United States Environmental Protection Agency

Example Moisture Mass Balance Calculations for Bioreactor Landfills

EPA-456/R-05-004
August 2005

Example Moisture Mass Balance Calculations for Bioreactor Landfills

Prepared for:
Mary Ann Warner, Project Officer
Information Transfer and Program Integration Division

Contract No. 68-D-02-0079
Work Assignment Numbers 1-03 and 2-04

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Information Transfer and Program Integration Division
Research Triangle Park, NC

1.0 INTRODUCTION

The purpose of this memorandum is to demonstrate example mass balance calculations that can be performed to estimate the moisture content of the waste mass in a bioreactor landfill. The Municipal Solid Waste Landfills NESHAP (40 CFR part 63, subpart AAAA) requires timely control of bioreactor landfills. As defined in the NESHAP, a bioreactor is a MSW landfill or a portion of a MSW landfill where any liquid, other than leachate or landfill gas condensate, is added in a controlled fashion to accelerate the anaerobic (without oxygen) biodegradation of the waste. The average moisture content of the waste in the area into which the liquid is added must be at least 40 percent (by weight) for the landfill or portion of the landfill to be considered a bioreactor. We have presented the example mass balance calculations based on the wet weight of waste. This is consistent with the approach detailed in the book, Landfill Bioreactor Design and Operation, by Debra Reinhart and Timothy Townsend and documented in the EPA Docket A-98-28 (Item IV-K-9).

The only two situations where the NESHAP requires a landfill owner/operator to calculate percent moisture content are:

1. If the landfill owner/operator adds liquids (other than leachate and condensate) and does NOT comply with the bioreactor control requirements. In this case, they must keep a record of calculations showing that the percent moisture content expected in the waste mass to which the liquid is added is less than 40 percent. If the moisture content is less than 40 percent, the landfill would not meet the definition of a bioreactor, and timely control would not be required. See section 63.1980(g) of subpart AAAA.

2. If the landfill owner/operator chooses to begin operating the bioreactor gas collection and control system within 180 days after achieving 40 percent moisture content instead of within 180 days after initiating liquids addition, as allowed under section 63.1947 (a)(2) or (c)(2). In this case, they must calculate percent moisture content to determine when the bioreactor reaches 40 percent moisture, keep records, and submit a report within 90 days of achieving 40 percent moisture content. See section 63.1980(h) of subpart AAAA. Note that a landfill owner/operator who adds liquids does NOT have to calculate percent moisture content if they meet the bioreactor control requirements within 180 days of initiating liquids addition (or by January 17, 2006 for existing landfills with bioreactors).

The NESHAP allows moisture content to be determined using a variety of methods, as long as the procedures and assumptions are documented and appropriate. A range of appropriate methods exist. For example, the landfill owner/operator can perform a simple mass balance calculation. The calculation must take into account the waste mass, moisture content of the incoming waste, mass of liquids added to the bioreactor (including recirculated leachate), precipitation falling on the bioreactor surface, and mass of water removed as leachate. The landfill can perform more complex mass balances using models that take into account additional factors such as surface runoff, landfill cover types that reduce the amount of precipitation entering the waste mass, and water loss mechanisms such as evapotranspiration. Another possible method for an established bioreactor would include sampling the moisture content of the waste at multiple locations within the bioreactor, and performing statistical calculations to determine the average percent moisture. However, it is expected that in most cases, a mass balance approach will be adequate to determine whether the moisture content is above or below 40 percent and comprehensive sampling will not be needed.

This memorandum provides two example mass balance calculation procedures, a simple method and a more complex method. However, landfill owners/operators are free to use other methods to take into account site-specific characteristics of their landfill. Many landfills may already have performed moisture balance calculations, and these can be used assuming the procedures and assumptions are documented, appropriate, and representative of current landfill conditions.

2.0 WATER BALANCE METHOD

The Water Balance Method was chosen to represent the example calculations used to model the mass balance of moisture within a bioreactor landfill because it is a relatively basic computation. The Hydrologic Evaluation of Landfill Performance (HELP) model is another, more advanced model that can be used as an alternative to the Water Balance Method. However, the HELP model is based on a volumetric moisture content of waste. Because the NESHAP specifies that the 40 percent moisture content is by weight, we do not recommend using the HELP model to conduct bioreactor mass balance calculations to meet the requirements of the NESHAP.

The Water Balance Method performs several calculations in sequence on a monthly time basis to estimate the average moisture content of the waste. It was originally designed to measure evapotranspiration from soils and was then adapted for landfill conditions. Our suggested procedure for using the Water Balance Method involves a two-tiered approach. Method A is a simplified equation that only incorporates factors which most significantly affect the average moisture content of the waste mass. The simplified equation also assumes that all precipitation falling directly on the landfill’s surface will become moisture in the waste mass. The primary factors that are accounted for in the simplified equation are:

- Incoming waste moisture,
- Precipitation (only precipitation that falls directly on the landfill’s surface; assuming that all surface runoff from adjacent areas is diverted around the landfill surface),
- Liquids addition (recirculated leachate, water, etc.), and
- Leachate production.

If landfill owners/operators are satisfied with the results of the Method A equation, then no further calculations are needed. However, if further analysis is required, then landfill owners/operators can proceed to Method B which comprises a more advanced set of calculations. This more complex procedure takes into account the four factors included in the simplified equation of Method A plus the following four elements:

- Moisture retained in the landfill surface or cover material,
- Surface runoff,
- Surface evaporation, and
- Evapotranspiration.

A detailed description of each step is discussed in Sections 2.1 and 2.2, respectively.

2.1 Method A: Simplified Equation

The potential moisture content of the waste mass in the bioreactor landfill can be estimated using the following simplified equation of the Water Balance Method:

$$PMC = \frac{(Lo * M) + P + LA - LCH}{M + \mathrm{P} + LA - \mathrm{LCH}} * 100 \qquad \text{(Equation 1)}$$

Where,
PMC = estimated potential moisture content of the waste mass (% moisture content on a wet weight basis);
L_o = moisture entering with the waste mass (kg moisture/kg total waste mass as received);
M = total waste mass in bioreactor cell on an as received basis (kg total waste mass as received);
P = total precipitation (kg total precipitation);
LA = total liquids added to the waste mass, including recirculated leachate (kg total liquids); and
LCH = total leachate collected (kg total leachate).

If the bioreactor landfill has been at steady state (i.e., no fluctuations in any of the factors above) since the bioreactor cell or entire bioreactor landfill opened, then *M*, *P*, *LA*, and *LCH* can be calculated as monthly averages instead of totals. However, this scenario is not likely to occur.

