DRAFT 2

Determination of Source of Irrigation Water for Calibration of Eastern Snake Plain Aquifer Model Version 2

University of Idaho
Idaho Water Resources Research Institute

Bryce A. Contor
Paul L. Pelot
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DESIGN DOCUMENT OVERVIEW

During calibration of the Eastern Snake Plain Aquifer Model Version 1.1 (ESPAM1.1), a series of Design Documents were produced to document data sources, conceptual model decisions and calculation methods. These documents served two important purposes; they provided a vehicle to communicate decisions and solicit input from members of the Eastern Snake Hydrologic Modeling Committee (ESHMC) and other interested parties, and they provided far greater detail of particular aspects of the modeling process than would have been possible in a single final report. Many of the Design Documents were presented first in a draft form, then in revised form following input and discussion, and finally in an "as-built" form describing the actual implementation.

This report is a Design Document for the calibration of the Eastern Snake Plain Aquifer Model Version 2 (ESPAM2). Its goals are similar to the goals of Design Documents for ESPAM1.1: To provide full transparency of modeling data, decisions and calibration; and to seek input from representatives of various stakeholders so that the resulting product can be the best possible technical representation of the physical system (given constraints of time, funding and personnel). It is anticipated that for some topics, a single Design Document will serve these purposes prior to issuance of a final report. For other topics, a draft document will be followed by one or more revisions and a final "as-built" Design Document. Superceded Design Documents will be maintained in a "superceded" file folder on the project Website, and successive versions will be maintained in a "current" folder. This will provide additional documentation of project history and the development of ideas.

INTRODUCTION

The ESPAM1.1 Design Document stated: "Recharge from surface-water irrigation is the largest component of aquifer recharge, and a large source of model uncertainty. The second-largest component of aquifer discharge is net withdrawals (calculated as consumptive use, or evapotranspiration) due to ground-water irrigation. The source of water for individual parcels must be identified so that diverted volumes of surface water are applied to the appropriate spatial locations" (Contor, 2004). Additional parameters for water-budget calculation, such as evapotranspiration adjustment coefficients, could potentially depend on the source of water assigned to a particular parcel.

Net extraction from ground-water pumping, on lands with no surface-water source, is calculated in the Recharge Tool using equation (1):

$$R_p = P - ET \qquad (1)$$

Where R_p = net impact of pumping
P = precipitation
ET = crop evapotranspiration

In the Eastern Snake River Plain, precipitation is generally low enough that R_p is negative. Pumping is not explicitly represented; R_p implicitly includes gross pumpage and percolation returns to the aquifer. R_p is spatially distributed across the irrigated area, which is a reasonable approximation when the distance from wells to irrigated lands is small relative to model grid size, as is the case in the model grid used for ESPAM1.1.

Net recharge from surface-water irrigation is calculated in the Recharge Tool using equation (2):

$$R_n = (D - R - C + P_o + P - ET) \qquad (2)$$

Where R_n = net recharge from irrigation
D = diversions from surface water
R = irrigation returns to surface water bodies
C = canal leakage separately represented[1]
P_o = offsite ground-water pumping separately represented[2]
(P and ET as defined above)

R_n is generally positive.

Careful inspection of equation (2) shows that if all the activities that do not occur on ground-water-irrigated parcels are set to zero, equation (2) is equivalent to equation (1) and can be validly applied to all irrigated lands.[3] If one considers a geographic region that includes the canals and offsite wells, equation (2) can be expanded to equation (3) to represent the full regional impact of irrigation

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[1] Since canal leakage is represented elsewhere in the recharge tool as a recharge at the location of the leaky canal, this term does not change the water budget but simply adjusts the spatial distribution of recharge.
[2] Since offsite pumping is represented elsewhere in the recharge tool as an extraction at the location of the offsite well, this term also affects only the spatial distribution of impact.
[3] On an individual model cell, equations (1) and (2) are applied on a pro-rata basis according to irrigated acreage in each irrigation entity. On mixed source parcels, R_p is multiplied by the ground-water source fraction and R_n is multiplied by the surface-water-source fraction. Because of the way source fractions are used in calculating diversion depth for surface-water entities, the mass balance implied in equations (2), (3) and (4) is preserved for all irrigated lands.

