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12.0 Appendixes

Appendix 3.0 Sampling depths for site characterisation

Table A3.0 Sample depths (cm) for calibration of EMI survey.

Series Sites	U1 U1-1 to U11	U2 U2-1to U2-6	U3 U3-1 to U3-4
Depths (cm)			
0-10		✓	✓
10-20	✓	✓	✓
20-30		✓	✓
30-40	✓	✓	✓
40-50		✓	✓
50-60	✓	✓	✓
60-70		✓	✓
70-80	✓	✓	✓
80-90		✓	✓
90-100		✓	✓

Appendix 3.1 Depth weighting for EMI calibration

Table A3.1 Depth weighting factors for calibration of apparent conductivity (EC_a) to electrical conductivity ($EC_{1:5}$).

	Depth (cm)	Depth Response		Depth Weighting Factors	
		EC_a - V	**EC_a - H**	**EC_a - V**	**EC_a - H**
Series I	10-20	0.55	1.4	0.24	0.48
	30-40	0.7	0.7	0.30	0.24
	50-60	0.6	0.5	0.25	0.17
	60-70	0.5	0.3	0.21	0.11
Series II & III	0-10	0.2	1.7	0.04	0.22
	10-20	0.6	1.3	0.11	0.17
	20-30	0.7	1.0	0.13	0.13
	30-40	0.75	0.8	0.14	0.11
	40-50	0.7	0.7	0.13	0.09
	50-60	0.7	0.6	0.13	0.08
	60-70	0.6	0.5	0.11	0.07
	70-80	0.5	0.4	0.09	0.05
	80-90	0.4	0.3	0.07	0.04
	90-100	0.4	0.3	0.07	0.04

EC_a-V - Apparent conductivity vertical orientation, EC_a-H - Apparent conductivity horizontal orientation.

Appendix 3.2 Electromagnetic Induction mapping (EMI38)

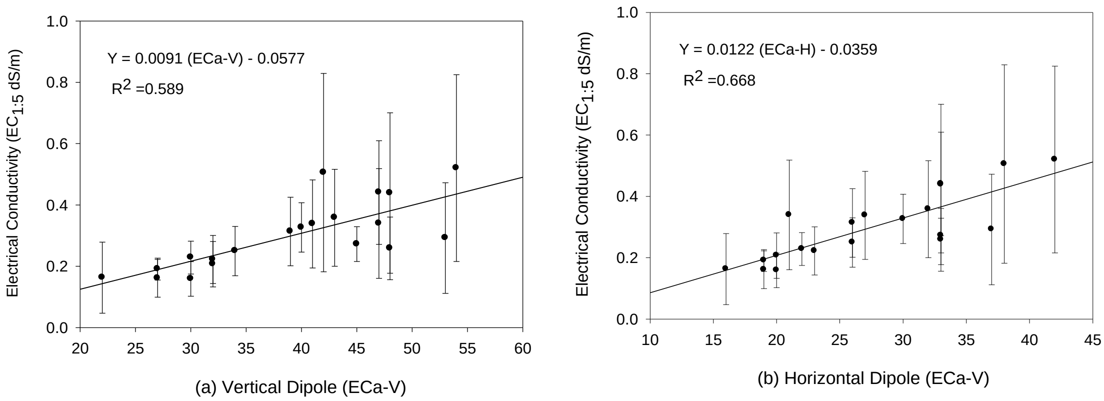


Figure A3.2.1 Linear regression between electrical conductivity (EC1:5) and apparent conductivity (a) Vertical dipole EC_a-V, (b) Horizontal dipole EC_a-H.

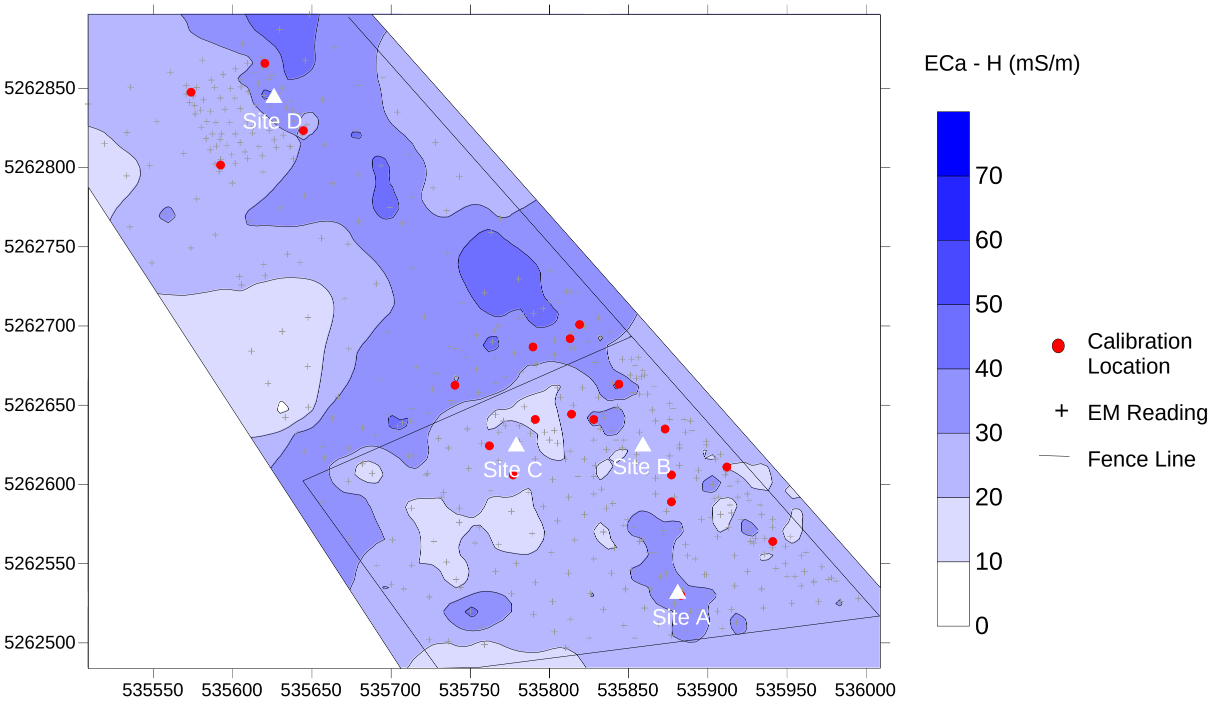


Figure A3.2.2. Apparent Electrical Conductivity – Horizontal Dipole (ECa-H).

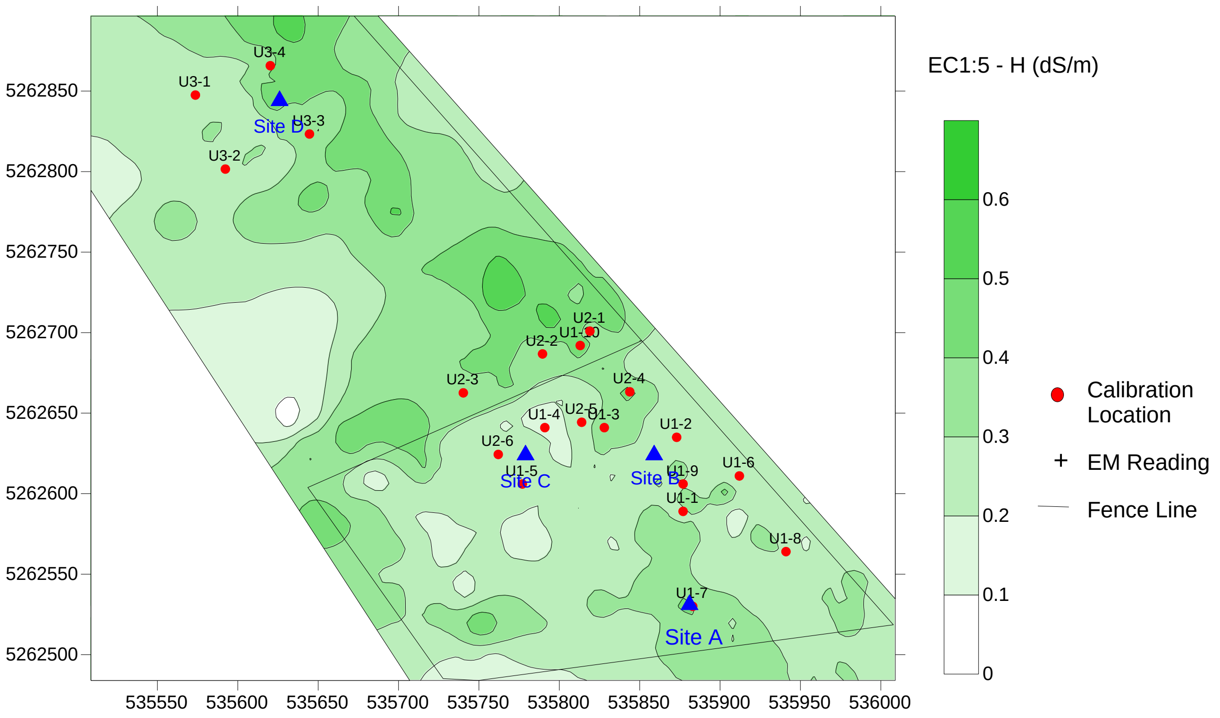


Figure A3.2.3 Electrical Conductivity – Horizontal Dipole (EC1:5 - H).

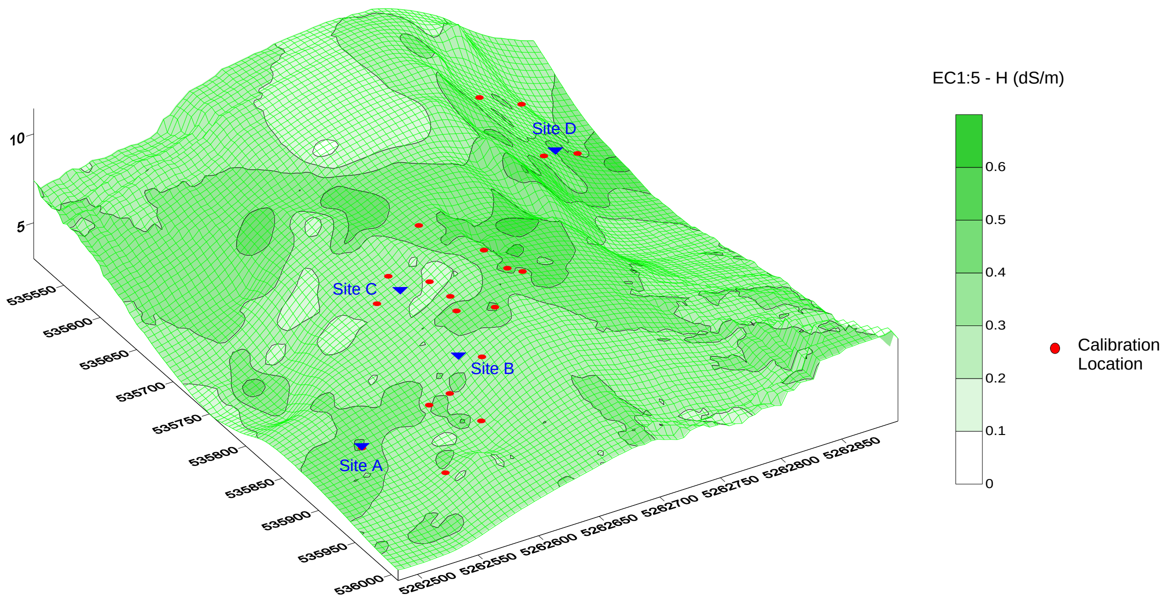


Figure A3.2.4 Elevation & Electrical Conductivity – Horizontal Dipole (EC1:5 - H).

Appendix 3.3 Liquid Limit

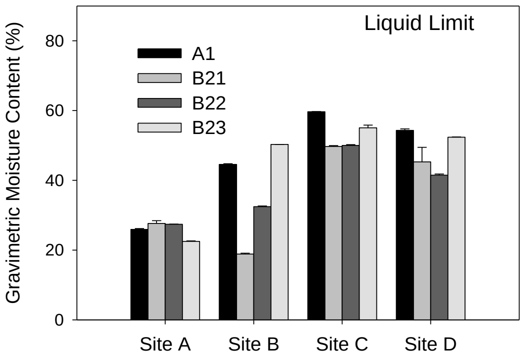


Figure A3.3 Liquid limit. Error bars represent 1 SD.

Appendix 3.4 Chemical soil properties

Table A3.4 Chemical soil properties.

