MEMORANDUM

To: ESHMC

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Date: April 2, 2010

Re: ET Adjustment Factors - Update to October 29, 2010 MEMO

Introduction

This memo is an update to the memo dated October 29, 2010 since decisions were made based on a presentation of ET adjustment factors at the February 2010 ESHMC meeting. As does the previous October 2010 memo, this memo briefly outlines the use of ET Adjustment Factors in calculating evapotranspiration for the ESPAM2 calibration water budget, the calculation methods for deriving adjustment factors, and details of the calculations. The memo includes a listing of the accompanying data files, and a table of the resulting ET Adjustment Factors.

Background

Calculation of evapotranspiration on irrigated lands in ESPAM2 will use a unique ET adjustment factor for sprinklers, and one for gravity irrigation, for each irrigation entity in the model input data. The purpose of ET adjustment factors is to adjust the traditional ET calculations for departures that may exist between actual ET and traditionally-calculated ET.

Factors that might cause actual ET to be less than traditionally-calculated ET include:

1. Water stress
    a. Chronic water stress in an entity
    b. Acute water stress in a single stress period or season
2. Poor soil
3. Insects or disease
4. Low-intensity management
5. Imprecision in underlying data
    a. GIS and RED overstate irrigated area
    b. Entity is in lower-ET area than county weather station
    c. Entity has lower-consumptive crops than county average

6. Imprecision in traditional calculations and coefficients

Actual ET may be greater than traditional ET under the following conditions:

1. Changes in conditions from when traditional coefficients were developed:
    a. More frequent irrigation
    b. More dense planting
    c. Greater dry-matter yield due to changes in management, crop varieties or other production inputs
    d. Longer growing season
2. Imprecision in underlying data
    a. GIS and RED understate irrigated area
    b. Entity is in higher ET area than county weather station
    c. Entity has higher-consumptive crops than county average
3. Imprecision in traditional calculations and coefficients.
4. Effects on or from non-irrigated lands adjacent to irrigated parcels.
    a. Advection of heat into irrigated lands causes actual ET to be higher than traditional calculation.
    b. Local overspray and runoff support ET in non-irrigated areas.

ET adjustment factors will compensate at least partially for many of these factors. Later in the memo we will further discuss how calculations do or do not address each of these.

Equation (1) shows how the adjustment factors will be used in the recharge-tool calculations:

$$ET = [(ADJ_{spr})(Area)(1-RED_{spr})(SPR) + (ADJ_{grav})(Area)(1-RED_{grav})(1-SPR)] * ET_{trad} \qquad (1)$$

ET = evapotranspiration volume on an individual irrigated parcel
ADJ_{spr} = ET adjustment factor for sprinklers
$Area$ = area of parcel
RED_{spr} = reduction for non-irrigated inclusions, sprinklers
SPR = sprinkler fraction for entity
ADJ_{grav} = ET adjustment factor for gravity
RED_{grav} = reduction for non-irrigated inclusions, gravity
ET_{trad} = depth of evapotranspiration on irrigated lands calculated by traditional methods

The recharge tool will summarize the irrigated area in each model cell by irrigation entity, and will apply Equation (1) to irrigated area from each entity, with the appropriate ET adjustment factors and sprinkler fraction for the given entity.

The value “Area” in Equation (1) will be the actual GIS parcel area for parcels that are 100% groundwater irrigated or 100% surface-water irrigated. Mixed-source parcels are represented in the data with two identical overlapping GIS polygons. For GIS polygons representing those parcels, the value “Area” will be the GIS area times the source fraction. Since the groundwater source fraction and surface-water source fraction always sum to 1.00, the area of the groundwater GIS polygons and the area of the surface-water GIS polygon will always sum to the actual GIS area of the representation of the parcel.

Table 1 lists the spatial and temporal extent of the application of each of the right-hand-side values in Equation(1).

