

Estimating Growing Season Hydraulic Loading Rate Using U.S. Bureau of Reclamation Agricultural Meteorological System (AgriMet) Data

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Introduction

In Idaho, wastewater approved for land application must be done in a manner that does not degrade ground water or result in fugitive wastewater such as runoff or wind drift beyond site boundaries.

Specific Req't's

Hydraulic and constituent loading must be such that they do not exceed the removal rate of the crop. One of these will be the land limiting constituent which determines the land area required for efficient treatment of the wastewater.

Optimum Hydraulic Loading

The optimum hydraulic loading rate is that which maintains efficient operation of the agronomic production system i.e. hydraulic loading is substantially equal to crop water use.

Optimum Hydraulic Loading

Hydraulic Loading \leftrightarrow Crop Water Use

- reduces crop growth and subsequently reduces constituent use. With an annual crop, growth is not recoverable.

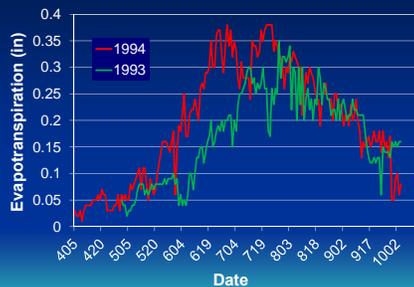
Crop Water Use

Crop water use is the sum of water loss to the atmosphere by evaporation from soil and plant surfaces and transpiration from the crop leaf internal structure during photosynthesis, commonly called evapotranspiration or ET.

Evapotranspiration

Evapotranspiration is dynamic as it depends upon crop type, crop growth stage, nutrient availability, and environmental conditions (solar radiation, temperature, humidity, wind speed).

Sugar Beet ET – Kimberly



Estimating ET

Wastewater land application permits may specify a source for estimating ET. For example:

- www.kimberly.uidaho.edu/ETIdaho/
- www.usbr.gov/pn/agrimet/

www.kimberly.uidaho.edu/ETIdaho/

ETIdaho 2009: Evapotranspiration and Consumptive Irrigation Water Requirements for Idaho
Please visit www.kimberly.uidaho.edu/ETIdaho/ for more information.

The ETIdaho web site provides estimates of Evapotranspiration (ET), net irrigation requirement (NIR), and effective precipitation (PEP) for various crops in Idaho. These estimates are based on data from 1993 to 2009. ET calculations are based on a modified Penman-Monteith equation (FAO standard) using meteorological data from 125 weather stations across Idaho. In addition to ET and NIR estimates for agricultural crops grown in Idaho, ET estimates are available for a number of other crops (orchards, vineyards, and riparian areas) and open water surfaces. The ET and NIR estimates are intended for use in design and management of irrigation systems, for water rights management and consumptive water right transfers, and for hydrologic studies. ET estimates are available for all times during the calendar year to provide information for land application design, operation, and management of waste streams from agriculture, food processing and other sources during the response period.

These dynamic web pages allow you to access historical ET data for the State of Idaho at various locations. Currently, the data are based on 109 [ETId](#) cooperative weather stations and 16 [AgriMet](#) stations located in predominantly agricultural areas throughout the state.

Find and explore the summary data for stations and land covers:

Click on this link to locate stations by [county](#) or

Please select a station from the following list:

- AgriMet - Aberdeen
- WWS - Aberdeen Equipment Station
- AgriMet - Aberdeen Data 1 Day
- WWS - Aberdeen Dam
- WWS - Aberdeen Dam
- WWS - Boise
- WWS - Aberdeen Dam
- WWS - Aberdeen
- AgriMet - Aberdeen
- AgriMet - Boise
- WWS - Boise 7 In
- WWS - Boise 10 In
- WWS - Boise 15 In
- WWS - Boise 20 In
- WWS - Boise 25 In
- WWS - Boise 30 In
- WWS - Boise 35 In
- WWS - Boise 40 In
- WWS - Boise 45 In
- WWS - Boise 50 In
- WWS - Boise 55 In
- WWS - Boise 60 In
- WWS - Boise 65 In
- WWS - Boise 70 In
- WWS - Boise 75 In
- WWS - Boise 80 In
- WWS - Boise 85 In
- WWS - Boise 90 In
- WWS - Boise 95 In
- WWS - Boise 100 In

www.kimberly.uidaho.edu/ETIdaho/

ETIdaho 2009: Evapotranspiration and Consumptive Irrigation Water Requirements for Idaho
Please visit www.kimberly.uidaho.edu/ETIdaho/ for more information.

