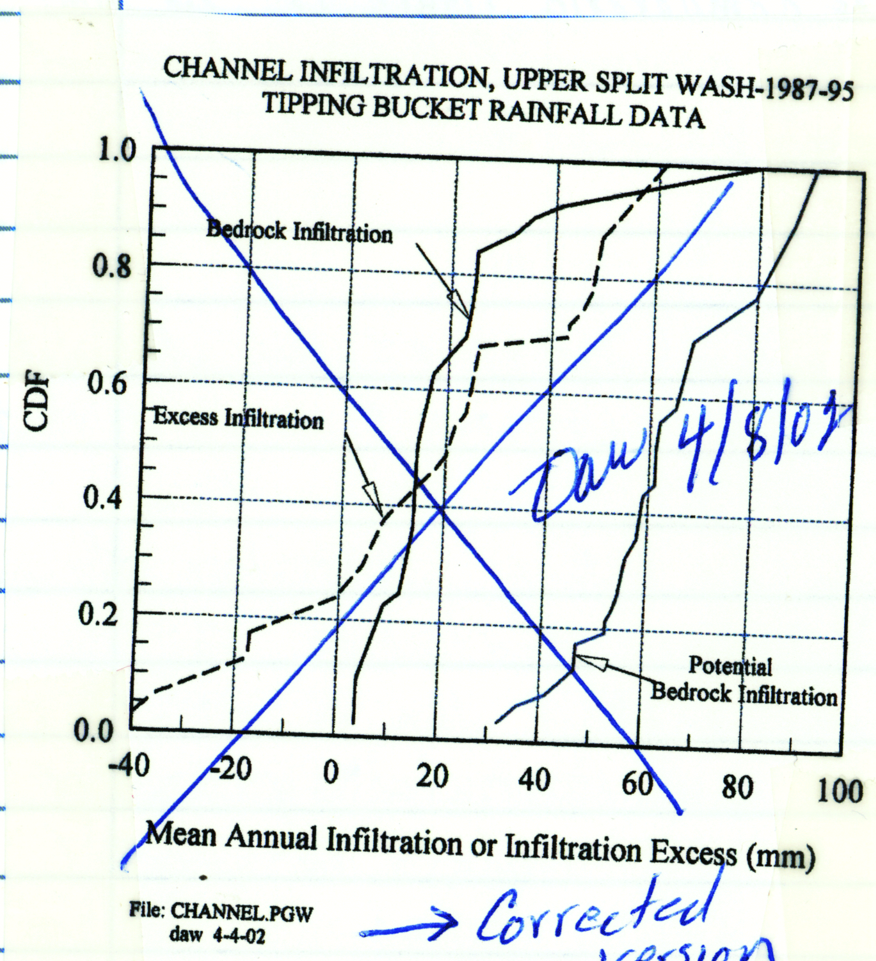
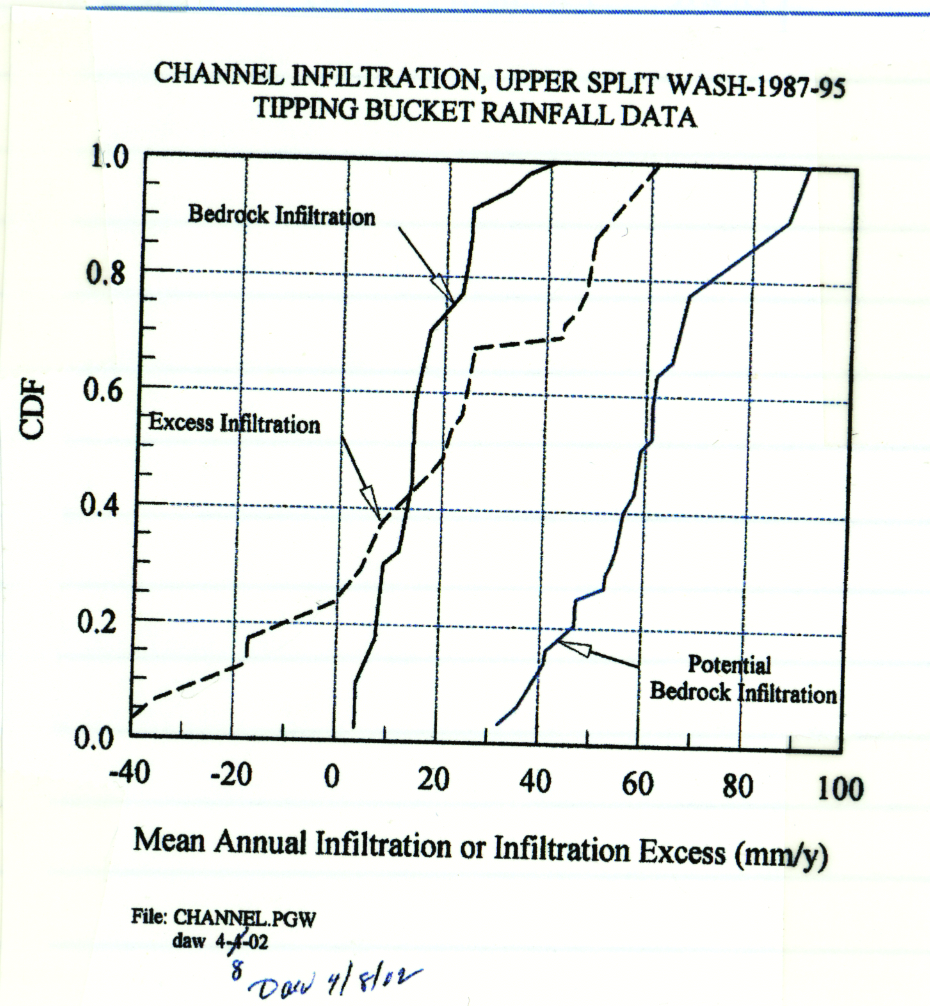
Daw 4/5/02

The excess precipitation (infiltration), bedrock infiltration during the storm F_b and the potential bedrock infiltration F_{bp} for channels are shown below



→ Corrected version



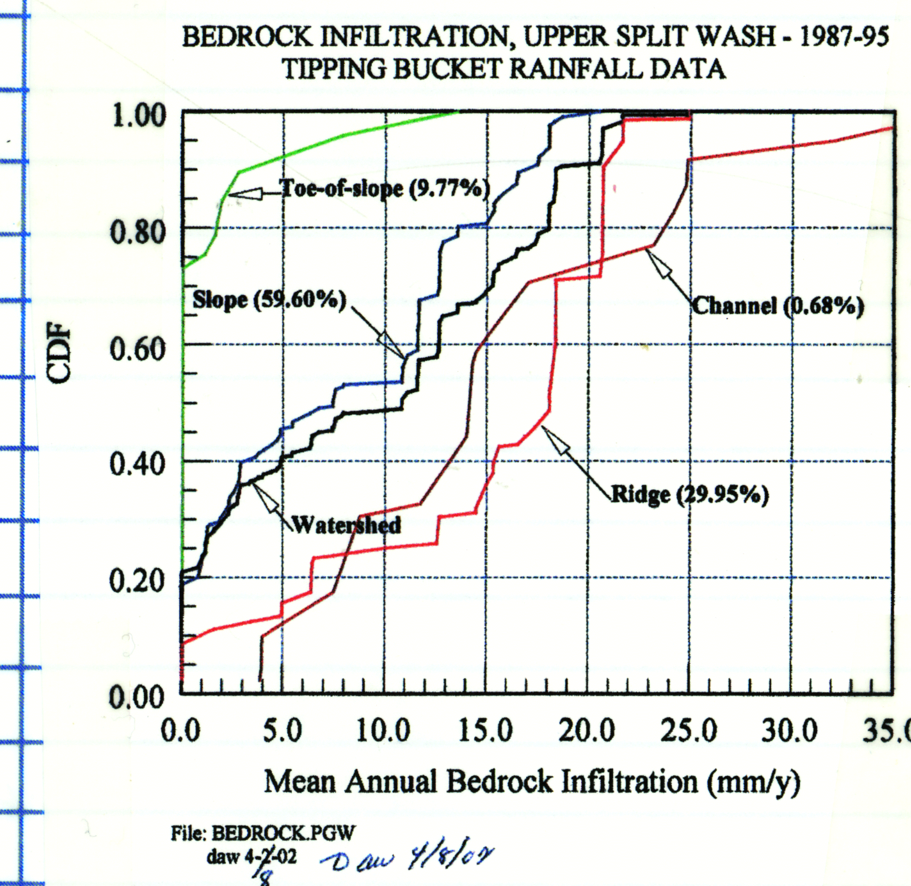
The summary statistic printed to the screen shows a mean annual bedrock infiltration during the storm of 9.30 mm/yr expressed over the entire area and 11.69 mm/y over about 80% of the area.

Daw 4/8/02

Note the corrected figure for channel infiltration above. The interpretation problem mentioned on the bottom of p98 caused channel (123) to be classified as a channel on bedrock. This caused the bedrock infiltration to be much too large (and the potential bedrock infiltration). The concentration of infiltration in channels is emphasized by the fig. Note that 50% of the channel area has $F_{bp} > 61$ mm. The channel area (25%) with negative excess infiltration are on bedrock or have

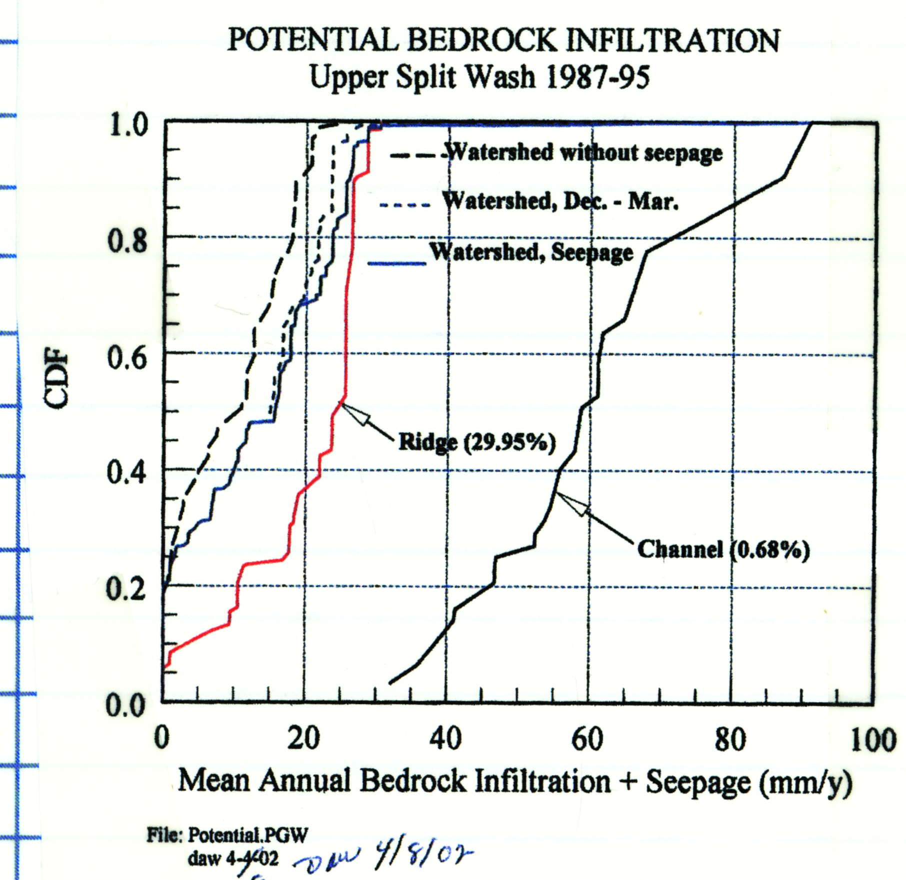
Daw 4/8/02

very shallow depths of alluvium.