upon the aquifer. The first set of parenthesis encloses on-farm impacts and the second set encloses off-farm activities.

$$R_n = (D - R - C + P_o + P - ET) + (C - P_o) \quad (3)$$

By combining like terms, equation (3) can be reduced to equation (4) which represents the regional net impact of irrigation, including ground-water, surface-water and mixed-source effects.

$$R_n = (D - R + P_o - ET) \quad (4)$$

This equation holds for a region as long as the four inputs on the right-hand side are correct. The location of ground-water-irrigated, surface-water-irrigated, and mixed-source parcels does not affect equation (4) nor the water budget, but simply the spatial distribution of R_n within the geographic region represented. With the current configuration of the Recharge Tool, this region is an irrigation entity.

Representation of the source of irrigation water in ESPAM1.1 was based on the authorized source of irrigation water according to Idaho Department of Water Resources water right, adjudication claim and adjudication recommendation data available in 2001 and 2002 (Contor, 2004). In ESPAM1.1, all parcels having only surface-water irrigation water rights were designated "surface-water irrigated," all parcels having only ground-water rights were designated "ground-water irrigated," and all parcels having both surface- and ground-water rights were designated "mixed source." On mixed-source lands, a fraction of supply was assigned to each source, with ground-water and surface-water fractions summing to 1.0 for each mixed-source parcel. A particular entity, for instance, might have a source fraction of 0.30 for ground-water irrigation and 0.70 for surface-water irrigation. Source fractions were based on surface-water diversion data and were assigned on an irrigation-entity-wide basis. The ESPAM1.1 Design Document (Contor, 2004) describes in more detail how the source fractions were determined and applied. Figure 1 shows the spatial distribution of ground-water fraction on mixed-source irrigated lands used in ESPAM1.1.

