand, India and South America. Dr. Merkley will be evaluating the impact that irrigation of Hill AFB has upon the canal, as well as modeling the amount of flooding which would occur if the canal is breached. This study should be complete within the next few months.

As per your request, I have attached a copy of metered water use and disposal for Hill AFB. Your patience in this matter is appreciated. If additional information is required or if we can be further help to you, please feel free to contact myself or Dr. Dan Adkins at 777-8790.

Sincerely

James R. VanOrman

JAMES R. VAN ORMAN
Director Environmental Management

Attachment:
1. Water Use HAFB

HAFB Water Use Information for Canal Company

WATER USE AT HILL AIR FORCE BASE

CALENDER YEAR - 91

PURCHASED: (Weber Basin)	329,666 K GALS*
PRODUCED: (Base Water Wells)	776,779 K GALS
TOTAL	1,106,745 K GALS
Metered Industrial & Sanitary Sewer	667,218 K GALS

CALENDER YEAR - 92

PURCHASED: (Weber Basin)	379,805 K GALS*
PRODUCED: (Base Water Wells)	845,735 K GALS
TOTAL	1,225,540 K GALS
Metered Industrial & Sanitary Sewer	494,290 K GALS

CALENDER YEAR - 93

PURCHASED: (Weber Basin)	313,998 K GALS* 964 acre-ft
PRODUCED: (Base Water Wells)	799,794 K GALS
TOTAL	1,113,792 K GALS
Metered Industrial & Sanitary Sewer	429,975 K GALS

Weber Basin contract w/HAFB 1012 AF M+I

*It should be noted that Hill AFB purchases considerably more water than it actually uses. From conversations with Weber-Basin Conservancy District for 1993 HAFB purchased 640 Ac-ft of irrigation water for the golf coarse, however the actual use metered by Weber-Basin was 365 Ac-ft. For irrigation for the rest of the base 139 Ac-ft was purchased while 117 Ac-ft were used.

$$\frac{(1 \text{ acre-ft})(43{,}560 \text{ ft}^2/\text{acre})}{(0.1337 \text{ ft}^3/\text{gal})} = 325{,}804 \text{ gal/acre-ft}$$

Ow 14

12 DEC 88

~~EHR~~ EaP
Paul B — Can you keep up on this issue. Plan on attending the next meeting

WEBER DAVIS CANAL

AT 1330 THIS DATE, A MEETING WAS HELD IN THE OFFICES OF THE WEBER DAVIS CANAL COMPANY TO DISCUSS PROBLEMS THAT HAVE PLAGUED THE COMPANY DURING THE RECENT PAST. IN ATTENDANCE WERE MEMBERS OF THE FOLLOWING ORGANIZATIONS:

CLEARFIELD HILLS APPTS.
UTAH DEPARTMENT OF TRANSPORTATION
UTAH ATTORNEY GENERAL'S OFFICE
WEBER, DAVIS CANAL EMPLOYEES
WEBER, DAVIS CANAL ATTORNEY
WEBER, DAVIS CANAL BOARD OF DIRECTORS
USAF DEE
USAF DEM

THE FOLLOWING PROBLEMS WERE ADDRESSED:

1. PEOPLE LIVING IN CLEARFIELD JUST WEST OF THE WEST GATE OF HILL AFB, HAVE BEEN EXPERIENCING FLOODING PROBLEMS IN THEIR HOMES.

2. THE CANAL COMPANY IS EXPERIENCING INFUSION OF STORM RUNOFF LONG AFTER THEIR WATER SUPPLY HAS BEEN TERMINATED, WHICH HAS BEEN FREEZING AND SUBSEQUENTLY CAUSING DAMAGE TO THE CONCRETE LINING OF THE CANAL.

3. THE STATE ENGINEER IS DEMANDING THE CANAL BE REPAIRED BEFORE ANY MORE IRRIGATION WATER IS ALLOWED IN.

4. REPAIRS CANNOT BE IMPLEMENTED WHILE CANAL HAS STANDING WATER IN IT OR, WHERE NOT CONCRETE LINED, THE SURFACE HAS DRIED SUFFICIENTLY TO ALLOW CONSTRUCTION EQUIPMENT.

5. CANAL COMPANY DOES NOT FEEL THEY SHOULD BEAR THE ENTIRE COST OF CONTINUAL REPAIRS WHILE THE DAMAGE IS BEING GENERATED BY INTRODUCTION OF UNAUTHORIZED STORM RUNOFF (i.e. HAFB IS REQUIRED BY PERMIT TO NOTIFY THE CANAL COMPANY BEFORE ANY STORM RUNOFF IS DISCHARGED INTO THE CANAL, APPARENTLY FAILING TO DO SO).

6. LAWSUITS AGAINST THE COMPANY FOR PROPERTY DAMAGE INCURRED DUE TO FLOODING IN THE CLEARFIELD AREA.

7. DIFFICULTY COMMUNICATING WITH BASE PERSONNEL REGARDING POND #4 AND BROKEN HEAD GATE (THE MANAGER OF THE COMPANY CONTENDS HE CALLED HAFB AND NOTIFIED THE PERSON RECEIVING THE CALL HAFB COULD NO LONGER RELEASE WATER FROM THIS POND HOWEVER CONTINUED TO DO SO).

