Kansas Geological Survey

Landscape-Scale Detection and Characterization of Small Water Bodies: A Progress Report

By

R.W. Buddemeier, R.O. Sleezer, S.L. Egbert, and F.J. deNoyelles

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Kansas NASA EPSCoR Phase II Program
Year 2 Progress Report

Name of Project: Landscape-Scale Detection and Classification of Small Water Bodies: Temporal Integration of Diverse Types of Data

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Name of Other Sponsors matching funds, other related grant funding agencies and amount of match/grants:
University of Kansas/KUCR (including KGS, KBS, EEB and Geography Depts.):
$16,642
Emporia State University:
$10,986

Please provide a one-page description of your project's progress:

Work was initiated on final receipt of funding authorization in early June, 2003. Project objectives are to answer the following questions:

1. What is the current inventory/distribution of small ponds in Kansas, and how accurately can this be assessed using readily available or easily acquired remote sensing data?
2. How can remotely sensed (e.g., spectral) information about ponds and their surrounding watersheds be used to classify ponds and their settings in terms of their water quality and probable ecological and biogeochemical functions?
3. How do the inventory, distribution, and functions or classification of ponds vary over time, and how do these relate to invariant (e.g., soils, topography) or more generally determined (e.g., land use-land cover, LULC) environmental characteristics?

[Objectives 1-3] Images of the two study areas (the Midland quadrangle, Jefferson Co., KS, and Allen SE quadrangle, Lyon Co, KS – place adjacent relevant areas in both counties) were assembled, scanned (if necessary), registered and rectified, and digitized. These images consisted of (1) historical air photos from a variety of sources, (2) existing electronic database images (e.g, the DOQQ and other images served by DASC), (3) multispectral (DuncanTech camera) images of the Midland Quadrangle available from recent KBS survey flights over that area, (4.) available satellite images (Landsat ETM and ASTER) for the study areas, and (5) derived products such as the Kansas Surface Water Database (KSWD) and the Surface Waters Information Management System (SWIMS). A sixth data acquisition effort supported a specific aerial photo mission over the Allen SE quadrangle in the Lyon Co study area (yielding 560 DuncanTech multispectral camera images covering 56 sq. mi. and 541 ponds).

[Objective 3] Aerial photos (hard copy and digital) that provided historical coverage at multiple times from the 1940s to the present were obtained, scanned (>1700 images), and registered/rectified (>2200 images). Ponds were identified and digitized (>3700 images for Lyon Co., and >2000 for the Midland quadrangle). Time histories of pond numbers for the two areas were constructed and compared; although current densities are similar, the historical trajectory of pond development has been quite different in the two areas (for details, see Appendix 1).

[Objective 1] DuncanTech multispectral images (1 m resolution) from the study areas were also processed. Landsat ETM images (30 m pixels, all areas) were acquired, processed, and automatically inventoried for water bodies, as were those ASTER images (15 m pixels) that could be acquired for the areas of interest. Comparison of results (Appendix 2) showed an expected decline in detection (number) sensitivity with increasing pixel size, but estimates of cumulative small water body surface area increased with pixel size. Estimates based on the 15 m resolution are not bad, and resolution in the 4-5 m range would be adequate to detect nearly all of the water bodies seen in the aerial photographs. Significantly, all sensing methods detected vastly more water bodies than were reported in the derived surface water database products (KSWD and SWIMS) available (see table and Appendix 2).

Table: Estimates of Number of Water Bodies and Total Surface Area (Midland Quadrangle, partial)

Data Set	# Water Bodies	% of Actual Number	Total Sfc. Area (sq. km.)	% of Actual Area
DuncanTech	97	100%	179.9	100%
ASTER	83	86%	202.0	112%
ETM+	58	60%	231.4	128%
KSWD	3	3%	26.1	15%
SWIMS	1	1%	23.6	13%

[Objective 2]The environmental/ecosystem characterization of ponds was also developed by comparing the spectral signals obtained from the DuncanTech images with near-synoptic ground truth observations of accessible ponds. Initial results of the analysis are very positive, with pond vegetation type and amount, water clarity/turbidity, and riparian vegetations type and amount all readily classifiable on the basis of analysis of the three spectral bands. These results are presented in more detail in Appendix 3.

Work in progress will compare detection sensitivities of the conventional aerial photographs (B&W and color) with the DuncanTech results, and place both into the context of previous literature estimates of pond densities based on available datasets. Further work will be carried out on the spectral classification (with camera and satellite results) and relationships to ecosystem or biogeochemical function. Dr. Xiaoyong Zhan (KGS) is modeling runoff characteristics to determine interception as a function of pond density and placement, and how that may affect water and sediment budgets over time. The project is on schedule, and is confirming the hypothesis that small water bodies are a neglected but very important feature of the landscape, and can be both inventoried and understood in terms of their function through remote sensing and associated analyses.

What evaluation mechanisms were in place for this project? Please describe.

Project evaluation relies upon a 4-tier process:

1. Project investigator/participant meetings and internal review and comparisons. Because one of the primary objectives of the project is intercomparison of the results of multiple methods (of both data acquisition and data interpretation), frequent critical evaluations of progress, findings, and procedures are carried out among and between the project teams. In addition, collegial review has been sought within the participating institutions (e.g., Dr. D. O. Whittemore at KGS and Dr. DeWayne Backhus at ESU).
2. External review of collaborative professionals. Drs. S. V. Smith and W. H. Renwick have solid records of accomplishment in the field and in fact have made major contributions to formulation of the problems addressed. Their continued indirect involvement in project-related activities provides the input of supportive but critical peers to evaluation of progress and products.
3. General public/interested party review and input. An informal website has been established (**www.kgs.ku.edu/Hydro/Ponds**) to present project concepts and results at a level appropriate for public information and education. Presentations at non-specialist meetings (e.g., Sleezer's "Good Morning Lecture" to ESU Faculty and Staff, and presentations at the Water and Future of Kansas Conference -- see Appendix 4) are being made to solicit a broad range of viewpoints and reactions to guide both future research and effective presentation of results.
4. Professional peer review of product publications and proposals. The project results are being prepared for submission to refereed journals and to funding programs that utilize peer reviewers and panels (see sections on Publications and Grants below).