Site	Depth	Horizon	Nitrate N	Ammonium	Phosphorus	Potassium	Sulphur	Organic Carbon	Conductivity	pH $CaCl_2$	pH H_2O	Exc. Ca	Exch. K	Exc. Mg	Exc. Na	Total N	Total P	Chloride	Exc. Al	KCl H	Exc. Acidity	ESP (no Al^{+3})	CEC	TEB	ESP with (Al^{+3})	ECEC	Base Saturation	Ca : Mg Ratio
	cm		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	dS/m			meq/100 g	meq/100 g	meq/100 g	meq/100 g	%	mg/kg	mg/kg	meq/100 g	meq/100 g	meq/100 g	%	meq/100 g	meq/100 g	meq/100 g	meq/100 g	meq/100 g	
A	0-10	A	6	2	17	49	4.2	1.83	0.09	5.7	6.5	1.21	0.04	0.58	0.08	0.15	153	28	0	0	0	4.34	1.91	1.91	4.34	1.91	1.00	2.11
A	12-14	A2	3	1	13	39	4.2	0.67	0.10	4.7	5.7	0.85	0.08	0.57	0.04	0.06	55	77	0.11	0.01	0.12	2.15	1.65	1.54	2.31	1.77	0.87	1.51
A	10-20	B21	3	1	6	69	3.6	0.81	0.18	5.4	6.3	1.39	0.07	2.06	0.25	0.09	51	152	0.14	0.05	0.19	6.16	3.92	3.78	6.46	4.11	0.92	0.68
A	20-30	B21	1	2	3	69	7.6	0.87	0.27	5.5	6.5	1.94	0.07	3.61	0.66	0.08	34	277	0	0	0	10.54	6.28	6.28	10.54	6.28	1.00	0.54
A	30-40	B22	1	2	3	77	27.9	0.58	0.42	6.2	7	1.73	0.07	3.95	0.84	0.06	26	528	0	0	0	12.69	6.59	6.59	12.69	6.59	1.00	0.44
A	40-50	B22	1	2	2	80	51.1	0.36	0.52	6.6	7.5	1.80	0.08	4.48	1.06	0.04	20	809	0	0	0	14.25	7.41	7.41	14.25	7.41	1.00	0.40
A	60-70	B22/B23	1	2	1	97	68.8	0.21	0.67	6.9	7.8	1.60	0.12	3.61	1.28	0.02	12	1023	0	0	0	19.36	6.62	6.62	19.36	6.62	1.00	0.44
A	90-100	B23	1	3	3	127	80.9	0.17	0.93	7	7.9	1.05	0.09	2.46	0.89	0.02	8	1283	0	0	0	19.79	4.49	4.49	19.79	4.49	1.00	0.43
A	120-130	D	1	2	5	168	60.4	0.16	0.94	7	7.9	3.47	0.37	10.2	4.89	0.02	13	1085	0	0	0	25.76	18.9	18.96	25.76	18.9	1.00	0.34
B	0-10	A	6	2	22	87	4	2.39	0.09	4.5	5.4	1.53	0.11	0.92	0.05	0.19	137	37	0.11	0.05	0.16	1.80	2.73	2.62	1.91	2.89	0.91	1.67
B	10-20	A1/A2	1	1	19	58	3.3	1.23	0.06	4.3	5.3	1.15	0.10	0.80	0.06	0.11	135	20	0.31	0.13	0.44	1.92	2.42	2.11	2.27	2.86	0.74	1.44
B	15-17	A2	4	1	27	55	2.3	0.58	0.04	4.8	5.9	0.77	0.07	0.32	0.02	0.06	82	28	0.08	0.01	0.09	1.70	1.26	1.18	1.82	1.35	0.87	2.41
B	20-30	B21	1	1	4	146	4.9	0.69	0.08	4	5.2	1.90	0.21	3.93	0.40	0.06	36	47	1.81	0.27	2.08	3.90	8.24	6.43	4.89	10.3	0.62	0.48
B	30-40	B21	1	1	3	119	5.7	0.59	0.10	4.1	5.3	1.59	0.20	4.71	0.60	0.05	17	64	1.98	0.27	2.25	5.29	9.08	7.10	6.60	11.3	0.63	0.34
B	40-50	B21/B22	1	2	3	98	8.5	0.42	0.09	4.1	5.3	1.23	0.17	4.72	0.59	0.04	14	75	1.66	0.21	1.87	5.75	8.37	6.71	7.03	10.2	0.66	0.26
B	60-70	B22	1	2	4	86	16.2	0.34	0.13	4.3	5.5	0.93	0.14	4.39	0.61	0.04	19	103	0.9	0.14	1.04	7.63	6.98	6.08	8.77	8.02	0.76	0.21
B	70-80	B22	1	2	4	99	27.3	0.28	0.17	4.5	5.6	0.99	0.14	3.79	0.57	0.03	20	137	0.37	0.07	0.44	8.99	5.86	5.49	9.66	6.30	0.87	0.26
B	110-120	B23	1	2	7	130	29	0.21	0.26	6.1	7.1	0.51	0.08	1.01	0.19	0.02	15	240	0	0	0	10.80	1.79	1.79	10.80	1.79	1.00	0.51
C	0-10	A	11	2	37	117	6	1.29	0.18	4.5	5.4	1.44	0.14	0.88	0.14	0.13	179	82	0.13	0.09	0.22	4.85	2.73	2.60	5.24	2.95	0.88	1.63
C	10-20	Ap/A2	3	2	17	113	5	1.17	0.08	4.5	5.4	1.45	0.15	2.27	0.26	0.1	83	23	0.64	0.17	0.81	4.58	4.78	4.14	5.36	5.59	0.74	0.64
C	16-18	A2	3	1	21	57	3.4	0.86	0.05	4.8	5.9	0.83	0.08	0.69	0.04	0.07	122	23	0.14	0.03	0.17	2.10	1.78	1.64	2.31	1.95	0.84	1.22
C	20-30	B21	1	1	6	109	5.4	0.74	0.08	4.4	5.4	1.47	0.17	3.63	0.53	0.06	32	47	1.37	0.2	1.57	6.11	7.17	5.80	7.45	8.74	0.66	0.41
C	30-40	B21	1	1	5	105	9.9	0.56	0.12	4.3	5.4	1.37	0.17	4.32	0.71	0.05	30	82	1.51	0.22	1.73	7.20	8.08	6.57	8.74	9.81	0.67	0.32
C	40-50	B22	1	1	5	75	21	0.46	0.18	4.3	5.3	1.43	0.17	4.64	0.76	0.04	23	132	1.21	0.18	1.39	7.89	8.21	7.00	9.22	9.60	0.73	0.31
C	60-70	B23	1	3	3	77	38.3	0.34	0.19	4.3	5.2	1.07	0.14	4.65	0.82	0.03	13	191	0.93	0.16	1.09	9.43	7.61	6.68	10.78	8.70	0.77	0.23
C	70-80	B23	1	3	3	77	64.2	0.24	0.40	4.4	5.4	0.75	0.12	2.93	0.74	0.03	2	528	0.26	0.08	0.34	14.33	4.80	4.54	15.34	5.14	0.88	0.26
C	120-130	2B24	1	2	5	113	65.9	0.2	0.60	5.5	6.5	1.03	0.15	5.12	1.76	0.02	7	819	0	0	0	21.85	8.07	8.07	21.85	8.07	1.00	0.20
D	0-10	A	17	2	89	97	7.4	2.25	0.15	6.2	6.8	5.40	0.12	1.50	0.06	0.19	313	69	0	0	0	0.83	7.08	7.08	0.83	7.08	1.00	3.59
D	10-20	A1/A2	17	2	13	55	9.9	1.24	0.18	4.4	5.4	2.64	0.12	4.57	0.32	0.1	99	105	0.54	0.1	0.64	3.58	8.19	7.65	3.86	8.83	0.87	0.58
D	20-30	B21	9	2	3	62	13.3	0.85	0.21	4.2	5.2	2.30	0.14	6.58	0.61	0.08	31	184	1.67	0.21	1.88	4.65	11.3	9.63	5.42	13.1	0.73	0.35
D	30-40	B21/B22	7	2	3	62	24.3	0.63	0.26	4.2	5.3	1.71	0.14	6.92	0.71	0.06	21	219	1.74	0.22	1.96	5.39	11.2	9.48	6.34	13.1	0.72	0.25
D	40-50	B22	7	2	3	57	30.3	0.53	0.28	4.2	5.2	1.45	0.14	7.28	0.80	0.05	19	256	1.48	0.2	1.68	6.25	11.1	9.68	7.19	12.8	0.75	0.20
D	60-70	B22	3	2	2	69	66.7	0.32	0.40	4.5	5.4	1.01	0.14	7.34	0.94	0.03	6	404	0.55	0.11	0.66	8.85	9.98	9.43	9.44	10.6	0.89	0.14
D	70-80	B22	1	2	2	96	90.3	0.24	0.50	5.6	6.4	0.95	0.13	6.84	0.86	0.02	12	490	0	0	0	9.82	8.78	8.78	9.82	8.78	1.00	0.14
D	100-110	B23	1	2	3	118	76.9	0.19	0.44	6.6	7.3	0.97	0.14	5.79	0.87	0.02	13	572	0	0	0	11.19	7.77	7.77	11.19	7.77	1.00	0.17
D	120-130	C	1	2	5	124	75	0.38	0.50	6.7	7.4	1.07	0.15	5.50	0.81	0.04	20	529	0	0	0	10.77	7.54	7.54	10.77	7.54	1.00	0.20

Appendix 4.0 Calibration of the rainfall simulator

Trials of a portable rotating disk rainfall simulator were conducted at two apertures, three water pressures, and a series of rotation speeds. Application uniformity was determined by placing 36 collection vials on a 1 x 1 meter grid. Total application rate was measured as the rainfall captured in a 1 x 1 meter pan over the 20 minute operation, including rainfall from the vials.
The amount of rain in each vial was measured after 20 minutes uninterrupted rainfall. Rainfall uniformity was calculated by;

Rainfall Uniformity (%) = 1 – (standard deviation / mean rainfall) x 100

Table A4.0 Rainfall simulator calibration.

Aperture	20 degree								10 degree					
Run Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Mean Calibration Application (mm)	11.57	12.48	13.56	13.65	11.69	12.71	15.43	10.47	8.52	8.52	8.52	8.35	7.98	7.74
Calibration Standard Deviation (mm)	3.55	2.63	2.50	1.89	2.51	1.73	2.95	4.21	1.09	1.90	0.86	0.92	1.53	0.86
Number of Measurements (n)	31	34	34	34	33	33	33	34	34	34	34	34	35	35
Water Pressure (KPa)	25	50	75	100	50	75	100	25	100	100	75	75	75	75
Rotation Speed (rpm)	46	46	46	22	22	22	100	100	25	100	25.5	22	19	24
Application Rate 1x1m^2 (mm/hr)	29.12	32.84	33.72	39.64		33.44	39.16	28.96	17.96	20.22	16.29	16.32	15.4	16.9
Application Uniformity (%)	69.3	79.0	82.0	86.2	78.6	86.4	80.9	59.8	87.2	77.7	89.9	89.0	80.9	89.0

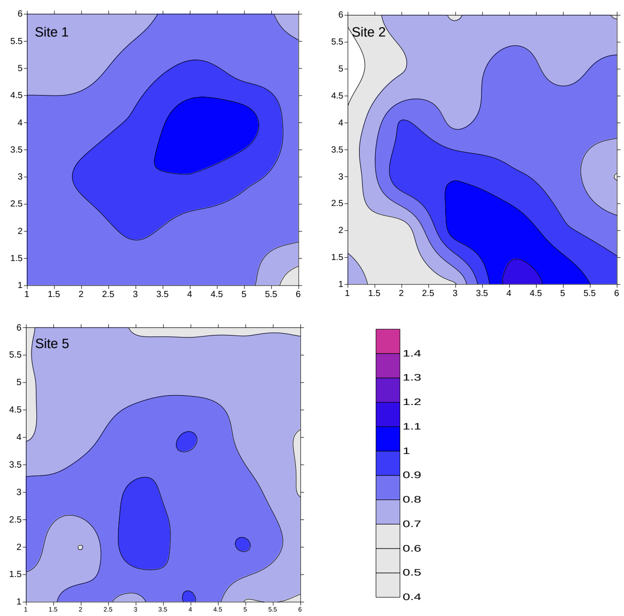


Figure A4.0 Plots of rainfall uniformity for each of the dye applications.