← Corrected Fig. from p 98.

The discussion on the top of p 99 is still valid.



← Corrected Fig. from p. 99

The discussion on p 99 is still valid

Daw 4/8/02

The file USWANNUAL.CDF has 9 columns, each 3 representing an element number, infiltration excess or infiltration in mm/y and a CDF for 1) Infiltration excess 2) Bedrock infiltration during the rainfall event and 3) Potential bedrock infiltration.

Examining the file, we find:

1) Infiltration excess:
   Greatest runoff (neg excess)
      channel elements 34, 48, 22 – on bedrock
      " " 180, 174 only 50 mm alluvium
      Plane elements 81, 153, 161 – 120 mm soil over bedrock
   Greatest runon:
      Channel elements, 199, 164, 209, 190, 157, 137, 131, 106, 115, 146, 216
      Plane elements 12, 19 – slope elements below disturbed areas
   Approximately zero runoff-runon:
      Plane elements 6, 13, 158, 132, 159, 160, 14
         all have deep soils THICK > 1000 m
         or have shallower soils ~~but a disturbed s~~ Daw 4/8/02
         and a long plane – plane 13. + no run-on.

2) Bedrock infiltration during the storm
   Zero: Deep soils or disturbed soils
   Maximum: Channels or ridge elements with shallow soils

3) Potential Bedrock infiltration
   Zero: Very deep soils or disturbed deep soils
   Maximum: All channel elements
      ridge elements with shallow soils.

Daw 4/8/02

Create a file with columns: REALCDF\THICK-F.DAT
   element # Soil depth (mm) Potential bedrock infiltration
   First 3 for planes, second three for channels
~~For channe~~ Daw 4/8/02 Selected planes only, all 20 channels
All data from file USWANNUAL.CDF
   Plot: THICK_F.PGW

Daw 4/9/02

A visual inspection of the plot of average annual potential bedrock infiltration reveals that for channels there appears to be an optimum depth. The infiltration increases with increasing depth of alluvium and then decreases.

Try fitting a polynomial curve using PSIPLOT

2nd order ~~degree~~: ~~Daw 4/9/02~~

$$F_{bp} = 35.77 + 0.246\,h - 0.000426\,h^2 \quad (mm/y)$$

COD = 0.654

where h = thickness of channel alluvium (mm)

3rd order ~~degree~~: Daw 4/9/02

$$F_{bp} = 38.01 + 0.123\,h + 3.49\times10^{-4}\,h^2 - 1.08\times10^{-6}\,h^3$$

COD = 0.674

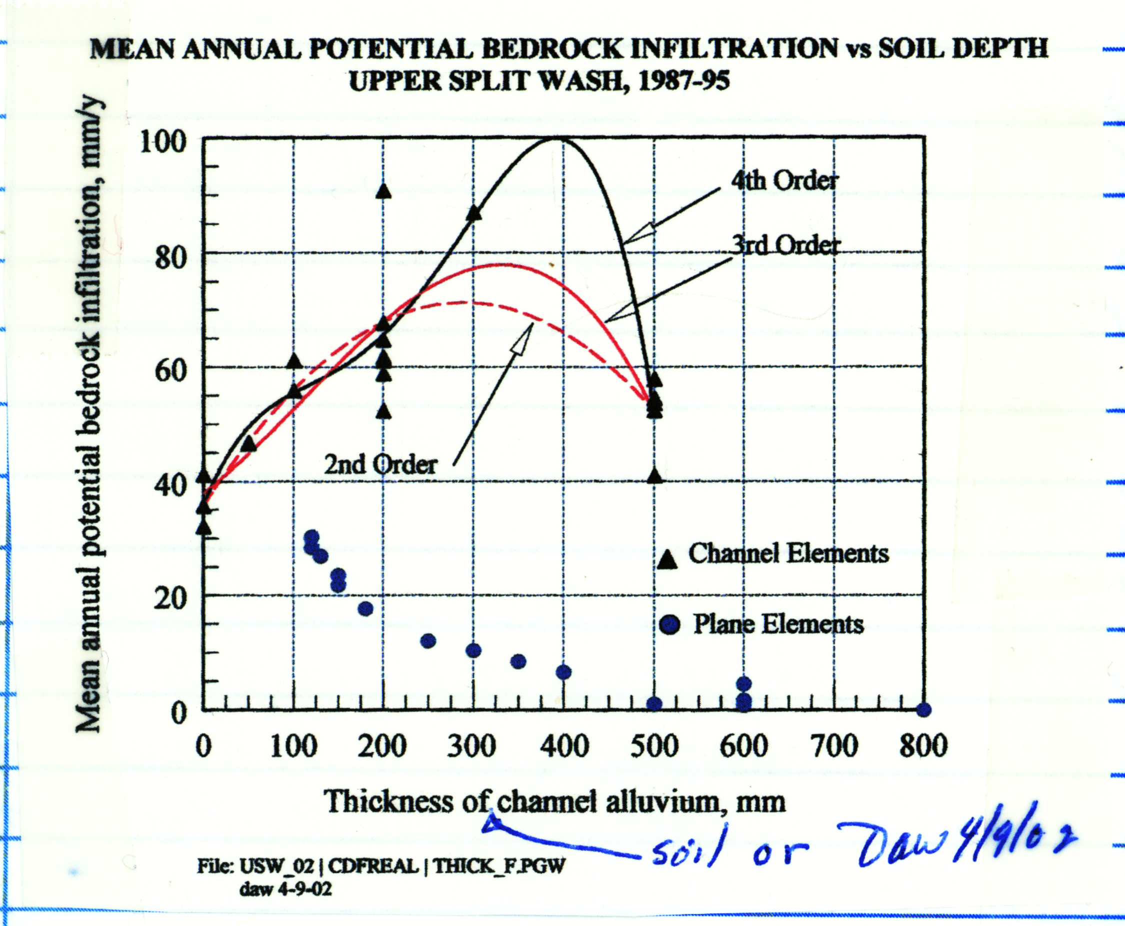
4th order:

$$F_{bp} = 35.79 + 0.404\,h - 0.00317\,h^2 + 1.26\times10^{-6}\,h^3 - 1.54\times10^{-8}\,h^4$$

COD = 0.720

The figure is shown on p 104

DAW 4/9/02 Upper Split Wash (Cont)



It appears that the "optimum" depth of channel alluvium is between 300 - 400 mm and that the maximum annual potential bedrock infiltration in channels is around 80 to 100 mm.

The plane elements have different characteristics, with a monotonically decreasing infiltration as soil depth increases. There were no plane elements coded as bare rock (i.e. THICK = 0), but if there were, it is likely that the mean potential infiltration would be smaller than those of the channels. Therefore it is possible that a maximum occurs around 100 mm.

DAW 4-12-02 Possibilities for combination of Upper Split Wash results and TPA analysis.

A GIS system can be used in conjunction with a DEM to classify $100 m^2$ (10m x 10m) pixels as either ridge + slope. However toe-of-slope and channel elements are quite small and may require special handling. One possibility would be to identify any element containing a channel as a combination toe-of-slope and channel element. After all of the pixels are apportioned, check to see if the

DAW 4-12-02

channel + toe-of-slope elements are equal to approximately 0.68% + 9.77% = 10.45% of the total area for watersheds of about 0.25 km^2. If greater, apportion some to slope elements. For larger watersheds the proportion of toe-of-slope and channel elements will increase.

Ridge DAW 4-12-02

~~Slope~~ elements: Conclusions on p 87 are still valid. The 1-D model should give reasonable results

DAW 4-15-02

Slope Elements: About 62% of the slope elements have net runoff (Fig. top of p 98) so the 1-D model results should be reasonable. The median run-on for the remaining 38% is only 2 - 3 mm/y

To assist in analyses compare bedrock ~~seepage~~ infiltration DAW 4-15-02 and potential bedrock infiltration for ridge, slope and toe-of-slope elements. Create figure C:\USW_02\CDFREAL\BED_SEEP.PGW See p. 106.

How much time would be required for the potential seepage to infiltrate bedrock?

The saturated conductivity of bedrock ranges from 0.355 to 0.682 mm/h. so for a storage above field capacity of 25 mm it would require a minimum of ~~70.4~~ 36.6 DAW 4/15/02 to 70.4 hrs. Because most of the bedrock infiltration is through cracks there would be some lateral movement of water. Of course there would also be a great deal of spatial variability. During this time period, some of the water could be removed by transpiration and evaporation.

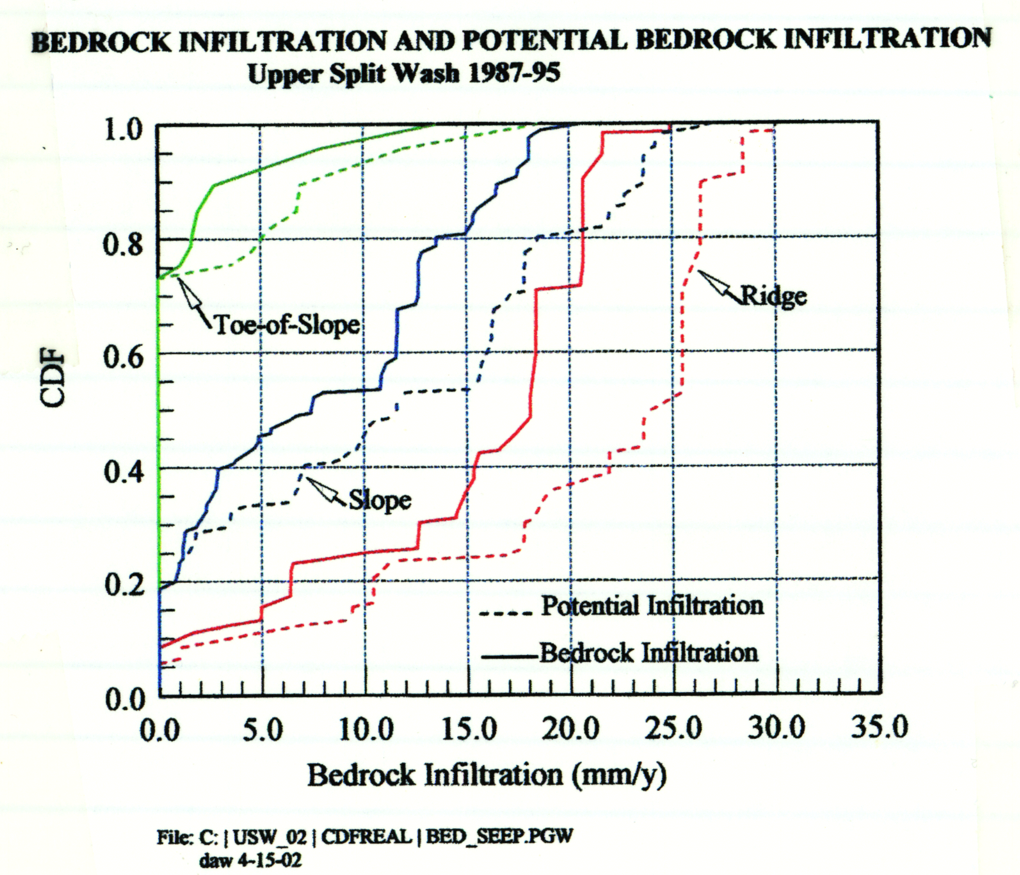
Daw 4-17-02

Consider the slope and Toe-of-slope elements in greater detail. Au = contributing area
A = area of element

