On-site Wastewater Management Training Course

Evapotranspiration Systems and Sizing by Water Balance

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Terminology

Evapotranspiration Systems referred to as:

- Evapotranspiration Absorption Systems ETA – Australia (unlined)
- Evapotranspiration Seepage Systems ETS – New Zealand (unlined)
- Or simply Evapotranspiration Systems ET, if lined

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Purpose

ETA/S Systems designed to:

- Maximise evapotranspiration
- Reduce absorption (drainage) in unlined systems
- Avoid absorption in lined systems
- Provide alternative to conventional trenches/beds in areas of low permeability soils (<0.5-1.5 m/d) e.g. clay loams, light, medium and heavy clays

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- Table L1 gives recommended DLRs of between 12 mm/d (CL) and 5 mm/d (LC/MC) based on soil texture
- Not necessary for annual evaporation to exceed annual precipitation
- Can use plant transpiration and void space storage to manage hydraulic load throughout seasons

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- DLRs are conservative values
- Any variation to be justified by full water balance for 12-month cycle (Appendix Q)
- No higher DLRs for Secondary treated effluent (may be better to use conventional trench or bed)
- Plant with grasses and shrubs which tolerate wet conditions and have high evapotranspiration capacity
- Construction outlined in Appendix L

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Water Balance Design

- Background outlined in Appendix Q in AS/NZS1547:2012
- Main factors:
  - Effluent largely disposed of through deep infiltration, interflow and evapotranspiration
  - Evapotranspiration is significant, but may not dominate water balance
  - Some deep infiltration is required to prevent salt build up
  - Not suited to shallow water tables unless using a lined system

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Important Components of ET Bed Design

- Crop Factors (Cf), Evaporation (E) and Evapotranspiration (ET) – explained further in water balance example later
- Capillary Water – movement of water laterally and upwards under surface tension
- Field Capacity (FC) – upper limit of available water storage in soil / medium
- Void Ratio (*n*) – proportion of bed available for water/air storage

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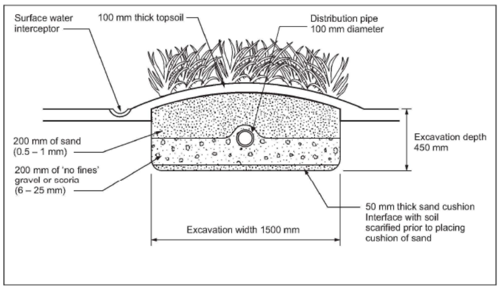
AS/NZS 1547:2012 ETA Bed Design Detail



(Source: Standards Australia 2012)

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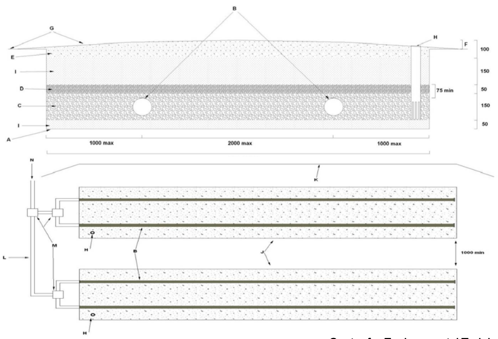
'Typical' ETA Bed Layout



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ETA Bed Installed

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Raised ETA Bed

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Consideration of Climatic Data

- Pan evaporation (E)
  - From nearest climatically similar meteorological station
- Rainfall (R)
  - From nearest climatically similar meteorological station
- Or use SILO data:
- https://www.longpaddock.qld.gov.au/silo/

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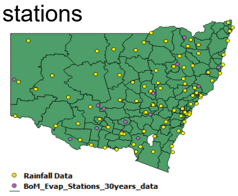
'Class A' Evaporation Pan

Total historical station coverage nationwide:

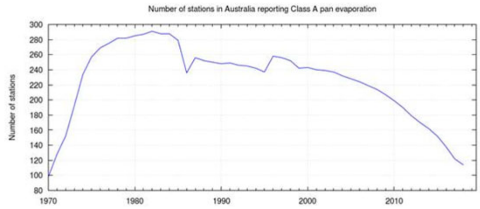
- 17,875 rainfall stations
- Only 601 evaporation stations



(Source: BoM)

