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Runoff Scaling in Large Rivers of the World

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Runoff and precipitation scaling with respect to drainage area is analyzed for large river basins of the world, those with mean annual runoff in excess of 10 k^3/yr. The usefulness of the specific runoff (runoff per unit drainage area, m/yr) to categorize runoff scaling laws across the complete spectrum of climatic and hydrologic conditions is evaluated. It is found that (1) runoff scales with drainage area in those river basins with specific runoff in excess of 0.15 m/yr (r^2 = 0.88); (2) runoff scaling with drainage area shows remarkably high statistical correlation (r^2 = 0.97) in river basins with specific runoff equal to or larger than 1.0 m/yr; (3) runoff does not increase with increasing drainage area in river basins with specific runoff below 0.15 m/yr, where no discernible statistical association was found between runoff and drainage area; and (4) precipitation depth (m/yr) is inversely proportional to drainage area raised to a fractional exponent in river basins with specific runoff in excess of 0.15 m/yr. **Key Words: runoff, specific runoff, runoff scaling, depth-area-duration curves, large rivers.**

Introduction: Runoff and Watershed Area

Hydrologists have long sought relations between runoff (in terms of peak values or total volume) and physiographic variables (watershed area, watershed shape, watershed mean slope, drainage pattern characteristics, etc.). Such relations have been studied based on dimensional analysis (Strahler 1958), regression and regional analysis (Leopold et al. 1964; Morisawa 1973), geomorphic/climatic interactions (Rodriguez-Iturbe et al. 1982), and, more recently, on probabilistic analyses of runoff scaling and multi-scaling (see, e.g., Smith 1992; Gupta et al. 1994). Power laws relating runoff (*Q*) associated with a specified return period (e.g., the 100-year event or 99% quantile) and drainage area (*A*) have been proposed by several authors. A typical example is the empirical power law,

$$Q(A) = CA^m \qquad (1)$$

in which *C* and *m* are coefficients applicable to watersheds within a hydroclimatically homogeneous region. Gray (1973) listed 35 similar formulas, and Chow (1964) compared many others. Equation (1) is a mathematical statement of the scaling of runoff with respect to watershed area. Thus, according to equation (1), the ratio of runoffs with the same return period from two watersheds of areas A_1 and A_2 must be $(A_1/A_2)^m$.

The first objective of this article is to examine the nature of mean runoff scaling with respect to drainage area for large rivers of the world (i.e., those with mean annual runoff equal to or larger than 10 km^3/yr). Watershed area has been used as the predictor variable in previous studies of runoff scaling. However, it has been limited to relatively small sizes, typically less than 25,000 km^2. This practical constraint on watershed size stems from the underlying assumptions of hydroclimatic homogeneity required by (1) empirical runoff-area relations, and (2) the more refined simple scaling and multi-scaling interpretations of runoff-area associations. In a departure from past practice, Loáiciga et al. (1996) studied the behavior of annual runoff over large rivers of the world, those with a mean annual runoff equal to or larger than 10 km^3. In that case, the smallest watershed area was 20,000 km^2 and the largest was 6,150,000 km^2. Loáiciga et al. (1996) were interested in the discrepancies between model-simulated and measured runoff for large rivers. The focus of this study is to investigate runoff-area scaling relations in these large river basins based on the global runoff-area data set presented by Milliman and Meade (1983).

The second objective of this article is to analyze the implications that runoff-area scaling has on precipitation-area relationships for large rivers. Runoff-area data are available for most large rivers of the world (Milliman and Meade 1983; Berner and Berner 1996). Yet, complete precipitation-area data of comparable accuracy are not available for many of those river basins. Therefore, runoff-area scaling laws may provide valu-

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able clues about precipitation-area statistical relationships. In addition, this article examines the usefulness of the specific runoff ($s \equiv$ runoff / drainage area, dimensions of length) in categorizing runoff scaling laws applicable to large rivers of the world.

Deterministic and Probabilistic Runoff Scaling

The power law in equation (1) represents a deterministic relationship between runoff of specified recurrence and watershed area. The estimation of the coefficients C and m can be carried out, for example, by the method of least squares. Statistical inference on the estimated coefficients (C and m) and runoff predictions requires the randomization of equation (1). One convenient way of doing this is to take logarithms on both sides of equation (1) and add an error term (v) to the resulting, linearized, equation. Specifically,

$$\log Q = \log C + m \log A + v \qquad (2)$$

It is seen from equation (2) that the coefficient m is the slope of the best-fit line for the Q versus A data on log-log paper. The coefficient C is to equal 10^{C^*}, in which C^* is the intercept of the Q versus A best-fit line of the Q axis. Alternatively, C and m are estimable by simple regression analysis.