Blackfoot (NWS - 100915)
 Station based on theory
For additional information on the data link
This site highlights the table and copyright information. Please do not copy or paste the data into other spreadsheets or other software without the data.

	Great May												Growing Season*	Non-Growing Season*	Annual	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec				
Mean	mm/day															
Monthly	0.26	0.08	0.11	1.26	4.19	6.45	6.16	3.94	1.42	1.27	0.27	0.24	0.07	0.01	31	84
11 Day Moving Average	0.26	0.11	0.30	1.30	4.11	6.41	6.34	3.90	1.32	1.27	0.27	0.21	0.24			
1 Day Moving Average	0.26	0.08	0.07	1.11	4.26	6.36	6.26	3.86	1.30	1.27	0.27	0.20	0.20			
3 Day Moving Average	0.26	0.07	0.10	1.11	4.16	6.40	6.31	3.91	1.31	1.25	0.26	0.20	0.20			
Standard Deviation	mm/day															
Monthly	0.39	0.21	0.31	1.11	1.91	1.42	0.97	0.70	0.66	1.04	0.31	0.37	0.17	117	36	103
11 Day Moving Average	0.44	0.41	0.36	1.12	1.89	1.79	1.09	0.82	1.06	1.24	0.31	0.44				
1 Day Moving Average	0.45	0.37	0.30	1.04	2.21	1.47	1.14	1.10	1.11	1.30	0.31	0.52				
3 Day Moving Average	1.09	0.70	0.94	2.21	2.97	2.71	2.01	1.61	2.12	1.44	1.10	1.17				
20% Exceedance	mm/day															
Monthly	0.02	0.36	0.21	2.08	3.32	7.22	6.68	3.76	4.21	2.17	0.09	0.01	0.06	396	3	154
11 Day Moving Average	0.20	0.26	0.40	1.30	4.36	8.44	7.72	6.27	4.95	1.64	0.46	0.21	0.30			
1 Day Moving Average	0.11	0.26	0.21	4.07	6.61	6.21	6.61	4.94	3.71	4.21	0.41	0.41	0.20			
3 Day Moving Average	0.45	0.70	1.20	6.04	8.94	8.92	9.21	7.81	6.42	2.87	0.79	0.31				
90% Exceedance	mm/day															
Monthly	0.76	0.06	0.06	0.31	2.01	2.21	3.86	4.86	2.62	0.27	0.21	0.21	0.21	794	10	759
11 Day Moving Average	0.41	0.46	0.44	0.81	1.26	1.11	1.41	1.81	1.21	1.20	1.20	1.00				
1 Day Moving Average	0.34	1.21	1.01	1.20	0.31	1.06	1.26	1.41	0.30	0.20	0.21	0.20				
3 Day Moving Average	0.74	0.40	0.21	4.01	0.31	1.11	0.71	0.71	0.71	0.81	0.41	0.41				
Ann Highest Peg	mm/day															
Monthly	0.08	0.31	0.41	2.01	3.21	7.11	7.21	3.94	4.21	2.24	0.27	0.27	0.27			
11 Day Moving Average	0.11	0.41	0.21	2.91	6.61	6.46	6.11	4.67	3.21	1.20	0.30	0.34				

AgriMet System

The AgriMet system is a cooperative agricultural weather station network, managed and operated by the U.S. Bureau of Reclamation, dedicated to agricultural crop water use estimation.

www.usbr.gov/pn/agrimet/

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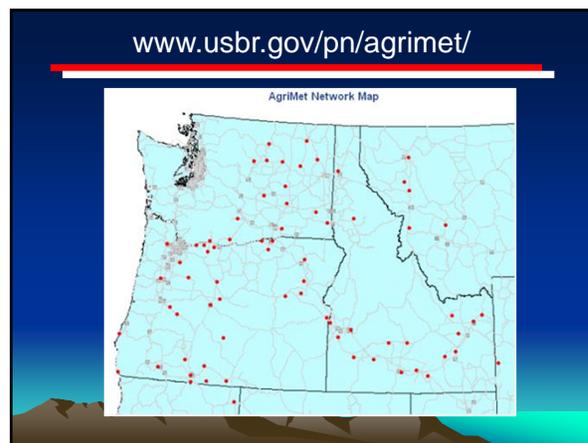
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AgriMet
The Pacific Northwest Cooperative Agricultural Weather Network

AgriMet is a combination of the words "agriculture" and "meteorology". It is a distributed network of automated agricultural weather stations operated and maintained by the Bureau of Reclamation. The stations are located in irrigated agricultural areas throughout the Pacific Northwest and are dedicated to regional crop water use modeling, agricultural research, frost monitoring, and irrigation pest and fertility management.