Table 1
Spatial and Temporal Extent
Of Values in Equation (1)
For ESPAM2

Value	Spatial Extent - Tool Capability	Spatial Extent As Applied	Temporal Resolution.-Tool Capability	Temporal Resolution As Applied
ADJ_{spr}	Irrigation Entity	Irrigation Entity	Same for all stress periods	Same for all stress periods
Area	Model Cell	Model Cell	Per stress period	Once for each irrigated-lands data set (1980, 1986, 1992, 2000, 2006)
RED_{spr}	Entire study area	Entire study area	Per stress period	Once for each irrigated-lands data set
SPR	Irrigation Entity	Irrigation Entity	Per stress period	5-year increments interpolated to stress periods
ADJ_{grav}[1]	Irrigation Entity	Irrigation Entity	Same for all stress periods	Same for all stress periods
RED_{grav}[2]	Entire study area	Entire study area	Per stress period	Once for each irrigated-lands data set

[1] As described below, the calculation of ADJ_{spr} and ADJ_{grav} are not independent, being based on a common underlying calculation. However, the recharge tool would allow independent values if we were able to derive them.
[2] The tool allows unique RED factors for sprinklers and gravity application methods, but we did not have adequate data to calculate unique values, so for all stress periods $RED_{grav} = RED_{spr}$.

Value	Spatial Extent - Tool Capability	Spatial Extent As Applied	Temporal Resolution.- Tool Capability	Temporal Resolution As Applied
ET_{trad}	Model Cell	County	Per stress period	Per stress period

In earlier discussions with the ESHMC, we had proposed varying the adjustment factors over time. However, as indicated in Table 1, we have neither acquired the data nor made the modifications to the recharge tool that would be needed to allow this.

Conceptual Outline of Calculating Adjustment Factors

The idea behind an adjustment factor is to modify the value of an estimate to more closely approximate the underlying true value. A perfect adjustment factor would operate as shown in Equation (2):

$$\text{True} = (\text{Adjustment Factor}) * (\text{Estimate}) \qquad (2)$$

From this equation, we can derive an equation for calculation of an appropriate adjustment factor:

$$\text{Adjustment Factor} = (\text{True}) / (\text{Estimate}) \qquad (3)$$

Obviously if we had enough data to calculate exactly the right adjustment factor for each parcel and stress period, we would not need adjustment factors; we would simple use the true data in all cases. However, Equation (3) still provides a conceptual model for basing adjustment factors on the data we do have.

In order to capture various effects that may vary by entity (such as entity-specific water stress and crop mix), we conceptually performed the Equation (3) calculations on an entity-by-entity basis, using only the actual irrigated polygons. We used year-2000 and year-2006 METRIC estimates to represent the true value. Figure 1 shows the year-2000 METRIC ET raster on the Snake Plain. This calculation essentially captured all within-parcel differences between the estimate and the assumed “true” value and provided a unique preliminary adjustment factor for each entity.

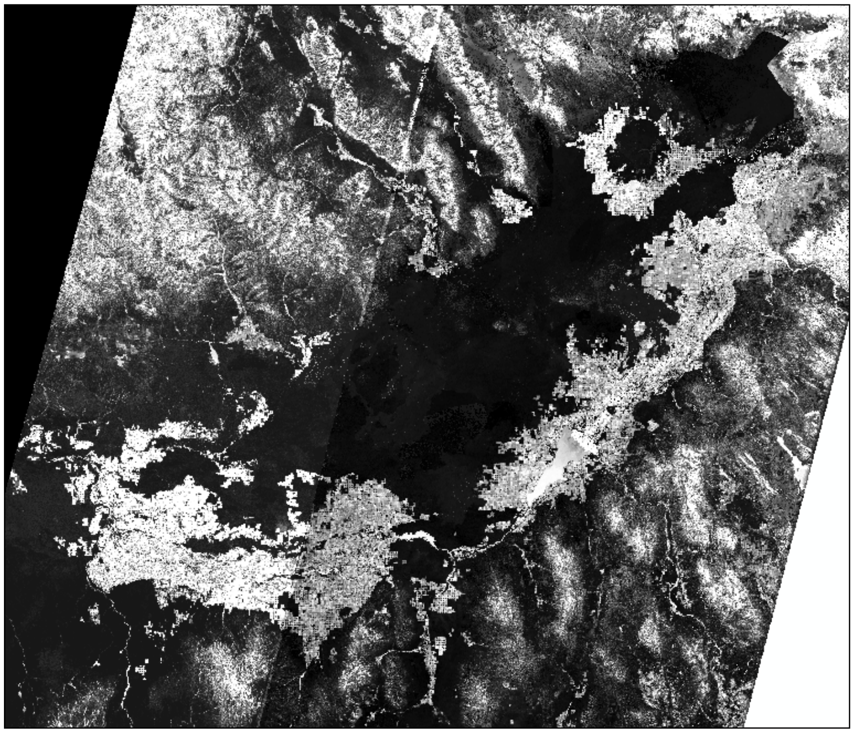

Figure 1. Path 39 and 40 Year-2000 METRIC ET on the Snake Plain.
White areas represent the highest values of ET.