A general interpretation of runoff dependence on watershed scale has emerged recently with the introduction of simple-scaling and multi-scaling probability distributions of runoff (Smith 1992; Gupta et al. 1994). Let $Q(A)$ denote random runoff indexed by watershed area A. Thus, for a fixed area A (and return period) there is a probability distribution that governs the magnitude of runoff. Q represents the estimator of a peak or quantile value or the total volume over a period of time. The runoff distribution follows a simple scaling law if the following holds:

$$Q(A) \sim \left(\frac{A}{A^*}\right)^m Q(A^*) \qquad \text{for all } A \qquad (3)$$

in which ~ means "distributed as" and A^* represents a reference drainage area. The reference area is the minimum-sized drainage area for which the scaling relation (3) is assumed to hold.

The similarity between equations (1) and (3) is obvious, but their difference is subtle, yet fundamental. While equation (1) represents a relationship between deterministic quantities, equation (3) relates two probability distributions. Thus, according to the simple-scaling equation (3), if the distribution of $Q(A^*)$ is known, so is the distribution of $Q(A)$. More complex models describing the scaling of runoff with drainage area have been reported in the last few years. For example, multi-scaling runoff distributions arise when the probabilistic dependence of runoff on watershed area cannot be described by the simple model of equation (3) over the entire range of area (see Gupta et al. 1994).

Runoff, Drainage Area, and Specific Runoff for Large River Basins

Table 1 contains drainage area and mean annual runoff data for the 47 largest rivers of the world. In this case, the criterion for qualifying as a large river is that mean annual runoff must be 10 km^3 or larger. The data of Table 1 suggest that drainage area alone is not an ideal criterion for classifying a river as large or small in terms of discharge. Some rivers have large drainage areas but relatively small mean annual runoff, in many cases less than 10 km^3. The Nile river has a total drainage area of 2,960,000 km^2, and yet its mean annual runoff is only 30 km^3. On the other hand, the Purari river (New Guinea) has a drainage area of only 31,000 km^2 but its mean annual runoff is an astonishing 77 km^3. On a per-unit-area basis, the Purari river produces more runoff than any other large river: its specific runoff is the largest at 2.48 m/yr.

The rivers have been ranked in Table 1 in descending order by specific runoff. A few rivers whose watersheds lie within wet equatorial latitudes, such as the Purari (New Guinea), Fly (New Guinea), Amazon (Brazil, flowing mostly west-east), Orinoco (Venezuela), and Magdalena (Colombia), have large specific runoffs, equal to or larger than 1.00 m/yr. The Hungho (Vietnam) and Irrawaddy (Burma) rivers, both with specific runoffs at or larger than 1.00 m/yr, are located within humid subtropical latitudes in regions of strong monsoonal activity. Rivers with the lowest specific runoff (less than 0.07 m/yr), such as the Colorado (United States), Huangho (China), Tigris-Euphrates (discharging to the Indian Ocean in Iraq), Orange (South

Table 1 *Data for Rivers of the World with Mean Annual Runoff Equal to or Larger than 10 km^3 /yr (adapted from Milliman and Meade 1983)*