From file: USWTOE.CDF in order

El. No.	Au/A	THICK(mm)	Potential Bedrock Infil mm/y	Contributing ele/depth
163	2.46	180	18.45	162/150mm 161/120 mm
69	8.5	150	11.97	68/200; 67/200; 66/150; 65; 150
156	5.6	400	6.94	155/200; 154/150; 153; 180
194	13.68	500	6.75	193/180; 192/200; 191/120
203	5.31	500	5.32	202/200; 201/140; 200/120
179	14.43	600	4.55	178/300; 177/300; 176/180; 175/120
25	6.9	500	3.59	24/300; 23/300

There is no clear-cut relation between potential infiltration and contributing area ratio. The depth of soil (THICK) of the toe element is most important. The depth of soil for upstream elements is also important, as this affects run-on.



Although the average annual rates are interesting they are difficult to relate to TPA because of the intermittency of the runon process.
Another complicating factor is that even for deep soils all of the run-on will not infiltrate because of

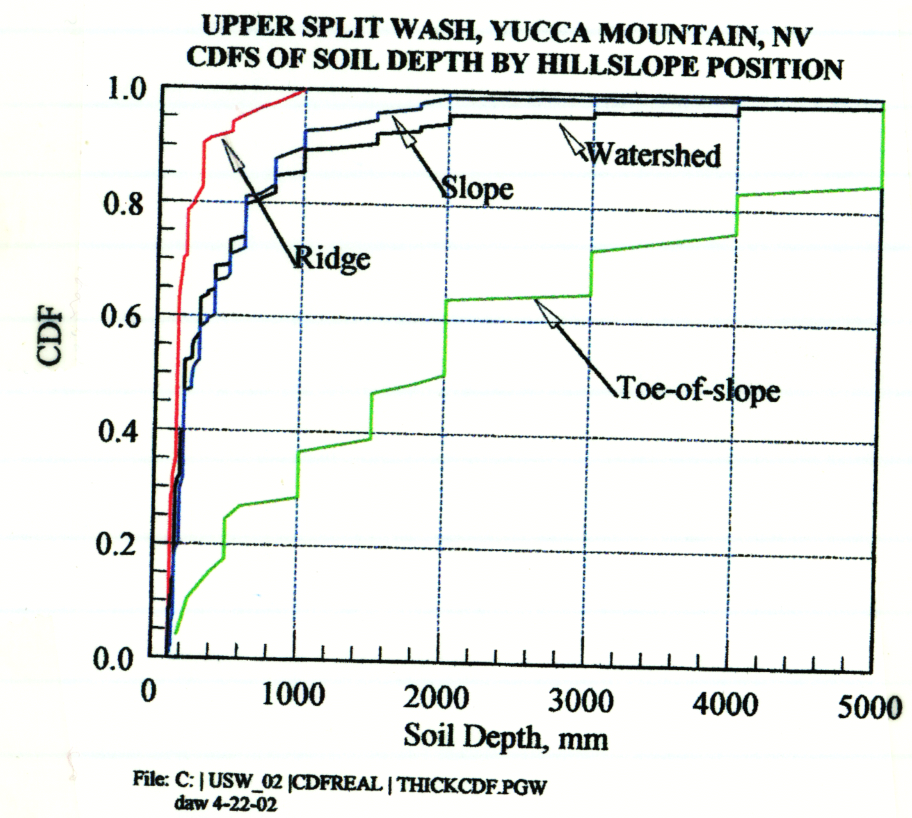
microtopographic variations. These variations are accounted for in KINEROS by the parameters RE and SPA.
However for shallow soil depths, for slope elements as well as ridge elements, the 1-D TPA analysis is O.K.

Daw 4-22-02

Create CDFs' of soil depth for slope, toe and ridge elements.

Save DMODEL.PRN as DMODEL.DAT
File has 3 cols.; Element No, Area, Slope Code ✓
add a 4th col with THICK for each element ✓

Adapt parts of program AVGCDFS.F95 to calculate CDFs of depth for each slope class.
Program name: CDFDEPTH.F95
CONTROL FILE: THICK.CON   OUTPUT FILE: THICK.CDF
The CDF's of soil depth conditioned on hillslope position are shown below.



Plane THICK
~ 10% of ridge area > 400 mm
~ 35% of slope area > 400 mm
~ 86% of toe area > 400 mm

Note: ridge elements will have virtually no run-on

Daw 4/24/02

Examine results for each runoff event for the plane elements showing the greatest potential bedrock infiltration.

DAW 4-24-02

Slope elements

From File: USWSLOPE.CDF upslope

Plane No	Au/A	THICK	Element#/THICK
168	1.51	130	167/120
140	2.26	130	139/140; 138/150
187	2.20	140	186/120
201	2.49	140	200/120
144	3.65	140	143/140; 142/130
139	3.00	140	138/150

38 of 101 slope plane elements receive run-on
66 " " " " " show bedrock infiltration and potential bedrock infiltration

Exploratory: Consider some extremes for hill slope elements
Factors that may be significant
1) Area weighted upslope soil thickness
2) Area ratio: Au/A
3) Precipitation for that event

DAW 4-24-02

Consider plane elements 144 and ~~44~~ 67
Consider rainfall events: G3_88_1 Run# SW_TBC1
S18_95_2 " SW_TBC12
G3_92_7 " SW_TBC15
S8_3995b " SW_TBC17

Plane 44 Contributing area = 4264 m^2
Note: 44 is not a good choice. It is below disturbed area

Plane 67 Contributing area = ~~10,580 m^2~~ DAW 4-24-02 6733 THICK = 200
Area = 3847 DAW 4/24/02 Au/A = 1.75
66 Area = ~~3882~~ 2851 DAW 4/24/02 THICK = 150 } Area wt. Av = 150 mm
65 Area = 3882 THICK = 150 }

DAW 4-24-02

Plane 144 Contributing area = 5039; Area = 1905 m^2; THICK = 140
Au/A = 2.65
143 Area = 2752 THICK = 140 } Area wt. Av = 135.5 mm
142 Area = 2288 THICK = 130 }

Run#	Precip. mm	P (67)	F (67)	RO (67)	F-P/RO (67)	P (144)	F (144)	RO (144)	F-P/RO (144)
SW_TBC1	38	146.17	146.07	7.22	-0.01	DW 4-24-02 ~~112.38~~ 72.38	~~79.37~~ 65.57	~~95.60~~ 25.31	-0.015
SW_TBC12	87	333.4	224.8	165.3	-0.66	165.1	103.1	179.8	-0.91
SW_TBC15	59	226.96	199.22	93.42	-0.30	112.38	~~[illegible]~~ 79.37	95.60	-0.34
SW_TBC17	80	~~146.17~~ 308.9 DAW 4-24-02	194.3	222.1	-0.51	152.9	80.8	202	-0.36

P = rainfall on element m^3
F = total infiltration m^3
RO = Run-on to element m^3

For both planes and for all events F-P/RO is negative, showing that rainfall alone was greater than infiltration.
These are all large storms that lead to large percentage of saturation. Consider smaller events

Run#	Precip mm	P (67)	F (67)	RO (67)	F-P/RO (67)	P (144)	F (144)	RO (144)	F-P/RO (144)
SW_TBC2	32	123.1	123.1	0		60.95	61.05	4.71	+0.02
SW_TBC11	30	116.98	116.98	0		57.92	57.9	0	

There was a small amout of run-on on plane 144 for Run# SW-TBC2

DAW 4-25-02

Modify AVGCDF5.F95 to accomodate single events
Involves removing seasonal statistics

New Program is STORMCDF.F95

DAW 4-25-02

Run Program STORMCDF.F95 for selected storms

File naming strategy:

Control file: TBC17CDF.CON in C:\USW_02

Run# "control"

output files:

watershed CDF	TBC17.CDF	All in \CDFREAL\
Ridge	TBC17RID.CDF	
Slope	TBC17SLO.CDF	
Toe	TBC17TOE.CDF	
Channel	TBC17CHA.CDF	

→ For Run SW_TBC17 Precip = 80 mm

Rock F = 11.75 mm over entire area

14.9 mm over 79% of area

DAW 4-26-02

Continue runs of STORMCDF.F95 for selected storms

Objective:

To get CDFs of Infiltration excess, bedrock infiltration during the storm and potential bedrock infiltration for a range of storm depths to provide insight into adjustments of TPA analyses for runoff-runon.

→ Run SW_TBC1 (Rain 63-88_1) Precip = 38 mm

Control file: TBC1CDF.CON

Output files: Format convention same as above

watershed CDF TBC1.CDF etc

ROCK F = 5.59 mm; 8.25 mm over 67.9% of area

7 of 59 ridge had net runon. All were below disturbed elements (DAW 4-26-02)

27 of 101 slope element had net runon > 1 mm

Of these many were below disturbed areas

DAW 4-26-02

These that were not are:

172 – 5.27 mm; 169 – 4.0 mm; 212 – 1.8 mm; 177 – 1.50 mm

178 – 1.27 mm; 207 – 0.868; 192 – 0.814

Element # 168 had the greatest bedrock and potential bedrock infiltration, yet had 4.34 mm of runoff. It received 3.55 m^3 of runoff from # 167, but the rainfall would have been sufficient to saturate it.

