Erosion and Sediment Transport Monitoring Programmes in River Basins (Proceedings of the Oslo Symposium, August 1992). IAHS Publ. no. 210, 1992.

The Vigil Network — long-term monitoring to assess landscape changes

W. R. OSTERKAMP
U.S. Geological Survey, Mail Stop 413, Box 25046,
Denver, Colorado USA 80225
W. W. EMMETT
U.S. Geological Survey, Mail Stop 413, Box 25046,
Denver, Colorado USA 80225

ABSTRACT Long-term monitoring of geomorphic, hydrologic, and biologic characteristics of landscapes provides a means of relating observed change to its cause. Identification of change in landscape characteristics, especially in arid areas where response to altered climate or land use is generally rapid and readily apparent, might provide initial indication that cultural activities have affected the environment. Three decades ago, a group of sites at which geomorphic, hydrologic, and biologic data would be collected periodically was established as the Vigil Network. The purpose was to record and interpret repeated observations of geomorphic, hydrologic, and biologic processes. This purpose persists, underscored by concerns about worldwide environmental change due to rapid population increase, land development, and advance technology. The intent remains that Vigil Network observations be preserved for future generation of scientists. This paper describes the background objectives, status, and plans for the Vigil Network, and includes a case-history example.

INTRODUCTION

The water planet, Earth, is uniquely dynamic within our solar system because water, in its solid, liquid, and gaseous forms, is constantly in motion or flux. The fluxes of fluids at or near the Earth's surface have a principal role in the complex geologic history that is preserved in the crustal rocks of the planet; they are the overwhelming cause of landscape changes that have occurred during the Quaternary Period, about the last 2 million years. Throughout the Quaternary Period, life on Earth has adjusted readily to the constantly changing fluxes, and during the late Quaternary, humans have used the fluxes as sources of energy, as means of transportation and livelihood, and as transport mediums for the disposal of wastes. During the last 200 years of the Industrial Revolution, however, the rapidly expanding global population with its corresponding development of natural resources and the discharge of waste products to reservoirs of air, soil, and water, has created imbalances that those reservoirs have been unable to assimilate readily.

The effects of these imbalances on present-day land-surface processes are difficult to measure, and typically the effects cannot readily be separated from those of natural processes of landscape change. Moreover, where fluxes and rates of natural or imposed landscape change are measurable, long-term data bases are almost always inadequate to discern trends. This paper describes and advocates a monitoring effort, ideally at a network of sites and small drainage basins, that emphasizes the collection of time-series data and provides the possibility of recognizing trends in geomorphic, hydrologic, and biologic change.

Geomorphologists and hydrologists habitually complain of too few data. For sites where data are available, they generally have been collected for specific purposes of water-resource development, and might not be appropriate to detect long-term change (Leopold, 1962a). The program described here emphasizes data collection at specific sites or in small drainage basins where land-use and other population factors are minimized, streamflow is unregulated, and biota, especially vegetation, are virtually undisturbed.

Background

Monitoring, the collection of repeated measurements at a site to obtain time-series data, has been a common practice of geomorphic investigation for many years. The first organized program of geomorphic networking to detect areal variations using time-series data at many sites, however, was begun only about three decades ago (Osterkamp et al., 1991). The efforts of Leopold and others (Leopold, 1962a, b, c; Emmett, 1965; Leopold & Emmett, 1965; Emmett & Hadley, 1968) resulted in the development of the Vigil Network, a group of an unspecified number of sites and small drainage basins where repeated measurements are made to identify possible change through time. Named from the Latin word, vigilio, to watch, the purpose of the Vigil Network is to collect geomorphic, hydrologic, and biologic data periodically at selected sites and small drainage basins, and to store these data in easily accessible data bases. Thus, any generation of natural scientists from any locale can contribute to the data base, as well as to retrieve data for comparison, interpretation, and detection of trends in landscape change.