Results from the calibration trials demonstrate that at 10 degree aperture, 75 kPa water pressure and rotation speed between 19 and 25 revolutions per minute, that rainfall uniformity ranged between 81 to 89 %.

Appendix 4.1 Initial correction for keystone distortion

Initial keystone correction factors for vertical soil images were determined by placing a 1x1 meter calibration board, at the same distance from the camera as the 0 cm soil slice and the 50 cm soil slice. Position and orientation of the calibration board was checked with a sprit level for both vertical and horizontal orientations. Images were taken at 22 mm and 18 mm focal lengths.

The calibration process for keystone distortion is presented for the 50 cm slice at 22 mm focal length.

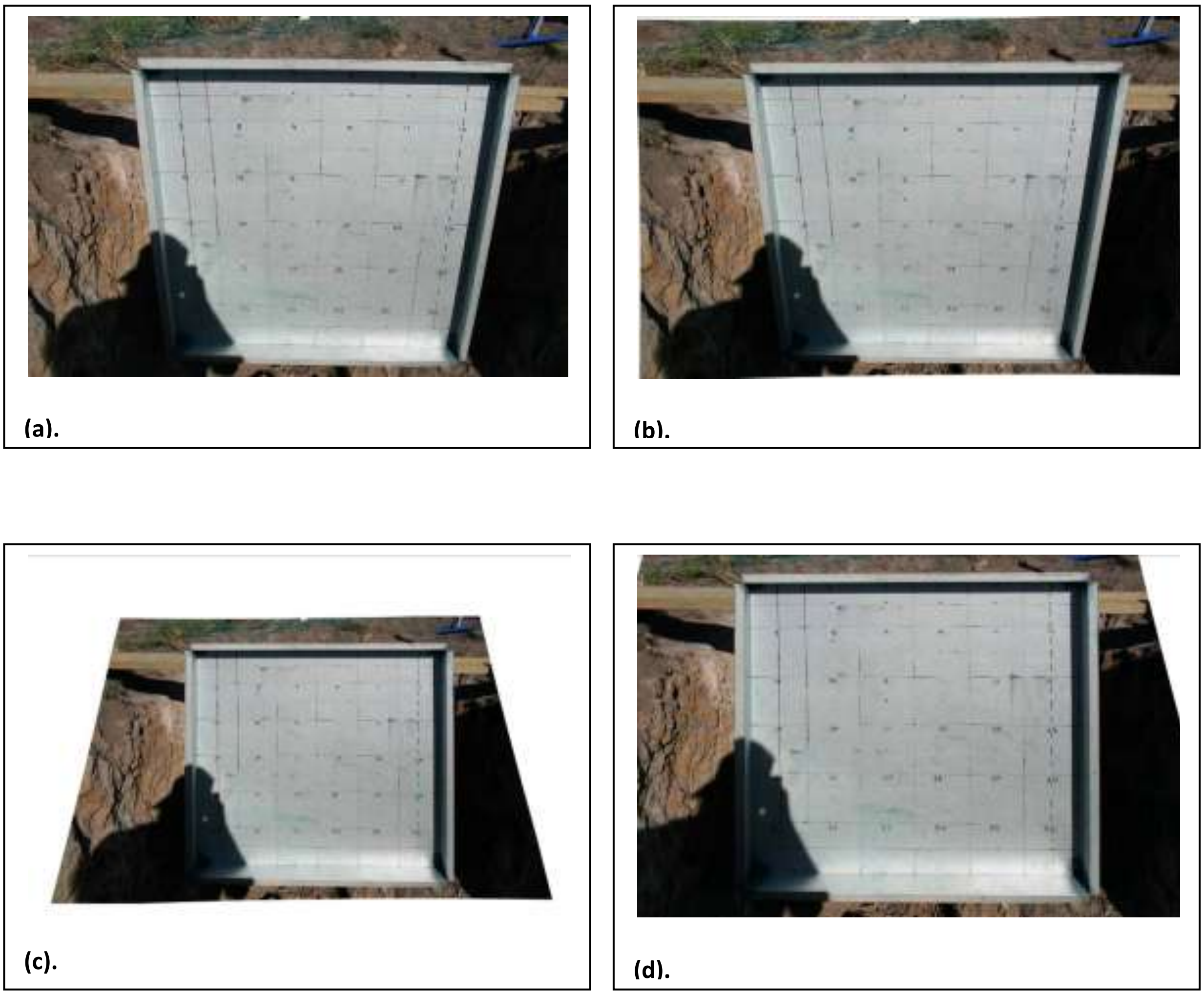


Figure A4.1 Correction for keystone distortion (a) original image (b) radial distortion corrected (c) Corrected for keystone distortion (+ 50), (d) final cropped image.

Table A4.1 Keystone correction based on focal length and position of the soil face.

Calibration Image No.	Position	Focal length (mm)	Keystone Correction Factor
2153	50cm slice	22	50
2154	50cm slice	18	60
2157	0cm slice	22	69
2158	0cm slice	18	85

Position is described as corresponding to distance from outer edge of calibrated area, corresponding to excavation depths.

The keystone correction factor was used as a starting point for correcting other images. Images were manually corrected using parallel grid and set squares positioned on the soil face with spirit level. Image correction was checked by measuring the number of pixels over a 50 cm length in both the horizontal and vertical orientation along the two set squares in the upper right and lower left corners of the excavated soil face.

Appendix 4.2 Effective and maximum rooting depth

Effective rooting depth was determined by visual observation of root presence during excavation of dye stained soil profiles, and diurnal changes (stepping) in soil moisture recorded by the EnviroSCAN soil moisture probe. Excavation during pedological investigations (Chapter 3.3.2) and dye tracer experiments (Chapter 4.3) revealed very few roots (native pasture) below 30 cm depth at all sites. The limited number of roots which did penetrate into the subsoil were largely confined to shrinkage cracks, sand infills or between ped faces, and did not penetrate more than a few centimetres into the soil columns.

Based on diurnal fluctuations in soil moisture, the effective rooting depth was estimated to be 30 cm, and the maximum rooting depth 50 cm. Soil moisture monitoring at site B, under the rainout shelter demonstrated strong diurnal changes in soil moisture (stepping) in response to evapotranspiration at 10 cm, 20 cm (not presented) and 30 cm depth (Figure 4.2). At 70 cm depth diurnal changes in soil moisture were slight (approximately 0.04 %vol.). The timing of these small soil water fluxes indicated they resulted from soil water redistribution rather than being directly related to root extraction, while at 50 cm depth the possibility existed that roots were directly drawing water from the soil.

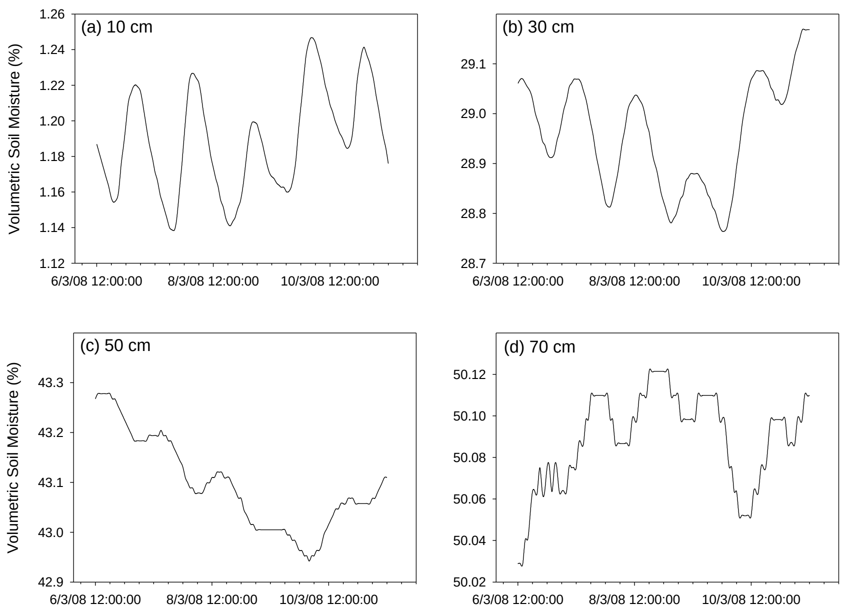


Figure A4.2 Diurnal soil moisture flux at Site B between 6/3/08 and 11/3/08 (a) 10 cm depth, (b) 30 cm depth, (c) 50 cm depth, (d) 70 cm depth.

Appendix 4.3 Dye tracer application via ponding in large rings

Two rates of dye tracer, 25 mm and 50 mm, were ponded within a 57.5 cm diameter ring which had been hammered 4 - 6 cm into the soil. 10 g L^{-1} Brilliant Blue dye tracer solution was applied to soil at 'dry' and 'wet' antecedent soil moisture conditions. The dry treatment was established following prolonged period without rainfall (rainout shelter not used), while the wet treatment was established via irrigation with sprinklers 3 -5 times a week for six weeks.

Dye application was conducted following 17.1 mm rainfall in the 24 hours prior to infiltration, which resulted in higher than desired soil moisture content between 0 – 3 cm depth.. The dye stained soil was excavated horizontally 2 - 3 days after application, using a 2.5 t excavator, garden leaf blower and by hand. Note that in the dry treatment excavation below 20 cm depth was not possible due to excessive soil strength (even with the 2.5 t excavator!). Images of dye stained soil were captured using Cannon 400D EOS digital camera in ambient light atop a 3.6 meter ladder to reduce image distortion. Images were corrected for radial and keystone distortion and dye stained soil converted to a binary image. The area of dye staining outside the ponded ring was determined by projecting the original surface of the ponded ring onto the equally scaled subsoil images. The portion of dye stained soil beneath the ponded ring was compared to outside the projected ring area to determine the extent of lateral flow.

Soil moisture prior to dye application is presented in Table 10.1-1.

Table 10.1-1 Gravimetric soil moisture prior to ponding of dye tracer in 57.5 cm diameter rings.

Depth	Site A		Site C	
(cm)	Dry	Wet	Dry	Wet
0-3			25.35	37.30
0-10	1.54	27.02	8.74	32.12
10-20.	3.57	27.32	4.30	25.68
20-30	9.75	15.57	3.22	29.25
30-40	13.88	18.33	4.79	28.85
40-50	15.20	21.29	17.24	25.84
50-60	17.16	24.61	15.44	23.40

Breakdown in the wetting front occurred between 2 - 7 cm depth in the dry treatments, and 4 - 8 cm depth in the wet treatments. Dye accumulation at the A/B boundary was minimal, however lateral dye movement away from the original application area was considerable, especially in the wet treatments below 15 cm depth, in which 60 % to 90 % of dye staining occurred outside the original application area (Figure A10.1-1). Lateral flow of the dye tracer at site C was however minimal compared to the extent of lateral dye tracer movement observed in a trial application of 50 mm dye tracer at site A (Figure 4.3-48).

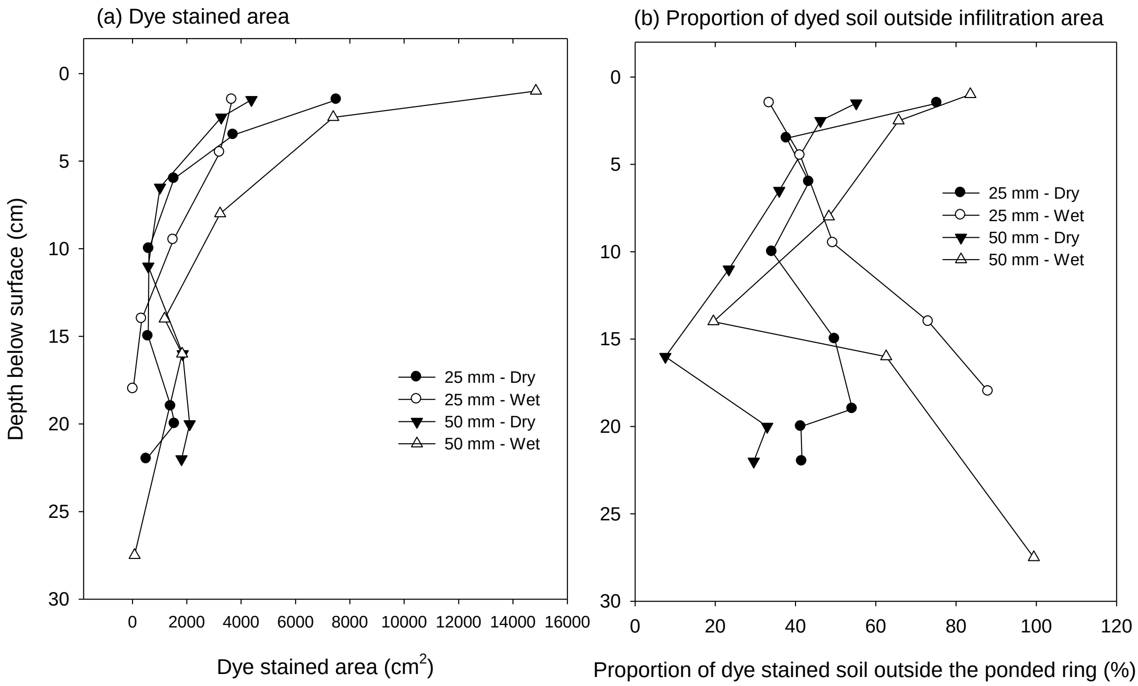
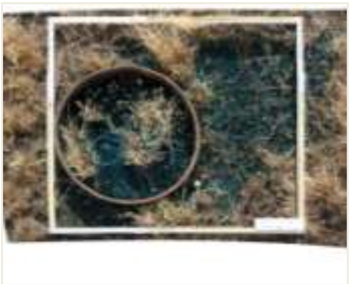


Figure A10.1-1 Site C, ponded infiltration, (a) dye stained area (b) proportion of dye stained soil outside the area of the infiltration ring.



