REPORT OF INVESTIGATION

UTAH GEOLOGICAL AND MINERAL SURVEY

No. 188

ASSESSMENT OF POTENTIAL DAMAGE TO REAL PROPERTY FROM MAJOR DEBRIS FLOW IN STANDEL COVE SUBDIVSION
Salt Lake County, Utah

For the Salt Lake County Commission

by
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Roy S. Baty, Jr.

October 1984

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by
Bruce N. Kaliser[1]
Roland W. Jeppson[2]
Roy S. Baty, Jr.[3]

Introduction

During May of 1984, two small debris flows occurred in Johnson's Hollow of Emigration Canyon (Figure 1 - Location Map, and Figure 2 - Vicinity Map). These flows passed through Standel Cove subdivision and into Emigration Canyon stream without any significant damage to the homes or drainage structures. Shortly after these events, an investigation revealed three large landslides located in Johnson's Hollow approximately 3/4 mile above the Standel Cove subdivision. The landslides have the potential of becoming large debris flows in the event precipitation produces sufficient saturation in the unstable masses.

Because of potential risk from the landslides, residents of Standel Cove Subdivision have claimed that their property has been devalued and have requested a reduction in county property taxes. In order to provide data to evaluate these claims, the Utah Geological and Mineral Survey was requested to assess the potential damage to the homes and property in Standel Cove subdivision. The assessment was specifically limited to potential damage to real property and therefore excludes risk to personal property and life.

[1]Utah Geological and Mineral Survey
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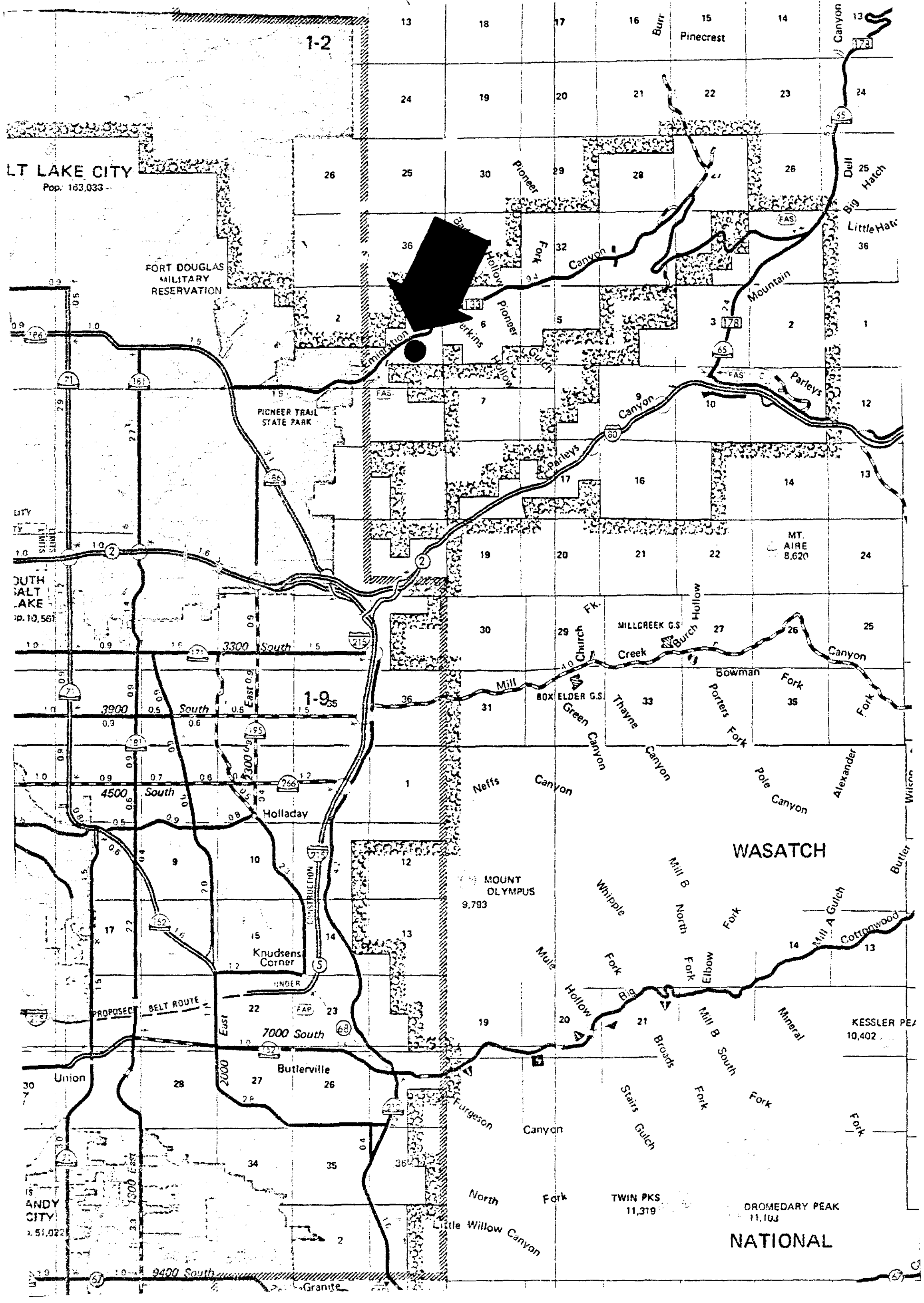
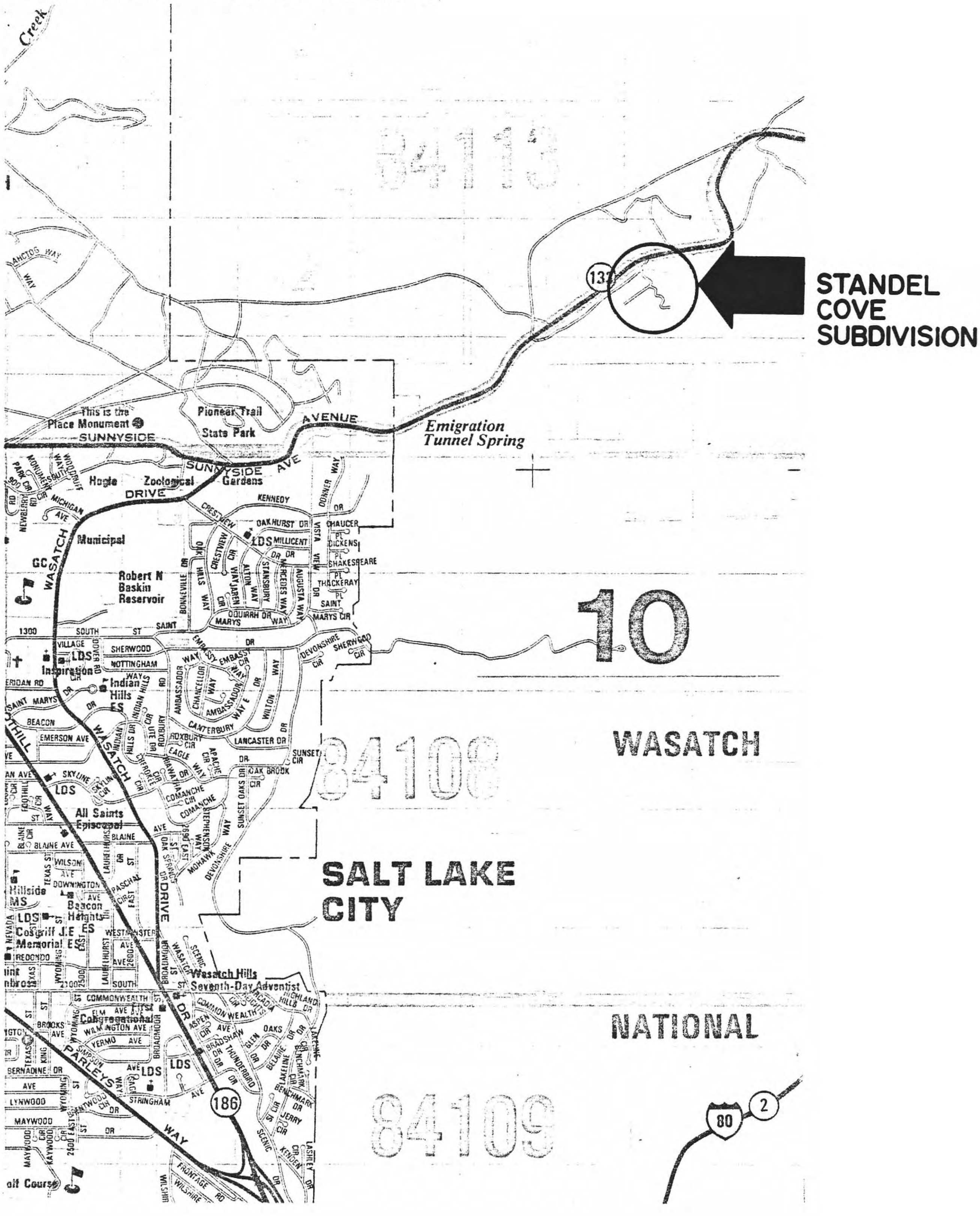


