# FINAL REPORT
# GCMRC REMOTE SENSING PROTOCOLS REVIEW PANEL



**BY**

**Lenn Berlin**
**John Brockhaus**
**Tommy Coleman**
**Barry Haack**
**Carol Johnston**
**Cleavy McKnight**
**Peter Murtha**
**Timothy Warner**

**FOR**

**David Garrett**
**Chief, Grand Canyon Monitoring and Research Center**
**U.S. Geological Survey**

**June 15, 1998**

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**Panel Mission:** To evaluate remotely sensed monitoring and research measurement methodology currently used by the GCMRC, identify opportunities for applying alternative remote sensing technologies to achieve information needs, and identify any alternative processing methods for new or existing remotely sensed data sets.

**Panel Charges:**

1. How well do existing GCMRC remote sensing protocols meet information needs as described in the revised management objectives, with respect to:

   A. System-wide two and three dimensional sand bar changes?
   B. Reach specific changes in pre-dam river terraces containing archaeological sites and arroyos?
   C. System-wide changes in riparian vegetation?
   D. System-wide changes in rapids (navigation) and debris-fan eddy complexes (fine sediment storage)?
   E. Reach-varied aquatic productivity?
   F. Reach-specific changes in backwater habitat distribution?
   G. Episodic inputs of suspended sediment to the mainstream?
   H. Changes in water quality parameters, including temperature, conductivity, and pH?
   I. Basin characteristics associated with sediment source areas (soil types and lithologies) within ungauged and gauged watersheds?
   J. Channel geometry and changes in geometry due to increased fine-sediment storage and evolving grain size distribution of bed sediments (bathymetry)?
   K. System wide shoreline topography?
   L. Other issues?

2. What alternative remote sensing technologies might better meet revised management objectives and information needs in new or existing areas? Please identify which technologies may be considered experimental as opposed to those considered to be operational.

3. In what areas should GCMRC have concerns about data continuity with previous remotely sensed data?

4. What are processing time requirements for remotely sensed data? How soon is it available to provide information on resource changes over time?

**Additional Comments:** In addition to addressing the above items, the Review Panel also addressed the following topics:

1. Comments regarding the review procedure and the Review Panel.
2. Comments for the remote sensing coordinator and researchers.
3. General comments.

**1. How well do existing GCMRC remote sensing protocols meet information needs as described in the revised management objectives?**

**A. System-wide, two- and three-dimensional (2-D, 3-D) sand bar changes:**

**i)** Very good 2-D data currently exists for 34 sand bars using oblique photo monitoring, but the need for these data was not made clear.

**ii)** What is the relationship between Utah State University (USU) and Northern Arizona University (NAU) studies?

**iii)** What is the relationship to management objectives and dam operations?

**iv)** The sand bar change program is not system wide.

**v)** The proposed 3-D, oblique photogrammetric technique is the key to calculating sand bar volumes; we applaud the efforts of Mark Manone (NAU) to test this technique. This technique would also appear to be applicable for monitoring beach campsites.

**vi)** Explore the use of digital or softcopy photogrammetric techniques with 1:4,800 digitized (25 μm scans or smaller) stereopairs and evaluate primary and secondary products (e.g., digital orthophotos with contours and grids, perspective-view images, DEM [digital elevation model] grayscale images, shaded-relief images, and anaglyphs) (contact Trent Hare, USGS Flagstaff Field Center).

**vii)** SIDE ISSUE: Is the sampling representative?

**B. Reach-specific changes in pre-dam river terraces containing archaeological sites and arroyos:**

**i)** Because of spatial resolution constraints, traditional airborne remote sensing would not be applicable for identifying archaeological sites marked by flake, sherd, and/or lithic scatters.

**ii)** Repetitive, vertical aerial photography might be most useful for monitoring terrace stability at known archaeological sites. Oblique photographs might also be useful for monitoring purposes at some sites; these photos could perhaps be obtained during videography and/or airphoto overflights.