8. POND #4... THE WEBER DAVIS CANAL COMPANY, HAVING CLAIMED NO COOPERATION FROM HAFB, ATTEMPTED TO CLOSE THE GATE ON POND #4 BUT WERE UNABLE ACCOMPLISH, IN ADDITION, THEY TOOK SAMLES OF WATER

FOUND IN THE POND AFTER NOTICING AN UNUSUAL COLOR AND SMELL, LAB ANALYSIS DISCLOSED CONCENTRATIONS OF 2-4-D, NOTHING POTENTIALLY HAZARDOUS. CANAL COMPANY DISPLEASED ABOUT MALFUNCTIONING HEAD GATE AND FAILURE OF HAFB TO NOTIFY.

9. CANAL COMPANY SEEKING TO PREVENT UNAUTHORIZED INTRODUCTION OF STORM RUNOFF INTO THEIR CANAL SYSTEM TO FACILITATE REPAIRS AND PREVENT FUTURE DAMAGE.

HAFB:

1. BAMBERGER POND DRAINS INTO UDOT STORM DRAINAGE LINE UNDER INTERSTATE 15 THAT USED TO OUTFALL ON UDOT PROPERTY IN THE VICINITY OF WHAT IS NOW THE CLEARFIELD HILLS APPARTMENTS. SOMEONE HAS DIVERTED THE UDOT LINE INTO THE WEBER DAVIS CANAL IMMEDIATELY ABOVE THE AREA EXPERIENCING FLOODING PROBLEMS WHICH ULTIMATELY HAS DRAWN ATTENTION TO HAFB. THE OUTFALL FROM BAMBERGER POND EVIDENTLY CANNOT BE COMPLETELY STOPPED AS THE GATE IS SHUT AND LOCKED WHILE OUTFALL CONTINUES.

2. POND #4 OUTFALL CANNOT BE STOPPED MECHANICALLY DUE TO A FAULTY HEAD GATE.

3. THE CANAL COMPANY CLAIMS "NO" PERMISSION, FOR LINE FROM THE FIRE TRAINING PIT AREA INTO THE CANAL.

4. WITHIN THE WEEK, THE CANAL COMPANY IS GOING TO OBTAIN AN ESTIMATE FOR CONDUCTING AN ENGINEERING ANALYSIS OF THE PROBLEMS IN AND AROUND THE CLEARFIELD HILLS APPARTMENTS. ONCE THE ESTIMATE HAS BEEN RECEIVED, THE COMPANY WILL SEND LETTERS TO U.D.O.T., CLEARFIELD HILLS, CLEARFIELD CITY, AND H.A.F.B., REQUESTING EACH BEAR A PORTION OF THE COST.

SUMMARY:

A. HILL HAS ATLEAST 4, MAYBE 5, STORM SEWER OUTFALL LINES DUMPING INTO THE IRRIGATION CANAL:

1. POND #4 (D&E HOUSING)
2. POND #7? (BAMBERGER)
3. 1100 & 1200 ZONES... THIS AREA DOES NOT DRAIN TO A RETENTION POND.
4. FIRE TRAINING FACILITY
5. TOOELE... WE'RE NOT ABSOLUTELY CERTAIN WHERE THIS STORM RUNOFF OUTFALLS.

THE LONG RANGE GOAL OF THE DAVIS - WEBER CANAL COMPANY IS TO HAVE ALL OUTSIDE INFUSION OF STORM RUNOFF TERMINATED WITHIN A REASONABLE PERIOD OF TIME. THE EXAMPLE THROWN OUT WAS FIVE YEARS, HOWEVER THEY MADE IT VERY CLEAR THEY WERE WILLING TO WORK WITH EACH ENTITY ON AN INDEPENDENT BASIS TO ACCOMPLISH THE GOAL.

NEXT MEETING SCHEDULED FOR 0900 HRS 27 DEC 88

file
18R
MW

24 JAN 89

DAVIS AND WEBER CANAL COMPANY
OVERVIEW OF COMMUNICATONS

UDOT-

1. FLATLY REFUSED THE CANAL COMPANYS PROPOSAL.

2. UDOT LINES FROM SUNSET THRU CLEARFIELD CONNECTED TO HILL DISCHARGE LINES. ALL BUT THE DISCHARGE FROM POND #4 HAS LATERALS CONNECTED FROM UDOT.

3. STATE ATTORNEY GENERALS OFFICE ISSUED RULING AND IS PREPARED TO DEFEND THE STATES RIGHT TO DISCHARGE INTO THE CANAL.

4. UDOT IS PREPARED TO ASSIST HILL IN THE DISPUTE.

5. THE DISTRICT MAINTENANCE DIRECTOR FOR UDOT NOTIFIED THE CANAL COMPANY THAT SHOULD THE COMPANY HAVE THE DISCHARGE POINTS PLUGGED, STATE PERSONNEL WOULD RESPOND TO CLEAR THE OBSTRUCTION.