When using Equation 1, landfill owners/operators must keep records of data and assumptions used to determine values of L_o, *M, P, LA*, and *LCH* for their bioreactor landfill. The following bullet points provide potential guidelines for determining and recording these values.

- L_o: According to Tchobanoglous' *Integrated Solid Waste Management: Engineering Principles and Management Issues*, most MSW in the United States has a moisture content of 15 to 40 percent, with 25% as typical. Moisture content of MSW depends primarily on the composition of the waste, the season of the year, and the humidity and weather conditions of the surrounding environment. For example, the moisture content of 100 kilograms of incoming wet waste can be estimated as: [(100 kg - *d*)/100 kg], where *d* is the total dry weight in kilograms of the solid waste components within the 100 kilograms of wet waste received.

- *M*: To calculate total waste mass, waste acceptance or waste placement data is needed and should be documented accordingly.

- *P*: Total precipitation in inches of water can be obtained from precipitation measurements at the landfill or from nearby weather station data. Convert the precipitation from inches to kilograms of moisture using the following equation:

  Total precipitation (*P*) = (in. of total precipitation) * (1 ft/12 in) * (ft^2 of bioreactor landfill surface) * (1 gal/0.134 ft^3) * (3.78 kg/gal water)

- *LA*: The total amount of liquids added can be estimated using measurements currently taken at the bioreactor site for design and operational purposes. For example, if a closed-loop bioreactor with horizontal trenches uses a flow meter to measure the amount of leachate recirculated, then flow meter reading records can be used to estimate total leachate addition (e.g., converting the flow rate each month to kilograms of leachate per month and then summing the monthly readings to obtain a total liquids added amount). Water introduced at the surface of the landfill via truck could be measured using a simple volume displacement calculation, such as: (gallons of water stored per tank truck) * (number of tank trucks emptied onto landfill surface) * (3.78 kilograms per gallon of water). The types of liquid addition methods vary by bioreactor landfill site, therefore, the types of measurement methods will differ as well. We recommend that each landfill owner/operator calculate total liquids using methods most appropriate for their bioreactor design.

- *LCH*: Similar to liquids addition, the total amount of leachate produced can be estimated using leachate collection records generated at the landfill bioreactor for design, operational, and possibly regulatory purposes. For example, if a bioreactor landfill uses a flow meter to measure the amount of leachate produced or collected, then flow meter reading records can be used to estimate total leachate generation (e.g., converting the total flow rate each month to kilograms of leachate per month and then summing the monthly readings to obtain a total leachate amount). The leachate value used in Equation 1 should include leachate that is recirculated as well as any excess leachate that may be treated or disposed of by other means. We recommend that each landfill owner/operator calculate total leachate generated using methods most appropriate for their leachate collection system design.

2.2 Method B: Advanced Set of Calculations

The following items are required inputs for Method B of the Water Balance Method calculations:

- Average monthly temperatures in degrees Fahrenheit (ºF)
- Site latitude
- Average monthly precipitation in inches of water
- Landfill surface conditions
- Soil & vegetation type for final cover (if any)

The 17 calculation steps of the advanced Water Balance Method procedure are listed below. Steps 1 through 16 of the sequence calculate and confirm the percolation of precipitation into the bioreactor landfill considering moisture contained in the landfill surface or final cover, surface runoff, evaporation losses, and evapotranspiration. Step 17 is very similar to Equation 1 for Method A. The only difference between Step 17 and Equation 1 is that Step 17 replaces the amount of precipitation with the amount of moisture that percolates into the waste mass. Attachment B contains a Microsoft Excel spreadsheet that provides example calculations for Steps 1 through 16. The foundation for this sequence of calculations and example spreadsheet comes directly from McBean's *Solid Waste Landfill Engineering and Design*.

Sequence of Calculations for the Advanced Water Balance Method (Method B):

Steps 1 - 5: Determine potential evapotranspiration

1. Collect average monthly temperatures (*T*) in ºF for the area surrounding the bioreactor landfill. Enter this information in the spreadsheet.

2. Using the monthly temperatures, determine the monthly heat index (*h*) for each month. Monthly heat indices can be determined using Table A1 in Attachment A. For months where the temperature is less than 32 ºF, set *h* to zero. Sum the monthly heat indices to obtain a yearly heat index (*H*).

3. Using the monthly temperatures and yearly heat index, find the Unadjusted Potential Evapotranspiration (*UPET*) for each month using Table A.2 in Attachment A.

4. Using the latitude at the bioreactor landfill site, find the monthly correction factor for sunlight duration (*r*) in Table A.3 in Attachment A.

5. Multiply the monthly *UPET* by the monthly *r* to result in the monthly Adjusted Potential Evapotranspiration (*PET*) for each month in inches of water.

Steps 6 - 9: Determine amount of precipitation that infiltrates the bioreactor landfill

6. Enter the average monthly precipitation (*P*) in inches of water for the bioreactor landfill site.

7. Enter the appropriate runoff coefficient ($C_{r/o}$) to calculate the runoff for each month. Table A.4 in Attachment A can be used to determine the most appropriate runoff coefficient based on the landfill surface conditions.

8. Multiply the monthly precipitation by the monthly runoff coefficient to obtain the runoff (*r/o*) for each month in inches of water.

9. Subtract the monthly *r/o* from the monthly *P* to obtain the monthly infiltration (*I*) in inches of water.

Steps 10 - 13: Calculate moisture storage in the landfill surface cover material

10. Subtract the monthly *PET* from the monthly *I* to determine the moisture available for storage at the landfill surface *(I - PET)* in inches of water.

11. For negative *(I - PET)* values only, add the *(I - PET)* value for the preceding month to the current month to calculate the Cumulative Water Loss (*ACCWL*). Begin the summation with zero accumulated water loss for the last month having a positive *(I - PET)* value.

12. Determine the monthly Soil Moisture Storage (*ST*) in inches of water for the landfill surface by following the steps outlined below:

    a. Determine the initial *ST* for the soil depth and type. Table A.5 can be used to configure the initial *ST* (retention) value.

    b. Assign the initial *ST* value to the months having a positive *(I - PET)* value, prior to months that have a negative *(I - PET)* value.

    c. Determine the *ST* for each subsequent month having a negative *(I - PET)* value. Use the monthly *ACCWL* values and Table A.6 to obtain the *ST*.

    d. For subsequent months having an *(I - PET)* value greater than or equal to zero, add the *(I - PET)* value for each month to the preceding month's *ST*. Be careful not to exceed the soil field capacity (i.e., fraction of water in the soil based on the dry weight of the soil). Enter the soil field capacity for monthly soil moisture storage if the sum exceeds the field capacity.