Number	River	Drainage area (10^4 km^2)	Mean runoff (km^3/yr)	Specific runoff (m/yr)
1	Purari	3.1	77	2.48
2	Fly	6.1	77	1.26
3	Orinoco	99	1100	1.11
4	Hungho	12	123	1.03
5	Amazon	615	6300	1.02
6	Irrawaddy	43	428	1.00
7	Magdalena	24	237	0.988
8	Susitna	5	40	0.800
9	Zhu Jiang	44	302	0.686
10	Po	7	46	0.657
11	Ganges/Brahmaputra	148	971	0.656
12	Copper	6	39	0.650
13	Hudson	2	12	0.600
14	Mekong	79	470	0.595
15	Rhone	9	49	0.544
16	Mehandi	13	67	0.515
17	Fraser	22	112	0.509
18	Damodar	2	10	0.500
19	Yangtze	194	900	0.464
20	St. Lawrence	103	447	0.434
21	Columbia	67	251	0.375
22	Zaire	382	1250	0.327
23	Severnay Dvina	35	106	0.303
24	Negro	10	30	0.300
25	Godavari	31	84	0.271
26	Danube	81	206	0.254
27	Indus	97	238	0.245
28	Yukon	84	195	0.232
29	Yenisei	258	560	0.217
30	Lena	250	514	0.206
31	Zambesi	120	223	0.186
32	Mississippi	327	580	0.177
33	Amur	185	325	0.176
34	MacKenzie	181	306	0.169
35	La Plata	283	470	0.166
36	Niger	121	192	0.159
37	Ob	250	385	0.154
38	Indigirka	36	55	0.152
39	Sao Francisco	64	97	0.151
40	Yana	22	29	0.132
41	Kolyma	64	71	0.111
42	Huangho	77	49	0.063
43	Tigris/Euphrates	105	46	0.043
44	Colorado	64	20	0.031
45	Murray	106	22	0.0208
46	Orange	102	11	0.0107
47	Nile	296	30	0.0101

Africa), Murray (Australia), and Nile (discharging to the Mediterranean Sea in Egypt in its south-north journey), are located in the dry midlatitudes and/or subject to strong rain-shadowing by mountain massifs. The Yana and Kolyma rivers, located within the low-humidity Russian subarctic continental and arctic regions, exhibit low specific runoffs of less than 0.15 m/yr. All other rivers considered in this work are found in a wide range of geographical-climatic zones, with specific runoffs between 0.15 and 1.00 m/yr.

Large rivers with specific runoff at or larger than 1.00 m/yr encompass a wide range of drainage areas, from 31,000 (Purari river) to 6,150,000 km² (the Amazon river). The same can be said of large rivers with specific runoff less than 0.15 m/yr, which include drainage areas from 220,000 (Yana river) to 2,960,000 km² (the Nile). Rivers with specific runoff between 0.15 and 1.00 m/yr have drainage areas ranging from 50,000 km^2 (Susitna river) to 1,250,000 km^2 (Zaire river). Figure 1 shows a plot of the ratio of mean annual runoff to drainage area, the so-called specific runoff ratio, for the rivers listed in Table 1. It is seen in Figure 1 that specific runoff has a weak association with drainage area when all the runoff-area data are considered. The impact of specific discharge on runoff scaling will be further explored below.

Runoff Scaling in Large River Basins

Consider again the simple-scaling equation (3). Taking expected values on both sides of equation (3) and letting $A^* = 1$, where 1 means one unit of area equal to 10^4 km^2 , yields the following:

$$q(A) = A^m q(1) \tag{4}$$

in which $q()$ denotes the expected value of $Q()$, in km³/yr, and A is the drainage area, in multiples of 10^4 km^2. Figure 2 shows a plot of the mean annual runoff, $q(A)$, as a function of drainage area for the rivers listed in Table 1. Rivers with specific runoffs equal to or larger than 1.00 m/yr (numbered 1 through 7) or less than 0.15 m/yr (numbered 40 through 47) are highlighted. These rivers (1–7 and 40–47) introduce a fair amount of scatter around the least-squares line in the log-log plot of runoff versus drainage area. The least-squares function fitted to the entire data in Figure 2 is:

$$q(A) = 11.55A^{0.63} \tag{5}$$

in which q is in km³/yr and A in multiples of 10^4 km². In equation (5), 11.55 is the least-squares estimate of $q(1)$, which is the mean annual runoff (in km³/yr) for a unit drainage area of 10^4 km^2. The coefficient of determination for the regression in equation (5) is $r^2 = 0.43$, indicating a weak relation between mean annual runoff and drainage area. This is attributed to those rivers with specific runoff equal to or larger than 1 m/yr (labeled 1 to 7 in Figure 2) and to those with specific runoff below 0.15 m/yr (labeled 40 to 47). The runoff and drainage area data for these