6. UDOT HAS SCHEDULED CONSTRUCTION ON SR193 THAT WILL RESULT IN A NEW STORM DRAIN OUTFALL THEY HAVE EXPRESSED WILLINGNESS TO ALLOW DISCHARGE FROM POND #4 INTO THIS LINE.

SYNOPSIS:

SHOULD THE CANAL COMPANY DECIDE TO PLUG (DISCONTINUE) DISCHARGES FROM BAMBERGER POND AND THE 1100/1200 ZONES OF HILL AFB, THE UTAH DEPARTMENT OF TRANSPORTATION WOULD REALIZE THE EFFECTS LONG BEFORE HILL AFB. AS A RESULT OF THEIR DECISION, AND THEIR WILLINGNESS TO WORK WITH HILL, ACTION WOULD BE TAKEN ON THEIR PART LONG BEFORE HILL WOULD BE FORCED TO RESPOND. THIS WOULD LEAVE ONLY POND #4 TO BE DEALT WITH AND IT HAS A SURFACE OVERFLOW TO POND #5.

CLEARFIELD CITY / DAVIS COUNTY

1. CLEARFIELD CITY HAS AGREED TO ENTER INTO THE AGREEMENT WITH THE CANAL COMPANY.

2. DAVIS AND WEBER COUNTIES HAVE BEEN TASKED BY THE CANAL COMPANY TO CONSTRUCT NEW DRAINAGE CHANNELS FOR NATURAL STREAMS AND RUNOFF CHANNELS THAT WERE INTERCEPTED BY CONSTRUCTION OF THE CANAL AND NOW DISCHARGE INTO THEIR STRUCTURE.

3. HILL OUTFALL INTO THE FIFE DITCH IS PICKED UP BY THE COUNTY AND DISCHARGED INTO HOWARDS SLOUGH WHICH IS BEING EXPANDED.

4. DAVIS COUNTY HAS CONTROL OVER KAYSCREEK AT THE HILL OUTFALL AND WILL ACCEPT ANY ADDITIONAL RUNOFF WE PROVIDE.

5. CLEARFIELD HAS TWO NEW LINES, ONE BY THE WEBER BASIN WATER CONSERVANCY DISTRICT ON THE SOUTH SIDE OF SR193 THAT COULD PROVIDE A DISCHARGE POINT FROM POND #4 IF HILL WOULD REIMBURSE FOR THE INCREASED LINE SIZE FROM 15" TO 18" AND CONSTRUCT THE NEW OUTFALL STRUCTURE FROM THE POND TO THE LINE. ANOTHER NEW LINE WILL BE CONSTRUCTED BY THE COUNTY FLOOD CONTROL DEPARTMENT AT 300 NORTH IN CLEARFIELD THAT COULD PROVIDE A DISCHARGE POINT FOR BAMBERGER POND IF REQUIRED. CONSTRUCTION ON THE SR193 PROJECT IS

TO COMMENCE THIS SPRING.

6. BOTH CLEARFIELD CITY AND THE DAVIS COUNTY FLOOD CONTROL OFFICE HAVE OFFERED ANY ASSISTANCE THEY CAN PROVIDE TO HILL.

SYNOPSIS:

BOTH CLEARFIELD CITY, AND THE DAVIS COUNTY FLOOD CONTROL OFFICES HAVE OFFERED TO ASSIST HILL IN ANY MANNER AT THEIR DISPOSAL. CLEARFIELD CITY AND DAVIS COUNTY HAVE OFFERRED A DISCHARGE POINT AT 300 NORTH FOR BAMBERGER POND, AND CLEARFIELD CITY HAS OFFERRED ANOTHER AT SR193 FOR POND #4, HAFB WOULD INCUR CONSTRUCTION COSTS FROM THE BASE TO THE CONNECTION POINTS.

AFLC (INFO.. BOB KEGGAN AFLC DEMU)

1. TO THE BEST OF HIS KNOWLEDGE, NO ALC'S HAVE UTILITY CONTRACTS FOR THE DISPOSAL OR DISCHARGE OF STORM WATER.

2. IF NO ALC'S HAVE THIS TYPE OF CONTRACT, THE AUTHORITY TO APPROVE HAS PROBABLY NEVER BEEN DELEGATED TO HQ AFLC WHICH WOULD REQUIRE HQ AF APPROVAL FOR A UTILITY CONTRACT REGARDLESS OF THE COST.

3. POSSIBLE LEGAL RAMIFICATIONS OVER PAYING HOOKUP OR IMPACT FEES AFTER THE FACT.

4. POSSIBLY COULD GO THROUGH THE CORPS OF ENGINEERS FOR SOME TYPE OF REALESTATE DOCUMENT PROVIDING FOR PERPETUAL DISCHARGE.

