Natural-Color and Color-Infrared Image Mosaics of the Colorado River Corridor in Arizona Derived from the May 2009 Airborne Image Collection

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Abstract:

The Grand Canyon Monitoring and Research Center (GCMRC) of the U.S. Geological Survey (USGS) periodically collects airborne image data for the Colorado River corridor within Arizona (fig. 1) to allow scientists to study the impacts of Glen Canyon Dam water release on the corridor's natural and cultural resources. These data are collected from just above Glen Canyon Dam (in Lake Powell) down to the entrance of Lake Mead, for a total distance of 450 kilometers (km) and within a 500-meter (m) swath centered on the river's mainstem and its seven main tributaries (fig. 1). The most recent airborne data collection in 2009 acquired image data in four wavelength bands (blue, green, red, and near infrared) at a spatial resolution of 20 centimeters (cm). The image collection used the latest model of the Leica ADS40 airborne digital sensor (the SH52), which uses a single optic for all four bands and collects and stores band radiance in 12-bits. Davis (2012) reported on the performance of the SH52 sensor and on the processing steps required to produce the nearly flawless four-band image mosaic (sectioned into map tiles) for the river corridor. The final image mosaic has a total of only 3 km of surface defects in addition to some areas of cloud shadow because of persistent inclement weather during data collection. The 2009 four-band image mosaic is perhaps the best image dataset that exists for the entire Arizona part of the Colorado River.

Some analyses of these image mosaics do not require the full 12-bit dynamic range or all four bands of the calibrated image database, in which atmospheric scattering (or haze) had not been removed from the four bands. To provide scientists and the general public with image products that are more useful for visual interpretation, the 12-bit image data were converted to 8-bit natural-color and color-infrared images, which also removed atmospheric scattering within each wavelength-band image. The conversion required an evaluation of the histograms of each band's digital-number population within each map tile throughout the corridor and the determination of the digital numbers corresponding to the lower and upper one percent of the picture-element population within each map tile. Visual examination of the image tiles that were given a 1-percent stretch (whereby the lower 1- percent 12-bit digital number is assigned an 8-bit value of zero and the upper 1-percent 12-bit digital number is assigned an 8-bit value of 255) indicated that this stretch sufficiently removed atmospheric scattering, which provided improved image clarity and true natural colors for all surface materials.

The lower and upper 1-percent, 12-bit digital numbers for each wavelength-band image in the image tiles exhibit erratic variations along the river corridor; the variations exhibited similar trends in both the lower and upper 1-percent digital numbers for all four

wavelength-band images (figs. 2-5). The erratic variations are attributed to (1) daily variations in atmospheric water-vapor content due to monsoonal storms, (2) variations in channel water color due to variable sediment input from tributaries, and (3) variations in the amount of topographic shadows within each image tile, in which reflectance is dominated by atmospheric scattering.

To make the surface colors of the stretched, 8-bit images consistent among adjacent image tiles, it was necessary to average both the lower and upper 1-percent digital values for each wavelength-band image over 20 river miles to subdue the erratic variations. The average lower and upper 1-percent digital numbers for each image tile (figs. 2-5) were used to convert the 12-bit image values to 8-bit values and the resulting 8-bit four-band images were stored as natural-color (red, green, and blue wavelength bands) and color-infrared (near-infrared, red, and green wavelength bands) images in embedded geotiff format, which can be read and used by most geographic information system (GIS) and image-processing software. The tiff world files (tfw) are provided, even though they are generally not needed for most software to read an embedded geotiff image.

All image data are projected in the State Plane (SP) map projection using the central Arizona zone (202) and the North American Datum of 1983 (NAD83). The map-tile scheme used to segment the corridor image mosaic followed the standard USGS quarter-quadrangle (QQ) map borders, but the high resolution (20-cm) of the images required further quarter segmentation (QQQ) of the standard QQ tiles, where the image mosaic covered a large fraction of a QQ map tile (segmentation shown in figure 6, where QQ_1 to QQ_4 shows the number convention used to designate a quarter of a QQ tile). To minimize the size of each image tile, each image or map tile was subset to only include that part of the tile that had image data. In addition, some QQQ image tiles within a QQ tile were combined when adjacent QQQ map tiles were small. Thus, some image tiles consist of combinations of QQQ map tiles, some consist of an entire QQ map tile, and some consist of two adjoining QQ map tiles. The final image tiles number 143, which is a large number of files to list on the Internet for both the natural-color and color-infrared images. Thus, the image tiles were placed in seven file folders based on the one-half-degree geographic boundaries within the study area (fig. 7). The map tiles in each file folder were compressed to minimize folder size for more efficient downloading. The file folders are sequentially referred to as zone 1 through zone 7, proceeding down river (fig. 7). The QQ designations of the image tiles contained within each folder or zone are shown on the index map for each respective zone (figs. 8-14).

Disclaimer:

Although these data have been processed successfully on a computer system at the U.S. Geological Survey, no warranty expressed or implied is made regarding the display or utility of the data on any other system, or for general or scientific purposes, nor shall the act of distribution constitute any such warranty. The U.S. Geological Survey shall not be held liable for improper or incorrect use of the data described and (or) contained herein.

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This Data Series includes the following Information:

DIRECTORY

index_maps

Colorado_River_Index_Map.pdf -- Index map stored in Adobe Acrobat (PDF) format displaying the extent of the Colorado River within Arizona in the geographic coordinate system. Index map is also provided in jpeg format.

Colorado_River_Image_Index_Map_Zonex.pdf -- Index map of the QQ image tiles contained within each of 7 zones of folders that were used to collate the image tiles. This information is displayed in the geographic coordinate system and stored in both PDF and jpeg formats.

image_files

Twenty-centimeter (20-cm) natural-color and color-infrared airborne-image mosaics in geotiff format with their tfw files. All images with their tfw and metadata files are compressed with standard file compression software to facilitate file transfer.

metadata

QQQ/QQ_SP_NAD83_Z202_NC.tif.txt -- FGDC compliant metadata files for each quarter-quarter-quadrangle (QQQ) or quarter-quadrangle (QQ) image tile. NC designates natural- color image data.

QQQ/QQ_SP_NAD83_Z202_CIR.tif.txt -- FGDC compliant metadata files for each quarter-quarter-quadrangle (QQQ) or quarter-quadrangle (QQ) image tile. CIR designates color- infrared image data.

shapefiles

Colorado_River_Image_Mosaic_Index.shp -- A shapefile showing the QQ image-tile and collated-tile zone boundaries for the Colorado River corridor within Arizona.

index.html -- http://pubs.usgs.gov/ds/780/

1_readme.txt and 1_readme.pdf -- This file.