The first Vigil Network sites were selected in 1962, shortly before the start of the International Hydrological Decade (IHD). The Vigil Network program was initiated as an international effort by the U.S. Geological Survey (USGS), with principal data repositories initially in the USGS Library, Washington, D.C., and in the library, Natural Geography Institute, University of Uppsala, Uppsala, Sweden. By 1965, slightly more than 60 Vigil Network sites and small drainage basins, mostly in the conterminous United States, had been selected (Hadley, 1965). Owing to the international scope of the program, the Coordinating Council of the IHD helped promote the collection of data at Vigil Network sites and basins (UNESCO, 1965). Because a close association was maintained between the IHD Council and the Vigil Network program, an effort was made at the end of the IHD to tabulate and interpret some of the Vigil Network data from the United States that had been collected during the previous 10 to 12 years (Emmett, 1974b). This effort illustrated the value of time-series data to detect landscape and channel changes as well as to identify changes in sediment budget and precipitation patterns. Vigil Network sites and basins discussed included several in Maryland and New Mexico (Emmett, 1974a); a more detailed analysis was provided for Last Day Gully near Hudson, Wyoming (Leopold & Emmett, 1965, Emmett & Hadley, 1968, & Emmett, 1974b).

Status

Subsequent to the IHD, interest in the Vigil Network waned and geomorphologists of that era had little or no knowledge of concepts of the Vigil Network or of the available data base. With the encouragement of L.B. Leopold, renewed attempts were begun recently (Osterkamp et al, 1990; 1991) to: (a) improve the accessibility of Vigil Network data by expanding and modernizing the repository system, (b) establish a continuing ability for maintaining Vigil Network files, (c) select new sites and small drainage basins, (d) revisit and update data at existing Vigil Network sites and basins, and (e) promote the first four items by educating a younger generation of natural scientists to the availability and value of Vigil Network data.

The Vigil Network currently (1991) includes 83 sites or small drainage basins in the United States (72), Sweden (6), Puerto Rico (3), Botswana (1), and Israel (1). Most of the sites and basins are listed with a summary of the data available from each in Osterkamp et al (1991). Some of the sites and basins were monumented for inclusion in the Vigil Network during and shortly after the IHD, but many others were monumented as early as 1931 and later were incorporated into the network. Only 10 new sites have been added to the Vigil Network since 1975.

A principal feature of the Vigil Network is the repositories for data sets of geomorphic, hydrologic, biologic, and related characteristics at a site or basin. These data sets need to be well documented and kept safe. Because the data sets might be collected during many years, perhaps during periods longer than the life span of individual scientists, the data need to be available for future generations of scientists to use and extend. Three principal international repositories maintain files of Vigil Network data. The main repository is now (1991) the USGS Library in Denver, Colorado, from which identical copies of file data, currently in microfiche form, are distributed to the Department of Physical Geography, Uppsala University, Uppsala, Sweden, and the Jewish National and Hebrew University Library, Jerusalem, Israel; microfiche copies also are distributed to USGS libraries in Reston, Virginia, and Menlo Park, California.

Microfiche copies of Vigil Network data are available for viewing at any of the repositories. Microfiche copies of new Vigil Network file material are prepared and distributed to repositories by USGS personnel in Denver, Colorado, USA. New entries can be sent to W.R. Osterkamp, USGS, Box 25046, Mail Stop 413, Denver Federal Center, Denver, Colorado 80225.

SITE AND BASIN CHARACTERISTICS

Trends in landscape change generally are difficult to identify owing to short periods of observations and the complexities of geology, climate, vegetation, and land use within individual drainage basins. Vigil Network sites and basins, therefore, generally are small to minimize the variability in landscape features and land-use conditions. Where precipitation commonly is deficient and vegetation responds rapidly to changes in available runoff and soil moisture, landscape response to climatic variability in turn is typically prompt and easily recognized. Thus, Vigil Network basins in arid and semiarid areas seem more appropriate for detecting changes in trends in landscape processes than do basins in wetter areas. No Vigil Network sites or basins presently are in polar landscapes, but high-latitude areas too might be particularly sensitive to subtle changes in climate.

ADVANTAGES OF A NETWORK APPROACH

Determining the causes of perceived changes in fluxes, such as runoff or sediment discharge, is rarely feasible during short time intervals of natural conditions. When observations are available for only a short period, perceptions of flux changes might be unreliable. Repeated measurements of instantaneous fluxes alone are inadequate to relate cause and effect, but through the collection of other data about site or basin characteristics, probable linkages to landscape reaction are feasible. Vigil Network data provide opportunities to identify these linkages .

Separating the reactions to induced versus natural changes in landscape characteristics also is difficult during short periods of observation. With increasing awareness of global environmental degradation, society is concerned about: (a) the adverse consequences of human activities on global landscapes, water, and biological resources; (b) the discharge of contaminants into air, water, and soil; and (c) natural hazards, such as floods and mass movements, that threaten life and property. These three concerns are directly related to the importance of land, air, and water resources to a nation's economic and social well being, and to the widely recognized vulnerability of the basic resources to natural and human-induced change. An objective of the Vigil Network observations is to discriminate the extent to which the continuing activities of humans have contributed to these environmental concerns.

