MIKE SHE Integrated Hydrological Modelling (One Water – One Resource – One Model)

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Objective

Application of Integrated Hydrological Modelling in the Study Area

Objective

- To evaluate the impacts of wet, average and dry climate and irrigation regimes on waterlogging catchment yield

- Complex integrated hydrological analyses of surface and subsurface water systems require process oriented and spatial distributed modelling.
- MIKE SHE can simulate water flow in the entire land phase of the hyd. cycle

MIKE SHE

Comparison of different hydrological models

Models	Hydrological process						
	SW	UZ	GW	Irrigation	Drainage	River/Lake	Flooding
Model Flow			X				
Hydrus 2D		X	X				
E2		X	X				
CROPWAT (FAO)				X			
SWIM	X						
RAFTXP	X						
UDD	X				X		
ROB	X						
CATCHSIM	X		X				
MIKE 11						X	
MIKE21						X	X
MIKE FLOOD							X
MIKESHE	**X**	**X**	**X**	**X**	**X**	**X**	**X**

Talk Outline

- Part 1

Integrated Hydrological Modelling (Description of MIKE SHE)

- Part 2

Application of Integrated Hydrological Modelling in Study Area

Talk Outline – Part 1

- Integrated Modelling (MIKE SHE)
  - Description of MIKE SHE
  - Integration of Hydrological Processes in MIKE SHE
  - Data Requirements
  - Application of MIKE SHE in different research areas

Talk Outline – Part 2

- Study Area
  - Location
  - Background
  - Significance
  - Hydrological Issues

Talk Outline – Part 2

- Calibration and Validation
  - Data used for Calibration and Validation
  - Simulations for Calibration and Validation
  - Statistical Analysis for calibration and Validation

- Modelling Scenarios
  - Classification of wet, average and dry Climate
  - Selection of Irrigation Rates
  - Application of Irrigation (time, depth, method)

Talk Outline – Part 2

- Results
  - Simulated Results of Water Table Depth (With and Without Irrigation)
  - Impact on Land with/without Irrigation (Extent of Waterlogging)
  - Impact on Water Resourses with/without Irrigation (Volume of Water)
- Summary

Part 1

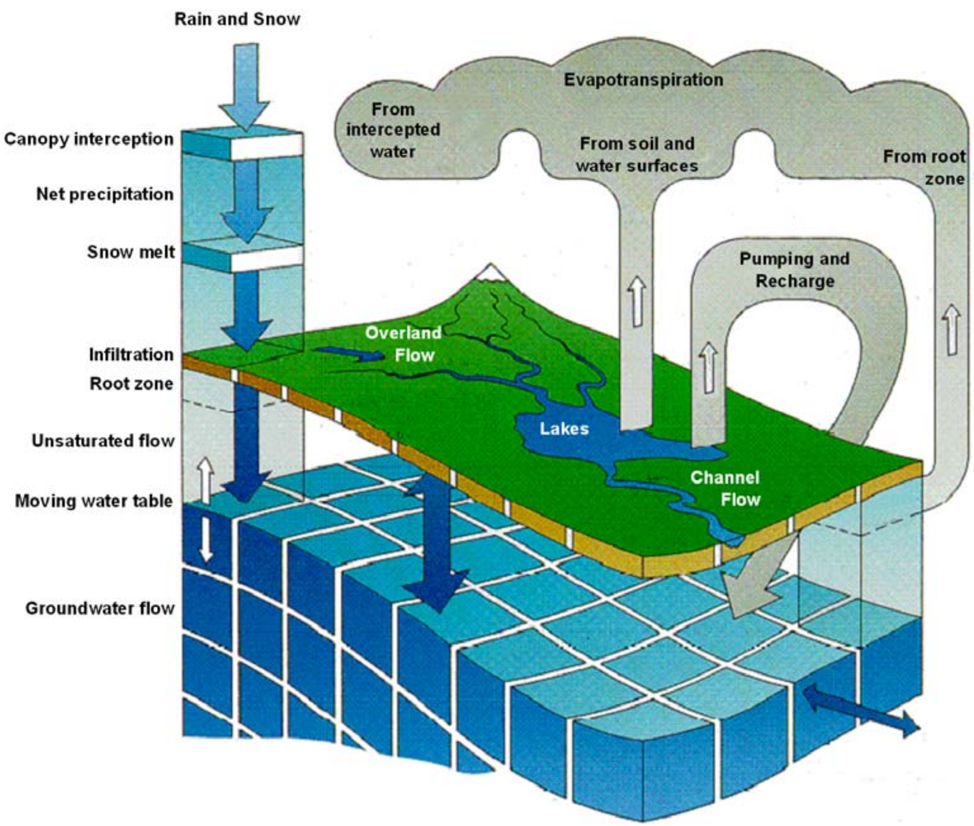
MIKE SHE

- MIKE SHE developed in 1990 (MIKE SHE_p, MIKE SHE_e)
- Physically based model
- Conservation of mass and momentum
- Modular structure
- Processes can be linked/unlinked with each other easily
- Fully distributed and integrated

Part 1

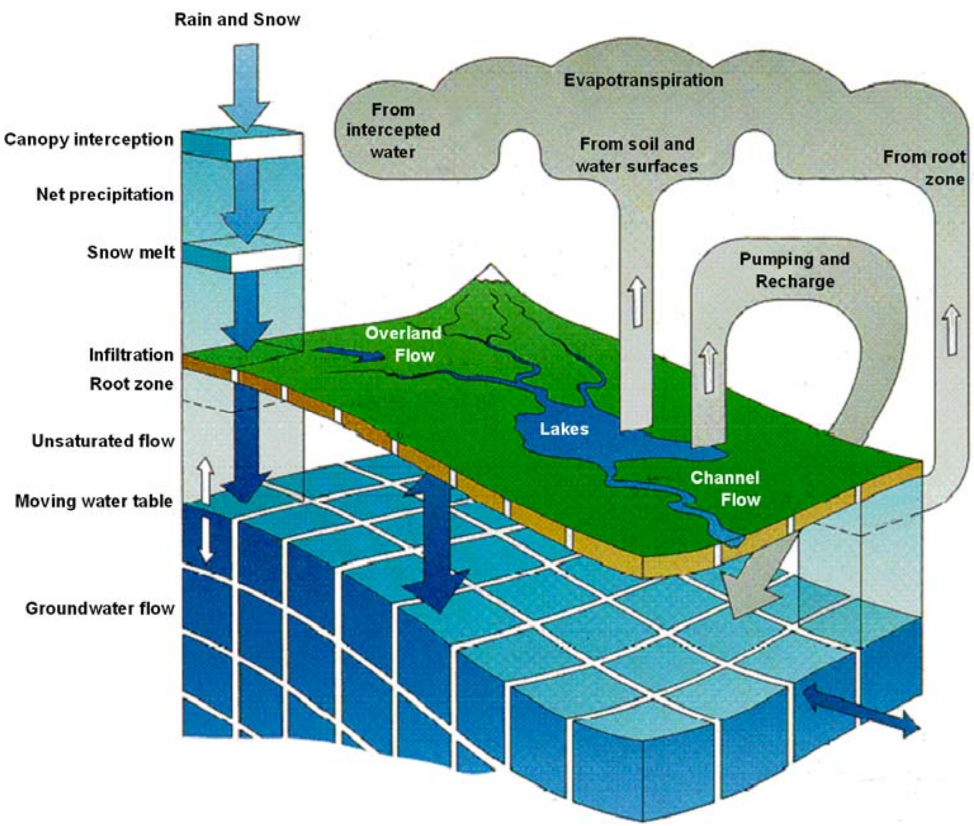
Hydrological Processes

- Evapotranspiration
  - Evaporation from the canopy
  - Evaporation from the soil
  - Evaporation from ponded water
  - Transpiration from roots
- Overland Flow
  - Detention storage
  - Surface runoff
- Channel flow
  - Flow in rivers
  - Flooding
- Unsaturated Zone flow
  - Infiltration
  - Moisture distribution
  - Moisture deficit
- Saturated Zone flow
  - Groundwater flow
  - Groundwater exchange