**iii)** Color infrared (CIR) and natural color vertical airphotos could be evaluated for ethnobotanical-resource monitoring when specific plant communities are involved. If successful, communities/habitats likely to contain target plants could be identified, and these communities/habitats could be located and monitored remotely.

iv) SIDE ISSUE: Have the in-house airphotos been analyzed to determine if any of the 300+ known archaeological sites are identifiable?

**C. System-wide changes in riparian vegetation:**

i) This program is not currently system-wide. Only nine sites have been mapped, and it is not clear if these sites are representative.

ii) What is the relationship between the work done by Ralston (1994 airphotos) and Patrick (1990 airphotos)?

iii) Alternatives to panchromatic and natural color airphotos should be explored; CIR photography would probably offer the best potential.

iv) Because water input from monsoonal precipitation is important ("leaf on"), the critical time for airphoto acquisitions should be during the late summer or early fall.

v) SIDE ISSUE: More effort is needed on biological research and monitoring.

**D. System-wide changes in rapids (navigation) and debris-fan eddy complexes (fine sediment storage):**

i) This program is not currently system-wide, but the current technologies could be extended throughout the system.

ii) Explore the use of computer-aided, texture analysis of digitized and/or digital airphotos; because of micro-shadowing differences, this image processing technique may prove useful for categorizing fan/bar surfaces.

iii) Explore the use of long-wavelength radar images for the texture (i.e., micro-roughness) analysis of fan/bar surfaces and rapids. Two systems are recommended: the Jet Propulsion Laboratory's (JPL) Airborne Synthetic Aperture Radar (AIRSAR) (http://www.jpl.nasa.gov/mip/airsar.html) and the Office of Naval Research's (ONR) SAR, which is operated by ERIM International. Both systems employ a P-band channel ($\lambda = 68$ cm), which offers the added potential for penetrating certain types of the canyon's riverine vegetation that obscures certain fan/bar surfaces. If radar images are acquired, a template should be used at selective sites for making roughness measurements at the centimeter scale. The vertical relief data, derived from the template measurements, can then be used to explain variations in echo return strength, and hence, variations in image brightness.

**E. Reach-varied aquatic productivity:**

i) Test underwater videography to monitor the presence and estimate the concentration of suspended algae or algae mats.

ii) Test one or more multispectral digital imaging systems, coupled with ground-based, multiband radiometer measurements (contact Pat Chavez, USGS Flagstaff Field Center), for suspended algae productivity assessments.

iii) SIDE ISSUE: Relative costs and benefits of remote vs field monitoring?

**F. Reach-specific changes in backwater habitat distribution:**

i) Unclear as to the areal distribution of information.

ii) What reach-specific monitoring is being done and where? The Panel is unclear as to the specifics of (a) changes in backwater habitat availability 1965-1997,
(b) area changes through time over a range of flows (8,000 - 45,000 cfs) using videography and airphotos, and (c) volumetric hypsometry.

**G. Episodic inputs of suspended sediment to the mainstream:**

i) This is not monitored remotely; field methods (gauging and water-sampling stations) are currently the most appropriate because of the infrequency and short duration of these events.

ii) Test in-stream monitoring of turbidity using passive optical sensors (with telemetry?) or multiband radiometer measurements (with telemetry?) as used by Pat Chavez in San Francisco Bay.

iii) SIDE ISSUE: Where are the gauging stations located?

**H. Changes in water quality parameters, including temperature, conductivity, and pH:**

i) Conductivity and pH characteristics cannot be observed directly through changes in water reflectance.

ii) Radiant (not kinetic) temperature data can be collected by remote sensors employing one or more channels in the water vapor window of the electromagnetic spectrum (8 - 14 μm). Consult with Mike Purcherelli regarding previous BOR-RSGIG studies involving thermal infrared (TIR) remote sensing.

**iii)** Test one or more multispectral digital imaging systems with a TIR capability, coupled with ground-based radiant temperature measurements (i.e., at critical backwater habitats).

**iv)** Consult with Pat Chavez regarding his monitoring program in San Francisco Bay (chlorophyll, suspended sediment, turbidity).