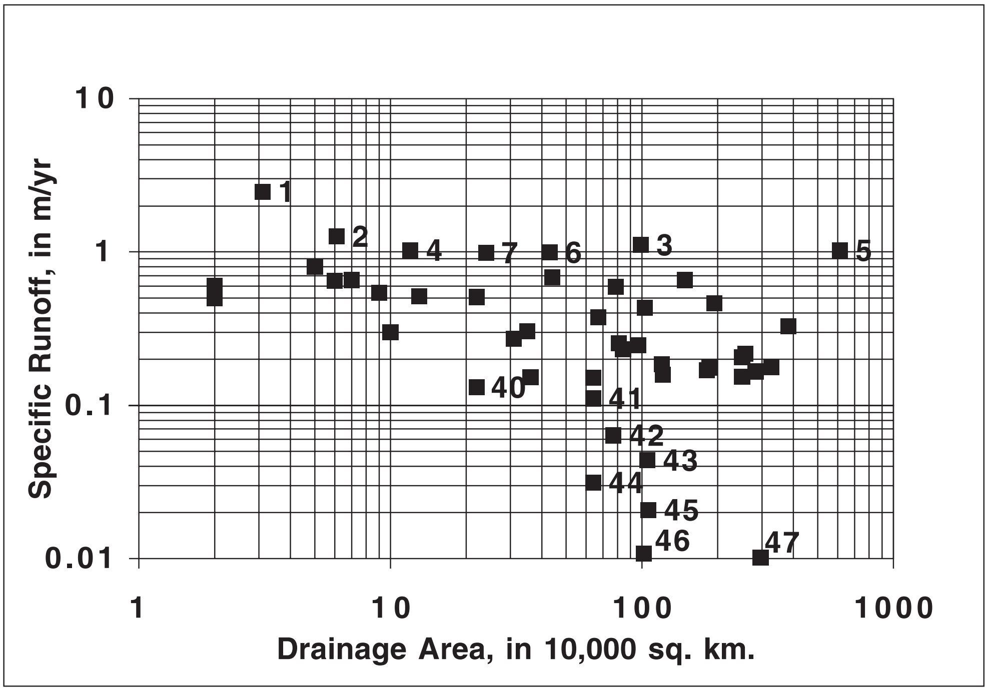

Figure 1: *Specific runoff vs. area for 47 largest rivers of the world. Numbers 1-7 denote rivers with specific runoff ≥ 1.00 m/yr and those numbered 40-47 have specific runoffs < 0.15 m/yr (see Table 1).*

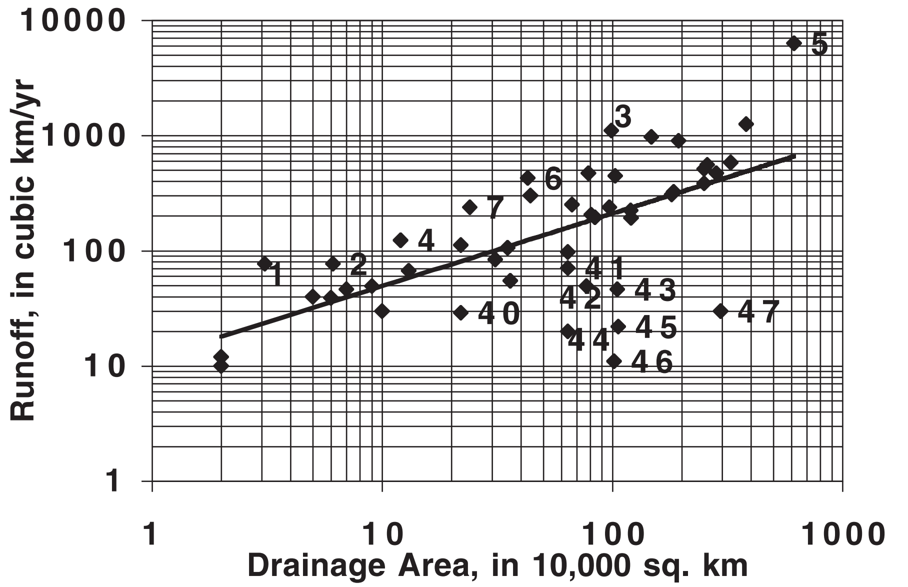

Figure 2: *Runoff vs. area for 47 largest rivers of the world. Least-squares line is given by $q(A) = 11.55A^{0.63}$ ($r^2 = 0.43$), in which q(A) is the mean annual runoff in km³ and A is drainage area in multiples of 10^4 km². Numbers 1-7 denote rivers with specific runoff s ≥ 1.00 m/yr and those numbered 40-47 have specific runoff s < 0.15 m/yr (see Table 1).*

rivers show the largest deviations from the best-fit line in Figure 2.