Part 1

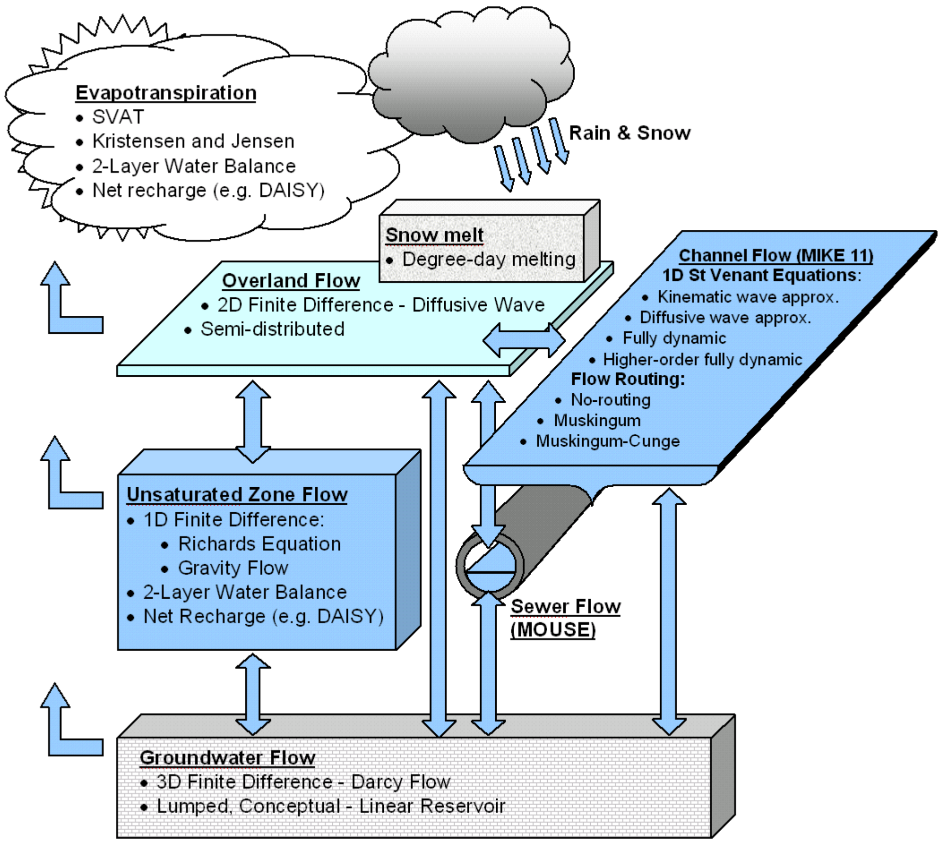
Mathematical model used



- Finite difference approach to solve partial difference eq.
    - Overland (2D Saint-Venant)
    - Channel (1D Saint-Venant)
    - UZ (1D Richard eq.)
    - GW (3D Boussinesq eq.)
- Analytical and Empirical
    - ET, inter, irri, drain

Part 1

Integration of Hydrological Processes in MIKE SHE



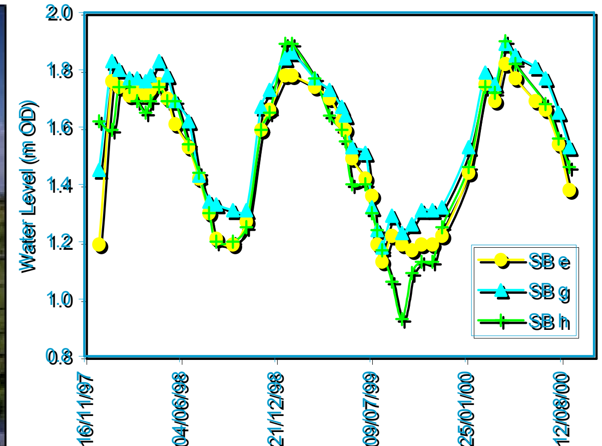
SVAT (Soil Vegetation Atmosphere Transfer).
Daisy is a soil plant atmosphere system model

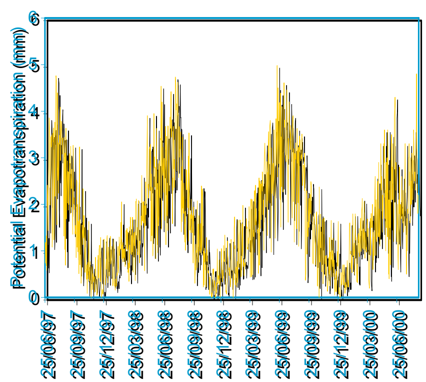
- Processes have different
  - Spatial scales
  - Time scales
- Processes mixed as required
- Time scales independent and automatically controlled
- Simpler processes are faster and require less data

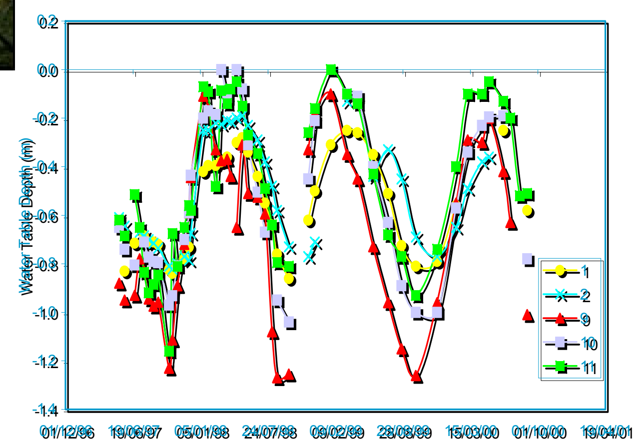
Part 1

Hydro-meteorological data requirements

Rainfall, evapotranspiration, surface water levels, watertable depth

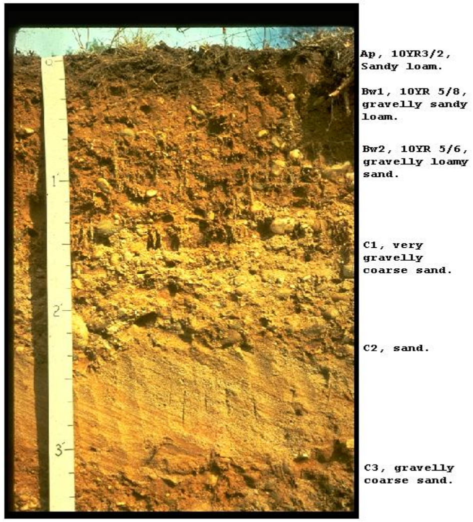






Part 1

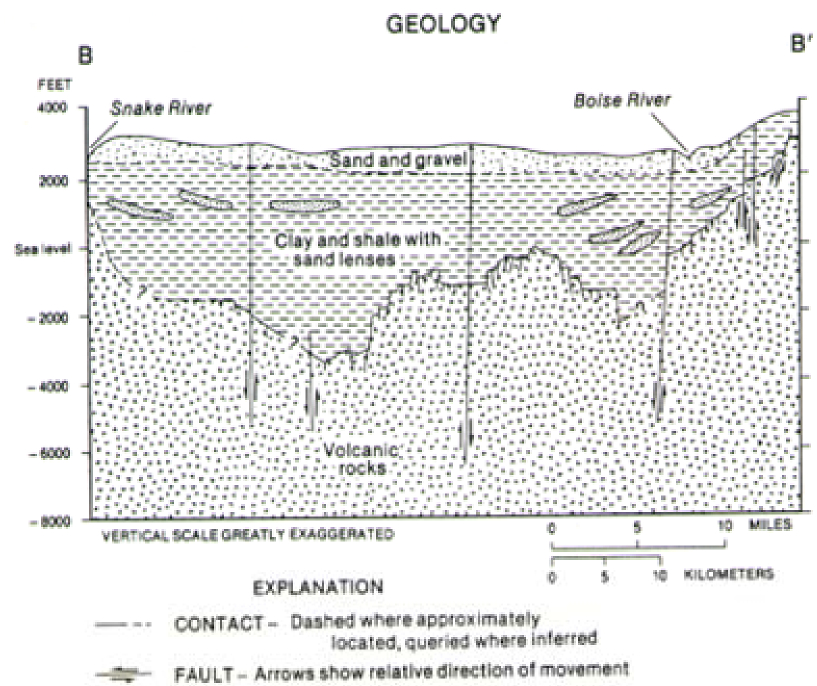
Hydrogeological data requirements



Profile of a Hickley soil series. Hnckley soils are excessively drained soils formed in glacial fluvial deposits of stratified sand and gravel.
Photo by P. Fletcher (USDA-NRCS)

- Surficial geology
- Soil properties (θ_s, θ_{fc}, K_s, etc.)
- Vegetation properties (root depth, LAI, etc.)