Reference Cited:

Davis, P.A., 2012, Airborne digital-image data for monitoring the Colorado River corridor below Glen Canyon Dam, Arizona, 2009—Image-mosaic production and comparison with 2002 and 2005 image mosaics: U.S. Geological Survey Open-File Report 2012–1139, 82 p., http://pubs.usgs.gov/of/2012/1139/.

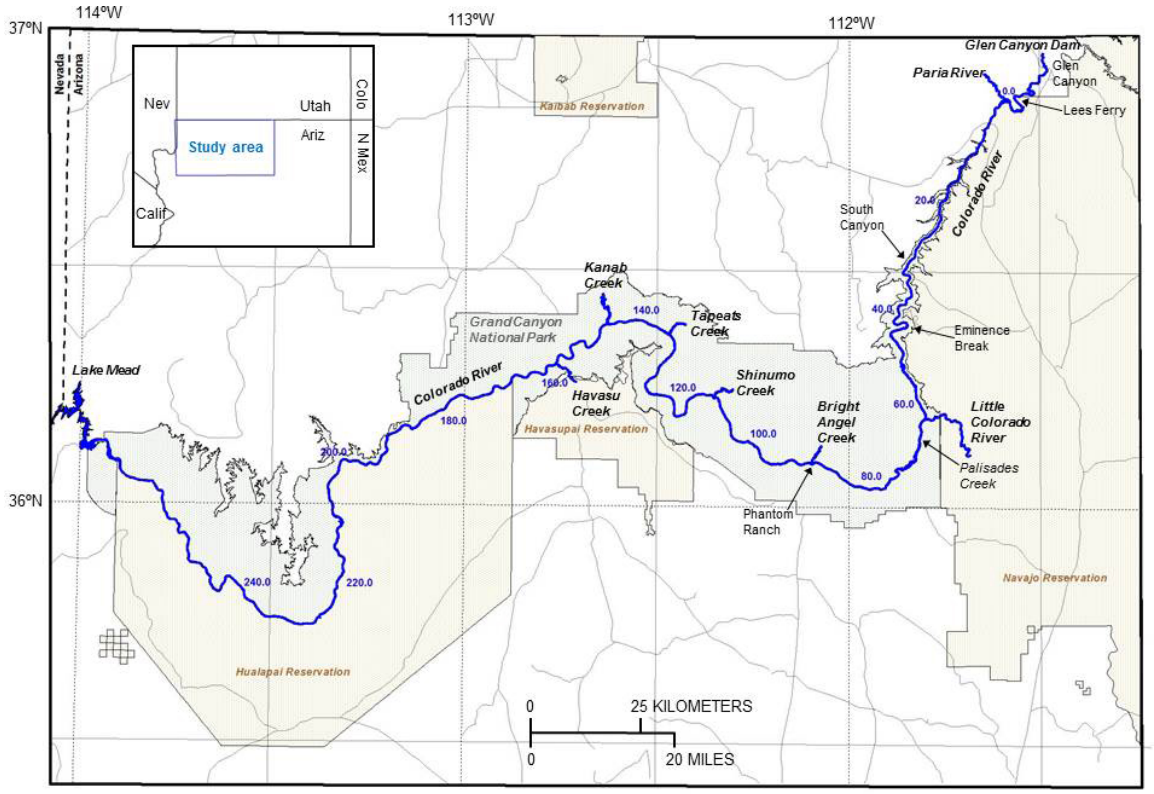

Figure 1. Map of the Colorado River corridor in Arizona that is monitored by the U.S. Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC). Blue line traces the course of the Colorado River; gray lines are roads and trails. Blue decimal numbers are river miles from Lees Ferry (river mile 0.0; river miles are negative upstream of Lees Ferry); Glen Canyon Dam is at river mile -16.0.

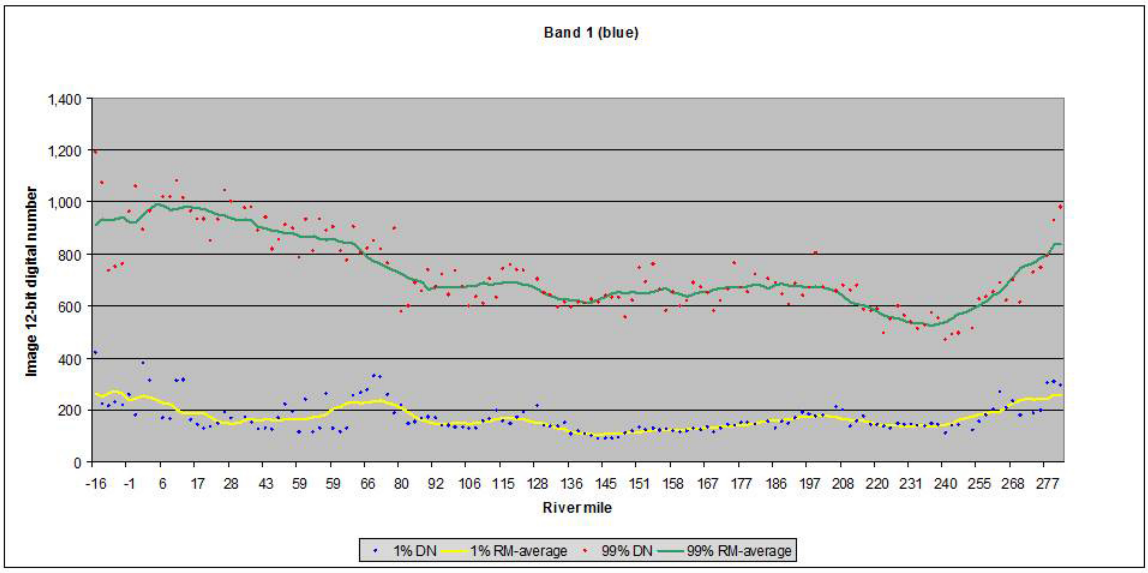

Figure 2. Graph of the band-1 (blue wavelength) digital numbers (DN) at the lower (blue points) and upper (red points) 1-percent (%) population of picture elements for each of the 143 image tiles relative to river mile (RM) along the Colorado River corridor. The yellow and green lines trace the 20-mile-average digital numbers for the lower and upper 1-percent picture-element population within the 143 image tiles.