13. Calculate the change in the *ST*, or *ΔST*, for each month in inches of water by subtracting the *ST* for the preceding month from the current month's *ST*.

Steps 14 - 16: Calculate actual evapotranspiration and percolation of moisture into the bioreactor landfill waste mass

14. Calculate the Actual Evapotranspiration (*AET*) by following the steps outlined below:

    a. For wet months where the *(I - PET)* value is greater than or equal to zero, set the *AET* equal to the *PET*.

    b. For dry months where the *(I - PET)* value is negative, use the following equation for the *AET*: $AET = PET + ((I - PET) - \Delta ST)$. This equation represents the fact that the evapotranspired amount is the amount potentially evapotranspired plus that available from excess infiltration that would otherwise add to soil moisture storage plus that available from previously stored soil moisture.

15. Calculate the monthly percolation (*PERC*) as follows:

a. For wet months where the *(I - PET)* value is greater than or equal to zero, use the following equation for the *PERC*: *PERC = ((I - PET) - ΔST)*.

b. For dry months where the *(I - PET)* value is negative, set the *PERC* equal to zero.

16. As a check for Steps 7 through 15, calculate the average monthly precipitation (*P*) in inches of water to be sure they match the original precipitation values entered in Step 6. The precipitation calculation is as follows: *P = PERC + AET + ΔST + r/o*.

Step 17: Estimate moisture content of the waste mass in the bioreactor landfill

17. Convert *PERC* from inches of moisture to kilograms of moisture per kilogram of waste (e.g., [PERC (in) * (1 ft/12 in) * (ft^2 of bioreactor landfill surface) * (1 gal/0.134 ft^3) * (3.78 kg/gal water)] / (total kg wet waste mass in bioreactor)). Then, estimate the potential moisture content of the waste mass, on a monthly wet weight basis, using the following equation:

$$PMC = L_o + PERC + LA - LCH \qquad \text{(Equation 2)}$$

Where,
PMC = estimated potential moisture content of the waste mass (kg moisture/kg wet waste);
L_o = average amount of moisture in the initial waste added each month (kg moisture/kg wet waste);
PERC = monthly percolation (kg moisture/kg wet waste);
LA = amount of liquids added to the waste each month, including recirculated leachate (kg liquids/kg wet waste); and
LCH = amount of leachate produced each month (kg leachate/kg wet waste).

L_o, *LA*, and *LCH* should be estimated and documented similarly to Method A procedures described under Equation 1 in Section 2.1. The difference between Equations 1 and 2 is that L_o, *LA*, and *LCH* are monthly values per kilogram of waste in Equation 2, not total values. Therefore, for Equation 2, monthly values will need to be determined and then divided by the amount of waste added each month.

3.0 REFERENCES

1. McBean, E.A., Rovers, F.A., and Farquhar, G.J. *Solid Waste Landfill Engineering and Design*. Prentice-Hall: New Jersey, 1995. Chapter 7 and Appendix C.

2. Tchobanoglous, G., Theisen, H., and Vigil, S. *Integrated Solid Waste Management: Engineering Principles and Management Issues*. McGraw-Hill: New York, 1993. pp. 70-73, 421-424.

Attachment A
Reference Tables for Water Balance Method Calculations

Table A.1. Monthly Values of Heat Indices Corresponding to Monthly Mean Temperatures

T°F	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
32	.00	.00	.00	.00	.01	.01	.02	.02	.03	.03
33	.04	.04	.05	.05	.06	.06	.07	.08	.09	.09
34	.10	.10	.11	.12	.13	.14	.15	.16	.17	.18
35	.19	.20	.21	.22	.23	.24	.25	.26	.27	.28
36	.29	.30	.32	.33	.34	.35	.36	.37	.39	.40
37	.41	.42	.43	.44	.46	.47	.48	.50	.51	.52
38	.54	.55	.56	.58	.59	.60	.62	.63	.65	.66
39	.68	.70	.71	.73	.74	.76	.77	.79	.80	.82
40	.83	.85	.86	.88	.90	.91	.93	.95	.96	.98
41	1	1.01	1.03	1.05	1.07	1.08	1.10	1.12	1.14	1.16
42	1.17	1.19	1.21	1.23	1.24	1.26	1.28	1.30	1.32	1.33
43	1.35	1.37	1.39	1.41	1.43	1.45	1.47	1.49	1.50	1.52
44	1.54	1.56	1.58	1.60	1.62	1.64	1.66	1.68	1.70	1.72
45	1.74	1.76	1.78	1.80	1.82	1.85	1.87	1.89	1.91	1.93
46	1.95	1.97	2.00	2.02	2.04	2.06	2.08	2.10	2.13	2.15
47	2.17	2.19	2.21	2.23	2.26	2.28	2.30	2.32	2.34	2.37
48	2.39	2.41	2.43	2.46	2.48	2.50	2.53	2.55	2.57	2.60
49	2.62	2.64	2.67	2.69	2.71	2.74	2.76	2.79	2.81	2.84
50	2.86	2.89	2.91	2.93	2.96	2.98	3.01	3.03	3.06	3.08
51	3.11	3.13	3.16	3.18	3.21	3.23	3.25	3.28	3.30	3.33
52	3.35	3.38	3.40	3.43	3.45	3.48	3.50	3.53	3.55	3.58
53	3.6	3.63	3.65	3.68	3.71	3.73	3.76	3.79	3.81	3.84
54	3.87	3.89	3.92	3.95	3.97	4.00	4.03	4.06	4.08	4.11
55	4.14	4.16	4.19	4.22	4.25	4.27	4.30	4.33	4.35	4.38
56	4.41	4.44	4.47	4.50	4.52	4.55	4.57	4.60	4.63	4.66
57	4.69	4.72	4.75	4.77	4.80	4.83	4.86	4.89	4.92	4.95
58	4.98	5.01	5.04	5.07	5.10	5.13	5.15	5.19	5.22	5.25
59	5.28	5.31	5.34	5.37	5.40	5.43	5.46	5.49	5.52	5.55
60	5.58	5.61	5.64	5.67	5.70	5.73	5.76	5.79	5.82	5.85
61	5.88	5.91	5.94	5.97	6.00	6.03	6.06	6.10	6.13	6.16
62	6.19	6.22	6.25	6.28	6.31	6.34	6.38	6.41	6.44	6.47
63	6.50	6.53	6.56	6.59	6.62	6.66	6.69	6.72	6.75	6.79
64	6.82	7.85	6.88	6.92	6.95	6.98	7.02	7.05	7.08	7.12
65	7.15	7.18	7.22	7.25	7.28	7.32	7.35	7.38	7.42	7.45
66	7.48	7.52	7.55	7.58	7.62	7.65	7.68	7.72	7.75	7.78
67	7.82	7.85	7.89	7.92	7.95	7.99	8.02	8.05	8.09	8.12
68	8.16	8.19	8.23	8.26	8.30	8.33	8.37	8.40	8.44	8.47
69	8.51	8.54	8.57	8.61	8.64	8.68	8.71	8.75	8.78	8.82
70	8.85	8.89	8.92	8.96	8.99	9.03	9.06	9.10	9.13	9.17