SYNOPSIS:

HAFB WOULD PROBABLY ENCOUNTER SEVERE LEGAL PROBLEMS IF ATTEMPTING TO INITIATE A UTILITY CONTRACT WITH THE CANAL COMPANY. DELAYS INCURRED WOULD RESULT IN FURTHER PROBLEMS WITH THE CANAL COMPANY. THE PERPETUAL RIGHT OF DISCHARGE OBTAINED THROUGH THE STATE ROAD COMMISSION AND THE FIFE DITCH COMPANY WAS ACCOMPLISHED VIA THE SERVICE CONTRACT ROUTE, THIS MAY BE AVAILABLE TO COMPENSATE THE CANAL COMPANY.

OPTIONS

1. ACCEPT THE D&W PROPOSAL IN ITS ENTIRETY AND FIND A WAY TO FINANCIALLY REIMBURSE (POSSIBLY SERVICE CONTRACT)

2. NEGOTIATE THEIR PROPOSAL AND FIND A WAY TO REIMBURSE.

3. REJECT THEIR PROPOSAL.
   A. DIVERT 1100 OUTFALL TO THE FIFE DITCH
   B. PREPARE CONTRACT TO HAVE POND #4 DISCHARGE INTO THE NEW SR193 STORM SEWER.
   C. COORDINATE WITH UDOT ON THE BAMBERGER OUTFALL TO FIND A SOLUTION, DISCHARGE INTO CLEARFIELD 300 NORTH OUTFALL WHEN COMPLETED, DIVERT INTO THE FIFE DITCH OUTFALL.

4. ACCEPT ONE TIME LUMP SUM PAYMENT ($46,500) OPTION IN RETURN FOR A 20 YEAR UNREVOCABLE AGREEMENT. INITIATE STUDY/OPTIONS FOR A PERMANENT BY-PASS OF THE CANAL BY CONSTRUCTING FACILITIES TO CONNECT HAFB TO AVAILABLE STORM DRAINAGE SYSTEM.

REGARDLESS OF WHICH OPTION IS SELECTED, IT SHOULD BE POINTED OUT TO THE CANAL COMPANY THAT TERMINATION OF OUR AGREEMENTS WILL RESULT IN "COMPLETE" TERMINATION INCLUDING IN THE LOSS OF THE OUTFALL STRUCTURE THEY ARE PRESENTLY USING TO CONTROL THE VOLUME OF WATER IN THEIR CANAL BY DISCHARGING EXCESS INTO OUR KAYSCREEK OUTFALL. THIS STRUCTURE WAS ORIGINALLY PROVIDED BY THE AIR FORCE UNDER OUR 1962 AGREEMENT AND HAS BEEN UPGRADED ON ATLEAST TWO DIFFERENT OCCASIONS. PERMISSION TO DISCHARGE WAS GIVE BY IMPLIED CONSENT WHEN THE STRUCTURE WAS ACCOMPLISHED BY THE AIR FORCE, RATHER THAN A FORMAL AGREEMENT SPECIFICALLY ALLOWING DISCHARGE.

GIVEN THE CANAL COMPANY EMPLOYEES HAVE HAD NO NEED TO PERFORM GOOD WATER MANAGEMENT FOR THE PAST 25 YEARS, THEY NO DOUBT HAVE LOST MUCH OF THE EXPERTISE REQUIRED TO ENSURE ONLY THE APPROPRIATE VOLUME OF WATER IS IN THE CANAL STRUCTURE AS IT REACHES ITS TERMINATION.

THE FEB 1, 1982 LETTER FROM COL BATTAGLIA (HILL AIR FORCE BASE COMMANDER) TO THE CANAL COMPANY (ATTN MR. A. WAYNE KIMBER) REASSURRED THE COMPANY THEY WERE FULLY AUTHORIZED TO DISCONTINUE DISCHARGE FROM POND #4 AT THEIR DISCRESSION AND PROVIDED THEM WITH THE PHONE NUMBER OF THE CIVIL ENGINEERING OPERATIONS BRANCH CHIEF TO CALL WHEN THEY DESIRED THE BAMBERGER POND OUTFALL DISCONTINUED.

IT WOULD ALSO BE IN THE BEST INTERESTS OF HILL AFB IF STORM RUNOFF FROM THE BASE WAS NOT BEING USED FOR IRRIGATION PURPOSES. CANAL WATER IS NOT ONLY HIGHLY VISIBLE BUT ALSO IS GOING TO BE USED TO PROVIDE A NON-POTABLE SUPPLY FOR IRRIGATION IN RESIDENTIAL AREAS OF KAYSVILLE.