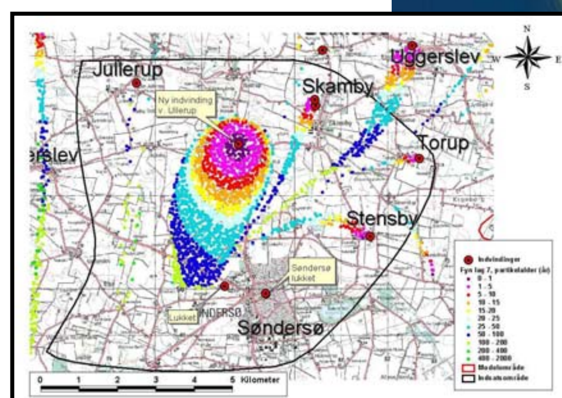
- Sub-surface geology conceptual model
- Geologic properties (K_x, Storage, etc.)
- Pumping rates
- Boundary conditions



Part 1

Application of MIKE SHE

- Has been used in hundreds of consulting and research projects around the world
  - Wetland restoration
  - Urban drainage
  - Source water protection
  - Water Resources Management
  - Flood forecasting



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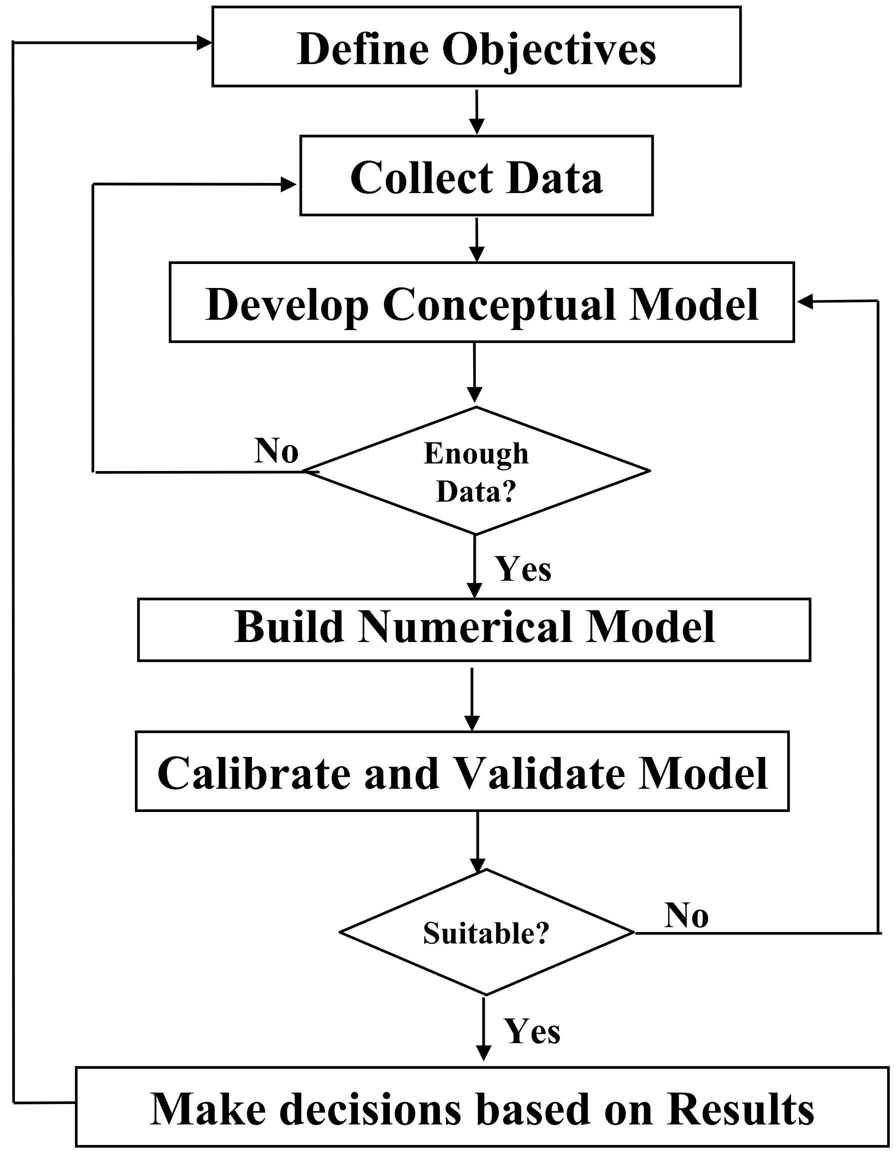
Part 1

Basic steps in building the MIKE SHE Model



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Part 1

Steps in building the MIKE SHE Model

- Defining the model domain and grids
- Defining the topography
- Specifying the recharge (precipitation)
- Defining the geological model
- Defining the vertical numerical discretisation
- Defining the initial conditions and the boundary conditions

Part 1

Best Integrated Model

MIKE SHE groundwater model selected as best management tool in US

Home › News › News Archive › 2001 › MIKE SHE groundwater model selected as best management tool in US

01 Jan. 0001 General News

MIKE SHE groundwater model selected as best management tool in US

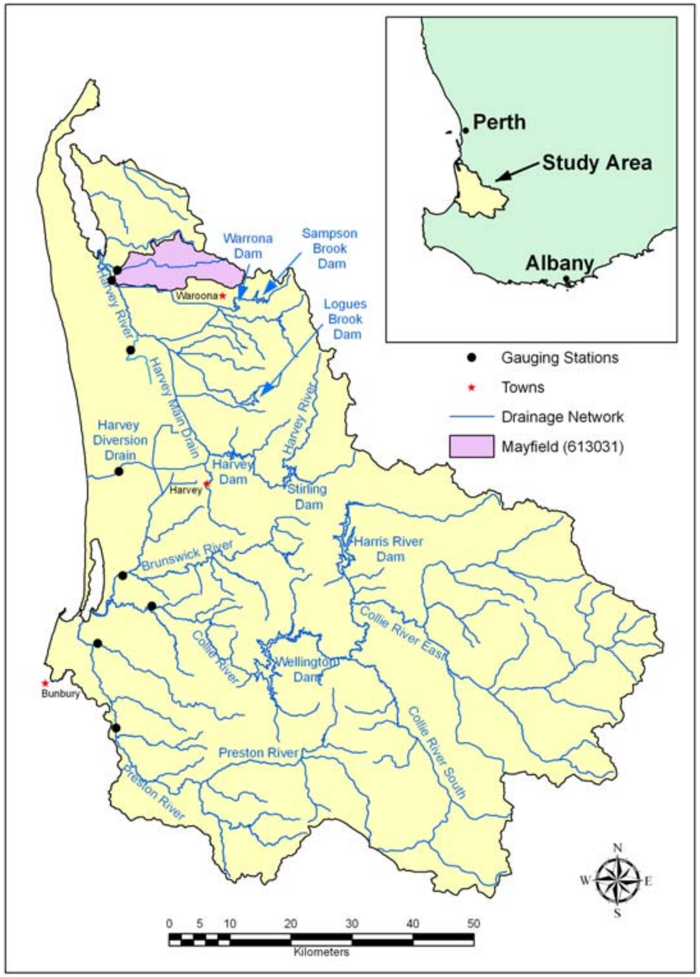
DHI Software selected as best management tool in detailed model intercomparison in US

In a recent model review, DHI's integrated groundwater and surface water simulation system MIKE SHE was selected as the best tool to model groundwater-surface water related issues. The intercomparison was carried out in connection with a controversial study for the Rocky Flats Environmental Technological Site, Denver, Colorado. MIKE SHE was preferred among 9 integrated hydrological models (mainly based on MODFLOW extensions). MIKE SHE was found to provide the best and most comprehensive description of the surface water - ground water interaction with a full dynamic coupled description of the relevant hydrological processes.

