Library Copy
Do Not Remove
Sept. 1987

MASTER DRAINAGE STUDY

FOR

NEAL RANCH

(A portion of)

WEISS CONSULTING ENGINEERS, INC.

COLORADO SPRINGS, COLORADO

RECEIVED
PUBLIC WORKS/ENGINEERING
COLORADO SPRINGS COLO.

SEP 03 1987
AM PM
7|8|9|10|11|12|1|2|3|4|5|6

MASTER DRAINAGE STUDY

FOR

NEAL RANCH
(A portion of)

WEISS CONSULTING ENGINEERS, INC.
Professional Engineer and Land Surveyor

September 3, 1987

Mr. Chris Smith
City Engineers Office
P. O. Box 1575
Colorado Springs, Colorado 80901

Dear Chris:

Reference is made to the review comments on my Master Drainage Study for Neal Ranch. We wish to acknowledge the Master Drainage Plan for Broadmoor South - Neal Ranch, prepared by KLH Engineers and approved June 25, 1982. There is an overlap between their report and this report. Our report is intended to cover only the presently undeveloped portions of Neal Ranch and will provide you with detention storage requirements for this area.

We acknowledge the Master Drainage Plan and Report for the Proposed J L Ranch Annexation is not filed with the Public Works Department as an approved drainage report.

Our statement that "this study assumes that all drainage channels will remain in the natural state", is subject to city criteria and the channels must be made stable and non-erosive. This will be addressed at the time of final drainage reports.

In Section VI FLOW ROUTING, all our reference to the generated flows is to the developed flows. Since some of the areas are not developable, the historic and developed flows are the same.

The graphic method of computation was used to determine the flows in each subbasin and will provide the required data for final drainage reports in those areas. We used hydrograph computations at all outfall points on the east side of the study to determine the requirement for detention storage. The purpose of the detention data is for sizing future detention ponds downstream that may be needed for several developments.

1815 North Tejon • Colorado Springs, CO 80907 • (303) 634-0373

The outfall points from this study will all be discharging into existing natural channels proposed in the J L Ranch report. We stated in our report that the highway fill provides an interim detention pond prior to permanent pond construction. This was just a statement of existing conditions and is not intended that you would be approving its use for such without further study outside the scope of this report.

You indicated that there is no master report for the basin on the north side of this study that covers the Star Ranch area. This subbasin study was included with the drainage report for Broadmoor Oaks Filing No. 1, which has been approved by your office.

We have marked land ownerships on three copies of the map for your information. We do not feel it is necessary to show the drainage flow quantities on the map since each point is identified by number and is readily cross referenced to the computation sheets and the hydrograph chart in the report.

We hope the above clarifications will answer the questions you had in the review comments. We are attaching this letter to the report and it will be considered part of the report. If you have any questions, please let me know.

Sincerely,

WEISS CONSULTING ENGINEERS, INC.

Jerry Weiss

G. J. Weiss

June 24, 1987

Mr. Gary Haynes
City Engineer
P. O. Box 1575
Colorado Springs, Colorado 80901

Dear Gary:

Transmitted herewith is the Master Drainage Study for the Neal Ranch, located east of the NORAD site on Cheyenne Mountain in southern Colorado Springs. This is a Hydrological Study only to determine the flows through the site as it now exists and to project the future flows in the developed condition.

Sincerely,

WEISS CONSULTING ENGINEERS, INC.

G J Weiss

G. J. Weiss PE-LS 4124

DRAINAGE REPORT STATEMENTS

Engineer's Statement:

The attached drainage plan and report were prepared under my direction and supervision and are correct to the best of my knowledge and belief. Said drainage report has been prepared according to the criteria established by the City for drainage reports and said report is in conformity with the master plan of the drainage basin. I accept responsibility for any liability caused by the negligent acts, errors or omissions on my part in preparing this report.

Gerald J. Weiss
Name PE- 4124

Seal

NEAL RANCH MASTER DRAINAGE
6-23-87

Developer's Statement:

The developer has read and will comply with all of the requirements specified in this drainage report.

DAVID M. SELLON CO.
Business Name

By: David M Sellon

Title: Pres.

Address: 660 S. POINTE CT.
COLO. SPR.

City of Colorado Springs:

Filed in accordance with Section 15-3-906 of the Code of the City of Colorado Springs, 1980, as amended.

City Engineer

9/21/87
Date

Conditions:

I. INTENT AND SCOPE OF REPORT

This study is intended to serve as a guide for drainage improvements to be constructed in the future. The Neal Ranch lies easterly from the NORAD site on the east face of Cheyenne Mountain. Drainage from these areas has been analyzed to determine the exterior flows that will be carried through the Neal Ranch. Permission was received to enter the Norad site to measure the size of the culverts under the Norad Road and to analyze the potential detention storage available on the upstream side of the culverts. It is our opinion that enough detention storage is available on their side to offset the increased runoff from their development. This report will assume the flows leaving the Norad site as being at the historic rate.

Reference is made to a Master Drainage Report and Plan for the J L Ranch, dated October 1986 and prepared by Becker-Johnson, Inc. The J L Ranch lies downstream from the Neal Ranch and will receive the outfall flow from all of the natural drainage channels coming through the study area. The J L Ranch report indicates that detention storage will be required on the upstream side of State Highway 115 with outfall structures to be sized to pass no more than historic flows. Our study will analyze the historic and developed flows along with detention storage requirements at the downstream side of the Neal Ranch.

This study will assume that all drainage channels through the Neal Ranch will remain in the natural state. No build areas or preservation easements would be established adjacent to the natural channels when the site is platted. This study will provide the flow requirements for culverts that will need to be installed for development. Detailed drainage reports will be submitted at that time giving cost estimates and drainage structure requirements.

It is proposed that this be treated as a "closed basin", whereby the developer pays no drainage fees for platting. In turn, all drainage improvements are constructed at developers expense and he receives no reimbursement for these costs.

II. GENERAL DESCRIPTION

The Neal Ranch is located in Sections 12 and 13, Township 15 South, Range 67 West of the 6th P.M. The study area covers about 1120 acres, which includes the area upstream from the Neal Ranch.

The site is bordered on the west by Norad and some undeveloped land. It is bordered on the north by

Broadmoor Oaks. It is bordered on the south by the Norad Road and on the east by J L Ranch.

The site lies in an unstudied drainage basin. This study was made using Corps of Engineers topography maps at a 1" = 100' scale, which were reduced to 1" = 200'. Panel 290 B of the Flood Insurance Maps indicates none of this site falls within a designated flood plain.

III. SITE CHARACTERISTICS

Slopes on the site range from 8% up to 60%, with the steeper slopes on the face of the mountain and along the sides of the drainageways. Most of the natural drainageways are well defined. They are also very stable with large rock lining the channel along with heavy underbrush and vegetation.

The Neal Ranch is about 40% covered with a dense scrub oak growth. About 10% of the ranch is covered with evergreen trees. The remainder of the ranch is covered with a heavy vegetation growth.

IV. SOILS

The majority of the soils in the Neal Ranch consist of the Jarre-Tecolote complex. These moderately sloping to very steep soils are on alluvial fans.

The Jarre soil, which makes up about 40% of the complex, is deep and well drained. It formed in alluvium derived from sandy sediment. Pertinent characteristics of this soil include moderate permeability, moderate available water capacity, medium to rapid surface runoff and a moderate to high hazard of erosion. The Jarre soil is categorized in Hydrologic Group B.