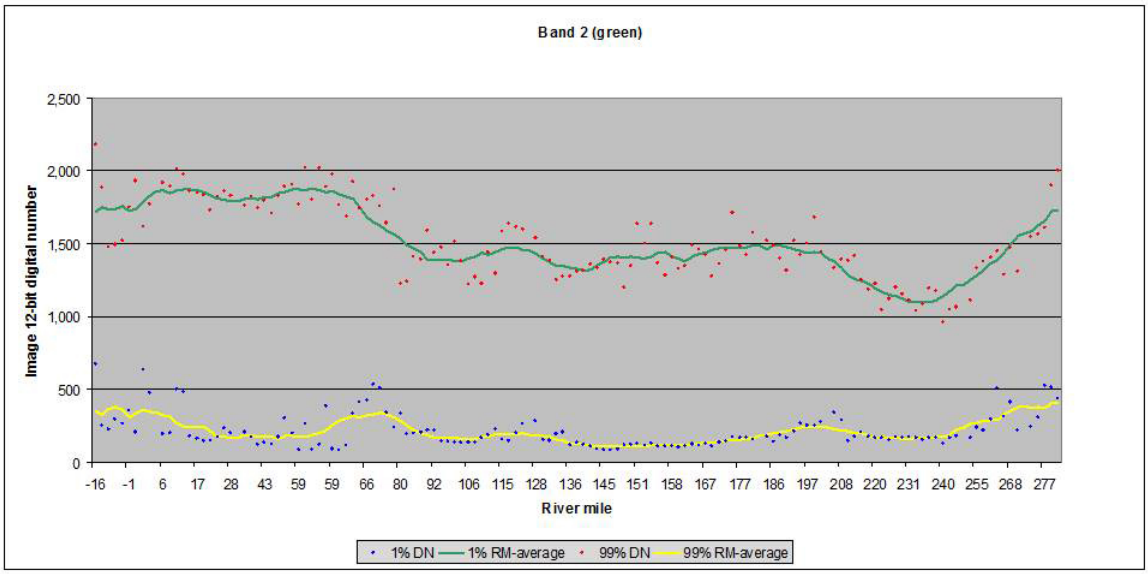

Figure 3. Graph of the band-2 (green wavelength) digital numbers (DN) at the lower (blue points) and upper (red points) 1-percent (%) population of picture elements for each of the 143 image tiles relative to river mile (RM) along the Colorado River corridor. The yellow and green lines trace the 20-mile-average digital numbers for the lower and upper 1-percent picture-element population within the 143 image tiles.

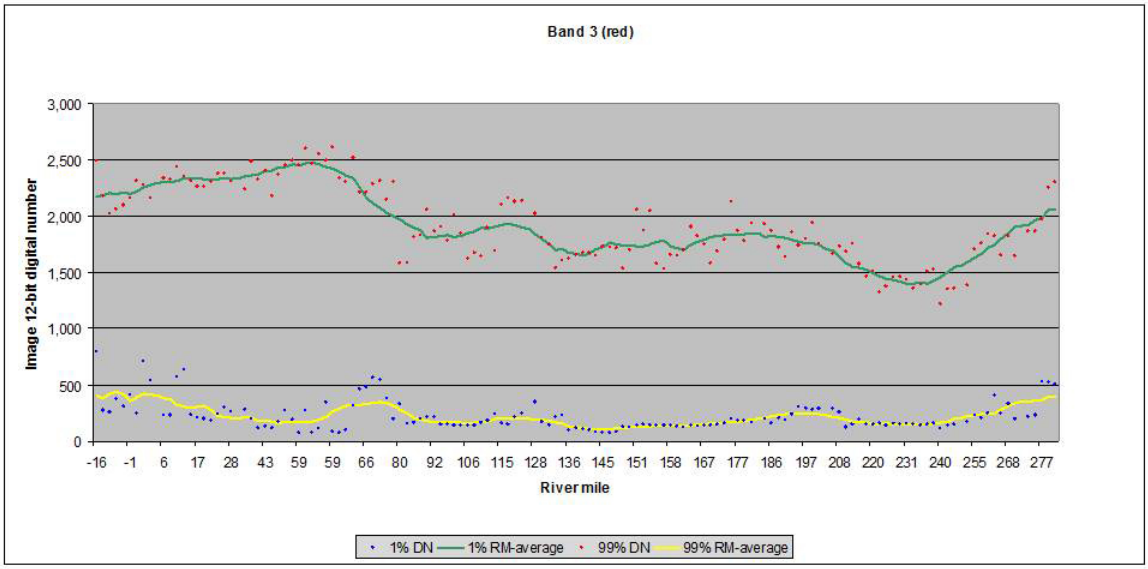

Figure 4. Graph of the band-3 (red wavelength) digital numbers (DN) at the lower (blue points) and upper (red points) 1-percent (%) population of picture elements for each of the 143 image tiles relative to river mile (RM) along the Colorado River corridor. The yellow and green lines trace the 20-mile-average digital numbers for the lower and upper 1-percent picture-element population within the 143 image tiles.

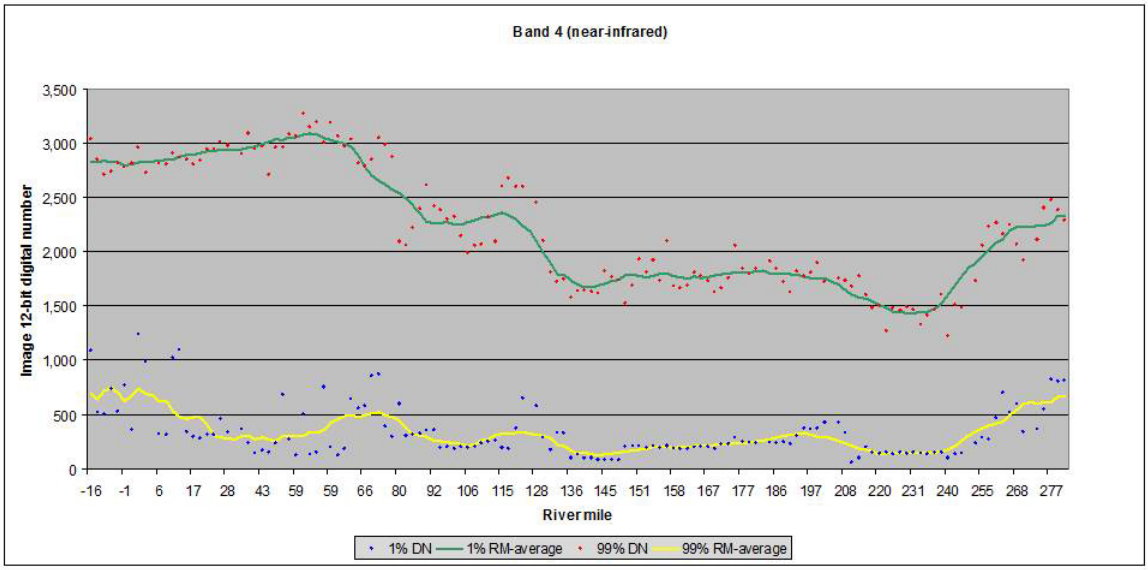

Figure 5. Graph of the band-4 (near-infrared wavelength) digital numbers (DN) at the lower (blue points) and upper (red points) 1-percent (%) population of picture elements for each of the 143 image tiles relative to river mile (RM) along the Colorado River corridor. The yellow and green lines trace the 20-mile-average digital numbers for the lower and upper 1-percent picture-element population within the 143 image tiles.