Because the non-irrigated parcels adjacent to irrigated lands are not assigned source fractions and irrigation entities, we could not perform calculations for out-of-parcel effects by entity. Instead, after applying the Equation (3) concept to obtain preliminary by-entity factors, we again applied the Equation (3) concept to all irrigated lands plus a 70-meter buffer to obtain a global coefficient. Figure 2 shows the need for the buffer outside as shown by the white (areas of high ET) outside of the irrigated lands. Figure 3 shows the 70-meter buffer applied to the irrigated lands shapefile. In this case the estimate calculation (denominator of right-hand side of Equation (3)) included the preliminary adjustment factor calculated for each entity.

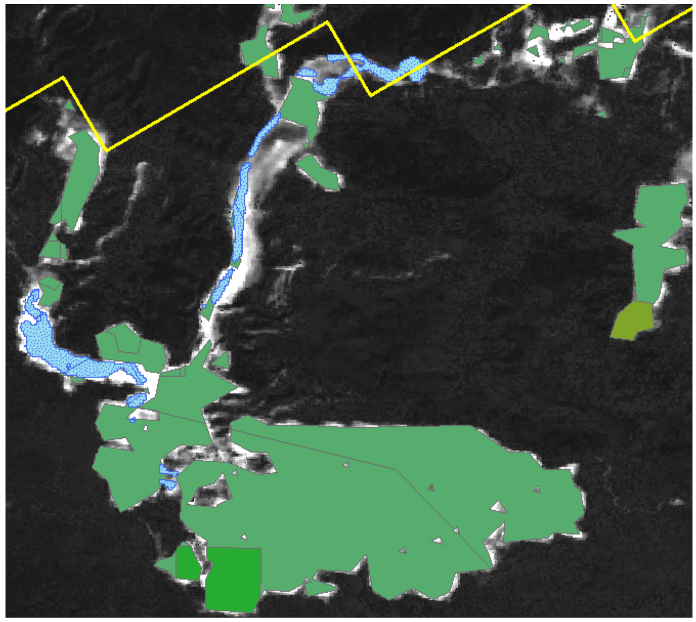

Figure 2. The green areas represent the irrigated lands year-2000 data set and the blue areas represent wetlands. The white areas outside of the irrigated lands represent areas of high ET. (Different shades of green represent different water sources)

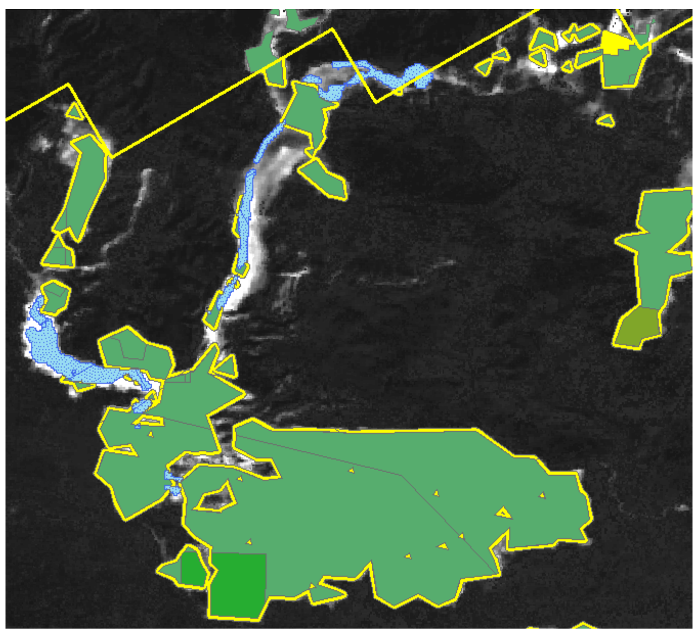

Figure 3. The yellow represents the 70-meter buffer applied to the irrigated lands year-2000 data set to encompass the high ET outside of the irrigated lands.

For each entity, the final adjustment factors will be the product of the preliminary by-entity factor and the global coefficient.

