Responses to Reviewer

I have read the comments from the other two reviewers, and I generally agree with their suggestions about this paper. However, I would like to add an additional comment or two.

Thank you for your valuable comments and suggestion which will improve the quality of the manuscript.

My most significant concern about this paper is the dataset that is used to derive the drainage density for the perennial streams. The authors use the National Hydrography Dataset to identify the extent of the perennial network. All of the results rely on this dataset accurately reflecting the actual extent (and lengths) of perennial stream networks. However, among geomorphologists this dataset is widely regarded as a very poor representation of channel network extents and perhaps sinuosity (even perennial stream networks) because it is ultimately derived from blue lines on old contour maps, and the criteria that were used to derive blue lines on maps were not necessarily scientific or consistent between different regions of the country. It might be appropriate for many purposes, but it may not be appropriate for identification of true drainage densities. The authors make no direct tests of the validity of this dataset for this purpose in the paper. Instead, they support its use only with a citation to Simley (2003). Unfortunately, this is only a newsletter and not peer reviewed literature. In addition, the weblink in the citation takes one to a list of newsletters, and none of the newsletters date from 2003 at that provided site. Thus, there is no evidence that this dataset can be reliably used for the purposes at hand.

Thank you for your comments on the quality of NHD dataset, particularly the perennial stream data.

For the citation to Simley (2003), it can be found in the "Archived NHD Newsletters" (http://nhd.usgs.gov/newsletter_archive.html#date2003) for May 2003, and the link for the PDF file is http://nhd.usgs.gov/newsletters/News_May_03.pdf. We agree with you that the NHD newsletter is not a peer reviewed article. However, it is an official document by USGS for introducing how the dataset is constructed and the uncertainty of the data. The following description is from Simley (2003): "Scientists are often concerned with the perennial and intermittent classification of a stream. The National Hydrography Dataset (NHD) records this classification in the Fcode field in the Drain table, with 46004 for perennial streams and 46001 for intermittent streams. These codes are based on the stream symbolization on the 7.5-minute series topographic map that was digitized as the source for the NHD, and in some cases may have been revised based on the updates of local data producers such as the U.S. Forest Service. The accuracy of the stream classification is based primarily on photointerpretation and field checking at the time the map was compiled or revised. The USGS and its partner agencies made a considerable effort to correctly classify the stream within the observation methods available when the original maps were made ……."

We agree with you on the uncertainty of NHD dataset, particularly the temporal stream uncertainty which has been discussed in the response to Prof. Sivapalan. However, NHD is the best available stream network dataset at the national level. For the uncertainty of perennial stream density, please refer our response below.

In addition, even if the dataset reliably represents "perennial" streams, we don't know the definition of perennial that was used to define those streams. The authors discuss various definitions of perennial streams, but they do not identify the definition that was used to delineate these stream networks or demonstrate that it was consistently applied through all regions. I believe the appropriateness of this dataset needs to be strongly documented and/or directly tested before we can have any confidence in the results. It would be much more convincing if the drainage densities were checked for a few stream networks with different aridity indices or runoff coefficients.

Thank you. Perennial stream in NHD is defined as "stream contains water throughout the year, except for infrequent periods of severe drought (Simley, 2006)."

At the time when the perennial stream in NHD is classified, field work has been conducted by USGS. "The NHD stream classification of perennial, intermittent or ephemeral hydrographic categories generally is based on the original 1:24,000-scale topographic maps. The streams courses shown on the maps were delineated from stereo photos, and were then classified in the field" (Simley, 2012). To verify the perennial stream density in the NHD dataset, we conducted a thorough literature search for published perennial stream density data (lines 19-25 on page 7578 and lines 1-13 on page 7579). However, "Climate change, landscape change, human engineering, inconsistencies in mapping, project policies and a number of other variables present opportunities for improvement. New methods using hydrologic modeling in GIS with field checking may yield better results (Simley, 2007)." Hopefully, we can obtain some research funds to conduct the field work as you suggested in the future.

Second, and not as important, it is peculiar to me that the hydrologic data that are used in the analysis are from 1971-2003. The authors justify this selection by saying they hope to "minimize the non-stationary signals of water balance." I don't see how any choice of time period could avoid that issue completely. However, isn't it more appropriate to choose the hydrologic data so that it coincides with the time period when the channel extents were mainly calculated? When were these calculated? It would be important to know. Given the origin of this data, I would guess that much of the data pre-dates 1971. In addition, even if the dates are unknown, all drainage densities would have experienced the older period of hydrologic data, while only perhaps some would have experienced the more recent period of flows.

Thank you for your insightful suggestion. We agree with you that both climate and perennial stream may change due to climate change and human activities. We re-plotted the figure using climate aridity index during the period of 1948-1970 as shown in Figure 1 below. Similar dependence of D_p on E_p/P is observed.