Element # 169 received 10.13 m^3 from # 168 and did have excess infiltration of 4 mm (3.14 m^3)

18 of 36 toe-of-slope elements had run-on > 1.0 mm ~50% of toe area. Only 3 elements had bedrock or potential bedrock F; 163 – 9.39 + 12.57; 69 – 4.25 + 4.25 mm, 156 – 0.1 to .1

The runoff-runon problem is very complicated and is a function of the storm characteristics and upslope conditions. One complication is that while rainfall alone might saturate a particular element, if it receives run-on from above, it may be saturated for a longer period of time + thus there will be more infiltration. A measure of this would be the difference between moisture deficit and infiltration

Run SW_TBC12 (Rain 518_95_2) Precip. = 87 mm

This had the greatest runoff volume and channel infiltration

Control file TBC12CDF.CON

.LST TBC12.LST

Rock F = 18.60 mm; 23.55 over 79% of the area

34 of 101 slope elements had net runon > 1 mm

Max net infil. excess # 19 – 23.76 mm (Below disturbed area)

DAW 4-29-2002

Examine slope and toe-of-slope elements with rainfall only and compare with results when subjected to run-on from upslope elements.

Strategy:

1) Run KINOZ_2W with parameter files for selected plane elements and with selected storm input.

2) Compare water balance statistics with the same plane elements as part of Upper Split Wash

Set up new directory: USW_02\OUTPLANE for output files

File name strategy:

For plane 68, analog to run SW_TBC1

Control file: PL68TBC1.FIL ✓

Output file: PL68TBC1.OUT

etc

DAW 4-29-02 .PAR File SW68J_A.PAR

Plane 68 THICK = 200 mm RE=100

error

Run #	Inflow (m^3)	Outflow (m^3)	Infil (m^3)	Rock F	Time sat. (min)
SWTBC1	7.34	7.34	53.50	7.59 mm	—
PL68TBC1	0	0	"	7.96	—
SWTBC17	336.61	376.84	72.84	16.09	1636
PL68TB17	0	40.98	72.79	16.32	1624
SWTBC12	273.96	311.01	84.82	22.97	5808
PL68TB12	0	38.21	84.42	23.24	5798

Note that the plane 68 with run-on had slightly more infiltration than the isolated plane 68. The differences between the saturation times and bedrock infiltration are within numerical error bounds.

DAW 4-30-2002

169 → Try element 169 with the same runoff events

.PAR file THICK = 350 mm RE=150 mm

Run#	Inflow (m^3)	Outflow (m^3)	Infil (m^3)	Rock F	ΔF	Time Sat (min)
SW_TBC1	10.13	6.98	32.97	0.32	3.99	—
P169TBC1	0	0	29.83	0.23		—
SW_TBC17	84.42	90.31	57.17	8.58		1808
P169TB17	0	5.49	57.56	10.15		1972
DAW 4/30/02						
SW_TBC12	68.69	73.03	63.66	15.67		7216
P169TB12	0	4.73	63.31	16.03		7164

DAW 4/30/02

THICK = 480, RE = 100 mm

172 → Try element 172 (mean annual excess of 5.59 mm) .PAR = P172J_A.

Mean annual Rock F = 1.89 mm/y ; Potential = 7.11 mm/y

Run#	Inflow	Outflow	Infil	Rock F	Time Sat	ΔF
SW_TBC1	22.51	18.57	31.70	—	—	
P172TBC1	0	0	27.84	—	—	3.86
						=5.95 mm
SW_TBC17	233.18	222.39	69.62	6.63	2040	
P172TB17	0	0	58.83	6.55	—	10.79 ✓
						14.7 mm
SW_TBC12	203.11	191.83	74.71	10.89	7212	
P172TB12	0	0	63.50	11.54	—	11.21 ✓
						15.77 mm

194 → Now look at a toe-of-slope element, plane 194 P194J_A.PAR

5 THICK = 500 ; RE = 150

	Run#	Inflow	Outflow	Infil	Rock F	Time Sat	ΔF
38 mm	SW_TBC1	44.66	41.28	34.25	—		
	P194TBC1	0	0	31.02	—		3.23
							3.95 mm
~~87~~ 80 mm	SW_TBC17	384.61	370.53	79.63	4.03	—	
DAW 5/6/02	P194TB17	0	0	65.54	5.73	—	14.09
~~80~~ 87 mm	SW_TBC12	346.06	332.41	84.34	10.61	—	17.26 mm
	P194TB12	0	0	70.75	10.37	—	13.59 ✓
							16.66 mm

DAW 4-30-02

Plane elements with shallow soils, 68 and 169 have little differences in infiltration although there is substantial run-on when part of a watershed. This happens because the low K_s of the bedrock rejects most of the runon (i.e. the plane element saturates) It also saturates when the plane is isolated.

However there are substantial differences for elements with deeper soils (172 and 194)

DAW 5-3-02

For slope and toe-of-slope elements, the additional infiltration due to run-on will be a function of soil depth of the element, D, mean soil depth for the upslope contributing area, $\bar{R}$, and storm precipitation, P. There will be some threshold T_p, below which there will be no runon.

Calculate $\bar{R}$ for 172 and 194

Plane	A(m²)	D(mm)	A×D	
170	3429	120	411,480	
171	3004	180	540,720	
172 Σ	6433	480	952,200 ÷ 6433	= 148 mm

172 A = 734 A_r = 6433/734 = 8.76

191	5803	120	696,360	
192	2048	200	409,600	
193	2497	180	449,460	
194 Σ	10,348	500	1,555,420	$\bar{R}$ = 150 mm

194 ; A = 816 m² A_r = 10,348/816 = 12.68

DAW 5-3-02

Consider the ratios of excess infiltration to storm precip for planes 172 and 194. DAW 5-6-02

Storm	Precip(mm)	ΔF/P 172	194	184
SW_TBC1	38	0.139 ✓	~~0.085~~ 0.104 ✓	0.019 ✓
SW_TBC17	~~87~~ 80 DAW 5-6-02	~~0.169~~ 0.183	0.~~198~~ 0.215	0.159 ✓
SW_TBC12	~~80~~ 87 DAW 5-6-02	0.~~191~~.178 DAW 5-6-02	0.~~208~~ 0.191 ✓ DAW 5-6-02	0.239 ✓

ΔF in mm. ΔF/P is the ratio of (Infiltration − Precip)/precip

DAW 5-6-02

Run plane 184 as isolated plane for the above 3 storms ✓

Control files: P184TBC1.FIL ; P184TB17.fil ; P184TB12.FIL

PAR = P184J_A.PAR

Mean annual excess = 12.85 mm ; RockF = 0 ; Potential = 0

Run #	Inflow(m³)	Outflow(m³)	Infil (m³)	RockF	Time sat	ΔF
SW_TBC1	4.76	3.42	69.55	—	—	0.757 mm ✓
P184TBC1	—	0	68.19	—	—	
SW_TBC17	167.89	145.04	166.97	—		12.75 ✓
P184TB17	—	0	144.09	—	—	
SW_TBC12	150.23	112.81	193.00	—	—	20.8
P184TB12	—	0	155.54	—	—	

	A(m²)	D(mm)	A×D
181	739	120	88,680
182	3557	180	640,260
183	1346	280	376,880
Σ	5,642		$\bar{R}$ = 195.9 = 196 mm
184	1795	800	

A_r = 5642/1795 = 3.14

DAW 5-8-02

Explore relationships between excess infiltration, ΔF, storm precipitation, P and Area ratio, A_r for the 3 storms and 3 plane elements shown on top of p116.

1) Create a data file for PSIPLOT

C:\USW_02\OUTREAL\EXCESSF.PDW

There is a high correlation between excess infiltration and precipitation

$$\Delta F = -7.58 + 0.285P \quad r^2 = 0.90$$

It appears that the area ratio, A_r also has an effect, but it appears to be curvilinear with area ratio of zero having no ΔF and with very large arearations not increasing ΔF above a certain level.

Examine output for SW_TBC15 P = 59 mm

plane	ΔF	ΔF/P
172	10.81	0.183
184	4.31	0.073
194	8.24	0.140

After adding the above data to file EXCESSF.PDW a multiple regression was obtained

$$\Delta F = -10.10 + 0.292P + 0.205 A_r \quad r^2 = 0.87$$

Examine additional plane elements to increase sample size of A_r

After adding the mean depth of upstream elements

$$\Delta F = -2.69 + 0.293P + 0.023 A_r - 0.0359 \bar{h} \quad r^2 = 0.875$$

Same number of points as above

DAW 5-8-02

Following information obtained from C:\USW_02\

Plane #	Area	Contributing Area	A_r
173 ✓	635.4	7,166.7	11.27
185 ✓	278.0	7,434.3	26.74
145 ✓	1103.8	6,944.7	6.29
215	698.4	4,408.8	6.31
189 ✓	406.8	2,619.6	6.44
114 ✓	677.3	3,729.8	5.50
105 ✓	367.5	3,089.9	8.41
97 ✓	353.8	2,019	5.71
118 ✓	360.8	836.5	2.32
203	921.7	3978.8	4.32

ΔF for Storm Run # (ΔF in mm)

Plane	SW_TBC1	SW_TBC12	SW-TBC15	SW_TBC17
173	4.450	DAW 5-8-02 ~~1.84~~ 39.12		
185	1.32	30.87		
97	0	1.84		
105	1.69	26.0		
114	1.95	26.77		
118	0	8.19		
145	4.45	29.23		
189	3.66	DAW 5-8-02 ~~39.12~~ 26.79		
203	2.89	11.49		
215	0	28.43		

DAW 5-9-02

A(m²)   d(mm)   A d

File: USW_02\AvgTHICK.qpw ← QuattroPro

Plane	A(sqm)	d,mm	A*d	Area	Avgd	SumAd
95	635.8	300	190740			
96	1363.2	800	1106560			
97	353.8	5000		2019	642.5458	1297300
103	2182.7	150	327405			
104	907.2	250	226800			
105	367.5	5000		3089.9	179.3602	554205
111	1647.1	150	247065			
112	1246.4	150	186960			
113	836.4	200	167280			
114	677.3	2000		3729.9	161.2121	601305
116	341.6	250	85400			
117	494.8	250	123700			
118	360.2	3000		836.4	250	209100
142	2287.6	130	297388			
143	2751.8	140	385252			
144	1904.8	140	266672			
145	1103.8	1500		6944.2	136.7057	949312
170	3427.4	120	411288			
171	3006.6	180	541188			
172	732.6	480	351648			
173	635.4	1500		7166.6	181.9725	1304124
181	737.8	120	88536			
182	3556.6	180	640188			
183	1345.4	280	376712			
184	1794.5	800	1435600			
185	278	1500		7434.3	341.799	2541036
186	812	120	97440			
187	676.2	140	94668			
188	1131.5	150	169725			
189	406.8	5000		2619.7	138.12	361833
200	1501.7	120	180204			
201	1008.4	140	141176			
202	1468.6	200	293720			
203	921.7	500		3978.7	154.5982	615100
214	4408.8	200	881760			
215	698.4	3000		4408.8	200	881760