- General Information about the AgriMet Program
 - General program information, station locations, installation dates, types of weather data collected, types of sensors and equipment used at AgriMet stations, information about crop water use charts and growing degree days, station photographs.
- AgriMet Weather Data
 - Get 5 days archive weather data, last 5 days hourly weather data, current weather data, access to historical weather database, types of weather data collected, station location and installation dates, key to weather parameter codes and data flags, information about growing degree days, precision data discrepancy.
- Crop Water Use Information



ET

Evapotranspiration is an energy limited process. The energy for the latent heat of evaporation comes from two sources: solar radiation (heat function) and advective energy transfer (wind function)

Combination Equation

Evapotranspiration models that take into account both radiation energy and advective energy are called combination equations. The classical combination equation is the Penman Equation. AgriMet uses a variant of the Penman equation.

1982 Kimberly-Penman Equation

The equation used by AgriMet is:

$$\lambda \cdot ET_r = \frac{\Delta}{\Delta + \gamma} (R_n - G) + \frac{\gamma}{\Delta + \gamma} \cdot 6.43 \cdot W_f (e_s - e_a)$$

Latent Energy Radiant Energy Advective Energy

$$\frac{\Delta}{\Delta + \gamma} + \frac{\gamma}{\Delta + \gamma} = 1 \quad \frac{\Delta}{\Delta + \gamma} \approx 0.75$$

1982 Kimberly-Penman Equation Wind Function

The wind function characterizes the effects of wind in the advection (motion of the atmosphere) of sensible heat for ET and is calculated as:

$$W_f = a_w + b_w \cdot U_2$$

1982 Kimberly-Penman Equation Wind Function

The empirical coefficients are calibrated for the effect that surrounding rangeland is wetter earlier in the year and has less advection of sensible heat than later in the year.

$$a_w, b_w = f(\text{day of year})$$

Reference Crop ET

The Kimberly-Penman equation estimates evapotranspiration for a alfalfa crop (ET_r) that is well-watered with 12 to 20 in of top growth which is denoted as ET_r .

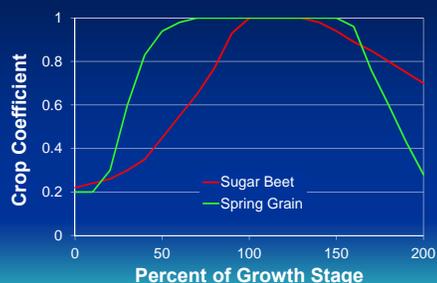
Crop ET

Estimated crop evapotranspiration, which is denoted as ET_c , is calculated as:

$$ET_c = K_c \cdot ET_r$$

where K_c is the crop coefficient.

Normalized Crop Coefficient



Normalized Crop Coefficient

Spring Grain

Growth Stage (%)	Crop Coefficient	Growth Stage Indicators
0	0.20	Emergence
.....	
70	1.00	Full Canopy
.....	
100	1.00	Heading
.....	
200	0.28	Leaves and Stem Dead

Scaled Crop Coefficient



Soil Water Budget

Using terminology of DEQ Guidance the soil water budget is:

$$IR_{net} = CU - (PPT_e + Carryover SM) + LR$$

where IR_{net} is net irrigation requirement, CU is crop consumptive use (ET), PPT_e is effective precipitation SM is soil moisture and LR is the leaching requirement.

Irrigation Water Req't

Using terminology of DEQ Guidance, the irrigation water requirement is:

$$IWR = \frac{IR_{net}}{E_i}$$

where IWR is irrigation water requirement and E_i is irrigation application efficiency.

Hydraulic Loading Rate Management

Daily maximum hydraulic loading rate can be determined using a running cumulative seasonal water balance:

$$IWR_j = \frac{\sum_{j-1} ET - \sum_{j-1} PPT_e}{E_i} - \sum_{j-1} Irrigation + \frac{\sum_j LR}{E_i}$$

where j is day of the growing season from start of crop growth and IWR_j is maximum application depth on day j .