'Class A' Evaporation Pan

- Diminishing number of evaporation stations
- Move to SILO data (5km x 5km intersections)



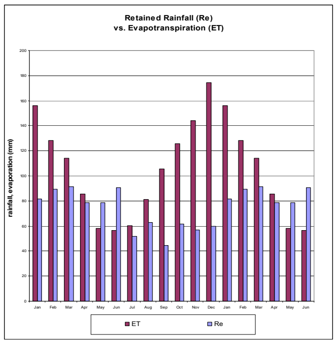
(Source: BoM)

Nominal Monthly Area Requirement

Month	Pan evapo-ration E mm	Evapotran-spiration ET ET=0.75E mm	Rainfall R mm	Retained rainfall R_r R_r=0.75R mm	LTAR per month mm	Disposal rate per month mm	Effluent applied per month L	Size of area m^2
Jan	207.7	155.8	109	81.75	0	74.01	27900	376.90
Feb	170.8	128.1	119	89.25	0	38.85	25200	648.65
Mar	151.9	113.9	122	91.50	0	22.43	27900	1244.15
Apr	114.0	85.5	105	78.75	0	6.75	27000	4000.00
May	77.5	58.1	105	78.75	0	-20.63	27900	-1352.73
Jun	75.0	56.3	121	90.75	0	-34.50	27000	-782.61
Jul	80.6	60.5	69	51.75	0	8.70	27900	3206.90
Aug	108.5	81.4	84	63.00	0	18.38	27900	1518.37
Sep	141.0	105.8	59	44.25	0	61.50	27000	439.02
Oct	167.4	125.6	82	61.50	0	64.05	27900	435.60
Nov	192.0	144.0	76	57.00	0	87.00	27000	310.34
Dec	232.5	174.4	80	60.00	0	114.38	27900	243.93

Table 3. Calculation of area for each month (disregarding storage of effluent).

Inputs (Re) vs. Outputs (ET)



- ET dominates the WB, but not completely
- Excess rainfall can be managed for periods of the year provided that there is storage available in the system

Depth of Stored Effluent

Month	First trial area m^2	Application rate (3) mm	Disposal rate per month (4) mm	(3) - (4) mm	Increase in depth of stored effluent mm	Depth of effluent for month (X - 1) mm	Increase in depth of effluent mm	Computed depth of effluent month (X) mm
Dec	1000							
Jan		27.9	74.01	-46.11	-153.70	0	+ -153.70	= 0
Feb		25.2	38.85	-13.65	-45.50	0	+ -45.50	= 0
Mar		27.9	22.43	5.47	18.23	0	+ 18.23	= 18.23
Apr		27.0	6.75	20.25	67.50	18.23	+ 67.50	= 85.73
May		27.9	-20.63	48.53	161.77	85.73	+ 161.77	= 247.50
Jun		27.0	-34.50	61.50	205.00	247.50	+ 205.00	= 452.50
Jul		27.9	8.70	19.20	64.00	452.50	+ 64.00	= 516.50
Aug		27.9	18.38	9.52	31.73	516.50	+ 31.73	= 548.23
Sep		27.0	61.50	-34.50	-115.00	548.23	+ -115.00	= 433.23
Oct		27.9	64.05	-36.15	-120.50	433.23	+ -120.50	= 312.73
Nov		27.0	87.00	-60.00	-200.00	312.73	+ -200.00	= 112.73
Dec		27.9	114.38	-86.48	-288.27	112.73	+ -288.27	= 0

Table 4. Depth of stored effluent.

The Use of Water Balances

- Will work through an example of an unlined ETA bed
- Have provided templates for water balances for beds and also irrigation areas
- Once you have practiced the skills required in doing water balances longhand they lend themselves to setting up spreadsheets to speed calculation

Water Balance Exercise

- Calculate the minimum area and depth of an evapotranspiration-absorption/seepage area for a three bedroom / five person dwelling
- BoM rainfall and pan evaporation data

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY PAN EVAPORATION (mm)	6.3	5.4	4.4	3.3	2.1	1.8	2.0	3.1	4.3	5.4	5.9	7.0
MEAN MONTHLY RAINFALL (mm)	93.3	99.6	92.1	70.3	58.8	56.4	35.9	45.8	40.2	64.1	76.1	71.7