Avgd = average thickness (depth) of upslope contributing area

Entered data for additional plane elements into OUTREAL\EXCESSF.PDW and ran multiple regression from PROSTAT

$$dF = -11.73 + 0.360P + 0.402A_r - 0.0225\bar{h}$$

COD = 0.682

For computed vs "observed" see figure p119

std dev of coefficients

-11.73 ± 3.16

0.360 ± 0.040

0.402 ± 0.129

-0.0225 ± 0.00583

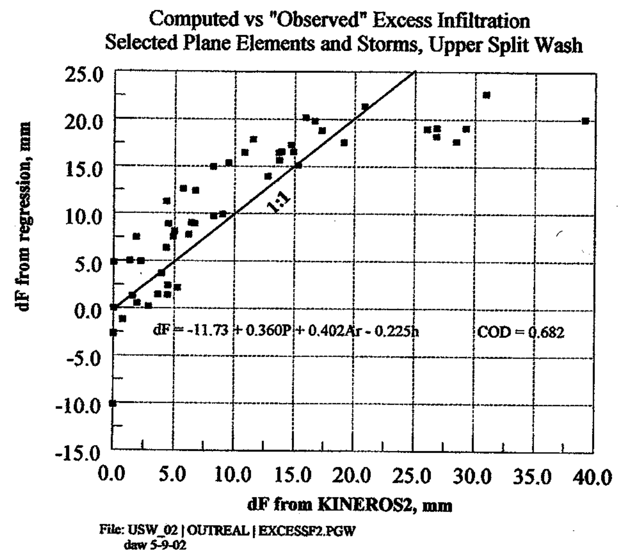
DAW 5-9-02

Alternate form

$$dF = -8.94 + 0.360P - 0.020\bar{h} \qquad COD = 0.617$$

Another 2 variable regression of the form

$dF = a + b_1 P + b_2 A_r$ had a smaller COD



DAW 5-10-02

Regression estimates are biased high for intermediate values of dF and are biased low for high values of dF, demonstrating the nonlinear nature of the relationship.

Now examine the relationship between mean annual excess infiltration and upslope ~~rela~~ DAW 5-10-02 parameters A_r and $\bar{h}$.

Copy EXCESSF.PDW to EXCESSAVG.PDW

Edit to form cols

Plane #

DAW 5-10-02

Run multiple regression with PROSTAT

$AvgdF = a + b_1 A_r + b_2 \bar{d}$

$a = 5.939 \pm 0.742$
$b_1 = 0.174 \pm 0.0549$
$b_2 = -0.0109 \pm 0.00349$

COD = 0.722

But need to increase sample size
Save USWANNUAL.CDF as RUNON.CDF
Import into PROSTAT ✓
Edit out channel elements and planes below disturbed areas. ✓
Save in prostat as RUNON.PDW

Export as QuattroPro file RUNON.WQ1 to calculate avg depth and contributing area

Add to AvgTHICK.QPW
Enter depths and areas

DAW 5-11-02
Added data to get 35 data points
Multiple regression

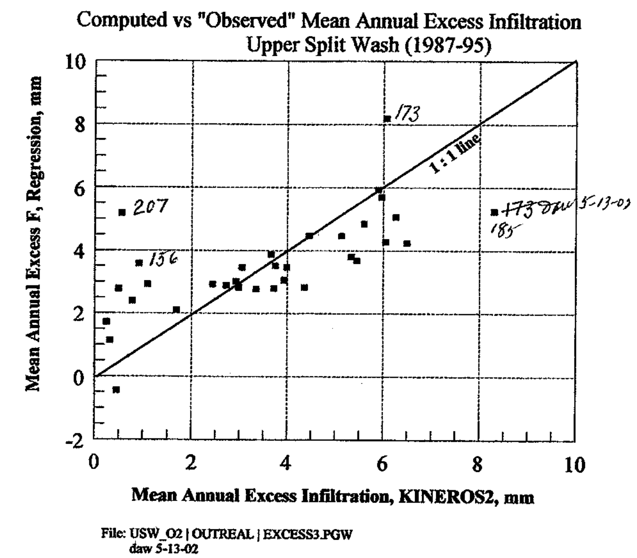
$AvgdF = 3.70 + 0.282 A_r - 0.00895 \bar{d}$ COD = 0.574
n = 35

With the larger sample size the R^2 value drops from 0.722 to 0.574. The larger sample included all plane elements that had positive mean annual infiltration excess but were not affected by an upslope disturbed area. However one should check outliers.

DAW 5-13-02
Major outliers: A plot of observed + computed AvgdF is shown below. Major outliers are identified

Plane #	AvgdF	Predicted $\bar{dF}$	Notes
173	8.29	5.25	Below 172 which has Runon
207	0.547	5.17	Upper Soil Saturates
156	0.908	3.58	upper soil saturates
185	6.05	8.18	

156 Upper soil saturates for SW_TBC17 THICK = 400 mm
207 THICK = 400 mm
172 Upper soil saturates
185 THICK = 1500



A new file EXCESSAV2.PDW was created with planes 156 and 207 omitted. A new regression was obtained

$AvgdF = 4.097 + 0.2999 A_r - 0.0104 \bar{d}$ COD = 0.665
r = 0.816
n = 33

Coefficient of determination is improved.
Regression coefficients are higly significant according to t test

DAW 5-13-02

Given the sensitivity of the runoff-runon process to the storm precipitation, soil depth, initial water content and the microtopographic parameter, this is probably the best that can be achieved.

DAW 5-14-02

Proposed procedure to adjust TPA results for existing climate.

1) Using a DEM model with 10x10 m resolution and a GIS with soil depth information calculate A_r and $\bar{d}$ for each pixel.

2) For each pixel with soil depth > 400 mm, estimate AvgdF from the regression eq. bottom of p 121.

3) Use the TPA estimates of deep percolation for all pixels with no runon.

4) For pixels with runon + depth > 400 mm find the TPA value for deep percolation from the response surface for the pixel depth, but with mean annual precipitation equal to the present value plus the mean annual excess infiltration. May be an underestimate.

5) Because the channel alluvium in Upper Split Wash is shallow (some on bedrock) some of the channel elements show positive runoff. However the duration of saturation is longer than that for upland elements so there is a greater opportunity for infiltration into bedrock.

DAW 5-14-02

Mean annual Infiltration Excess, Bedrock Infiltration and potential bedrock infiltration are shown in the following table from file C:\USW-02\CDFREAL\USWCHANNL.CDF

Chan #	Infil excess (mm)	CDF	Chan #	Bedrock Infil (mm)	CDF	Chan #	Potential Bed Infil	CDF
34	-39.503	0.033	106	3.843	0.023	34	32.019	0.033
48	-35.764	0.063	137	3.943	0.044	48	35.758	0.063
22	-30.365	0.083	115	3.948	0.077	22	41.157	0.083
180	-17.574	0.129	131	3.953	0.098	180	46.639	0.129
174	-17.312	0.172	216	8.740	0.228	174	46.828	0.172
72	-0.697	0.237	98	11.720	0.249	137	52.303	0.193
64	4.363	0.294	157	13.987	0.365	98	52.394	0.214
123	8.102	0.372	209	14.112	0.416	131	53.628	0.235
98	10.181	0.393	199	14.280	0.491	106	54.505	0.258
199	18.276	0.468	164	14.467	0.511	72	55.816	0.323
164	20.009	0.488	190	14.952	0.534	115	57.868	0.356
209	21.530	0.538	146	16.993	0.628	199	58.849	0.431
190	23.598	0.562	72	23.153	0.693	164	61.089	0.451
157	25.838	0.678	64	24.131	0.750	64	61.120	0.508
137	43.019	0.699	180	24.751	0.796	209	61.775	0.559
131	43.352	0.720	174	24.812	0.839	190	64.767	0.583
106	45.807	0.743	34	32.019	0.872	157	67.732	0.699
115	47.611	0.776	48	35.758	0.902	123	79.624	0.776
146	49.151	0.870	22	41.157	0.923	216	86.948	0.906
216	61.331	1.000	123	79.624	1.000	146	90.755	1.000

DAW 5-15-02

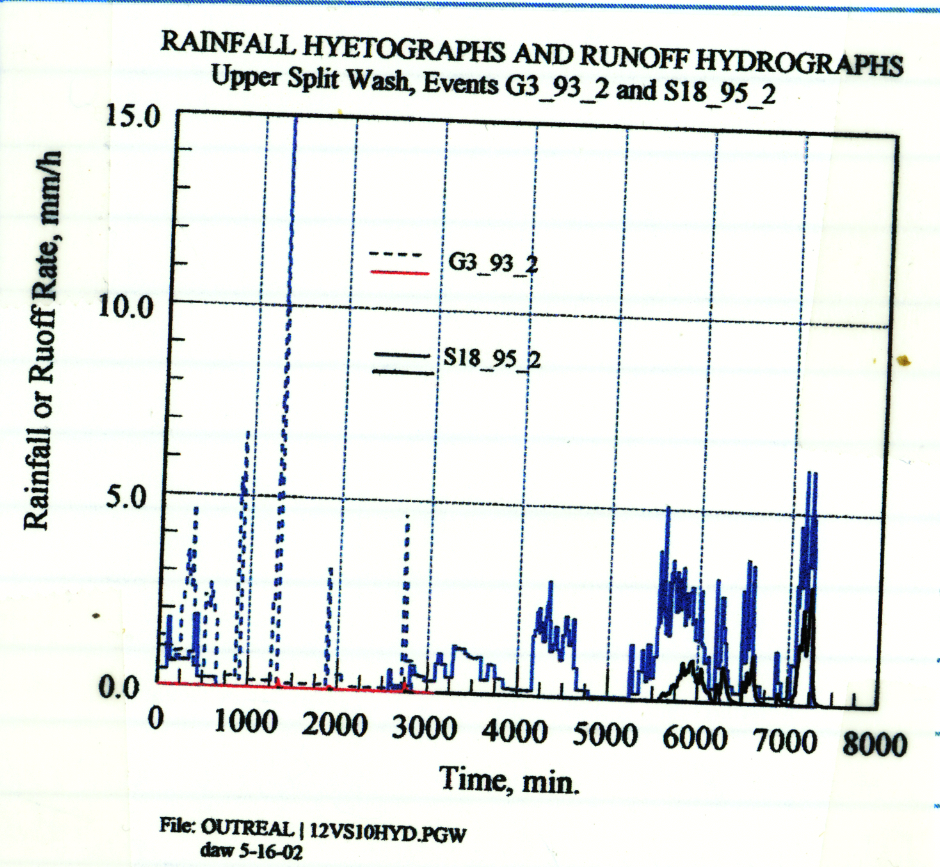
Run Program STORMCDF.F95 for remaining storms
(See p 110 for file naming strategy