GENERAL HIGHWAY MAP, S.L.CO., U.D.O.T., 1981

SHEET NO. 18

SCALE 1" = 10,560'

FIGURE 1: LOCATION MAP



1983 CONTINENTAL GLOBAL CORPORATION

SCALE 1" = 2,400'

FIGURE 2 : VICINITY MAP

Aerial photographs in the Utah Geological and Mineral Survey files, documenting 1983 events, reveal the presence of one debris slide scar but apparently its effects escaped the notice of Standel Cove residents. No local residents recollect ever having seen water, mud or debris flowing out of the drainage subsequent to any previous runoff or cloudburst event.

Following the events, aerial and ground reconnaissance by the Utah Geological and Mineral Survey and the Salt Lake County Engineering Divison have confirmed the presence of a significant hazard in the destabilized ancient landslide terrain at the head of Johnson's Hollow. At this writing, we are aware of four distinct slump type landslide masses.

Landslide Situation

The largest and easternmost of these slump type ground failures is approximately 600 feet long and 150 feet wide. Average depth to the failure surface is unknown, but it is likely to be at least 15 feet. At the toe of this mass there is a typical shallow debris slide failure 110 feet long, 40 feet wide, and with an average depth of 3 feet. This failure is on a slope of about 1-1/2 horizontal to 1 vertical. As the landslide continues to move, it will continue to maintain an oversteepened unstable toe slope (see Figure 3 for Schematic).

To the west and approximately at right angles to the largest landslide is another landslide approximately 145 feet long and 40 feet wide. This landslide mass has not matured to the extent of the two slides to its east and west; nevertheless, it poses a clear threat to

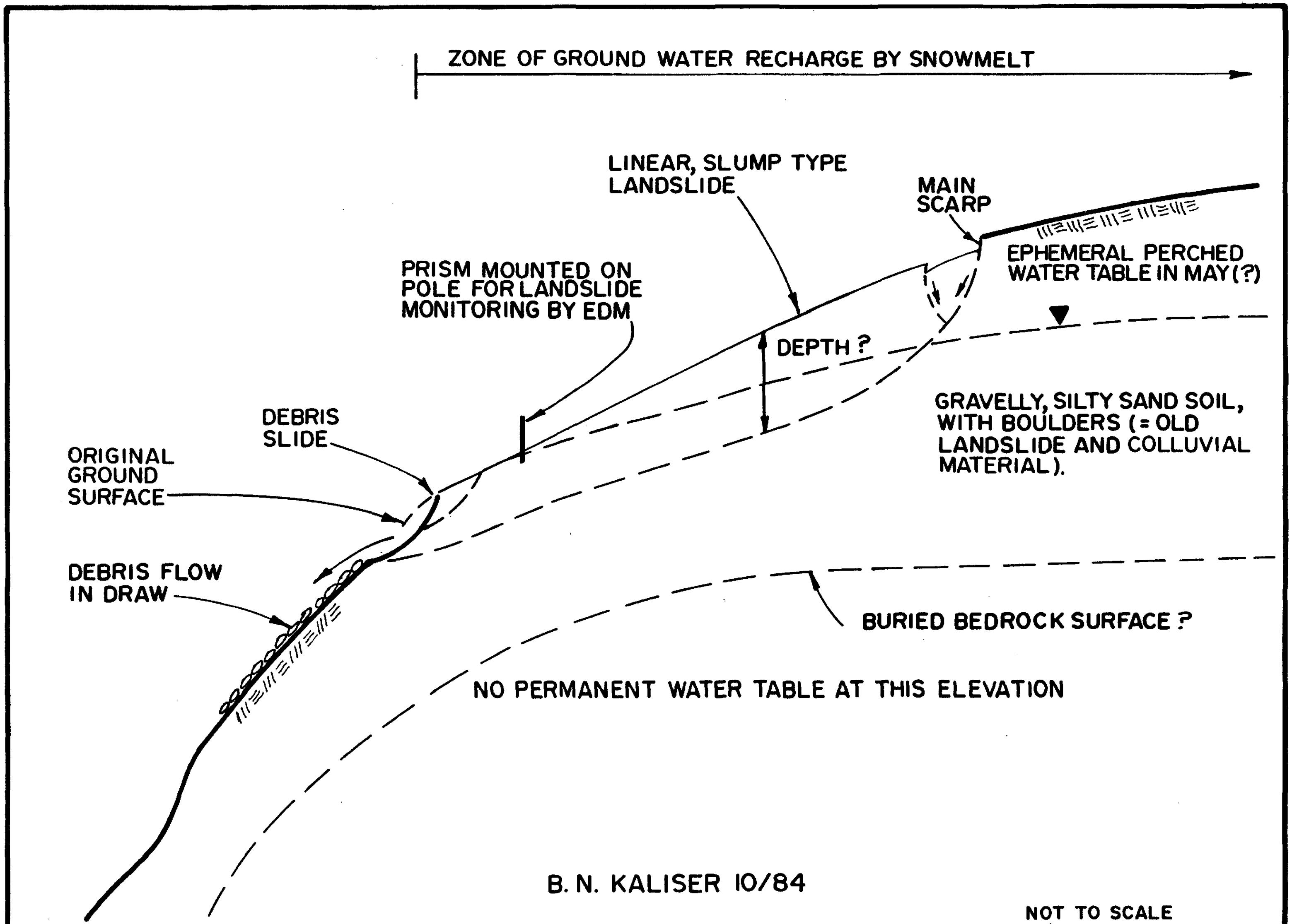


FIG. 3 LANDSLIDE SITUATION IN CROSS SECTION
JOHNSON'S HOLLOW, SALT LAKE COUNTY

create a debris slide and debris flow at its toe in another Spring snowmelt season. The bottom half of the slide is on a slope of 2 to 1 to 1-3/4 to 1. There is clear evidence of an older trace of a landslide scarp 80 feet farther upslope.