**v)** Test one or more multispectral digital imaging systems with channels sensitive to changes in chlorophyll concentration, suspended sediment loads, and turbidity levels. Important band centers include the following: 0.41 μm--turbidity; 0.44 μm--chlorophyll absorption peak; 0.49 μm--chlorophyll and other pigments; 0.51 μm--turbidity, suspended sediment; 0.56 μm--chlorophyll, suspended sediment; 0.62 μm--suspended sediment; 0.66 μm--chlorophyll absorption; and 0.68 μm--chlorophyll flourescence.

**I. Basin characteristics associated with sediment source areas (soil types and lithologies) within ungauged and gauged watersheds:**

**i)** Although remote sensing image data acquired from earth resource satellites could be used for this type of regional-scale mapping project, it would seem to be much more practical to synthesize the relevant data from existing paper and digital maps. In this regard, the National Geologic Map Database Project (GMDP) and the Global Land Information System (GLIS) web pages should be consulted (http://ngmdb.usgs.gov/ngmdb/ngmdb_home.html and http://edcwww.cr.usgs.gov/webglis).

**ii)** GCMRC staff should review and perhaps purchase "The Colorado River Basin Atlas" (CD-ROM), a joint project between ERIM International and NASA The current release (Version 1) includes: Advanced Very High Resolution Radiometer (AVHRR) coverage of the entire basin and Landsat image data for select areas, GIS data layers include boundaries (basin, state, county, city), population, hydrology (water flow, dams, rivers, lakes), transportation, and land use for the entire basin. The CD-ROM also contains the software to use the data. For more information about this product, contact Larry Reed at (313) 994-1200 ext. 3606 (http://www.erim-int.com/ESG/commerce/colorado.htm).

**J. Channel geometry and changes in geometry due to increased fine-sediment storage and evolving grain size distribution of bed sediments (bathymetry):**

**i)** Current bathymetry techniques are good, and the coordination of transect and bathymetric surveying should be strengthened.

**ii)** The radio tagging of boulders to monitor coarse bedload transport is a good idea, which should be continued.

**iii)** The ground penetrating radar (GPR) unit recently purchased by the USGS Marine Division should be tested for beach profiling and for profiling the alluvial/rock interface in the mainstream. For the latter type of profiling, the antenna unit must be in physical contact with the water surface.

**iv)** Test RoxAnn (http://fox.nstn.ca/~nordsea/#RoxAnn), QTC-VIEW (http://www.questercorp.com), and perhaps other operational, digital signal processor systems for sub-bottom acoustic profiling.

**v)** Explore the use of photogrammetry to do bathymetry mapping upstream of the Paria River where the water is clear.

**vi)** The rotating sonar unit produces truly unique data sets, and its use should continue with the side-scan sonar surveys.

**vii)** Underwater videography should be tested for monitoring suspended sediment, algae, and turbidity, and potentially for the quantitative measurement of bed characteristics (cobble/boulder sizes) and/or detecting changes in bed morphology through time.

**viii)** Continue investigating the application of multibeam sonar for bathymetry surveys.

**ix)** Investigators involved in bathymetry surveys should consider joining GROUNDTRUTH, which is a web-based discussion forum for the exchange of information regarding the classification of sediments by acoustic, seismic, radar, lidar, and video sensing (http://www.groundtruth.org).

**K. System-wide shoreline topography:**

**i)** We strongly support the continued expansion of the baseline mapping of the canyon, which has worked so well for about 100 river miles; this is a KEY dataset. We recommend that the mapping be completed ASAP, within budget constraints.

**ii)** The 1-m contour interval seems to be adequate for established studies, and the supporting materials produced by Horizons, Inc. (1:2,400-scale orthophotoquads, 1:4,800-scale contact prints, digital topographic maps, and digital Arc/Info tapes) are important products.

**iii)** If not currently employed, we urge Horizons, Inc. to consider using the new method of on-board GPS during photo acquisitions to produce topographic information at a reduced cost because of the minimal need for establishing field control.