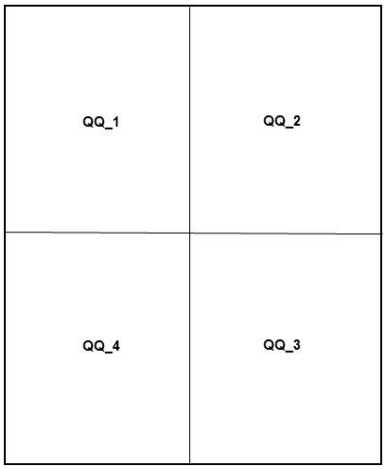

Figure 6. Segmentation and number-designation scheme for quartering U.S. Geological quarter-quadrangle (QQ) map tiles when the airborne image data fill a large fraction of a map tile and the image tile needed to be sectioned (into QQQ image tiles) to reduce its file size. QQ_1 through QQ_4 are examples the numbered naming convention for QQQ map tiles.

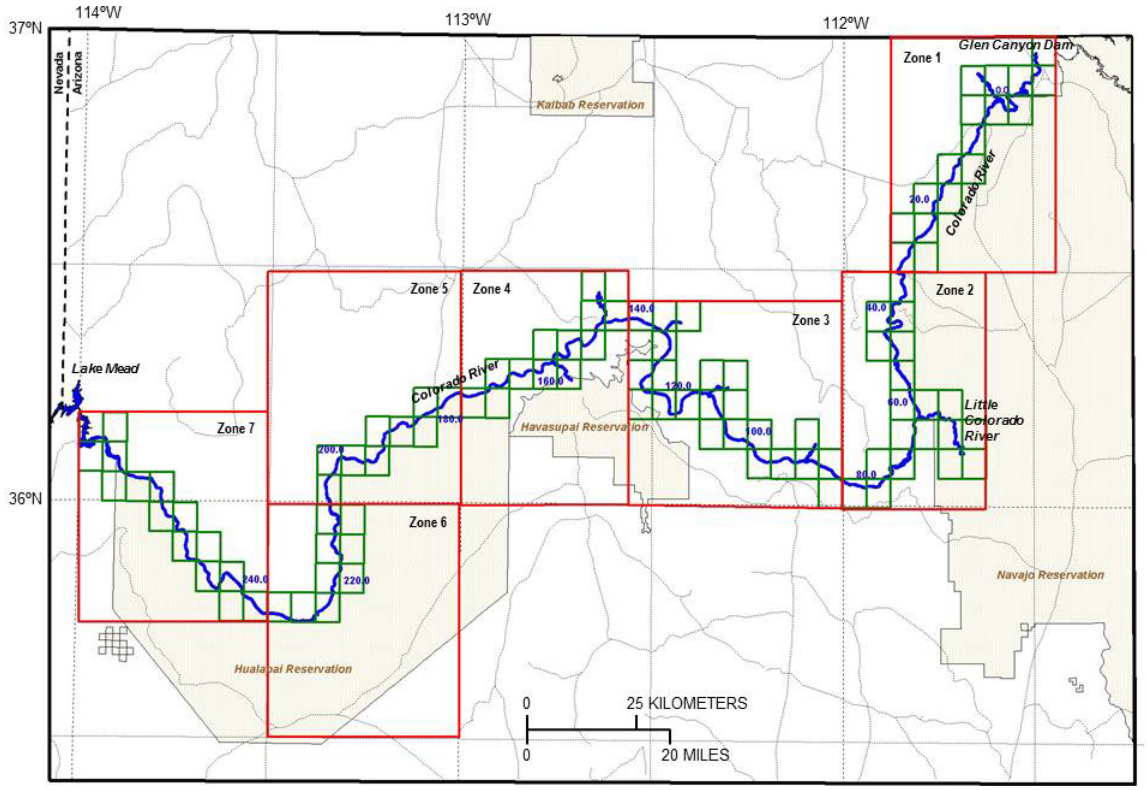

Figure 7. Map of the Colorado River ecosystem, showing the U.S. Geological Survey quarter-quadrangle (QQ) map-tile scheme (green boxes) used to segment the corridor's image mosaic into image tiles. The 143 QQ and QQQ image tiles were collated and compressed into seven folders or zones (red boxes) to facilitate internet posting and downloading of the image tiles. Blue line traces the course of the Colorado River; gray lines are roads and trails. Blue decimal numbers are river miles from Lees Ferry (river mile 0.0; river miles are negative upstream of Lees Ferry); Glen Canyon Dam is at river mile -16.0.