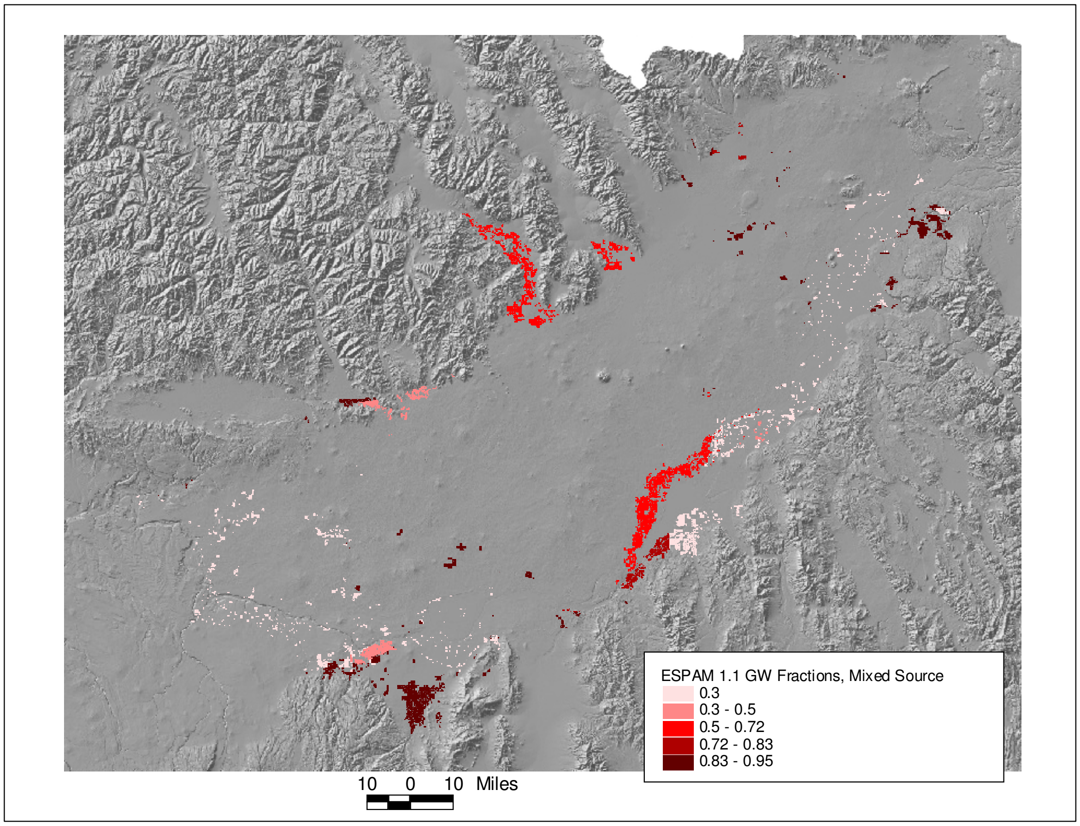

Figure 1. ESPAM1.1 ground-water fraction on mixed-source lands.[4]

During the fall of 2007, Idaho Water Resources Research Institute (IWRRI) reviewed aerial imagery, water rights GIS data and scanned images of paper water-right files for a statistical sampling of approximately 300 mixed-source irrigated parcels in south eastern Idaho, along with field inspection of a random sub-sample of parcels with access to Snake River water (Contor and others, 2008). An important outcome of this study was that very few parcels are physically mixed source; nearly all the parcels with both ground-water and surface-water rights are physically supplied from only one source or the other. This and other results are considered in light of the following questions for calibration of ESPAM2:

1. Is the ESPAM1.1 determination of source consistent with current water rights, claims and recommendations data?
2. Is there a possibility that the uniform representation of ground-water fraction across mixed-source irrigation entities distorts the representation of the impact of irrigation upon springs and reaches of the Snake River?
3. Can the source of irrigation water be represented with finer spatial resolution than was used in ESPAM1.1?

[4] Mixed-source lands that are served by wells for which actual diversion data are available are omitted from this figure. This affects organized irrigation companies in the Mud Lake area.

The first question is important because the first water-right determination was made during a period of rapid processing of claims, recommendations and partial decrees in the Snake River Basin Adjudication. Consequently, today's water-rights, claims and recommendations data bases are significantly different from those used in ESPAM1.1. One important difference is that many claims polygons used in ESPAM1.1 included detailed representation of individual parcels as either irrigated or not irrigated under a particular surface-water company or district's shares. However, in the process of the Snake River Basin Adjudication, many of these polygons have been superceded by large polygons that cast a broad boundary over entire service areas, obscuring the parcel-by-parcel detail that was present in the older data. This precludes simply repeating the analysis; if the ESPAM1.1 determination must be replaced, a new method, which will undoubtedly be more extensive and costly than the ESPAM1.1 evaluation, must be identified and applied.

The second question is whether the uniform representation of mixed-source lands distorts the spatial distribution of recharge. This is important because the primary purpose of ESPAM2 is to estimate impacts that stresses upon the aquifer (for instance, recharge or irrigation pumping) will have upon surface-water bodies. The process of calibration involves using known time series of impacts and known time series of spring discharges and river gains and losses. Figure 1 reveals that in ESPAM1.1, the ground-water extraction fraction was applied uniformly over large areas of mixed-source lands within some entities. The reality could be that there are discrete locations within these entities predominantly irrigated only by surface water, with other locations predominantly supplied from ground water. If true, this could distort the "known" data used to calibrate the model and therefore reduce the quality of the resulting calibration.

The third question is essentially a follow-up question to the second: Can we develop a more realistic method to represent the actual source of irrigation water on these mixed-source parcels?

This design document discusses these three questions and presents a proposal for the determination of source of irrigation water for calibration of ESPAM2. It is presented to provide transparency, stimulate discussion and seek input from the ESHMC.

APPLICATION OF DATA TO THREE QUESTIONS

<u>Is the ESPAM1.1 Determination of Water Source Consistent With Current Data?</u>

All the sample points were chosen to correspond to lands identified as "mixed source" in ESPAM1.1. Approximately seven percent of the sample points were in locations where gaps occurred in the water-rights GIS data (primarily associated with lands under Native American sovereign jurisdiction). Of the remaining points, the current water-right status agreed with ESPAM1.1 determination on 88% to 95% of the points[5]. In every case, the change in status was due determinations made in the Snake River Basin Adjudication. Table 1 shows the status of the 24 points (5% to 12% of the total) where ESPAM1.1 disagreed with current data.