MONETARY REIMBURSEMENT (000$)

1. NONE _____
2. 10-20 _____
3. 20-30 _____
4. 30-40 _____
5. 46.5 _____

AGREEMENT PERIOD

1. PERPETUAL _____
2. 30 YRS _____
3. 20 YRS _____
4. 10 YRS _____
5. 5 YRS _____

(HILL PAID THE FIFE DITCH COMPANY $7,266.50 FOR A PERPETUAL AGREEMENT IN 1972)

Fax Transmittal Sheet

To: Dr. Gary Merkley
BIE USU

Fax No.: 797-1248

Number of Pages: 5

From: Dan Adkins
OO-ALC/EMR
7276 Wardleigh Road
Hill A.F.B., Utah 84056-5127
Phone: 801-777-8790/8791/8792
Fax: 801-777-1866

Subject: Amount of water in Canal

Comments: I wasn't sure how many diversions there are prior to the school, I don't think there are many, however you can get a lot of information etc. from the River Commissioner Blaine Johnson at 479-5794.
Attached is what should be the max amount of water in the canal, i.e., releases at the head of the canal

Please call if there are any problems receiving this transmission.

UTAH DIVISION OF WATER RIGHTS
WEBER RIVER
DAVIS AND WEBER CANAL AT HEAD

THE MEASURING STATION IS LOCATED N 1658 AND E 1831 FEET FROM THE SW CORNER OF SECTION 30 TOWNSHIP 5N RANGE 1E, SL B&M.
COMMON DESCRIPTION: Near South Weber
DIVERTING WORKS: CONCRETE HEADWORKS WITH RADIAL WOOD CONTROL GATE
MEASURING DEVICE: 12 FOOT PARSHALL FLUME
RECORDS RATING: G (E,G,F,P)
WATER RIGHT NUMBER: 35- 8044

COMMENTS:
****
1988 Begining June 6, Flow includes Weber Basin shares to gateway tunnel.
1989 Beginning June 11, flow includes Weber Basin shares delivered to gateway tunnel.

CALENDAR YEAR 1990
DAILY DISCHARGE IN CFS

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1				0	102	225	84	0	0	41			
2				0	105	215	84	0	0	0			
3				0	122	213	84	0	0	0			
4				0	166	213	84	0	0	0			
5				0	224	240	84	0	0	0			
6				0	246	248	84	0	0	0			
7				0	130	260	46	0	0	0			
8				0	130	267	46	0	0	0			
9				0	130	262	46	0	0	0			
10				0	130	264	46	0	0	0			
11				0	130	252	46	0	0	0			
12				0	130	252	46	0	0	0			
13				0	130	248	46	0	0	0			
14				0	130	245	46	0	0	0			
15				0	130	252	0	0	0	0			
16				59	159	261	0	0	0	0			
17				66	159	250	0	0	0	0			
18				68	159	249	0	0	0	0			
19				87	159	250	0	0	0	0			
20				112	159	212	0	0	46	0			
21				130	159	212	0	0	46	0			
22				135	159	212	0	0	84	0			
23				100	212	212	0	0	84	0			
24				79	212	212	0	0	84	0			
25				98	253	212	0	0	84	0			
26				104	248	212	0	0	84	0			
27				102	241	212	0	0	84	0			
28				103	245	130	0	0	84	0			
29				94	246	130	0	0	84	0			
30				97	240	130	0	0	84	0			
31					225		0	0		0			
TAL (AC-FT)				2840	10656	13390	1732	0	1678	82			30377

dry year

UTAH DIVISION OF WATER RIGHTS
WEBER RIVER
DAVIS AND WEBER CANAL AT HEAD

THE MEASURING STATION IS LOCATED N 1658 AND E 1831 FEET FROM THE SW CORNER OF SECTION 30 TOWNSHIP 5N RANGE 1E, SL B&M.
COMMON DESCRIPTION: Near South Weber
DIVERTING WORKS: CONCRETE HEADWORKS WITH RADIAL WOOD CONTROL GATE
MEASURING DEVICE: 12 FOOT PARSHALL FLUME
RECORDS RATING: G (E,G,F,P)
WATER RIGHT NUMBER: 35- 8044

COMMENTS:
****
1988 Begining June 6, Flow includes Weber Basin shares to gateway tunnel.
1989 Beginning June 11, flow includes Weber Basin shares delivered to gateway tunnel.

CALENDAR YEAR 1992
DAILY DISCHARGE IN CFS

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1									0				
2									0				
3									0				
4									0				
5									0				
6									0				
7									0				
8									0				
9									0				
10									0				
11									0				
12									0				
13									0				
14									0				
15									0				
16									0				
17									0				
18									46				
19									46				
20									46				
21									46				
22									46				
23									46				
24									46				
25									23				
26									0				
27									0				
28									10				
29									10				
30									0				
31													
)TAL (AC-FT)									730				730

UTAH DIVISION OF WATER RIGHTS
WEBER RIVER
DAVIS AND WEBER CANAL AT HEAD

THE MEASURING STATION IS LOCATED N 1658 AND E 1831 FEET FROM THE SW CORNER OF SECTION 30 TOWNSHIP 5N RANGE 1E, SL B&M.
COMMON DESCRIPTION: Near South Weber
DIVERTING WORKS: CONCRETE HEADWORKS WITH RADIAL WOOD CONTROL GATE
MEASURING DEVICE: 12 FOOT PARSHALL FLUME
RECORDS RATING: G (E,G,F,P)
WATER RIGHT NUMBER: 35- 8044

COMMENTS:
****
1988 Begining June 6, flow includes Weber Basin shares to gateway tunnel.
1989 Beginning June 11, flow includes Weber Basin shares delivered to gateway tunnel.