**iv)** Convert vector contour maps into raster Digital Elevation Models (DEMs).

## L. Other issues:

**Georeferencing**

i) Should GCMRC surveyors accompany all field parties, or should field parties be trained to take their own GPS readings (post-processing could be completed after field work)?

ii) Do field parties need accurate, real-time GPS readings (e.g., navigation to waypoints)? If so, OmniSTAR (http://www.omnistar.com) or another real-time, submeter differential GPS correction system should be investigated.

iii) The Survey Department should develop a system-wide database of ground control points identifiable on the airphotos for use by field researchers.

iv) Field researchers should make use of orthophotoquads whenever possible.

v) Questions relating to GPS purchases should be directed to Carol Johnston.

**Endangered Species**

i) Kanab ambersnail at Vaseys Paradise--explore the use of a digital color infrared camera for obtaining oblique photographs seasonally, or on an event basis, from an opposite-shore vantage point, and compare with the 1990 vegetation map. Pat Chavez uses this type of CCD camera.

ii) Southwestern willow flycatcher--a system-wide vegetation map as a baseline is needed for habitat distribution.

iii) Humpback chub--could radiotelemetry be used? Radiotelemetry of fish was used during the 1996 experimental flood; results indicated that fish remained in, or returned to, their "home" locations.

**1998 Labor Day Overflight**

i) At a minimum, obtain panchromatic airphotos for the entire canyon and color infrared airphotos for several important reaches (e.g., vegetation monitoring sites). To minimize shadow problems, the panchromatic exposures should be unfiltered, not minus-blue. Shadow areas will be black on the color infrared exposures, unless they are obtained during cirrus overcast conditions. In addition, although Horizons, Inc. has used Kodak Double-X Aerographic 2405 film in the past; should a panchromatic film with improved resolution be used (balanced against lighting conditions)? Refer to the following table.

| Film | Film Speed | Resolution (lines/mm) High Contrast | Low Contrast |
|---|---|---|---|
| Double-X 2405 | 400 | 125 | 50 |
| Aero LX 2408 | 64 | 250 | 63 |
| Panatomic X 2412 | 40 | 400 | 125 |
| High Definition Aerial 3414 | 8 | 800 | 250 |

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**ii)** Capture alternative remotely sensed data for the entire canyon or for the same reaches selected for the color infrared photography. If possible, all data should be obtained at a similar scale and be fully evaluated for all GCRMC applications.

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## Alternative Sensor Systems for 1998 Labor Day Overflight

HYDICE (Hyperspectral Digital Imaging Collection Experiment)

210 channels
spectral range: 0.4 - 2.5 μm
operated by ERIM International for the Office of Naval Research
platform: CV-580 (twin turbo-prop)
contact: Dr. Ron Resmini
SAIC/SITC
11781 Lee Jackson Memorial Hwy, Suite 500
Fairfax, VA 22033-3309
(706) 691-3600

ATLAS (Airborne Terrestrial Applications Sensor)

14 channels
spectral range: 0.45 - 12.2 μm (6 VISNIR, 2 SWIR, 6 TIR)
ground resolution: 2.5 - 25 m
platform: Learjet 23
contact: Thomas Stanley, Aircraft Program Manager
Commercial Remote Sensing Program Office
NASA Stennis Space Center, MS 39529
(601) 688-7779
tstanley@ssc.nasa.gov
**no charge program

ADAR (Airborne Data Acquisition and Registration)

ADAR System 3000
advanced single camera system
configurable for B&W, color, color IR, or thermal IR digital aerial photography

ADAR System 5500
four camera multispectral system
captures both color and color IR digital images simultaneously

contact: Positive Systems, Inc.
250 Second Street East
Whitefish, MT 59937
(406) 862-7745
positive@possys.com
http://www.possys.com

Flight Landata Systems

VIFIS (Variable Interference Filter Imaging System
3 progressive scan CCD cameras with interference filters
144 spectral channels
ground resolution: 1 m at 2,000 m