TYPES OF DATA

Various types of data are collected at Vigil Network sites or small drainage basins depending on landscape basin characteristics, the specific objectives for use of the data, and special interests of the investigator of the moment. In humid areas with thickly weathered soil zones, emphasis might be placed on hillslope processes; Young pits, for example, have been constructed at Vigil Network sites in Puerto Rico to monitor rates and depths of soil creep. From sites and basins in humid areas in southeastern United States, data typically include channel cross sections and occasionally sedimentation or erosion data. From sites in arid and semiarid areas, measurements of channel cross sections and longitudinal profiles are collected, as are, less commonly, erosion and vegetation data. Other types of data that are consistent with Vigil Network objectives include: discharges of water, sediment, solutes, and pollutants; tree-ring and mass-movement information; cliff- and headcut recession rates; particle-size distributions; reservoir sedimentation rates; pollen spectra; soil-moisture and soil-chemistry profiles; and vegetation quadrats. Pertinent landscape-characteristics information commonly includes geology, hydrology, vegetation types, and climatic descriptors.

AN EXAMPLE OF USEFULNESS OF THE VIGIL NETWORK

Worldwide, many ephemeral-stream channels in small semiarid drainage basins of moderate relief have exhibited patterns of cyclic filling and flushing of sediment during the Holocene Epoch. Leopold et al. (1966) and Emmett (1974b) suggested that these sequences of alluviation and erosion have been responses to changes in climate; other investigators have proposed episodic erosion as a threshold response to over-steepened valley reaches (see, for examples, Schumm, 1975; Patton and Schumm, 1975). A usefulness of the Vigil Network is to help provide a long-term record of measurements so that trends in landscape change can be identified and insightful interpretation given to the observed trends. This usefulness is demonstrated in the case history that follows.

Last Day Gully is a Vigil Network site established in 1962. The gully is a small, ephemeral channel about 1.5 kilometers northeast of Hudson, Wyoming (lat 42°53'33"N., long 108°34'19"W) (Fig. 1). The main channel extends about 1 kilometer from the watershed divide near station 33+00 to its end at station 0+00, and the gully terminates in a small, semicircular alluvial fan. The area of the watershed is about 22 hectares, the average altitude is about 1,570 meters above the National Geodetic Vertical Datum of 1929, the relief between the divide and the fan is about 43 meters, and precipitation averages about 250 millimeters per year.

The principal of the measurements at Last Day Gully are surveys of 13 benchmarked cross sections; 12 of the sections begin at the gully mouth (station 0+00) and extend upstream at 91-meter intervals to

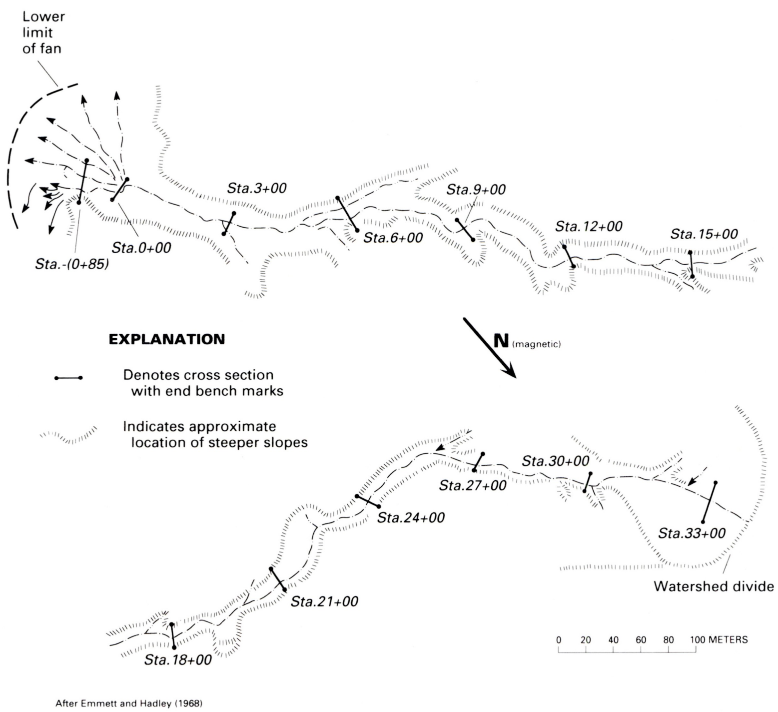

FIG. 1 Planimetric map of Last Day Gully, Wyoming (modified from Emmett and Hadley, 1968).