Part 2

Study Area

- About 90 km from Perth
- Growing rapidly
- Mining/urbanisation
- Sub-division
- Hobby Farms



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Part 2

Background/History

- The settlement started in 1890
- Total area is 112,000 ha and 34,400 ha is irrigable
- Nearly 90% is cleared land
- Harvey Weir completed in 1916
- Seven Irrigation Dams
- About 10,000 ha is irrigated every year
- About 65% water used for dairy
- About 30% for beef
- 1914-1996 Govt Sponsored
- $120 Million/annum (ABS 2000)

Part 2

Significance/Issues

- Significance
  - Provide 40% dairy and beef requirement
  - Vegetable, grapes and citrus
  - $120 million product (ABS 2000)
  - 500 Farms and many thousands supporting community
  - Hobby farming
  - Water resource for Perth (90 km)
- Issues
  - Over irrigation-winter waterlogging, salinity
  - Water losses from earthen irrigation channels
  - Accessibility
  - Water shortage in summer
  - Urbanisation (reduction in Ag land)

Part 2

Irrigation Data

Annual Water Delivered to each District (ML)							
District	98-99	99-00	2000-01	2001-02	2002-03	2003-04	2004-05
Waroona	6 942	6 563	7 299	5 954	5 644	9 149	8 622
Harvey	40 888	37 895	43 027	30 441	26 088	42 004	41 462
Collie North	34 360	31 230	37 045	31 658	30 452	48 886	42 456
TOTAL Water (ML)	82 190	75 688	87 371	68 053	62 184	100 039	92 540

(Source: www.harveywater.com.au)

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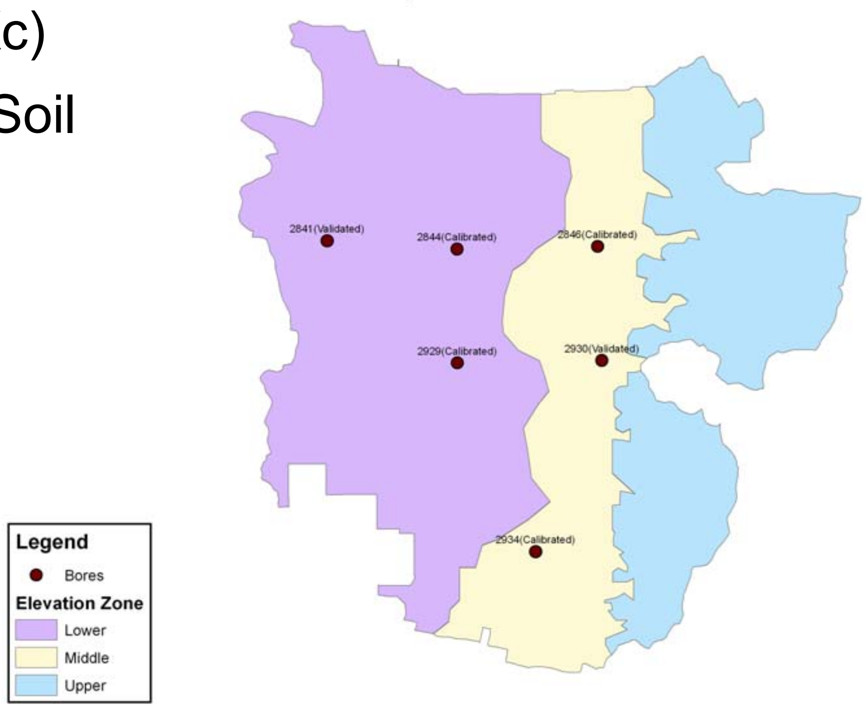
Part 2

Other Data

- Meteorological
- Crop (LAI, root depth, Kc)
- Hydraulic properties of Soil
- Irrigation
- Stream flow data
- Topography
- Drainage network
- Drain depths