Next, rivers with specific runoff equal to or larger than 1.00 m/yr (1–7 in Figure 2) or specific runoff less than 0.15 m/yr (40–47 in Figure 2) were discarded and a least-squares function was fitted to the remaining set of data points. A graph is shown in Figure 3. The least-squares function was in this case (for the specified range of specific runoff, *s)* :

$$q(A) = 7.90A^{0.771} \qquad 0.15 < s < 1.00 \qquad (6)$$

in which q and A are in km³/yr and in multiples of 10^4 km²/yr, respectively, and s is in m/yr. The coefficient of determination associated with equation (6) is $r^2 = 0.88$, a significant improvement relative to the least-squares function (5) (shown in Figure 2). The least-squares estimate of the mean annual runoff for a unit drainage area equal to 10^4 km² is $q(1)$= 7.90 km³/yr according to equation (6). Notice that the power law of equation (6) applies to drainage areas between 20×10^4 and $3{,}820 \times 10^4$ km², which comprises the entire range of drainage area considered herein with the exception of the Amazon river, which has the largest drainage area at 6,150 x 10^4 km².

A power law was fitted to runoff-area data for rivers 1–7, i.e., those with a specific runoff equal to or larger than 1.0 m/yr. Graphical results are shown in Figure 4. The regression equation is in this case:

$$q(A) = 17.53A^{0.887} \qquad s \geq 1.0 \qquad (7)$$

where q and A are expressed in m/yr and multiples of 10^4 km², respectively. The coefficient of determination $r^2 = 0.97$ for the power law of equation (7), a remarkably high positive correlation between runoff and area for these large, humid, river basins.

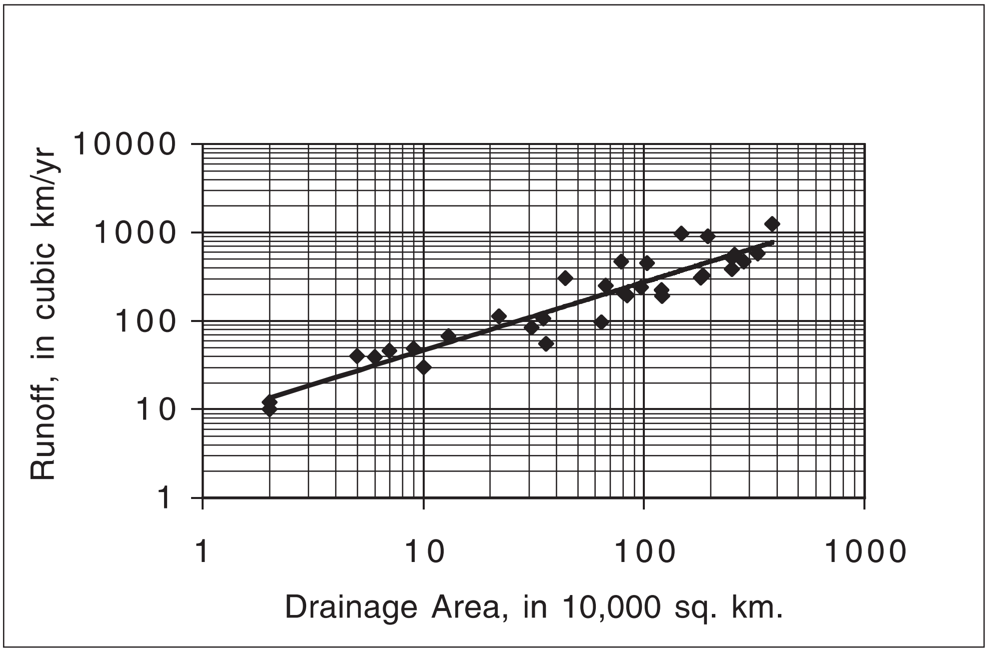

Figure 3: *Runoff vs. area for large rivers with specific discharge 0.15 < s < 1.00 m/yr. Least-squares line is given by $q(A) = 7.90A^{0.771}$ (r^2 = 0.88). q(A) is the mean annual runoff in km^3 and A is drainage area in multiples of 10^4 km^2.*

Lastly, the data for rivers 40–47, those with specific runoff less than 0.15 m/yr, were analyzed for possible patterns of statistical association between runoff and drainage area. None was found, with a number of statistical models (e.g., power, logarithmic, and linear models) yielding r^2 very near zero (in all cases < 0.01).