CAMIS (Computerized Airborne Multicamera Imaging System)
4 progressive scan CCD cameras
spectral range: 0.47 - 0.8 μm (true color and color IR)
ground resolution: 1 m at 2,000 m

platform: Cessna Cutlass 206
contact: Dr. Xiuhong Sun
Flight Landata, Inc.
P.O. Box 528
Newburyport, MA 01950
(978) 682-7767
http://www.flidata.com

U.S. Dept. of Agriculture (USDA) Multispectral Digital Video System

Configuration #1
3 CCD video cameras
spectral range: visible/near IR (0.4 - 1.1 μm)
color, color IR images

Configuration #2 (simulates Landsat Thematic Mapper [TM] 3,4,5 imagery)
2 CCD video cameras and 1 tube video camera
spectral sensitivities: camera 1: 0.625 -0.635 μm (visible red)
camera 2: 0.845 - 0.857 μm (near IR)
camera 3: 1.631 - 1.676 μm (mid IR)

contact: Jim Everitt
USDA-ARS
2413 E. Highway 83
Weslaco, TX 78596-8344
(210) 969-4824
j-areritt@tamu.edu

<u>U.S. Dept. of Energy (DOE) Remote Sensing Laboratory, operated by Bechtel Nevada</u>

Sensor/Camera Platforms

1) MBB BO-105 helicopter (**may be an ideal platform for the canyon)
   Linhoff 4 X 5" camera (vertical configuration)
   Kodak Color Digital Camera with 2000 X 3000 CCD array
   Daedalus 1268 ATM (Airborne Thematic Mapper)
      9 channels: 8 from 0.42 - 1.05 μm
                  1 from 1.55 - 1.75 μm
      2 thermal IR channels: 3.0 - 5.0 μm
                             8.5 - 14.0 μm
      optional channel: 2.08 - 2.35 μm (replaces 3.0 - 5.0 μm channel)
   ITRES-CASI (Compact Airborne Spectrographic Imager)
      Mode 1: spatial-fixed bandwidths
      Mode 2: spectral-hyperspectral/multichannel
      up to 288 channels between 0.4 and 0.9 μm

OR

   Daedalus 3600 AMS (Airborne Multispectral Scanner) with ITRES-CASI
      8 channels from 0.42 - 1.04 μm
      1 channel from 3.0 - 5.4 μm
      1 channel from 8.4 - 14.5 μm

2) The above Daedalus/CASI sensor payloads, in addition to a Leica RC-30 mapping camera, can be flown on a Beechcraft King Air B-200 (twin turbo-prop) or a Cessna Citation 550 (twin engine jet).

contact: Dave Hawley
Bechtel Nevada, Remote Sensing Laboratory
316 Atlas Circle
North Las Vegas, NV 89030
(702) 295-8089

Office of Naval Research (ONR) Synthetic Aperture Radar (SAR)

operated by ERIM International for ONR
wavelengths: P-band (~68 cm) and possibly L-band (~25 cm)
platform: CV-580 (twin turbo-prop)
contact: Dave Ager (at ERIM International)
(313) 994-1200, ext. 2407

Jet Propulsion Laboratory (JPL) Airborne Synthetic Aperture Radar (AIRSAR)

wavelengths: C-band (6 cm)
L-band (25 cm)
P-band (68 cm)
platform: NASA DC-8 (4 engine jet)
contact: Leon Maldinaldo (818) 354-1506 or Yunling Lou (818) 354-2647
http://www.jpl.nasa.gov/mip/airsar.html

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iii) Use GPS and attitude detection (to remove tip and tilt) to collect georeferencing data.

iv) Acquire simultaneous ground-based measurements (e.g., radiometers) for correlation with the airborne data.

v) Explore the use of a remote-controlled helicopter--20-lb payload, georeferencing equipment; a remote-controlled boat platform is another option (contact Carol Johnston).