The preliminary by-entity adjustment factors compensate for the following potential sources of difference between actual and traditionally-estimated ET:

1. Water stress
    a. Chronic stress in individual entities, confounded by any acute stress that may have occurred in year 2000. This was also done for 2006.
2. Poor soil
3. Insects or disease
4. Low-intensity management
5. Imprecision in underlying data
    a. Entity is in lower-ET area than county weather station
    b. Entity has lower-consumptive crops than county average
    c. Entity is in higher ET area than county weather station
    d. Entity has higher-consumptive crops than county average
6. Imprecision in traditional calculations and coefficients
7. Changes in conditions from when traditional coefficients were developed:
    a. More frequent irrigation
    b. More dense planting
    c. Greater dry-matter yield due to changes in management, crop varieties or other production inputs
    d. Longer growing season

The global coefficient compensates for the following potential differences:

1. Imprecision in underlying data
    a. GIS and RED understate irrigated area
    b. GIS and RED overstate irrigated area
2. Effects on or from non-irrigated lands adjacent to irrigated parcels.
    a. Advection of heat into irrigated lands causes actual ET to be higher than traditional calculation.
    b. Local overspray and runoff support ET in non-irrigated areas.

The hazard of imprecision or bias in METRIC data remains, but it has appeared from ESHMC meeting discussions that we and the ESHMC generally feel that METRIC is currently the best available science for representing evapotranspiration on irrigated lands.

Specifics of Calculations

Calculation of the preliminary adjustment factor “A” for each entity was based on Equation (4):

$$\Sigma\ (A - 0.025)\ (1\text{-}SPR)\ X + \Sigma\ (A + 0.025)\ (SPR)\ X = \Sigma\ X_{METRIC} \qquad (4)$$

A = preliminary adjustment factor for entity
X = traditional ET volume for entity
X_{METRIC} = METRCI ET volume for entity

All summations are across all polygons for the given entity

Calculation of traditional ET volume X is performed for each GIS polygon as follows:

$$X = (Area)\ (1\text{-}RED)\ (SrcFrac)\ (ET_{trad}) \qquad (5)$$

SrcFrac = Fraction of supply that comes from the water source for the given polygon. For single-source parcels this value is 1.00. For mixed-source parcels, the source fraction for the groundwater polygon and the source fraction for the surface-water polygon sum to 1.00.

Calculation of METRIC ET volume X_{METRIC} is performed for each GIS polygon as follows:

$$X_{METRIC} = (Area)\ (SrcFrac)\ (ET_{METRIC}) \qquad (6)$$

ET_{METRIC} = GIS average depth of METRIC ET raster across irrigated polygon. Where a polygon intersects both the LANDSAT Path 39 raster and the LANDSAT Path 40 raster, we selected the greater ET depth. This is because the rasters are populated with a value of zero in the margins of the image. Parcels that straddle the boundary of lands actually represented will have low average values because they include regions of artificial zero values from the image margins.

Equation (4) is essentially a specific embodiment of conceptual Equation (2). Equation (4) was solved for value A, yielding Equation (5):

$$A = (\Sigma\ X_{metric})/(\ \Sigma\ X) + 0.025 - 0.05(SPR) \qquad (5)$$

Equation (5) was processed for each parcel in GIS, as described in the GIS Processing section below. Equation (5) is a specific embodiment of conceptual Equation (3).

The difference between sprinkler and gravity preliminary adjustment factors is accommodated by a simple difference of 0.05 (as represented by the terms "A – 0.025" and "A + 0.025" in Equation (4)). This is because we found that except for center pivots, we were unable to reliable discriminate between gravity and sprinkler irrigation in aerial images. The difference of 0.05 was carried forward from ESPAM1.1 because it was originally obtained from the professional judgment of Dr. Rick Allen and because it was confirmed in ESPAM1.1 with a sample of parcels where the actual application method was confirmed by field inspection. The operation of the "C" coefficient described below will slightly modify the difference between final sprinkler and gravity coefficients for each entity (depending on rounding, differences in final sprinkler/gravity coefficients range between 0.05 and 0.06), but this is within the precision of our knowledge.

For the global coefficient C, conceptual Equation (2) can be specifically embodied by Equation (6):

$$C\,[\,\Sigma\,(A - 0.025)\,(1\text{-}SPR)\,X + \Sigma\,(A + 0.025)\,(SPR)\,X\,] + \Sigma Y = \Sigma\, X_{METRIC} + \Sigma\, Y_{METRIC} \qquad (6)$$

C = Global coefficient
Y = Expected volume of ET on 70-meter buffer around irrigated Lands, if no runoff, overspray or other edge effects were present
Y_{METRIC} = METRIC ET volume of ET on 70-meter buffer, including all runoff, overspray and other edge effects.

