2005 INNOVATIONS AWARDS PROGRAM

APPLICATION

Deadline: April 4, 2005

Be advised that CSG reserves the right to use or publish in other CSG products and services the information that you provide in this Innovations Awards Program Application. If you object to CSG potentially using or publishing the information contained in this application in other CSG products and services, please advise us in a separate attachment to your program's application.

1. Program Name: **Mapping Evapotranspiration from Satellites Project**

2. Administering Agency: Idaho Department of Water Resources (IDWR)

3. Contact Person: **William J. Kramber**, Senior Remote Sensing Analyst

4. Address: P.O. Box 83720, Boise, Idaho 83720

5. Telephone Number: 208-287-4878

6. FAX Number: 208-287-6700

7. E-mail Address: bill.kramber@idwr.idaho.gov

8. Web site Address: http://www.idwr.state.id.us/gisdata/et.htm

9. **Please provide a two-sentence description of the program.**

The Mapping Evapotranspiration from Satellites Project, a cooperative effort of the University of Idaho, the Idaho Department of Water Resources, NASA, and the private sector, is an operational tool for water administration in the State of Idaho. This technology utilizes satellite image-data to compute a complete radiation and energy balance, sensible heat, and evapotranspiration or ET (water that is transpired by vegetation or evaporated from the soil) for the area covered by the satellite image.

10. **How long has this program been operational?**
    In development since 2000. Operational, January 2004.

11. Why was the program created? What problem[s] or issue[s] was it designed to address?

IDWR and the University of Idaho worked from 2000 to 2005 under a NASA grant to develop the means to map evapotranspiration from satellite data and to apply the data in water resources problems.

Before the advent of the ET model METRIC, which is an acronym for "Mapping EvapoTranspiration at High Resolution with Internalized Calibration", IDWR used a cumbersome method to estimate ET for its ground water models.

The old method required mapping irrigated acres in each county, applying a nominal crop percentage to the acreage figures, then applying a crop-specific ET coefficient using those percentages as input to an ET equation. This method did not have an accuracy associated with it, but since the ET equation started at crop emergence and ended at crop harvest, it was clear that early- and late-season soil evaporation was not included, so the ET estimate was low. This method also computed one ET value for a large area.

METRIC, on the other hand, can generate ET estimates between any two given dates. The accuracy of METRIC compares favorably with measured ET. For a full growing season, the differences between METRIC ET and ET measured from a precision weighing lysimeter have been as low as 4%, although errors for specific dates have been as high as 25%. Another advantage of METRIC ET data over the old method of developing ET data is that METRIC data produces an ET surface over an entire satellite image so variations in ET from field to field and within fields are shown.

12. Describe the specific activities and operations of the program in chronological order.

This was one of eleven 'Infomart' projects across the United States awarded as part of a NASA program called the Earth Observing System Data and Information System (EOSDIS). The Raytheon Company administers these Infomarts as part of their Synergy Program. This work is supported by funding from The Idaho Department of Water Resources, the University of Idaho's Departments of Biological and Agricultural Engineering and Civil Engineering, and by a NASA/Synergy grant.

The Idaho Synergy project was structured in phases. Each phase was designed to stand on its own, with self-contained goals, tasks, and products, while building on the accomplishments of previous tasks.

Phase I (1/2000 - 12/2000) of the project was completed at the end of 2000. Phase I was limited in scope, designed to apply the European SEBAL ET model to the Bear River Basin in Idaho, to evaluate the results, and to suggest modifications if necessary. The results of Phase I were encouraging, and Phase II was funded.

Phase II (1/2001 - 12/2001) was a much more ambitious project, processing multiple years of Landsat data through SEBAL on the Eastern Snake River Plain. The work included making modifications to the SEBAL model suggested by Phase I, the comparison of SEBAL ET with ET measured by the precision weighing lysimeters at the Kimberly Research Station near Twin Falls, and the comparison of SEBAL-computed ET with estimated ground-water pumpage for water rights on the Eastern Snake Plain.

Phase III (1/2002 - 12/2002) was designed to further refine the SEBAL model, and to demonstrate that it could be used operationally as a tool for administering water rights. It is with the Phase III modifications that METRIC fully diverged from SEBAL.

