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RESEARCH ARTICLE

FLOW DYNAMICS OF RIVER DIKHU, NAGALAND

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ABSTRACT

This paper describes the basic concepts of open channel flow and important conditions effecting the flow behavior of river channels. The study of open channels traditionally includes the discussion of flow in river. In this paper, the Dikhu river in Nagaland was selected to assess the flow regime in different months/seasons of the year. The statistical interpretation was the most important feature of prediction during the research tenure.

INTRODUCTION

Water being a prime natural resource, has many surprising properties that are important to life and it covers three fourth of Earth's surface. Quality water is vital to the social, health and economic well being of all people. Water too is a commodity with its inherent nature of falling down because of the gravitational pull, which creates the storage, the streams, the tributaries and the rivers, that meet in the sea. Rivers are of immense importance geologically, biologically, historically and culturally. Although they contain only about 0.0001% of the total amount of water in the world at any given time, rivers are vital carriers of water and nutrients to all areas around the earth. They are critical components of the hydrological cycle, acting as drainage channels for surface water. The world's rivers drain nearly 75% of the earth's land surface. The river ecosystem is formed by the interaction between river biota and their hydro-geochemical environment. It is characterized by the continuous transport of various substances, such as organic matter and the nutrients, from the soils of the drainage basin to the river and from there, downstream with the flowing water. River ecosystems are adapted to the natural hydrological regime and many components of these systems rely on floods for the exchange, not just of water, but also energy, nutrients, sediments and living organisms (Acreman, 2000).

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River ecosystem contains many other smaller types of ecosystems, including many of that which does not lie within the open-water channel. River ecosystem is also unique in that they are relatively small volume, but open, ecosystems with high rates of energy throughout. Therefore, understanding a river ecosystem is clearly a challenging and complicated task. Dikhu River is one of the most prominent rivers of Nagaland. River Dikhu, which has a total length of about 160 km, originates from Nuroto Hill area in Zunheboto district. The river flows across the Mokokchung and the Longleng districts. The main tributaries of river Dikhu are .Yangyu of Tuensang district and Nanung in the Langpangkong range in Mokokchung district. The Dikhu River is one of the tributaries of Brahmaputra, one of the mightiest rivers of India. The Dikhu River is not only a prime tourist attraction, but also a significant source of livelihood for the people. The water makes the area around the river fertile. Since Long leng is primarily an agricultural district, the Dikhu River serves as a lifeline to its people.

MATERIALS AND METHODS

Study Area

Nagaland is dissected by a number of seasonal and perennial rivers and rivulets. Of the rivers, Dhansiri, Doyang and Dikhu flow westward into the Brahmaputra. Dikhu River is one of the most prominent rivers of Nagaland. River Dikhu, which has a total length of about 160 km, originates from Nuroto Hill area in Zunheboto district. The river flows across the Mokokchung and the Longleng districts.

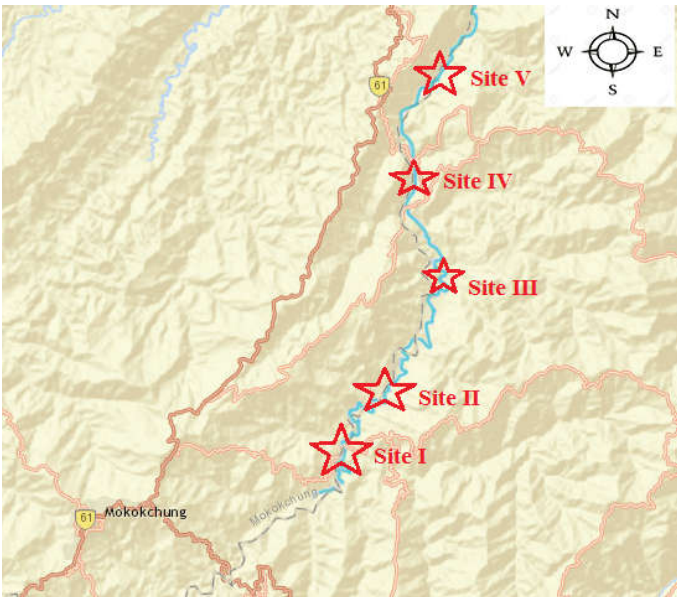
The main tributaries of river Dikhu are Yangyu of Tuensang district and Nanung in the Langpangkong range in Mokokchung district.