Table A.1. Monthly Values of Heat Indices Corresponding to Monthly Mean Temperatures (Continued)

T°F	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
71	9.2	9.24	9.27	9.31	9.34	9.38	9.42	9.45	9.49	9.53
72	9.57	9.60	9.64	9.67	9.71	9.75	9.78	9.82	9.85	9.89
73	9.93	9.97	10.01	10.04	10.08	10.12	10.15	10.19	10.22	10.26
74	10.30	10.34	10.37	10.41	10.45	10.48	10.52	10.56	10.60	10.64
75	10.67	10.71	10.75	10.78	10.82	10.86	10.89	10.93	10.97	11.01
76	11.05	11.09	11.13	11.17	11.20	11.24	11.28	11.31	11.35	11.39
77	11.43	11.47	11.51	11.54	11.58	11.62	11.66	11.70	11.74	11.76
78	11.82	11.85	11.89	11.93	11.97	12.01	12.05	12.09	12.13	12.17
79	12.21	12.25	12.29	12.33	12.37	12.41	12.45	12.49	12.53	12.57
80	12.61	12.65	12.69	12.73	12.77	12.81	12.85	12.89	12.93	12.97
81	13.01	13.05	13.09	13.13	13.17	13.21	13.25	13.29	13.33	13.37
82	13.41	13.45	13.49	13.53	13.57	13.61	13.65	13.69	13.73	13.77
83	13.81	13.85	13.89	13.94	13.98	14.02	14.06	14.10	14.14	14.18
84	14.22	14.26	14.31	14.35	14.39	14.43	14.47	14.52	14.56	14.60
85	14.64	14.69	14.73	14.77	14.81	14.85	14.90	14.94	14.98	15.02
86	15.07	15.11	15.15	15.19	15.23	15.28	15.32	15.36	15.40	15.45
87	15.49	15.53	15.58	15.62	15.66	15.71	15.75	15.79	15.84	15.88
88	15.92	15.97	16.01	16.05	16.10	16.14	16.18	16.23	16.27	16.31
89	16.36	16.40	16.44	16.49	16.53	16.57	16.62	16.66	16.70	16.75
90	16.79	16.83	16.88	16.92	16.96	17.01	17.05	17.09	17.14	17.18
91	17.23	17.27	17.32	17.36	17.41	17.45	17.49	17.54	17.58	17.63
92	17.67	17.72	17.76	17.81	17.85	17.89	17.94	17.98	18.03	18.07
93	18.12	18.16	18.21	18.25	18.30	18.34	18.39	18.43	18.48	18.52
94	18.57	18.62	18.66	18.71	18.75	18.80	18.84	18.89	18.93	18.98
95	19.03	19.07	19.12	19.16	19.21	19.25	19.30	19.34	19.39	19.44
96	19.48	19.53	19.58	19.62	19.67	19.71	19.76	19.81	19.86	19.90
97	19.95	20.00	20.04	20.09	20.14	20.18	20.23	20.28	20.32	20.37
98	20.42	20.46	20.51	20.56	20.60	20.65	20.70	20.74	20.79	20.84
99	20.88	20.93	20.98	21.03	21.08	21.13	21.17	21.22	21.27	21.32
100	21.36	21.41	21.46	21.51	21.56	21.60	21.65	21.70	21.75	21.79
101	21.84	21.89	21.94	21.99	22.03	22.08	22.13	22.18	22.23	22.29
102	22.33	22.38	22.42	22.47	22.52	22.57	22.62	22.67	22.71	22.76
103	22.81	22.86	22.91	22.96	23.00	23.05	23.10	23.15	23.20	23.25
104	23.30									

"Example - for a temperature of 77.5°F, I = 11.62"

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values

I Value (25.0–80)

T°F	25	27.5	30	32.5	35	37.5	40	42.5	45	47.5	50	52.5	55	57.5	60	62.5	65	67.5	70	72.5	75	77.5	80	T°F
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
32.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32.5
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33
33.5	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33.5
34	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
34.5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34.5
35	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	35
35.5	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	35.5
36	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	36
36.5	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	36.5
37	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	37
37.5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	37.5
38	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	38
38.5	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	38.5
39	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	39
39.5	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	39.5

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

I VALUE (82.5 – 40)

T°F	82.5	85	87.5	90	92.5	95	97.5	100	102.5	105	107.5	110	112.5	115	117.5	120	122.5	125	127.5	130	132.5	135	137.5	140	T°F
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32
32.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32.5
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33
33.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33.5
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
34.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34.5
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35
35.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35.5
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36
36.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36.5
37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37
37.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37.5
38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38
38.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38.5
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39
39.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39.5

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

T°F	I Value (25.0–80)																							T°F
	25	27.5	30	32.5	35	37.5	40	42.5	45	47.5	50	52.5	55	57.5	60	62.5	65	67.5	70	72.5	75	77.5	80	
40	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	40
40.5	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	40.5
41	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	41
41.5	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	41.5
42	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	42
42.5	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	42.5
43	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	43
43.5	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	43.5
44	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	44
44.5	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	44.5
45	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	45
45.5	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	45.5
46	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	46
46.5	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	46.5
47	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	47
47.5	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	47.5

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

I VALUE (87.5 – 140)

T°F	82.5	85	87.5	90	92.5	95	97.5	100	102.5	105	107.5	110	112.5	115	117.5	120	122.5	125	127.5	130	132.5	135	137.5	140	T°F
40	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40
40.5	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40.5
41	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41
41.5	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41.5
42	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42
42.5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42.5
43	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43
43.5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	43.5
44	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	0	44
44.5	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	0	44.5
45	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	45
45.5	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0	0	45.5
46	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0	46
46.5	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	46.5
47	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	47
47.5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	47.5

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

I VALUE (82.5 – 140)