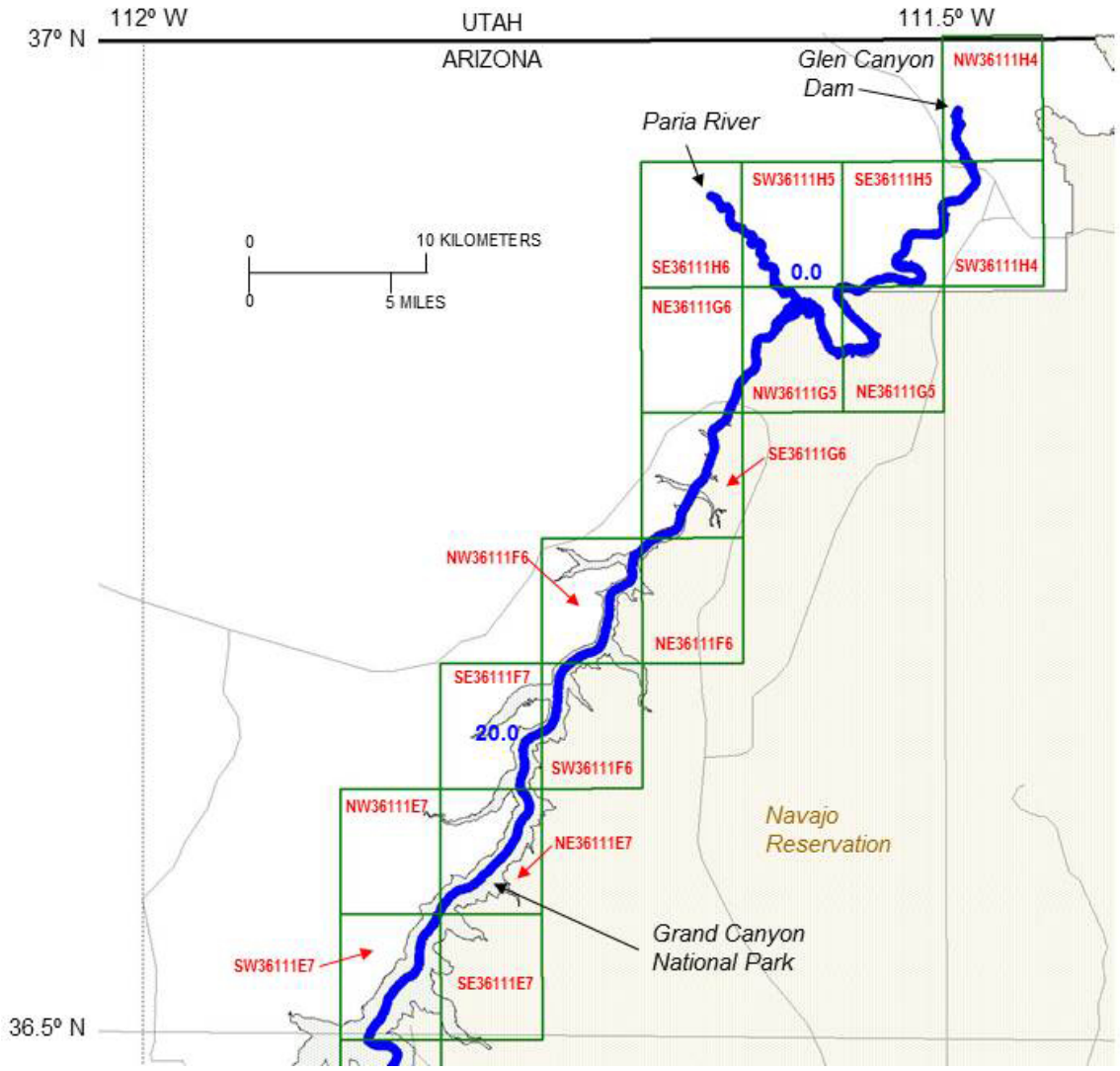

Figure 8. Map of the quarter-quadrangle (QQ) map tiles contained within zone 1 of the Colorado River corridor. Blue line traces the course of the Colorado River. Blue decimal numbers are river miles from Lees Ferry (river mile 0.0; river miles are negative upstream of Lees Ferry); Glen Canyon Dam is at river mile -16.0.

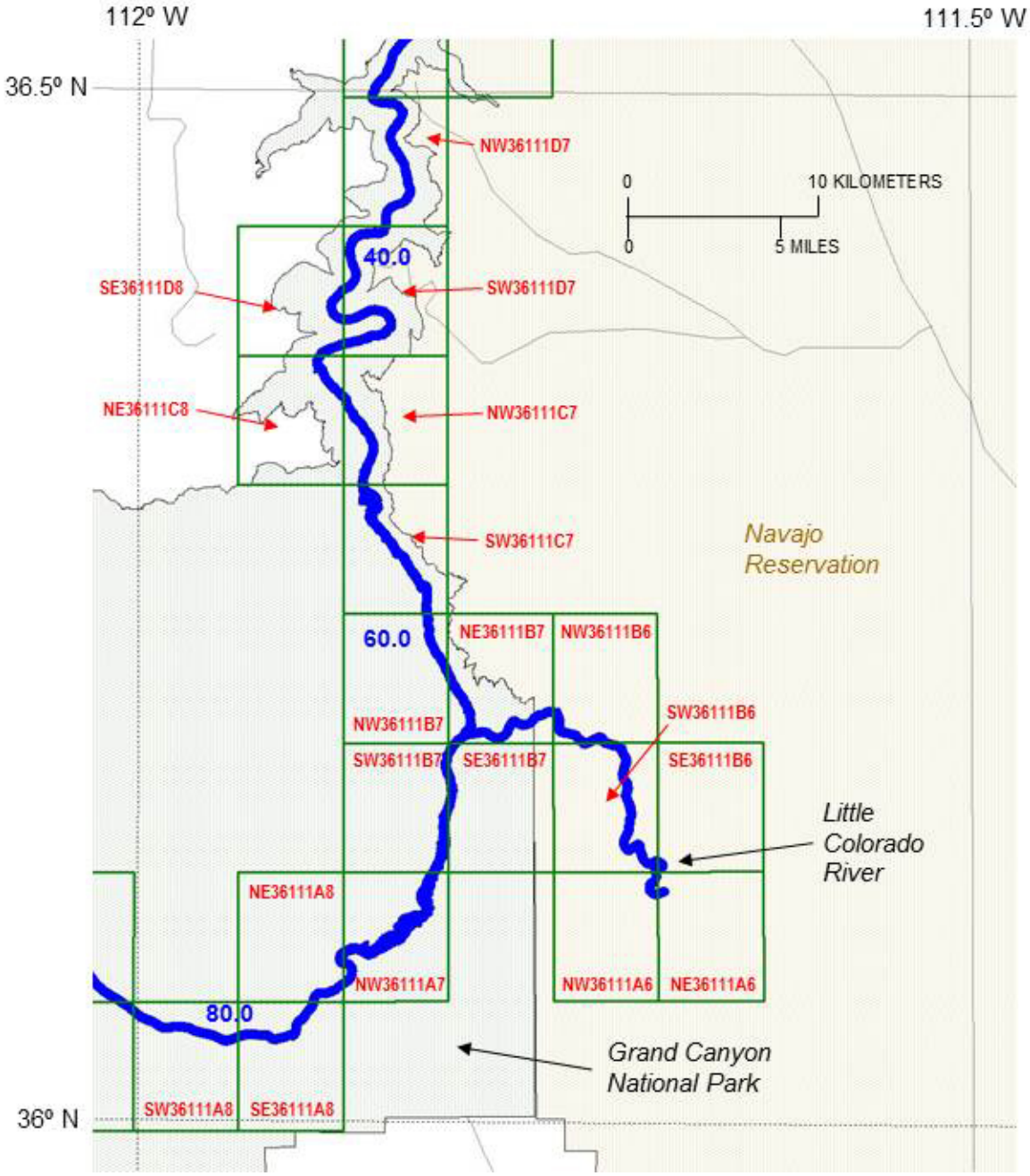

Figure 9. Map of the quarter-quadrangle (QQ) map tiles contained within zone 2 of the Colorado River corridor. Blue line traces the course of the Colorado River. Blue decimal numbers are river miles from Lees Ferry (river mile 0.0; river miles are negative upstream of Lees Ferry); Glen Canyon Dam is at river mile -16.0.