Table 1
Points where current data disagreed with ESPAM1.1 determination of water-right status. All points are on or very near the Eastern Snake Plain Aquifer.

ESPAM1.1	Current Data	No. Points
Mixed-source	Ground-water only	8
Mixed-source	Surface-water only	15
Mixed-source	No irrigation rights	1

Changes in the IDWR water-rights representation of canal company and irrigation district service areas indicate that repeating the analysis would require extensive effort. Discrepancies in identification of irrigation water source only introduce changes in spatial distribution of recharge and not in the water budget. Approximately 90% of the points for which a current water-right determination could be made agreed with the ESPAM1.1 determination of source. Therefore, it is proposed to use the ESPAM1.1 water-rights extraction as a basis for source maps for ESPAM2 calibration.

Does the current uniform representation of ground water on mixed-source lands distort spatial distribution of recharge within individual entities?

If a tract of mixed-source land the size of an irrigation entity had a concentration of ground-water irrigation in one location and a concentration of surface-water irrigation in another, the ESPAM1.1 representation of uniform distribution of ground water and surface water could represent a spatial distortion of recharge and discharge. Since ground-water irrigation depletes the aquifer during time periods when surface-water irrigation replenishes it, this distortion could adversely affect the ability of the model to match temporal variation in reach gains. During the January 2008 ESHMC meeting, participants identified Springfield, Idaho as the location where this effect would be likely to be of greatest concern within the study area, illustrated in Figure 2 (from Contor, 2008).

[5] The range is the alpha = 0.05 confidence interval for a binomial experiment (Snedecor and Cochran, 1980)

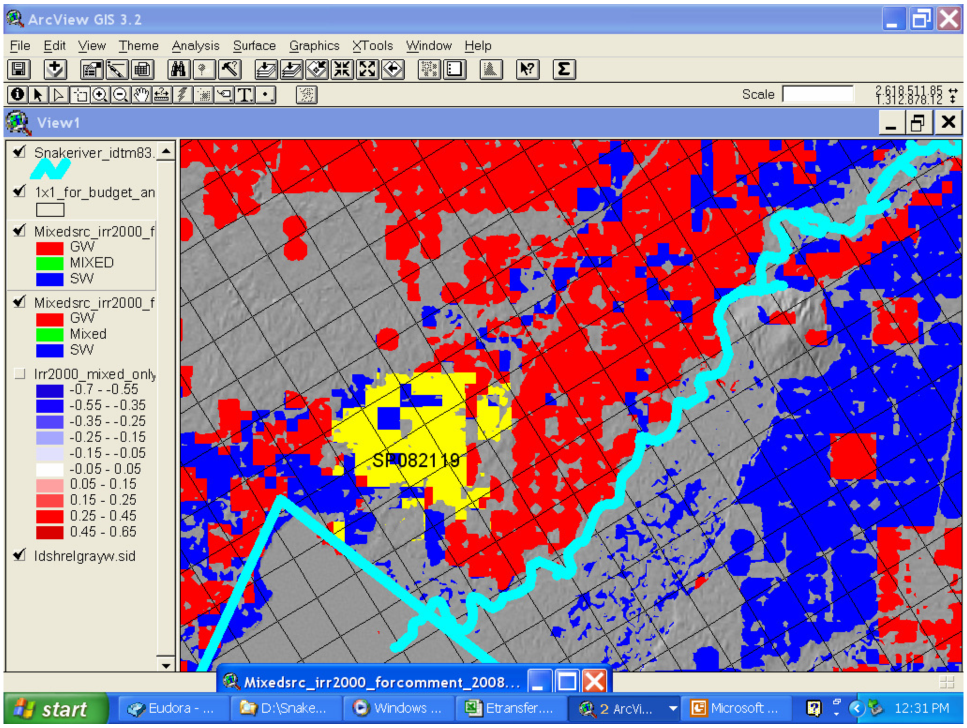

Figure 2. Yellow-coded lands are the subject of the test. Red (ground water) and blue (surface water) colors are preliminary determinations under "proximity" method.