T°F	82.5	85	87.5	90	92.5	95	97.5	100	102.5	105	107.5	110	112.5	115	117.5	120	122.5	125	127.5	130	132.5	135	137.5	140	T°F
48	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	48
48.5	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	0	48.5
49	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0	49
49.5	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	49.5
50	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	50
50.5	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	50.5
51	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	51
51.5	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	51.5
52	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	52
52.5	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	52.5
53	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	53
53.5	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	53.5
54	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	54
54.5	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	54.5
55	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	55
55.5	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	55.5

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

	I Value (25.0–80)																							
T°F	25	27.5	30	32.5	35	37.5	40	42.5	45	47.5	50	52.5	55	57.5	60	62.5	65	67.5	70	72.5	75	77.5	80	140
48.5	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	48.5
49	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	49
49.5	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	49.5
50	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	50
50.5	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	50.5
51	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	51
51.5	0.08	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	51.5
52	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	52
52.5	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	52.5
53	0.09	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	53
53.5	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	53.5
54	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	54
54.5	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	54.5
55	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	55
55.5	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	55.5

Table A2.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

I Value (25.0– 80)

T°F	25	27.5	30	32.5	35	37.5	40	42.5	45	47.5	50	52.5	55	57.5	60	62.5	65	67.5	70	72.5	75	77.5	80	T°F
56	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	56
56.5	0.1	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	56.5
57	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	57
57.5	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.07	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	57.5
58	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	58
58.5	0.11	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	58.5
59	0.11	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	59
59.5	0.11	0.11	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	59.5
60	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	60
60.5	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	60.5
61	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	61
61.5	0.12	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	61.5
62	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	62
62.5	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	62.5
63	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	63
63.5	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	63.5

I VALUE (82.5 – 140)

T°F	82.5	85	87.5	90	92.5	95	97.5	100	102.5	105	107.5	110	112.5	115	117.5	120	122.5	125	127.5	130	132.5	135	137.5	140	T°F
56	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	56
56.5	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	56.5
57	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	57
57.5	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	57.5
58	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	58
58.5	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	58.5
59	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	59
59.5	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	59.5
60	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	60
60.5	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03	60.5
61	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	61
61.5	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	61.5
62	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	62
62.5	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	62.5
63	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	63
63.5	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	63.5

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

I Value (25.0–80)

T°F	25	27.5	30	32.5	35	37.5	40	42.5	45	47.5	50	52.5	55	57.5	60	62.5	65	67.5	70	72.5	75	77.5	80	T°F
64	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	64
64.5	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	64.5
65	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	65
65.5	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.1	0.1	65.5
66	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.1	66
66.5	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	66.5
67	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	67
67.5	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	67.5
68	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	68
68.5	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	68.5
69	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	69
69.5	0.15	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0;.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	69.5
70	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	70
70.5	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	70.5
71	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	71
71.5	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	71.5

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

I VALUE(82.5 – 140)

T°F	82.5	85	87.5	90	92.5	95	97.5	100	102.5	105	107.5	110	112.5	115	117.5	120	122.5	125	127.5	130	132.5	135	137.5	140	T°F
64	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	64
64.5	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	64.5
65	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	65
65.5	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	65.5
66	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	66
66.5	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	66.5
67	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	67
67.5	0.11	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	67.5
68	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	68
68.5	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	68.5
69	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08	69
69.5	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	69.5
70	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	70
70.5	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	0.09	70.5
71	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.09	0.09	71
71.5	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	0.1	71.5

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

I VALUE (25.0 – 80)

T°F	25	27.5	30	32.5	35	37.5	40	42.5	45	47.5	50	52.5	55	57.5	60	62.5	65	67.5	70	72.5	75	77.5	80	T°F
72	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	72
72.5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	72.5
73	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	73
73.5	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	73.5
74	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	74
74.5	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	74.5
75	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	75
75.5	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	75.5
76	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	76
76.5	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	76.5
77	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	77
77.5	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	77.5
78	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	78
78.5	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	78.5
79	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	79
79.5	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	79.5
80	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	80

Table A.2. Values of Unadjusted Daily Potential Evapotranspiration (in.) for Different Mean Temperatures and I Values (Continued)

I VALUE (82.5 – 140)

T°F	82.5	85	87.5	90	92.5	95	97.5	100	102.5	105	107.5	110	112.5	115	117.5	120	122.5	125	127.5	130	132.5	135	137.5	140	T°F
72	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.1	0.1	72
72.5	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	72.5
73	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	73
73.5	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	73.5
74	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	74
74.5	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	74.5
75	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	75
75.5	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	75.5
76	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	76
76.5	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	76.5
77	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.16	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	77
77.5	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	77.5
78	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	78
78.5	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	78.5
79	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	79
79.5	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	79.5
80	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	80

Table A.3. Mean Possible Monthly Duration of Sunlight in the Northern Hemisphere (12 hours)

Northern Latitudes	January	February	March	April	May	June	July	August	September	October	November	December
0	31.2	28.2	31.2	30.3	31.2	30.3	31.2	31.2	30.3	31.2	33.3	31.2
1	31.2	28.2	31.2	30.3	31.2	30.3	31.2	31.2	30.3	31.2	33.3	31.2
2	31.2	28.2	31.2	30.3	31.5	30.5	31.2	31.2	30.3	31.2	33.3	30.9
3	30.9	28.2	30.9	30.3	31.5	30.5	31.5	31.2	30.3	31.2	30.9	30.9
4	30.9	27.9	30.9	30.6	31.8	30.9	31.5	31.5	30.3	30.9	30.9	30.6
5	30.6	27.9	30.9	30.6	31.8	30.9	31.8	31.5	30.3	30.9	29.7	30.6
6	30.6	27.9	30.9	30.6	31.8	31.2	31.8	31.5	30.3	30.9	29.7	30.3
7	30.3	27.6	30.9	30.6	32.1	31.2	32.1	31.8	30.3	30.9	29.7	30.3
8	30.3	27.6	30.9	30.9	32.1	31.5	32.1	31.8	30.6	30.9	29.4	30.0
9	30.0	27.6	30.9	30.9	32.4	31.5	32.4	31.8	30.6	30.9	29.4	30.0
10	30.0	27.3	30.9	30.9	32.4	31.8	32.4	32.1	30.6	30.8	29.4	29.7
11	29.7	27.3	30.9	30.9	32.7	31.8	32.7	32.1	30.6	30.8	29.1	27.9
12	29.7	27.3	30.9	31.2	32.7	32.1	33.0	32.1	30.6	30.8	29.1	27.4
13	29.4	27.3	30.9	31.2	33.0	32.1	33.0	32.4	30.6	30.8	28.8	27.4
14	29.4	27.3	30.9	31.2	33.0	32.4	33.3	32.4	30.6	30.8	28.8	29.1
15	29.1	27.3	30.9	31.2	33.3	32.4	33.6	32.4	30.6	30.8	28.5	29.1
16	29.1	27.3	30.9	31.2	33.3	32.7	33.6	32.7	30.6	30.8	28.5	28.8
17	28.8	27.3	30.9	31.5	33.9	32.7	33.9	32.7	30.6	30.0	28.2	28.8
18	28.8	27.0	30.9	31.5	33.9	33.0	33.9	33.0	30.6	30.0	28.2	28.5
19	28.5	27.0	30.9	31.5	33.9	33.0	34.2	33.0	30.6	30.0	27.9	28.5
20	28.5	27.0	30.9	31.5	33.0	33.3	34.2	33.3	30.6	30.0	27.9	28.2
21	28.2	27.0	30.9	31.5	33.0	33.3	34.5	33.3	30.6	29.9	27.9	28.2
22	28.2	26.7	30.9	31.8	34.2	33.9	34.5	33.3	30.6	29.7	27.9	27.9
23	27.9	26.7	30.9	31.8	34.2	33.9	34.8	33.6	30.6	29.7	27.9	27.9
24	27.9	26.7	30.9	31.8	34.5	34.2	34.8	33.6	30.6	29.7	27.3	27.9