The previous analysis suggests strong statistical correlation between runoff and drainage area for river basins with large specific runoff. Conversely, runoff and drainage area do not correlate well in cases where the specific runoff is less than 0.15 m/yr. Rivers with specific runoff less than 0.15 m/yr exhibit a common denominator: relatively small water supply per unit drainage area. In this case, evaporation (E) is a strongly dominant factor over runoff (Q) in the hydrologic equation , $P = E + Q$, where P denotes precipitation. Under these circumstances, the runoff-area data indicate that no runoff scaling laws exist, and, as a corollary, that drainage area does not correlate positively with drainage area.

Some Implications of the Power Law Relating Runoff and Drainage Area

Equations (6) and (7) indicate that the mean annual runoff of large rivers with specific discharge larger than 0.15 m/yr is a power function of drainage area, where the exponent m is less than one but larger than zero. Therefore, runoff increases with increasing drainage area. What are the implications of the previous findings for runoff scaling with respect to precipitation-area relations? Precipitation data for many large river basins do not have adequate spatial coverage. Runoff-area data, on the other hand, have been compiled with reasonable accuracy. This is not surprising, since runoff can be measured at a few strategically located sites to estimate mean annual discharge from large river basins. Precipitation, on the other hand, typically has high spatial variability, thus requiring extensive monitoring networks to assess basin-scale averages with acceptable accuracy (i.e., within ± 5% of the actual mean). It is useful, therefore, to

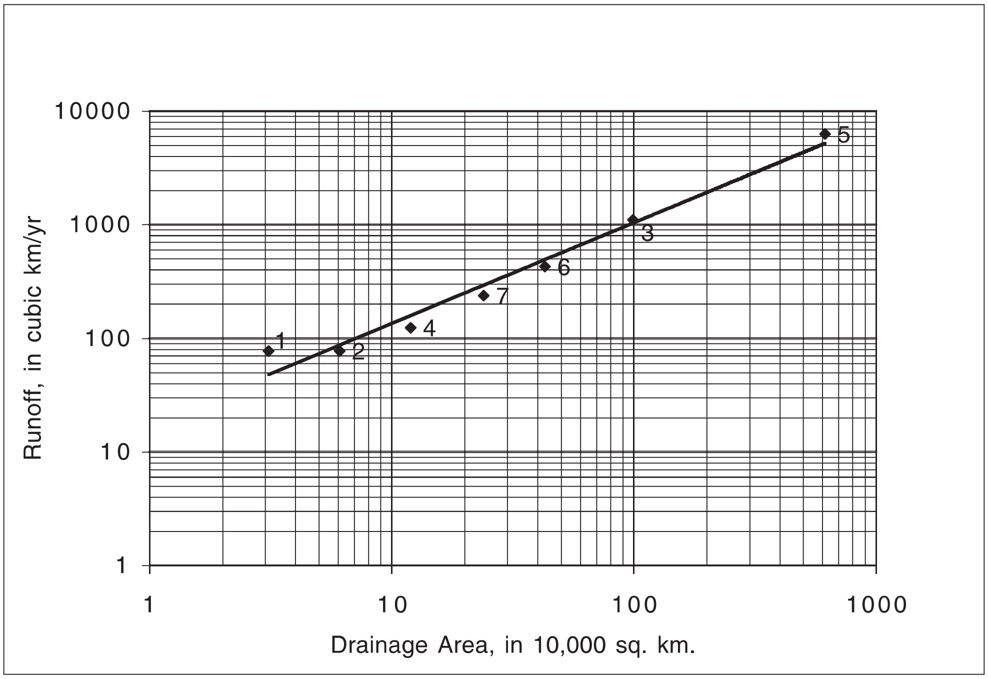

Figure 4: *Runoff vs. area for large rivers of the world with s ≥ 1.0 m/yr. Least-squares line is given by $q(A) = 17.53A^{0.887}$ ($r^2 = 0.97$). q(A) is the mean annual runoff in km^3 and A is drainage area in multiples of 10^4 km^2.*