The yellow-colored lands are the subject of the test. In ESPAM1.1 these were represented as mixed-source with uniform distribution of ground-water and surface-water irrigation according to the local irrigation entity's source fractions. Evidence suggests that in reality this area is predominantly ground-water irrigated. The analysis assumed the worst-case scenario, which would be that the lands colored yellow are actually irrigated solely from ground water. If that were the case, the estimated local distortion in stress due to the uniform representation of ESPAM1.1 could be two feet per year (Contor, 2008). A corresponding volume of water (based on irrigated acreage of the yellow-colored lands) was applied to the cell labeled in the Figure, using the Eastern Snake Plain Aquifer recharge tool (Cosgrove and others, 2007). The simulation results indicate that the distortion in representation of reach gains to the Near Blackfoot to Neeley reach of the river is about 12 cubic feet per second (cfs) in the summer, seven cfs in the winter and five cfs in the spring. This over-estimates the actual distortion, because the offsetting reductions that would occur elsewhere within the irrigation entity were not represented. Relative to total gains in the reach and uncertainties in the target data, this distortion is minimal. This test indicates the practical impact of the ESPAM1.1 simplification upon matching reach gains is minor. However, the impact on matching water levels in wells is also important.

Can the source of irrigation water be represented with finer spatial resolution than was done in ESPAM1.1?

To refine the spatial distribution of water source, a heterogeneous scheme of source fractions must be imposed on mixed-source lands within any given irrigation entity. Several possibilities exist, including the following (Contor, 2008):

1. A "proximity" method. Mixed source lands within 400 meters of an irrigation well[6] are deemed to be ground-water supplied and all others are deemed to be surface-water supplied.
2. A "dual radius" method. All mixed-source parcels within 100 meters of an irrigation well are deemed to be ground-water supplied, all parcels further than 1000 meters from an irrigation well are deemed to be surface-water supplied, and all other parcels are listed as "mixed-source undetermined," with the fraction of supply from ground water set at 50%.
3. "Dual 2," a modified dual radius method where all parcels within 100 meters of a well are assigned 90% ground-water source fraction, parcels further than 1000 meters are assigned a 10% ground-water fraction, and other mixed-source parcels are assigned 50%.
4. A "variable radius" method where the ground-water fraction of parcels ranges from 10% to 80% depending on distance from irrigation wells.[7]
5. A "no company" method where mixed-source lands are deemed to be surface-water irrigated if the ground-water right is in the name of a canal company or irrigation district, and deemed to be ground-water irrigated otherwise.

These methods all produce overall percentages of ground-water-only and surface-water-only parcels consistent with field inspection. The methods that assign parcels as solely ground water or solely surface water correctly represent up to 70% of individual parcels. This means, however, that they will be incorrect on 30% or more of individual parcels examined. This is probably too high an error rate from a perception standpoint. Based on this reasoning, the "proximity," "dual radius" and "no company" methods are rejected. Further, while the "no company" method produced a useful spatial distribution, assigning physical water source based on ownership could be construed to mean any number of things that the modeling project would certainly not intend to assert.

The "dual 2" and "variable radius" methods both avoid assigning any individual parcel as 100% ground-water irrigated or 100% surface-water irrigated. From a perception standpoint, the ground-water fraction on these parcels can be presented as a *probability* that an individual parcel is irrigated by ground water, rather than an actual determination for each parcel. The "dual 2" method is preferred above "variable radius" because it is more straightforward to apply.

[6] Irrigation wells are identified from IDWR water-rights GIS data available on the Internet.
[7] Zero to 100 meters = 80%, 900 to 1000 meters = 20%, over 1000 meters = 10%. Between 100 meters and 900 meters, the fraction is linearly interpolated between 20% and 80% at increments of ten percentage points.

Further, since it uses only three different percentages, it conveys the appropriate precision in our ability to estimate physical water source on a parcel-by-parcel basis.