Table A.3. Mean Possible Monthly Duration of Sunlight in the Northern Hemisphere (12 hours) (Continued)

Northern Latitudes	January	February	March	April	May	June	July	August	September	October	November	December
25	27.9	26.7	30.9	31.8	34.5	34.2	35.1	33.6	30.6	29.7	27.3	27.3
26	27.6	26.4	30.9	32.1	34.8	34.5	35.1	33.6	30.6	29.7	27.3	27.3
27	27.6	26.4	30.9	32.1	34.8	34.5	35.4	33.9	30.9	29.7	27.0	27.3
28	27.3	26.4	30.9	32.1	35.1	34.8	35.4	33.9	30.9	29.4	27.0	27.3
29	27.3	26.1	30.9	32.1	35.1	34.8	35.7	33.9	30.9	29.4	26.7	26.7
30	27.0	26.1	30.9	32.4	35.4	35.1	36.0	34.2	30.9	29.4	26.7	26.4
31	27.0	26.1	30.9	32.4	35.4	35.1	36.0	34.2	30.9	29.4	26.4	26.4
32	26.7	25.8	30.9	32.4	35.7	35.4	36.3	34.5	30.9	29.4	26.4	26.1
33	26.4	25.8	30.9	32.7	35.7	35.7	36.3	34.5	30.9	29.1	26.1	25.9
34	26.4	25.8	30.9	32.7	36.0	36.0	36.6	34.8	30.9	29.1	26.1	25.8
35	26.1	25.5	30.9	32.7	36.3	36.3	36.9	34.8	30.9	29.1	25.8	25.5
36	26.1	25.5	30.9	33.0	36.3	36.6	37.5	34.8	30.9	29.1	25.8	25.2
37	25.8	25.5	30.9	33.0	36.9	36.9	37.5	35.1	30.9	29.1	25.5	24.9
38	25.5	25.2	30.9	33.0	36.9	37.2	37.8	35.1	31.2	28.8	25.2	24.9
39	25.5	25.2	30.9	33.3	36.9	37.2	37.8	35.4	31.2	28.8	25.2	24.6
40	25.2	24.9	30.9	33.3	37.5	37.5	38.1	35.4	31.2	28.8	24.9	24.3
41	24.9	24.9	30.9	33.3	37.5	37.8	38.1	35.7	31.2	28.8	24.9	24.0
42	24.6	24.6	30.9	33.6	37.8	38.1	38.4	35.7	31.2	28.5	24.9	23.7
43	24.3	24.6	30.6	33.6	37.9	38.4	38.7	36.0	31.2	28.5	24.3	23.1
44	24.3	24.3	30.6	33.6	38.1	38.7	38.7	36.3	31.2	28.5	24.3	23.0
45	24.0	24.3	30.6	33.9	38.4	38.7	39.3	36.3	31.2	28.2	23.7	22.5
46	23.7	24.0	30.6	33.9	38.7	39.0	39.6	36.3	31.2	28.2	23.7	22.2
47	23.1	24.0	30.6	34.2	39.0	39.0	39.9	37.0	31.5	27.9	23.4	21.9
48	22.0	23.7	30.6	34.2	39.3	39.6	40.2	37.0	31.5	27.9	23.1	21.9
49	22.9	23.7	30.6	34.5	39.3	41.2	40.8	37.2	31.5	27.9	22.8	21.3
50	22.2	23.4	30.6	34.5	39.9	40.8	41.1	37.5	31.8	27.9	22.8	21.0

Table A.4. Runoff Coefficients

Surface Conditions: Grass cover (slope)	Runoff Coefficient
Sandy soil, flat, 2%	0.05 – 0.10
Sandy soil, average, 2–7%	0.10 – 0.15
Sandy soil, steep, 7%	0.15 – 0.20
Heavy soil, flat, 2%	0.13 – 0.17
Heavy soil, average, 2–7%	0.18 – 0.22
Heavy soil, steep, 7%	0.25 – 0.35

Source: Fenn et al., 1975

Table A.5. Provisional Water Holding Capacities for Combinations of Soil and Vegetation

Soil Type	Available Water mm/m	Available Water in./ft	Root Zone in.	Root Zone ft	Applicable Soil Moisture Retention Table mm	Applicable Soil Moisture Retention Table in.
Shallow-Rooted Crops (spinach, peas, beans, beets, carrots, etc.)						
Fine sand	100	1.2	.50	1.67	50	2.0
Fine sandy loam	150	1.8	.50	1.67	75	3.0
Silt loam	200	2.4	.62	2.08	125	5.0
Clay loam	250	3.0	.40	1.33	100	4.0
Clay	300	3.6	.25	.83	75	3.0
Moderately Deep-Rooted Crops (corn, cotton, tobacco, cereal grains)						
Fine sand	100	1.2	.75	2.50	75	3.0
Fine sandy loam	150	1.8	1.00	3.33	150	6.0
Silt loam	200	2.4	1.00	3.33	200	8.0
Clay loam	250	3.0	.80	2.67	200	8.0
Clay	300	3.6	.50	1.67	50	6.0
Deep-Rooted Crops (alfalfa, pastures, shrubs)						
Fine sand	100	1.2	1.00	3.33	100	4.0
Fine sandy loam	150	1.8	1.00	3.33	150	6.0
Silt loam	200	2.4	1.25	4.17	250	10.0
Clay loam	250	3.0	1.00	3.33	250	10.0
Clay	300	3.6	.67	2.22	200	8.0
Orchards						
Fine sand	100	1.2	1.50	5.00	150	6.0
Fine sandy loam	150	1.8	1.67	5.55	250	10.0
Silt loam	200	2.4	1.50	5.00	300	12.0
Clay loam	250	3.0	1.00	3.33	250	10.0
Clay	300	3.6	.67	2.22	200	8.0
Closed Mature Forest						
Fine sand	100	1.2	2.50	8.33	250	10.0
Fine sandy loam	150	1.8	2.00	6.66	300	12.0
Silt loam	200	2.4	2.00	6.66	400	16.0
Clay loam	250	3.0	1.60	5.33	400	16.0
Clay	300	3.6	1.17	3.90	350	14.0