About 160 feet east of the old scarp, evidence has recently (Fall, 1984) been discovered of a less well defined landslide which moved in the Spring of 1984.

The fourth landslide mass is well defined and located close to the center of the bowl-like feature at the top of Johnson's Hollow. It is about 100 feet long and in a separate draw which has its confluence with the eastern main draw where the other slides occur. Two debris flows in 1984 originated from a separate debris slide at the toe of this landslide mass. It appears that the lower debris slide, with a volume of about 140 cubic yards, occurred first, followed by the upper, with a volume of about 75 cubic yards. These shallow slides are on slopes of about 2 to 1 and 1-1/4 to 1, respectively, and each is being further deformed and oversteepened as the lower landslide mass moves down slope.

Additional ground cracking has been observed in the Johnson's Hollow topographic bowl which is indicative of an even wider zone of instability. It is likely that the total area of instability will increase if the wet cycle continues with the possible development of additional distinct landslide masses.

Debris flow events are very probable in Johnson's Hollow in the future in our opinion. The probability is high that one or more of these will reach Standel Cove subdivision. The probability is lower, but nevertheless a major concern, that a significant debris flow will inundate portions of the subdivision. Our damage assessment assumes that this will occur.

Procedure of Assessment

A three man multi-disciplinary team (the authors of this report) was formed consisting of an engineering geologist, a civil/municipal engineer and a hydraulic/hydrologic engineer. Two of the team members had prior knowledge of the landslide terrain in Johnson's Hollow and the drainage below. All three people participated jointly in a traverse of the lower 1,000 feet of the drainage and the Standel Cove subdivision lots.

The team decided upon a rating system of 0 (no risk) to 100 (total destruction) for evaluating the risk to each home and its appurtenances. At the time of an on-site inspection, considerations were given to:

1. Location and orientation of the homes with respect to the potential debris flow path.
2. Construction type of each home and other structures (wells, fences, etc.,) on the property.
3. Location and area of glass surfaces.
4. Subsurface levels in the home.
5. Landscaping and natural vegetation.
6. Outbuildings.

In the field, each individual recorded his determined value following an inspection of the lot, and all three were averaged in order to arrive at a single value for the given property. In no instance was there a significant discrepancy in the three values. Not all properties in the subdivision had visible addresses so the "Sidwell" number was taken from the County Assessor's map (Figure 4) to identify the parcels.

The team hydrologist has simulated debris flows using a computer model (Appendix A). This technique indicates the travel time and thickness of debris flow surges that might reach Standel Cove subdivision.

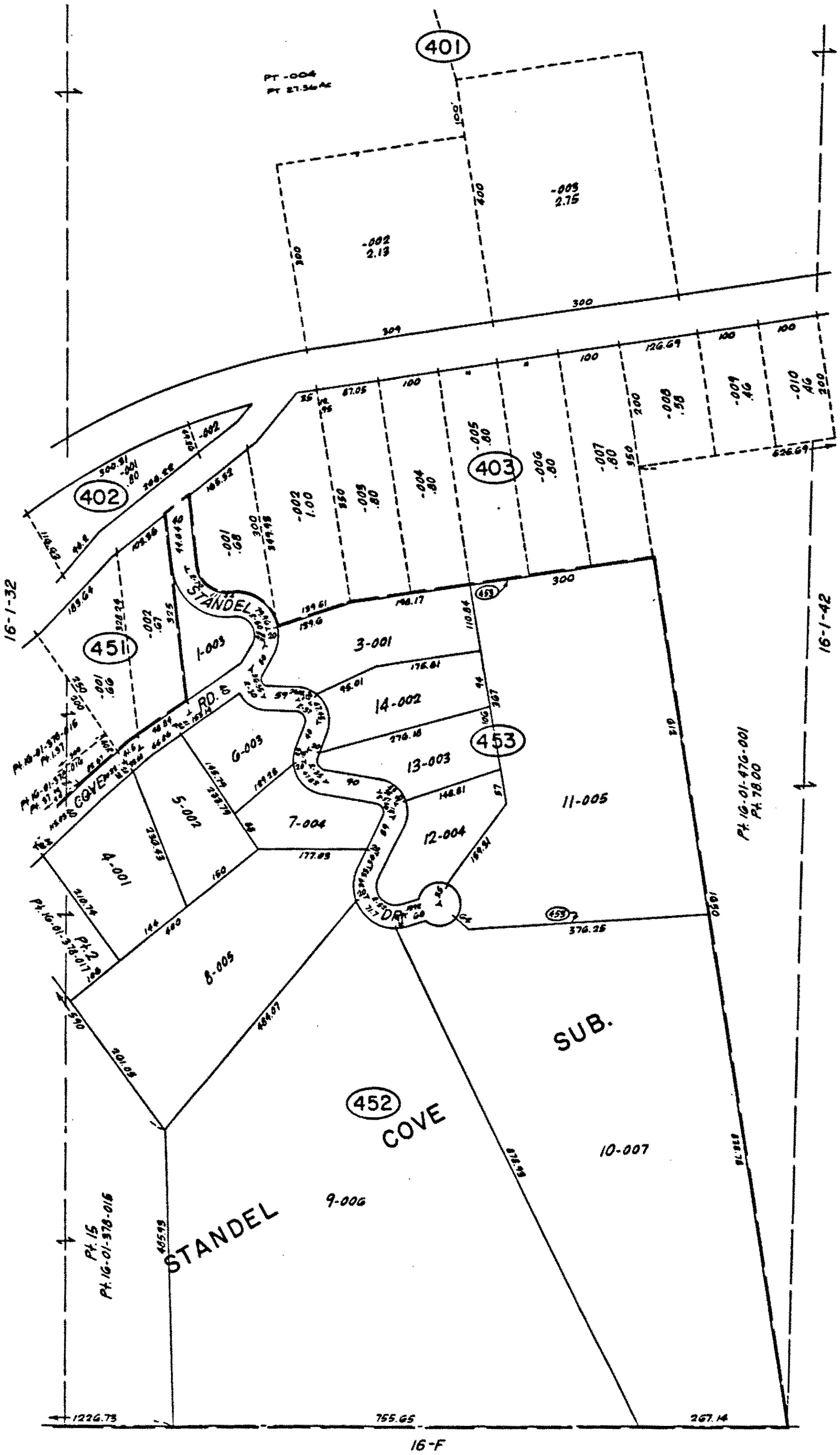
Results

The computer simulations show debris thickness of approximately 3.5 feet as the flows enter the upper reach of the Standel Cove subdivision. Should the debris flow stop when the flow path gradient is considerably reduced or where arrested by trees or other obstructions, and subsequently be over-ridden by later debris flows, then a greater depth of debris can be expected to accumulate.

Within the subdivision, 16 lots were examined for potential debris flow impact; of these 9 were judged to be in danger of sustaining damage from a debris flow event. Percent losses were judged to range from 0% to 22% (Table 1).

Conclusions

On the basis of our examinations in the Johnson's Hollow drainage, we formed a concensus that a debris flow threat exists there. Debris flows can originate from one or more of at least four distinct landslide



SCALE: 1" = 100'

16-1-41

SALT LAKE CO.