Control file	Run	Rain	% Sat.	Rock F	~~Potential~~ Over Sat. Area Rock F (DAW 5-15-02)	
TBC2CDF.CON	SW_TBC2	(Rain G3_91_1)	57.7	3.82	6.26	
TBC3CDF.CON	SW_TBC3	G3_92_1	55.3	2.37	4.29	
	SW_TBC4	G3_92_2	52.4	4.00	7.64	28mm ✓
	SW_TBC5	G3_92_3	53.3	3.93	7.10	
	SW_TBC6 ✓✓	G3_92_4	61.4	3.47	5.66	
	SW_TBC7 ✓	G3_92_5	61.3	3.12	5.09	
	SW_TBC8 ✓✓	G3_96_6 (DAW 5-15-02)	61.4	3.21	5.23	
	SW_TBC9 ✓✓	G3_93_1	61.3	3.36	5.47	
✓	SW_TBC10 ✓✓	G3_93_2	67.7	5.55	8.19	37
	SW_TBC11 ✓✓	S18_95_1	63.3	4.79	7.56	
	SW_TBC13 ✓✓	G3_87_1	31.7	0.49	1.59	
	SW_TBC14 ✓✓	G3_87_7	52.0	2.29	4.41	
	SW_TBC15 ✓✓	G3_92_7	66.5	6.41	9.65	
	SW_TBC16 ✓	S18_94_1	51.0	0.89	1.73	

Daw 5-16-02

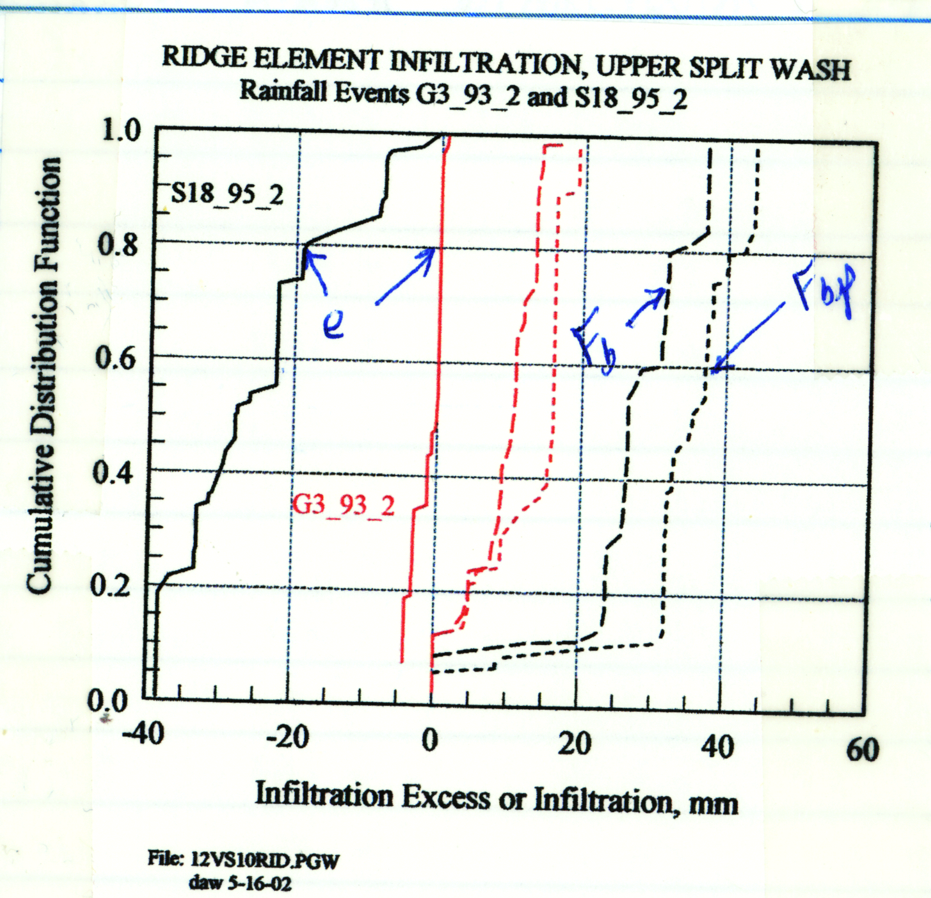
It is useful to compare runoff hydrographs and infiltration CDFs for two rainfall events with quite diffent intensity patterns and total storm depths. Storms are G3_93_2 with a total depth of 37 mm and duration of 47h-7min and S18_95_2 with a total depth of 87 mm over a time period of 5 days. Rainfall hyetographs and runoff hydrographs are shown below. Runoff volumes were:

G3_93_2	0.28 mm
S18_95_2	14.42 mm



The CDF files for each hillslope class and for channels were plotted and extreme values identified. Plane and channel numbers are shown in the Fig. on p125.

Ridge ~~Slope~~ Elements Daw 5-23-02



Information from files TBC10RID.CDF and TBC12RID.CDF show that the elements with maximum values of excess and infiltration are:

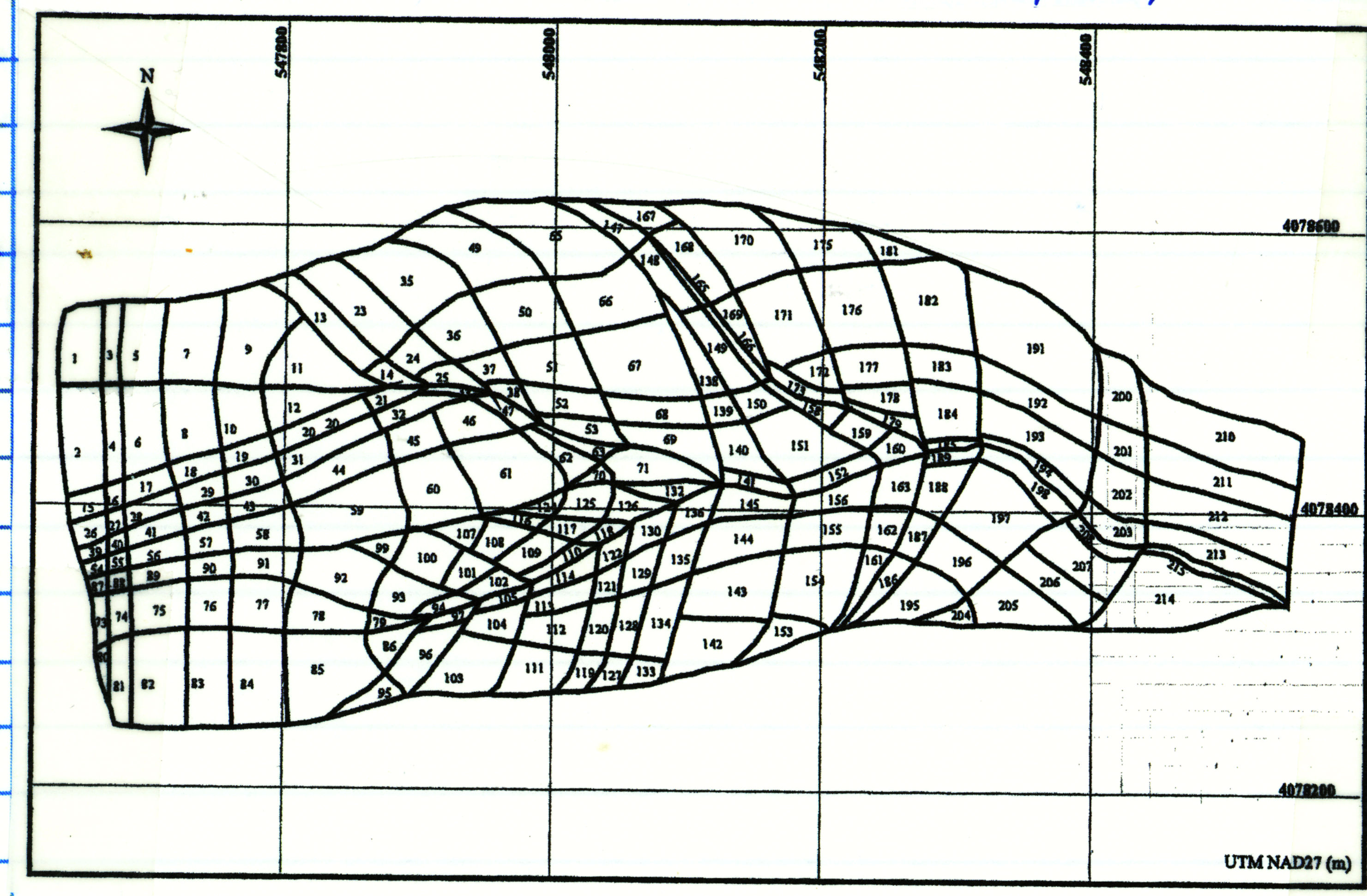
Daw 5-25-02

	S18_95_2	G3_93_2
e	~~9~~1/-0.33	89/0.86
F_b	167/37.07	167/17.02
F_{bp}	65/43.51	167/20.08
R.O.max	204/38.47	191/4.19

where F_b is bedrock infiltration during the storm, F_{bp} is "potential" bedrock infiltration and e is infiltration excess in mm

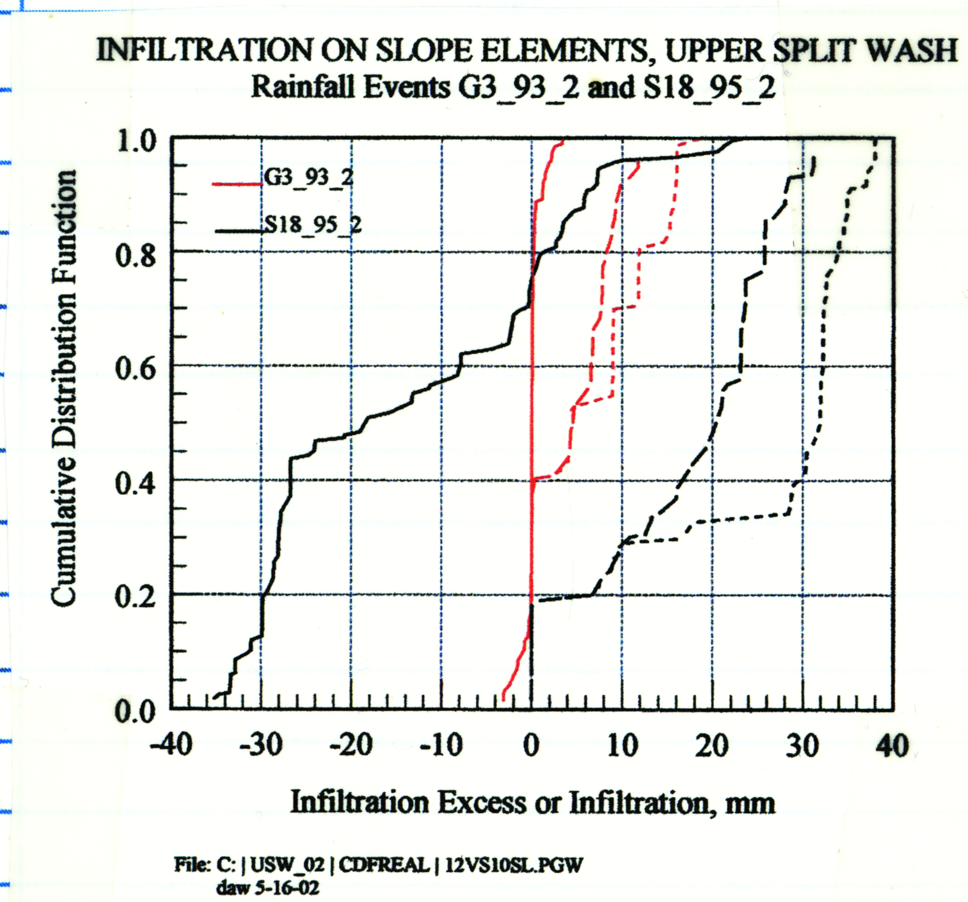
Daw 5-25-02

Both planes (65 and 167) are at the crest and have the same bedrock K_s. However 65 has 30 mm more soil so F_{bp} is greater for the larger storm.