Notes:

These figures are for mature vegetation. Young cultivated crops, seedlings, and other immature. vegetation will have shallower root zones and, hence, have less water available for the use of. the vegetation. As the plant develops from a seed or a young sprout to the mature form, the root. zone will increase progressively from only a few inches to the values listed above. Use of a series ofsoil moisture retention tables with successively increasing values of available moisture permits the soil moisture to be determined throughout the growing season.

Table A.6. Soil Moisture Retention Table for Various Amounts of Potential Evapotranspiration for a Root Zone Water-Holding Capacity of Four Inches (Continued)

PET	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	4.00	3.99	3.98	3.97	3.96	3.95	3.94	3.93	3.92	3.91
0.1	3.90	3.89	3.88	3.87	3.86	3.85	3.84	3.83	3.82	3.81
0.2	3.80	3.79	3.78	3.77	3.76	3.75	3.74	3.73	3.72	3.71
0.3	3.70	3.69	3.68	3.67	3.66	3.65	3.64	3.63	3.62	3.62
0.4	3.61	3.60	3.59	3.58	3.57	3.56	3.55	3.54	3.54	3.53
0.5	3.52	3.51	3.50	3.49	3.48	3.47	3.46	3.46	3.45	3.44
0.6	3.43	3.42	3.41	3.40	3.39	3.38	3.38	3.37	3.36	3.35
0.7	3.34	3.33	3.32	3.31	3.30	3.30	3.29	3.28	3.27	3.26
0.9	3.26	3.25	3.24	3.23	3.23	3.22	3.21	3.20	3.19	3.19
0.9	3.18	3.17	3.16	3.16	3.15	3.14	3.13	3.12	3.12	3.11
1.0	3.10	3.09	3.09	3.08	3.07	3.06	3.05	3.05	3.04	3.03
1.1	3.02	3.02	3.01	3.00	2.99	2.98	2.98	2.97	2.96	2.95
1.2	2.94	2.94	2.93	2.92	2.91	2.90	2.90	2.89	2.88	2.87
1.3	2.86	2.86	2.85	2.84	2.83	2.82	2.82	2.81	2.80	2.79
1.4	2.79	2.78	2.77	2.76	2.75	2.75	2.74	2.73	2.73	2.72
1.5	2.72	2.71	2.70	2.70	2.69	2.68	2.68	2.67	2.66	2.66
1.6	2.65	2.64	2.64	2.63	2.62	2.62	2.61	2.60	2.60	2.59
1.7	2.58	2.58	2.57	2.57	2.56	2.55	2.54	2.54	2.53	2.52
1.8	2.51	2.51	2.50	2.49	2.49	2.48	2.48	2.47	2.47	2.46
1.9	2.45	2.45	2.44	2.43	2.43	2.42	2.41	2.40	2.40	2.39
2.0	2.39	2.38	2.38	2.37	2.36	2.36	2.35	2.35	2.34	2.34

Table A.6. Soil Moisture Retention Table for Various Amounts of Potential Evapotranspiration for a Root Zone Water-Holding Capacity of Four Inches (Continued)

PET	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.1	2.33	2.33	2.32	2.32	2.31	2.30	2.29	2.29	2.28	2.28
2.2	2.27	2.27	2.26	2.25	2.25	2.24	2.24	2.23	2.22	2.22
2.3	2.21	2.21	2.20	2.19	2.19	2.18	2.18	2.17	2.16	2.16
2.4	2.15	2.15	2.14	2.14	2.13	2.13	2.12	2.12	2.11	2.11
2.5	2.10	2.10	2.09	2.09	2.08	2.08	2.07	2.07	2.06	2.06
2.6	2.05	2.05	2.04	2.04	2.03	2.03	2.02	2.02	2.01	2.01
2.7	2.00	2.00	1.99	1.99	1.98	1.98	1.97	1.97	1.96	1.96
2.8	1.95	1.95	1.94	1.94	1.93	1.93	1.92	1.89	1.91	1.91
2.9	1.90	1.90	1.89	1.89	1.88	1.88	1.87	1.87	1.86	1.86
3.0	1.85	1.85	1.84	1.84	1.83	1.83	1.82	1.82	1.81	1.81
3.1	1.80	1.80	1.79	1.79	1.78	1.78	1.78	1.77	1.77	1.76
3.2	1.76	1.75	1.75	1.74	1.73	1.73	1.72	1.72	1.71	1.71
3.3	1.71	1.70	1.70	1.69	1.69	1.69	1.68	1.68	1.67	1.67
3.4	1.67	1.66	1.66	1.65	1.65	1.65	1.64	1.64	1.63	1.63
3.5	1.63	1.62	1.62	1.61	1.61	1.61	1.60	1.60	1.59	1.59
3.6	1.59	1.58	1.58	1.57	1.57	1.57	1.56	1.56	1.55	1.55
3.7	1.55	1.54	1.54	1.53	1.53	1.53	1.52	1.52	1.51	1.51
3.8	1.51	1.50	1.50	1.49	1.49	1.49	1.48	1.48	1.47	1.47
3.9	1.47	1.46	1.46	1.45	1.45	1.45	1.44	1.44	1.43	1.43
4.0	1.43	1.42	1.42	1.41	1.41	1.41	1.40	1.40	1.40	1.39
4.1	1.39	1.39	1.38	1.38	1.38	1.37	1.37	1.37	1.36	1.36
4.2	1.36	1.35	1.35	1.35	1.34	1.34	1.34	1.33	1.33	1.33
4.3	1.32	1.32	1.32	1.31	1.31	1.31	1.30	1.30	1.30	1.29
4.4	1.29	1.29	1.28	1.28	1.28	1.28	1.27	1.27	1.27	1.26
4.5	1.26	1.26	1.25	1.25	1.25	1.25	1.24	1.24	1.24	1.23