Study Sites

For the present investigation, five sampling sites were selected on the basis of accessibility and vegetation. The description of study sites is given as under:

Sampling site –1: Longmisa Noksen

Site I is located upstream. It has pebbles, sand and hard rock bed with vegetation covering at both sides of the river. It also has nearby agricultural lands and tree plantations. The land use pattern includes agricultural farmland and plantation. The watershed property of the water includes agricultural runoff. There were also no visible sources of waste disposal. It has a stretch of 2.18km and width varying from 9.56 m to 40.29 m.



Sampling site – 2 Longmisa- Chuchu

Site II is located upstream. It has a stretch of 898.87 m and width varying from 12.56 m to 32.29 m. It has pebbles, sand and hard rock bed with vegetation covering at both sides of the river. It also has nearby agricultural lands and tree plantations. The land use pattern includes agricultural farmland and plantation.

Sampling site – 3 Longkong

Site III is located upstream. It has a stretch of 1.48km and width varying from 8.56 m to 42.29 m. The area is composed of pebbles, sand and hard rock bed with vegetations covering both sides of the river. The main types of vegetation include trees and shrubs. The watershed properties of the river include mainly agricultural runoffs.

Sampling site – 4 Changtongya Yaongyimsen

Site IV is located upstream. It has a stretch of 1.88 km and width varying from 7.56 m to 39.29 m. The area is composed of pebbles, sand and hard rock bed with vegetations covering both sides of the river. The main types of vegetation include trees and shrubs. The watershed properties of the river include mainly agricultural runoffs.

Sampling site – 5 Changtongya Longleng

Site V is located midstream and doesn't not have any adjacent farmland but it consists of short shrubs. It has a stretch of 1.68 km and width varying from 7.56 m to 33.29 m. The watershed properties of the river include mainly runoffs from adjacent soil and upstream agricultural runoffs.

Current/Flow

The units that are typically used to express discharge include m^3/s (cubic meters per second), ft^3/s (cubic feet per second or cfs) and/or acre-feet per day (Dunne and Leopold, 1978). A commonly applied methodology for measuring, and estimating, the discharge of a river is based on a simplified form of the continuity equation. The equation implies that for any incompressible fluid, such as liquid water, the discharge (Q) is equal to the product of the stream's cross-sectional area (A) and its mean velocity ($\bar{u}$), and is written as:

$$Q = A\bar{u}$$

where

- Q is the discharge ($[L^3T^{-1}]$; m^3/s or ft^3/s)
- A is the cross-sectional area of the portion of the channel occupied by the flow ($[L^2]$; m^2 or ft^2)
- $\bar{u}$ is the average flow velocity0 ($[LT^{-1}]$; m/s or ft/s)

RESULTS

Average monthly discharge (m^3sec^{-1}) were calculated for five study sites in Dikhu river. Help was sought from the Meterological Department in context with the monthly rainfall, vapour pressure and water velocity. Variable trends in flow measurements were recorded in the flow, which is depicted in Table 1 & Figure 1. At site 1, the minimum flow was recorded in the month of Dec'14 (0.2 cusecs) during the tenure of research from Nov'14 to October '16. The peak flows were recorded in summer months with highest value of 9.53 cusecs in May'15 and 9.23 cusecs in Jun'16. Flow duration parameters and curve is depicted in Table 2 and Figure 2. At site 2, the minimum flow was recorded in the month of Dec'14 (0.21 cusecs) during the tenure of research from Nov'14 to October '16. The peak flows were recorded in summer months with highest value of 9.02 cusecs in July'15 and 9.34 cusecs in Jun'16. Flow duration parameters and curve is depicted in Table 3 and Figure 3. At site 3, the minimum flow was recorded in the month of Nov'14 to Jan'14 (0.03 cusecs) during the tenure of research from Nov'14 to October '16. The peak flows were recorded in summer months with highest value of 0.43 cusecs in Jun'15 & July'15 and 0.47 cusecs in Jun'16. Flow duration parameters and curve is depicted in Table 4 and Figure 4. At site 4, the minimum flow was recorded in the month of Nov'14 & Jan'14 (0.03 cusecs). The peak flows were recorded in summer months with highest value of 0.43 cusecs in July'15 and 0.48 cusecs in Jun'16. Flow duration parameters and curve is depicted in Table 5 and Figure 5. At site 5, the minimum flow was recorded in the month of Dec'14 (0.3 cusecs). The peak flows were recorded in summer months with highest value of 14.295 cusecs in

May'15 and 13.845 cusecs in Jun'16. Flow duration parameters and curve is depicted in Table 6 and Figure 6.