Water Balance Exercise

- Three test pits excavated on the proposed disposal area indicate that the soils are 475 mm weakly structured clay loam overlying moderately structured light clay to a depth of 2,000 mm. Use the recommended design loading rate derived from Table L1 of AS/NZS 1547:2012 (see the Field Workshop and Design Exercise section of these Course Notes)

Water Balance Exercise

- Calculate the evapotranspiration-absorption/seepage area using the worksheets provided on the following pages
- The evapotranspiration-absorption area is to be constructed of imported aggregate, is to have a maximum depth of 400 mm with a minimum of 50 mm freeboard (i.e. maximum depth of stored effluent is 350 mm)
- Conventional beds may have between 300 mm and 600 mm of aggregate, ETA/ETS beds 400 mm of aggregate and sand

Calculation of evapotranspiration-absorption area size by water balance method

Size of area for each month

(1) Month	(2) Pan evaporation E mm	(3) Evapo transpiration ET $ET = 0.75E$ mm	(4) Rainfall R mm	(5) Retained rainfall R_r $R_r = 0.75R$ mm	(6) DLR per month mm	(7) Disposal rate per month (3)-(5)+(6) mm	(8) Effluent applied per month L	(9) Size of area (8)/(7) m^2
Jan								
Feb								
Mar								
Apr								
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								
First trial area = average monthly area =								m^2

Depth of stored effluent (first trial)

(1) Month	(2) First trial area m^2	(3) Application rate (8)/(2) mm	(4) Disposal rate per month (7) mm	(5) (3) - (4) mm	(6) Increase in depth of stored effluent (5)/n mm	Depth of effluent for month (X - 1) mm	(7) Increase in depth of effluent + (6) mm	Computed depth of effluent month (X) mm
Dec		-	-	-	-	0		
Jan								
Feb								
Mar								
Apr								
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								

n = effective void space factor. For imported durable aggregate, n = 0.3

Conclusions and Discussion

- Can use water balances to size/check size of all land application areas
- Previous example of unlined bed
- Slight modification for lined bed or trench (LTAR/DLR = 0)
- Similar water balance used for sizing irrigation areas, but considers soil as an infinitely thin store (i.e. no soil storage) for conservative sizing

References

- Patterson RA, (2006). Evapotranspiration Bed Designs for Inland Areas. Septic Safe Technical Sheet Reference 05/15. NSW Department of Local Government, July 2006

Month	Pan evapo-ration E mm	Evapotran-spiration ET $ET=0.75E$ mm	Rainfall R mm	Retained rainfall R_r $R_r=0.75R$ mm	LTAR per month mm	Disposal rate per month mm	Effluent applied per month L	Size of area m^2
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Feb	170.8	128.1	119	89.25	0	38.85	25200	648.65
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Jun	75.0	56.3	121	90.75	0	-34.50	27000	-782.61
Jul	80.6	60.5	69	51.75	0	8.70	27900	3206.90
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Nov	192.0	144.0	76	57.00	0	87.00	27000	310.34
Dec	232.5	174.4	80	60.00	0	114.38	27900	243.93

Table 3. Calculation of area for each month (disregarding storage of effluent).

Month	First trial area	Application rate (3)	Disposal rate per month (4)	(3) - (4)	Increase in depth of stored effluent	Depth of effluent for month (X - 1)	Increase in depth of effluent	Computed depth of effluent month (X)
	m^2	mm	mm	mm	mm	mm	mm	mm
Dec	1000							
Jan		27.9	74.01	-46.11	-153.70	0	+ -153.70	= 0
Feb		25.2	38.85	-13.65	-45.50	0	+ -45.50	= 0
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Jun		27.0	-34.50	61.50	205.00	247.50	+ 205.00	= 452.50
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Dec		27.9	114.38	-86.48	-288.27	112.73	+ -288.27	= 0

Table 4. Depth of stored effluent.

WATER BALANCE ANALYSIS WORKSHOP SESSION

Calculation of evapotranspiration-absorption/seepage area size by the water balance method.

Using the following information using your Course Notes, calculate the minimum area and depth of an evapotranspiration-absorption/seepage area for a three bedroom / five person dwelling.