Phase IV (1/2003 - 12/2003) was designed to begin the transition to an operational system.

Phase V (1/2004 - 2/2005) was designed to transition METRIC into an operational system.

13. Why is the program a new and creative approach or method?

The University of Idaho derived METRIC from another ET model, the Surface Energy Balance Algorithm for Land (SEBAL), which has been under development in the Netherlands since 1990. METRIC computes a complete surface energy balance for each pixel of a Landsat satellite image. The underlying principle of the model is that evaporating liquids absorb energy. While the principle is simple, implementing it to result in accurate maps of ET is very complex.

Landsat satellite data is the preferred data source for METRIC, although the model can be run with any satellite that has both visible and thermal infrared channels. Landsat is preferred because it is an operational system with a large data archive, and its 30-meter pixels are small enough to map ET within individual agricultural fields. Landsat data are easy to order and inexpensive to buy - $375 for a Landsat 5 scene. METRIC can be run for any time-step from 24-hours to an entire season.

The METRIC model has been designed primarily for agricultural applications but METRIC has been used to compute ET for a variety of land use and land cover types including urban and built-up areas and rangeland.

14. What were the program's start-up costs? (Provide details about specific purchases for this program, staffing needs and other financial expenditures, as well as existing materials, technology and staff already in place.)

The METRIC program was accomplished at IDWR entirely with existing staff. The start-up costs have been significant, but the bulk of those costs have been one-time expenditures related to the research done to get the METRIC model into a production mode.

A more realistic accounting of start-up costs would be for another state to implement METRIC, because those costs would not include the research and development costs. Assuming that a state agency has an active GIS capability, the start-up costs would be significant, but reasonable. METRIC can be run by a single person, so the lowest start-up costs would be incurred by hiring a single individual who already knew METRIC, which would avoid a significant amount of training. The personnel cost would vary, depending on the agency. Hardware and software costs are relatively modest: a large, dedicated workstation would cost approximately $5,000 to $7,000. If image-processing software were needed, that cost would depend on the software package – probably on the order of $10,000.

15. What are the program's annual operational costs?

The annual operational costs are variable. The need for METRIC data is on a project-by-project basis and is not continuous, so the model is run on an as-needed basis. IDWR personnel estimate the cost of running METRIC on one date of Landsat imagery at $2,435. Of that cost, $765 is for purchasing and orthocorrection the data. The remaining cost is personnel time. One Landsat image covers approximately 10,000 square miles.

16. How is the program funded?

IDWR funds METRIC processing through a combination of internal funds and dedicated project funds. Some applications that need ET data use the existing year 2000 ET data for southern Idaho. One application, MIKE Basin simulation in the Lemhi River Basin, has been funding METRIC processing for three years. The funds supporting this project are from IDWR, the U.S. Bureau of Reclamation, and the Bonneville Power Administration.

17. Did this program require the passage of legislation, executive order or regulations? If YES, please indicate the citation number.

NO

18. What equipment, technology and software are used to operate and administer this program?

METRIC is best run on a computer with as much disk space and RAM as possible. As part of the Synergy grant, IDWR purchased a robust workstation-class PC running Windows 2000. The PC has 2 GB of RAM and 420 GB of disk storage. IDWR's spatial data are managed and served from two Spatial Data Servers. These servers are located in the GeoSpatial Technology Section and are maintained by section personnel. The servers have a combined capacity of 2.6 terabytes of storage protected in RAID 5. See: http://www.idwr.state.id.us/gisdata/hardware.htm

19. To the best of your knowledge, did this program originate in your state? If YES, please indicate the innovator's name, present address, telephone number and e-mail address.

Yes, IDWR is the only water resources organization in the country at either the state or the federal level that runs an energy-balance ET model.

William J. Kramber, (208) 287-4878, bill.kramber@idwr.idaho.gov

20. Are you aware of similar programs in other states? If YES, which ones and how does this program differ?

We are not aware of another state that runs METRIC or any other energy-balance ET model based on satellite images.