Table 1. Average monthly water discharge (m^3 sec^{-1}) in various study sites of Dikhu river during the tenure of research

Month	Site 1	Site 2	Site 3	Site 4	Site 5
November '14	0.45	0.39	0.42	0.38	0.38
December '14	0.2	0.21	0.23	0.19	0.20
January '15	0.44	0.45	0.36	0.48	0.45
February '15	0.44	0.49	0.39	0.51	0.49
March '15	1.42	1.57	1.50	1.52	1.66
April '15	2.47	2.99	2.39	2.89	2.56
May '15	9.53	8.98	8.99	8.76	7.99
June '15	8.84	8.80	8.72	8.59	8.49
July '15	8.54	9.02	8.49	9.11	9.31
August '15	6.14	6.14	6.20	6.21	6.18
September '15	4.7	4.3	4.81	4.19	4.36
October '15	1.14	1.15	1.12	1.09	1.15
November '15	0.55	0.49	0.62	0.48	0.53
December '15	0.35	0.40	0.41	0.41	0.46
January '16	0.56	0.52	0.60	0.49	0.52
February '16	0.56	0.50	0.58	0.52	0.54
March '16	1.55	2.0	1.67	1.99	1.89
April '16	3.02	4.02	3.12	4.10	3.92
May '16	8.56	7.99	8.70	7.85	7.65
June '16	9.23	9.34	10.0	9.29	9.16
July '16	8.39	8.99	8.58	9.04	8.88
August '16	6.25	6.27	6.32	6.38	6.56
September '16	4.7	4.3	4.85	4.88	4.92
October '16	1.14	1.15	1.09	1.22	1.32
Mean	3.715417	3.769167	3.756667	3.77375	3.732083

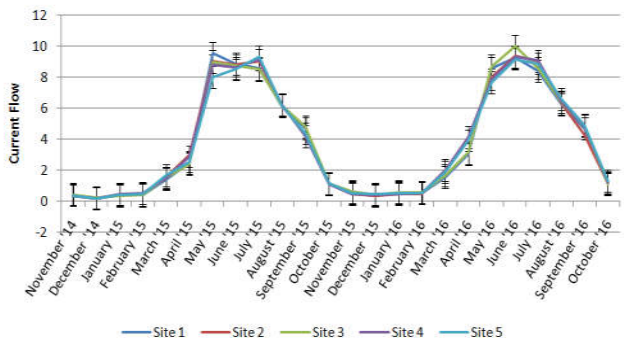


Fig. 1. Average monthly water discharge (m^3 sec^{-1}) in various study sites of Dikhu river during the tenure of research

Table 2. Flow duration curve parameters for site 1 in Dikhu river system

MWD	x^2	Rank	E(x)	ln(x)	ln[-ln E(x)]
9.53	90.82089	1	0.047619	2.254445	1.113344
9.23	85.19289	2	0.095238	2.222459	0.855
8.84	78.1456	3	0.142857	2.179287	0.66573
8.56	73.27361	4	0.190476	2.1471	0.50575
8.54	72.9316	5	0.238095	2.144761	0.361224
6.14	37.6996	6	0.285714	1.814825	0.225351
4.7	22.09	7	0.333333	1.547562	0.094048
3.02	9.120399	8	0.380952	1.105257	-0.03554
2.47	6.1009	9	0.428571	0.904218	-0.1657
1.55	2.4025	10	0.47619	0.438255	-0.29849
1.42	2.0164	11	0.52381	0.350657	-0.43599
1.14	1.2996	12	0.571429	0.131028	-0.5805
0.56	0.3136	13	0.619048	-0.57982	-0.73486
0.56	0.3136	14	0.666667	-0.57982	-0.90272
0.55	0.3025	15	0.714286	-0.59784	-1.08924
0.45	0.2025	16	0.761905	-0.79851	-1.3022
0.44	0.1936	17	0.809524	-0.82098	-1.55443
0.44	0.1936	18	0.857143	-0.82098	-1.86982
0.35	0.1225	19	0.904762	-1.04982	-2.30175
0.2	0.04	20	0.952381	-1.60944	-3.02023