Yarloop catchment and bores location



Part 2

Calibration of Model

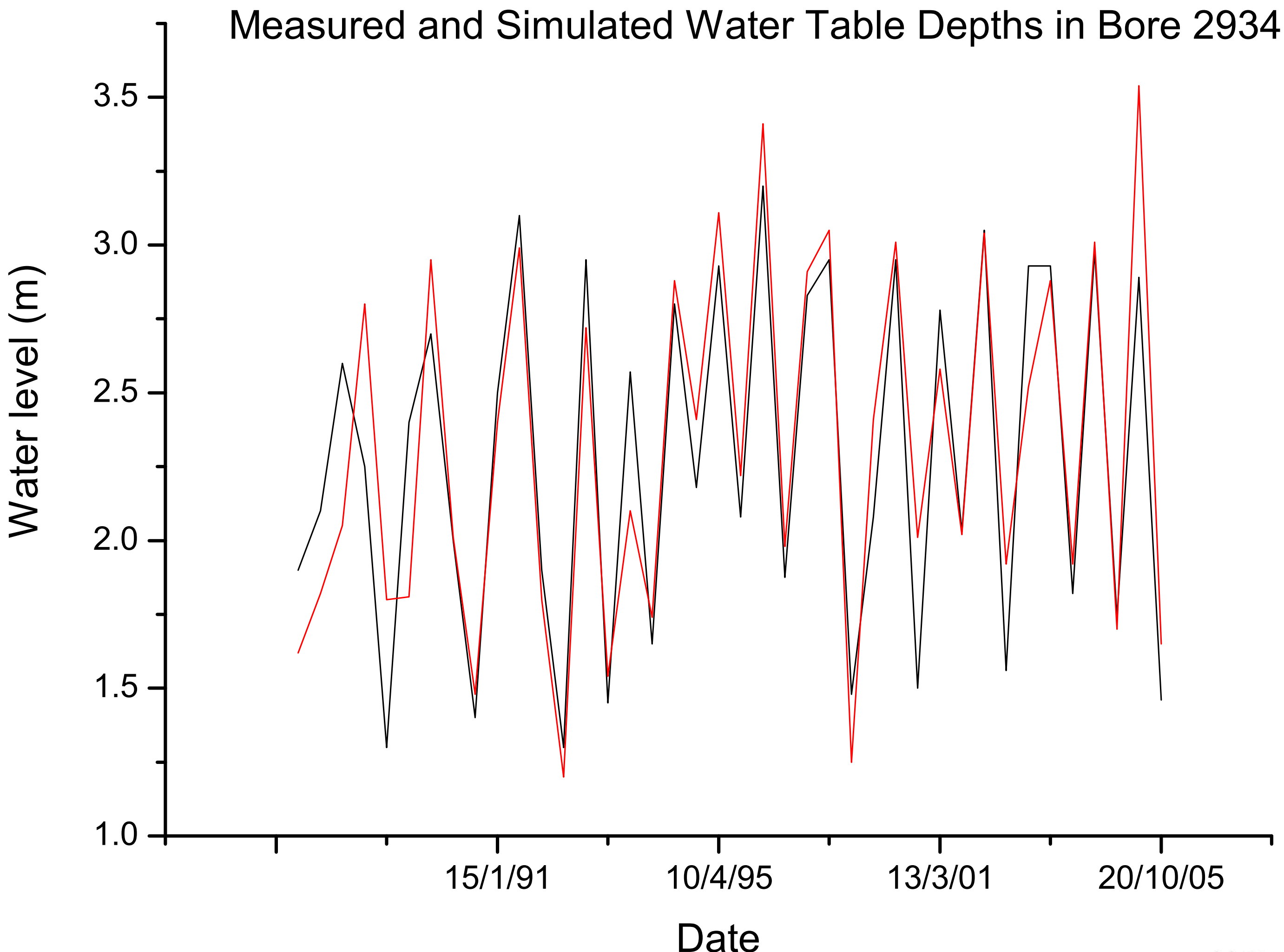
Calibrated and Observed Data

WATER TABLE DEPTH BORE 2844 (m)			WATER TABLE DEPTH BORE 2929 (m)		
Date	Observed	Simulated	Date	Observed	Simulated
15/09/1983	0.84	1.9	15/09/1983	1.9	1.52
2/08/1988	1.67	1.5	2/08/1988	2.1	1.9
6/12/1988	2.6	1.98	6/12/1988	2.6	2.5
8/03/1989	3.1	3.15	9/03/1989	2.25	2.8
4/07/1989	1.6	2.01	4/07/1989	1.3	1
16/10/1989	1.7	1.81	12/10/1989	2.4	2.5
16/01/1990	3.1	2.95	16/01/1990	2.7	2.95
5/04/1990	3.4	3.82	5/04/1990	2	1.9
16/07/1990	2.5	2.48	18/07/1990	1.4	1.48
17/10/1990	1.88	1.9	17/10/1990	2.5	2.4
15/01/1991	3.3	2.99	15/01/1991	3.1	3.2
4/04/1991	3.6	3.25	8/04/1991	1.9	2.02
10/07/1991	1.7	1.6	10/07/1991	1.3	1.2
18/09/1991	1.35	2.8	17/09/1991	2.95	2.85
16/04/1992	3.56	3.21	21/04/1992	1.45	1.5
24/09/1992	1.7	2.1	24/09/1992	2.57	2.6
24/03/1993	3.4	2.9	25/03/1993	1.65	1.74
14/09/1993	1.46	1.3	13/09/1993	2.8	2.7
7/04/1994	3.7	3.52	7/04/1994	2.18	2.41
24/11/1994	2.97	3.11	24/11/1994	2.93	2.9
10/04/1995	3.78	3.59	10/04/1995	2.08	2.22
10/11/1995	2.65	2.68	10/11/1995	3.2	3.1
17/05/1996	3.77	3.85	21/05/1996	1.875	1.98
17/10/1996	1.945	2.01	17/10/1996	2.83	2.91
3/06/1997	3.65	3.59	3/06/1997	2.95	3.05
24/05/1998	4.37	4.1	24/05/1998	1.48	1.25
8/12/1998	3.17	4.25	23/09/1998	2.08	2.41
19/05/1999	4.46	4.24	8/12/1998	2.95	3.01
5/10/2000	1.95	2.5	6/05/1999	1.5	1.4
14/03/2001	4.12	3.97	4/10/2000	2.78	2.58
25/09/2001	1.91	1.8	14/03/2001	2.03	2.02
4/04/2002	4.24	4.01	25/09/2001	3.05	3.04
17/09/2002	1.58	1.92	17/09/2002	1.56	1.92
10/04/2003	4.08	3.94	14/05/2003	2.93	2.52
2/09/2003	1.7	1.88	2/09/2003	2.93	2.88
5/04/2004	3.74	3.6	6/04/2004	1.82	1.92
7/09/2004	1.5	1.6	6/09/2004	2.98	3.01
5/04/2005	3.68	3.54	4/04/2005	1.74	1.7
			18/10/2005	2.89	3.54

Michael Juul (DHI) helped in Calibration and Validation

Part 2

Measured and Simulated Watertable Depths



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Part 2

Calibration of Model (Correlation)

Correlation between Observed and Simulated Water Table Depths

Correlation	Bore 2844	Bore 2929	Bore 2934	Bore 2930
R	0.83	0.85	0.93	0.87
R2	0.69	0.73	0.87	0.76

Part 2

Model Validation

Validated and Observed Data for Yarloop Catchment for Bores 2841 and 2937					
WATER TABLE DEPTH BORE 2841 (m)			WATER TABLE DEPTH BORE 2937 (m)		
Date	Observed	Simulated	Date	Observed	Simulated
4/08/1988	2.505	2.52	2/08/1988	8	7.8
9/12/1988	2.05	1.98	21/09/1988	7.1	7.4
8/03/1989	2.4	2.45	6/12/1988	7.6	7.5
17/01/1990	2.4	2.95	12/10/1989	7.1	7.5
11/07/1990	2.2	2.15	16/01/1990	8.5	8.54
17/10/1990	2.18	2.2	5/04/1990	9.5	9.52
15/01/1991	2.2	2.32	17/10/1990	8.54	8.56
5/04/1991	2.8	2.99	15/01/1991	9.3	9.38
10/07/1991	2.15	2.22	12/04/1991	9.5	9.25
24/09/1991	2.05	1.98	10/07/1991	8.8	8.54
7/04/1992	2.35	2.45	18/09/1991	5.85	6.05
24/09/1992	2.06	2.15	15/04/1992	9.45	9.34
24/03/1993	1.95	1.92	24/09/1992	6.36	6.48
13/09/1993	1.97	1.9	24/03/1993	9.5	9.56
6/04/1994	2.28	2.35	14/09/1993	9.02	9.02
3/06/1997	1.83	1.92	7/04/1994	10.09	10.5
24/05/1998	2.77	2.8	24/11/1994	9.21	9.25
24/09/1998	1.94	1.87	10/04/1995	10.56	10.25
8/12/1998	2.55	2.52	10/11/1995	8.88	8.75
5/05/1999	3.02	3.08	17/05/1996	10.46	10.25
4/10/2000	2.06	2.01	17/10/1996	7.005	6.98
13/03/2001	2.31	3.28	29/05/1997	10.43	9.89
25/09/2001	2.02	2.05	24/05/1998	10.42	10.26
4/04/2002	2.71	2.78	19/05/1999	9.89	10.12
17/09/2002	1.97	1.85	5/10/2000	7.4	7.8
10/04/2003	2.94	2.88	14/03/2001	9.7	9.4
2/09/2003	1.98	2.02	17/09/2002	9.71	9.54
5/04/2004	2.28	2.25	2/09/2003	9.79	9.85
7/09/2004	1.95	1.94	5/04/2004	10.6	10.5
5/04/2005	2.42	2.38	7/09/2004	9.2	9.52
20/10/2005	2.01	1.96	5/04/2005	10.4	10.5

Part 2

Model Validation

Correlation between Calibrated and Observed Data

Correlation	Bore 2841	Bore 2937
R	0.87	0.91
R2	0.75	0.82

Part 2

Modeling Scenarios

Description of Scenarios with and without irrigation in three climates

IRRIGATION (ML/Y/H)	TYPE OF CLIMATE		
	WET (W)	AVERAGE (A)	DRY (D)
0	S1 = SW-I0	S2 = SA-I0	S3 = SD-I0
10	S4 = SW-I10	S5 = SA-I10	S6 = SD-I10
16	S7 = SW-I16	S8 = SA-I16	S9 = SD-I16
On demand	S10 = SW-$I_{40\%\ and\ 100\%}$	S11= SA-$I_{40\%\ and\ 100\ \%}$	S12= SD-$I_{40\%\ and\ 100\%}$

(Note Subscripts SW=Wet, SA=Average, SD= Dry, I0, I10 and I16 = 0, 10 and 16 mega litres/year irrigation, $I_{40\%\ and\ 100\%}$=Irrigation start at when soil moisture contents are at 40% of saturation and stop when it reach at 100% saturation)

