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Preserving geomorphic data records of flood disturbances

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ABSTRACT

No central database or repository is currently available in the USA to preserve long-term, spatially extensive records of fluvial geomorphic data or to provide future accessibility. Yet, because of their length and continuity these data are valuable for future research. Therefore, we built a public accessible website to preserve data records of two examples of long-term monitoring (40 and 18 years) of the fluvial geomorphic response to natural disturbances. One disturbance was ∼50-year flood on Powder River in Montana in 1978, and the second disturbance was a catastrophic flood on Spring Creek following a ∼100-year rainstorm after a wildfire in Colorado in 1996.

Two critical issues arise relative to preserving fluvial geomorphic data. The first is preserving the data themselves, but the second, and just as important, is preserving information about the location of the field research sites where the data were collected so the sites can be re-located and re-surveyed in the future. The latter allows long-term datasets to be extended into the future and to provide critical background data for interpreting future landscape changes. Data were preserved on a website to allow world-wide accessibility and to upload new data to the website as they become available. We describe the architecture of the website, lessons learned in developing the website, future improvements, and recommendations on how also to preserve information about the location of field research sites.

1. Introduction

Long-term monitoring records of fluvial geomorphic processes are invaluable contributions to answer current and future scientific research questions, and for addressing engineering problems, land management issues, and stream restoration. Geomorphic records describe: (1) properties of stream networks, (2) the geometry and the characteristics of the sediment and vegetation composing channel beds, channel banks, point bars, floodplains, and terraces, (3) measurements of the hydraulic forces on the bed and banks, (4) concentrations of suspended sediment and bed-load sediment, and (5) the processes of sediment erosion, transport, and deposition. Currently, these types of records are used for engineering designs of bridges and culverts, rainfall-runoff modeling, flood-inundation mapping related to insurance [9], and studies of channel stability [42], sediment sources [10,3,48], stratigraphy of oil and gas deposits [43], river navigation [24], extreme floods [50,14], landscape change [30,6,36], climate change [4], wildlife habitats [11,27,13], and river restoration [49,17]. A report published by the National Research Council of the United States National Academy of Sciences maintains that "the most significant technical challenges include a dearth of sites with instrumentation [measurements] for long-term (decadal or more) monitoring of basic Earth surface characteristics and processes..." [38].

In the future, as yet unknown geomorphic questions covering different time and spatial scales may be asked. This was recognized by Luna Leopold, who was the Chief Hydrologist for the U.S. Geological Survey (1956–66), and he established the Vigil Network with the purpose "to record and interpret repeated observation of basic geomorphic and hydrological processes" (p. 333, [40]). Eighty-two sites in Sweden, United States, Puerto Rico, Israel, and Botswana were initially archived in this database (http://wwwpaztcn.wr.usgs.gov/vigil/). However, the database is difficult to discover, has not been updated, and accessibility is limited [5] so a National Stream Morphology Database was proposed to address this issue [9]. As of this time (2015), no central database or repository for geomorphic data has been established within the U.S. Geological Survey (USGS) as has been done for the hydrologic data (National Water Information System, NWIS; http://waterdata.usgs.gov/nwis) and remote sensing imagery (Earth Resources Observation and Science, EROS; http://eros.usgs.gov/).

The USGS Data Management website (http://www.usgs.gov/datamanagement/index.php) provides guidance throughout the

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data lifecycle on preserving data that includes creating metadata and capturing workflow. At the present time the Federal Geographic Data Committee endorses the Content Standard for Digital Geospatial Metadata (CSDGM), but is transitioning to the International Organization for Standardization (ISO). A link to a creation tool for Digital Object Identifiers (http://mercury-ops2.ornl.gov/DOI/) is available on the USGS Data Management website. The USGS ScienceBase (http://www.sciencebase.gov) is a possible repository for geomorphic data and is linked to the USGS Science Data Catalog, which has tags for animal behavior, biogeochemistry, ecosystems, hazard mitigation, and hydrology, but no tag for geomorphology at the present time. That being said, all cross-section information (a form of geomorphic data) associated with USGS stream gages is stored and available to the public from the National Water Information System (NWIS). Other cross-section information and photographs used to support conclusions in USGS Series reports are contained in those reports as illustrations or in appendixes of those reports (e.g., [29,31]). Some USGS Science Centers are creating GUI-based map interfaces to provide geomorphic-related photos and cross-section data to the public (e.g., http://sofia.usgs.gov/exchange/ding_wqs/index.php and http://woodshole.er.usgs.gov/field-activity-data/2005-004-FA) (Keith Kirk, USGS, per. communication, 20 January 2015).