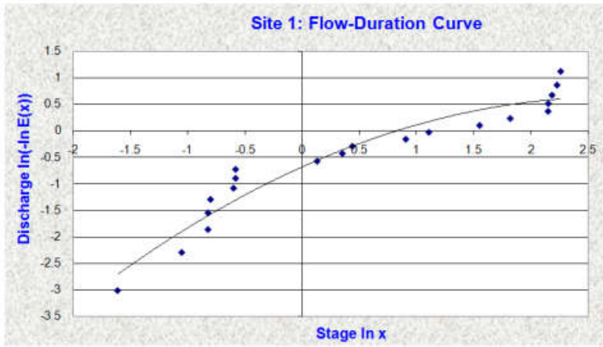


Figure 2. Flow duration curve for site 1 in Dikhu river system

Table 3. Flow duration curve parameters for site 2 in Dikhu river system

MWD	x^2	Rank	E(x)	ln(x)	ln[-ln E(x)]
9.34	87.2356	1	0.047619	2.234306	1.113344
9.02	81.3604	2	0.095238	2.199444	0.855
8.98	80.64039	3	0.142857	2.195	0.66573
8.8	77.44	4	0.190476	2.174752	0.50575
7.99	63.8401	5	0.238095	2.078191	0.361224
6.14	37.6996	6	0.285714	1.814825	0.225351
4.3	18.49	7	0.333333	1.458615	0.094048
4.02	16.1604	8	0.380952	1.391282	-0.03554
2.99	8.9401	9	0.428571	1.095273	-0.1657
2	4	10	0.47619	0.693147	-0.29849
1.57	2.4649	11	0.52381	0.451076	-0.43599
1.15	1.3225	12	0.571429	0.139762	-0.5805
0.52	0.2704	13	0.619048	-0.65393	-0.73486
0.5	0.25	14	0.666667	-0.69315	-0.90272
0.49	0.2401	15	0.714286	-0.71335	-1.08924
0.49	0.2401	16	0.761905	-0.71335	-1.3022
0.45	0.2025	17	0.809524	-0.79851	-1.55443
0.4	0.16	18	0.857143	-0.91629	-1.86982
0.39	0.1521	19	0.904762	-0.94161	-2.30175
0.21	0.0441	20	0.952381	-1.56065	-3.02023

Table 4: Flow duration curve parameters for site 3 in Dikhu river system

MWD	x^2	Rank	E(x)	ln(x)	ln[-ln E(x)]
0.47	0.2209	1	0.047619	-0.75502	1.113344
0.43	0.1849	2	0.095238	-0.84397	0.855
0.43	0.1849	3	0.142857	-0.84397	0.66573
0.35	0.1225	4	0.190476	-1.04982	0.50575
0.35	0.1225	5	0.238095	-1.04982	0.361224
0.29	0.0841	6	0.285714	-1.23787	0.225351
0.25	0.0625	7	0.333333	-1.38629	0.094048
0.22	0.0484	8	0.380952	-1.51413	-0.03554
0.22	0.0484	9	0.428571	-1.51413	-0.1657
0.19	0.0361	10	0.47619	-1.66073	-0.29849
0.16	0.0256	11	0.52381	-1.83258	-0.43599
0.08	0.0064	12	0.571429	-2.52573	-0.5805
0.07	0.0049	13	0.619048	-2.65926	-0.73486
0.05	0.0025	14	0.666667	-2.99573	-0.90272
0.05	0.0025	15	0.714286	-2.99573	-1.08924
0.05	0.0025	16	0.761905	-2.99573	-1.3022
0.04	0.0016	17	0.809524	-3.21888	-1.55443
0.03	0.0009	18	0.857143	-3.50656	-1.86982
0.03	0.0009	19	0.904762	-3.50656	-2.30175
0.03	0.0009	20	0.952381	-3.50656	-3.02023

DISCUSSION

Water is extremely valuable and all life depends upon it. Terrestrial as well as aquatic biodiversity is dependent on water networks and their flow characteristics. Waters and freshwater biodiversity constitute a valuable natural resource in economic, cultural, aesthetic, scientific and educational terms.