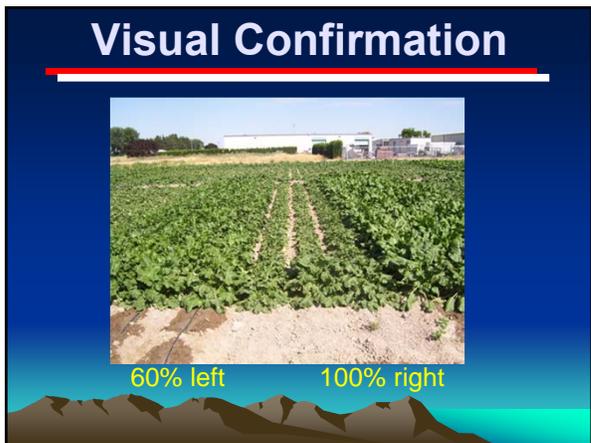
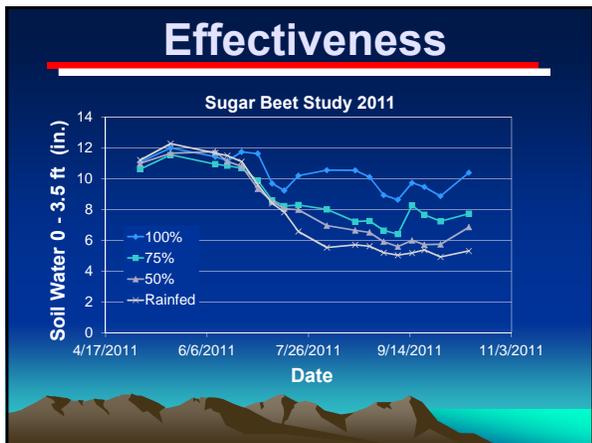
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www.usbr.gov/pn/agrimet/chart/nmpich.txt
*****
* ESTIMATED CROP WATER USE - Apr 17, 2012  NMPI *
*****
* DAILY *
* CROP WATER USES (IN) * DAILY * * * * *
* CROP START* PERMAN ET - Apr* FORE *COVER* TERM* SUM * DAY* DAY *
* DATE*-----* CAST * DATE* DATE* ET * USE* USE *
* 13 14 15 16 * * * * *
*****
* ET# 02/15* 0.18 0.25 0.25 0.09 * 0.20 *02/15*10/10* 7.2 * 1.3* 2.5 *
* ANPF 03/15* 0.18 0.20 0.20 0.07 * 0.16 *05/15*10/10* 2.5 * 1.0* 1.8 *
*****
* ALPH 03/15* 0.14 0.20 0.20 0.07 * 0.16 *05/15*10/10* 2.5 * 1.0* 1.8 *
* PAST 03/10* 0.11 0.16 0.16 0.06 * 0.13 *05/05*10/10* 2.5 * 0.8* 1.5 *
*****
* LAMN 03/10* 0.14 0.20 0.20 0.07 * 0.16 *06/25*10/10* 3.3 * 1.0* 2.0 *
* WGRN 02/15* 0.18 0.25 0.25 0.09 * 0.20 *05/05*07/05* 5.8 * 1.2* 2.5 *
* SORN 03/15* 0.12 0.18 0.18 0.07 * 0.14 *06/10*07/25* 1.9 * 0.8* 1.4 *
*****
* SORN 04/05* 0.04 0.05 0.06 0.02 * 0.04 *06/20*08/05* 0.4 * 0.3* 0.4 *
*****
    
```

Numerical Example

Location: Treasure Valley LR = 0
 Center Pivot System $E_i = 0.9$
 Water Application Depth = 0.6

Date	ET	ΣET	ΣPPT_e	$\Sigma (ET - PPT_e) / E_i$	$\Sigma Irrig$	IWR	Irrig
	in.	In.	in.	in.	in.	in.	in.
4/12	0.14	1.89	0.0	2.10	1.8	0.30	
4/13	0.14	2.03	0.0	2.26	1.8	0.46	
4/14	0.20	2.23	0.0	2.48	1.8	0.68	0.6
4/15	0.20	2.43	0.0	2.70	2.4	0.30	
4/16	0.07	2.50	0.07	2.70	2.4	0.30	



Summary

The AgriMet system provides data that can be used to determine hydraulic loading rates for wastewater land application systems in a relatively simple and effective manner.

- ## Potential Issues
1. Lack of AgriMet station near wastewater land application site.
 2. Lack of crop coefficient curve.

Alfalfa vs. Grass Reference Crop ET

Two reference crop definitions are in use in various parts of the world. Caution must be exercised not to mix grass-based crop coefficient values with alfalfa reference ET and vice versa.

Crop Coefficient Conversion

$$K_{c(\text{grass})} = K_{\text{ratio}} \cdot K_{c(\text{alfalfa})}$$

where K_{ratio} ranges from 1.0 to 1.3, depending upon climate; 1.05 for humid, calm conditions, 1.2 for semi-arid, moderately windy conditions, and 1.35 for arid, windy conditions.