OTHER CONSIDERATIONS

Source of irrigation water could be a required input for some model uses. Though not absolutely necessary, in model use it is attractive to use data and methods consistent with calibration. Of particular concern to the ESHMC is the use of water-source data in evaluation of potential administrative actions. In this context, some comparisons were made between the ESPAM1.1 representation and the alternate methods. Two points are important:

1. In any evaluation of administrative actions, the relevant irrigation water source will be the *post-action* condition. Proper evaluation of this must include adjustment for the expected response of owners of mixed-source lands to the administrative action. Even if current source fractions were perfectly represented in calibration data, these would not be likely to represent the post-action condition.
2. ESPAM1.1 represents the best effort at the time of the last calibration, but it is not a perfect representation. Comparisons between it and alternate methods are interesting, but simply finding a difference between ESPAM1.1 and an alternate method does not provide guidance for whether the alternate method should be adopted.

All the alternate methods reasonably represented the overall fraction of mixed-source parcels physically supplied by ground water. Figure 3 shows the comparison of acres in the vicinity of the Near Blackfoot to Neeley reach, a reach important to river gains. Figure 4 and Figure 5 compare the indicated effective ground-water acreage on mixed-source lands by entity, for the entire plain.[8]

[8] Figures 3 through 5 are from Contor, 2008.

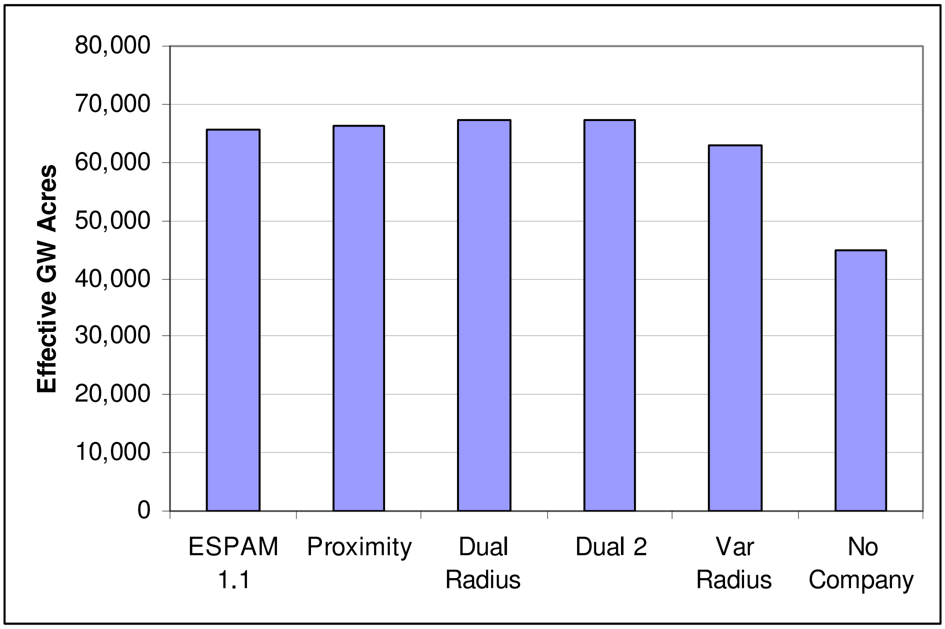

Figure 3. Effective ground-water acreage indicated on mixed-source lands in the vicinity of the Near Blackfoot to Neeley reach of the Snake River.