**Image Analysis**

i) Consult with Pat Chavez on a regular basis concerning image processing issues.

ii) Make use of softcopy photogrammetry resources and personnel at the USGS Flagstaff Field Center.

iii) Make use of Bureau of Reclamation RSGIG resources and personnel.

iv) When possible, hire a senior-level remote sensing scientist/coordinator for GCMRC; the person should be someone who knows how remote sensing can be applied to scientific questions.

v) Explore the acquisition of new image processing software for the workstation environment (e.g., ERDAS-IMAGINE, ENVI, USGS-MIPS, and USGS-ISIS.

vi) Analyze existing/historical airphotos to obtain long-term data sets.

**Lake Powell**

i) Pat Chavez's techniques for San Francisco Bay are applicable.

ii) Lakes are more amenable than rivers to many traditional remote sensing systems and techniques.

**2. What alternative remote sensing technologies might better meet revised management objectives and information needs in new or existing areas? Please identify which technologies may be considered experimental as opposed to those considered to be operational.**

i) Experimental remote sensing systems: HYDICE, VIFIS, CAMIS, USDA- Digital Video System, JPL-AIRSAR, and ONR-SAR.

ii) Operational remote sensing systems: ATLAS, ADAR, Linhoff Camera, Leica RC-30 Mapping Camera, Kodak Digital Cameras (color and color IR), Daedalus 1268 ATM, Daedalus 3600 AMS, and ITRES-CASI.

iii) RoxAnn and QTC-VIEW are operational, digital signal processor systems.

iv) Explore the use of scanning LIDAR (Light Detection And Ranging) for obtaining elevation data beneath vegetation canopies. LIDAR might also be useful for mapping vegetation canopy heights and monitoring changes in canopy heights. LIDAR is experimental.

v) Explore the use of in-stream optical sensors (operational); would maintenance be a problem, causing more "intrusion" into the canyon? Pat Chavez suggests that permanently-mounted radiometers (with telemetry?) could be tested (experimental).

vi) Explore the possibility of obtaining high-resolution satellite imagery from current and planned satellite systems (e.g., IRS-1C, EarlyBird, QuickBird, OrbView). These data are likely to be expensive unless the Grand Canyon is selected as a test site. In this regard, GCMRC might attempt to secure outside funding.

vii) Explore the possibility of purchasing and evaluating KVR-1000 digitized photography from the Russian COSMOS satellites. The KVR-1000 is a high resolution camera employing a 1-m focal-length lens that provides panchromatic photographs with 2-m resolution. Inquiries can be directed to:

SPIN-2, Aerial Images, Inc.
2121 K Street NW, Suite 650
Washington, DC 20037
(202) 293-0421
sales@spin-2.com
http://www.spin-2.com (page includes several KVR-1000 examples)

**viii)** On-line catalogs of imagery, GIS data layers and metadata should be compiled.

**3. In what areas should GCMRC have concerns about data continuity with previous remotely sensed data?**

**i)** We strongly endorse the continuation of airphoto acquisitions, but the annual cycle may not be needed, except for special events.

**ii)** Explore using another type of panchromatic film with finer resolution.

**iii)** To reduce or minimize shadowing effects on panchromatic photography, there seems to be several possibilities:

a. acquire photography without a minus-blue filter,
b. overfly when there is a cirrus overcast (shadowless photos),
c. careful selection/mix of date and time of day relative to the topographic conditions,
d. convert critical frames to digital format and use image enhancement/correction methods to suppress the shadow effects.

**iv)** Explore alternative sensors to replace airborne videography; the need for airborne videography is not clear.

**v)** For episodic events of limited spatial extent and requiring quick data acquisition, handheld analog or digital photography and/or vertical photography with a simple mount might be an alternative to airborne videography.

**vi)** Investigate new digital imaging systems and their potential for GCMRC applications.

**vii)** Investigate georeferencing of imagery with GPS and attitude detection (to remove tip and tilt).

**viii)** There was a request for a recommendation as to what spatial resolution would be most appropriate for GCMRC applications. This is difficult for the Panel to recommend without a better understanding of the monitoring features and parameters. However, for the materials presented, it seems that a spatial resolution in the 1- to 5-m range would be adequate.