For each polygon in the 70-meter buffer, the value Y is calculated as:

$$Y = (Area_{buff})\,(ET_{NIR\text{-}SOIL}) \qquad (7)$$

$Area_{buff}$ = GIS area of individual polygon in buffer
$ET_{NIR\text{-}SOIL}$ = ET depth expected for given soil type, if no edge effects were present.

To avoid confounding coefficient C with any differences between METRIC ET on non-irrigated lands and other representations of non-irrigated ET, we obtained the $ET_{NIR\text{-}SOIL}$ depths by GIS analysis of the METRIC rasters on a second buffer that extended 200 meters beyond the 70-meter buffer. We felt this buffer was far enough from irrigated parcels to avoid any edge effects from irrigation, but since it was adjacent to the 70-meter buffer, it would give a good representation of the ET that would be expected in the 70-meter buffer if irrigation edge effects were not present. Figure 4 shows the buffer extended 200 meters beyond the 70-meter buffer.

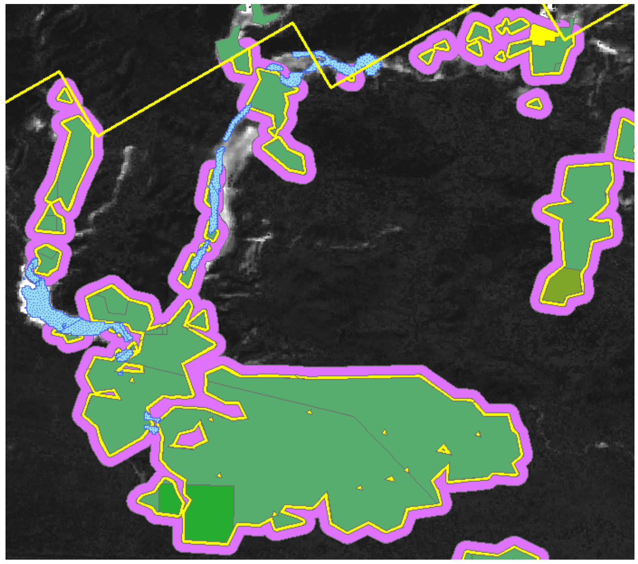

Figure 4. The purple areas show the buffer extended 200 meters beyond the 70-meter buffer around the year-2000 irrigated lands.

The value Y_{METRIC} is:

$$Y_{METRIC} = (Area_{buff})\ (ET_{METRIC}) \qquad (8)$$

As with ET_{METRIC} on irrigated lands, where both a Path 39 and Path 40 value were present, we used the larger value to represent METRIC ET.

Because wetlands have large ET depths and are represented elsewhere in the model, we removed wetlands from the 70-meter and 200-meter buffers as shown in Figure 4 above. Wetlands had already been removed from the irrigated-lands GIS when those data were created.

To obtain a specific realization of conceptual Equation (3) for calculation of (C), Equation (6) was solved to yield Equation (9):

$$C = (\Sigma X_{metric} - \Sigma Y_{metric})/[(\Sigma(A - 0.025)(1 - SPR)X + \Sigma(A+0.025)(SPR)X] \qquad (9)$$

For each entity, the final adjustment factors were calculated as follows:

$$ADJ_{spr} = (A + 0.025)\ C \qquad (10)$$

$$ADJ_{grav} = (A - 0.025)\ C \qquad (11)$$

Available Data

METRIC ET values for year-2000 and year-2006 irrigated lands data sets were both available. At the ESHMC meeting in February 2010, values for the adjustment factors (sprinkler and gravity) were presented. Members of the ESHMC committee agreed to use an average of the two years.

Certain members of the committee were concerned about the difference in adjustment factors for specific ground water and surface water entities and Dr. Rick Allen mentioned that cloud cover may have affected the METRIC ET results. The committee agreed to use an average of the two years when cloud cover was not affecting the satellite images, since cloud cover created the need to use averages when estimating METRIC ET for 2000 or 2006. In March 2010, Ricardo Trezza of IWRRI-Kimberly provided image files (30 m) of the Eastern Snake River Plain which consisted of a clearness index for 2000 and 2006.