Collaborative efforts took place with the following:

[X] In Same Department
Name of Department/Type of Collaboration
Project is intrinsically collaborative, involving multiple students and faculty/staff from each of two academic departments and two organized research units at the University of Kansas [See lists of investigators above, and participants below].

[X] Other Departments in Same Institution
Name(s) of department/Type of Collaboration
Project multiple students and faculty/staff from each of two academic departments and two organized research units at the University of Kansas; in addition, students employed by or contributing to the project are pursuing academic degrees in other departments (e.g., Computer Science and Electrical Engineering).

[X] Other Institution of Higher Education
Name of Institution(s)/Type of Collaboration
Emporia State University [Dr. R. O. Sleezer, co-investigator]
Miami University (Ohio) [Dr. W. H. Renwick] -- peer review; collaborative planning, analysis, and publication of results.
CICESE (Ensenada, Mexico) [Dr. S. V. Smith] -- as above

[ ] Community College
Name of institution(s)/Type of Collaboration

[ ] K-12 Institution
Name of company or organization, location, and type of collaboration

[ ] Teacher Resource Centers
Name of Teacher Resource Center/Type of Collaboration

[ ] Non-Profit Organizations
Name of organization(s)/Type of Collaboration

[ ] Organization(s) Representing Women, Underrepresented Minorities, or Persons with Disabilities
Name of organization(s)/Type of Collaboration

[ ] Industry/Business
Name of institution(s)/Type of Collaboration

Collaboration with NASA Installations: (If any of the following are checked, please provide name, department, phone number, and type of collaboration. If no collaboration is yet established, please state.)

No formal collaborations have been established yet; however, the following points are related and relevant:

1. Dr. James R. Irons (Goddard; deputy project scientist for Landsat 7 and the project scientist for the next Landsat mission, currently referred to as the Landsat Data Continuity Mission) was contacted in the initial stages of the proposal development and expressed interest in the project and its outcomes; he is being informed of progress and findings to date, and will be re-contacted to explore possibilities in light of the findings obtained so far.
2. The project team, in combination with some of the external collaborators, will submit a proposal in response to NASA Research Announcement NRA-04-OES-01 (Carbon Cycle Science) that will build on and extend to continental scales some of the work and findings developed in this project.
3. The project is conducted in part at, and by staff and students involved with, the Kansas Applied Remote Sensing Program (KARS), home of the Great Plains Regional Applications Center (GP RESAC), one of seven NASA regional applications centers. Project activities are closely interactive with the missions and activities of the GP RESAC.

[ ] Ames Research Center, CA

[ ] Dryden Flight Research Center, CA

[ ] Goddard Space Center, MD

[ ] Jet Propulsion Lab, CA

[ ] Johnson Space Center, TX

[ ] Kennedy Space Center, FL

[ ] Langley Research Center, VA

[ ] John Glenn Research Center, Lewis Field, OH

[ ] Marshall Space Flight Center, AL

[ ] Wallops

[ ] Stennis Space Center, MS[ ] NASA Headquarters, DC

Collaboration with NASA Enterprises (please describe):

[ ] Code M. Human Exploration and the Development of Space

[ ] Code Y. Mission to Planet Earth

[ ] Code R. Aeronautics and Space Transportation Technology

[ ] Code S. Space Science

Collaborations with:

[ ] Space Grant Consortium program
Name of Space Grant and program/Type of Collaboration

[ ] Other EPSCoR Programs
Name of EPSCoR Program/Type of Collaboration

[ ] Other Federal Government Agency
Name of agency or program/Type of Collaboration

[X] Other State Agencies
Name of agency or program/Type of Collaboration

Kansas Data Access and Support Center (DASC): evaluation of hydrologic, GIS, and database products used by and disseminated to both state agencies and the general public (ongoing).

Kansas Department of Agriculture, Division of Water Resources; Kansas Water Office; Kansas Division of Wildlife and Parks; Kansas State University: initial stages or planned collaboration on application of results to land and water use classification for hydrology, habitat and agriculture (in development)

[ ] Other Groups or Agencies
Name of agency or program/Type of Collaboration

[ ] Other EPSCoR Agencies:

[ ] Department of Defense

[ ] Department of Energy

[ ] Environmental Protection Agency

[ ] National Institute of Health

[ ] National Science Foundation

[ ] US Department of Agriculture

Please provide the names of the participants involved and indicate gender and ethnic background on the following table.

Names:

	Male	Male Underrepresented (include disabled)	Female	Male Underrepresented (include disabled)	Unknown Race/Gender
Faculty					
Robert Buddemeier	X				
Stephen Egbert	X				
F. J. deNoyelles	X				
Richard Sleezer	X				
William Renwick	X				
Stephen V. Smith	X				
Post-Doc					
Xiaoyong Zhan		X			
Graduate Student					
Michael Houts	X				
Patrick Taylor	X				
Brianna Mosiman			X		
Asif Iqbal		X			
Jon Vopata	X				
Elizabeth Wilson-Agin			X		
Undergraduate Student					
Zachary Andereck	X				
Administrator					
Research Assistant/Tech					
David Young	X				
Other					

If other, please specify:

Describe any recruitment and/or retention strategies for members of underrepresented groups (women, minorities, or persons w/disabilities) that ensure participation in this project:

Due to the short duration of both the proposal process and the project itself, no-project specific recruitment could be undertaken, and there is no retention to consider beyond the strategies and procedures in place within the participating institutions and administrative units – with which we fully comply.

Activities funded by this project:

[x] Seed money for research

[ ] Technical writing services

[x] Travel to present paper

[x] Student Assistant

[ ] Travel to attend conference/workshop

[x] Computer Services

[x] Establish research collaboration

[x] Develop information resources for research opportunities

[ ] Visiting Scholar

[ ] Hold conference or workshop

[ ] Other (Specify)

[x] Proposal Preparation

Publication Citations related to NASA EPSCoR funding. Please indicate peer-reviewed/refereed (if applicable), presentation (if applicable), include all of citation:

The following abstracts have been accepted for presentation at the annual Water and the Future of Kansas Conference, March 11, 2004, Lawrence KS. Abstract texts are attached in Appendix 1.