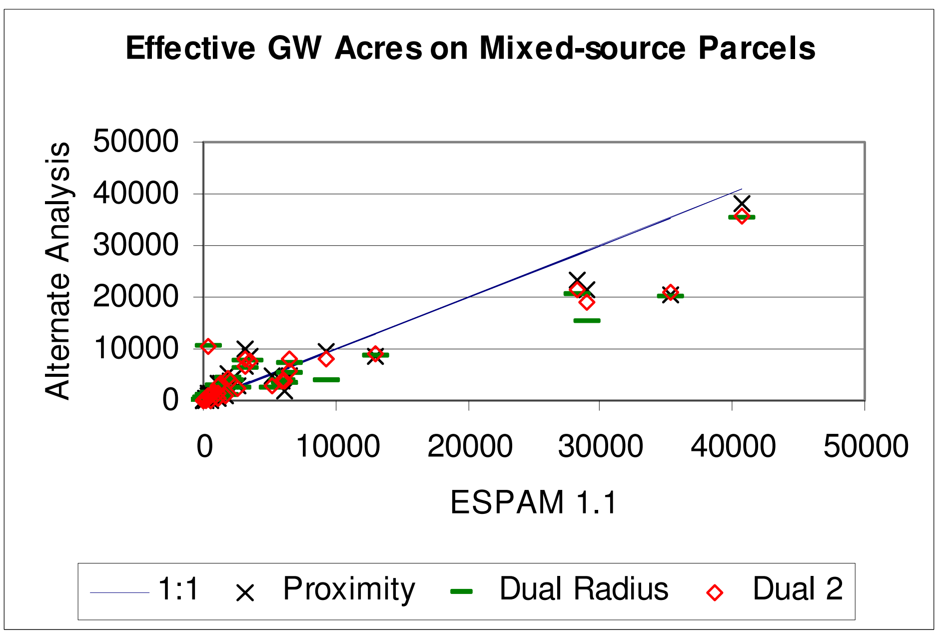

Figure 4. Cross Plot of total effective ground-water acreage by irrigation entity for alternate methods.

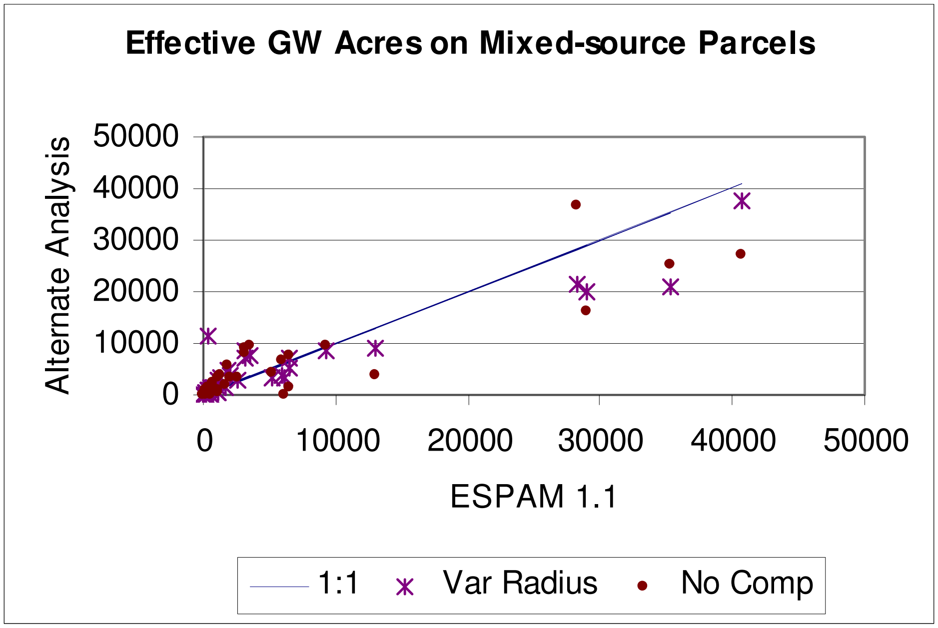

Figure 5. Cross Plot of total effective ground-water acreage by irrigation entity for alternate methods.

An additional consideration is that it would be desirable to identify a method that could be easily updated as new water-rights data become available. All the methods considered are essentially equivalent in this respect, though the "no company" method would require a small amount of hand processing.

DISCUSSION

In considering these results, several points are important:

1. The treatment of mixed-source lands will not affect the total calibration water budget.
2. The treatment of mixed-source lands will not change the distribution or allocation of water between irrigation entities.
3. The water budgets of individual irrigation entities will not change.
4. The only effect on calibration will be on the spatial distribution of recharge within each irrigation entity.
5. The ESHMC identified one location where the spatial distribution within an entity might make a difference in reach-gains matching. The test described above indicated that the potential effect is small.
6. More properly assigning source to individual parcels should aid in aquifer-head matching throughout the study area.
7. While comparisons with the ESPAM1.1 representation are interesting, we have no reason to believe the ESPAM1.1 representation is more correct than the alternate methods.