21. Has the program been fully implemented? If NO, what actions remain to be taken?

The program is fully funded in the sense that ET data are being developed and used operationally to support the appropriate applications. At IDWR, applications of hydrologic modeling have a regular, recurring need for ET data, and are funding METRIC processing as needed. Other departmental applications use ET data but do not necessarily need the data to be generated on a recurring, year-after-year basis. For example, the Idaho Water Resource Board is buying back Snake River water rights. METRIC data for the year 2000 are being used as an impartial check on the actual volume of water used by the candidate water rights. The METRIC ET helps set a realistic environment for negotiation of the final volume of water purchased.

22. Briefly evaluate (pro and con) the program's effectiveness in addressing the defined problem[s] or issue[s]. Provide tangible examples.

IDWR has demonstrated how METRIC can be used in a number of ways over the last 5 years. The applications have been in hydrologic modeling, water resource planning, and water administration.

The most successful application is in hydrologic modeling. ET maps made from METRIC are especially useful for hydrologic modeling because ET is an important component for computing aquifer recharge. Landsat's combination of large aerial coverage and relatively small pixel size are well suited for the ground water models run by IDWR. Modelers have used the output from METRIC to refine estimates of aquifer recharge in the recalibration of the MODFLOW ground water-model of the eastern Snake River Plain aquifer.

IDWR and the U.S. Bureau of Reclamation launched a series of projects in order to develop surface water budget models for various river basins in Idaho using a MIKE Basin simulation. The MIKE Basin simulation is used as a tool to evaluate diversion operation plans in order to meet minimum stream flow requirements for anadromous fish passage, and to educate stakeholders of the complex hydrologic and water allocation concepts that encompass the Lemhi River management.

One of the most important inputs to the MIKE BASIN models is a daily ET rate. The advantage of METRIC ET data over point ET data is that METRIC data produces an ET surface over an area that shows variations in ET from field to field.

When IDWR water planners needed to understand how water use changes as irrigated farmland is converted to residences, the planners turned to METRIC. By overlaying polygons of land use and land cover for the year 2000 on a METRIC map of seasonal (March 1 to October 31, 2000) ET, IDWR analysts generated the data shown in Table 1.

Class Name	ET in mm
Petroleum Tank Farm	237
Rangeland	242
Barren	335
Commercial / Industrial	380
Transportation	420
Idle Agriculture	436
Feedlot	479
Dairy	524
Public	548
New Subdivision	606
Farmstead	609
Rural Residential	657
Urban Residential	684
Irrigated Crops	812
Recreation	826
Water	924
Wetland	1,025

Table 1. The seasonal ET in millimeters for 17 categories of land use and land cover in the lower Boise Valley for the year 2000.

The U.S. Department of the Interior has identified areas in the western U.S. that are at risk for conflict over water supply during the next 20 years (Figure 1).

Both southwest Idaho and eastern Idaho are among those areas. The significance of the data in the previous Table 1 is that for the first time, ET has been computed specifically for different types of land cover, which provides a quantitative basis on which to make projections about the future of water demand in the rapidly-expanding urban areas of Idaho, as well as the rest of the arid western U.S.