<u>Posters</u>

1. R. O. Sleezer, D. P. Young, J. Vopata, E. Wilson, and Z. Andereck. ASSESSING TEMPORAL CHANGES IN PONDS AND POND NUMBERS USING HISTORICAL AIR PHOTOS: A COMPARISON BETWEEN THE MIDLAND AND ALLEN SE QUADRANGLES.
2. S.L. Egbert, B.N. Mosiman, and P. Taylor. A COMPARISON OF POND INVENTORIES USING SATELLITE AND AIRBORNE SENSORS.
3. D. P. Young, R. O. Sleezer, X. Zhan, and R. W. Buddemeier. WATERSHED PARAMETERIZATION USING GEOSPATIAL MODELING AND PRELIMINARY ASSESSMENT OF THE EFFECTS OF SMALL IMPOUNDMENTS (PONDS).
4. M. Houts, J. deNoyelles, R. O. Sleezer, and D. P. Young. USING MULTISPECTRAL AIRBORNE IMAGERY TO INVENTORY AND ASSESS RURAL WATER BODIES.

<u>Oral</u>

5. R. W. Buddemeier, R. O. Sleezer, D. P. Young, S. Egbert, F. J. deNoyelles, X. Zhan, W. H. Renwick, and S. V. Smith. SMALL ARTIFICAL WATER BODIES: A NEGLECTED BUT IMPORTANT FACTOR IN WATER SUPPLY AND ENVIRONMENTAL QUALITY.

<u>Publications in preparation</u>:

Sleezer, R. O., Young, D. P. Vopata, J. A Tale of Two Quadrangles: Using historical airphotos to study temporal changes in the number of ponds in two locales in Eastern Kansas. Current Research in Earth Science.

Sleezer, R. O., Renwick, W. H., and others to be determined. Comparative geography, history, and landscape effects of pond development in different mid-continent land-use regimes. Journal of Soil and Water Conservation.

Presentations:

Sleezer, R. O. In pursuit of artificial ponds, puddles, and transient damp patches. Presentation to faculty and staff as part of the ESU Good Morning Lecture series. October 2003.

Patents, Patent Applications, or Invention Disclosures related to NASA EPSCoR funding. Please include all of citation:

Grants & Financial Awards. Please include the name of grant, name of PI, granting agency(ies), length and date of award:

The project team (R. W. Buddemeier, PI), in combination with some of the external collaborators, will submit a proposal in response to NASA Research Announcement NRA-04-OES-01 (Carbon Cycle Science) that will build on and extend to continental scales some of the work and findings developed in this project.

Sleezer, R. O. and Renwick, W. H. will submit a proposal to study the cultural aspects of pond construction and use to the NSF Geography Program in August 2004.

How is this project contributing to the economic development of the state?

The project is preparing students to work in teams with a variety of technologies to solve problems that transcend disciplinary boundaries – critical attributes for an effective workforce, at both state and national levels.

Project results (water and sediment budgets and movement) have a direct bearing on the critical problems, such as reservoir siltation and water quality, that have the potential to limit or inhibit economic development.

Describe senior faculty mentoring junior faculty in this project.

Junior faculty (Sleezer, Egbert) are taking leadership roles in a collaborative, multidisciplinary project with the senior faculty (Buddemeeir, deNoyelles) providing active participation, and advice. Experience in program and project development, management, and funding are the experiential results, as well as extended contacts within the larger research community.

Which non-Ph.D. granting institutions are involved in this project?

Direct participation: Emporia State University, Emporia, KS
Indirect/collaborative participation: Miami University (Oxford, Ohio)

Appendix 1: Summary results submitted by the ESU team (with KGS support and participation)

Some Summary Statistics for Lyon County/Allen SE Quadrangle

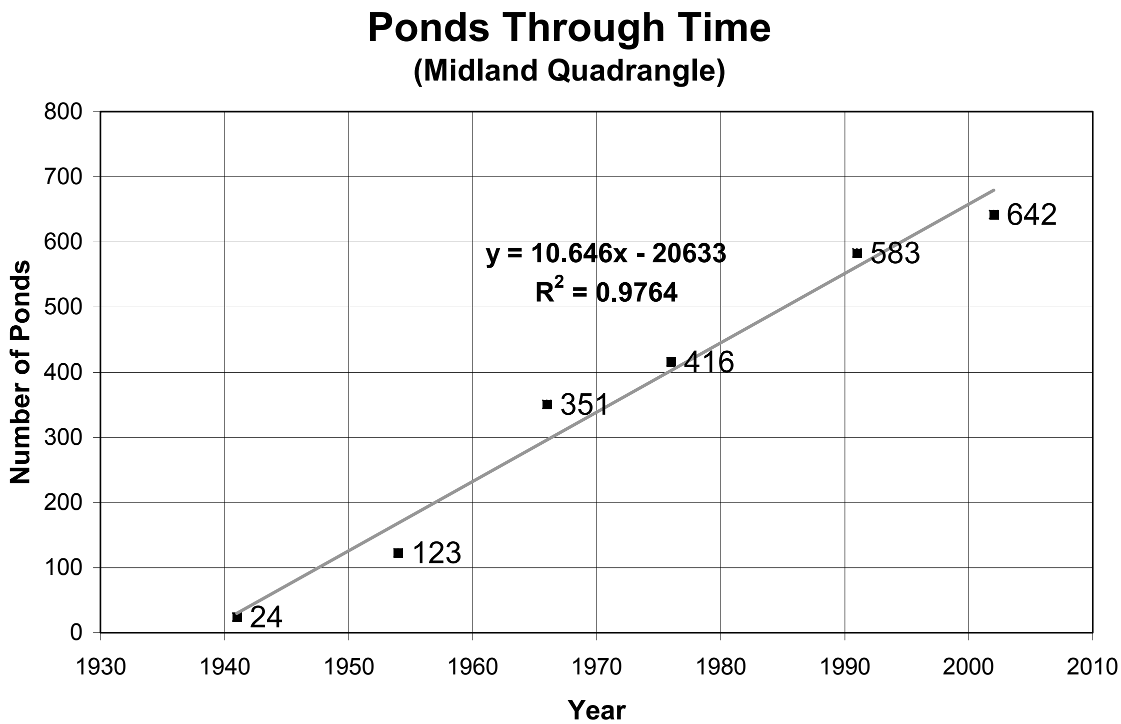
Year	Lyon County/Allen SE Quad	# of Images Scanned	# of Images Registered and Rectified	Allen SE Mosaic Compiled	# of Ponds Digitized
1944-45	Lyon County	250	250	Yes	247
1959	Lyon County	234 (Scanned by KU Library)	234	Yes	479
1979	Lyon County	240 (Scanned by KU Library)	240	Yes	495
1980	Lyon County	850	850	Yes	498
1991	USGS DOQQ	None (Digital Already)	None (Already Reg. & Rec.)	No	472
1993	Lyon County	850	800	Yes	473
1997	Lyon County	None (Digital Already)	None (Already Complete from Lyon County)	No	496
2003	Allen SE	None (Digital Already)	560	Yes	541

