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Establishing a pre-mining geochemical baseline at a uranium mine near Grand Canyon National Park, USA

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ABSTRACT

During 2012, approximately 404,000 ha of Federal Land in northern Arizona was withdrawn from consideration of mineral extraction for a 20-year period to protect the Grand Canyon watershed from potentially adverse effects of U mineral exploration and development. The development, operation, and reclamation of the Canyon Mine during the withdrawal period provide an excellent field site to understand and document off-site migration of radionuclides within the withdrawal area. As part of the Department of Interior's (DOI's) study plan for the exclusion area, the objective of our study is to utilize pre-defined decision units (DUs) in areas within and surrounding the Canyon Mine to demonstrate how newly established incremental sampling methodologies (ISM) combined with multivariate statistical methods can be used to document a repeatable and statistically defensible measure of pre-mining baseline conditions in surface soils and stream sediment samples prior to ore extraction. During the survey in June 2013, the highest pre-mining 95% upper confidence level (UCL) concentrations with respect to As, Mo, U, and V were found in the triplicate samples collected from surface soils in the mine site DU designated as M1. Gamma activities were slightly elevated in soils within the M1 DU (up to 28 μR/h); however, off-site gamma activities in soil and stream-sediment samples were lower (<6 to 12 μR/h). Hierarchical cluster analysis (HCA) was applied to 33 chemical constituents contained in the multivariate data generated from the analysis of triplicate samples collected in the soil and stream sediment DUs within and surrounding Canyon Mine. Most of the triplicate samples from individual DUs were grouped in the same dendrogram cluster when using a similarity value (SV) of 0.70 (unitless). Different group membership of triplicate samples from two of the four haul road DUs was likely the result of heterogeneity induced by non-native soil material introduced from the gravel road base or from vehicular traffic. Application of HCA and ISM will provide critical metrics to meet DOI's long-term goals for assessing off-site migration of radionuclides resulting from mining and reclamation in the current (2015) exclusion area associated within the Grand Canyon watershed and the associated national park.

1. Introduction

Legacy U mining and milling operations have resulted in soil and water contamination at many sites throughout the western United States (Campbell et al., 2014). In 1978, the U.S. Congress passed the Uranium Mill Tailings Radiation Control Act (UMTRCA) that directed government agencies to stabilize, dispose of, and control materials contaminated by U milling operations (Peterson et al., 2008). While UMTRCA has addressed the remediation of legacy U milling sites, there are over 4000 mines with a history of U production in the western United States that also can pose environmental risks (Peterson et al., 2008). Geochemical assessments of groundwater, surface water, soils, and stream sediments before and after U mining can develop important metrics to better understand the potential environmental effects of resource extraction (Campbell et al., 2014). Recent geochemical assessments of 150 waste dumps associated with legacy U mining and exploration in Utah found elevated levels of U, As, Mo, and Se in soils and stream sediments (Freeman et al., 2008; Beisner et al., 2010; Marston et al., 2012).

The Grand Canyon (Fig. 1) has long been recognized as one of the most treasured landscapes on our planet and was designated as the 17th U.S. National Park in 1919 (Anderson, 2000). Discovery of high-grade U ore in breccia pipe deposits led to U extraction on patented claims within Grand Canyon National Park (GCNP) from 1956 to 1969 (Alpine, 2010). Increased U mining claim activity from 2004 to 2008 in northern Arizona generated concerns about potential mining-related impacts to natural, cultural, and social resources in GCNP (U.S. Department of Interior, 2012). In 2009, as a result of increasing public concern, the U.S. Secretary of the Interior proposed a two-year withdrawal of approximately 404,000 ha of Federal land near GCNP (Fig. 1) into north, east, and south parcels. The purpose of this