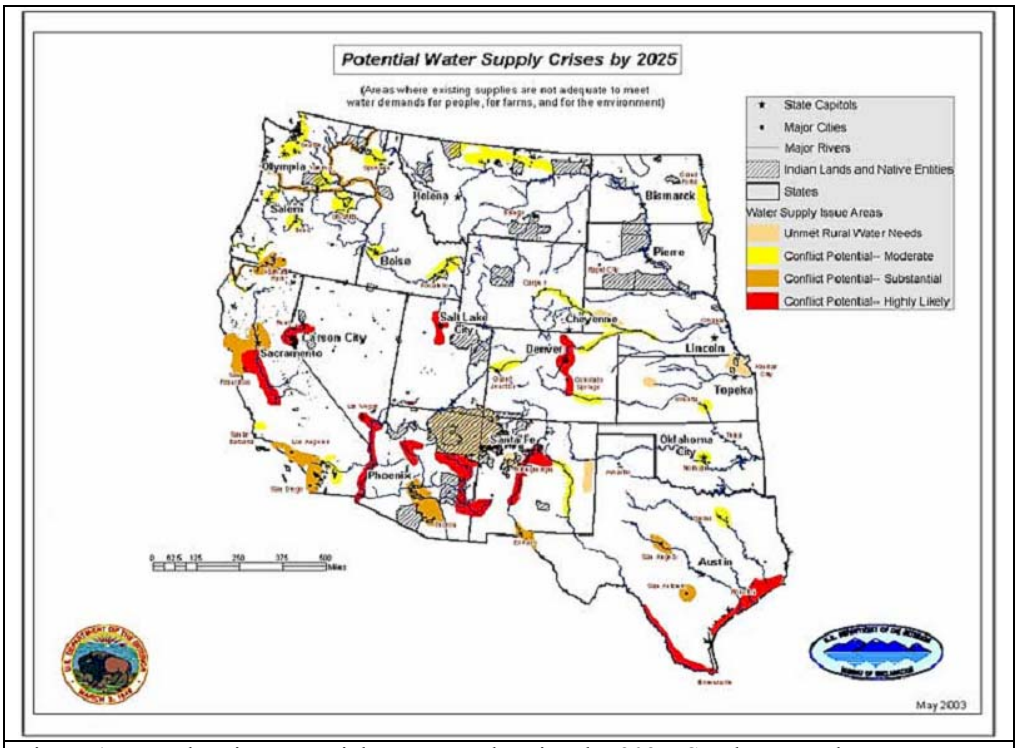

Figure 1. Map showing potential water supply crises by 2025. Southwest and Eastern Idaho are identified as having a moderate potential for crisis.

IDWR has demonstrated other applications of METRIC ET maps, as well. These applications include monitoring the depletion of the Eastern Snake Plain Aquifer, and monitoring compliance with water rights.

IDWR has METRIC information at www.idwr.idaho.gov/gisdata/et.htm. An ET map for most of southern Idaho is available on the Internet from IDWR's Internet Map Server at http://maps.idwr.idaho.gov/et.

23. How has the program grown and/or changed since its inception?

The METRIC program has evolved significantly since its inception. The program began as a research project evaluating the European SEBAL ET model with the goal of finding a better method of computing and mapping ET, and evolved through 5 phases. Each successive phase built on the previous phases, with METRIC evolving out of

modifications made to SEBAL. The goal of the fifth phase, and one of main goals of the NASA Synergy program, was program sustainability as an operational system.

Each project phase has a defined goal.

Phase 1(1/2000 - 12/2000) of the project was designed to apply the SEBAL ET model to the Bear River Basin in Idaho, and to evaluate the results. The results were promising, and proposal from IDWR and UI for a second year of funding was accepted.

Phase 2 (1/2001 - 12/2001) processed multiple years of Landsat data through SEBAL on the Eastern Snake River Plain. The work included making modifications to the SEBAL model suggested by Phase 1, and the comparison of SEBAL ET with ET measured by the precision weighing lysimeters at the Kimberly Research Station near Twin Falls. This phase included the first pilot application, which compared SEBAL-computed ET with estimated ground-water pumpage for water rights on the Eastern Snake Plain.

Phase 3 (1/2002 - 12/2002) further refined the SEBAL model, by incorporating the U.S. Bureau of Reclamation's AgriMet data into the model, and demonstrated that SEBAL ET could be used operationally as a tool for administering water rights. It is with the Phase III modifications that METRIC fully diverged from SEBAL. In Phase 3, IDWR demonstrated that METRIC ET data could be generated and put in the hands of water-right field-agents within 2 weeks of a satellite overpass.

Phase 4 (1/2003 - 12/2003) was designed to begin the transition to an operational system. The METRIC model was extended to other, non-agricultural types of land cover such as rangeland, urban land, and residential areas.

Phase 5 (1/2004 - 2/2005) was designed to transition METRIC into an operational system. IDWR and UI worked with other water-resource organizations, primarily the U.S. Bureau of Reclamation, to get METRIC accepted as an operational water-resource tool.

24. What limitations or obstacles might other states expect to encounter if they attempt to adopt this program?

METRIC is a complex model, and should not be considered a turnkey piece of software. Getting accurate results from METRIC requires extensive training in the use of the model, as well as expertise in several areas such as remote sensing, agricultural practices, and evapotranspiration.

The start-up costs for a state to successfully run METRIC are significant, and do present an obstacle to other states running METRIC. Nevertheless, the SEBAL ET model is run in the United States as a commercial venture. Other states would be well advised to invest in a commercially generated ET product for evaluation.