Part 2

Classification of climates in three Scenarios

Simple approach was adopted

1982 Wet Year (839 mm) ->

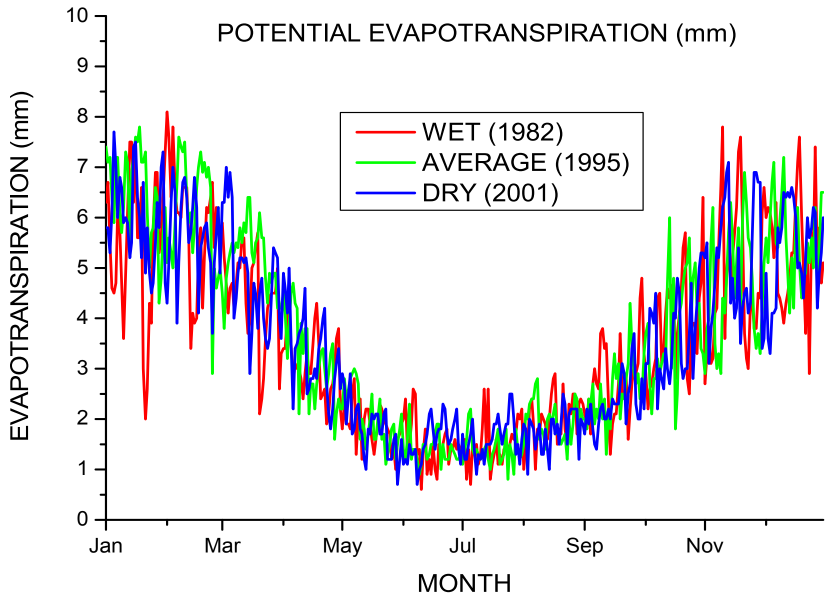
1995 Average Year (738 mm) ->

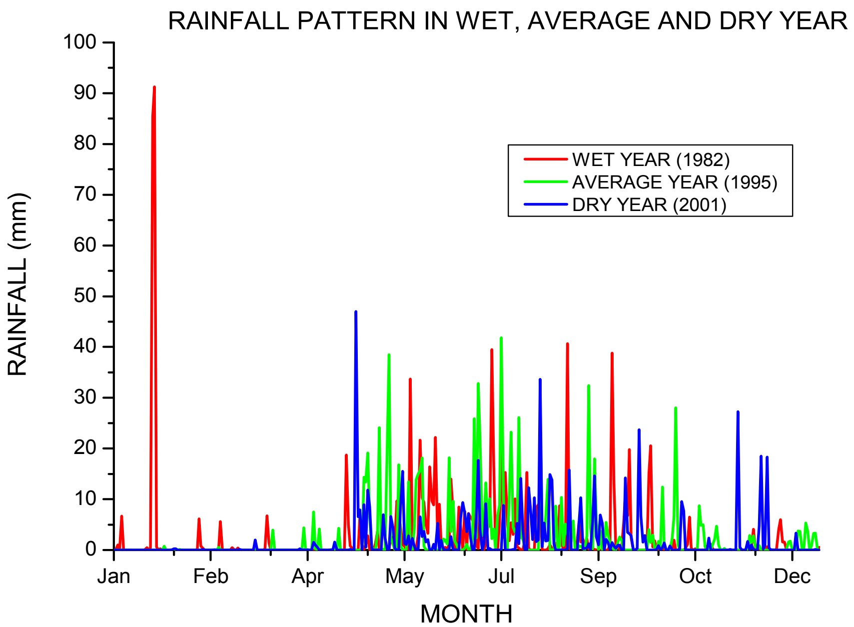
2001 Dry Year (596 mm) ->

Year	Rainfall (mm)
1976	835
1977	717
1978	863
1979	719
1980	996
1981	929
1982	839
1983	772
1984	806
1985	744
1986	654
1987	528
1988	834
1989	669
1990	570
1991	800
1992	783
1993	583
1994	511
1995	738
1996	903
1997	738
1998	702
1999	987
2000	807
2001	596
2002	667
2003	648
2004	658

Part 2

Rainfall and ET





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Part 2

Selection of Irrigation Rates

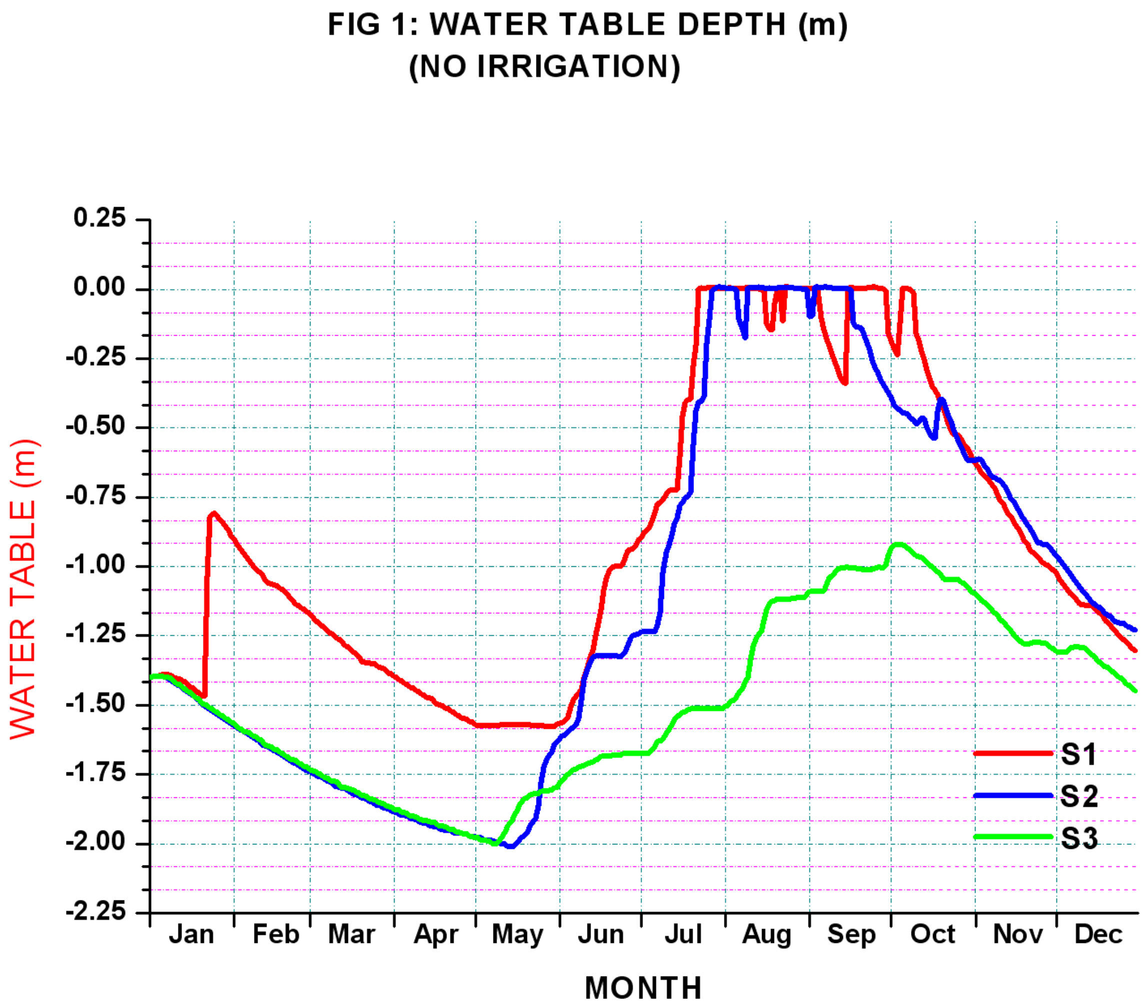
Average Irrigation water to each District (ML/Ha)							
Year	98-99	99-2000	2000-01	2001-02	2002-03	2003-04	2004-05
TOTAL Water (ML)	82 190	75 688	87 371	68 053	62 184	100 039	92 540
Total irrigated area	9780	9448	8665	9397	9397	7676	8132
Ml / ha	8.4	8	10.1	7.2	6.6	13	11.4

(Source: www.harveywater.com.au)

- Ave Irrigation Rate = 10 ML/Ha/Year
- Over Irrigation Rate = 16 ML/Ha/Year
- No Irrigation = 0 ML/Ha/Y
  (To represent untreated and baseline for comparison)
- On Demand