Detailed grid with plane element numbers

Slope Elements Files TBC12SLO.CDF and TBC10SLO.CDF



Although slope elements receive runon (e is +) they have less F_b and F_{bp} because the soils are deeper.

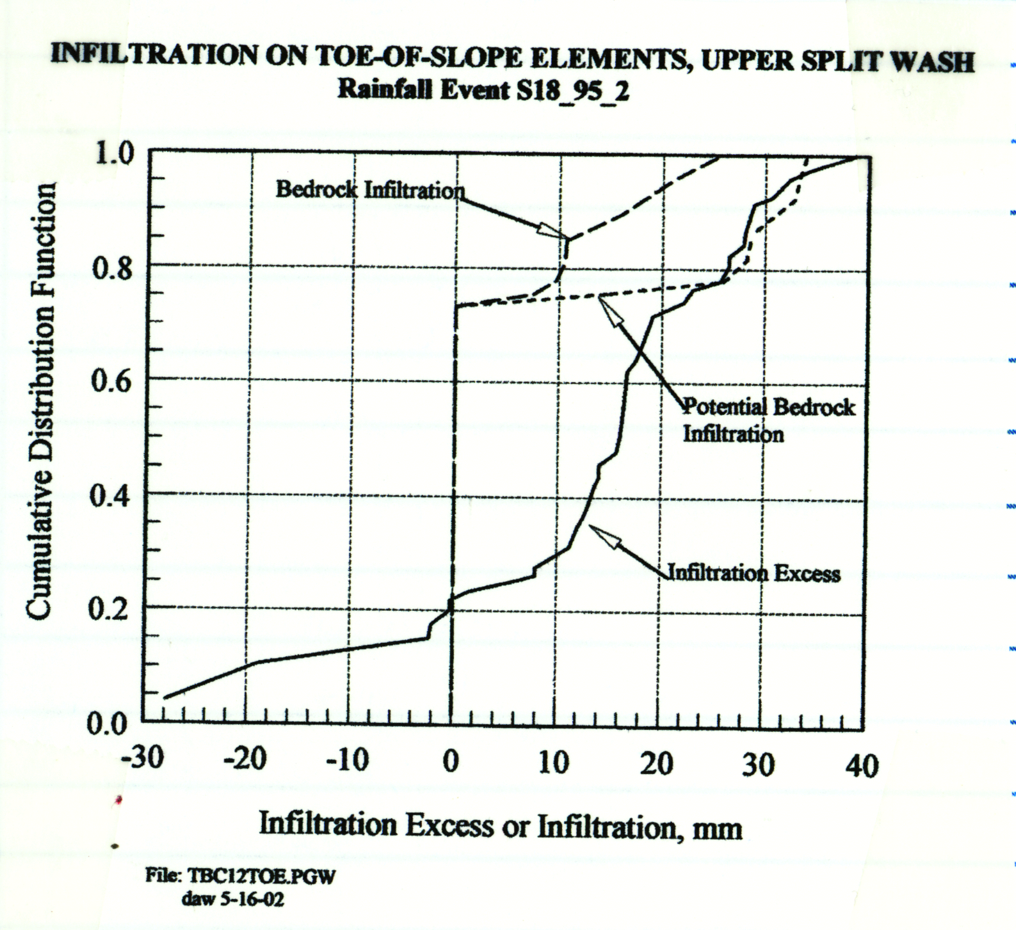
	S18_95_2	G3_93_2
e	19/23.76	12/3.04
F_b	168/31.3	168/13.25
F_{bp}	45/38.03	168/18.54
Ro max	143/35.19	7/3.08

xx/yy
xx = element No.
yy = depth in mm.

Daw 5-25-02

Toe-of-slope Elements Files: TBC12TOE.CDF + TBC10TOE.CDF

Only CDFs for event S18_95_2 are shown on the Fig below because there was very little e, F_b or F_{bp} for G3_93_2



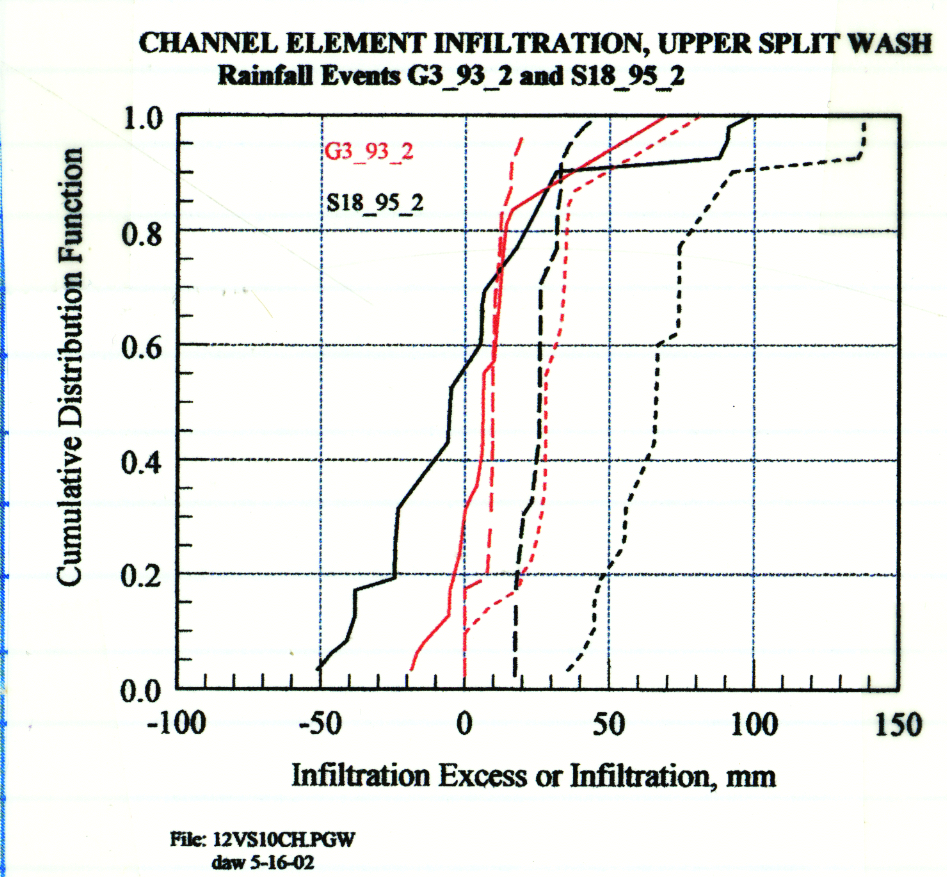
The toe-of-slope elements have more runon but less F_b and F_{bp} because the soils are much deeper.

	S18_95_2	G3_93_2
e	173 / 38.8	194 / 3.00
Fb	163 / 25.66	163 / 8.27
Fbp	163 / 33.95	163 / 11.83
RO max	163 / 27.83	160 / -0.0006

Channel Elements Files TBC12CHA.CDF and TBC10CHA.CDF

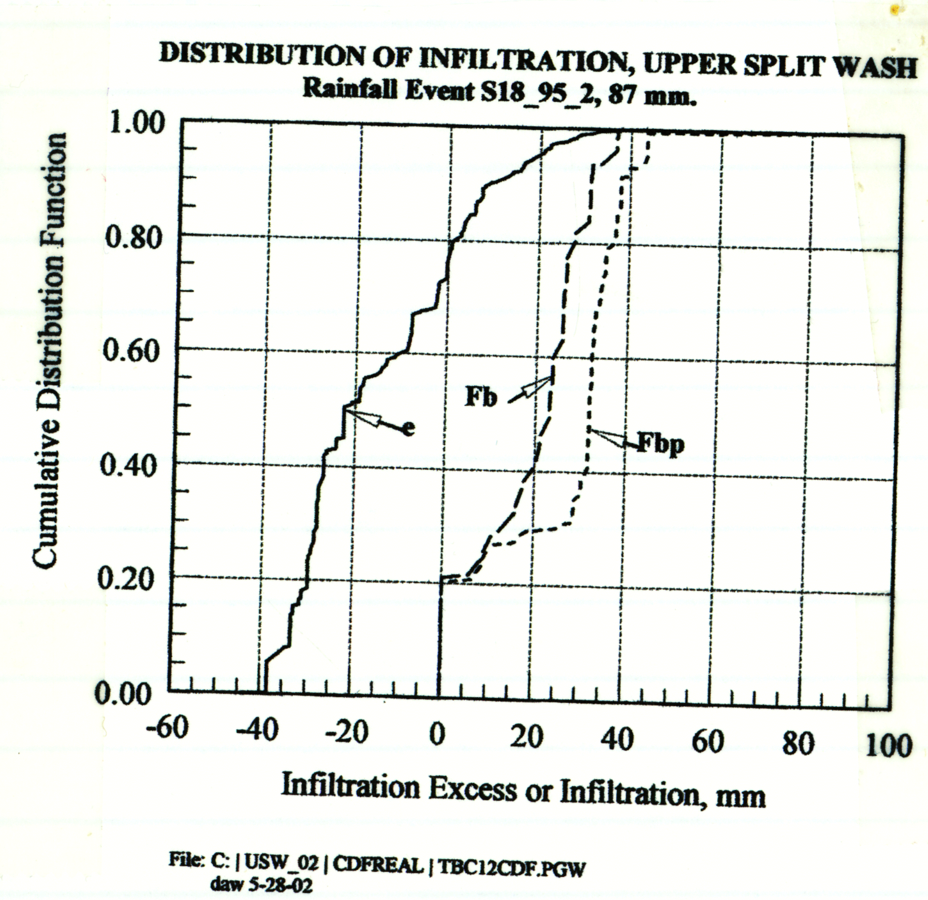
	S18_95_2	G3_93_2	
e	137 / 98.79	216 / 69.28	
Fb	22 / 45.75	22 / 23.01	Bedrock channel - large cont. area
Fbp	115 / 137.71	216 / 81.55	
ROmax	34 / 51.17	34 / 18.57	Below 22 Ks = 0.355 (bedrock)

Daw 5-25-02



The CDFs in the adjacent figure demonstrate the concentration effect of channel elements and that the maximum F_{bp} depends on the magnitude of the storm. For S18_95_2, ~45% of the channel areas had net runon (e+) while for the smaller storm 70% had net runon. This reflects saturation of channel alluvium during larger runoff events with consequent greater F_b. F_{bp} is affected by the thickness of the alluvium and the magnitude of the storm. For the larger storm, channel 115 with THICK = 500 mm had more F_{bp} than 216 with Thick = 300 mm while the reverse was true for the smaller storm.