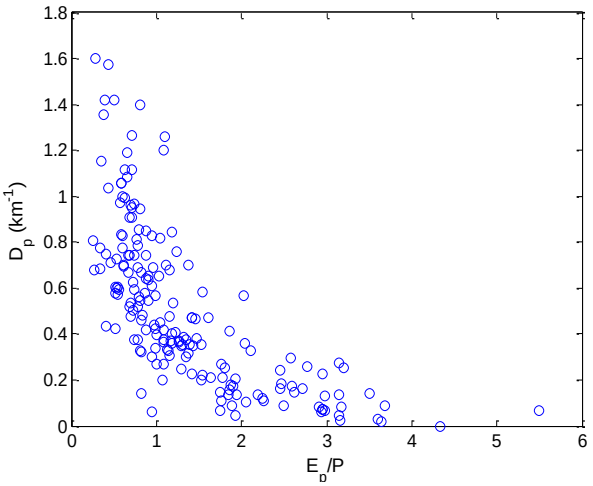

Figure 1. D_p (km^{-1}) ~E_p/P where the Ep and P data is the average during the period of 1948 to 1970.

Third, the authors acknowledge that many other factors (geology, topography, etc.) might affect the perennial drainage density, and they suggest that these factors should be investigated in the future. It might be worth considering whether any of these variables are correlated with the variables that are studied and thus might be lurking variables. In particular, I'm curious whether the relief of the watersheds (as a proxy for watershed slope, which will affect erosion and thus channel formation) is related to the aridity index in the dataset. It might be relatively easy to check and might strengthen the support for a direct relationship between the hydrologic variables and the drainage density.

Thank you for your suggestion. Watershed properties (such as topography, soil and vegetation) co-evolve with the climate system. To compute the average slope in each watershed, we downloaded the 90-m DEM SRTM data for North America from http://dds.cr.usgs.gov/srtm/version2_1/SRTM3/. Figure 2 shows the relationship between slope by percentage and climate aridity index. Generally, slope is higher in the humid region. Correspondingly, higher slope is coupled with higher perennial stream density as shown in Figure 3. We would argue that 1) Both slope and perennial stream are controlled by climate aridity index in certain levels; 2) Mean annual climate aridity index is the first order control perennial stream density like rainfall partitioning, but other factors such as slope are the second order control.

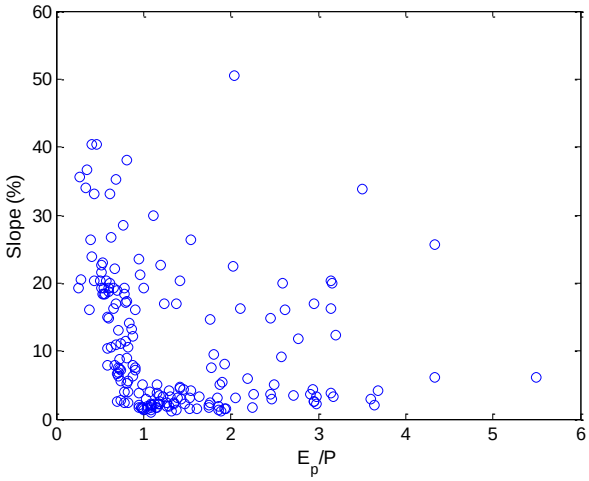

Figure 2: Slope (%) versus climate aridity index for the case study watersheds

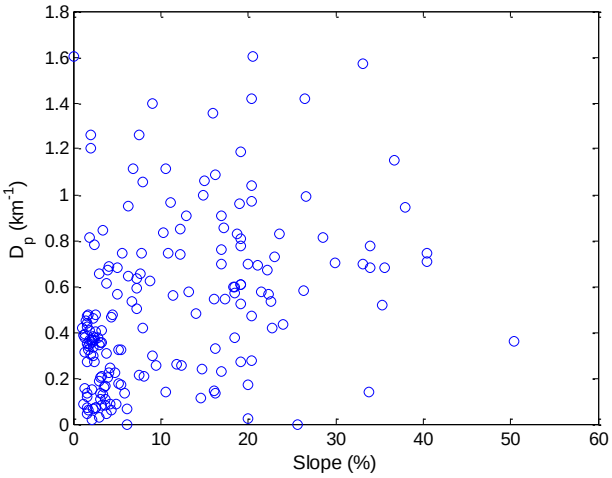

Figure 3: Perennial stream density versus slope (%) for the case study watersheds

Finally, I think the conclusions need to be more carefully written. For example, they state that the perennial stream density is "strongly correlated" with the mean annual runoff coefficient. However, I don't think any correlations are actually given in the paper (perhaps I missed them).

Thank you for your comments. The correlation coefficient between Q_b/P and D_p/D_p^* is 0.73 which will be added in the revised manuscript.

Reference

Simley, J. (2012), National Hydrography Dataset Newsletter, U.S. Geological Survey Report, 11(6).

Simley, J. (2006), National Hydrography Dataset Newsletter, U.S. Geological Survey Report, 5(6).

Simley, J. (2007), National Hydrography Dataset Newsletter, U.S. Geological Survey Report, 6(11).