Depth 0 cm, SA = 5636 cm^2

SO = 3625 cm^2

Depth 1-2 cm, SA = 7510 cm^2

SO = 5655 cm^2

Depth 3-4 cm, SA = 3716 cm^2

SO = 1404 cm^2



Depth 6cm, SA = 1528 cm^2

SO = 662 cm^2

Depth 10 cm, SA = 606 cm^2

SO = 207 cm^2

Depth 15 cm, SA = 583 cm^2

SO = 290 cm^2



Depth 18-20 cm, SA = 1410 cm^2

SO = 764 cm^2

Depth 18-22 cm, SA = 1558 cm^2

SO = 644 cm^2

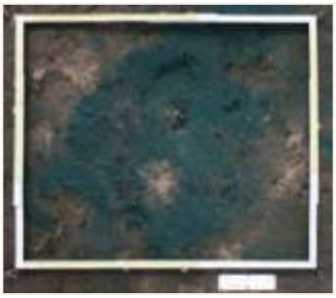
Depth 18-25 cm, SA = 518 cm^2

SO = 215 cm^2

Figure A4.3.1 Site C, 25 mm dye tracer application, dry treatment. Horizontal excavation demonstrating pattern of dye staining with depth. D – depth below surface, SA – total dye stained area, SO – dye stained area outside the application area of the ponded ring.

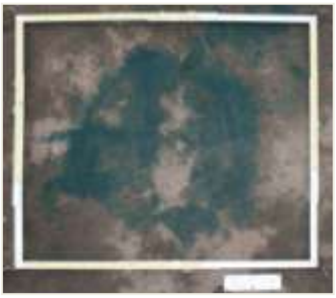
Depth 0 cm, SA = 3493 cm^2

SO = 1616 cm^2



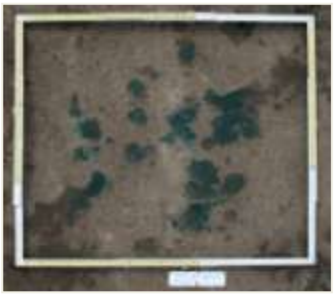
Depth 1-2 cm, SA = 4378 cm^2

SO = 2414 cm^2



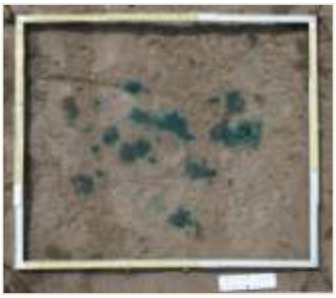
Depth 2-3 cm, SA = 3265 cm^2

SO = 1508 cm^2



Depth 6-7 cm, SA = 1011 cm^2

SO = 363 cm^2



Depth 10-12 cm, SA = 583 cm^2

SO = 136 cm^2

Depth 15-17 cm, SA = 1849 cm^2

SO = 140 cm^2

Depth 18-22 cm, SA = 2107 cm^2

SO = 693 cm^2

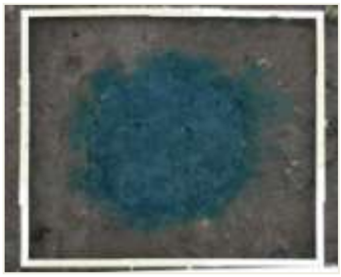
Depth 18-25 cm, SA = 1806 cm^2

SO = 536 cm^2

Figure A4.3.2 Site C, 50 mm dye tracer application, dry treatment. Horizontal excavation demonstrating pattern of dye staining with depth. D – depth below surface, SA – total dye, SO – dye stained area outside the application area of the ponded ring.

Depth 0 cm, SA = 2216 cm^2
SO = 335 cm^2

Depth 1-2 cm, SA = 3665 cm^2
SO = 1228 cm^2



Depth 4-5 cm, SA = 3214 cm^2
SO = 1324 cm^2

Depth 9-10 cm, SA = 1504 cm^2
SO = 742 cm^2

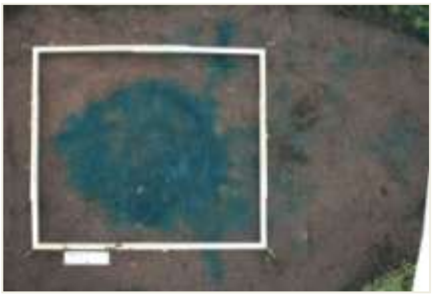
Depth 14 cm, SA = 341 cm^2
SO = 249 cm^2

Depth 18 cm, SA = 29 cm^2
SO = 25 cm^2

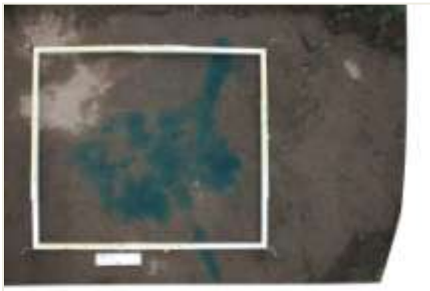
Figure A4.3.3 Site C, 25 mm dye tracer application, wet treatment. Horizontal excavation, SA – total dye stained area, SO – dye stained area outside the application area of the ponded ring.

Depth 0 cm, SA = 3562cm^2, SO = 1719 cm^2

Depth 1 cm, SA = 14840 cm^2, SO = 12402 cm^2



Depth 2-3 cm, SA = 7385 cm^2, SO = 4850 cm^2



Depth 8 cm, SA = 3219 cm^2, SO = 1554 cm^2

Depth 14 cm, SA = 1182cm^2, SO = 230 cm^2

Depth 16 cm, SA = 1823 cm^2, SO = 1141 cm^2

Depth 25-30 cm, SA = 79 cm^2, SO = 79 cm^2

Figure A4.3.4 Site C, 50 mm dye tracer application, wet treatment. Horizontal excavation demonstrating pattern of dye staining with depth. D – depth below surface, SA – total dye stained area, SO – dye stained area outside the application area of the ponded ring.

Appendix 5.0 Plant available water content (PAWC)

The Plant Available Water Content (PAWC) was determined using both *in situ* soil moisture monitoring (Chapter 6.3) and the soil water characteristic (Chapter 5.3). In the *in situ* approach the drained upper limit or field capacity was determined from *in situ* soil moisture monitoring. The lower limit or Permanent Wilting Point (PWP) was determined following a similar procedure to Dalgliesh and Foale (1998) in which a rainout shelter was used to enhance drying at sites B and D. At sites A and C determination of the lower soil moisture limit was conducted following a prolonged dry period (before June 08). The upper limit or field capacity (FC) was determined as the soil moisture content following 2 days drainage after prolonged rainfall or irrigation. The PWP was also determined from the soil water characteristic at -1500 kPa.

Insufficient seasonal drying of subsoils resulted in underestimation of PAWC from *in situ* soil moisture monitoring data. Using the PWP determined from the soil water characteristic at -1500 kPa, the PAWC for the effective root zone (0 – 30 cm) ranged from 57.8 mm at site D to 76.4 mm at site A, and between 100.4 mm at site C to 127.9 mm at site A for the maximum root zone (0 - 50 cm).

Table A5.1 Plant Available Water Content (mm) determined by *in situ* soil moisture monitoring and the lower limit from the soil water characteristic at -1500 kPa.

		Site A		Site B		Site C		Site D	
Lower limit determination		*In situ*	-1500 kPa	*In situ*	-1500 kPa	*In situ*	-1500 kPa	*In situ*	-1500 kPa
Rooting depth (cm)	0-30	65.3	76.4	87.1	67.1	67.4	63.9	63.6	57.8
	0-50	92.7	127.9	120.4	105.0	82.2	100.4	93.6	104.4
	0-70	115.2	187.7	143.4	141.7	94.1	134.0	112.2	151.9
	0-90	129.8	235.1	168.6	182.4	105.0	189.9	122.0	201.9
	0-110	119.7	276.4	162.8	234.6	110.0	260.3	114.2	254.8

Appendix 6.0 Details of the determination of the soil water characteristic using suction plates and pressure chamber analysis.

The surface of the cores were cut level with the core edge to give a known volume, and where required, picked back to remove smearing and expose soil pores. Cores were wet-up using de-aired 0.01 M $CaCl_2$ solution in 2 cm increments over a three to five day period, before being completely immersed for a 20 to 35 day period (prolonged saturation was required for clay subsoils). After wetting, any soil protruding from the cores (swelling) was removed and weighed, and the mass of the core reweighed to establish a known mass-volume at saturation.

Cores were imbedded on the ceramic plates using diatomaceous earth to ensure good contact between the plate and the soil. All analysis was conducted in a 20 ^{o}C constant temperature room. Equilibration times ranged from 5 to 35 days depending on soil texture, thickness of the contact material, and matric potential. Water loss was monitored twice daily using graduated burettes. Equilibration was said to have occurred when water loss (from all cores) was less than 0.2 ml over three consecutive days. The matric potential datum was set at the interface between the base of the soil core and the ceramic plate. Where soil loss from the cores had occurred during wetting up or during measurement, the loss of soil volume was determined by recording the mass of <250 µm oven dried sand (bulk density 1.53 g cm^{-3}) required to fill the core.

A five bar pressure chamber with a 3 bar porous plate was used to determine volumetric soil moisture Between -10 kPa and -300 kPa following the procedure 504.02 Cresswell (2002), and Reynolds and Topp (2008). For each soil layer, three undisturbed 35 X 60 mm cores were wet up in de-aired 0.01 M $CaCl_2$ (described above) and placed on the porous plate using diatomaceous earth to ensure good contact between the base of the soil core and the ceramic plate. Outflow from the plate was monitored 2 to 3 times a week. Time to reach equilibrium varied from two weeks for sands, to six to nine weeks for clays.

Volumetric soil moisture was determined at four potentials between -300 kPa and -1500 kPa, from < 2 mm sieved samples in a 15 bar pressure chamber according to the procedure outlined in method 504.02 Cresswell (2002), and Reynolds and Topp (2008). Samples were wet-up using de-aired 0.01 M $CaCl_2$ water for at least 24 hours prior to dewatering. Equilibration time ranged from five days for sands to 1 - 3 weeks for clays.

Appendix 6.1 Method description for Wind (evaporative) determination of the soil water characteristic and unsaturated hydraulic conductivity.

1) Three intact 6 cm x 6 cm diameter cores were obtained from all major soil horizons when slightly below field capacity.
2) Cores were saturated with deionised water from the bottom up, at a rate of 3 cm per day for a period between 7 days (sands) and 50 days (clays).
3) Cores were allowed to freely drain (did not occur in clays).
4) Insertion holes were drilled in to the cores by hand, and core weight recorded.
5) The core was attached to a brass plate via marine silicon to prevent evaporative loss from the soil base.
6) Tensiometers were inserted and sealed to the core with Vaseline. The upper surface of the core was loosely capped and allowed to equilibrate (3-6 hours).
7) The cap was removed and evaporation commenced, data logged every 5 minutes.
8) For sandy soils evaporation was assisted with a small portable fan.
9) Clays were capped with a drilled plate to reduce evaporation rate and maintain a linear hydraulic gradient.
10) With sandy soils fan assisted evaporation was terminated when the hydraulic gradient reached -3 cm cm^{-1}. The core was re-capped and re-equilibrated before commencing a second evaporative phase under ambient conditions.
11) Measurement cease once the upper tensiometers exceeds the functional working range -70 to -120 KPa.
12) Residual moisture content and bulk density determined by oven drying 105 °C.