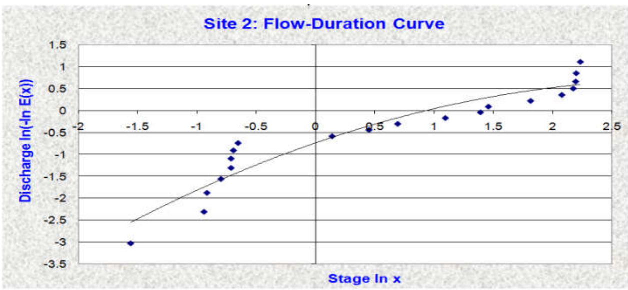


Figure 3. Flow duration curve for site 2 in Dikhu river system

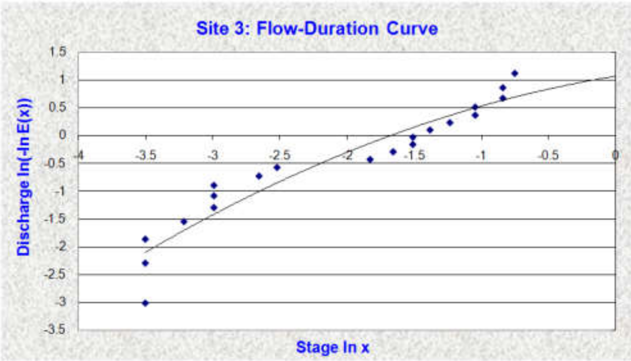


Figure 4. Flow duration curve for site 3 in Dikhu river system

Table 5. Flow duration curve parameters for site 4 in Dikhu river system

MWD	x^2	Rank	E(x)	ln(x)	ln[-ln E(x)]
0.48	0.2304	1	0.047619	-0.73397	1.113344
0.43	0.1849	2	0.095238	-0.84397	0.855
0.39	0.1521	3	0.142857	-0.94161	0.66573
0.35	0.1225	4	0.190476	-1.04982	0.50575
0.3	0.09	5	0.238095	-1.20397	0.361224
0.22	0.0484	6	0.285714	-1.51413	0.225351
0.22	0.0484	7	0.333333	-1.51413	0.094048
0.22	0.0484	8	0.380952	-1.51413	-0.03554
0.2	0.04	9	0.428571	-1.60944	-0.1657
0.2	0.04	10	0.47619	-1.60944	-0.29849
0.15	0.0225	11	0.52381	-1.89712	-0.43599
0.07	0.0049	12	0.571429	-2.65926	-0.5805
0.06	0.0036	13	0.619048	-2.81341	-0.73486
0.05	0.0025	14	0.666667	-2.99573	-0.90272
0.05	0.0025	15	0.714286	-2.99573	-1.08924
0.04	0.0016	16	0.761905	-3.21888	-1.3022
0.04	0.0016	17	0.809524	-3.21888	-1.55443
0.04	0.0016	18	0.857143	-3.21888	-1.86982
0.03	0.0009	19	0.904762	-3.50656	-2.30175
0.03	0.0009	20	0.952381	-3.50656	-3.02023