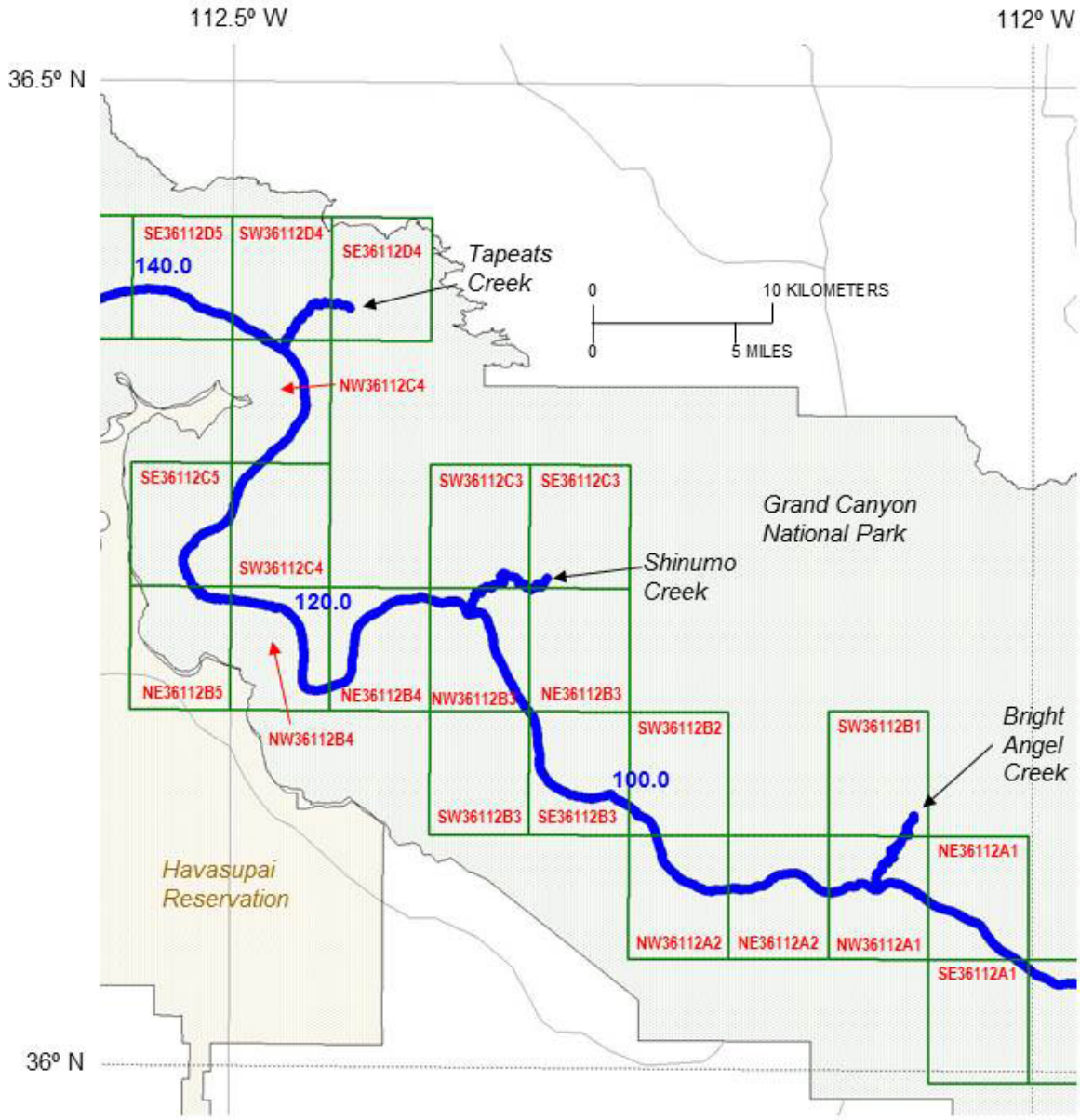

Figure 10. Map of the quarter-quadrangle (QQ) map tiles contained within zone 3 of the Colorado River corridor. Blue line traces the course of the Colorado River. Blue decimal numbers are river miles from Lees Ferry (river mile 0.0; river miles are negative upstream of Lees Ferry); Glen Canyon Dam is at river mile -16.0.

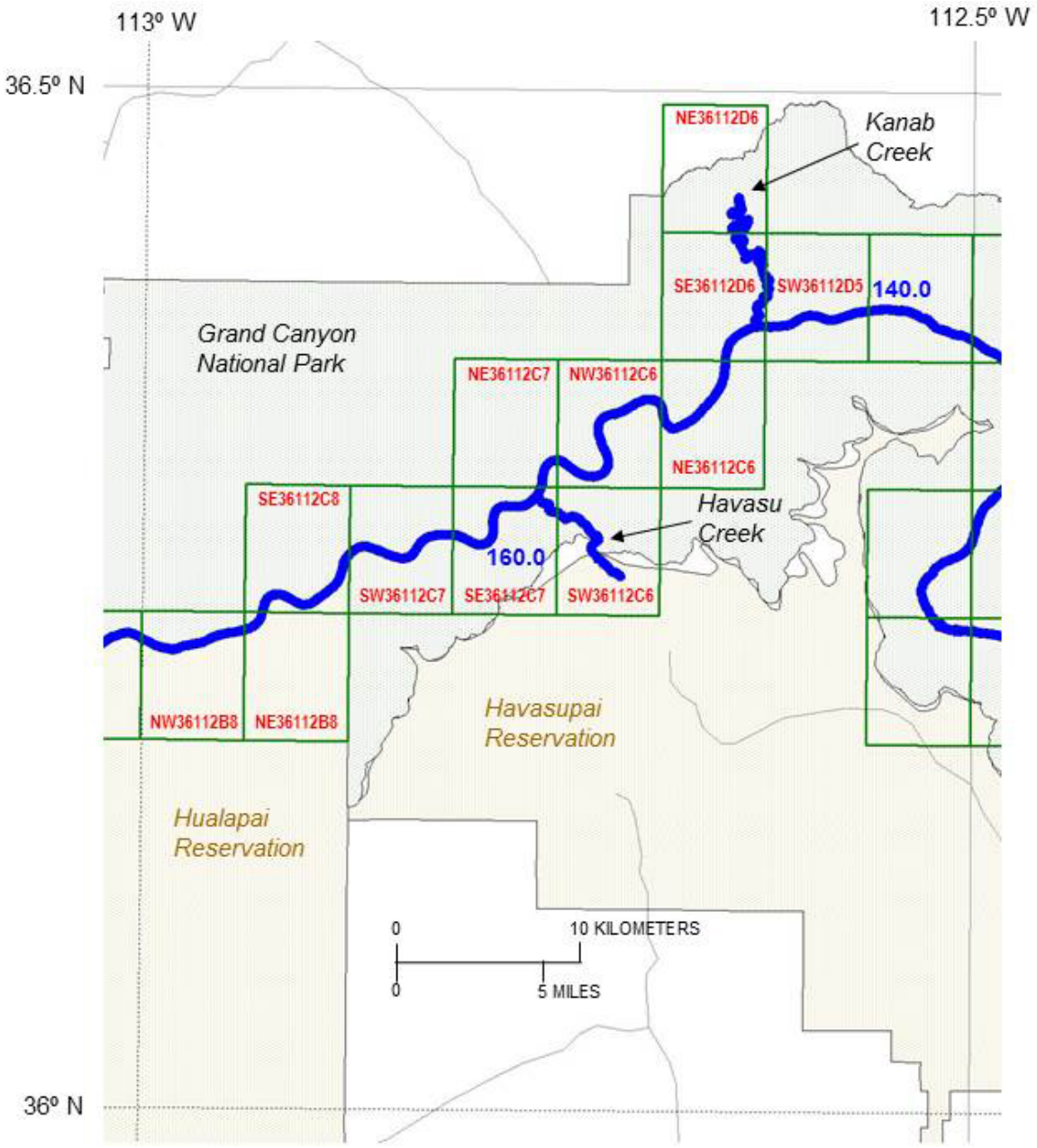

Figure 11. Map of the quarter-quadrangle (QQ) map tiles contained within zone 4 of the Colorado River corridor. Blue line traces the course of the Colorado River. Blue decimal numbers are river miles from Lees Ferry (river mile 0.0; river miles are negative upstream of Lees Ferry); Glen Canyon Dam is at river mile -16.0.