**ix)** An issue raised was the need to lower the flow level to obtain airphotos at the same level as in previous years. If it is necessary for monitoring purposes to have data acquired at the same flow level, this seems to be the only possibility. There are no operational methods using airborne remote sensing to observe submerged features, such as sand bars, through turbid water.

**4. What are processing time requirements for remotely sensed data? How soon is it available to provide information on resource changes over time?**

i) Time frames:
- Film processing = weeks,
- Most digital systems = minutes to seconds,
- Analog video systems = hours (video images are available for viewing in minutes to seconds, but importing them into a digital analysis system, such as TNT-MIPS, can take hours.

**ii)** There is a big difference between having an image and extracting information from it.

## Additional Comments

### Comments Regarding the Review Procedure and the Review Panel

Provide detailed charge to the Review Panel in advance.

Continue to inform presenters in advance as to the charge, so that the presentations can be tightly focused.

Principal Investigators should make the presentations to the Review Panel.

Need more opportunities for informal interaction with GCMRC staff--perhaps an informal social evening in lieu of a formal restaurant dinner.

Receiving reading materials in advance was helpful.

Panel composition--need more surveying, photogrammetric, ground-based remote sensing, and bathymetric expertise.

Panel members should be given a tour of in-house facilities at the Flagstaff Field Center and be able to examine existing data products. It might be useful to inform future Panel members in advance of the USGS Flagstaff Field Center's web site.

A field trip to the Grand Canyon would have been great!

**Comments for the Remote Sensing Coordinator and Researchers**

Determine whether information needs for each management objective can be obtained through remote sensing.

For information needs that can be addressed using remote sensing, prepare an assessment of each information need with respect to the best scale and methodology to use--temporal, spatial, and spectral.

Determine the appropriate extent (both areal and temporal) of monitoring for each information need--system-wide, specific sites representative of the entire system, or individual sites with special significance (e.g., Vaseys Paradise).

There should be an appropriate mix of applied and research-oriented remote sensing.

Monitoring for the long-term record and monitoring to develop new scientific knowledge represent two different needs with differing requirements.

When available, provide future Panels with examples of how monitoring/research results have influenced management actions.

**General Comments**

Videography--make copies of 3/4" videotapes onto standard VHS videotapes for convenience.

Per Pat Chavez's suggestion, compile an on-line catalog of low-resolution browse images with index maps and metadata. Researchers could then choose appropriate frames to be professionally scanned at a high resolution for specific projects (e.g., digital or softcopy photogrammetry).

Image acquisition is not the same thing as monitoring.

Extrapolation of findings:-- (a) How representative is the sampling? Perform statistical analyses, and investigate the applications of geostatistics. (b) Subdivide the canyon into biophysical units. (c) Map ecology onto a biophysical units base. (d) Develop models/empirical relationships, which will increase predictive power.

Continue and expand accuracy assessments throughout the research effort.

Provide a glossary of acronyms to future Panel members.

Panel is impressed with the amount of data collected, current knowledge, and research efforts, especially the pursuit of new methods (e.g., bathymetry, rotating sonar, radio-tagged boulders, 3-D oblique photogrammetry).

Panel is impressed with the amount of data collected, current knowledge, and research efforts, especially the pursuit of new methods (e.g., bathymetry, rotating sonar, radio-tagged boulders, 3-D oblique photogrammetry).

Radio-tagging of boulders should continue at the same site, in case of future unplanned floods.

MPEG movies and other annomations (e.g., rotating sonar, sand bar changes) are powerful communication tools, especially for public relations.

Panel applauds the experimental approach of the 1996 flood and its implications.

Panel strongly supports the effort to tie all research/monitoring findings into the GIS database.

Web-based database management and data acquisition are laudable.

Good coordination with other agencies, but continue to expand (e.g., Pat Chavez, BOR-RSGIG).

The willingness to be reviewed is laudable.

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