station 33+00, about 1,000 meters from the gully mouth. A thirteenth cross section is 26 meters downslope on the fan at alluvial station -(0+85) (Fig. 1). Station numbers shown in figure 1 are consistent with standard engineering practices and distances, in feet, that were used at the time the cross sections were established. Near-yearly resurveys of the cross sections were conducted during the 1960s; in addition, resurveys were made in 1973 and 1991. Altogether, eight surveys have been made of the thirteen cross sections during the 29-year period of record, 1962-91. All surveys at all sections illustrate changes in ground-surface altitude during the period of record. Herein, data from the first (1962), a middle (1973), and the last (1991) surveys made at four of the cross sections are used to demonstrate the usefulness of Vigil Network type observations. The chosen cross sections, in the downstream direction, are stations 33+00, 24+00, 0+00, and -(0+85) (Fig. 2).

The uppermost station, 33+00, is a rilled but ungullied hillside cross section about 30 meters downslope from the watershed divide. Typical of unchanneled hillslope areas at Last Day Gully, new gullies are not presently (1991) being cut, and the chance occurrence of a new or enlarged gully at a section is only an indication of upstream migration of isolated headcuts in the gully system. The ground surface at station 33+00 shows little change with time during the 29-year period. Erosion-pin lines established elsewhere in the basin also indicate little change. Small values of hillslope erosion recorded at pins are within the accuracy of repeat level surveys and thus are not part of the measurements at cross sections such as those shown in figure 2.

At the downstream alluvial fan of Last Day Gully, station -(0+85) is a cross section across the fan surface. As shown in figure 2, rills on the fan are aggrading to the level of the unrilled fan surface. (For purposes of sediment budgets, little to no sediment goes downslope beyond the fan.)

Station 0+00 was originally (1962) the downstream end of the cut channel. Subsequent to the original survey, aggradation has nearly obliterated the cut channel and sediment is filling the gully even beyond the extent of the original channel width. Aggradation at station 0+00 probably is due to channel sediment-transport processes as well as effects of changing base level caused by continued deposition on the alluvial fan.

Station 24+00 is about 750 meters upstream from station 0+00. Repeat surveys at station 24+00 show aggradation, but at a rate less than that at most downstream cross sections. Aggradation at station 24+00 probably is due mostly to sediment-transport processes as it is unlikely that base-level effects extend to distant, upstream cross sections. Sections upstream from station 24+00 show little or no aggradation.

In summary, Vigil Network observations at Last Day Gully indicate modest hillslope erosion, little change in size of headwater channels, no new gully entrenchment or enlargement except by occasional headcut advance, modest channel aggradation at mid-reach cross sections, and more extensive channel/valley aggradation at downstream cross sections of the gully. The data are in general agreement with those of nearly two decades ago (Emmett, 1974b). That is, as typified by data of Last Day Gully, channels in a large area of the semiarid western United States are aggrading and valley bottoms are becoming inundated by alluvium.

There is little doubt that Vigil Network observations enabled the identification of a geomorphic trend. As similar observations are