The procedure was found to have many potential errors in both the methodology and calculation of soil parameters. Potential errors included;

1) Errors in cumulative measurement of evaporative loss due to tensiometer cables affecting recorded soil weight.
2) Tensiometers failure due to the presence of small air bubbles.
3) Tensiometers misalignment.
4) Inadequate drainage (only apparent for sands).
5) Air compression during tensiometers installation resulting in displacement of moisture from soil pores (apparent in clay soils).
6) Inadequate evaporative flux to determine hydraulic conductivity.
7) Establishment of non-linear flux gradient –too rapid evaporation.

8) No ability to account for volumetric shrinkage.

Tensiometers were corrected for zero error assuming both tensiometers contribute equally to error, (6 cm high core) by;

$$\psi_{ave} = (\psi_{1.5} + \psi_{4.5})/2$$

Such that the corrected head is given by;

$\psi_{1.5} = \psi_{ave} - 1.5$

$\psi_{4.5} = \psi_{ave} - (-1.5)$

ψ_{ave} = Average tension during equilibrium (hPa).

$\psi_{1.5}$ = Tension upper tensiometer (hPa).

$\psi_{4.5}$ = Tension lower tensiometer (hPa).

Iterative soil water content was determined according to

$$S_i = ((M_e - M_o) + (M_s - M_e) - (M_{ci} \times C)) / \pi \times R^2$$

$$C = (M_s - M_e) / M_{ct}$$

S_i = Iterative soil water storage (g).

M_s = Soil mass prior to evaporation (g).

M_e = Soil mass at end of evaporation (g).

C = Correction factor due to error resulting from cable interference.

M_{ci} = Cumulative loss in soil moisture for each time interval (scales) (g).

M_{ct} = Total loss in soil moisture over measurement period (scales) (g).

M_o = Oven dried soil mass (g).

R = Core radius (mm).

Error occurred in the measurement of cumulative mass of water evaporated from the soil cores as a result of interference by sagging of the tensiometer cables. This was corrected by determining the difference in cumulative mass lost by drying and the total change in mass before and after evaporation. The average correction factor was 1.020 (SD, 0.109, n=51).

Appendix 6.2 Determination of volumetric soil shrinkage (SSCC)

Analysis was conducted on five intact clods (26 to 133 cm^3) collected from four horizons between 20 cm and 100 cm at sites A and B. Intact clods were collected when subsoils were moist to reduce the effect of unconfined swelling during wetting. Intact soil clods were slowly wet-up at ψ -30 cm for four to seven days using Haines apparatus to prevent dispersion and damage to natural clod structure. Clods were then wet-up at zero supply potential (ψ = 0 cm) for a further five days, before being equilibrated at ψ -1.0 kPa for five to seven days to ensure consistent starting soil moisture near field capacity.

Paired measures of soil mass and volume were taken over a two to three week period in which soil clods were gently dried by slow airflow over the clod supplied by an aquarium pump. Soil volume was determined by evacuating the air from around the sample and immersing it in water to determine volume by Archimedes' principle. Final clod density (after drying at 105 ^{o}C) was determined by the intact clod method (Cresswell and Hamilton 2002) in which warmed clods were coated in Vaseline to prevent water entry. The smeared clods were suspended on a thin thread and immersed in water, to determine volume by Archimedes' principle. Experience revealed a number of potential errors associated with the measurement of soil volume, including; (i) air entrapment on the surface of the balloon, (ii) differences in orientation of the contracted balloon between measurements, (iii) differences in the ability to extract air from around the clod, (iv) difficulty measuring volume displacement of the setup equipment and balloon.

The SSCC curves and derivatives of the SSCC analysis were determined using 2nd and 3rd order polynomial equations, which provided a good fit (R squared >0.9) in most cases. While more complicated models and equations have been used to describe the SSCC, (reviewed by Cornelis *et al.* (2006)), they were not considered necessary due to the good fit with the polynomial equations and requirement for simple SSCC relationships for parameterisation of soil water models.

Calculations are presented for;

Iterative clod volume

$$V_{ci} = V_{si} - V_{st}$$

Iterative gravimetric moisture content

$$M_{gi} = [(M_i - M_{if} – M_{cw}) – M_{cd}] / M_{cd}$$

Iterative clod density on an oven dried basis

$$D_{ci} = M_{cd} / V_{ci}$$

Iterative volumetric moisture content

$$M_{vi} = D_{ci} \text{ x } M_{gi}$$

Final oven dried density (correction for Vaseline coating)

$$D_c = M_c / V_c - V_v$$

$V_v = (M_{cv} - M_c) / D_v$

Clod porosity

$$\Phi_{clod} = 1- (D_{ci} / D_p)$$

Void ratio

$$e = V_{\text{pores}} / V_{\text{solids}}$$

$$e = \Phi_{clod} / (1- \Phi_{clod})$$

Moisture ratio

$$v = V_{\text{water}} / V_{\text{solids}}$$

$$v = M_{gi} \times D_p$$

Where

D_c = Clod density on oven dried basis (g cm^{-3}).
D_p = Particle Density 2.65 (g cm^{-3}).
D_v = Density of Vaseline = 0.8679 (g cm^{-3}).
D_{ci} = Iterative clod density on oven dried basis (g).
M_i = Iterative clod and apparatus mass (g).
M_{gi} = Iterative gravimetric soil moisture (g).
M_{cd} = Mass of oven dried (105°C) clod (g).
M_{cw} = Mass of final clod prior to drying (g).
M_{if} = Mass of final soil clod and setup apparatus (g).
M_{vi} = Iterative volumetric moisture content (cm^3 cm^{-3}).
M_{gi} = Iterative gravimetric soil moisture (g g^{-1}).
M_{cv} = Mass oven dried clod with Vaseline coating (g).
M_c = Mass of oven dried clod (no Vaseline) (g).
V_{ci} = Iterative clod volume (cm^3).
V_{si} = Clod volume with apparatus (mass of displaced water) (cm^3).
V_{st} = Volume of set up apparatus and balloon (cm^3).
V_c = Volume of Vaseline coated clod (cm^3).
V_v = Volume of Vaseline coating (cm^3).
V_{sat} = Clod volume at -1.0 kPa (saturation) (cm^3).
Φ_{clod} = Iterative Intra-Clod Porosity (cm^3 cm^{-3}).
Φ_{crack} = Porosity resulting from intra-ped cracks (crack porosity) (cm^3 cm^{-3}).
Φ_{total} = Total porosity (cm^3 cm^{-3}).
e = Void ratio.
v = Void ratio.
V_{pores} = volume of pores (cm^3).
V_{solids} = volume of solids (cm^3).

Appendix 6.3 Details of *in situ* determination of unsaturated hydraulic conductivity using disk permeameters (tension infiltrometers)

Infiltration measurements were conducted sequentially from highest ψ -12.4 to lowest ψ -1.2 cm tension on the same sand pad, without removing the device. Between four and seven tension infiltrometers were operated sequentially at the same tension to obtain replicate data for each horizon. Measurements were recorded every two to five minutes for a duration of 20 to 60 minutes depending on time to establish steady state flow. The number of replicates varied as a result of; air entry at high negative tensions, lack of available space for placing disks on top of soil columns (B21 horizon), limited variability at highly negative supply potentials.

Contact between the tension infiltrometer and the soil was provided by a 3 mm thick pad of <250 µm washed sand. Measurements of the A1 horizon required removal or cutting surface vegetation to within 3 mm of the surface, while subsoil measurements required excavation, removal of overburden and picking back of smeared soil to expose soil pores. Measurement of the A2 horizon was conducted by carefully removing the A1 horizon and cleaning the surface of the A2 by picking back smeared surfaces. Difficulties with measurement in the A2 horizon resulted from its variable thickness which could not be established prior to measurement. Consequently immediately following cessation of infiltration, the soil beneath the disk was excavated to assess flow depth and thickness of the A2 horizon. If flow was found to be confounded by the B horizon, data was rejected or limited to infiltration at ψ -134 and ψ -84 kPa supply potentials in which infiltration was restricted to the A2 horizon.

Initial measurements of unsaturated hydraulic conductivity on the top of the B horizon were complicated by difficulty establishing level sand pads. Where the depth of the sand pad exceeded about 1 cm, uncontrolled leakage or saturated flow from the sand pad resulted in overestimation of unsaturated hydraulic conductivity at supply potentials close to saturation (ψ = 0) . The upper surface of the B2 horizon was re-measured following levelling of the upper surface of the B horizon, picking back the soil surface and constructing a level 3 mm thick sand pad.

Table A6.3 Soil moisture prior disk permeameter measurements.

Site	Soil Moisture Treatment	Horizon	Gravimetric Moisture (g g^{-1})	Bulk Density (g cm^{-3})	Volumetric Moisture (v v^{-1})
A	Dry	A1	0.02	1.36	0.03
		A2	0.01	1.60	0.01
		B21	0.11	1.67	0.18
		B22	0.10	1.91	0.19
		B23	0.15	1.75	0.26
	Wet	A1	0.21	1.37	0.29
		A2	0.13	1.60	0.20
		B21	0.20	1.59	0.32
		B22	0.18	1.67	0.30
B	Dry	A1	0.02	1.29	0.03
		A2	0.02	1.62	0.03
		B21	0.08	1.60	0.13
		B22	0.13	1.77	0.18
		B23	0.14	1.73	0.23
	Wet	A1	0.26	1.35	0.35
		A2	0.17	1.60	0.27
		B21	0.16	1.75	0.27
		B22	0.23	1.50	0.35
C	Dry	A1	0.01	1.42	0.02
		A2	0.01	1.60	0.01
		B21	0.12	1.63	0.20
		B22	0.11	1.83	0.21
		B23	0.14	1.70	0.25
	Wet	A1	0.28	1.30	0.36
		A2	0.17	1.60	0.28
		B21	0.23	1.46	0.34
		B22	0.18	1.68	0.30
D	Dry	Ap	0.03	1.35	0.05
		B21	0.13	1.71	0.22
		B22	0.11	1.68	0.19
	Wet	Ap	0.16	1.33	0.21
		B21	0.15	1.71	0.25
		B22	0.15	1.70	0.25
		B23	0.14	1.72	0.25

Appendix 6.4 Laboratory estimation of unsaturated hydraulic conductivity – evaporation.

Unsaturated hydraulic conductivity close to saturation was similar between sites and soil horizons. The unsaturated hydraulic conductivity of the A1 and A2 horizons ranged over five orders of magnitude from 10^{1} near saturation to 10^{-4} at -60 kPa. The unsaturated hydraulic conductivity of three B2 horizons increased by approximately two to three orders of magnitude between -10 kPa and saturation as a consequence of greater mesopore and macropore flow. Notable exceptions include the B22 horizon at site A and the B23 horizons at sites B and D in which macropore flow was either not able to be determined (minimal gradient between tensiometers) or soil contained few functional macropores.