Bureau of Meteorology rainfall and pan evaporation data for the nearest station is provided below.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DAILY PAN EVAPORATION (mm)	6.3	5.4	4.4	3.3	2.1	1.8	2.0	3.1	4.3	5.4	5.9	7.0
MEAN MONTHLY RAINFALL (mm)	93.3	99.6	92.1	70.3	58.8	56.4	35.9	45.8	40.2	64.1	76.1	71.7

Three test pits excavated on the proposed disposal area indicate that the soils are 475 mm weakly structured clay loam overlying moderately structured light clay to a depth of 2000 mm. Use the recommended design loading rate derived from Table L1 of AS/NZS 1547:2012 (see the Field Workshop and Design Exercise section of these Course Notes).

Calculate the evapotranspiration-absorption/seepage area using the worksheets provided on the following two pages.

The evapotranspiration-absorption area is to be constructed of imported aggregate, is to have a maximum depth of 600 mm with a minimum of 50 mm freeboard (i.e. maximum depth of stored effluent is 550 mm).

Calculation of evapotranspiration-absorption area size by water balance method

Size of area for each month

(1) Month	(2) Pan evaporation E mm	(3) Evapo transpiration ET $ET = 0.75E$ mm	(4) Rainfall R mm	(5) Retained rainfall R_r $R_r = 0.75R$ mm	(6) DLR per month mm	(7) Disposal rate per month (3)-(5)+(6) mm	(8) Effluent applied per month L	(9) Size of area (8)/(7) m^2
Jan								
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Jul								
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Sep								
Oct								
Nov								
Dec								
							First trial area = average monthly area =	m^2

Depth of stored effluent (first trial)

(1) Month	(2) First trial area m^2	(3) Application rate (8)/(2) mm	(4) Disposal rate per month (7) mm	(5) (3) - (4) mm	(6) Increase in depth of stored effluent (5)/n mm	Depth of effluent for month (X - 1) mm	(7) Increase in depth of effluent + (6) mm	Computed depth of effluent month (X) mm
Dec		-	-	-	-	0		
Jan								
Feb								
Mar								
Apr								
May								
Jun								
Jul								
Aug								
Sep								
Oct								
Nov								
Dec								

n = effective void space factor. For imported durable aggregate, n = 0.3

Minimum Area Method Water Balance and Wet Weather Storage Calculations

Design Wastewater Flow	(Q)	L/day														
Design Percolation Rate	(R)	mm/wk														
Parameter	**Symbol**	**Formula**	**Units**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Total**
Days in month	(D)	-	days													
Precipitation	(P)	-	mm/month													
Evaporation	(E)	-	mm/month													
Crop factor	(C)	-	-													
Outputs																
Evapotranspiration	(ET)	E x C	mm/month													
Percolation	(B)	(R/7) x D	mm/month													
Outputs		(ET+B)	mm/month													
Inputs																
Precipitation	(P)	-	mm/month													
Possible Effluent Irrigation	(W)	(ET + B) -P	mm/month													
Actual Effluent Production	(I)	H/12	mm/month													
Inputs		(P + I)	mm/month													
Storage	(S)	(P+I) - (ET+B)	mm/month													
Cumulative storage	(M)	-	mm													
Irrigation Area	**(L)**	**365 x Q/H**	**m^2**													
Storage	**(V)**	**largest M**	**mm**													
		(V x L)/1000	**m^3**													

Monthly Water Balance used to Determine Wet Weather Storage for a Medium Rainfall Region with a Nominated Irrigation Area

Design Wastewater Flow	(Q)	L/day	
Design Percolation Rate	(R)	mm/wk	
Land Area	(L)	m^2	

Parameter	**Symbol**	**Formula**	**Units**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Total**
Days in month	(D)	-	days													
Precipitation	(P)	-	mm/month													
Evaporation	(E)	-	mm/month													
Crop factor	(C)	-	-													
Inputs																
Precipitation	(P)	-	mm/month													
Effluent Irrigation	(W)	(Q x D)/L	mm/month													
Inputs		(P+W)	mm/month													
Outputs																
Evapotranspiration	(ET)	E x C	mm/month													
Percolation	(B)	(R/7) x D	mm/month													
Outputs		(ET+B)	mm/month													
Storage	(S)	(P+W) - (ET+B)	mm/month													
Cumulative storage	(M)	-	mm													
Storage	**(V)**	**largest M**	**mm**													
		(V x L)/1000	**m^3**													