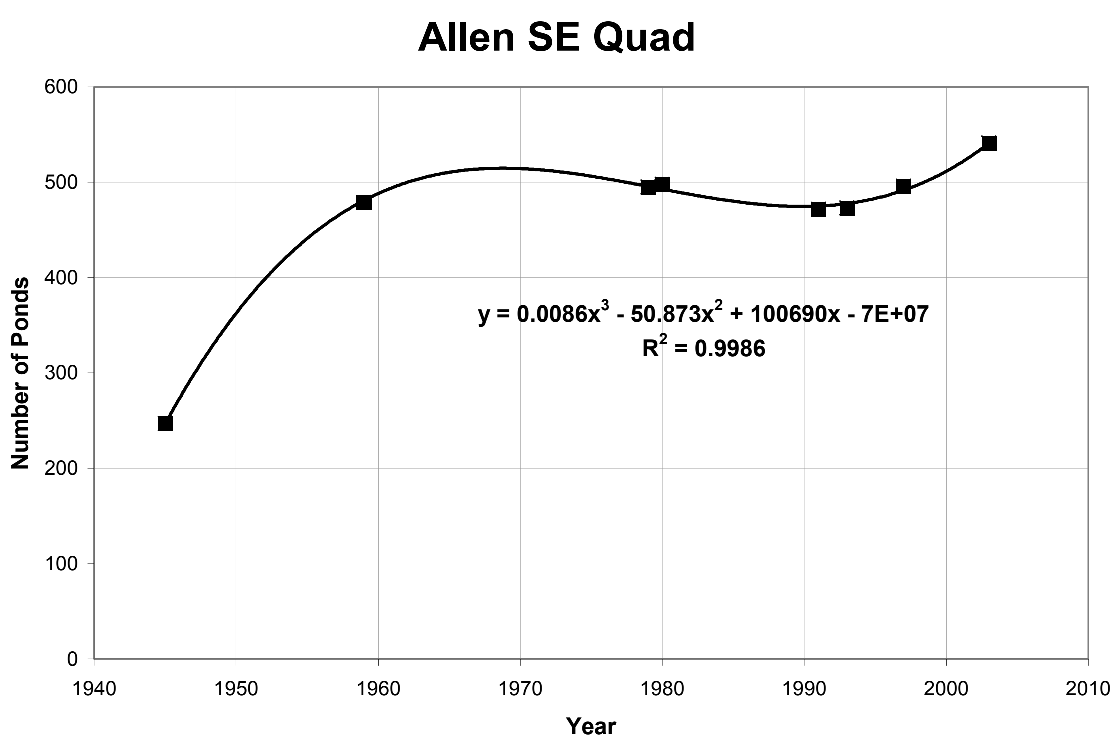
Summary Statistics for Leavenworth/Douglas/Jefferson County/Midland Quadrangle
(Images were already registered and rectified.)

Year	Number of Ponds Digitized Each Year
1941	24
1954	123
1966	351
1976	416
1991	583
2002	642

Other activities include quality control checking of digitized pond polygons (in-progress), comparisons between pond building through time and county level agricultural statistics (in-progress), field checking the locations of ponds, compilation of a journal article comparing pond numbers in the Midland and Allen SE quads through time (in-progress) and digital ground truth photos taken in the field to confirm the character of ponds (>100 photos taken). In addition a presentation was given at ESU of findings to date regarding changes in pond numbers with time.

Graphs for Allen SE and Midland Quad ponds through time.





Appendix 2: Summary of Results submitted by KBS/KARS Remote Sensing team

Using Remotely Sensed Images to Estimate the Number and Surface Area of Ponds in Northeast Kansas

Stephen L. Egbert, Brianna N. Mosiman, and Patrick Taylor
Report prepared by Patrick Taylor and Stephen L. Egbert

Overview

Artificial ponds far outnumber natural water bodies in the Kansas landscape, and they play a substantial role in modifying the environment. For a number of reasons, including their small size, their location primarily on private property, and variations in their numbers and locations over time, small artificial ponds are often underrepresented on the digital map products and databases normally used for hydrologic analyses. To address the issue of the underestimation of ponds, images from three different satellite and airborne sensors were used to see how accurately they could locate and inventory ponds in a study area in Jefferson County in northeast Kansas. Landsat Enhanced Thematic Mapper (ETM+) 30-meter multispectral imagery, Terra ASTER 15-meter multispectral imagery, and 1-meter multispectral imagery from a DuncanTech airborne digital camera were used to create maps of water bodies. Our objective was to determine by how much the number of ponds in the Kansas landscape is underestimated using satellite imagery at different spatial resolutions.