obtain precipitation-area scaling relationships indirectly, that is, from runoff-area scaling laws. How do the power laws in equations (6) and (7) relate to mean annual precipitation depth (*P*, dimensions of length) in the drainage area? The volume of precipitation in a drainage area *A* is equal to $P \bullet A$ (dimensions of volume). The runoff associated with that volume of precipitation is $q = K \bullet P \bullet A$, where *K* is the so-called runoff coefficient. The runoff coefficient lies in the interval $0 \leq K \leq 1$. *K* measures the fraction of precipitation that becomes runoff. It takes values below 0.3 in dry river basins, where a large fraction of precipitation is vaporized to the atmosphere, while it rises above 0.4 in humid basins, where soils are frequently near saturation. For other basins, the runoff coefficient lies, with remarkable consistency, between 0.3 and 0.4 (Zektser and Loáiciga 1993). Therefore, except in extreme cases, *K* may be treated as though independent of drainage area size. Dividing either equation (6) or (7) by $K \bullet A$, and introducing a dimensional conversion factor (Φ) to produce precipitation *P* in m/yr, yields a scaling law for mean precipitation:

$$P = \frac{\Phi}{K} \cdot A^{m-1} \qquad s > 0.15 \tag{8}$$

where *m-1* equals -0.229 or -0.113 for equations (6) or (7), respectively; Φ equals 0.790 or 1.753 for equations (6) or (7), respectively; *P* is in m/yr; and *A* is expressed in multiples of 10^4 km^2.

Equation (8) establishes that mean precipitation depth is inversely proportional to drainage area raised to a fractional exponent (when specific discharge exceeds 0.15 m/yr). This kind of dependence of mean precipitation depth on drainage area is intriguing in view of the fact that depth-area-duration data indicate that, for a given duration of a precipitation event, the depth of precipitation tends to drop as the storm-covered area increases (see, e.g., Chow 1964). Thus, our analysis suggests that patterns of depth-area association observed at the scale of individual precipitation events carry over to the scale of large river basins and are reflected in the relation between mean annual precipitation depth and drainage area.

Summary and Conclusions

This paper has analyzed the relation among (1) mean annual runoff and drainage area, (2) mean precipitation depth and drainage area, and (3) the role of specific runoff as an indicator variable with which to categorize runoff scaling laws for large rivers of the world. Following previous experience with area-runoff relations for small rivers, a simple scaling of runoff with respect to drainage area was assumed as a working hypothesis in this study of large rivers. The results of our analysis indicate that:

1. Specific runoff is useful for categorizing runoff scaling laws in large rivers. Such scaling laws show strong statistical association between mean annual runoff and drainage area in river basins where specific runoff exceeds 0.15 m/yr. In large rivers with specific runoff less than 0.15 m/yr, no discernible association was identified between runoff and drainage area. In fact, for the latter rivers, the data indicate that mean runoff does not increase with increasing drainage area.
2. Specifically, for the range of specific runoff between 0.15 and 1.00 m/yr, mean annual runoff (in km^3/yr) is proportional to $A^{0.771}$. In river basins with specific runoff in excess of 1.0 m/yr, runoff is proportional to $A^{0.887}$. The statistical correlation between runoff and drainage area is excellent for river basins with specific runoff in excess of 0.15 m/yr. The coefficient of determination is $r^2 = 0.88$ for the scaling law of rivers with specific runoff between 0.15 and 1.0 m/yr, while it is equal to 0.97 for those rivers with specific runoff equal to or larger than 1.0 m/yr.
3. Mean annual precipitation depth (in m/yr) was determined from runoff-area power laws. Precipitation is proportional to $A^{-0.229}$ for those rivers with specific runoff between 0.15 and 1.0 m/yr, while it is proportional to $A^{-0.113}$ in rivers with specific runoff in excess of 1.0 m/yr. Precipitation depth decreases with increasing drainage in large rivers with specific runoff in excess of 0.15 m/yr. Our analysis suggests that in dry regions, where evaporation consumes a large portion of the precipitation, runoff is not positively correlated with area size. As the specific runoff increases above 0.15 m/yr, so does the statistical association between runoff and drainage area size.
4. The established usefulness of the specific runoff in categorizing runoff and precipitation scaling laws for large rivers is significant. It suggests that the "homogeneity" needed to establish scaling laws is ensured by similarity in the excess precipitation per unit area available to generate runoff. This conclusion takes further relevance given that it is supported by runoff-area data stemming from large river basins encompassing the spectrum of climatic and hydrologic conditions encountered worldwide.