The Tecolote soil, which makes up about 30 percent of the complex, is deep and well drained. It formed in alluvial fan sediment derived from acid igneous rock. Pertinent characteristics of this soil include moderate permeability, low to moderate available water capacity, medium surface runoff, and a moderate hazard of erosion. The Tecolote soil is categorized in Hydrologic Group B.

The soils in a small portion of the southwest portion of subject site consist of the Bresser sandy loam series. This deep, well drained soil formed in arkosic alluvium and residuum on terraces and uplands. Pertinent characteristics of this soil include moderate permeability, moderate available water capacity, medium surface runoff and a moderate hazard of erosion. The Bresser soil is categorized in Hydrologic Group B.

The soils in a portion of the contributing external drainage areas consist of the rock outcrop - Coldcreek-Tolman complex. This strongly sloping to extremely steep complex is on mountains.

Rock outcrop, which makes up about 30% of the complex, occurs throughout the complex, most commonly on the upper part of the slopes. Pertinent characteristics include rapid runoff. Rock outcrop is categorized in Hydrologic Group D.

The Coldcreek soil, which makes up about 30% of the complex, is deep and well drained. It formed in mixed, acid igneous material. Pertinent characteristics of this soil include moderate permeability, moderate available water capacity, medium surface runoff and a moderate hazard of erosion. The Coldcreek soil is categorized in Hydrologic Group B.

The Tolman soil, which makes up about 20% of the complex, is shallow and well drained. It formed in medium textured residuum derived from acid igneous rock. Pertinent characteristics of this soil include moderate permeability, low available water capacity, medium surface runoff and a moderate hazard of erosion. The Tolman soil is catergorized in Hydrologic Group D.

The source for soil data is the "Soil Survey of El Paso County Area, Colorado", prepared by the United States Department of Agriculture Soil Conservation Service.

V. METHOD OF COMPUTATION

The hydrological computations were made using the USDA-SCS Synthetic Hydrograph Method, as modified and prescribed by the city of Colorado Springs in their 1977 publication, "Determination of Storm Runoff Criteria". The current city criteria utilizes the Type II-A, 6 hour, 5 year and/or 100 year return internal storms. This study utilizes the Type II-A, 24 hour, 5 year, 10 year and 100 year return internal storms, since a new drainage criteria manual will be adopted in the near future.

A curve number of 90 was used for the rock outcrop soil D portion of the site as it exists in the natural state. A curve number of 55 was used for the B soil in its natural state and a curve number 66 for this soil in the developed state. This site, as planned, will be developed with 75% of the area left pervious and 25% impervious. The combined curve number for this type of development is lower than the normal development, because the site will have very little grading done and a large part of the natural growth is retained.

Calculations were made in the sub-basins, as shown on the attached computation sheet. The upper and lower sub-basins were combined into one basin to get the total flow at the outfall. These basins are long and skinny and it was felt that the graphic method did not give a true reading for the outfall. Therefore, outfall hydrographs were computed using the basic hydrological computations. The amount of detention storage required to hold the outfall to the historic peak level was also calculated.

VI. FLOW ROUTING

Basin A-1 is the upper basin on the south side of the study lying west of the Norad Road. It generates a 5 year flow of 109 CFS and outfalls at Point 1 through an existing 42" CMP.

Basin A-2 is the lower basin that falls in the proposed development of Neal Ranch. It generates a 5 year developed flow of 13 CFS and outfalls under Norad Road in existing twin 36" CMP. Hydrograph Point 2 shows a 100 year developed flow of 264 CFS and the 100 year historic flow of 244 CFS.

Basin A-3 is a small basin lying west of Norad Road and has a 5 year flow of only 1 CFS. It outfalls at Point 3 through an existing 42" CMP.

Basin A-4 is in the proposed development area. There is no easily identified drainage channel through the basin. It generates a 5 year developed flow of

23 CFS. Hydrograph Point 4 shows a 100 year historic flow of 51 CFS and developed flow of 88 CFS.

Basin B-1 generates a 5 year flow of 48 CFS and discharges under Norad Road through a 30" CMP and a 24" CMP into Basin B-2.

Basins B-2 and B-3 are in the developed area and generate 5 year flows of 26 CFS and 20 CFS respectively. They combine their flows at Point 6. Hydrograph Point 6 has a 100 year historic flow of 161 CFS and developed flow of 232 CFS.

Basin B-4 starts at the top of Cheyenne Mountain and discharges a 5 year flow of 430 CFS through a 66" CMP under Norad Road. Basin B-5 is in the proposed development area and generates a 5 year flow of 26 CFS. The combined outfall at Hydrograph Point 8 has a 100 year historic flow of 664 CFS and a developed flow of 705 CFS.

Basin C-1 consists of the mountainside as well as some land that can be developed. It generates a 5 year developed flow of 220 CFS outfalling at Point 9. Basin C-2 is in the proposed development and generates a 5 year developed flow of 25 CFS. Hydrograph Point 10 has a 100 year historic flow of 394 CFS and a developed flow of 488 CFS.

Basins D-1 and D-2 consist of the mountainside as well as some land that can be developed. They generate 5 year developed flows of 179 CFS and 70 CFS respectively. Basins D-3 and D-4 are in the proposed development and generate 5 year developed flows of 33 CFS and 15 CFS respectively. Hydrograph Point 13 has a 100 year historic flow of 536 CFS and a developed flow of 690 CFS.

VII. RECOMMENDATIONS

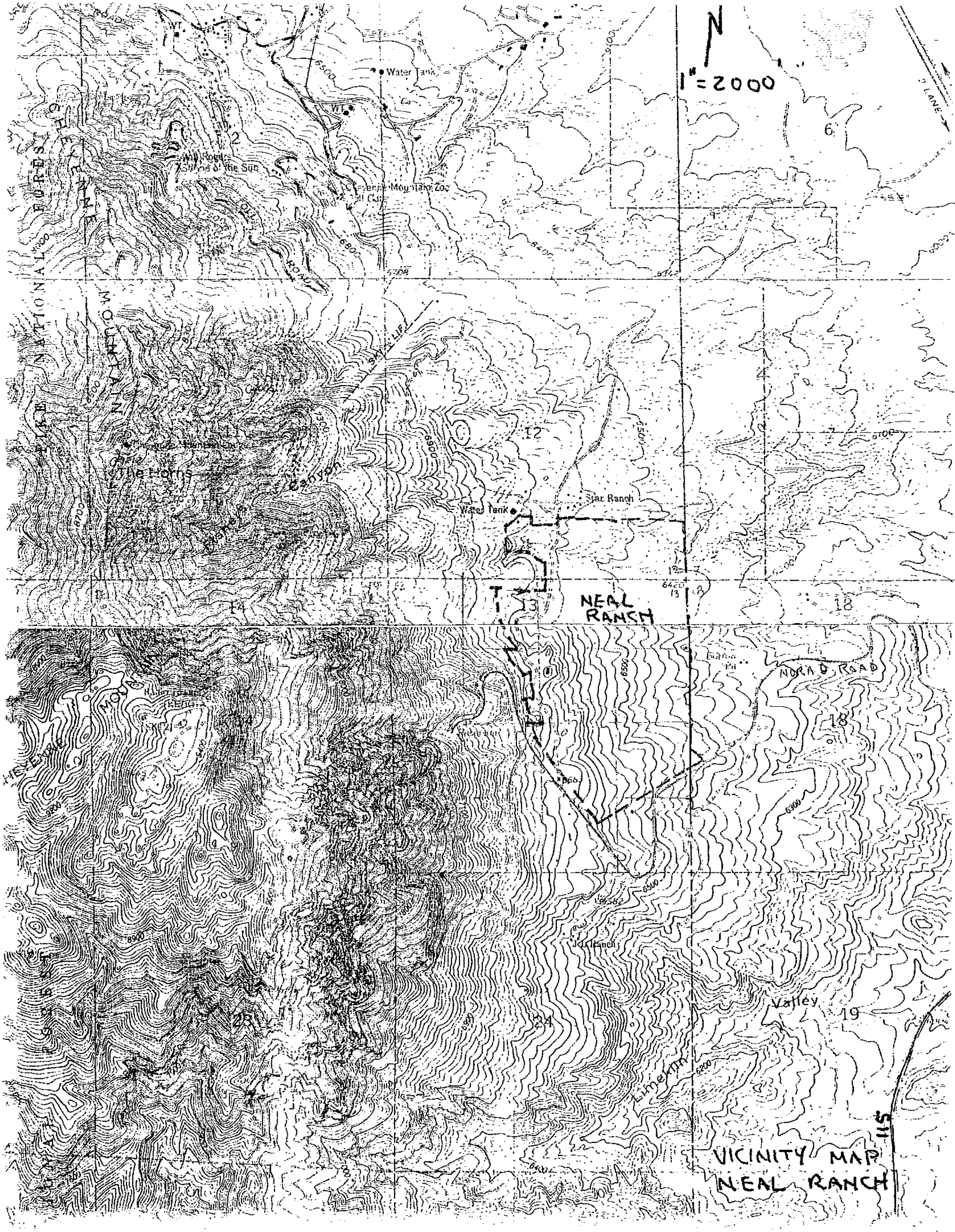
This report is a hydrological study only so no cost estimate is included. Detailed drainage reports will be submitted as the land is platted and developed. Our study will provide a basis for sizing the required drainage at that time.