CALENDAR YEAR 1993
DAILY DISCHARGE IN CFS

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1				0	29	240	294	130	130	130			
2				0	27	239	290	130	130	130			
3				0	28	189	280	130	130	130			
4				0	16	173	269	130	130	130			
5				0	0	164	269	130	130	130			
6				0	3.0	144	270	130	130	130			
7				0	0	107	272	130	130	130			
8				0	0	0	280	130	130	42			
9				0	0	6.6	294	130	130	0			
10				0	0	32	292	130	130	0			
11				0	18	45	288	130	84	0			
12				0	34	59	290	130	84	0			
13				0	35	61	289	130	84	0			
14				0	35	199	290	130	84	0			
15				55	74	239	212	130	84	0			
16				6.1	95	240	212	130	84	0			
17				0	82	214	212	130	84	0			
18				0	94	219	212	130	130	0			
19				2.0	129	222	212	130	130	0			
20				32	166	220	130	130	130	0			
21				14	183	232	130	130	130	0			
22				0	189	230	130	130	130	0			
23				15	188	234	130	130	130	0			
24				7.1	187	326	130	130	130	0			
25				0	198	239	130	130	130	0			
26				6.1	240	237	130	130	130	0			
27				9.1	243	246	130	130	130	0			
28				15	240	254	130	130	130	0			
29				11	240	262	130	130	130	0			
30				28	242	263	130	130	130	0			
31					242		130	130		0			
TOTAL (AC-FT)				400	6458	10979	13074	7998	7096	1889			47894

near peak capacity in early July

UTAH DIVISION OF WATER RIGHTS
WEBER RIVER
DAVIS AND WEBER CANAL AT HEAD

THE MEASURING STATION IS LOCATED N 1658 AND E 1831 FEET FROM THE SW CORNER OF SECTION 30 TOWNSHIP 5N RANGE 1E, SL B&M.
COMMON DESCRIPTION: Near South Weber
DIVERTING WORKS: CONCRETE HEADWORKS WITH RADIAL WOOD CONTROL GATE
MEASURING DEVICE: 12 FOOT PARSHALL FLUME
RECORDS RATING: G (E,G,F,P)
WATER RIGHT NUMBER: 35- 8044

COMMENTS:
****
1988 Begining June 6, Flow includes Weber Basin shares to
gateway tunnel.
1989 Beginning June 11, flow includes Weber Basin shares delivered to
gateway tunnel.

CALENDAR YEAR 1994
DAILY DISCHARGE IN CFS

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1				0	24								
2				0	35								
3				0	44								
4				0	46								
5				0	51								
6				0	65								
7				0	73								
8				0	70								
9				0	107								
10				0	137								
11				0	159								
12				0	176								
13				63	182								
14				39	171								
15				33	165								
16				33	169								
17				34	176								
18				35	180								
19				37	193								
20				38	207								
21				46	206								
22				65	241								
23				77	263								
24				78	261								
25				71	261								
26				53	260								
27				42	260								
28				32	257								
29				24	257								
30				24	257								
31					258								
OTAL (AC-FT)				1638	10342								11980

Fax Transmittal Sheet

To: Dr. Gary Merkley
BIE USU

Fax No.: 757-1248

Number of Pages: 3

From: Dan Adkins
OO-ALC/EMR
7276 Wardleigh Road
Hill A.F.B., Utah 84056-5127
Phone: 801-777-8790/8791/8792
Fax: 801-777-1866

OGDEN AIR LOGISTICS CENTER

Subject: Rough + Dirty Calculations on Hill AFB golf course irrigation affect on water table.

Comments:

Please call if there are any problems receiving this transmission.

Golf Coarse Calculations

Ref: Base CE

The base uses 476 ac-ft of water on the 156 acre golf course which equals 3.05 ft. of water applied.

Ref: "Golf Course Water Use Study Utah Dept. Natural Resources"

3.05 is within normal range for golf coarses in Utah.

Ref: "USU Irrigation Engineering Extension Service"

Etr seasonal for Kaysville = 32.5" for Alfalfa
Etr = 1.2 Eto for clipped grass
Evapotranspiration for clipped grass is 27.08 in.

3.05' (12") - 27.08" = 9.52 inches of excess water above ET is applied over entire season to golf course, i.e., which might infiltrate. (sprinklers; probably a lot of wind drift and evap).

Ref: "Hill AFB OU6 RI Report May 1994"

Annual precipitation averaged over 1982-1993 is 25.3 in.
Seasonal precipitation averaged over 1982-1993 is 10.75"

Ref: Hargreaves unpublished book, & Book Irrigation Principals and Practices, & California Dept. of Water Resources, & Utah Dept. of Water Resources.

Defining field capacity as the amount of water the soil will hold against the force of gravity and using one of the more shallow depths to water table on the golf course.