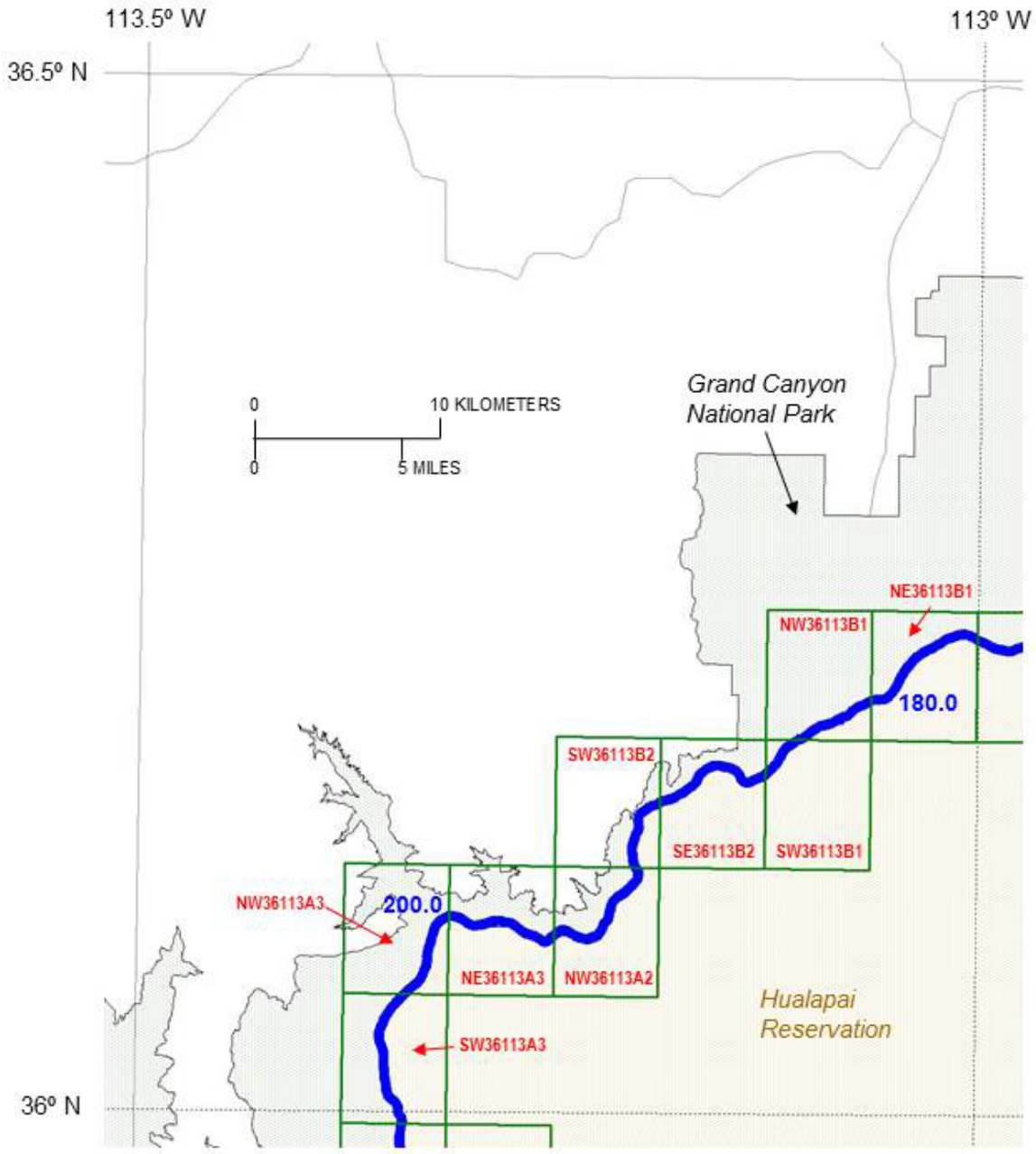

Figure 12. Map of the quarter-quadrangle (QQ) map tiles contained within zone 5 of the Colorado River corridor. Blue line traces the course of the Colorado River. Blue decimal numbers are river miles from Lees Ferry (river mile 0.0; river miles are negative upstream of Lees Ferry); Glen Canyon Dam is at river mile -16.0.