W. 1/2 S.E. 1/4 SEC. 1 T. 1 S. R. 1 E.

FIGURE 4

TABLE 1

INDIVIDUAL PROPERTY LOSS ASSESSMENTS MADE BY
TECHNICAL TEAM FOR MAJOR DEBRIS FLOW
FROM JOHNSON'S HOLLOW

LOT, (Sidwell) NUMBER*	% LOSS	REMARKS
9-006	10	2 buildings on the lot; well included
11-005	0	Damage confined to debris removal from road
10-007	0	
8-005		Exempt because home will post-date this assessment
12-004	0	579 Standel Drive
7-004	2	Landscaping only
13-003	22	557 Standel Drive
6-003	6	
14-002	12	
3-001	7	Most debris dropped upstream
5-002	0	
1-003	2	Protection afforded by concrete basement wall
001.68	1	
002.67	0	1690 Sunnydale Lane
001.80	0.5	Swimming pool could be filled
001.66	0	1626 Sunnydale Lane
002-1.00	0	1720 Sunnydale Lane

*From Sidwell Sheet No. 16-1-41, Salt Lake County Assessor's Office (Figure 4) masses that currently exist in the active state in the topographic bowl at the head of the drainage.

In addition to empirical judgment on potential volumes of debris that could emerge from the channel of Johnson's Hollow into the subdivision, we have employed a computer simulation model which collaborates the empirical judgment. We concluded that in a severe debris flow event in Johnson's Hollow, one property could suffer significant damage, four properties moderate damage, and four properties slight damage.

APPENDIX

COMPUTER SIMULATIONS OF DEBRIS FLOWS THAT MAY OCCUR IN JOHNSON'S HOLLOW

Using the computer program described in Jeppson and Rodrigues (1983) for simulation of debris flows, hypotheoretical situations were constructed by Jeppson as possible debris flow events within Johnson's Hollow. These situations do not represent predicted events in any way; rather they represent possible situations that might occur. Some data has been provided by Kaliser and Baty but the effort has been limited for defining the channel geometry, its geologic material, hydraulic properties and determining the available amounts of materials within the channel likely to scour from its bed and sides and contribute to the magnitude of the debris flow. The flow rates from a debris slide in the upper reaches of the canyon are amounts that have been arbitrarily selected for use to investigate what the depths and velocities of the debris flow would be as predicted by the computer simulation.
Tables A-1 through A-11 give some of the results from computer simulations #1 and #2. Simulations are based on: (1) specifying flow rate at the source equal to 60 c.f.s. at time zero for both simulations, (Table A-3 shows how the source flow rates have been changed as a function of time), (2) specifying the amount of lateral debris flow input through the channel due to bed scour, and (3) specifying the bottom widths and channel side slopes according to limited field measurements.

To illustrate some of the features of these simulations, three graphs are given. Figure A-1 shows the amount of discharge for simulation #1 that would exist in the channel as a function of the channel position if the debris flow were at steady-state with the initial inflow at the source at 60 c.f.s., and the bed scour contribution coming along the channel. The bed scour contribution was not changed as a function of time for the simulations. Figure A-2 shows what steady-state debris flow depths would be in the specified channel with this discharge in the channel. Figure A-3 shows how the source flow rate was specified to change as a function of time for simulation #1.

Simulation #2 has a flatter channel bottom slope just before entering the subdivision than #1. To accomplish this flatter slope here, the slope was increased slightly just upstream therefrom so that the total drop in elevation is still approximately consistent with that given on the U.S.G.S. topographic map.

There are four tables that give the time-dependent solution for each of the simulations #1 and #2. These tables are numbered A-3 through A-10. The first four of these tables apply for simulation #1 and the second four apply for simulation #2. Each set of these four tables gives the following: (1) the depth of debris flow as a function of time and position along the channel, (2) the flow rate (c.f.s.) as a function of time and position along the channel, (3) the cross-sectional area of the debris flow as a function of time and position along the channel, and (4) the top width of the debris flow as a function of time and position along the channel.

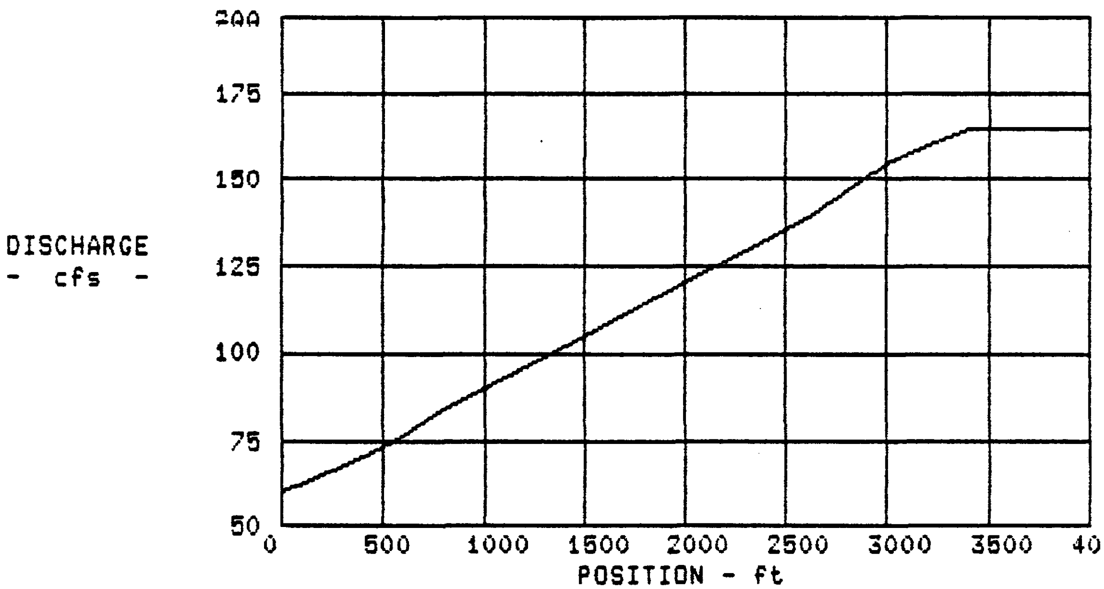


Figure A-1 . Debris flowrate in the channel contributed by the 60 cfs at the source and the lateral inflow that is contributed due to bed scour. This flowrate as a function of channel position would be the flowrate if a steady-state condition existed for the debris flow.

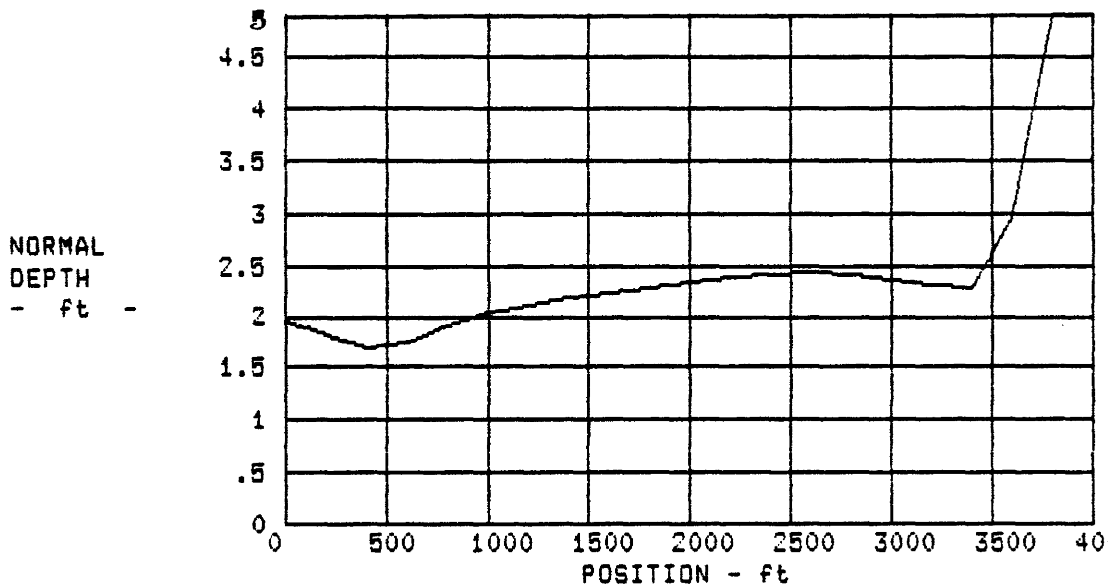


Figure A-2 . Depths of debris flows that would exist under steady-state flow with 60 cfs coming in at the beginning of the channel and being added to by bed scour as given on Figure 1 .