Based on our assumption that the maps derived from the 1-meter airborne digital imagery would provide the most detailed and accurate estimate of the actual number of ponds in the study areas, we used them as the basis for comparison with the maps derived from Landsat and ASTER imagery. We computed the number of water bodies, their size classes, and the total water surface area. In addition to comparing results of the digital airborne camera inventory to maps from the two satellite sensors, we also compared them to two inventories of water bodies that were previously created: the Kansas Surface Water Database (KSWD) and the Surface Waters Information Management System (SWIMS).

Data Sets

Duncan Tech (DT) Digital Aerial Imagery: The 1-meter Duncan Tech digital aerial camera acquires imagery with three spectral bands:

Band 1	Blue/Green	0.45 - 0.52 µm
Band 2	Red	0.63 - 0.69 µm
Band 3	NIR	0.76 - 0.90 µm

44 scenes from three dates: 12 April 2003, 9 May 2003, and 9 June 2003

ASTER: *A*STER is a multi-band sensor on board NASA's Terra satellite. For this study, only the three 15-meter spectral bands were used:

Band 1	Green	0.52 - 0.60 µm
Band 2	Red	0.63 - 0.69 µm
Band 3	NIR	0.76 - 0.86 µm

Image date: 6 August 2001

Landsat Enhanced Thematic Mapper (ETM+): The Landsat 7 ETM+ imagery used for this project was a six-band dataset with 30-meter spatial resolution. (The thermal band was removed for this analysis because of its 60 m spatial resolution):

Band 1	Blue/Green	0.45 - 0.52 µm
Band 2	Green	0.52 - 0.60 µm
Band 3	Red	0.63 - 0.69 µm
Band 4	NIR	0.76 - 0.90 µm
Band 5	Mid IR	1.55 - 1.75 µm
Band 6	Mid IR	2.08 - 2.35 µm

ImageDate: 21 July 2001

Kansas Surface Water Database (KSWD): The Kansas Surface Water Database (KSWD) was derived from 2000 and 2001Landsat ETM+ imagery at a minimum mapping unit of 1.5 acres. It was completed in 2003 and is distributed through the Kansas Data Access and Support Center (DASC) at the Kansas Geological Survey.

Surface Water Information Management System (SWIMS): The Surface Waters Information Management System (SWIMS) was created using the Environmental Protection Agency's (EPA) River Reach Files (RF3). The RF3 files were developed from 1:500,000-scale NOAA aeronautical charts and 1:100,000-scale digital line graphs developed by USGS. It also is available online at the Kansas Data Access and Support Center (DASC) at the Kansas Geological Survey.

Data Processing

ASTER

The ASTER image was processed using an unsupervised classification procedure in ERDAS Imagine. Using the ISODATA clustering algorithm, 100 spectral clusters were defined. The clusters that represented water were then combined into a 'Water' class and the remaining classes were combined into a class called 'Non-Water.' The result was a raster data set with two classes: water and non-water, that was then brought into ArcMAP and converted to a polygon shapefile. Using the Editor extension, all polygons were visually confirmed to represent actual water bodies. If a polygon did not represent a water body (typically edge polygons), it was deleted. The result was a vector-format estimate of the water bodies. The reason for converting from raster to vector format was to be able to calculate the surface area of each polygon. To facilitate extracting surface area, a tool was developed using ArcObjects to extract each polygon area from the "shape" field within the shapefile.

Landsat Enhanced Thematic Mapper (ETM+)

The ETM+ image was processed in the same manner as the ASTER image, first using an unsupervised classification procedure in ERDAS Imagine. Using the ISODATA clustering algorithm, 100 spectral clusters were defined. The clusters that represented water were then combined into a 'Water' class and the remaining classes were combined into a class called 'Non-Water.' The result was a raster data set with two classes: water and non-water, that was then brought into ArcMAP and converted to a polygon shapefile. Using the Editor extension, all polygons were visually confirmed to represent actual water bodies. If a polygon did not represent a water body (typically edge polygons), it was deleted. The result was a vector-format estimate of the water bodies.

DuncanTech Digital Aerial Imagery

Forty-four scenes from three different dates (12 April 2003, 9 May 2003, and 9 June 2003) were mosaicked together using ERDAS Imagine. All water bodies were then digitized into a vector layer using standard heads-up digitizing procedures. The resulting vector layer was then saved as a polygon shapefile, which was then brought into ArcMap for calculation of the number of water bodies and their surface areas. In addition a polygon layer was created that represented the extent of all the 44 DuncanTech images. This layer constituted the extent of the study sites within the study area and was used to clip all other map layers.

Kansas Surface Water Database (KSWD)

The KSWD was clipped to the extent of the 44 Duncan Tech images. It was converted from a raster layer to a polygon shapefile. The number of ponds and their surface area were then calculated.

Surface Water Information Management System (SWIMS)

This dataset was downloaded from DASC in shapefile format. The polygons were clipped to the extent of the 44 DuncanTech scenes and the resulting shapefile was added to ArcMap, where the number of ponds and surface area were calculated.

Results

As expected, the number of ponds identified by each of the three multispectral sensors (ETM+, ASTER, and DuncanTech) varied directly with spatial resolution, with the greatest number of ponds being identified by the sensor with the highest spatial resolution (DuncanTech digital aerial camera). In particular, it is noteworthy that imagery from Landsat's ETM+ sensor, which is the most widely available low-cost multispectral imagery source, successfully mapped only 60% of the actual ponds in the study sample. Based on the results, it appears likely that multispectral imagery with spatial resolution on the order of 4 meters (such as imagery from the Ikonos and Quickbird satellites) would permit mapping small ponds with sufficient accuracy without incurring the storage and processing overhead entailed in using 1-meter imagery.

An interesting, and somewhat unexpected result was that the total estimated surface area actually increased with poorer (i.e., coarser) spatial resolution. This is undoubtedly attributable to the large relative size of the coarser pixels and the tendency of the image processing methodology to identify mixed water pixels as belonging to the water class.

As expected, the two surface water databases (KSWD and SWIMS) grossly underestimated the number of water bodies, although, to be fair, neither database was designed to be an inclusive map of all water bodies. It does underscore, however, the potential danger of using databases for purposes for which they were not designed – in this case the identification and mapping of small, but environmentally important, farm ponds.