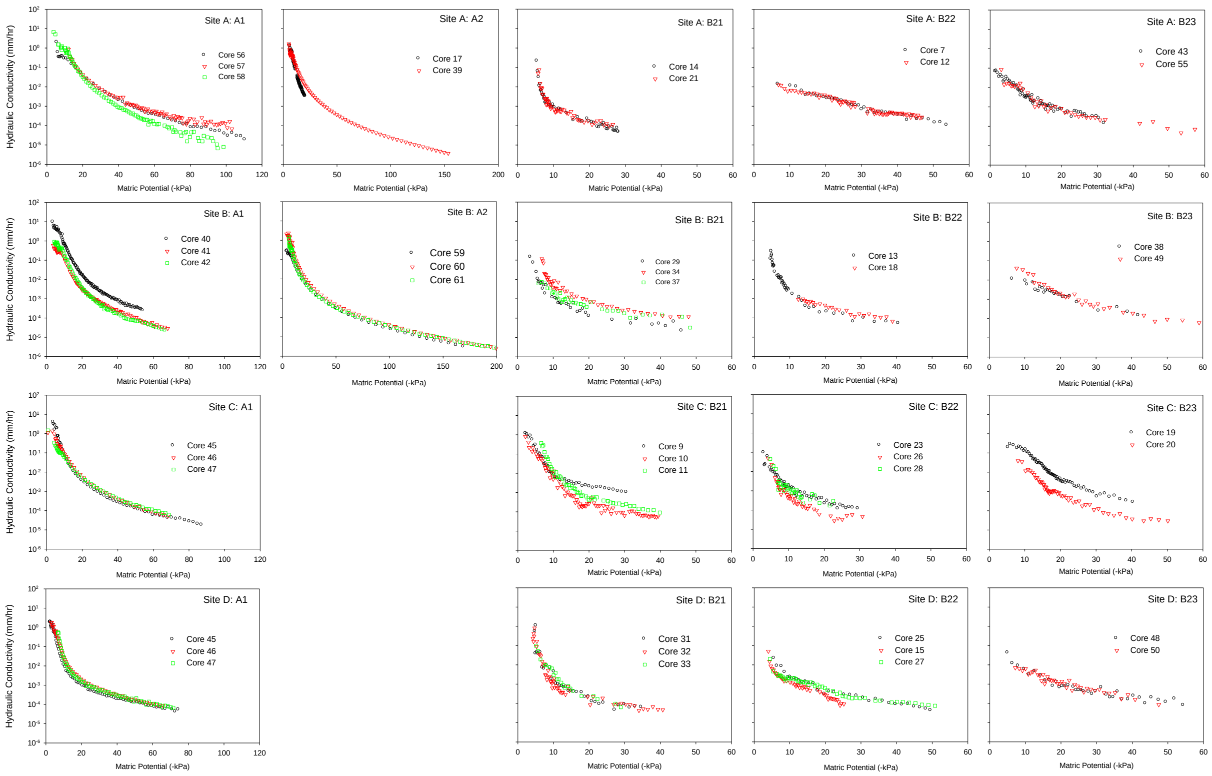


Figure A6.4 Unsaturated hydraulic conductivity determined by evaporative approach on 60 x 60 mm diameter cores.

Appendix 6.5 Determination of hydraulic conductivity on 100 mm diameter cores

Table A6.5 Saturated (ψ +10 mm) and unsaturated (ψ -10 &-30 mm) hydraulic conductivity determined from 100 mm diameter cores.

Site	Horizon	Matric Potential (mm)	Mean Hydraulic Conductivity (mm hr^{-1})	Standard Deviation (mm hr^{-1})	Sample number (n)	Standard Error (mm hr^{-1})
A	A1	-30	12.89	9.02	7	3.41
		-10	20.70	8.98	7	3.39
		10	52.40	40.14	4	20.07
	B21	-30	0.34	0.20	4	0.10
		-10	0.56	0.46	4	0.23
		10	1.12	0.63	3	0.36
	B22	-30	0.40	0.56	3	0.32
		-10	1.12	1.06	3	0.61
		10	0.99	0.78	3	0.45
	B23	-30	0.11	0.04	2	0.03
		-10	0.13	0.05	2	0.03
		10	7.11	7.40	2	5.23
B	A1	-30	6.37	6.90	5	3.09
		-10	8.77	7.45	7	2.81
		10	46.67	8.21	5	3.67
	A2	-30	5.34	3.84	8	1.36
		-10	12.22	10.39	8	3.67
		10	39.42	16.82	8	5.95
	B21	-30	1.15	0.18	2	0.13
		-10	94.82	133.12	2	94.13
		10	45.91	59.94	3	34.61
	B22	-30	0.08	0.05	3	0.03
		-10	0.12	0.11	3	0.06
		10	0.24	0.07	3	0.04
	B23	-30	0.15	0.19	3	0.11
		-10	0.19	0.16	3	0.09
		10	1.46	1.68	3	0.97
C	A1	-30	7.33	1.42	3	0.82
		-10	12.81	6.00	3	3.46
		10	11.97	0.14	2	0.10
	B21	-30	0.39	0.32	4	0.16
		-10	2.18	1.66	4	0.83
		10	2.65	1.35	4	0.67
	B22	-30	0.04	0.01	3	0.01
		-10	0.06	0.02	3	0.01
		10	0.30	0.01	3	0.01
	B23	-30	0.05	0.04	3	0.02
		-10	0.09	0.03	3	0.02
		10	0.42	0.27	3	0.16
D	A1	-30	4.77	1.95	3	1.13
		-10	7.16	1.41	3	0.82
		10	21.66	11.87	3	6.85
	B21	-30	19.50	17.91	3	10.34
		-10	11.12	9.66	3	5.58
		10	1.71	1.12	3	0.65
	B22	-30	0.15	0.06	3	0.04
		-10	1.09	1.14	3	0.66
		10	0.24		1	
	B23	-30	0.38	0.41	3	0.24
		-10	4.63	7.61	3	4.39
		10	36.26	9.25	2	6.54

Appendix 6.6 Data from tension infiltrometers (disk permeameters)

Table A6.6 Disk permeameter data

Horizon	Supply Potential (mm)	Site A							
		Soil Moisture Treatment - Dry				Soil Moisture Treatment - Wet			
		Mean Hydraulic Conductivity (mm/hr)	Standard Deviation	n	Standard Error	Mean Hydraulic Conductivity (mm/hr)	Standard Deviation	n	Standard Error
A1	-109	3.04	1.04	3	0.60	1.99	0.30	5	0.14
	-69	6.42	1.19	8	0.42	2.65	0.54	6	0.22
	-39	12.70	2.39	5	1.07	5.95	0.84	6	0.34
	-19	25.77	5.75	5	2.57	11.47	3.43	6	1.40
	-13	45.57	13.60	6	5.55	14.57	5.48	6	2.24
A2	-109	0.46	0.24	5	0.11	0.83	0.36	4	0.18
	-69	0.87	0.55	6	0.22	1.07	0.19	6	0.08
	-39	1.41	0.94	6	0.38	2.46	0.80	6	0.33
	-19	3.90	1.94	6	0.79	5.94	2.99	6	1.22
	-13	6.19	3.40	5	1.52	8.89	3.31	6	1.35
B21	-109	0.34	0.13	6	0.05	0.27	0.06	3	0.03
	-69	0.63	0.38	6	0.16	0.51	0.13	6	0.05
	-39	1.95	1.00	6	0.41	0.79	0.14	6	0.06
	-19	8.25	4.33	6	1.77	1.66	0.29	6	0.12
	-13	21.82	8.66	6	3.53	2.55	0.34	6	0.14
B22	-109	0.43	0.05	4	0.02	0.49	0.10	5	0.04
	-69	0.76	0.20	4	0.10	0.88	0.13	5	0.06
	-39	2.10	0.44	5	0.20	2.14	0.20	5	0.09
	-19	3.63	0.54	5	0.24	3.59	0.79	5	0.35
	-13	5.65	0.63	5	0.28	5.36	1.70	5	0.76
B23	-109	0.26	0.12	4	0.06				
	-69	0.58	0.13	5	0.06				
	-39	1.52	0.34	6	0.14				
	-19	2.66	0.41	6	0.17				
	-13	4.18	0.50	6	0.20				
		Site B							
		Soil Moisture Treatment - Dry				Soil Moisture Treatment - Wet			
		Mean Hydraulic Conductivity (mm/hr)	Standard Deviation	n	Standard Error	Mean Hydraulic Conductivity (mm/hr)	Standard Deviation	n	Standard Error
A1	-109	3.70	1.35	5	0.60	6.44	2.76	4	1.38
	-69	4.31	1.11	4	0.55	7.76	3.64	4	1.82
	-39	11.02	1.93	5	0.86	10.01	4.97	5	2.22
	-19	25.81	9.64	6	3.94	13.56	7.60	5	3.40
	-13	48.39	17.42	6	7.11	23.51	13.44	5	6.01
A2	-109	0.25	0.14	6	0.06	1.14	0.76	4	0.38
	-69	0.49	0.11	6	0.04	1.57	1.50	4	0.75
	-39	0.95	0.37	6	0.15	1.78	0.76	6	0.31
	-19	2.34	0.58	7	0.22	2.93	0.96	6	0.39
	-13	4.03	0.65	6	0.26	3.71	1.45	7	0.55
B21	-109	0.20	0.08	8	0.03	0.20	0.05	3	0.03
	-69	0.33	0.12	8	0.04	0.16	0.12	4	0.06
	-39	1.46	0.90	8	0.32	0.66	0.15	5	0.07
	-19	6.31	4.73	8	1.67	1.52	0.44	5	0.20
	-13	12.14	8.71	8	3.08	2.96	0.70	5	0.31
B22	-109	0.11	0.03	4	0.01	0.13	0.07	5	0.03
	-69	0.15	0.06	5	0.03	0.30	0.23	5	0.10
	-39	0.68	0.18	6	0.07	0.80	0.14	5	0.06
	-19	2.69	1.74	6	0.71	0.93	0.32	4	0.16
	-13	5.74	3.78	6	1.54	1.62	0.44	4	0.22
B23	-109	0.35	0.15	4	0.07				
	-69	0.55	0.34	5	0.15				
	-39	1.24	0.48	6	0.20				
	-19	2.34	0.94	6	0.39				
	-13	3.28	0.64	6	0.26				
		Site C							
		Soil Moisture Treatment - Dry				Soil Moisture Treatment - Wet			
		Mean Hydraulic Conductivity (mm/hr)	Standard Deviation	n	Standard Error	Mean Hydraulic Conductivity (mm/hr)	Standard Deviation	n	Standard Error
A1	-109	0.83	0.81	3	0.47	4.79	0.84	4	0.42
	-69	3.65	2.04	5	0.91	7.36	1.63	6	0.67
	-39	9.32	1.64	5	0.73	11.29	3.05	6	1.24
	-19	18.62	2.00	5	0.90	16.98	4.58	6	1.87
	-13	30.78	5.61	5	2.51	23.11	4.49	6	1.83
A2	-109	0.31	0.06	4	0.03	3.84	0.69	3	0.40
	-69	0.70	0.38	7	0.15	2.76	0.99	3	0.57
	-39	1.37	0.60	7	0.23	5.02	3.32	5	1.48
	-19	2.93	1.19	7	0.45	8.23	2.43	5	1.09
	-13	6.88	2.94	7	1.11	16.95	15.34	5	6.86
B21	-109	0.06	0.05	5	0.02	1.17	0.51	4	0.26
	-69	0.28	0.06	5	0.03	2.14	0.76	4	0.38
	-39	0.70	0.51	5	0.23	2.88	0.79	5	0.35
	-19	4.11	3.66	5	1.64	3.28	1.52	5	0.68
	-13	15.82	15.68	5	7.01	5.49	1.60	5	0.71
B22	-109	0.22	0.14	3	0.08	0.65	0.35	4	0.17
	-69	0.35	0.11	6	0.05	0.62	0.37	5	0.17
	-39	0.66	0.13	6	0.05	1.31	0.37	5	0.16
	-19	1.44	0.18	6	0.08	2.69	0.67	6	0.27
	-13	2.46	0.38	6	0.16	3.81	0.54	6	0.22
B23	-109	0.31	0.16	3	0.09				
	-69	0.32	0.16	6	0.06				
	-39	1.02	0.23	6	0.09				
	-19	2.00	0.46	6	0.19				
	-13	2.63	1.00	5	0.45				
		Site D							
		Soil Moisture Treatment - Dry				Soil Moisture Treatment - Wet			
		Mean Hydraulic Conductivity (mm/hr)	Standard Deviation	n	Standard Error	Mean Hydraulic Conductivity (mm/hr)	Standard Deviation	n	Standard Error
A1	-109	1.24	0.42	3	0.24	1.07	0.61	4	0.31
	-69	2.03	0.30	4	0.15	1.50	0.58	5	0.26
	-39	3.65	1.00	4	0.50	2.61	0.83	5	0.37
	-19	11.19	4.53	5	2.03	3.71	1.60	5	0.72
	-13	20.71	7.43	6	3.03	6.20	2.36	5	1.06
B21	-109	0.16	0.07	5	0.03	0.07	0.03	3	0.02
	-69	0.35	0.09	6	0.04	0.28	0.25	4	0.12
	-39	1.64	1.02	6	0.42	1.16	0.76	4	0.38
	-19	9.76	7.08	6	2.89	5.02	2.32	4	1.16
	-13	23.99	13.25	6	5.41	13.40	7.03	4	3.52
B22	-109	0.20	0.12	6	0.05	0.32	0.22	5	0.10
	-69	0.45	0.22	6	0.09	0.58	0.39	6	0.16
	-39	1.70	0.67	6	0.27	1.48	0.58	6	0.24
	-19	5.61	3.32	6	1.36	2.52	1.01	6	0.41
	-13	12.57	9.70	6	3.96	4.39	1.75	6	0.71
B23	-109	0.16	0.07	4	0.03				
	-69	0.41	0.15	6	0.06				
	-39	1.06	0.31	6	0.13				
	-19	2.43	0.51	6	0.21				
	-13	3.49	0.85	6	0.35				