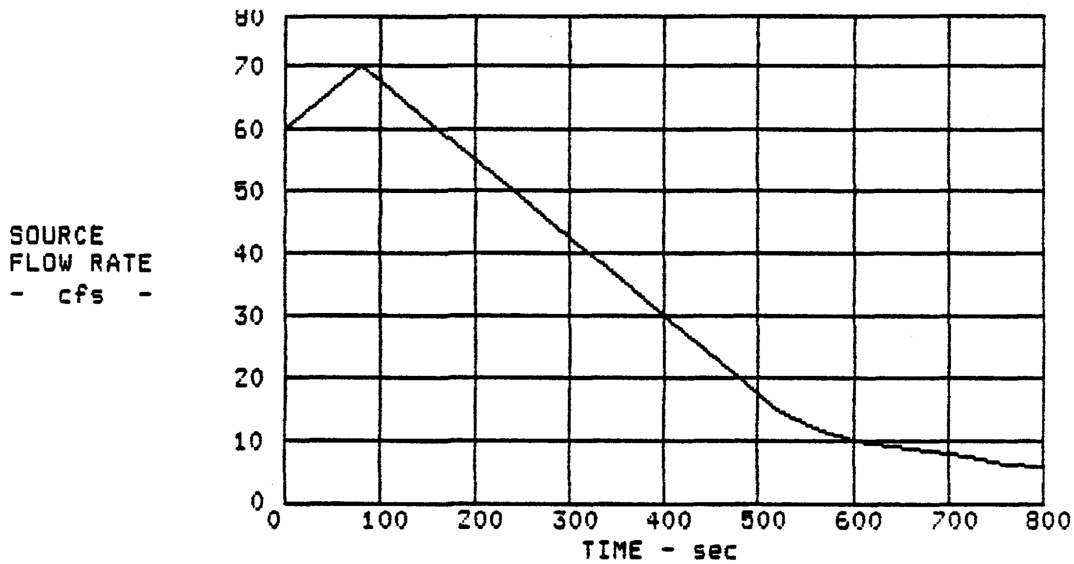


Figure A-3 . Change in volumetric flowrate as a function of time at the beginning of the channel for simulation # 3. This flowrate would be that contributed from the slide source area.

Table A-1. Definition of Johnson's Canyon for simulations #1 and # 2.

Dist. from beg. (ft)	Simulation # 1 bottom slope	width bottom (ft)	side slope	scour inflow (cfs)	Simulation # 2 bottom slope	width bottom (ft)	side slope	scour inflow (cfs)
0	.344	3.0	2.0		.344	3.0	2.0	
				12				10
480	.558	3.5	2.0		.558	3.5	2.0	
				14				12
860	.394	4.0	2.0		.394	4.0	2.0	
				16				14
1400	.346	4.5	2.0		.346	4.5	2.0	
				18				16
2000	.320	5.0	2.0		.346	5.0	2.0	
				20				14
2650	.296	6.0	2.0		.300	6.0	2.0	
				15				8
3000	.274	8.0	2.25		.270	8.0	2.25	
				10				4
3380	.252	10.0	2.5		.150	10.0	2.5	
				0				0
3670	.024	25.0	2.5		.024	25.0	2.5	
				0				0
4000	.024	25.0	2.5		.024	25.0	2.5	

Table A-2. Flowrates that were specified as a function of time at the beginning of the channel in defining part of the computer problem for debris flow simulations # 1 and # 2 .

For computer simulation # 1

Time (sec)	0	40	80	120	160	200	240	280	320	360
Q(1) (cfs)	60	65	70	65	55	50	45	40	35	30
Time (sec)	400	440	480	520	560	600	640	680	720	740
Q(1) (cfs)	25	20	15	12	10	9	8	7.5	6.0	5.5

For computer simuation # 2

Time (sec)	0	40	80	120	160	200	240	280	320	360
Q(1) (cfs)	60	65	70	65	50	45	35	30	25	20
Time (sec)	400	440	480	520	560	600	640	680	720	740
Q(1) (cfs)	15	12	10	9	8	7.5	6.0	5.5	5.0	4.5

Table A-3. Depths of simulated debris flow in Johnson's Canyon as obtained from computer solution # 1 that assumes that the debris slide contributes a flowrate of 60 cfs at the initiation of the debris flow.

time	Position from the beginning of the channel, feet																				
sec	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
40	2.0	1.8	1.7	1.7	1.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
80	2.0	1.8	1.7	1.7	2.0	2.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
120	2.0	1.8	1.8	1.8	2.1	2.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
160	2.1	1.9	1.8	1.8	2.0	2.4	2.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
200	2.0	1.9	1.8	1.9	2.0	2.2	2.6	2.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
240	1.9	1.8	1.8	1.8	2.1	2.0	2.5	2.7	2.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
280	1.9	1.7	1.7	1.7	2.1	2.1	2.1	2.8	2.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
320	1.8	1.6	1.7	1.7	2.0	2.1	2.0	2.3	3.0	2.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
360	1.7	1.6	1.6	1.6	1.9	2.1	2.0	2.0	2.6	3.1	2.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
400	1.6	1.5	1.5	1.6	1.8	1.9	2.0	2.0	2.1	2.7	3.2	2.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
440	1.5	1.4	1.5	1.5	1.8	1.8	2.0	2.0	2.0	2.1	3.0	3.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
480	1.4	1.3	1.4	1.4	1.8	1.8	1.9	1.9	2.0	1.9	2.3	3.0	3.5	3.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
520	1.3	1.2	1.4	1.3	1.7	1.7	1.8	1.8	2.0	1.9	1.9	2.4	3.0	3.5	3.3	0.1	0.1	0.1	0.1	0.1	0.1
560	1.2	1.1	1.3	1.3	1.7	1.7	1.8	1.8	1.9	1.9	1.8	2.0	2.4	2.9	3.5	3.3	0.1	0.1	0.1	0.1	0.1
600	1.0	0.9	1.3	1.2	1.6	1.6	1.7	1.7	1.8	1.9	1.8	1.8	2.1	2.2	3.0	3.3	0.1	0.1	0.1	0.1	0.1
640	0.9	0.8	1.2	1.1	1.5	1.6	1.6	1.7	1.7	1.8	1.9	1.7	1.9	1.9	2.3	2.9	3.2	3.3	0.1	0.1	0.1
680	0.9	0.7	1.1	1.0	1.5	1.5	1.6	1.6	1.7	1.7	1.9	1.7	1.8	1.8	1.9	2.3	2.7	3.2	3.3	0.1	0.1
720	0.8	0.6	1.0	1.0	1.4	1.5	1.5	1.6	1.7	1.6	1.8	1.7	1.7	1.8	1.6	2.0	2.0	2.8	3.3	3.3	0.1
760	0.8	0.6	1.0	0.9	1.3	1.4	1.5	1.5	1.6	1.5	1.7	1.7	1.6	1.9	1.5	1.8	1.6	2.2	3.3	3.5	0.1
800	0.8	0.5	0.9	0.9	1.3	1.4	1.5	1.4	1.6	1.5	1.6	1.7	1.5	1.8	1.5	1.7	1.6	1.7	3.2	3.6	3.5
840	0.7	0.5	0.9	0.9	1.3	1.3	1.4	1.4	1.5	1.5	1.4	1.7	1.4	1.8	1.5	1.5	1.7	1.2	3.1	3.7	3.5