Geomorphic response to disturbances (e.g., floods, wildfire, earthquakes, tsunamis, and landslides) is of interest to scientists as well as to land and emergency managers. This paper describes one of the first efforts by scientists in the USGS National Research Program to preserve long-term geomorphic records collected after two flood disturbances. This research continues and therefore we elected to create a website (with the action link http://dx.doi.org/10.5066/F70Z719C) where existing data for Powder River in Montana could be preserved and made available to the public and where new data for Powder River and Spring Creek in Colorado, once approved by the USGS internal review process, could be added annually instead of using a repository such as USGS ScienceBase. We also continue to upgrade the website by implementing USGS data management policies and guidelines for preserving data. When the current research at either site ends, then the dataset for that site will be easily moved to a selected repository where it will have the best chance of being discovered and used by future researchers. Policies of the U.S. Office Management and Budget (OBM) require that data collected by U.S. government agencies be available to the public into perpetuity. Perpetuity is defined as the useful life, which based on the U.S. National Archive and Records Administration (NARA) schedule for this type of data is 100 years or until no longer needed, whichever is longer (Keith Kirk, USGS, per. communication, 20 January 2015).

In this context, we consider it appropriate to account for our own sources of inspiration (1) to establish and preserve long-term data collection efforts, and (2) for the hope that these efforts might be exploited by future generations of geomorphologists. Our most immediate source of inspiration was the long-term study of fluvial geomorphic change in Watts Branch (Maryland, USA) that was begun by Luna Leopold in 1952, whose data are archived in Philadelphia at the American Philosophical Society. The Watts Branch sites have been re-located by Andrew Miller and additional scientific papers have been published [18,19]. Also strongly inspiring was the re-survey of old (1887–89) cross-shore profiles (74 out of original 229) by John Zeigler and his colleagues in 1958–59 to document shoreline erosion on the outer arm of Cape Cod [51,52]. And most inspiring of all, perhaps, was the initial 42 years (1874–1915) of annual topographic re-surveys made of the Rhone Glacier by the Swiss Army and later used by Mercanton [23] for a doctoral dissertation. The surveys were discontinued at the onset of World War I, but re-located and re-surveyed after the war and the data have served glaciology and climate science: as an unparalleled historical record [7,39], as basis for the construction and calibration of predictive numerical models (e.g., [46,8]), and in studies of climate change (e.g., [45]).

2. Monitoring methods of channel change

The first disturbance that caused substantial channel change was an extreme flood of Powder River in southeastern Montana (Fig. 1) in May 1978 in response to unusually heavy rainfalls caused by an anomalous atmospheric circulation pattern [41,30,35,26]. The second disturbance was the May 1996 Buffalo Creek wildfire (Fig. 2) that burned entire trees and severely altered soil properties in the Front Range Mountains near Denver, Colorado. Subsequent rain in July 1996 produced catastrophic floods on Buffalo Creek (two people were killed; [1]) and on Spring Creek [25,32–34]. The spatial scale of these two watersheds affected by flood disturbance is quite different—the monitored reach of Powder River drains an area of 22,657 square km, whereas Spring Creek drains an area of 26.8 square km.

2.1. Channel cross sections

Powder River is a muddy, perennial, northward-flowing meandering river (Fig. 1) bordered by groves of cottonwoods. River slopes average 0.001 through the monitored reach. Bankfull width [47] is approximately 50 m, mean annual discharge is 12.7 $m^3 s^{-1}$ (500 million $m^3 y^{-1}$), and Powder River transports an average of 2–3 million metric tons of suspended sediment per year [29]. Powder River is essentially a "natural river" with no major anthropogenic manipulations (e.g., dam, diversions, and recreation) except pumping from the river to irrigate alfalfa fields during the spring and summer. "Natural" landscapes are difficult to find [38] and thus Powder River is suitable as a "geomorphic standard" to use to guide river restoration and to evaluate the effect of "human actions" on other rivers. It already has been identified as a "reference standard in the Large Prairie River classification" [44].

Initially, 20 channel cross sections were fortuitously established and monumented along a 93-km reach of Powder River during the summers of 1975 and 1977 before the extreme flood of 1978 [29]. Channel cross sections are designated by 'PR' and the river distance rounded to the nearest kilometer (as the river length varies with time; see for example p. 4. [26]) downstream from the mouth of Crazy Woman Creek (e.g., PR151, Fig. 1). This designation system allows new cross sections to be established at a later time without having to renumber or use letters (e.g., PR141.7). The letter 'A' is used to identify cross sections that were lost (during the flood of 1978) and re-established near the original cross section, or new cross-sections that were established on cutoffs created by the flood of 1978 (e.g., PR122A and PR141A). The first channel cross section (PR113) is 0.5 km upstream from the bridge over Powder River at Moorhead, Montana (near the Wyoming-Montana state line), which is the current site of a stream gage (USGS 06324500 Powder River at Moorhead, Montana or PR113.5 in our designation system). The last of the channel cross sections (PR206) was 1.3 km downstream from the US 212 highway bridge at Broadus, Montana where another stream gage (USGS 06324710 Powder River at Broadus, Montana or PR204.7 in our designation system) was operated from 1975 to 1992. The locations of all but one of the 20 original channel cross sections were recovered after the flood of 1978, and the original data and subsequent surveys provided before-and-after data with which to evaluate flood's effects ([26]; see also Fig. 3 of this paper). Four additional cross-channel sections (PR122A, PR141A, PR156A, and PR200A) were established and monumented after the flood. All cross sections were re-surveyed