The clearness index consists of values between 0 and 1, where a value of 1 means that all images (images of individual months for April through October) were clear of cloud cover and a value of 0 means that all images were cloudy. A value of 0.800 would imply that approximately 80% of the seasonal ET value was based on cloud free imagery and about 20% was based on an estimated value. For 2000 and 2006, an average clearness index was found for each entity. Given the results in clearness between the two years, a value of 0.700 (approximately 5 out of the 7 months for the entire area occupied by the entity were clear) was chosen as the lowest value of clearness accepted in order to use the adjustment factor. If the clearness value was 0.700 or above for both 2000 and 2006, an average value for the adjustment factor was applied. If one of the values between 2000 and 2006 was less than 0.700, the calculated adjustment factors with the clearness value of 0.700 or above was used as the final ET adjustment value. One exception was made for IEGW600. The clearness index in 2000 was less than 0.700; however, this entity was not present in the 2006 data; therefore, the ET adjustment factors were based on the year 2000 estimates. Table 2 shows the clearness index values for 2000 and 2006.

Table 2
Clearness Index Values
For Each Entity for ESPAM2

Entity ID	Yr-2000 Clearness Index (CI)	Yr-2006 Clearness Index (CI)	Yr-2000 Clearness	Yr-2006 Clearness	How was ET Adj Factor Calculated?
IEGW501	0.994	0.889	CLEAR	CLEAR	Average
IEGW502	0.833	0.924	CLEAR	CLEAR	Average
IEGW503	0.863	0.932	CLEAR	CLEAR	Average
IEGW504	0.910	0.924	CLEAR	CLEAR	Average
IEGW505	0.711	0.781	CLEAR	CLEAR	Average
IEGW506	0.786	0.923	CLEAR	CLEAR	Average
IEGW507	0.992	0.929	CLEAR	CLEAR	Average
IEGW508	0.994	0.964	CLEAR	CLEAR	Average

Entity ID	Yr-2000 Clearness Index (CI)	Yr-2006 Clearness Index (CI)	Yr-2000 Clearness	Yr-2006 Clearness	How was the ET Adj Factor Calculated?
IEGW509	0.937	0.880	CLEAR	CLEAR	Average
IEGW600	0.597	(Not an entity in 2006)	NOT CLEAR		2000
IESW000	0.682	0.743	NOT CLEAR	CLEAR	2006
IESW001	0.980	1.000	CLEAR	CLEAR	Average
IESW002	0.881	0.958	CLEAR	CLEAR	Average
IESW005	0.821	0.819	CLEAR	CLEAR	Average
IESW008	0.789	0.736	CLEAR	CLEAR	Average
IESW009	0.816	0.892	CLEAR	CLEAR	Average
IESW010	0.994	0.954	CLEAR	CLEAR	Average
IESW011	0.818	0.923	CLEAR	CLEAR	Average
IESW012	0.691	0.753	NOT CLEAR	CLEAR	2006
IESW014	0.853	0.926	CLEAR	CLEAR	Average
IESW015	0.675	0.712	NOT CLEAR	CLEAR	2006
IESW016	0.696	0.912	NOT CLEAR	CLEAR	2006
IESW018	0.896	0.885	CLEAR	CLEAR	Average
IESW019	0.902	0.911	CLEAR	CLEAR	Average
IESW020	0.797	0.863	CLEAR	CLEAR	Average
IESW022	0.863	0.901	CLEAR	CLEAR	Average
IESW025	0.943	0.841	CLEAR	CLEAR	Average
IESW027	1.000	1.000	CLEAR	CLEAR	Average
IESW028	0.862	0.834	CLEAR	CLEAR	Average
IESW029	0.822	0.929	CLEAR	CLEAR	Average
IESW030	0.867	0.889	CLEAR	CLEAR	Average
IESW031	0.659	0.735	NOT CLEAR	CLEAR	2006
IESW032	0.991	0.988	CLEAR	CLEAR	Average
IESW034	0.902	0.954	CLEAR	CLEAR	Average
IESW035	0.802	0.880	CLEAR	CLEAR	Average
IESW036	0.696	0.828	NOT CLEAR	CLEAR	2006
IESW037	0.802	0.911	CLEAR	CLEAR	Average
IESW038	0.692	0.780	NOT CLEAR	CLEAR	2006
IESW039	0.684	0.715	NOT CLEAR	CLEAR	2006