Table A-4. Flowrates (cfs) of simulated debris flow in Johnson's Canyon as obtained from computer solution # 1 that assumes that the debris slide contributes a flowrate of 60 cfs at the initiation of the debris flow.

time sec	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
40	60.0	65.0	70.0	76.4	83.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
80	60.0	59.5	58.9	58.8	58.6	57.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
120	65.0	64.9	64.8	64.4	64.4	64.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
160	70.0	70.1	74.7	76.8	79.7	95.1	64.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
200	65	70	77	84	87	101	107	65	1	1	1	1	1	1	1	1	1	1	1	1	1
240	60	67	76	82	96	90	120	113	65	1	1	1	1	1	1	1	1	1	1	1	1
280	55	61	74	75	97	93	95	144	93	1	1	1	1	1	1	1	1	1	1	1	1
320	50	54	70	71	89	98	83	116	150	94	1	1	1	1	1	1	1	1	1	1	1
360	45	48	63	67	81	93	88	84	137	158	95	1	1	1	1	1	1	1	1	1	1
400	40	43	56	62	76	83	90	81	92	154	164	95	1	1	1	1	1	1	1	1	1
440	35	39	51	56	73	74	85	82	83	94	179	144	1	1	1	1	1	1	1	1	1
480	30	34	48	49	70	67	78	77	84	74	116	181	160	144	1	1	1	1	1	1	1
520	25	28	44	43	66	63	72	71	82	74	80	129	186	224	145	1	1	1	1	1	1
560	20	22	41	38	61	58	67	65	75	77	69	91	127	198	239	146	1	1	1	1	1
600	15	16	36	33	56	55	62	62	66	75	70	72	99	114	222	231	1	1	1	1	1
640	12	11	32	29	51	51	56	59	60	67	72	63	85	84	132	221	225	231	1	1	1
680	10	9	27	26	46	48	51	55	57	59	71	60	74	76	85	147	206	284	232	1	1
720	9	6	24	23	42	44	47	50	55	52	66	60	64	74	64	109	122	251	225	233	1
760	8	5	21	21	38	40	44	44	53	48	58	61	56	75	54	92	80	164	220	156	1
800	8	4	19	19	36	37	42	40	49	47	50	62	49	74	51	77	73	87	202	126	156
840	6	4	18	17	35	34	39	38	43	47	42	61	44	69	53	61	81	42	176	112	121

Position from the beginning of the channel, feet

Table A-5. Cross-sectional areas of simulated debris flow in Johnson's Canyon as obtained from computer solution # 1 that assumes that the debris slide contributes a flowrate of 60 cfs at the initiation of the debris flow.

time sec	Position from the beginning of the channel, feet 0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
40	13.5	12.3	11.4	12.3	14.9	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
80	13.5	12.1	11.5	12.1	15.4	15.9	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
120	14.4	12.7	12.3	12.5	16.7	19.6	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
160	15.2	13.2	12.8	13.4	16.4	21.1	21.3	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
200	14.2	13.0	12.5	13.8	16.2	19.2	25.0	21.8	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
240	13.4	12.4	12.1	13.1	16.9	16.9	22.8	27.6	22.2	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
280	12.6	11.6	11.8	12.2	16.7	17.1	17.9	27.7	29.8	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
320	11.8	10.7	11.3	11.6	15.4	17.7	16.1	21.4	32.1	30.3	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
360	11.0	9.9	10.5	11.2	14.3	17.0	17.1	16.7	25.0	34.8	30.8	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
400	10.2	9.2	9.7	10.7	13.7	15.6	17.3	16.5	18.2	27.9	37.0	31.7	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
440	9.3	8.6	9.1	10.0	13.4	14.4	16.5	16.7	17.0	19.0	32.1	38.8	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
480	8.4	7.9	8.8	9.1	13.1	13.6	15.5	16.1	17.4	16.0	22.3	34.5	43.5	40.8	0.7	0.8	0.9	1.1	2.1	2.4	2.5
520	7.5	7.0	8.4	8.4	12.6	13.0	14.7	15.1	17.0	16.2	17.1	24.5	34.5	45.0	45.1	0.8	0.9	1.1	2.1	2.4	2.5
560	6.5	5.9	7.9	7.7	12.1	12.4	14.0	14.3	15.9	16.8	15.6	19.0	24.6	34.5	50.3	50.4	0.9	1.1	2.1	2.4	2.5
600	5.4	4.8	7.4	7.1	11.4	11.9	13.3	13.9	14.7	16.4	15.9	16.2	20.5	23.2	39.3	50.4	0.9	1.1	2.1	2.4	2.5
640	4.7	3.9	6.7	6.5	10.7	11.4	12.5	13.4	13.8	15.2	16.4	14.9	18.4	18.7	26.6	41.5	54.3	63.1	2.1	2.4	2.5
680	4.2	3.2	6.1	6.1	10.0	10.9	11.8	12.9	13.4	13.9	16.3	14.7	16.9	17.6	19.9	30.1	41.4	60.6	97.2	2.4	2.5
720	4	3	6	6	9	10	11	12	13	13	15	15	16	18	16	25	28	51	99	109	3
760	4	2	5	5	9	10	11	11	13	12	14	15	14	18	15	22	21	37	100	118	3
800	4	2	5	5	9	9	10	10	12	12	13	15	13	18	14	20	20	25	96	123	118
840	3	2	5	5	8	9	10	10	11	12	11	15	12	17	15	17	22	16	89	128	118

Table A-6. Top Widths (ft) of simulated debris flow in Johnson's Canyon as obtained from computer solution # 1 that assumes that the debris slide contributes a flowrate of 60 cfs at the initiation of the debris flow.