The outfall points for the Neal Ranch are listed along with their flows from the hydrograph calculations.

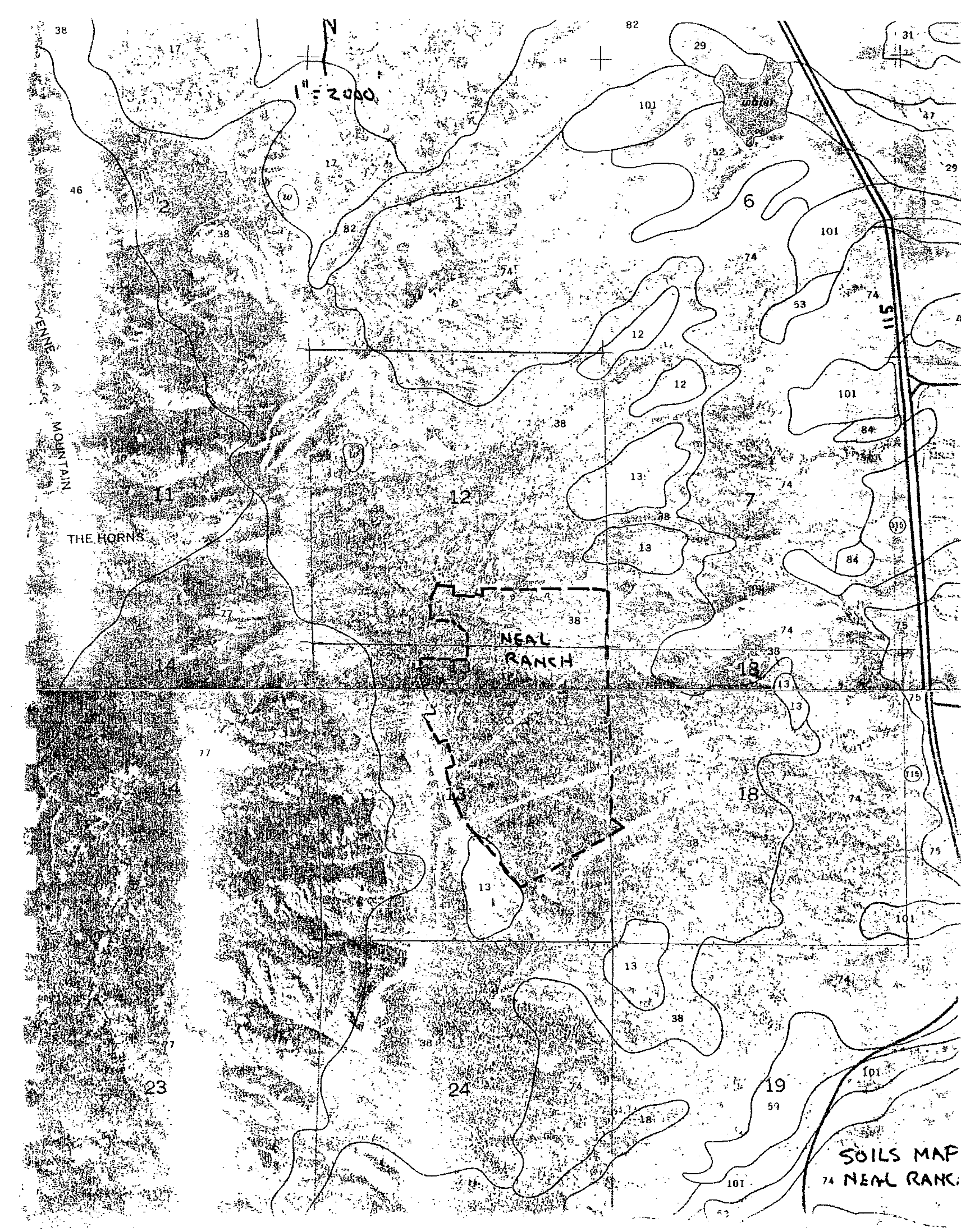
Hydrograph Point	100 Year Flows (CFS) Historic	Developed	Required Detention
2	244	264	39,549
4	51	88	74,007
6	161	232	146,018
8	664	705	82,622
10	394	488	232,045
13	532	690	370,905

It is recommended that all drainageways through the Neal Ranch be left in their natural condition. As development takes place, building sites should be located outside the drainageways. As road culverts are installed, they should be designed with erosion protection on the downstream side to reduce the velocities to the capability of the natural channel.

We do not recommend that detention storage be designed on the site. The slopes are steep and would not allow efficient storage. We recommend that combined detention ponds be constructed on Gates Land Company and J L Ranch properties adjacent to Highway 115. The highway fill provides an interim detention pond prior to the permanent pond construction.



N
1" = 2000
Water Tank
Cheyenne Mountain Zoo
The Horns
Canyon
Water Tank
Star Ranch
NEAL
RANCH
NORAD ROAD
Valley
115
VICINITY MAP
NEAL RANCH


N
1" = 2000'
NEAL RANCH
THE HORNS
MOUNTAIN
water
SOILS MAP
NEAL RANC

	MAJOR BASIN	SUB BASIN	AREA Planim. Read. AC	AREA MILE	BASIN LENGTH	BASIN HEIGHT	Tc	K	SOIL GROUP	DEV. TYPE	CURVE NO. HIST	CURVE NO. DEV	FLOW Q HIST	FLOW Q DEV	FLOW qp	q HIST	q DEV	
①	A	1	91.83	0.14348	4000	1945	0.10		D B		76	76	0.76	0.76	1000	109	109	5Y
													1.22	1.22		175	175	10Y
													2.21	2.21		317	317	100Y
	A	2	11.94	0.01865	1400	160	0.10		B	2 DU/A	55	66	0.10	0.37	1000	2	7	5Y
													0.28	0.69		5	13	10Y
													0.79	1.46		15	27	100Y
②	A	1&2	103.77	0.16214	5400	2105	0.14		D B		73	75	0.63	0.72	920	94	107	5Y
													1.05	1.17		157	175	10Y
													1.97	2.13		294	318	100Y
③	A	3	4.59	0.007172	1000	175	0.10		B		60	60	0.20	0.20	1000	1	1	5Yr
													0.45	0.45		3	3	10Y
													1.07	1.07		8	8	100
	A	4	45.0	0.070305	3000	290	0.15		B	2 DU/A	55	66	0.10	0.37	900	6	23	5Y
													0.28	0.69		18	44	10Y
													0.79	1.46		50	92	100Y
④	A	3&4	49.59	0.07748	4000	465	0.18		B		56	66	0.12	0.37	830	8	24	5Yr
													0.31	0.68		20	44	10Yr
													0.84	1.46		54	94	100Yr

HYDROLOGIC COMPUTATION – BASIC DATA

PROJ: NEAL RANCH MASTER DRAINAGE

By: JJW

Date: 6-10-87

24 HOUR DURATION

WEISS CONSULTING ENGINEERS, INC.