Table A.6. Soil Moisture Retention Table for Various Amounts of Potential Evapotranspiration for a Root Zone Water-Holding Capacity of Four Inches (Continued)

PET	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
4.6	1.23	1.23	1.22	1.22	1.22	1.22	1.21	1.21	1.21	1.20
4.7	1.20	1.20	1.19	1.19	1.19	1.19	1.18	1.18	1.18	1.17
4.8	1.17	1.17	1.16	1.16	1.16	1.16	1.15	1.15	1.15	1.14
4.9	1.14	1.14	1.13	1.13	1.13	1.13	1.12	1.12	1.12	1.11
5.0	1.11	1.11	1.10	1.10	1.10	1.10	1.09	1.09	1.09	1.09
5.1	1.08	1.08	1.08	1.07	1.07	1.07	1.07	1.06	1.06	1.06
5.2	1.05	1.05	1.05	1.04	1.04	1.04	1.04	1.03	1.03	1.03
5.3	1.02	1.02	1.02	1.01	1.01	1.01	1.01	1.00	1.00	1.00
5.4	1.00	1.00	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.98
5.5	0.98	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.96	0.96
5.6	0.95	0.95	0.95	0.94	0.94	0.94	0.94	0.93	0.93	0.93
5.7	0.92	0.92	0.92	0.92	0.91	0.91	0.91	0.91	0.90	0.90
5.8	0.90	0.90	0.90	0.89	0.89	0.89	0.89	0.89	0.88	0.88
5.9	0.88	0.88	0.88	0.87	0.87	0.87	0.87	0.87	0.86	0.86
6.0	0.86	0.86	0.86	0.85	0.85	0.85	0.85	0.85	0.84	0.84
6.1	0.84	0.84	0.84	0.83	0.83	0.83	0.83	0.83	0.82	0.82
6.2	0.82	0.82	0.82	0.81	0.81	0.81	0.81	0.80	0.80	0.80
6.3	0.80	0.79	0.79	0.79	0.79	0.79	0.78	0.78	0.78	9.78
6.4	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.76	0.76
6.5	0.76	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.74	0.74
6.6	0.74	0.74	0.74	0.73	0.73	0.73	0.73	0.73	0.72	0.72
6.7	0.72	0.72	0.72	0.72	0.71	0.71	0.71	0.71	0.71	0.70
6.8	0.70	0.70	0.70	0.70	0.70	0.69	0.69	0.69	0.68	0.68
6.9	0.68	0.68	0.68	0.68	0.67	0.67	0.67	0.67	0.67	0.67
7.0	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.65	0.65

Table A.6. Soil Moisture Retention Table for Various Amounts of Potential Evapotranspiration for a Root Zone Water-Holding Capacity of Four Inches (Continued)

PET	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
7.1	0.65	0.65	0.65	0.64	0.64	0.64	0.64	0.64	0.54	0.63
7.2	0.63	0.63	0.63	0.63	0.63	0.62	0.62	0.62	0.62	0.61
7.3	0.61	0.61	0.61	0.61	0.61	0.61	0.60	0.60	0.60	0.60
7.4	0.60	0.60	0.60	0.59	0.59	0.59	0.59	0.59	0.58	0.58
7.5	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.57	0.57	0.57
7.6	0.57	0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.56	0.56
7.7	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.55
7.8	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.53	0.53
7.9	0.54	0.53	0.53	0.53	0.53	0.52	0.52	0.52	0.52	0.52

PET	0.05	0.05	PET	0.00	0.05	PET	0.00	0.05
8.0	0.52	0.51	9.0	0.40	0.40	10.0	0.31	0.31
8.1	0.50	0.50	9.1	0.39	0.39	10.1	0.30	0.30
8.2	0.49	0.48	9.2	0.38	0.38	10.2	0.30	0.29
8.3	0.48	0.47	9.3	0.37	0.37	10.3	0.29	0.28
8.4	0.47	0.46	9.4	0.36	0.36	10.4	0.28	0.28
8.5	0.45	0.45	9.5	0.35	0.35	10.5	0.27	0.27
8.6	0.44	0.44	9.6	0.34	0.34	10.6	0.27	0.26
8.7	0.43	0.43	9.7	0.34	0.33	10.7	0.26	0.26
8.8	0.42	0.42	9.8	0.33	0.32	10.8	0.25	0.25
8.9	0.41	0.41	9.9	0.32	0.32	10.9	0.25	0.24

Note: A storage ability equal to 4 in. of water is the combination of the ability of a given soil to store water and the thickness of the soil layer that provides the equivalent of 4 in. of water

Attachment B
Microsoft Excel Spreadsheet Showing Method B Water Balance Example Calculation

TECHNICAL REPORT DATA

(Please read Instructions on reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-456/R-05-004		

4. TITLE AND SUBTITLE Example Moisture Mass Balance Calculations for Bioreactor Landfills	5. REPORT DATE August 2005
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Amy Alexander Eastern Research Group, Inc.	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Air Quality Planning and Standards Mail Drop E143-02 Research Triangle Park, NC 27711	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. 68-D-02-0079
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Research Triangle Park, NC 27711	13. TYPE OF REPORT AND PERIOD COVERED Final Report
	14. SPONSORING AGENCY CODE EPA/200/04

15. SUPPLEMENTARY NOTES

To be published at: http://www.epa.gov/ttn/atw/landfill/landflpg.html

16. ABSTRACT

This document contains example mass balance calculations for estimating the moisture content of the waste mass in a bioreactor landfill. Under the National Emission Standards for Hazardous Air Pollutants for Municipal Solid Waste Landfills (landfills NESHAP), a portion of a landfill operated as a bioreactor has timely control requirements. The landfills NESHAP allows moisture content to be determined using a variety of methods, as long as the procedures and assumptions are documented and appropriate. Although a range of appropriate measures exist, a mass balance approach is expected to be adequate in determining whether the moisture content of the waste is above or below 40 percent. Two example mass balance calculations are presented, a simple method and a more complex method. The simplified equation incorporates factors such as incoming waste moisture, liquids addition, and leachate production, which most significantly affect the average moisture content of the waste mass. The more complex procedure accounts for additional factors such as moisture retained in the landfill, surface runoff and evaporation, and evapotranspiration.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Bioreactor landfill Air pollution Clean Air Act NESHAP Moisture content	Air Pollution control Nonmethane organic compounds Methane	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(Report)*	21. NO. OF PAGES
Release Unlimited	Unclassified	36
	20. SECURITY CLASS *(Page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

United States Environmental Protection Agency	Office of Air Quality Planning and Standards Information Transfer and Program Integration Division Research Triangle Park, NC	Publication No. EPA-456/R-05-004 August 2005