The role of specific discharge in power scaling of large-river runoff opens up a host of interesting questions. Among them, one that deserves further research is to what extent the scaling laws determined in this article apply to all other rivers. This would ascertain whether or not the role of specific discharge is fundamental to runoff-scaling. ■

Literature Cited

Berner, E. K., and R. A. Berner. 1996. *Global Environment.* Upper Saddle River, NJ: Prentice Hall.

Chow, V. T., ed. 1964. *Handbook of Applied Hydrology.* New York: Mc Graw Hill Inc.

Gray, D. M., ed. 1973. *Handbook on the Principles of Hydrology.* Port Washington, NY: Water Information Center, Inc.

Gupta, V. K., O. J. Mesa, and D. R. Dawdy. 1994. Multiscaling theory of flood peaks: Regional quantile analysis. *Water Resources Research* 30(12): 3,405–21.

Leopold, L., M. G. Wolman, and J. P. Miller. 1964. *Fluvial Processes in Geomorphology.* New York: W. H. Freeman.

Loáiciga, H. A., J. B. Valdes, R. Vogel, J. Garvey, and H. Schwarz. 1996. Global warming and the hydrologic cycle. *Journal of Hydrology* 147(1–2): 83–128.

Milliman, J. D., and R. H. Meade. 1983. World-wide delivery of river sediment to the oceans. *Jourrnal of Geology* 91(1):1–21.

Morisawa, M., ed. 1973. *Fluvial Geomorphology*. Binghampton, NY: New York State University.

Rodriguez-Iturbe, I., M. Gonzalez-Sanabria, and R. L. Bras. 1982. A geomorphoclimatic theory of the instantaneous unit hydrograph. *Water Resources Research* 18 (4):887–86.

Smith, J. A. 1992. Representation of basin scale in flood peak distributions. *Water Resources Research* 28(11):2,993–99.
Strahler, A. 1958. Dimensional analysis applied to fluvially eroded land forms. *Bulletin of the Geological Society of America* 69:279–300.
Zektser, I. S. and H. A. Loáiciga. 1993. Ground water fluxes in the global hydrologic cycle: Past, present, and future. *Journal of Hydrology* 144:405–27.

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Support for, and Impacts of, Publishing in the *Annals of the AAG:* The Authors and an Editor Speak

Stanley D. Brunn
University of Kentucky

A survey of 176 authors who published in the *Annals* between 1988 and 1993 provides insights into why authors submitted their research to the journal, what support they received, and the impacts of the publication on their careers. Most decided themselves to submit their work, and one-third received support from research grants; cartographic assistance and graduate assistants were less important. The major benefits of publishing in the *Annals* were visibility in one's department, contact with other geographers, and requests for reprints. Most authors presented their ideas at professional meetings prior to submission. Promotion and salary increases were benefits for women, assistant professors, associate professors, and physical geographers. Authors considered their articles as original examinations that yielded new results, contributed to theory, stimulated debate, and helped bridge gaps inside and outside of geography. These results are useful in helping individual authors and for administrators in identifying the kinds of research support needed by authors publishing in the *Annals*. **Key Words: research support, impacts of publishing, voices of authors, career planning.**

How important to one's professional career is publishing an article in the *Annals*? What are the benefits as seen by graduate students, those seeking promotion and tenure, those hoping for salary increases, and full professors? Are there any differences in the impact of publication for women and men, and between physical and human geographers?

These are among the questions that stimulated this research. While most professional geographers would consider an article in the *Annals* to be important in advancing their careers, we are less certain about how to measure its importance. The questions above are of interest not only to prospective authors and those who are successful in publishing in the journal, but to individuals and committees responsible for assembling promotion and tenure files, those providing salary increases, graduate assistants seeking employment, and physical and human geographers. The presentation is based on a survey of authors who published in the *Annals* from 1988 to 1993.

Articles exist in the literature that identify, with rankings, what geographers consider major journals (Lee and Evans 1984, 1985; Turner 1988; Wheeler 1990). The *Annals* ranks very favorably (often the highest) in many of these studies. We also have articles by former editors providing advice to potential authors that discuss how to prepare manuscripts for publication, the importance of good writing, the criteria used by reviewers, and how to persevere in the midst of difficult odds (Hanson 1988; De Souza 1988; Brunn 1988; Kenzer 1989). And we have articles that discuss the promotion and tenure processes

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