5 YR P = 2.6"
10 YR P = 3.3"
100 YR P = 4.6"

Page 1 of Pages 4

	MAJOR BASIN	SUB BASIN	AREA Planim Read AC	AREA MILE	BASIN LENGTH	BASIN HEIGHT	Tc	K	SOIL GROUP	DEV. TYPE	CURVE NO. HIST	CURVE NO. DEV	FLOW Q HIST	FLOW Q DEV	FLOW qp	q HIST	q DEV	
(5)	B	1	42.70	0.06672	3000	1530	0.10		D B		75	75	0.72	0.72	1000	48	48	5 YR
													1.17	1.17		78	78	10 YR
													2.13	2.13		142	142	100 YR
	B	2	50.51	0.078922	3400	430	0.15		B	2 DU/A	55	66	0.10	0.37	900	7	26	5 YR
													0.28	0.69		20	49	10 YR
													0.79	1.46		56	104	100 YR
	B	3	38.11	0.05954	3400	400	0.15		B	2 DU/A	55	66	0.10	0.37	900	5	20	5 YR
													0.28	0.69		15	37	10 YR
													0.79	1.46		42	78	100 YR
(6)	B	1,2&3	131.32	0.20519	6400	1980	0.18		D B		62	69	0.25	0.47	850	44	82	5 YR
													0.52	0.84		91	147	10 YR
													1.20	1.68		209	293	100 YR
(7)	B	4	206.61	0.32283	6600	2660	0.17		D B		89	89	1.55	1.55	860	430	430	5 YR
													2.18	2.18		605	605	10 YR
													3.34	3.39		941	941	100 YR
	B	5	51.42	0.08035	3600	405	0.17		B		55	66	0.10	0.37	860	7	26	5 YR
													0.28	0.69		19	48	10 YR
													0.79	1.46		55	101	100 YR
(8)	B	4&5	258.03	0.403117	10,200	3065	0.25		B D		82	84	1.07	1.20	760	328	368	5 YR
													1.42	1.77		496	542	10 YR
													2.72	2.91		833	(892)	100 YR

HYDROLOGIC COMPUTATION – BASIC DATA

PROJ: NEAL RANCH MASTER DRAINAGE By: JJW Date: 6-10-87

24 HOUR DURATION

WEISS CONSULTING ENGINEERS, INC.

5YR P: 2.6"
10YR P: 3.3"
100YR P: 4.6"

	MAJOR BASIN	SUB BASIN	AREA Planim. Read. AK	AREA MILE	BASIN LENGTH	BASIN HEIGHT	Tc	K	SOIL GROUP	DEV. TYPE	CURVE NO. HIST	CURVE NO. DEV	FLOW Q HIST	FLOW Q DEV	FLOW qp	q HIST	q DEV	
(9)	C	1	184.11	0.28768	6000	2400	0.15		D B		74	78	0.67	0.85	900	173	220	5 YR
													1.11	1.35		287	350	10 YR
													2.05	2.38		531	616	100 YR
	C	2	46.83	0.073175	2700	240	0.14		B		55	66	0.10	0.37	920	7	25	5 YR
													0.28	0.69		19	46	10 YR
													0.79	1.46		53	98	100 YR
(10)	C	1&2	230.94	0.360847	8700	2640	0.22		B D		70	76	0.50	0.76	790	143	217	5 YR
													0.89	1.22		254	348	10 YR
													1.75	2.21		499	630	100 YR

HYDROLOGIC COMPUTATION – BASIC DATA

PROJ: NEAL RANCH MASTER DRAINAGE

By: bgw

Date: 6-10-87

24 HOUR DURATION

WEISS CONSULTING ENGINEERS, INC.

5 YR P = 2.6"

10 YR P = 3.3"

100 YR P = 4.6"

Page 3 of Pages 4

	MAJOR BASIN	SUB BASIN	AREA Planim. Read. AS	AREA MILE	BASIN LENGTH	BASIN HEIGHT	Tc	K	SOIL GROUP	DEV. TYPE	CURVE NO. HIST	CURVE NO. DEV	FLOW Q HIST	FLOW Q DEV	FLOW qp	q HIST	q DEV	
(11)	D	1	158.40	0.2475	7200	2680	0.18		D B		76	78	0.76	0.85	850	160	179	5YR
													1.22	1.35		257	284	10YR
													2.21	2.38		465	501	100 YR
(12)	D	2	94.58	0.147785	5200	1470	0.16		D B		62	71	0.25	0.54	880	33	70	5YR
													0.52	0.94		68	122	10YR
													1.20	1.82		156	237	100YR
	D	3	64.28	0.100436	2800	235	0.15		B		55	66	0.10	0.37	900	9	33	5YR
													0.28	0.69		25	62	10YR
													0.79	1.46		71	132	100YR
	D	4	28.93	0.045196	2800	275	0.14		B		55	66	0.10	0.37	920	4	15	5YR
													0.28	0.69		12	29	10YR
													0.79	1.46		33	61	100YR
(13)	D	1,2,3,4	346.19	0.54092	10,000	2915	0.25		B D		67	73	0.40	0.63	760	164	259	5YR
													0.74	1.05		304	432	10YR
													1.53	1.97		628	810	100YR

HYDROLOGIC COMPUTATION – BASIC DATA

PROJ: NEAL RANCH MASTER DRAINAGE By: DJW Date: 6-10-87

24 HOUR DURATION

WEISS CONSULTING ENGINEERS, INC.

5YR P: 2.6"
10YR P: 3.3"
100YR P: 4.6"

OLIVER E. WATTS, PE-LS
CONSULTING ENGINEER, INC.
614 ELKTON DRIVE
COLORADO SPRINGS, COLORADO 80907
303-593-0173

June 16, 1987

Mr. G.J. Weiss, PE-LS
1815 N. Tejon Street
Colorado Springs, CO 80907

SUBJECT: Neal Ranch
Master Drainage Plan Computations

Dear Jerry

At your request, I have reviewed your basic hydrologic computations of the Neal Ranch, and I've computed the outfall hydrographs on the fully developed and historic basis, and the amount of detention required to hold the outfall to the historic peak level.

All of these computations are based on the current criteria of the 100-year, 24 hour storm, which will not change under the new, proposed criteria. The enclosed computations are provided, along with two of the basic runoff sheets, which have been used by me for all detention since I developed it for the 1977 Sand Creek basin study, and they have been approved for use by both the City and the County.