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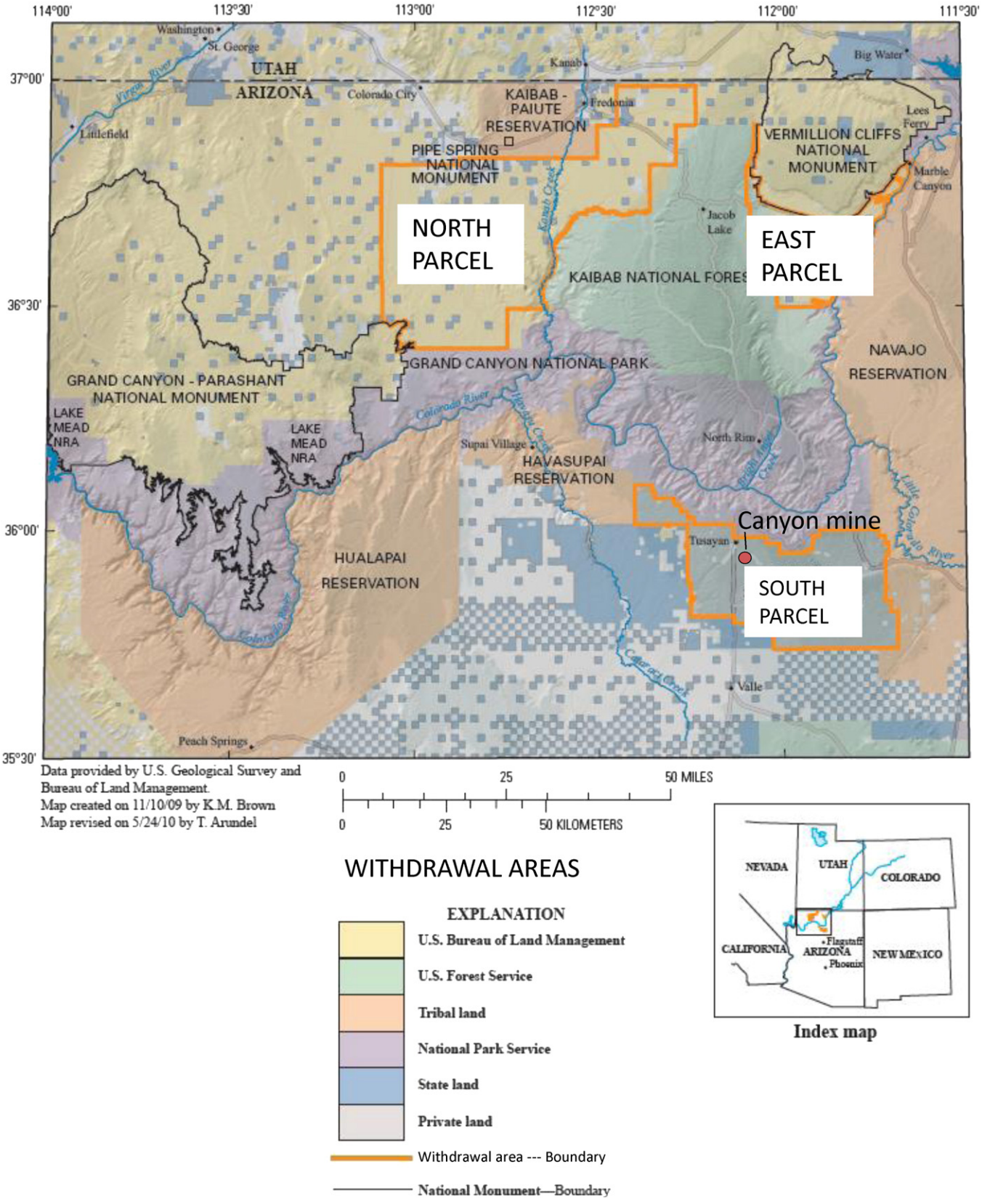

Fig. 1. Map showing withdrawal areas relative to Grand Canyon National Park and land ownership. NRA, National Recreation Area. Modified from Alpine (2010).

withdrawal was to examine the potential effects of restricting these areas from new mine development for the next 20 years. Short-term scientific investigations conducted by the U.S. Geological Survey (USGS) during the initial 2-year withdrawal period (Alpine, 2010) resulted in the decision to extend the withdrawal for a 20-year period in order to protect GCNP and the associated watershed from potentially