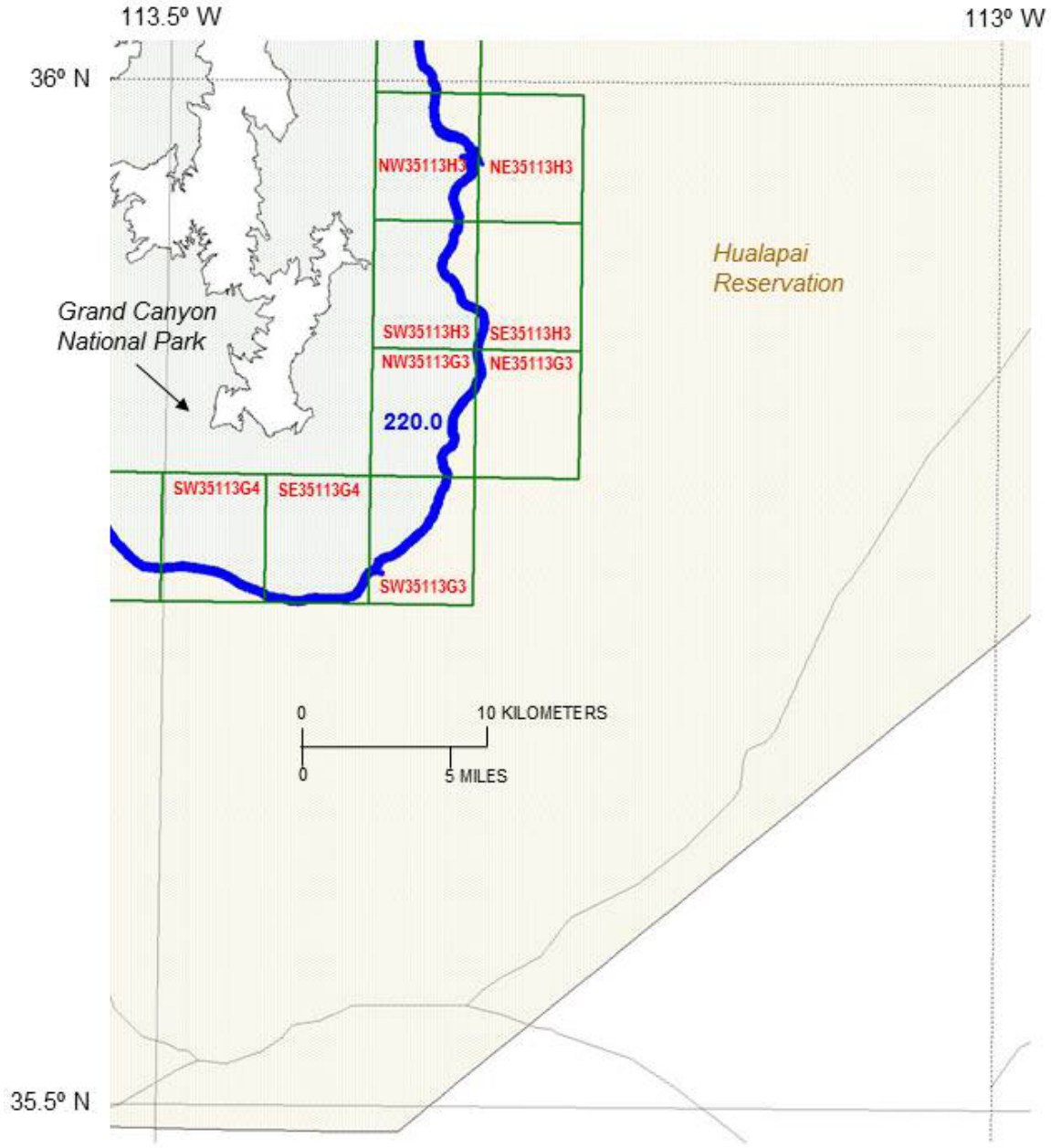

Figure 13. Map of the quarter-quadrangle (QQ) map tiles contained within zone 6 of the Colorado River corridor. Blue line traces the course of the Colorado River. Blue decimal numbers are river miles from Lees Ferry (river mile 0.0; river miles are negative upstream of Lees Ferry); Glen Canyon Dam is at river mile -16.0.

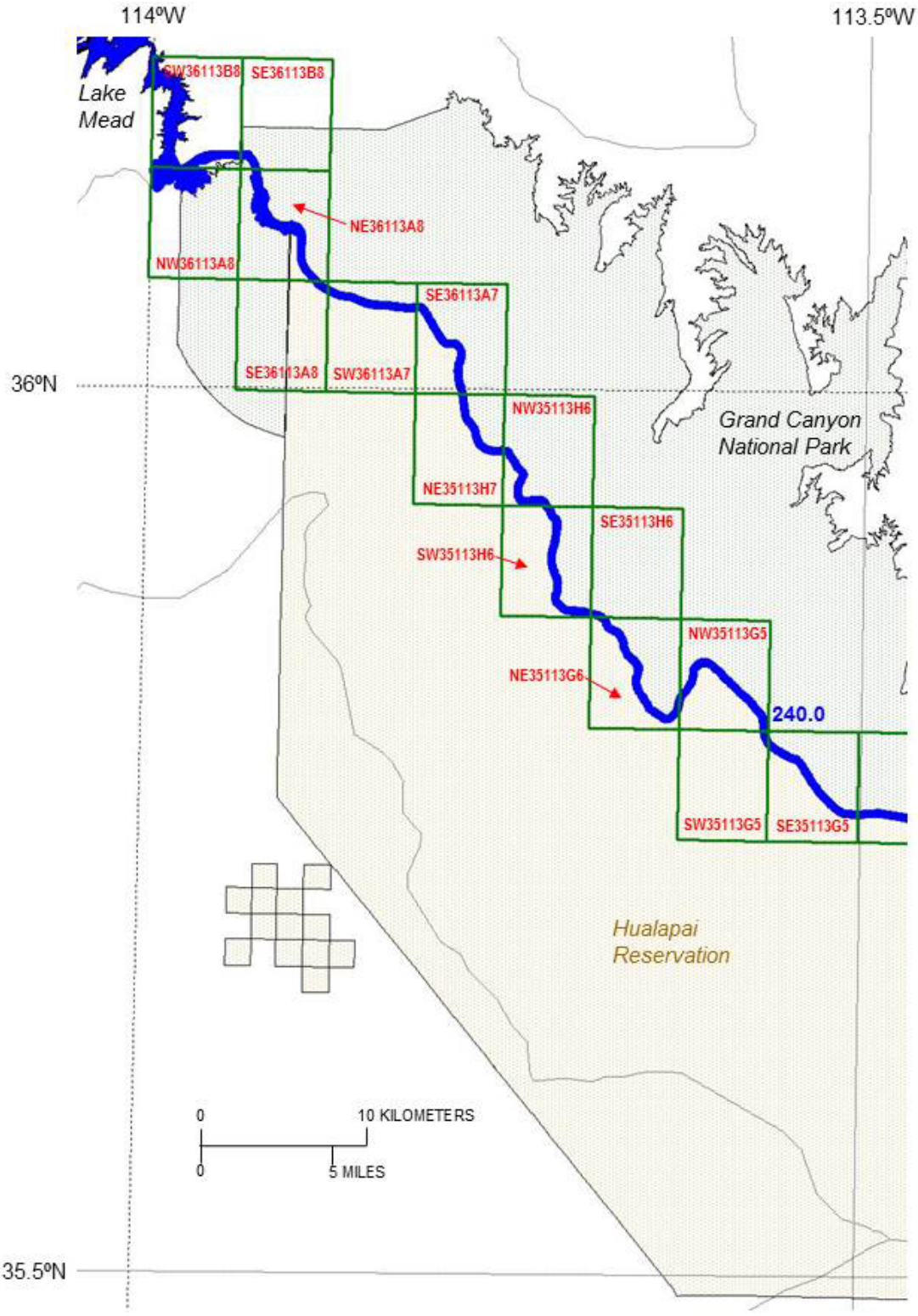

Figure 14. Map of the quarter-quadrangle (QQ) map tiles contained within zone 7 of the Colorado River corridor. Blue line traces the course of the Colorado River. Blue decimal numbers are river miles from Lees Ferry (river mile 0.0; river miles are negative upstream of Lees Ferry); Glen Canyon Dam is at river mile -16.0.