I have no problem with your basic hydrologic computations, although I had to extend the time of concentration to three decimal points for my purposes. Your peak runoff may be used for any of the individual basins. In computing the outfall hydrographs, however, it should be noted that the basins are very long and narrow, with extreme elevation differential. In these cases, it is best to combine hydrographs and provide hydrograph detention by channel storage, routing individual hydrographs downstream to combine them with the basic hydrograph of the downstream portions. In some basins, I have had to do this numerous times, but in this case, only two individual basins are required. The peak outfall runoff and required detention storage are as follows:

Hydrograph Point	Basins Used	Developed/Historic Peak Runoff - cfs	Detention - CF
2	A1, A2	264/244	39,549
4	A3, A4	88/ 51	74,007
6	B1, B2, B3	232/161	146,018
8	B4, B5	705/664	82,622
10	C1, C2	488/394	232,045
13	D1, D2, D3, D4	690/536	370,905

Please contact me if I may answer any questions.

Sincerely,

Oliver E. Watts
Consulting Engineer

Encl

TABULAR DISCHARGES FOR TYPE IIA STORM (csm/in) Tc = 0.10

Tt	5.0	5.5	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.2	7.5	8.0	8.5	9.0	10.0	12.0
0.00	14	38	275	937	741	562	219	105	76	61	47	36	31	30	29	28	24	22	19	14	10	10	10
0.25	12	22	39	82	243	576	648	542	429	222	116	79	59	41	35	31	28	22	18	16	14	12	8
0.50	9	16	21	25	39	78	215	443	548	539	505	291	153	97	68	47	34	26	20	16	14	12	9
0.75	7	12	15	17	20	24	38	73	143	292	456	487	449	424	257	142	73	64	22	18	15	11	8
1.00	5	9	11	12	14	16	19	24	37	67	122	244	393	444	426	367	230	84	37	24	16	12	8
1.50	4	6	7	8	8	9	10	11	13	15	17	22	33	53	115	217	388	357	156	62	32	19	11
2.00	2	4	4	5	5	6	6	7	8	8	9	10	12	13	16	20	55	224	351	141	80	35	16
2.50	2	4	4	5	5	5	5	6	6	6	7	7	7	8	9	9	12	31	223	324	149	57	24
3.00	2	2	3	3	4	4	5	5	5	5	6	6	6	7	7	7	7	10	37	220	304	74	34
3.50	1	2	2	2	3	3	3	3	4	4	4	5	5	5	5	6	6	6	13	54	287	158	39
4.00	0	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	4	5	6	13	62	274	39

Oliver E. Watts
Consulting Engineer
Colorado Springs

TABULAR DISCHARGES FOR TYPE IIA STORM (csm/in) Tc = 0.20 hours

Tt	5.0	5.5	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	7.0	7.2	7.5	8.0	8.5	9.0	10.0	12.0
0.00	15	38	200	504	794	500	309	151	85	57	42	37	30	27	26	25	23	22	20	15	10	10	10
0.25	12	22	32	59	158	403	597	625	379	249	145	86	57	40	34	29	25	20	16	15	12	13	8
0.50	9	16	21	24	33	56	146	328	485	544	388	289	182	110	69	46	33	24	18	14	12	11	8
0.75	7	12	15	17	20	23	32	55	130	273	486	490	375	307	210	132	64	31	20	15	13	10	7
1.00	6	9	12	13	14	16	19	23	31	52	93	194	334	422	451	333	217	91	34	20	14	10	7
1.50	3	6	7	8	8	9	10	12	13	15	17	21	28	44	88	169	327	398	124	52	30	16	9
2.00	2	4	5	5	5	6	7	7	8	8	10	10	12	14	16	23	54	190	362	131	55	25	12
2.50	1	2	3	3	3	4	4	5	5	5	6	7	7	8	8	10	15	32	198	336	136	37	16
3.00	0	0	1	1	2	2	3	3	3	3	4	4	5	5	5	6	7	12	38	201	315	64	21
3.50	0	0	0	1	1	1	2	2	2	2	3	3	4	4	4	5	6	7	15	46	299	140	25
4.00	0	0	0	0	0	1	1	1	1	1	2	2	2	3	3	3	4	5	7	15	52	285	32

Oliver E. Watts
Consulting Engineer
Colorado Springs

Oliver E. Watts
CONSULTING ENGINEER

Project Neal Ranch Master Drainage
Calc. by OEWatts date 6-16-87
Checked by ______ date ______

HYDROGRAPH DEVELOPMENT

100 yr 24 hr IIa Storm $q_p = KAQ$
I = 4.6" Re: GJ Weiss Basin Comp's of 6.10.87 (4 pages)

HYDROGRAPH PT #2

Basin A-1 + A-2
A = 0.16214 SM Tc = 0.140 CN = 73 Historic 75 Developed
Q = 1.97 Historic 2.13 Developed
Incremental Runoff CF = $\frac{\Sigma CFS \Delta T_{HRS}}{2} \times 3600$ $q_p = 0.3194K$ (11) $q_p = 0.3454K$ (12)

$T_b = 2.67 T_p$

TIME HRS	Developed K	Developed q_p	Historic q_p	Δq_p	Inc Runoff CF Inc	Inc Runoff CF Σ
0	0	0	0	0		0
					3362	
5.0	14.4	4.99	4.60	0.37		3362
					1220	
5.5	38	13.12	12.14	0.99		4582
					2645	
5.7	245	84.61	78.26	6.36		7227
					4711	
5.8	763.8	263.78	243.97	19.81		11,938 ← q_p
					7125	
5.9	762.2	263.23	243.46	19.77		19,063
					6067	
6.0	537.2	185.53	171.59	13.94		25,130
					3700	
6.1	255	88.07	81.45	6.62		28,830
					1768	
6.2	123.4	42.62	39.42	3.20		30,598
					948	
6.3	79.6	27.49	25.43	2.06		31,546
					648	
6.4	59.4	20.51	18.97	1.54		32,194
					487	
6.5	45	15.54	14.37	1.17		32,681
					381	
6.6	36.4	12.57	11.63	0.94		33,062
					312	
6.7	30.6	10.57	9.77	0.79		33,374
					277	
6.8	28.8	9.95	9.20	0.75		33,651
					265	
6.9	27.8	9.60	8.88	0.72		33,916
					255	
7.0	26.8	9.26	8.56	0.70		34,170

Project Neal Ranch
Calc. by OEW date 6.16
Checked by ______ date ______

Oliver E. Watts
CONSULTING ENGINEER

PT#2 - cont

Time HRS	K	Dev q_p	Hist q_p	Δ q_p	Inc Runoff-CF Inc	Σ
					1144	
7.5	22	7.60	7.03	0.57		35,314
					966	
8.0	19.4	6.70	6.20	0.50		36,280
					233	
9.0	10	3.45	3.19	0.26		36,513
					3035	
15.49	0	0	0	0		39,549 ← (2)

HYDROGRAPH PT#4

Basins A-3 + A-4
A = 0.07748 sm   Tc = 0.177 hrs (10)   CN: 56 historic   66 Developed
Q: 0.84 historic   1.46 Developed
q_p = 0.0651 K (12)   0.1131 K (11)