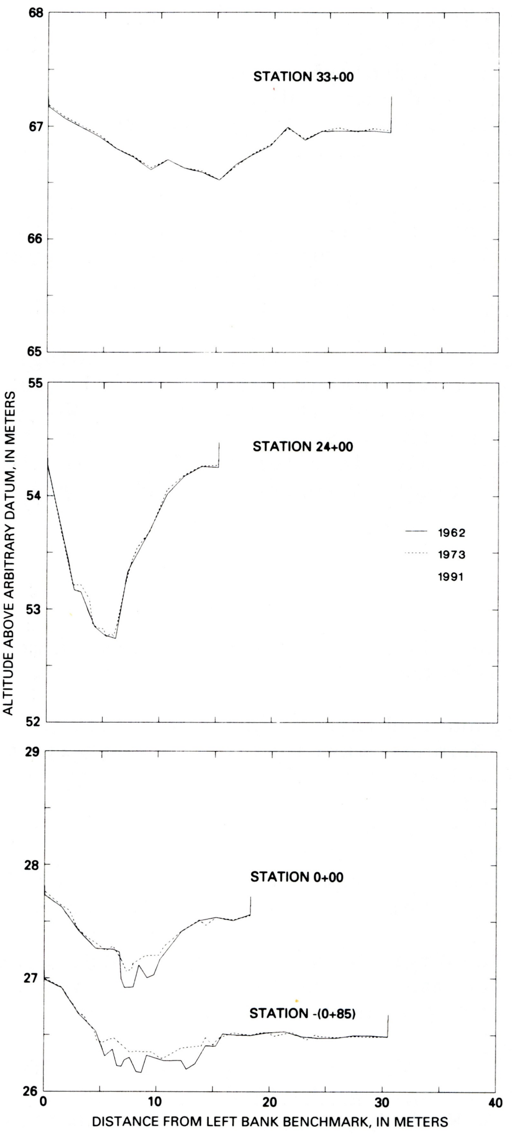

FIG. 2 Example of repetitive measurement for three surveys at four cross sections, Last Day Gully, Wyoming.

made at locations of varying geologic, hydrologic, and cultural characteristics, causes can be hypothesized that relate trends to land use and climate change. By detection or identification of trend, the Vigil Network facilitates a resolution of the larger question of cause and effect.

SUMMARY AND FUTURE NEEDS

The Vigil Network, now (1991) about three decades old, has the following objectives (Emmett & Hadley, 1968):

(a) to facilitate international cooperation in hydrology and long-term programs of landscape observations.
(b) to collect geomorphic, hydrologic, and biologic data periodically at selected sites and small drainage basins leading to the detection of possible changes in landscape form or process.
(c) to preserve the results of the measurements for future generations of scientists.

The Vigil Network currently comprises 83 sites and small drainage basins, mostly in the conterminous United States. Thus, increased participation, especially in other countries and continents, is urgently needed if the objectives of the Vigil Network are to be fulfilled. The Vigil Network provides an opportunity for natural scientists to make a significant contribution with little time and effort. A considerable range of geomorphic and hydrologic features in a considerable range of environments can be easily documented and monitored for change by scientists worldwide. We encourage the investigators developing these data bases to store them as Vigil Network files, and where suitable sites for long-term observation are known, we encourage investigators to establish new Vigil Network sites and basins.

REFERENCES

Emmett, W.W. (1965) The Vigil Network: Methods of measurement and a sampling of data collected. Symposium of Budapest, IASH Publ. 66, 89-106.

Emmett, W.W. (1974a) Channel changes. Geology, 2(6), 271-272.

Emmett, W.W. (1974b) Channel aggradation in western United States as indicated by observations at Vigil Network sites. Z. Geomorphol. Suppl. Bd., 21 (December), 52-62.

Emmett, W.W. & Hadley, R.F. (1968) The Vigil Network: Preservation and access of data. USGS Circ. 460-C.

Hadley, R.F. (1965) Selecting sites for observation of geomorphic and hydrologic processes through time. Symposium of Budapest, IASH Publ. 66, 217-233.

Leopold, L.B. (1962a) The Vigil Network. Bull. IASH, 7(2), 5-9.

Leopold, L.B. (1962b) The man and the hill. USGS Circ. 460-A.

Leopold, L.B. (1962c) A National network of hydrologic bench marks. USGS Circ. 460-B.

Leopold, L.B. & Emmett, W.W. (1965) Vigil Network sites: A sample of data for permanent filing. Bull. IASH, 10(3), 12-21.

Leopold, L.B. Emmett, W.W. & Myrick, W.W. (1966) Channel and hillslope proceesses is a semiarid area, New Mexico. USGS Prof. Papers 352-G, 193-253.

Osterkamp, W.R., Emmett, W.W. & Leopold, L.B. (1990). The Vigil Network--a reviving of interest. EOS 71 (12), 338.

Osterkamp, W.R., Emmett, W.W., & Leopold, L.B. (1991) The Vigil Network: a means of observing landscape change in drainage basins. Hydrol. Sci. J., 36(4), 331-344.

Patton, P.C. & Schumm, S.A. (1975) Gully erosion, northwestern Colorado: a threshold phenomenon. Geology, 3(2), 88-90.

Schumm, S.A. (1975) Episodic erosion: a modification of the geomorphic cycle. In: Theories of Landform Development (ed. by W.N. Melhorn & R.C. Flemal) (Proc. Sixth Annual Geomorphology Symp. Ser., Sept. 1975), 69-85. Publs. in Geomorphology.

UNESCO (1965) UNESCO/NS/198.