Appendix 6.7 SSCC data and volumetric shrinkage

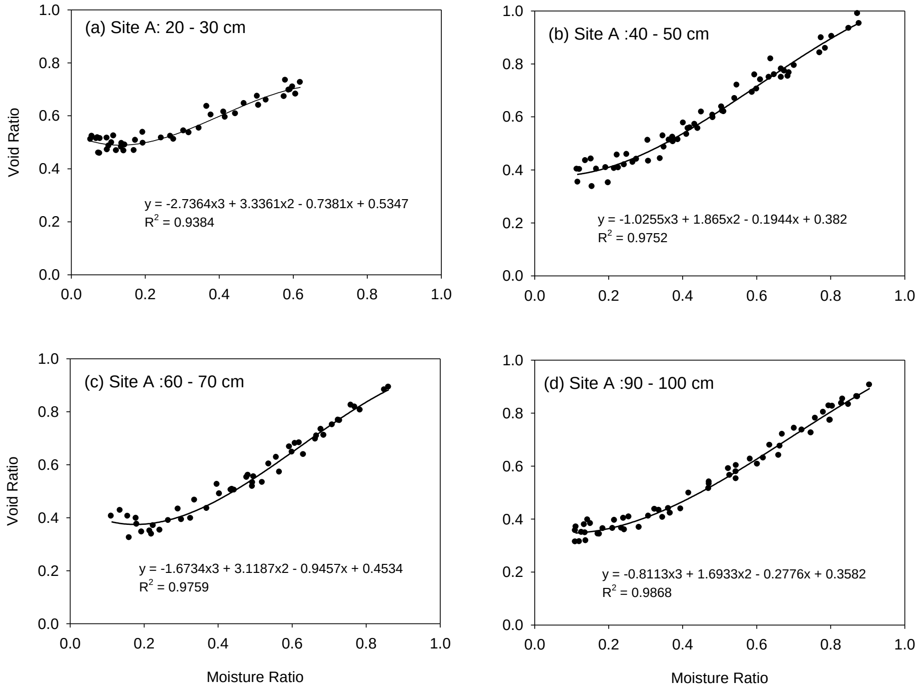


Figure A6.7.1 Soil shrinkage characteristic curves (SSCC), site A.

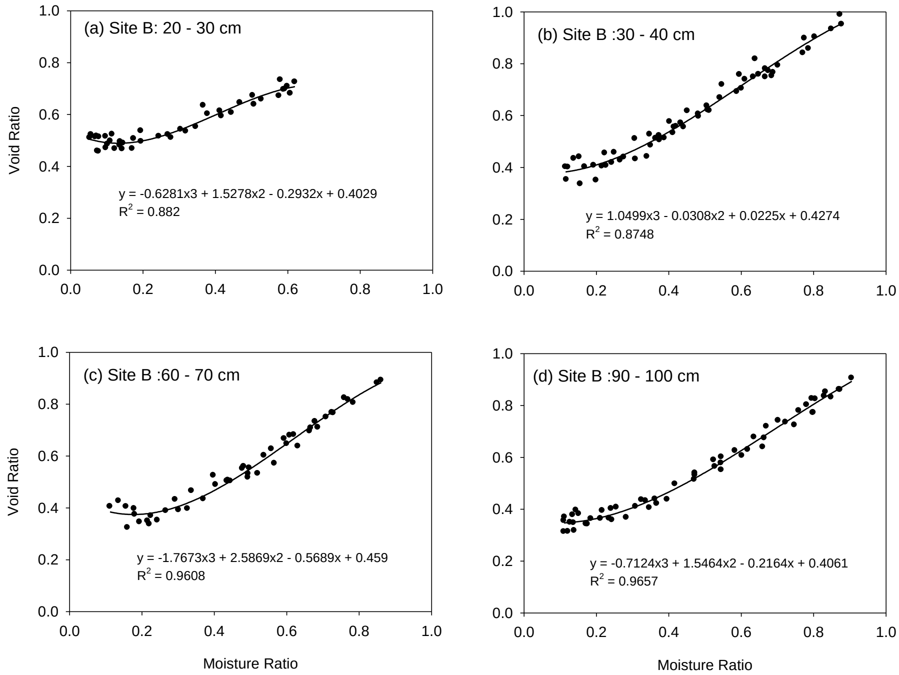


Figure A6.7.2 Soil shrinkage characteristic curves SSCC, site B.

Table A6.7.1 Third order polynomial regression of SSCC curves (void ratio / moisture ratio).

		3rd order Polynomial				Replicates (n)	R squared
		ax^3	bx^2	cx^1	d		
Site A	20-30cm	-2.736	3.336	0.738	0.535	4	0.938
	40-50cm	-1.025	1.865	0.194	0.382	5	0.975
	60-70cm	-1.673	3.119	0.946	0.453	4	0.976
	90-100cm	-0.811	1.693	0.278	0.358	4	0.987
Site B	20-30cm	-0.628	1.528	0.293	0.403	3	0.882
	30-40cm	-1.050	-0.031	0.023	0.427	3	0.875
	60-70cm	-1.767	2.587	0.569	0.459	4	0.961
	90-100cm	-0.712	1.546	0.216	0.406	4	0.966

Table A6.7.2 Third order polynomial regression of clod density vs volumetric moisture content.

		3rd order Polynomial				Replicates (n)	R squared
		ax^3	bx^2	cx^1	d		
Site A	20-30cm	1.6E-05	1.20E-03	0.018	1.708	4	0.925
	40-50cm	1.3E-05	1.29E-03	0.022	1.804	5	0.957
	60-70cm	9.5E-06	1.09E-03	0.021	1.801	4	0.872
	90-100cm	5.6E-06	7.58E-04	0.013	1.905	4	0.976
Site B	20-30cm	-2.7E-07	-2.69E04	2.32E-03	1.912	3	0.816
	30-40cm	-5.1E-06	1.80E-05	2.81E-04	1.854	3	0.838
	60-70cm	9.7E-06	-9.15E-04	0.015	1.795	4	0.944
	90-100cm	4.5E-06	-5.94E-04	7.72E-03	1.866	4	0.9525

Appendix 7.0 Model choice and capability

The HYDRUS suite of models includes one dimensional and two dimensional options as well as single pore domain and multiple pore domain applications for simulating preferential flow. HYDRUS-1D includes single porosity, dual porosity and dual permeability functionality, however its use is limited to one dimensional applications, consequently funnel flow and lateral flow are unable to be simulated. Parameterisation of the dual permeability option in HYDRUS-1D is particularly difficult as model conceptualisation requires knowledge of the van Genuchten parameters α and *n* for both the micropore and macropore domains.

HYDRUS 2D/3D is able to simulate two dimensional flow including lateral flow along the A / B horizon boundary and funnel flow through sand infills. However the dual permeability functions within HYDRUS-2D/3D are currently restricted. Preliminary trials with the single pore domain option resulted in model instability when saturation developed at the A / B horizon boundary. Correspondence with Jiri Simunek author of the HYDRUS indicated that HYDRUS was unlikely to be able to simulate the range of preferential processes presented in Chapter 4.0 "….*HYDRUS will not be able to simulate such details as you show (Chapter 4.0)…… The model is based on continuous approach and thus it assumes that there is a REV (representative elementary volume) over which various variables are averaged" (Simunek 2008 pers. comm.).*

The review of preferential flow modelling presented by Simunek *et al.* (2003) concluded with the statement …"*At present it is still very difficult to use the more complex dual-permeability model involving two coupled Richards equations to describe preferential flow and transport (HYDRUS) under field conditions, partly because of the large number of parameters involved, and the current lack of standard experimental techniques to obtain them. At present no examples exist of such applications in the soil science and vadose zone hydrology literature. Hence, the use of these models has so far been restricted to theoretical applications and laboratory studies carried out under well-defined and controlled conditions. The dual permeability model MACRO, based on the kinematic wave equation for flow in macropores, requires fewer parameters, has been frequently applied to long-term transient field experiments and is also being used for risk assessment for pesticide leaching within the EU."*

MACRO 5.1 is the easiest of the dual permeability models to parameterise, it is numerically stable and able to simulate both short and long term climate data. MACRO has capacity to simulate flow in both shrinkage cracks and macropores. Being a 1D model it is not able to simulate funnel flow, lateral flow or represent finger flow.

Appendix 7.1 Inverse simulation of infiltration from disk permeameter

Inverse parameterisation was conducted in Hydrus 2D/3D using van Genuchten- Mualem model with no hysteresis following the procedure by Simunek *et al.* (1998c). Inverse simulation involved 6 time variable boundary conditions related to sequential changes in supply potential of the disk permeameter, maximum iterations was set to 25, with 0.0001 m m^{-3} water content tolerance, and 0.1 cm pressure head tolerance, with no precipitation or evaporation. The flow area consisted of a single material layer 50 x 50 cm grid, 225 node, rectangular domain discretization, with a free drainage lower boundary. All weighting coefficients were all assigned a value of 1 including final moisture content. Initial estimates of the van Genuchten parameters were determined from desorption of undisturbed soil cores. Minimum and maximum values for K_{sat} were set to one order of magnitude above and below the measured saturated hydraulic conductivity (ψ = +0.10 kPa) (Chapter 6.2.5). In the dry treatment, the minimum Qr was set to be slightly lower than the initial soil moisture to prevent model instability. The maximum Qs was allowed to exceed the measured saturated water content from soil water cores to account for increased porosity created by shrinkage cracks which was not apparent in the desorption approach (discussed Chapter 8.2.3.1).

Appendix 7.2 Additional notes on model parameterisation for simulating dye staining experiments using Hydrus-1D and Macro 5.5

Hydrus-1D used the van Genuchten- Mualem model with no hysteresis, atmospheric upper boundary surface with runoff, and deep drainage lower boundary, the maximum iterations was 30, water content tolerance was 0.001 m m^{-3}, and the pressure head tolerance ranged from 1.0 – 0.1 cm. MACRO 5.1 had no irrigation, no tillage, no crop, no field drains, water tension at the bottom of the soil profile was -1000 cm, initial soil temperature was 10 degrees.

Difficulty occurred with the identification of appropriate initial soil water content. In the dry treatment soil moisture determined by the EnviroSCAN was less than the residual soil moisture (Qr) in the A1 and B21 horizons. Initial soil moisture was increased from 0.05 to 0.09 m m^{-3} in the A1 horizon, and from 0.21 m m^{-3} to 0.30 m m^{-3} in the B21 horizon. In the B22 and B23 horizons the initial soil moisture had to be reduced from 0.28 m m^{-3} to 0.33 m m^{-3} to be less than Qs to enable simulations to be conducted. In the wet treatment the initial soil moisture (EnviroSCAN) was considerably higher than Qs for most soil horizons. Where the initial soil moisture content (EnviroSCAN) exceeded Qs, the initial soil moisture content was reduced to be approximately 0.02 m m^{-3} below Qs value to enable simulations to run.