TIME - HRS.	K	q_p Dev	q_p Hist	Δ q_p - CFS -	Inc Runoff - CF Inc	Σ
0	0	0	0	0	0	0
					6386	
5.0	14.77	1.67	0.96	0.71		6386
					2282	
5.5	38	4.30	2.47	1.83		8668
					5082	
5.7	255.75	28.93	16.65	12.29		13,749
					7431	
5.8	603.59	68.28	39.28	29.00		21,180
					11,980	
5.9	781.81	88.44	50.88	37.56		33,161 ← q_p
					11,207	
6.0	514.26	58.17	33.47	24.70		44,368
					6939	
6.1	288.30	32.61	18.76	13.85		51,307
					3707	
6.2	140.42	15.88	9.14	6.75		55,014
					1932	
6.3	82.93	9.38	5.40	3.98		56,946
					1217	
6.4	57.92	6.55	3.77	2.78		58,163
					874	
6.5	43.15	4.88	2.81	2.07		59,037
					691	
6.6	36.77	4.16	2.39	1.77		59,727
					580	

Oliver E. Watts
CONSULTING ENGINEER

Project: Neal Ranch
Calc. by: OEW date: 6.16
Checked by: date:

PT #4 - Cont

TIME -HRS-	K	qp Dev	qp Hist	Δ qp -cfs-	Inc Runoff - CF Inc	Σ
6.7	30.23	3.42	1.97	1.45		60,307
					500	
6.8	27.69	3.13	1.80	1.33		60,808
					470	
6.9	26.69	3.02	1.74	1.28		61,278
					453	
7.0	25.69	2.91	1.67	1.23		61,731
					2058	
7.5	22	2.49	1.43	1.06		63,789
					1809	
8.0	19.77	2.24	1.29	0.95		65,597
					2575	
9.0	10	1.13	0.65	0.48		68,172
					5835	
15.75	0	0	0	0		74,007 ← (4)

HYDROGRAPH PT #6

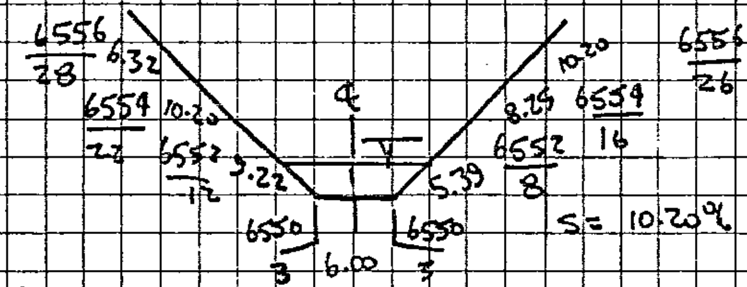
Basins B1 + B2 + B3
Tc: 0.10 0.151 0.155

Basin	A-SM	Developed CN	Developed Q	Developed qp	Dev'l Historic CN	Dev'l Historic Q	Dev'l Historic qp
B1	0.06672	75	2.13	0.1421K	75	2.13	0.1421K (11)
B2	0.07892	55	0.79	0.0623K (12)	66	1.46	0.1152K (14)
B3	0.05954	55	0.79	0.0470K (13)	66	1.46	0.0869K (15)

Offset Basin B1 By Travel Time in channel in Basin B2

Average Cross Section is @ Inv El 6550

Ave qp = B1 + B2 Dev'p
A = 0.1456
CN = 70
Q = 1.75
qp = Tc = 0.175
K = 850
qp = 217 CFS



S = 10.20%

n = 0.060
Rocky, Dry, Brushy, Windy

For d:

Elev	A	WP	R	Q	V
6554	84.00	39.06	2.156	1107	
6552	26.00	20.61	1.2615	240.1	9.23

$$\text{Basin } B_1: T_T = \frac{3420'}{9.23 \times 3600} = 0.1029 \text{ hrs For Basin B1}$$

Oliver E. Watts
CONSULTING ENGINEER

Project: New Ranch
Calc. by: OEW date: 6.16
Checked by: ______ date: ______

HP#6 - cont

TIME -HRS-	B1 K	B1 q_p	B2 K	B2 q_p Dev'p	B2 q_p Hist	B3 K	B3 q_p Dev'p	B3 q_p Hist	Peak Total q_p Dev'p	Peak Total q_p Hist	q_p Δ	Increase Runoff -CF- (increment)	Increase Runoff -CF- (cumulative)
0	0	0	0	0	0	0	0	0	0	0	0		
5.0	13.18	1.87	14.51	~~0.90~~ 1.67	0.90	14.55	~~0.68~~ 1.26	0.68	~~3.46~~ 4.81	3.46	1.35	12159	12,15
5.5	31.41	4.46	38	4.38	2.37	38	3.30	1.79	12.14	8.62	3.53	4389	16,54
5.7	177.86	25.27	236.75	27.27	14.75	233.75	20.31	10.99	72.86	51.01	21.85	9137	25,68
5.8	585.08	83.14	716.17	82.50	44.62	698.85	60.73	32.85	226.37	160.60	65.77	15771	41,45
5.9	536.02	76.17	768.03	88.48	47.85	770.15	66.93	36.20	231.57	160.21	71.36	24683	66,14
6.0	567.76	80.68	530.38	61.10	33.04	527.90	45.87	20.11	187.65	133.83	53.82	22533	88,6
6.1	395.58	56.21	264.90	30.52	16.50	268.50	23.33	12.62	110.06	85.33	24.73	14138	102,8
6.2	284.87	40.48	128.46	14.80	8.00	130.30	11.32	6.12	66.60	54.61	11.99	6610	109,43
6.3	221.29	31.45	80.59	9.28	5.02	80.95	7.03	3.80	47.76	40.27	7.49	3507	112,93
6.4	127.27	18.08	58.96	6.79	3.67	58.80	5.11	2.76	29.99	24.52	5.46	2332	115,27
6.5	75.40	10.71	44.45	5.12	2.77	44.25	3.85	2.08	19.68	15.56	4.12	1724	116,99
6.6	53.70	7.63	36.51	4.21	2.27	36.55	3.18	1.72	15.01	11.62	3.39	1352	118,34
6.7	42.52	6.04	30.49	3.51	1.90	30.45	2.65	1.43	12.20	9.37	2.83	1119	119,46
6.8	34.53	4.91	28.47	3.28	1.77	28.35	2.46	1.33	10.65	8.01	2.64	984	120,44
6.9	31.47	4.47	27.47	3.16	1.71	27.35	2.38	1.29	10.01	7.47	2.54	933	121,38
7.0	29.23	4.15	26.47	3.05	1.65	26.35	2.29	1.24	9.49	7.04	2.45	899	122,28
7.5	22	3.13	22	2.53	1.37	22	1.91	1.03	7.57	5.53	2.04	4042	126,32
8.0	18.59	2.64	19.51	2.25	1.22	19.55	1.70	0.92	6.59	4.78	1.81	3467	129,79
9.0	11.65	1.66	10	1.15	0.62	10	0.87	0.47	3.68	2.75	0.93	4927	134,71
6.49 15.49	0	0		0.04	0.02		0.03	0.02	0.08	0.04	0.04	11283	146,0
0.26 15.75	0	0	0	0	0	0	0	0	0	0	0	18	146,018

Oliver E. Watts
CONSULTING ENGINEER

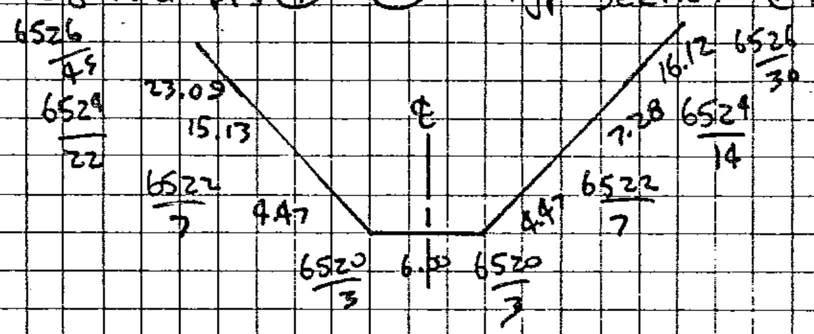
Project: Neal Ranch
Calc. by: OEW date: 6-16
Checked by: ______ date: ______