time sec	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
40	10.8	10.4	10.1	10.6	11.6																
80	10.8	10.4	10.2	10.5	11.8	12.0															
120	11.2	10.6	10.5	10.7	12.2	13.2															
160	11.4	10.8	10.7	11.0	12.1	13.6	13.8														
200	11.1	10.7	10.6	11.1	12.1	13.1	14.8	13.9													
240	10.8	10.5	10.4	10.9	12.3	12.3	14.2	15.5	14.1												
280	10.5	10.1	10.3	10.5	12.2	12.4	12.7	15.6	16.1												
320	10.2	9.8	10.1	10.3	11.8	12.6	12.1	13.8	16.7	16.3											
360	9.9	9.4	9.8	10.2	11.4	12.4	12.5	12.4	14.9	17.4	16.5										
400	9.5	9.2	9.5	9.9	11.2	11.9	12.5	12.4	12.9	15.7	17.9	16.8									
440	9.1	8.9	9.2	9.6	11.1	11.5	12.3	12.4	12.6	13.3	16.8	18.4									
480	8.8	8.6	9.0	9.3	11.0	11.2	11.9	12.2	12.7	12.3	14.2	17.4	19.5	19.0							
520	8.3	8.1	8.9	9.0	10.8	11.0	11.7	11.9	12.6	12.4	12.7	15.0	17.5	19.9	20.7						
560	7.8	7.6	8.7	8.7	10.6	10.8	11.4	11.6	12.2	12.5	12.3	13.4	15.1	17.6	21.7	22.8					
600	7.2	7.0	8.4	8.4	10.3	10.6	11.2	11.4	11.8	12.4	12.4	12.6	14.0	14.9	19.5	22.8					
640	6.8	6.4	8.1	8.1	10.0	10.4	10.9	11.3	11.5	12.1	12.5	12.2	13.4	13.6	16.5	20.9	24.5				
680	6.5	6.0	7.8	7.9	9.8	10.2	10.6	11.1	11.4	11.6	12.5	12.1	12.9	13.3	14.6	18.3	21.8	27.0	37.8		
720	6.4	5.7	7.5	7.7	9.5	10.0	10.4	10.8	11.3	11.2	12.2	12.1	12.5	13.3	13.6	16.9	18.7	25.0	38.0	41.4	
760	6.2	5.4	7.3	7.5	9.3	9.8	10.2	10.5	11.2	11.0	11.7	12.2	12.1	13.3	13.1	16.2	16.9	22.3	38.2	42.5	
800	6.1	5.3	7.1	7.3	9.2	9.5	10.1	10.2	10.9	11.0	11.2	12.3	11.7	13.3	13.0	15.6	16.6	19.4	37.6	43.0	42.5
840	5.8	5.2	7.0	7.2	9.1	9.3	9.9	10.0	10.6	11.0	10.8	12.2	11.4	13.0	13.2	14.8	17.2	16.9	36.7	43.7	42.5

Table A-7. Depths of simulated debris flow in Johnson's Canyon as obtained from computer solution # 2 that assumes that the debris slide contributes a flowrate of 60 cfs at the initiation of the debris flow.

time	Position from the beginning of the channel, feet																				
sec	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
40	2.0	1.8	1.7	1.7	1.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
80	2.0	1.8	1.7	1.7	1.9	1.9	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
120	2.0	1.8	1.7	1.7	2.0	2.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
160	2.1	1.9	1.8	1.8	2.0	2.3	2.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
200	2.0	1.9	1.8	1.8	2.0	2.2	2.5	2.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
240	1.8	1.7	1.7	1.8	2.0	2.0	2.4	2.7	2.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
280	1.7	1.6	1.6	1.6	2.0	2.0	2.0	2.7	2.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
320	1.5	1.5	1.5	1.5	1.9	2.0	1.9	2.2	2.9	2.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
360	1.4	1.3	1.4	1.5	1.8	1.9	1.9	1.9	2.4	3.0	2.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
400	1.3	1.2	1.3	1.4	1.7	1.8	1.9	1.9	2.0	2.5	3.1	2.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
440	1.2	1.1	1.2	1.3	1.6	1.7	1.8	1.9	1.8	2.0	2.6	3.1	2.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
480	1.0	1.0	1.2	1.2	1.5	1.6	1.7	1.8	1.8	1.8	2.0	2.8	3.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
520	0.9	0.9	1.1	1.1	1.5	1.5	1.6	1.7	1.7	1.8	1.7	2.2	2.9	3.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
560	0.9	0.8	1.0	1.1	1.4	1.5	1.5	1.7	1.6	1.8	1.6	1.7	2.2	2.9	3.1	0.1	0.1	0.1	0.1	0.1	0.1
600	0.8	0.8	1.0	1.0	1.3	1.5	1.4	1.6	1.5	1.7	1.6	1.6	1.8	2.3	3.0	3.1	0.1	0.1	0.1	0.1	0.1
640	0.8	0.7	0.9	1.0	1.3	1.4	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.8	2.3	3.0	3.1	0.1	0.1	0.1	0.1
680	0.8	0.7	0.9	1.0	1.2	1.4	1.3	1.5	1.5	1.5	1.5	1.6	1.5	1.7	1.7	2.5	3.2	3.1	0.1	0.1	0.1
720	0.7	0.7	0.8	1.0	1.2	1.3	1.3	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.5	1.9	2.8	3.2	3.1	0.1	0.1
760	0.7	0.7	0.8	0.9	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.5	1.4	1.5	1.5	1.5	2.3	3.2	3.2	0.1	0.1
800	0.6	0.7	0.8	0.9	1.2	1.3	1.3	1.3	1.3	1.4	1.3	1.4	1.4	1.5	1.5	1.4	1.7	2.9	3.2	3.2	0.1
840	0.6	0.7	0.8	0.9	1.2	1.2	1.3	1.3	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.3	2.5	3.3	3.2	0.1

Table A-8. Flowrates (cfs) of simulated debris flow in Johnson's Canyon as obtained from computer solution # 2 that assumes that the debris slide contributes a flowrate of 60 cfs at the initiation of the debris flow.

time	Position from the beginning of the channel, feet																				
sec	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
40	60.0	64.2	68.3	73.8	80.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
80	60.0	59.9	59.8	59.3	59.0	58.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
120	65.0	64.5	63.9	63.3	63.2	62.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
160	70.0	69.4	72.8	74.4	76.5	90.1	62.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
200	65	70	75	81	83	95	101	63	1	1	1	1	1	1	1	1	1	1	1	1	1
240	50	61	71	78	90	85	112	107	63	1	1	1	1	1	1	1	1	1	1	1	1
280	45	53	66	69	90	86	89	133	91	1	1	1	1	1	1	1	1	1	1	1	1
320	35	42	58	61	80	88	78	106	141	91	1	1	1	1	1	1	1	1	1	1	1
360	30	34	50	54	69	81	80	77	124	150	92	1	1	1	1	1	1	1	1	1	1
400	25	29	42	48	62	70	78	73	82	140	159	92	1	1	1	1	1	1	1	1	1
440	20	24	36	41	57	60	70	71	72	87	154	165	93	1	1	1	1	1	1	1	1
480	15	19	32	35	52	53	61	68	67	74	85	178	144	1	1	1	1	1	1	1	1
520	12	15	28	30	47	49	52	62	60	72	62	108	176	144	1	1	1	1	1	1	1
560	10	12	25	26	41	46	45	57	53	67	60	69	119	183	144	1	1	1	1	1	1
600	9	10	22	24	37	44	40	52	48	60	60	59	75	127	195	145	1	1	1	1	1
640	8	9	19	23	33	41	37	47	45	52	57	55	62	77	142	210	145	1	1	1	1
680	8	8	17	22	30	38	34	42	42	45	52	53	54	65	75	174	199	147	1	1	1
720	6	8	15	21	28	36	33	38	40	41	46	51	49	60	56	96	187	179	148	1	1
760	6	8	14	19	27	33	32	34	37	39	40	49	45	55	53	58	125	187	138	1	1
800	5	8	13	18	27	31	31	32	34	38	36	45	42	49	53	49	69	164	139	139	1
840	5	8	13	17	27	29	30	31	31	36	33	41	40	44	49	52	40	123	139	105	1