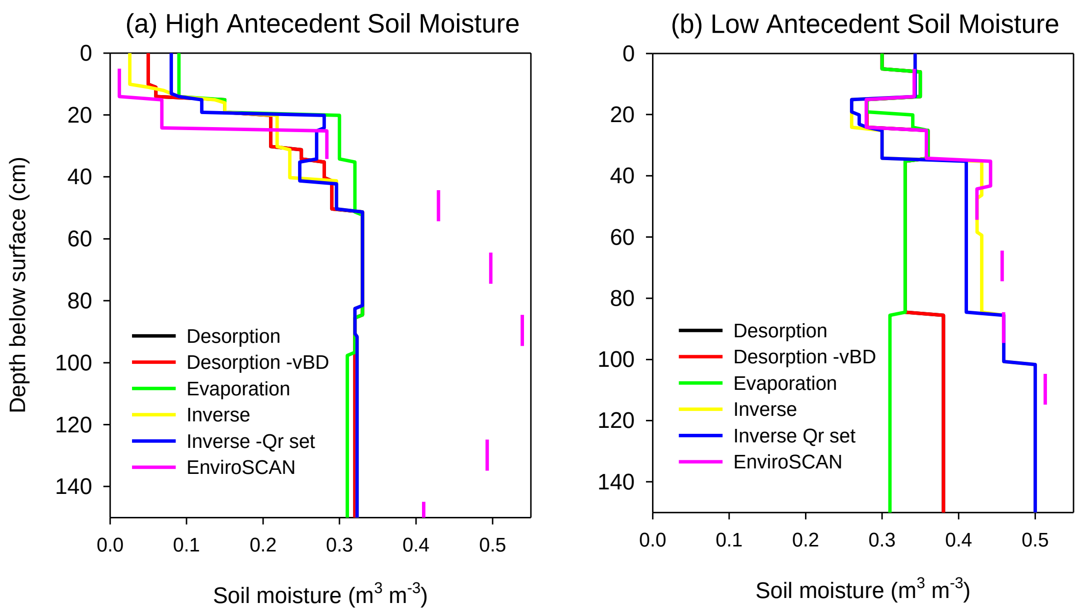


Figure A7.1 Comparison of initial soil moisture used for HYDRUS 1D modelling (a) high antecedent soil moisture (b) low antecedent soil moisture**.**

Appendix 7.3 Difference in volume of applied dye tracer and measured / estimated change in soil moisture

The change in soil moisture determined by both dye staining (profile area) and the soil moisture probe were considerably lower than the 25 mm of dye tracer applied to the two soil water treatments (Table 10.1-1). This difference between the applied and 'recovered' volume of dye tracer ranged from -1.48 mm to 8.12 mm in the dry treatment, and 6.44 mm to 18.42 mm in the wet treatment. In the dry treatment the dye staining approach overestimated (>25 mm) the change in soil moisture at three of the four sites, presumably due to error associated with the assumptions in Chapter 8.2.1.3. In the wet treatment, the change in soil moisture determined by both the dye approach and the EnviroSCAN was less than 25 mm at all sites. In the wet treatment, between 73.7 % (site A) and 32.2 % (site C) of the applied tracer was 'lost', presumably as lateral flow through the A1 horizon as runoff was prevented in the bound plots.

Table 10.1-1 Estimated change in soil moisture 0 -100 cm (mm) following infiltration of the dye tracer

Site	Soil Moisture Treatment	Profile Area (100 x 100cm)	Probe Area (2 x 10 x100 cm)	Soil Moisture Probe @ 48 Hrs	Soil Moisture Probe (maximum change)	Applied Dye Tracer (mm)
Site A	Dry	23.52	na	na	na	25
	Wet	6.58	7.34	1.56*	11.93*(3.5hrs)	25
Site B	Dry	33.12	21.25	21.94	23.86 (2.03hrs)	25
	Wet	11.77	12.57	4.47	11.05 (3.15)	25
Site C	Dry	29.88	na	na	na	25
	Wet	13.56	13.57	6.91	7.99 (3.60hrs)	20
Site D	Dry	28.47	29.12	29.23	45.19 (2.26hrs)	25
	Wet	10.65	10.16	1.36	6.52 (4.28 hrs)	25

* Site A: Soil moisture probe only operated 0-60 cm in the wet treatment.

Appendix 8.0 Digital animations (CD Rom)

<u>Instructions for CD Rom</u>

Place CD in computer, the title page should automatically load. Click ok to allow PowerPoint viewer. Animations can be started by clicking on the images. If the title page does not load start the animations directly from the CD or click *play.bat* to start the tile page. If animations appear blocky or jumpy, copy the animation files (mov, avi, or wmv) file to hard drive and run them manually.

8.1 Animation of dye tracer studies

8.1.1 Animation of image correction and dye staining analysis procedure.

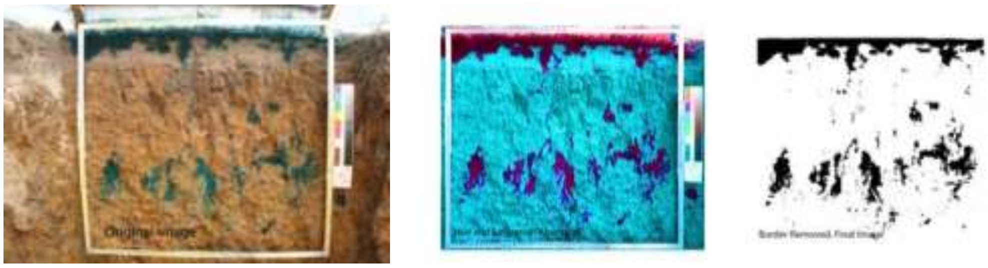


Figure A8.1 selected frames from animation: *Image correction technique_0001.wmv*

8.1.2 Summary of dye tracer studies at site B

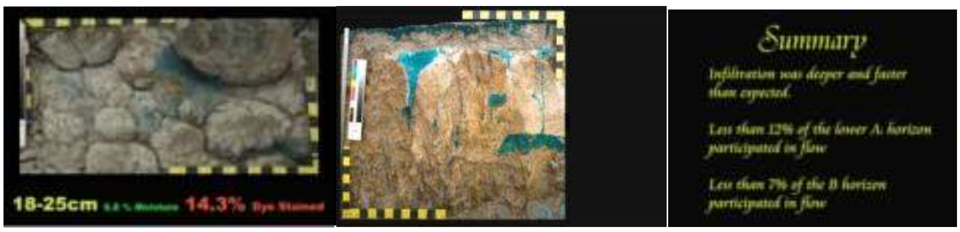


Figure A8.2 Selected frames from animation: *Dye tracer summary.wmv*

8.1.3 Horizontal excavation of dye tracer at site B.

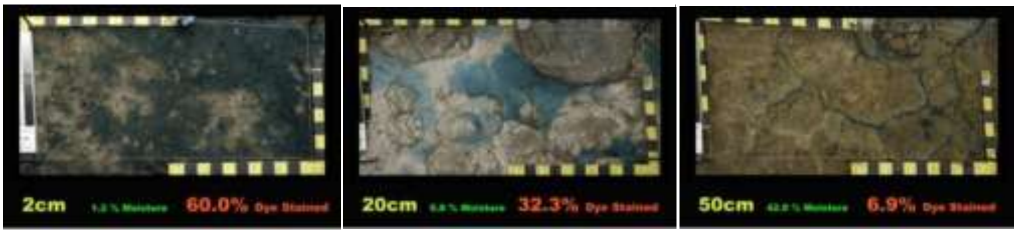


Figure A8.3 Selected frames from animation: *Dye tracer-horizontal infiltration.mov*

High resolution animation of dye staining excavation at site B.

8.1.4 Reconstruction of dye infiltration, site B.

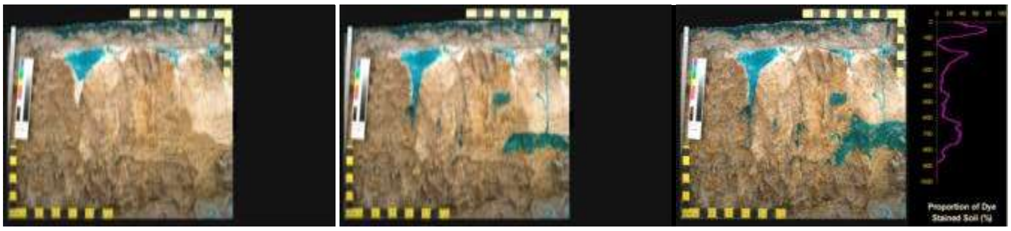


Figure A8.4 Selected frames from animation: *Vertical annimation.avi (mov)*

Conceptual reconstruction of dye tracer infiltration and redistribution into the dry soil moisture treatment at site B. Images were manipulated in Photoshop CS3 by sequentially' removing' the dye stained soil from the original image of dye staining (2400 mins).

8.2 Animation of WDPT test –water repellence

Figure A8.5 Selected frames from animation: *WDPT.wmv*

Extreme water repellence caused the droplets of water to evaporate over a three hour period rather than infiltrate into the soil.

8.3 Animation of infiltration within a Hele-Shaw tank.

Figure A8.6 Selected frames from animation: *Run A – hydrophobic.wmv*

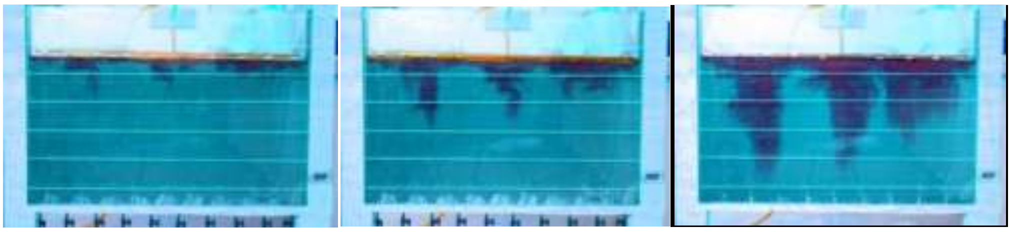


Figure A8.7 Selected frames from animation: *Run B – hydrophillic.wmv*

Figure A8.8 Selected frames from animation: *Run C – hydrophilic.wmv*

Figure A8.9 Selected frames from animation: *Run D – hydrophilic.wmv*

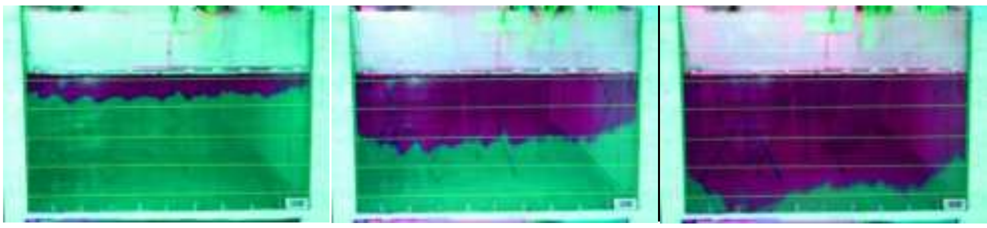


Figure A8.10 Selected frames from animation: *Run E – hydrophilic.wmv*

Figure A8.11 Selected frames from animation: *Run H – hydrophilic.wmv*

8.3 Animation of HYDRUS 2D-3D simulations

8.3.1 Animation of effect of sand infills on infiltration into soil at low antecedent soil moisture.

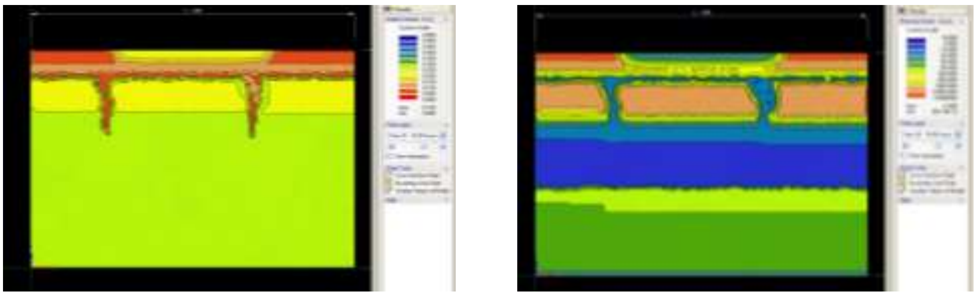


Figure A8.11 Still image of HYDRUS 2D simulation infiltration into soil at low antecedent soil moisture (a) Moisture content: *Dry treatment-water content.avi* (b) Pressure head: *Dry treatment-pressure head.avi*

8.3.2 Animation of dye tracer infiltration into wet treatment

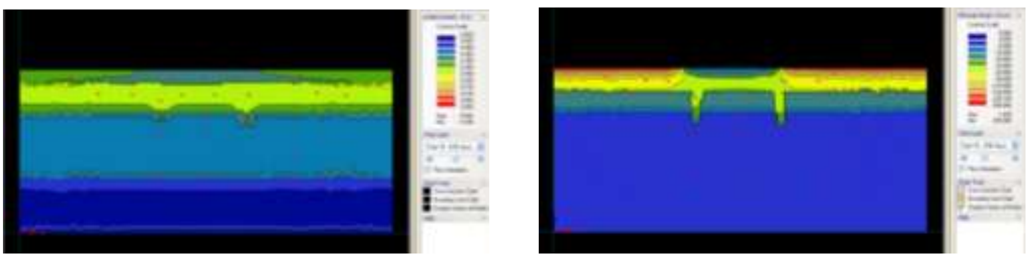


Figure A8.10 Still image of HYDRUS 2D simulation infiltration into soil at high antecedent soil moisture (a) Moisture content: *Wet treatment-water content.avi* (b) Pressure head: *Wet treatment-pressure head.avi*