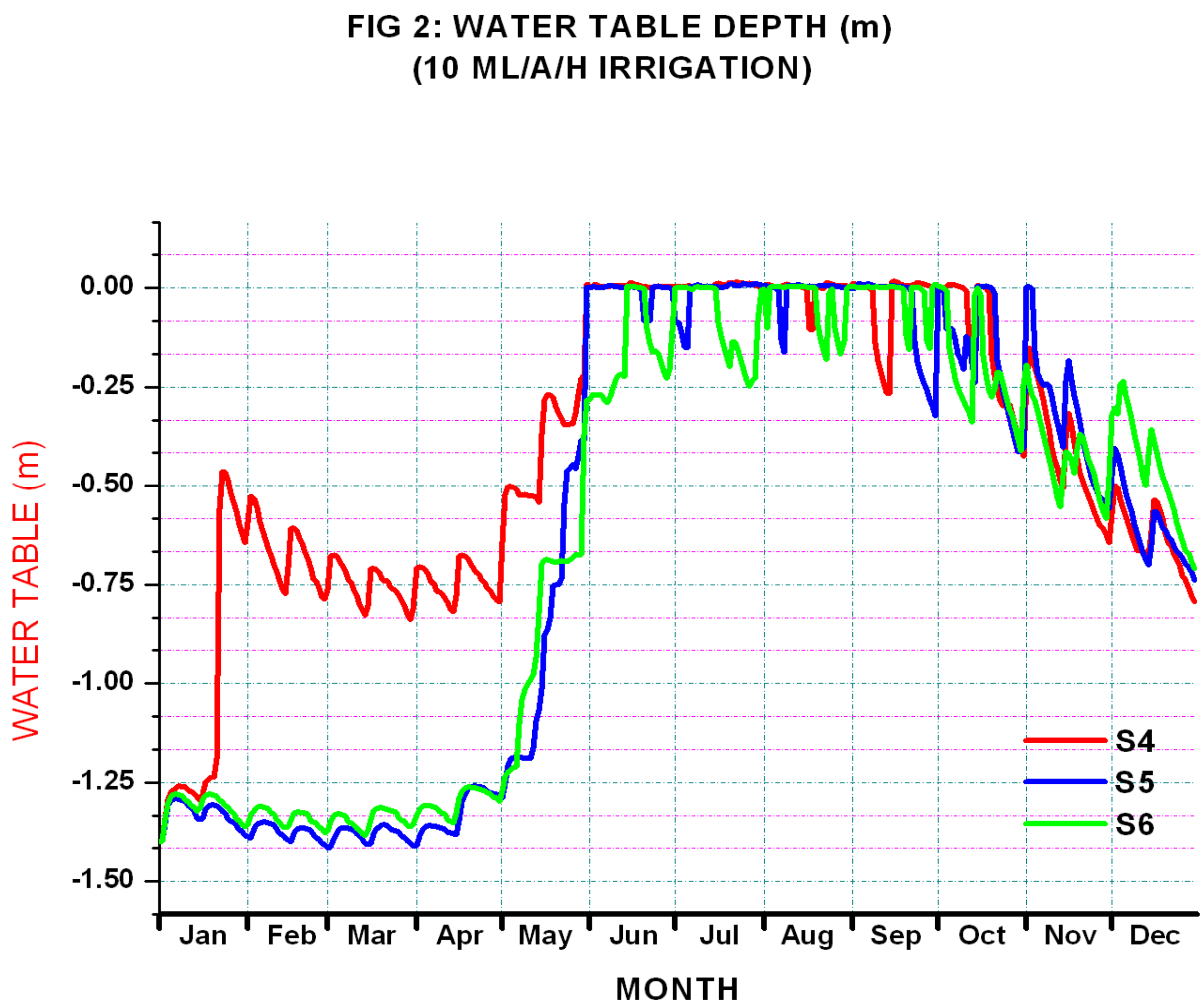
Part 2

Simulated Watertable Depths



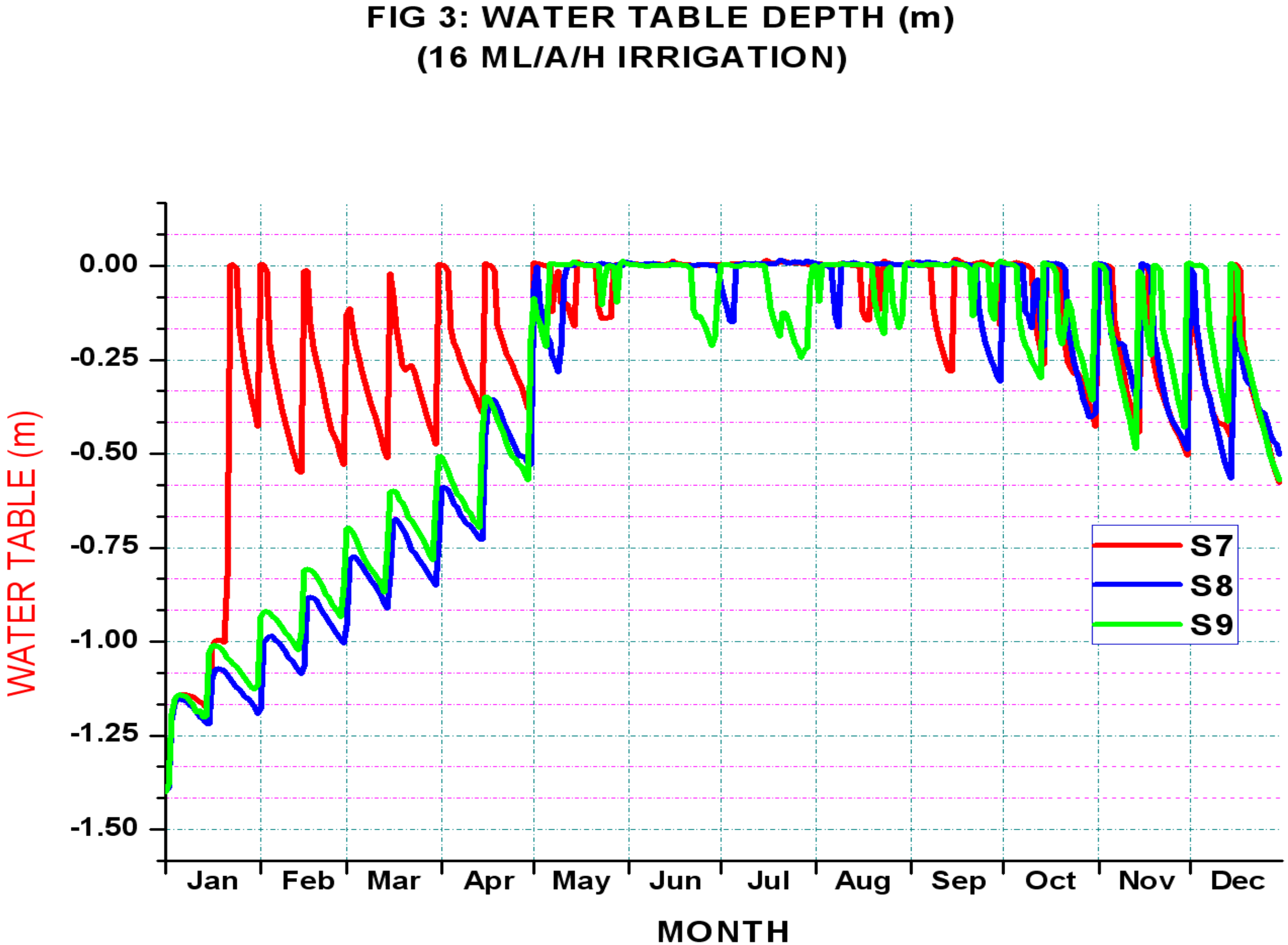
Part 2

Simulated Watertable Depths



Part 2

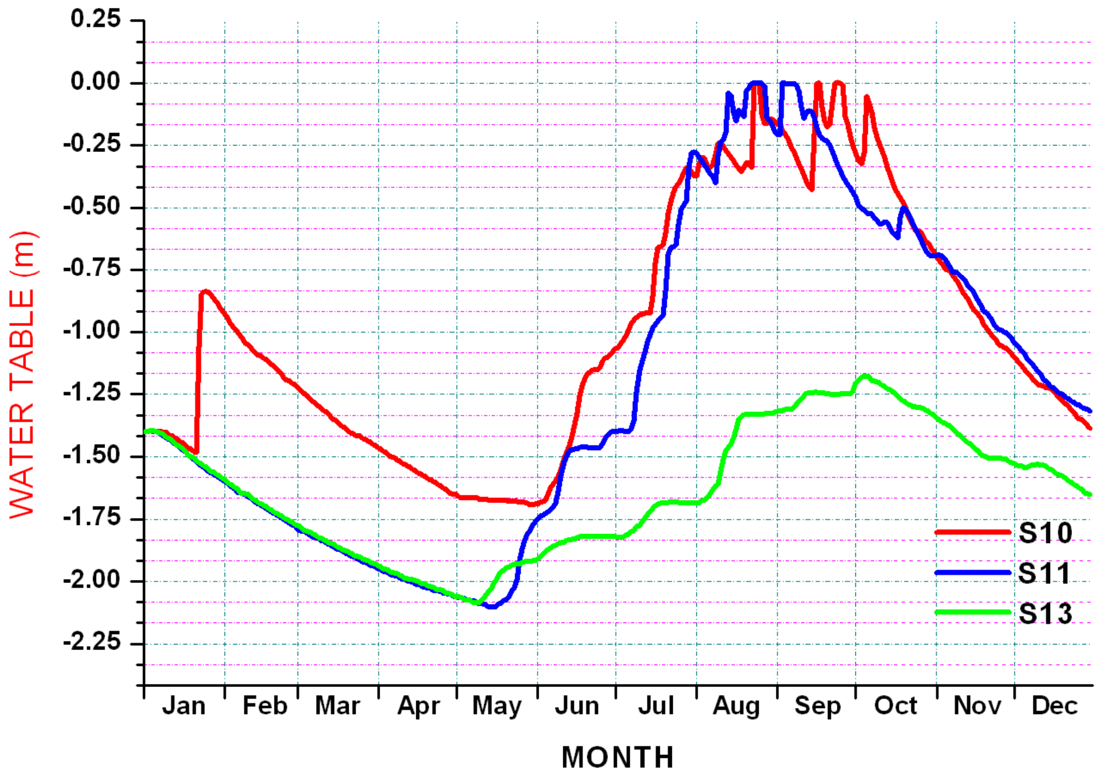
Simulated Watertable Depths



Part 2

Simulated Watertable Depths

FIG 4: WATER TABLE DEPTH (m)
(IRRIGATION ON DEMAND)



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Part 2

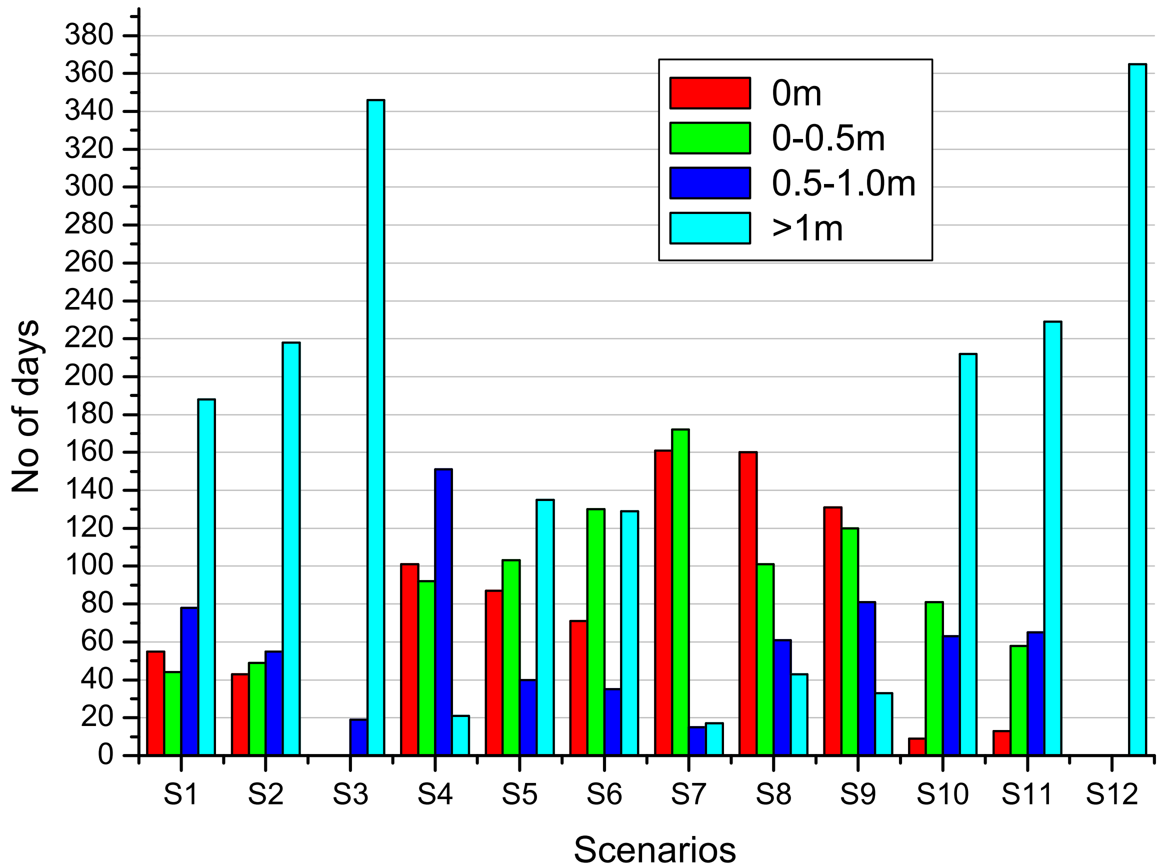
Extent of Waterlogging

Extent of Waterlogging with and without Irrigation in three Climates

SCENARIOS	WATER TABLE DEPTH OUT OF 365 DAYS (m)			
	0	0-0.5	0.5-1.0	≥ 1
S1	55	44	78	188
S2	43	49	55	218
S3	0	0	19	346
S4	101	92	151	21
S5	87	103	40	135
S6	71	130	35	129
S7	161	172	15	17
S8	160	101	61	43
S9	131	120	81	33
S10	9	81	63	212
S11	13	58	65	229
S12	0	0	0	365

Part 2

Extent of Waterlogging



Climate Impact on Land (increased waterlogging)

SCENARIOS	No of days of waterlogging risk days	
	0-0.5	Comparison with S11
S1	99	28
S2	92	21
S3	0	-71
S4	193	122
S5	190	119
S6	201	130
S7	333	262
S8	261	190
S9	251	180
S10	90	19
S11	71	0
S12	0	-71

Part 2

Outflow from the Catchment

IRRIGATION	ANNUAL VOLUME OF OUT FLOWS (GL)		
(ML/Y/H)	WET CLIMATE	AVERAGE CLIMATE	DRY CLIMATE
0	12.74	13.3	0.01
10	53.47	34.02	14.46
16	67.4	46.54	25.58
On Demand	13.5	14.2	6.7

Part 2

Climate Impact on Water Resources

Comparison	INCREASE IN ANNUAL WATER OUT FLOW (GL)		
	WET CLIMATE	AVERAGE CLIMATE	DRY CLIMATE
10-OD	40	20	14
16-OD	54	32	25

Comparison	INCREASE IN ANNUAL WATER OUT FLOW/HA (ML)		
	WET CLIMATE	AVERAGE CLIMATE	DRY CLIMATE
10-OD	5.0	2.5	1.7
16-OD	6.7	4.0	3.1

Summary

- Model predicted waterlogging during peak winter season for wet and average climates and no irrigation
- Without irrigation in dry climate no waterlogging was predicted
- With irrigation the waterlogging was predicted for all three climates
- Waterlogging increased with increased irrigation rates
- Waterlogging was also increased when the climate was wet
- With irrigation and wet climate higher waterlogging risks are predicted which are likely to have adverse impacts on productivity
- Catchment outflows increased with higher irrigation rates and wetter climate
- Water resources were heavily wasted because of irrigation during average and wet climates
- **There was minimal water wastage in the case of on demand irrigation**

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