HYDROGRAPH POINT #8

Basin	Tc-hr	A-SM	Developed CN	Developed Q	Developed qp	Historic CN	Historic Q	Historic qp
B-4	0.161	0.32283	89	3.39	1.0944 K (11)	89	3.39	(11)
B-5	0.165	0.08035	66	1.46	0.1173 K (12)	55	0.79	0.0635 K (13)
Σ ≠	0.252	0.4032	84	2.91				

→ K = 760 qp = 892 CFS ≠

For Time of Travel Pts (7) – (8) Typ Section @ Elev 6520



S = 8.93 %
n = 0.060 clocked, Brushy

Ford:

Elev	A	WP	R	Q	V - fps
6522	20.00	14.94	1.338	179.8	
6524	70.00	37.35	1.874	787.5	
6526	181.00	76.56	2.364	2377	
24.13	77.30			892	11.54

Basin B4 $T_B = \frac{3780}{11.54 \times 3600} = 0.0910$ hrs

TIME -HRS-	Basin B4 K	Basin B4 qp	Developed Basin B5 K	Developed Basin B5 qp	Total qp -CFS	Historic B5 qp	Historic Σ qp	Δ qp -CFS	Increased Runoff-CF Inc	Increased Runoff-CF Σ
0	0	0	0	0	0	0	0	0		0
5.8	13.66	14.94	14.65	1.72	16.67	0.93	15.87	0.80	7179	7179
5.5	32.18	35.21	38	4.46	39.67	2.41	37.63	2.04	2557	9736
5.7	158.46	173.42	226.25	26.54	199.95	14.37	187.79	12.17	5115	14,851
5.8	452.71	495.45	655.55	76.90	572.35	41.63	537.07	35.27	8540	23,391
5.9	561.44	614.44	775.45	90.96	705.40	49.24	663.68	41.72	13,858	37,250
6.0	504.64	552.27	521.70	61.20	613.47	33.13	585.41	28.06	12,561	49,811
6.1	492.06	538.51	277.50	32.55	571.06	17.62	556.13	14.93	7739	57,550
6.2	300.32	328.68	134.90	15.82	344.50	8.57	337.24	7.26	3995	61,545
6.3	283.13	309.86	79.15	9.28	319.14	5.03	314.88	4.26	2073	63,618
									1333	

Oliver E. Watts
CONSULTING ENGINEER

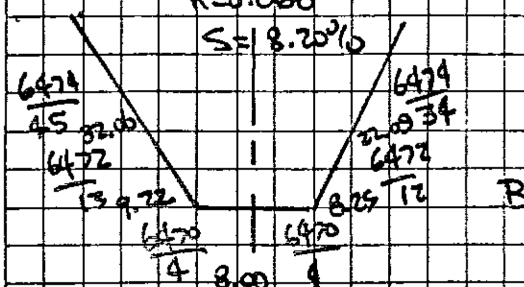
Project: Neil Ranch
Calc. by: OEW date: 6-16
Checked by: ________ date: ________

HP# 8 - CONT	Developed					Historic		Δ	Increased Runoff - CF	
TIME	Basin B4		Basin B5		Total	Basin B5	Total	q_p		
- HRS.	K	q_p	K	q_p	q_p	q_p	q_p	- CFS	Inc	Σ
6.4	124.04	135.75	58.4	6.85	142.60	3.71	139.46	3.14		64,951
									989	
6.5	76.61	83.84	43.75	5.13	88.97	2.78	86.62	2.35		65,940
									778	
6.6	53.59	58.65	36.65	4.30	62.95	2.33	60.98	1.97		66,718
									648	
6.7	40.36	44.17	30.35	3.56	47.77	1.93	46.10	1.63		67,366
									566	
6.8	32.61	35.69	28.05	3.29	38.98	1.78	37.47	1.51		67,932
									535	
6.9	29.79	32.61	27.05	3.17	35.78	1.72	34.32	1.46		68,467
									515	
7.0	28.47	31.16	26.05	3.06	34.21	1.65	32.81	1.40		68,982
									2329	
7.5	21.22	23.23	22	2.58	25.81	1.40	24.62	1.19		71,311
									2019	
8.0	17.81	19.49	19.65	2.30	21.79	1.25	20.74	1.05		73,330
									2850	
9.0	11.02	12.06	10	1.17	13.23	0.64	12.70	0.53		76,180
									6442	
15.75	0	0	0	0	0	0	0	0		82,622 ← (8)

HYDROGRAPH POINT NO. 10 :

		Basin No	C1	C2
		Tc	0.50	0.145
		A-SM	0.28768	0.073175
Developed:		CN	78	66
		Q	2.38	1.46
		q_p	0.6847 K (11)	0.1068 K (12)
Historic:		CN	74	55
		Q	2.05	0.79
		q_p	0.5897 K (13)	0.0578 (14)

Routing C1 To HP#10: q_p = 616 CFS ± EL 6470 Typical



WSEL	A	WP	R	Q	V
6474	137.00	79.62	1.7207	1395	
6472	33.00	25.47	1.2956	278.1	
7260	64.46			616	9.56

Basin C1: $T_T = \frac{2640}{9.56 \times 3600} = 0.0767$ hrs

Oliver E. Watts
CONSULTING ENGINEER

Project: Neil Ranch
Calc. by: OEW date: 6.16
Checked by: ________ date: ________

HP #10 - Cont

TIME HRS	Developed q_p K C_1	K C_2	C C_1	C C_2	Σ	HISTORIC q_p C_1	C_2	Σ	Δ q_p	Increm. CF	Cumulative CF
0	13.16	14.45	9.01	1.54	10.55	7.76	0.84	8.60	1.96		0
5.0	0	0	0	0	0	0	0	0	0	17,608	17,608
5.5	33.09	38	22.66	4.06	26.71	19.51	2.20	21.71	5.00	6268	23,876
5.7	175.50	241.25	120.16	25.77	145.93	103.49	13.94	117.44	28.49	12,057	35,933
5.8	520.98	742.15 (~~356.3~~)	356.72	79.26	435.98	307.22	42.90	350.12	85.86	20,583	56,516
5.9	593.46	764.85	406.34	81.69	488.03	349.96	44.21	394.17	93.86	32,349	88,865
6.0	518.26	534.10	354.85	57.04	411.90	305.62	30.87	336.49	75.41	30,468	119,333
6.1	374.04	259.50	256.11	27.71	283.82	220.57	15.00	235.57	48.25	22,259	141,592
6.2	267.82	125.70	183.38	13.42	196.80	157.93	7.27	165.20	31.60	14,373	155,965
6.3	179.80	80.05	123.11	8.55	131.66	106.03	4.63	110.66	21.00	9468	165,433
6.4	113.18	59.20	77.49	6.32	83.81	66.74	3.42	70.16	13.65	6237	171,670
6.5	70.90	44.75	48.54	4.78	53.32	41.81	2.59	44.40	8.93	4064	175,734
6.6	50.62	36.45	34.66	3.89	38.55 (~~29.85~~)	29.85 (~~2.11~~)	2.11 (~~31.96~~)	31.96	6.59	2794	178,528
6.7	38.94	30.55	26.66	3.26	29.93	22.96	1.77	24.73	5.20	2122	180,650
6.8	32.18	28.65	22.04	3.06	25.10	18.98	1.66	20.63	4.46	1739	182,389
6.9	29.65	27.65	20.30	2.95	23.25	17.48	1.60	19.08	4.17	1554	183,943
7.0	27.57	26.65	18.88	2.85	21.73	16.26	1.54	17.80	3.93	1458	185,401
7.5	21.69	22	14.85	2.35	17.30	12.79	1.27	14.06	3.14	6364	191,765
8.0	18.73	19.47	12.83	2.08	14.90	11.05	1.12	12.17	2.73	5287	197,052
10.0	10.77	10 (~~7.37~~)	7.37	1.07	8.44	6.35	0.58	6.93	1.51	15,269	212,321
12.0	9.39	10	6.43	1.07	7.49	5.54	0.58	6.12	1.38	10,402	222,723
15.75	0	0	0	0	0	0	0	0	0	9322	232,045