Table: Estimates of Number of Water Bodies and Total Surface Area

Data Set	# Water Bodies	% of Actual Number	Total Sfc. Area (sq. km.)	% of Actual Area
DuncanTech	97	100%	179.9	100%
ASTER	83	86%	202.0	112%
ETM+	58	60%	231.4	128%
KSWD	3	3%	26.1	15%
SWIMS	1	1%	23.6	13%

Table: Commission and Omission Errors in Satellite Imagery-Derived Estimates

Sensor	Commission Error	Omission Error
ASTER	6	20
ETM+	1	40

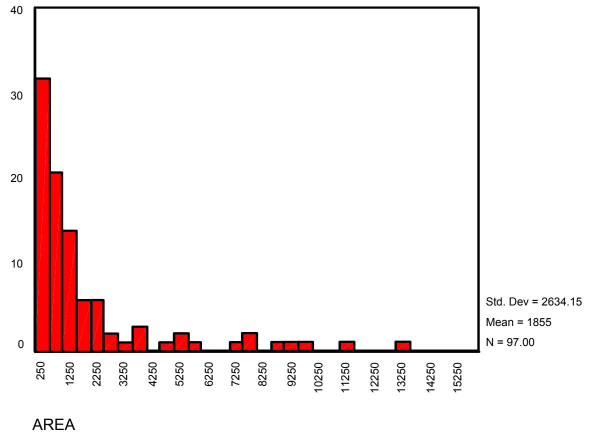
Explanation:

- ASTER erroneously identified 6 non-existent ponds, but failed to identify 20 ponds that were mapped using the DuncanTech imagery
- ETM+ erroneously identified 1 non-existent pond, but failed to identify 40 ponds that were mapped using the DuncanTech imagery

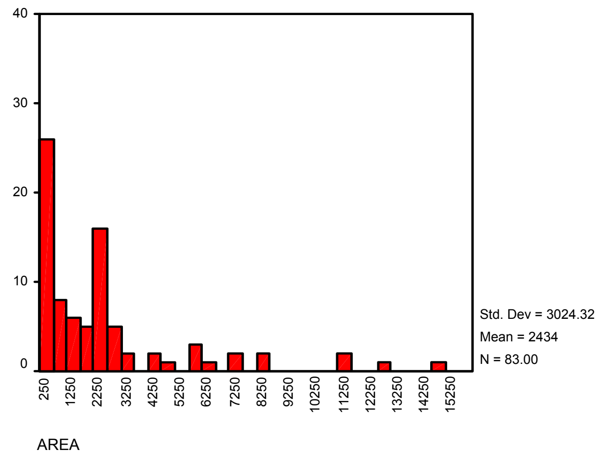
The figure below graphically illustrates that, as expected, it is the smallest water bodies that are missed by the ASTER and ETM+ sensors because of the relatively coarse spatial resolution (15 meters and 30 meters, respectively) of those sensors.

Figure: Size Distribution of Water Bodies, by Sensor
(Y-axis = # of ponds; X-axis = surface area, in square meters)

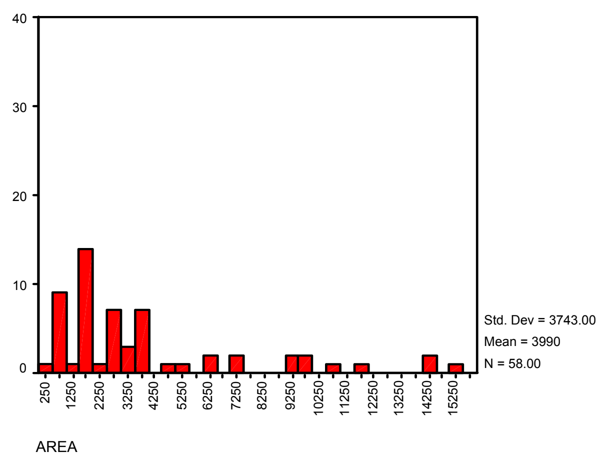
DuncanTech (1 m)



ASTER (15 m)



ETM+ (30 m)



Appendix 3: Summary of results submitted by KBS/KARS Pond characterization team

Using Multispectral Airborne Imagery to Inventory and Assess Rural Water Bodies

Michael Houts, Jerry deNoyelles, Richard Sleezer, Dave Young

Report prepared by Michael Houts

Overview

Multispectral satellite imagery is commonly used to map water bodies and vegetation conditions, but the coarse spatial and temporal resolution often make it less than ideal for certain projects. To address this issue, a multispectral airborne imaging system was developed around a DuncanTech MS3100 digital camera that can provide sub meter data when and where researchers need it. The system acquires data from the blue, red, and near infra-red portions of the spectrum while a log file records the GPS location of each picture allowing for easy geo-referencing.

The imaging system was recently utilized to inventory and assess the conditions of the numerous small rural ponds that are scattered across Kansas. Airborne imagery was acquired over 100 experimental ponds at the University of Kansas and approximately 56 square miles in Lyon County. Researchers analyzed spectral patterns against field observations and documentation about the ponds history. Special emphasis was placed on identifying shoreline vegetation conditions and the succession stage of the pond. It was found that the imagery could distinguish a variety of pond shoreline conditions and was also useful for assessing water turbidity levels (indication of sedimentation rate). Using the imaging system, researchers were able to obtain information about a much larger area for the same time and cost than would have been possible using traditional field sampling.

Data Sets

Duncan Tech (DT) Digital Aerial Imagery: The 1-meter Duncan Tech digital aerial camera acquires imagery with three spectral bands:

Band 1	Blue/Green	0.45 - 0.52 µm
Band 2	Red	0.63 - 0.69 µm
Band 3	NIR	0.76 - 0.90 µm

Location 1: Nelson Environmental Study Area, University of Kansas, Lawrence, Kansas.
- 4 aerial images from June 27, 2003
  - images covered less than one mile and contained 104 experimental ponds
- Field observations and photographs from June 30, 2003

Location 2: Allen SE quad, north east Lyon County, Kansas.
- 560 aerial images from November 6, 2003,
  - image area covered 56 square miles and contained 541 ponds.
- Field observations and photographs

Methods:

DuncanTech images of ponds were compared with the field data and photos from the corresponding pond to visually identify and assess shoreline vegetation and water body characteristics. After patterns began to emerge, researchers utilized the multispectral properties of the imagery in an attempt to quantify the differences in turbidity and vegetative conditions.