For a moderately coarse sandy loam Avg. FC = 23%

Ref: Montgomery Watson Well Data.

GC-2M depth to water table 22.7 ft. Elev. 4753 Elev. (South Well) GC-3F 13.5 ft. Elev. (North Well). Note: Well data indicates flow in southern direction away from OU1.

Using shallower depth to water table (conservative)

13.5' soil (.23) = 3.11' = 37.26" of water stored in vadose zone.
37.26" is greater than 25.3" of annual precipitation

Therefore for worse case assume precipitation equilibrates field capacity.

Therefore maximum amount of irrigation water reaching water table is 9.52" over entire season. This confirms the modeling done in

1989 by Montgomery-Watson which indicates 8.5 in. are added by irrigation. Additionally, well data and A&E modeling indicates much of the shallow aquifer flows south west away from the golf course. However assuming all flow is northward.

Irrigation season April 15 to Oct 15, approx. 180 days and application is uniform over entire season .053 in/day per unit area is added to golf course. Horizontal hydraulic conductivity geometric average is 3 fpd. Assuming min. slope is where slowest flow rate will occur and therefore mounding if any. i = .051. Q = KiA = K(hl/L)A A=1

Therefore ability of aquifer to allow outflow is much greater than additional inflow due to irrigation and it is conservative to assume continuous steady state condition will result in a maximum increase in water table equal to inflow depth. Therefore .053 in increase in water table, if one assumes a wall of water all at once then 9.52 in. There is probably no significant impact on hydraulic head and therefore pore pressure on the slope due to irrigation at the golf course, i.e., slope stability

In addition to this the OU1 drainage system currently removes 15 million gallons annually from the shallow aquifer. Kevin Borne indicates that he is budgeting for a 1995 project which should completely capture shallow ground water flow in OU1. If golf coarse irrigation is a problem to the canal it should be taken care of by this project. Additionally, average precipitation is nearly half the rate of evaporation in the area and there should not be a problem in the OU2 & OU4 area due to this.

Slope stability problems under OU2 and OU4, the canal company indicates that infiltration due to the base construction has changed storm runoff and infiltration is the problem. The rate of precipitation is approximate 50% the rate of evaporation.

However, it should be noted that much of the recharge to the aquifer results from the mountains East of Hill acting as a groundwater recharge basin, Ref. OU5 RI Feb. 1994.

UTAH DIVISION OF WATER RIGHTS
WEBER RIVER
DAVIS AND WEBER CANAL AT HEAD

THE MEASURING STATION IS LOCATED N 1658 AND E 1831 FEET FROM THE SW CORNER OF SECTION 30 TOWNSHIP 5N RANGE 1E, SL B&M.
COMMON DESCRIPTION: Near South Weber
DIVERTING WORKS: CONCRETE HEADWORKS WITH RADIAL WOOD CONTROL GATE
MEASURING DEVICE: 12 FOOT PARSHALL FLUME
RECORDS RATING: G (E,G,F,P)
WATER RIGHT NUMBER: 35- 8044

COMMENTS:
****
1988 Begining June 6, Flow includes Weber Basin shares to gateway tunnel.
1989 Beginning June 11, flow includes Weber Basin shares delivered to gateway tunnel.

CALENDAR YEAR 1990
DAILY DISCHARGE IN CFS

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1				0	102	225	84	0	0	41			
2				0	105	215	84	0	0	0			
3				0	122	213	84	0	0	0			
4				0	166	213	84	0	0	0			
5				0	224	240	84	0	0	0			
6				0	246	248	84	0	0	0			
7				0	130	260	46	0	0	0			
8				0	130	267	46	0	0	0			
9				0	130	262	46	0	0	0			
10				0	130	264	46	0	0	0			
11				0	130	252	46	0	0	0			
12				0	130	252	46	0	0	0			
13				0	130	248	46	0	0	0			
14				0	130	245	46	0	0	0			
15				0	130	252	0	0	0	0			
16				59	159	261	0	0	0	0			
17				66	159	250	0	0	0	0			
18				68	159	249	0	0	0	0			
19				87	159	250	0	0	0	0			
20				112	159	212	0	0	46	0			
21				130	159	212	0	0	46	0			
22				135	159	212	0	0	84	0			
23				100	212	212	0	0	84	0			
24				79	212	212	0	0	84	0			
25				98	253	212	0	0	84	0			
26				104	248	212	0	0	84	0			
27				102	241	212	0	0	84	0			
28				103	245	130	0	0	84	0			
29				94	246	130	0	0	84	0			
30				97	240	130	0	0	84	0			
31					225		0	0		0			
AL (AC-FT)				2840	10656	13390	1732	0	1678	82			30377

UTAH DIVISION OF WATER RIGHTS
WEBER RIVER
DAVIS AND WEBER CANAL AT HEAD

THE MEASURING STATION IS LOCATED N 1658 AND E 1831 FEET FROM THE SW CORNER OF SECTION 30 TOWNSHIP 5N RANGE 1E, SL B&M.
COMMON DESCRIPTION: Near South Weber
DIVERTING WORKS: CONCRETE HEADWORKS WITH RADIAL WOOD CONTROL GATE
MEASURING DEVICE: 12 FOOT PARSHALL FLUME
RECORDS RATING: G (E,G,F,P)
WATER RIGHT NUMBER: 35- 8044

COMMENTS:
****
1988 Begining June 6, Flow includes Weber Basin shares to
gateway tunnel.
1989 Beginning June 11, flow includes Weber Basin shares delivered to
gateway tunnel.