(10)

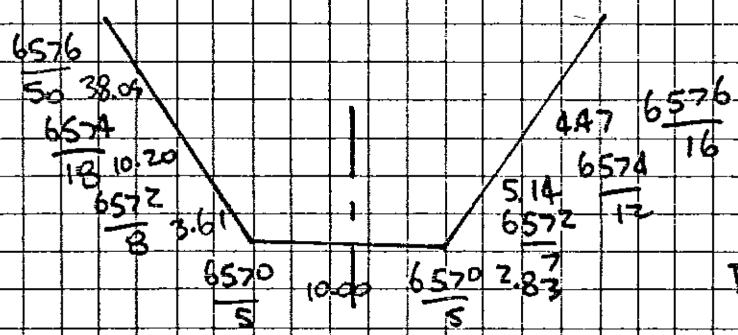
Project Neil Ranch
Calc. by OEW date 6-16
Checked by ______ date ______

Oliver E. Watts
CONSULTING ENGINEER

HYDROGRAPH POINT NO 13

Basin		D1	D2	D3	D4
	Tc-hr	0.178	0.154	0.152	0.144
	A SM	0.2475	0.14785	0.100436	0.045196
~~Developed~~ Historic	CN	76	62	55	55
	Q	2.21 (12)	1.20 (13)	0.79 (14)	0.79 (15)
	qp	0.5470 K (11)	0.1773K (12)	0.0793K (13)	0.0357K (14)
~~Historic~~ Developed	CN	78	71	66	66
	Q	2.38 (16)	1.82 (17)	1.46 (18)	1.46 (19)
	qp	0.5891K (15)	0.2690K (16)	0.1466K (17)	0.0660K (18)

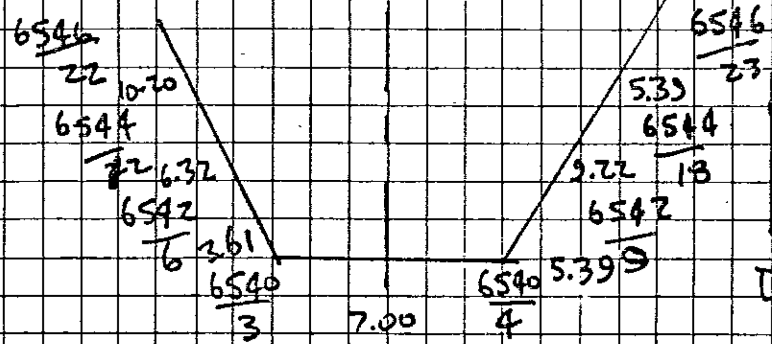
Routing D1 To HP#13 qp = 501 cfs Elev 6570 Typ
n = 0.060 S = 9.09%



WSEL	A	WP	R	Q	V
6574	70.00	31.78	2.2026	885	
6572	25.00	16.44	1.5207	247	
72.80	42.925			501	11.67

$D_1: T_T = \frac{2600}{11.67 \times 3600} = 0.0619$ hrs (10)

Routing D2 To HP#13 qp = 237 cfs Elev 6540 Typical
n = 0.060 S = 8.20%



WSEL	A	WP	R	Q	V
6544	67.00	31.54	2.1243	785	
6542	22.00	16.00	1.3750	193	
42.15	25.35			237	9.35

$D_2: T_T = \frac{2860}{9.35 \times 3600} = 0.0850$ hrs (11)

Hyd # 13 - Cont

TIME	K				Historic Developed Q_p					Developed Historic Q_p					Δ	Σ
HRS	D1	D2	D3	D4	D1	D2	D3	D4	Σ	D1	D2	D3	D4	Σ	Q_p	CF
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.0	14.09	13.68	14.52	14.44	7.71	2.42	1.15	0.52	~~12.44~~ 11.80	8.30	3.68	2.13	0.95	15.06	3.26	29,340 / 29,340
5.5	34.03	32.56	38	38	18.62	5.77	3.01	1.36	28.76	20.05	8.76	5.57	2.51	36.88	8.12	10,244 / 39,584
5.7	171.19	166.76	236.00	242.00	93.64	29.57	18.71	8.64	150.56	100.84	44.86	34.60	15.97	196.28	45.71	19,380 / 58,964
5.8	464.02	487.81	711.84	746.48	253.82	86.49	56.45	26.65	423.41	273.35	131.22	104.36	49.27	558.20	134.79	32,490 / 91,454
5.9	~~617.90~~ 632.39	575.02	768.56	764.32	~~337.88~~ 345.92	101.95	60.95	27.29	536.10	372.54	154.68	112.67	50.45	690.34	154.24	52,025 / 143,479
6.0	495.67	513.64	529.76	534.72	271.13	91.07	42.01	19.09	~~218.93~~ 423.30	292.00	138.17	77.66	35.29	543.12	119.82	49,331 / 192,810
6.1	368.19	387.54	265.80	258.60	201.40	68.71	21.08	9.23	300.42	216.90	104.25	38.97	17.07	377.18	76.76	35,385 / 228,195
6.2	256.23	285.17	128.92	125.24	140.16	50.56	10.22	4.47	205.41	150.95	76.71	18.90	8.27	254.82	49.41	22,71[illegible] / 250,906
6.3	118.67	190.01	80.68	79.96	64.91	33.69	6.40	2.85	107.85	69.91	51.11	11.83	5.28	138.13	30.27	14,343 / 265,249
6.4	103.73	119.25	58.92	59.24	56.74	21.14	4.67	2.11	84.67	61.11	32.08	8.64	3.91	105.78	21.06	9,240 / 274,489
6.5	66.75	73.99	44.40	44.80	36.51	13.12	~~4.9~~ 3.52	1.60	54.75	39.32	19.90	6.51	2.96	68.69	13.94	6300 / 280,789
7.0	26.59	28.72	26.44	26.68	~~4.72~~ 14.54	5.09	2.10	0.95	~~12.86~~ 22.69	15.66	7.73	3.98	1.76	~~41.89~~ 29.03	~~16.17~~ 6.34	18,[illegible]2 / [illegible]
8.0	18.95	18.65	19.52	19.44	10.37	3.31	1.55	0.69	15.92	11.16	5.02	2.86	1.28	20.32	4.40	19337 / 318,378
9.0	10.60	10.99	10	10	5.86	1.95	0.79	0.36	8.90	6.24	2.96	1.47	0.66	11.33	2.43	12288 / 330,666
12.0	9.50	9.32	10	10	5.20	1.65	0.79	0.36	8.00	5.60	2.51	1.47	0.66	10.23	2.23	25,174 / 355,840
15.753															0	15,065 / 370,905

Oliver E. Watts
CONSULTING ENGINEER

Project Ne-Ranch
Calc. by [illegible]
Checked by
date 6-16
date