Entity ID	Yr-2000 Clearness Index (CI)	Yr-2006 Clearness Index (CI)	Yr-2000 Clearness	Yr-2006 Clearness	How was ET Adj Factor Calculated?
IESW040	0.979	0.887	CLEAR	CLEAR	Average
IESW041	0.994	0.996	CLEAR	CLEAR	Average
IESW044	0.713	0.914	CLEAR	CLEAR	Average
IESW051	0.552	0.727	NOT CLEAR	CLEAR	2006
IESW052	0.522	0.805	NOT CLEAR	CLEAR	2006
IESW053	0.788	0.663	CLEAR	NOT CLEAR	2000
IESW055	0.806	0.844	CLEAR	CLEAR	Average
IESW056	0.703	0.833	CLEAR	CLEAR	Average
IESW057	0.833	0.936	CLEAR	CLEAR	Average
IESW058	0.989	0.969	CLEAR	CLEAR	Average
IESW059	0.936	0.893	CLEAR	CLEAR	Average

Calculated ET Adjustment Factors

Final values for the sprinkler and gravity adjustment factors are tabulated in Table 3.

Table 3
Gravity and Sprinkler
Adjustment Factors for ESPAM2

Entity ID	Sprinkler ADJ	Gravity ADJ	Source
IEGW501	1.050	1.015	GW
IEGW502	0.947	0.791	GW
IEGW503	0.952	0.915	GW
IEGW504	0.981	0.988	GW
IEGW505	0.874	0.846	GW
IEGW506	0.893	0.821	GW
IEGW507	0.976	0.894	GW
IEGW508	0.912	0.828	GW
IEGW509	0.980	0.908	GW
IEGW600	0.818	0.818	GW
IESW000	0.839	0.790	SW
IESW001	0.994	0.936	SW
IESW002	1.074	1.085	SW
IESW005	0.888	0.910	SW
IESW008	1.018	0.976	SW

Entity ID	Sprinkler ADJ	Gravity ADJ	Source
IESW009	1.096	1.066	SW
IESW010	1.041	1.000	SW
IESW011	1.059	1.028	SW
IESW012	1.079	0.882	SW
IESW014	1.052	1.041	SW
IESW015	1.116	1.067	SW
IESW016	0.915	0.867	SW
IESW018	1.136	1.161	SW
IESW019	1.073	1.100	SW
IESW020	1.075	1.049	SW
IESW022	1.027	1.005	SW
IESW025	0.958	0.932	SW
IESW027	0.978	0.961	SW
IESW028	1.068	1.027	SW
IESW029	1.116	1.083	SW
IESW030	1.016	1.008	SW
IESW031	0.700	0.652	SW
IESW032	1.017	0.961	SW
IESW034	1.091	1.069	SW
IESW035	1.003	0.979	SW
IESW036	1.123	1.074	SW
IESW037	1.182	1.125	SW
IESW038	1.068	1.019	SW
IESW039	0.976	0.927	SW
IESW040	0.962	0.925	SW
IESW041	1.012	0.968	SW
IESW044	1.187	1.112	SW
IESW051	0.934	0.885	SW
IESW052	1.087	1.039	SW
IESW053	1.061	1.013	SW
IESW055	1.196	1.158	SW
IESW056	1.068	1.015	SW
IESW057	0.940	0.924	SW
IESW058	1.038	0.997	SW
IESW059	1.018	0.960	SW

Results

While not every entity in Table 3 above was thoroughly examined, adjustment factors for entities where adjustment factors are expected to be high or low were checked to make sure the calculations made sense. Several entities had ET adjustment factors that followed expectations:

1. IEGW600 was expected to have low adjustment factors because it is characterized by high pumping lifts.
2. IESW005 was expected to have low adjustment factors because it typically has a water short supply.
3. IESW015 was expected to have high adjustment factors because it consists of a wetland.
4. IESW029 was expected to have high adjustment factors because it contains lots of alfalfa.
5. IESW044 was also expected to have high adjustment factors because it contains lots of alfalfa as well.
6. IESW031 was expected to have low adjustment factors because it mostly consists of potatoes and grains.
7. IESW051 was expected to have low adjustment factors because it has pasture land and is not intensively managed.
8. IESW008 was expected to have lower adjustment factors relative to IESW053 because it has junior priority rights relative to IESW053.
9. IESW039 was expected to have low adjustment factors because it at a high elevation.
10. IESW040 was expected to have low adjustment factors because it is chronically water short.

One calculated adjustment factor was counter to expectations:

> IESW059 was expected to have low adjustment factors because it is typically water short. Its adjustment factors were not particularly high, but neither were they low.