It does not appear that there is any strong technical reason to favor any of the methods over another. However, perceptions of the resulting representations may be important. These favor the “dual 2” method.

DESIGN DECISION

It is proposed that the “dual 2” method be used to calculate the ground-water fraction on mixed-source lands for calibration of ESPAM2. Details include:

1. Lands identified as mixed-source in the ESPAM1.1 water-rights analysis will be represented as mixed-source in ESPAM2. Some manual adjustment will be made based on investigation of paper water-right files for suspect parcels. A list of adjustments made will be provided as an appendix to a revision of this design document.
2. The fraction of supply from ground water on mixed-source lands will be assigned according to proximity to irrigation wells in the current IDWR water rights, claims and recommendations data bases.
    a) Parcels within 100 meters of irrigation wells will be assigned 90% probability of being served by ground water (ground-water source fraction equals 90%).
    b) Parcels greater than 1000 meters from irrigation wells will be assigned 10% probability of being served by ground water (ground-water fraction equals 10%).
    c) All other mixed-source parcels will be assigned 50% ground water, 50% surface water.
3. The existing recharge-tool calculation methods will be retained.
4. As with ESPAM1.1, actual pumping and surface-water diversion data will be used to calculate the impact of mixed-source irrigation in the Mud Lake area, for parcels within organized companies and districts.

Figure 6 shows preliminary results of the proposed method in the Near Blackfoot to Neeley area. IWRRI requests input from the ESHMC on these proposals.

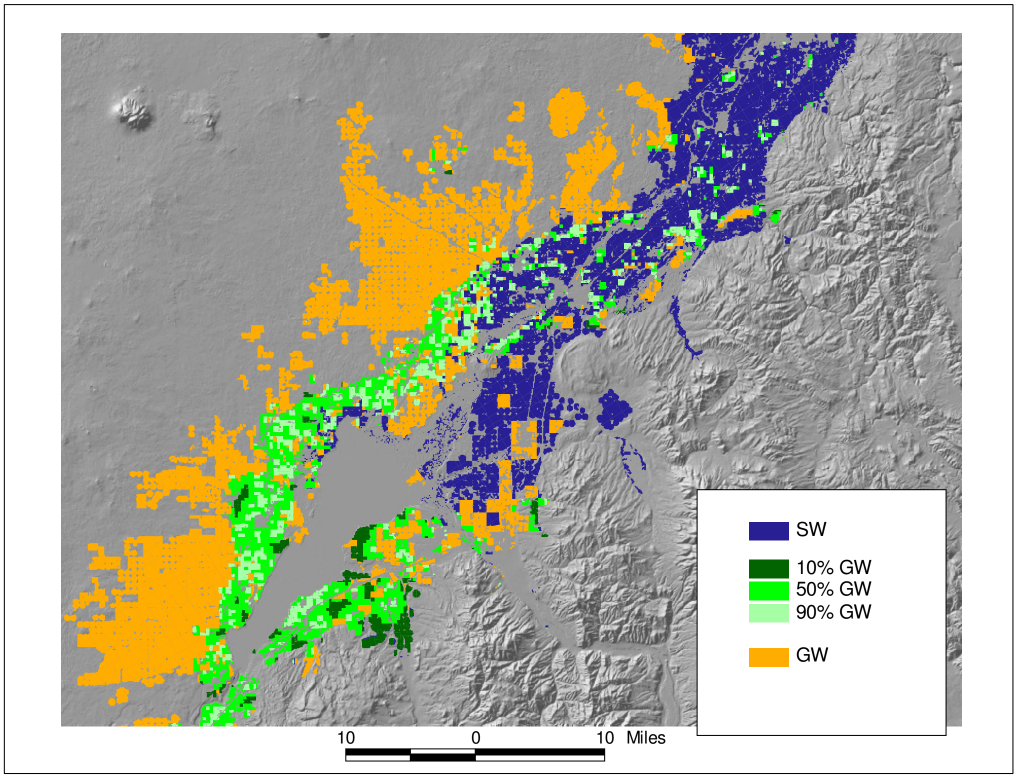

Figure 6. Source fraction by the Dual 2 method, Near Blackfoot to Neeley area.

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