The maximum channel F_{bp} was over 3 times as great as that for ridge elements for S18_95_2 and over 4 times as great for the smaller storm. This factor may be important in the interpretation of tracer data in groundwater.



Daw 5-28-02

← CDFs for entire watershed

DAW 6-4-02

For report update, run events 11SEP5A.PRE and PAUG4.PRE with KINEROS2 version 02-1, and updated parameter files. These are simulated storms

Control file	Precip file	.OUT file	R.O vol	Chan F	Qp
SW_S5A.FIL	11SEP5A.PRE	SW_S5A.OUT	6.93	0.51	9.28
SW_AUG4.FIL	PAUG4.PRE	SW_AUG4OUT	11.92	0.81	43.98

It is instructive to compare channel infiltration for these two events with primarily Hortonian flow with winter events with more rainfall, but much lower intensities. Summary water balances are shown below

Run Number code

	SW_AUG4	SW_S5A	SW_TBC12	SW_TBC17
Rain (mm)	26.7	37.3	86.7	80.3
Infiltration (mm)	13.6	29.8	71.6	61.6
Channel Infil (mm)	0.8	0.5	0.6	0.6
Outflow (mm)	11.9	6.9	14.4	18.0

Although the total rainfall amounts and runoff amounts for PAUG4 and 11SEP5A are smaller than for the winter storms, total channel infiltration is higher. This is apparently due to the much greater runoff rates that result in greater depths of flow and consequently greater wetted perimeters. It should be noted that only a few of the plane elements ~~for~~ DAW 6-4-02 showed bedrock infiltration for the August and September storms. Because the vegetation in and adjacent to the rather narrow channels of Upper Split Wash would be actively transpiring during the summer and fall (if water is available) it is unlikely that much of the infiltrated water would become deep percolation. However runoff from intense storms such as these could infiltrate into wider channels downstream and could contribute to deep percolation at lower elevations.

DAW 6-5-02

Possible adjustment of TPA results to account for channels

Because channel geometries are not well represented by a 10 x 10 m grid and the alluvium depths would not be modeled well by hillslope soil depth models, another approach is required.

One approach is to assume that the ratios of TPA deep percolation on ridge elements to deep percolation in channels is the same as the ratio of potential bedrock infiltration for ridge elements to potential bedrock infiltration for channel elements for Upper Split Wash or

$$\frac{\bar{F}_r}{\bar{F}_c}(TPA) = \frac{\bar{F}_r}{\bar{F}_c}(USW)$$

To calculate the means of the distributions of annual average potential bedrock infiltration for ridge and channel elements

Used PROSTAT with file USWCHANNL.CDF to calculate the areal average of mean annual channel potential bedrock infiltration

$\bar{F}_c(USW) = 61.88$ mm

Used PROSTAT with file USW~~CHANNL~~RIDGE.CDF DAW 6-5-02 to calculate the areal average of mean annual ridge potential bedrock infiltration

$\bar{F}_r(USW) = 20.04$ mm

DAW 6-6-02

The ratio $\frac{\bar{F}_r}{\bar{F}_c} = 0.32$

Thus one could approximate the mean annual deep percolation in channels from the relation

$\bar{F}_c(TPA) = \bar{F}_r(TPA)/0.32$. This quantity could be

DAW 6-6-02
applied to the percentage of area covered by channels.

DAW 6-11-02 Sensitivity Studies

The previous sensitivity analysis was done without the rain-on-channel option and the improved output of flux through the lower layer. (See Scientific Notebook 367 p 84-106) and Table 3-7 in Woolhiser and Fedors (2000). It is unlikely that there would be much change in the sensitivity coefficients except possibly S_{cr}, the sensitivity of total channel infiltration. However, it would be wise to repeat at least some of the analyses to verify (or disprove) this statement.

1. Create new folder C:\USW_02\SENSITIV
All control and parameter files will be in this directory

DAW 6-12-02
I checked with Carl Unkrich, ARS-USDA, Tucson regarding the multiplier feature in KINEROS that can be used in sensitivity studies. However the multipliers currently active in KINEROS do not include watershed properties such as THICK, K_s of bedrock, SAT or RE so it will be necessary to modify parameter files.

As in previous sensitivity studies, I will use 4 rainfall events for inputs: 58-3995b, 63-88-1, 518-95-2 and 63-92-7

File naming convention

	Perturbed	58-3995b	63-88-1	518-95-2	63-92-7
A	THICK	SEN17A	SEN1A	SEN12A	SEN15A
B	K_s bedrock	" B	" B		
C	SAT	" C	" C	etc	
D	RE	" D	" D		

DAW 6-12-02
The number refers to the run number in Table p 93.
This convention will apply to all files .fil, .PAR, .OUT etc.

It may be of interest to perturb THICK of channel elements separately. That will be series E
Note: Since SAT and THICK have opposite effects (i.e. are related) it is easier to change SAT in parameter files so as a first trial will not perturb THICK

Dimensionless sensitivity coefficient

$$S = \frac{\Delta F}{F} \div \frac{\Delta P}{P} = \frac{\Delta F}{\Delta P}\frac{P}{F}$$

where F is the objective function and P is the parameter or watershed descriptor in question. To reduce the number of computer runs, use a one-sided approximation to $\Delta F/F$ ie $\frac{\Delta F}{F} = \frac{F_2 - F_1}{F_1}$

Use $\Delta P = 0.2P$

$$\therefore S = \frac{F_2 - F_1}{F_1}\left(\frac{1}{0.2}\right)$$

Parameter file conversion

SWCHJ_AL.PAR → SENJ_AC.PAR ✓ SAT X 1.2 .325 → 0.39 ; .13 → 0.156
" " → SENJ_AB.PAR ✓ K_s bedrock X 1.2
There are 4 values for bedrock K_s
Changes made: 0.682 → 0.818
0.503 → 0.603
0.355 → 0.426
0.418 → 0.502

DAW 6-13-02 Sensitivity (Con't)

Run Case SEN17C (Increase SAT) Event 58_3995b

Vol = 19.69 mm Chan F = 0.519 mm Q_p = 3.45 mm/h

Sensitivities (Base values from p 93)

Volume $S_V = \frac{(19.69 - 18.04)}{0.2 \times 18.04} = 0.457$

channel Infil.

$S_{CF} = \frac{0.519 - 0.56}{0.2 \times 0.56} = -0.366$

Peak Runoff rate.

$S_{QP} = \frac{3.45 - 3.33}{0.2 \times 3.33} = 0.180$

DAW 6-14-02

Run Program STORMCDF.F95 control file SEN17C.CON ✓

Create files SEN17C.LST ✓ IWC = 0.1498

Rock F = ~~12.765~~ mm 12.06 DAW 6-17-02 (DAW 6-17-02)

= ~~16.19~~ ✓ mm over ~~78.8~~% of area

14.70 DAW 6-17-02 82.0

$S_{ASAT} = \frac{\text{~~78.8~~ 82} - 79}{0.2 \times 79} = 0.190$ (82 DAW 6-17-02)

$S_{FAVE} = \frac{\text{~~12.76~~ 12.06} - 11.75}{0.2 \times 11.75} = 0.132$ (12.06 DAW 6-17-02)

~~S_{FSAT}~~ $= \frac{\text{~~16.19~~ 14.70} - 14.9}{0.2 \times 14.9} = -0.067$ (14.70 DAW 6-17-02)

For base values see p 110

DAW 6-13-02 Sensitivity (Cont)

Run Case SEN17B (Increase Bedrock K_s - Event 58-3995b)

Vol = 16.80 Chan F = 0.541 Q_p = 3.17 mm/h

$S_V = \frac{(16.80 - 18.04)}{0.2 \times 18.04} = -0.344$

$S_{CF} = \frac{0.541 - 0.56}{0.2 \times 0.56} = -0.170$

$S_{QP} = \frac{3.17 - 3.33}{0.2 \times 3.33} = -0.240$

Run Program STORM.CDF.F95 control file: SENSITIV\SEN17B.CON ✓

SEN17B.LST IWC = .131

Rock F = 12.76 mm

= 16.19 over 78.8%

$S_{ASAT} = \frac{78.8 - 79}{0.2 \times 79} = -0.0127$

$S_{FAVE} = \frac{12.76 - 11.75}{0.2 \times 11.75} = 0.430$

$S_{FSAT} = \frac{16.19 - 14.9}{0.2 \times 14.9} = 0.433$

Daw 6-13-02 Sensitivity (Cont)

Run SEN1B (Increase Bedrock K_s, Event G3_88_1)
Vol = 0.63 mm Chan. F = 0.436 Q_p = 0.516

$S_V = \frac{0.63 - 0.90}{0.2 * 0.90} = -1.500$

$S_{CF} = \frac{0.436 - 0.47}{0.2 * 0.47} = -0.362$

$S_{Qp} = \frac{0.516 - 0.80}{0.2 * 0.80} = -1.78$ 75 Daw 6-17-02

STORMCDE.F95 SEN1B.CON

Rock F = 5.73 mm over entire area
= 8.58 mm over 66.8 % of area

Daw 6-14-02

$S_{ASAT} = \frac{66.8 - 67.9}{0.2 \times 67.9} = -0.081$

$S_{FAVE} = \frac{5.73 - 5.59}{0.2 \times 5.59} = 0.125$

$S_{FSAT} = \frac{8.58 - 8.25}{0.2 \times 8.25} = 0.200$

Note: Overbank portion of channel 123 is included in the above 3 coefs for SEN1B but not for SW_TBC1 (see p 110)

Daw 6-13-02 Sensitivity (Cont)

Run Case SEN1C (INCREASE SAT, Event G3_88_1)
Vol = 1.20 mm Chan F = 0.456 Q_p = 1.31 mm/h

$S_V = \frac{1.20 - 0.90}{0.2 * 0.90} = 1.67$

$S_{CF} = \frac{0.456 - 0.47}{0.2 * 0.47} = -0.149$

$S_{Qp} = \frac{1.31 - 0.80}{0.2 \times 0.80} = 3.19$

SEN1C.CON

Daw 6-14-02

ROCK F = 5.96 mm
= 8.68 over 68.7 % of area

$S_{ASAT} = \frac{68.7 - 67.9}{0.2 \times 67.9} = 0.058$

$S_{FAVE} = \frac{5.96 - 5.59}{0.2 \times 5.59} = 0.33$

$S_{FSAT} = \frac{8.68 - 8.25}{0.2 \times 8.25} = 0.26$