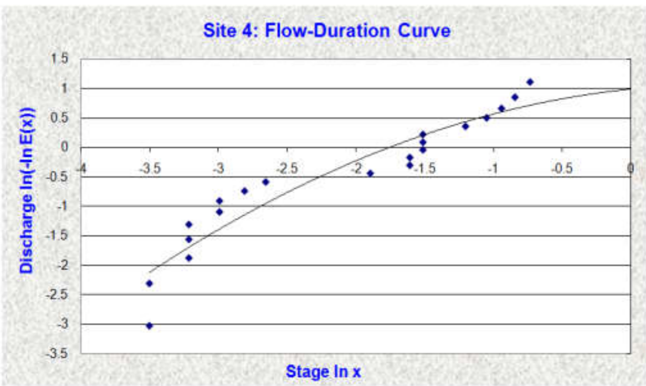


Figure 5. Flow duration curve for site 4 in Dikhu river system

Table 6. Flow duration curve parameters for site 5 in Dikhu river system

MWD	x^2	Rank	E(x)	ln(x)	ln[-ln E(x)]
14.295	204.347	1	0.047619	2.65991	1.113344
13.845	191.684	2	0.095238	2.627924	0.855
13.26	175.8276	3	0.142857	2.584752	0.66573
12.84	164.8656	4	0.190476	2.552565	0.50575
12.81	164.0961	5	0.238095	2.550226	0.361224
9.21	84.8241	6	0.285714	2.22029	0.225351
7.05	49.7025	7	0.333333	1.953028	0.094048
4.53	20.5209	8	0.380952	1.510722	-0.03554
3.705	13.72702	9	0.428571	1.309683	-0.1657
2.325	5.405625	10	0.47619	0.84372	-0.29849
2.13	4.536901	11	0.52381	0.756122	-0.43599
1.71	2.9241	12	0.571429	0.536493	-0.5805
0.84	0.7056	13	0.619048	-0.17435	-0.73486
0.84	0.7056	14	0.666667	-0.17435	-0.90272
0.825	0.680625	15	0.714286	-0.19237	-1.08924
0.675	0.455625	16	0.761905	-0.39304	-1.3022
0.66	0.4356	17	0.809524	-0.41552	-1.55443
0.66	0.4356	18	0.857143	-0.41552	-1.86982
0.525	0.275625	19	0.904762	-0.64436	-2.30175
0.3	0.09	20	0.952381	-1.20397	-3.02023

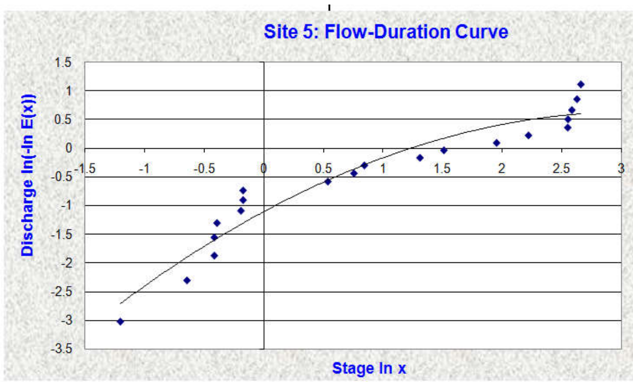


Figure 6. Flow duration curve for site 5 in Dikhu river system

Water flow is the key factor in lotic systems influencing their ecology. The strength of water flow can vary between systems, ranging from torrential rapids to slow backwaters that almost seem like lentic systems. The speed of the water flow can also vary within a system and is subject to chaotic turbulence. This turbulence results in divergences of flow from the mean down slope flow vector as typified by eddy currents. The mean flow rate vector is based on variability of friction with the bottom or sides of the channel, sinuosity, obstructions, and the incline gradient (Allan, 1995). In addition, the amount of water input into the system from direct precipitation, snowmelt, and/or groundwater can affect flow rate.

Flowing waters can alter the shape of the streambed through erosion and deposition, creating a variety of habitats, including riffles, glides, and pools (Cushing and Allan, 2001). In most open channel problems it is necessary to study the flow behavior only under steady and uniform conditions. The most attractive advantages are their low capital cost and that they require negligible routine maintenance. They are flexible not only in installation but also in the kinds of material that can be transported. They require minimal or zero power and they are safe to be used. Hence the description of channel sections with variation of velocity is very important in Flow dynamics of open channels. David *et al*. (2007) characterized the flow dynamics and sediment transport around paired deflectors used to enhance fish habitat in the Nicolet River, Quebec.

On the other hand, Débora *et al.* (2009) quantified the bedload transport in the Paraná river in the Porto São José cross section (22°45'52"S; 53°10'34"W), between Porto Primavera and Itaipu dams, Brazil. While as flow structure and dynamics in large tropical river confluence: example of the ivaí and paraná rivers, Southern Brazil. *São Paulo,* was carried out by José *et al.,* (2009). Vermeul *et al*. (2011) enumerated the river-induced flow dynamics in long-screen wells and their impact on aqueous samples. Whether river flow dynamics are governed dominantly by a large number of variables or by only a very few variables has been and continues to be an unresolved question. The (seemingly) irregular behaviors of river flow phenomena and the (significant) variability they exhibit both in time and in space have led a majority of researchers to employ the concept of stochastic process for modeling and prediction of their dynamics. The ability of the stochastic models to fairly represent the important (statistical) characteristics of river flow series and the reasonably good predictions achieved on their evolutions have further strengthened our view on the usefulness of the stochastic process concept for river flow (Manjula, 2015). Recent Advances in Understanding Flow Dynamics and Transport of Water-Quality Constituents in the Sacramento–San Joaquin River Delta was recently enumerated by Schoellhamer *et al.* 2016.

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