Results:

The near infra-red data from the images provided detailed insights in to the condition and extent of floating and shoreline vegetation.

Spectral analysis of the data showed that turbidity was positively correlated with reflectance values from the blue and red wavelengths. This relationship allows researchers to stratify water bodies by their turbidity levels.

So What:

The ability to use aerial imaging to assess the vegetation in and around water bodies, as well their turbidity levels can provide useful information for land, water, and resource managers. Using aerial photography, large areas of land can be assessed in a much more time and cost efficient manner than using traditional ground surveys. Additionally, the aerial photos allow access to water bodies that are difficult to access due to geographic barriers and/or land ownership issues. For example, it took only 4 hours to acquire the 560 images that contained 496 ponds scattered throughout 56 square miles or rural Lyon County.

Appendix 4: Publications/presentations

Copies of the accepted abstracts (Water and Future of Kansas conference) mentioned in the body of the report are attached.

SMALL ARTIFICAL WATER BODIES: A NEGLECTED BUT IMPORTANT FACTOR IN WATER SUPPLY AND ENVIRONMENTAL QUALITY.

R. W. Buddemeier[a], R. O. Sleezer[b], D. P. Young[a], S. Egbert[c], F. J. deNoyelles[d], X. Zhan[a], W. H. Renwick[e], and S. V. Smith[f]

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Recent studies[1] have shown that artificial ponds of various types and purposes are ubiquitous features of the landscape in many areas of the US, far outnumbering natural water bodies. Because they are small, mostly on private property, and their numbers and locations vary over time, they are very poorly represented on the digital map products and databases normally used for hydrologic analyses. However, in many areas they are a major factor in controlling the residence time of surface water, in trapping sediment, and in providing a network of biogeochemical reactors that modify loads of nutrients and other solutes. By filtering and slowing the movement of surface water, pond networks have a positive effect on development of surface water supplies in that they trap sediment and may prolong the life of larger supply reservoirs; however, they also tend to reduce net runoff at the expense of evaporation and infiltration. In terms of water quality, particularly in agricultural areas, ponds may provide some of the beneficial effects of riparian zones by intercepting and transforming nutrients and contaminants. Ecologically, the ponds provide habitat diversity and may partly replace diminished wetland inventories, but many are in areas that lacked natural water bodies and thus can serve as homes or pathways for non-native pest or invasive species.

Kansas straddles the North American transition from very high pond densities in the east to much lower densities in the west,[1] and thus provides an ideal mesocosm in which to explore issues of pond detection, inventory, histories, and hydrologic and biogeochemical effects at the landscape scale. A multi-institutional interdisciplinary project[2] is applying a combination of remote sensing, field characterization, and modeling studies to calibrate satellite observations (Landsat TM and ASTER) with multispectral and conventional aerial photography, and to evaluate the potential application of results to a wide range of water resource and environmental studies. Case study efforts focus on Jefferson and Lyon counties, with detailed investigation of the Midland and Allen SE quadrangles.

Results confirm the under-reporting of ponds in available data sources and show similarly high densities in both the Midland (9.3/mi2; 3.5/km$^{2)}$ and Allen SE (8.6/mi2; 3.2/km^2) quads, but historical air photos dating back to the 1940s indicate very different temporal patterns of development in the two case study areas. Spectral analysis of satellite and camera images indicates that the tools are capable of identifying a wide range of pond water quality and ecological conditions, and initial watershed spatial model analyses are being used to test and refine earlier, more general results or assumptions about the effects of ponds on the net evaporation budget, filtration effectiveness for sediment retention, and relationships between pond numbers and types and land use. The presentation will illustrate the results being obtained and their potential importance to water resource and environmental quality issues.

[1]Smith, S. V., Renwick, W. H., Bartley, J. D., and Buddemeier, R. W. 2002. Distribution and significance of small, artificial water bodies across the United States landscape. The Science of the Total Environment 299:21-36.
[2]Supported by NASA and KTECH through the KU EPSCoR Program

A Comparison of Pond Inventories Using Satellite and Airborne Sensors

S.L. Egbert, B.N. Mosiman, and P. Taylor. 2004. A Comparison of Pond Inventories Using Satellite and Airborne Sensors, *Water and the Future of Kansas 20th Annual Conference*. Manhattan, Kansas. March 11, 2004.

Artificial ponds exist throughout the Kansas landscape, far outnumbering natural water bodies, and they play a substantial role in modifying the environment. For example, they trap sediment, thereby affecting biogeochemical cycles, and they also provide habitat diversity and may provide a partial counterbalance to lost wetlands. For a number of reasons, including their small size, their location primarily on private property, and variations in their numbers and locations over time, small artificial ponds are often underrepresented on the digital map products and databases normally used for hydrologic analyses. To address the issue of the underestimation of ponds, images from three different satellite and airborne sensors were used to see how accurately they could locate and inventory ponds in three different study areas in Lyon and Jefferson counties. Landsat Enhanced Thematic Mapper (ETM+) 30m multispectral imagery, Terra ASTER 15m multispectral imagery, and digital orthoquads (DOQs) derived from 1m aerial photography were used to create maps of water impoundments. For the Landsat and ASTER imagery, an unsupervised clustering and classification technique was applied; for the DOQs both traditional manual methods (primarily heads-up on-screen digitizing) as well as object-oriented segmentation algorithms were applied. For each study area, we computed the number of water bodies, their size classes, and the total water surface area. Based on our assumption that the maps derived from the DOQs would provide the most detailed and accurate estimate of the actual number of ponds in the study areas, we used them as the basis for comparison with the maps derived from Landsat and ASTER imagery. Since it is generally impractical (due to cost and time considerations) to manually map small ponds from detailed imagery, our objective was to determine by how much we underestimate the number of ponds in the Kansas landscape using satellite imagery. In addition to comparing results of the DOQ inventory to maps from the two satellite sensors, we also compared them to two inventories of water bodies that were previously created. The most recent is the Kansas Surface Water Database (KSWD) which was derived from 2000 and 2001 Landsat ETM+ imagery at a minimum mapping unit of 1.5 acres and became available for use in 2003. The second inventory of water bodies is the Surface Waters Information Management System (SWIMS). This database was created using the Environmental Protection Agency's (EPA) River Reach Files (RF3). The RF3 files were developed from 1:500,000-scale NOAA aeronautical charts and 1:100,000-scale digital line graphs developed by USGS.