CALENDAR YEAR 1992
DAILY DISCHARGE IN CFS

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1									0				
2									0				
3									0				
4									0				
5									0				
6									0				
7									0				
8									0				
9									0				
10									0				
11									0				
12									0				
13									0				
14									0				
15									0				
16									0				
17									0				
18									46				
19									46				
20									46				
21									46				
22									46				
23									46				
24									46				
25									23				
26									0				
27									0				
28									10				
29									10				
30									0				
31													
AL (AC-FT)									730				730

UTAH DIVISION OF WATER RIGHTS
WEBER RIVER
DAVIS AND WEBER CANAL AT HEAD

THE MEASURING STATION IS LOCATED N 1658 AND E 1831 FEET FROM THE SW CORNER OF SECTION 30 TOWNSHIP 5N RANGE 1E, SL B&M.
COMMON DESCRIPTION: Near South Weber
DIVERTING WORKS: CONCRETE HEADWORKS WITH RADIAL WOOD CONTROL GATE
MEASURING DEVICE: 12 FOOT PARSHALL FLUME
RECORDS RATING: G (E,G,F,P)
WATER RIGHT NUMBER: 35- 8044

COMMENTS:
****
1988 Begining June 6; Flow includes Weber Basin shares to gateway tunnel.
1989 Beginning June 11, flow includes Weber Basin shares delivered to gateway tunnel.

CALENDAR YEAR 1993
DAILY DISCHARGE IN CFS

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1				0	29	240	294	130	130	130			
2				0	27	239	290	130	130	130			
3				0	28	189	280	130	130	130			
4				0	16	173	269	130	130	130			
5				0	0	164	269	130	130	130			
6				0	3.0	144	270	130	130	130			
7				0	0	107	272	130	130	130			
8				0	0	0	280	130	130	42			
9				0	0	6.6	294	130	130	0			
10				0	0	32	292	130	130	0			
11				0	18	45	288	130	84	0			
12				0	34	59	290	130	84	0			
13				0	35	61	289	130	84	0			
14				0	35	199	290	130	84	0			
15				55	74	239	212	130	84	0			
16				6.1	95	240	212	130	84	0			
17				0	82	214	212	130	84	0			
18				0	94	219	212	130	130	0			
19				2.0	129	222	212	130	130	0			
20				32	166	220	130	130	130	0			
21				14	183	232	130	130	130	0			
22				0	189	230	130	130	130	0			
23				15	188	234	130	130	130	0			
24				7.1	187	326	130	130	130	0			
25				0	198	239	130	130	130	0			
26				6.1	240	237	130	130	130	0			
27				9.1	243	246	130	130	130	0			
28				15	240	254	130	130	130	0			
29				11	240	262	130	130	130	0			
30				28	242	263	130	130	130	0			
31					242		130	130		0			
TAL (AC-FT)				400	6458	10979	13074	7998	7096	1889			47894

UTAH DIVISION OF WATER RIGHTS
WEBER RIVER
DAVIS AND WEBER CANAL AT HEAD

THE MEASURING STATION IS LOCATED N 1658 AND E 1831 FEET FROM THE SW CORNER OF SECTION 30 TOWNSHIP 5N RANGE 1E, SL B&M.
COMMON DESCRIPTION: Near South Weber
DIVERTING WORKS: CONCRETE HEADWORKS WITH RADIAL WOOD CONTROL GATE
MEASURING DEVICE: 12 FOOT PARSHALL FLUME
RECORDS RATING: G (E,G,F,P)
WATER RIGHT NUMBER: 35- 8044

COMMENTS:
****
1988 Begining June 6, Flow includes Weber Basin shares to gateway tunnel.
1989 Beginning June 11, flow includes Weber Basin shares delivered to gateway tunnel.

CALENDAR YEAR 1994
DAILY DISCHARGE IN CFS

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1				0	24								
2				0	35								
3				0	44								
4				0	46								
5				0	51								
6				0	65								
7				0	73								
8				0	70								
9				0	107								
10				0	137								
11				0	159								
12				0	176								
13				63	182								
14				39	171								
15				33	165								
16				33	169								
17				34	176								
18				35	180								
19				37	193								
20				38	207								
21				46	206								
22				65	241								
23				77	263								
24				78	261								
25				71	261								
26				53	260								
27				42	260								
28				32	257								
29				24	257								
30				24	257								
31					258								
)TAL (AC-FT)				1638	10342								1198C~