Table A-9. Cross-sectional areas of simulated debris flow in Johnson's Canyon as obtained from computer solution # 2 that assumes that the debris slide contributes a flowrate of 60 cfs at the initiation of the debris flow.

time sec	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
	Position from the beginning of the channel, feet																				
40	13.5	12.1	11.2	12.1	14.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
80	13.5	12.1	11.3	11.8	14.9	15.3	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
120	14.4	12.5	12.0	12.2	16.1	18.8	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
160	15.2	13.1	12.4	13.0	15.8	20.1	20.5	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
200	14.2	12.9	12.3	13.4	15.7	18.4	23.7	21.0	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
240	11.8	11.7	11.6	12.6	16.2	16.3	21.7	26.1	21.4	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
280	11.0	10.5	10.9	11.5	15.8	16.3	17.3	26.0	28.4	0.5	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
320	9.3	9.0	9.9	10.5	14.3	16.5	15.5	20.1	29.8	28.9	0.5	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
360	8.4	7.9	8.9	9.7	12.9	15.4	15.9	15.8	22.9	32.2	29.3	0.5	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
400	7.5	7.0	8.0	8.9	12.0	13.9	15.6	15.4	16.7	25.0	34.2	30.8	0.6	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
440	6.5	6.3	7.3	8.1	11.4	12.5	14.5	15.3	15.2	17.4	26.9	37.2	32.3	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
480	5.4	5.4	6.7	7.3	10.8	11.7	13.1	14.7	14.5	15.6	17.4	31.5	37.4	0.6	0.7	0.8	0.9	1.1	2.1	2.4	2.5
520	4.7	4.7	6.2	6.6	10.1	11.1	11.9	13.9	13.6	15.3	13.9	21.1	33.9	39.1	0.7	0.8	0.9	1.1	2.1	2.4	2.5
560	4.2	4.1	5.8	6.1	9.3	10.8	10.8	13.1	12.6	14.7	13.7	15.5	23.5	36.7	43.2	0.8	0.9	1.1	2.1	2.4	2.5
600	3.9	3.6	5.3	5.8	8.6	10.4	10.1	12.3	11.8	13.5	13.7	14.0	17.0	25.5	41.5	48.1	0.9	1.1	2.1	2.4	2.5
640	3.7	3.3	4.9	5.7	8.0	10.0	9.5	11.5	11.3	12.3	13.4	13.5	14.9	18.1	29.1	47.8	51.4	1.1	2.1	2.4	2.5
680	3.5	3.2	4.5	5.5	7.6	9.6	9.2	10.7	10.9	11.3	12.6	13.3	13.8	16.1	19.1	36.0	54.2	57.5	2.1	2.4	2.5
720	3.1	3.2	4.2	5.3	7.4	9.1	9.0	10.1	10.6	10.7	11.6	13.0	13.0	15.4	15.6	23.9	46.1	61.5	89.4	2.4	2.5
760	2.9	3.2	4.0	5.2	7.3	8.6	8.9	9.5	10.1	10.4	10.6	12.6	12.4	14.6	15.3	17.1	34.0	60.2	92.4	2.4	2.5
800	3	3	4	5	7	8	9	9	10	10	10	12	12	14	15	16	23	53	95	104	3
840	3	3	4	5	7	8	8	9	9	10	9	11	12	13	15	16	17	44	97	104	3

TableA-10 Top Widths (ft) of simulated debris flow in Johnson's Canyon as obtained from computer solution # 2 that assumes that the debris slide contributes a flowrate of 60 cfs at the initiation of the debris flow.

time sec	0	200	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2600	2800	3000	3200	3400	3600	3800	4000
40	10.8	10.4	10.1	10.5	11.4																
80	10.8	10.3	10.1	10.4	11.6	11.8															
120	11.2	10.5	10.4	10.5	12.0	12.9															
160	11.4	10.7	10.6	10.9	11.9	13.4	13.5														
200	11.1	10.7	10.5	11.0	11.9	12.8	14.4	13.7													
240	10.1	10.2	10.2	10.7	12.0	12.1	13.9	15.1	13.9												
280	9.9	9.7	9.9	10.2	11.9	12.1	12.5	15.1	15.8												
320	9.1	9.1	9.6	9.9	11.4	12.2	11.9	13.4	16.1	15.9											
360	8.7	8.6	9.1	9.5	10.9	11.9	12.1	12.1	14.3	16.8	16.1										
400	8.3	8.1	8.7	9.2	10.6	11.3	12.0	12.0	12.5	14.9	17.3	16.9									
440	7.8	7.8	8.4	8.8	10.3	10.8	11.6	11.9	12.0	12.7	15.5	18.4	17.6								
480	7.2	7.3	8.1	8.5	10.1	10.5	11.1	11.7	11.7	12.2	12.8	17.0	18.8								
520	6.8	6.9	7.8	8.1	9.8	10.3	10.6	11.5	11.4	12.1	11.7	14.2	18.0	19.6							
560	6.5	6.5	7.6	7.9	9.5	10.1	10.3	11.2	11.1	11.9	11.6	12.5	15.3	19.0	21.3						
600	6.4	6.3	7.4	7.7	9.2	10.0	10.0	10.9	10.8	11.5	11.6	12.0	13.4	16.2	20.9	23.4					
640	6.2	6.1	7.1	7.7	8.9	9.9	9.7	10.6	10.6	11.0	11.5	11.9	12.7	14.0	17.9	23.3	24.4				
680	6.1	6.0	6.9	7.6	8.7	9.7	9.6	10.3	10.4	10.7	11.2	11.8	12.3	13.4	15.1	20.6	25.0	26.4			
720	5.8	6.0	6.7	7.5	8.6	9.5	9.5	10.0	10.3	10.4	10.8	11.7	12.0	13.1	13.9	17.4	23.3	27.1			
760	5.7	6.0	6.6	7.4	8.6	9.3	9.5	9.8	10.1	10.3	10.5	11.5	11.7	12.9	13.8	15.3	20.5	26.9	37.2		
800	5.6	6.0	6.6	7.3	8.6	9.1	9.4	9.7	9.9	10.3	10.2	11.3	11.6	12.5	13.8	14.8	17.7	25.6	37.5	40.8	
840	5.4	6.0	6.6	7.1	8.6	9.0	9.3	9.6	9.7	10.2	10.0	11.0	11.5	12.2	13.6	15.1	15.7	23.6	37.8	40.8	

Table A-11 Position of the debris flows leading surge as a function of time for simulation #1 and simulation #2.

Time (sec)	Simulation #1 Position (ft)	Simulation #1 Advance (ft)	Simulation #2 Position (ft)	Simulation #2 Advance (ft)
0	800		800	
		232		228
40	1032		1028	
		152		160
80	1184		1188	
		147		150
120	1331		1337	
		140		141
160	1470		1479	
		138		139
200	1608		1618	
		137		138
240	1745		1756	
		164		166
280	1909		1922	
		163		165
320	2072		2087	
		162		164
360	2234		2251	
		159		157
400	2393		2408	
		214		152
440	2607		2560	
		206		215
480	2813		2775	
		190		207
520	3003		2981	
		172		189
560	3176		3170	
		271		172
600	3447		3342	
		221		163
640	3668		3505	
		153		150
680	3822		3655	
		139		103
720	3960		3758	
		90		95
760	4050		3853	
		90		86
800	4141		3939	
		70		65