Using Multispectral Airborne Imagery to Inventory and Assess Rural Water Bodies

Michael Houts[1], Jerry deNoyelles[2],…

[1] Kansas Applied Remote Sensing Program
[2] Kansas Biological Survey

Key words: water, ponds, succession, riparian, remote sensing

Multispectral satellite imagery is commonly used to map water bodies and vegetation conditions, but the coarse spatial and temporal resolution often make it less than ideal for certain projects. To address this issue, a multispectral airborne imaging system was developed around a DuncanTech MS3100 digital camera that can provide sub meter data when and where researchers need it. The system acquires data from the blue, red, and near infra-red portions of the spectrum while a log file records the GPS location of each picture allowing for easy geo-referencing.

The imaging system was recently utilized to inventory and assess the conditions of the numerous small rural ponds that are scattered across Kansas. Airborne imagery was acquired over 100 experimental ponds at the University of Kansas and approximately 56 square miles in Lyon County. Researchers analyzed spectral patterns against field observations and documentation about the ponds history. Special emphasis was placed on identifying shoreline vegetation conditions and the succession stage of the pond. It was found that the imagery could distinguish a variety of pond shoreline conditions and was also useful for assessing water turbidity levels (indication of sedimentation rate). Using the imaging system, researchers were able to obtain information about a much larger area for the same time and cost than would have been possible using traditional field sampling.

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Assessing Temporal Changes in Ponds and Pond Numbers Using Historical Air Photos: A Comparison Between the Midland and Allen SE Quadrangles

R. O. Sleezer, D. P. Young, J. Vopata, E. Wilson, and Z. Andereck

Recent work has demonstrated the importance of the cumulative effects of small artificial impoundments (ponds) on landscape-scale cycles of water, sediment, and carbon at scales ranging from local to continental. Initial analyses of data currently available for the contiguous 48 United States indicate that commonly-used available maps and electronic coverages under-represent the number and areal density of small pond features by up to two orders of magnitude. They also do not provide a clear picture of the temporal changes in ponds and pond numbers that have occurred over the past 60 years. There are four basic questions that need to be addressed. How do we accurately detect and count small artificial water bodies (ponds)? 2) How many ponds have been built? 3) How have the numbers and spatial distribution of ponds changed during the last 60+ years? 4) What are the ecological, biogeochemical, and environmental functions and effects of ponds in an altered landscape?

This research addresses the first three perceived needs by studying ponds using historical air photos for two topographic quadrangles in eastern Kansas. Eastern Kansas contains a high density of ponds within a variety of topographic and land use settings, making it an ideal site to evaluate detection and classification techniques for ponds as well as their environmental effects. Air photo coverage begins in the 1940s for both quadrangles and at least 6 sets of air photos from different time intervals are available for both areas. By digitizing ponds using digital imagery in a GIS format, temporal changes in the numbers of ponds, their variations in size, and their life expectancy in different topographic, land use, and geological settings can be assessed.

Results indicate that more ponds were built earlier (1940s) in areas dominated by cattle grazing (Allen SE quad, Lyon County). Pond numbers in the Midland quad (Jefferson County) have increased through time at a rate of about 10 per year from 24 in 1941 to 642 in 2002. The functional intention of ponds within the Allen SE quad appears to still be water for cattle while many of the new ponds in the Midland quad appear to be used for other purposes. Ponds also appear to be temporal features in that some appear to fill in and disappear from the landscape thereby complicating their detection in relatively short periods of time ($\leq$ 40 years) while others are apparently more permanent.

Watershed parameterization using geospatial modeling and preliminary assessment of the effects of small impoundments (ponds).

D. P. Young, R. O. Sleezer, X. Zhan, and R. W. Buddemeier

Small watershed impoundments (ponds) cumulatively have major effects on surface drainage and on the transport of suspended and dissolved materials. However, they are often small enough to be missed in most mapping and water-body inventory activities, many have lifetimes on the order of a few decades, and they may be “replaced” by new ponds in different locations. In areas of relatively high pond density, the hydrologic landscape is a shifting mosaic of small sub-watersheds.

The cumulative importance of the networked impoundments and the difficulty of individual detection and characterization places a premium on the ability to predict occurrences and behavior from knowledge of the environment and land use, and on the ability to extrapolate or generalize from case studies, or from limited samples and information.

We address these issues using concurrent ‘top-down’ and ‘bottom-up’ techniques.

As input for developing a predictive model of pond siting, functions, and lifetimes, we use TOPAZ and a recently-developed user-interface. TOPAZ (Topographic Parameterization) is a computer model tool for automated digital landscape analysis: topographic evaluation, drainage identification, watershed segmentation, and subcatchment parameterization. Primarily applications of TOPAZ are to assist with topographic evaluation and watershed parameterization in support of hydrologic modeling and analysis, and to provide quantitative analysis for a variety of geomorphological, environmental, and remote sensing studies. We apply it to a digital elevation model (DEM) to develop a parameterized substrate on which to overlay the known occurrences and longevities of ponds in a case study area, in order to develop potentially robust hydrologic and topographic relationships.

Concurrently, in the same larger case-study watershed, we perform detailed GIS analyses of the individual pond sub-basins, using land use and soil type coverages as well as records (time series air photos) of pond life histories. This detailed analysis of the landscape relationships of individual impoundments, and of their evolution over time, nests within the larger context provided by the TOPAZ model to build toward reliable predictors of pond densities and effects based on widely available and easily analyzed datasets.