New Watershed Codification System for Indian River Basins

Kuldeep Pareta [1,*], Upasana Pareta [2]

[1] Water Resource Division, Spatial Decisions, New Delhi, India
[2] Department of Mathematics, PG Collage, District Sagar (M.P.), India

Peer Review History[1]

Abstract: *The international watershed codification system for the Indian River basin is proposed for the better water resource management & monitoring, river basin planning, innovative research in hydrology, and sustainable water resource development. Based on natural system, the sub-continent largest transboundary to mini-watershed boundaries have been delineated from SRTM, ASTER, & CARTOSAT DEM data. The nine-digit watershed codification is proposed for the Indian River basins, recognizing each hydrologic unit with unique international code that provides a single stand to synergize all the development programs related to river basin planning, and natural/water resource management, and avoiding doubling of interventions of various departments & ministries.*

Keywords: *Watershed codification, Indian river basin, DEM data, GIS.*

1. Introduction

India with 2.4% of the world's total area has 17.31% of the world's population; but has only 4% of the total available fresh water. India has a 3.29 billion hectare geographical area, which is covered by 72 major rivers and its numerous tributaries. A major part of Indian population is rural and engaged with agricultural activities; for this, the river basin management plays is vital role to source the fresh water. The Government of India (GoI) has adopted watershed management as a strategy to address the sustainable agricultural productivity in the rainfed areas as a national policy since 2003. The main objective of this study is to accumulate information on the overall Indian River basins to smallest hydrological units (mini-WS), and create an international single nine-digit code to the mini-WS that can be applied towards strategy and policy, primarily for the Ministry of Water Resources as well as general guidelines for the State Water Resources Departments (GoI, 1999).

2. Method description of existing systems

Various codification systems for river basins have been developed by various organizations in India such as All India Soil and Land Use Survey, National Commission for Integrated Water Resources Development Plan, Central Water Commission, Central Groundwater Board, National Remote Sensing Centre of Indian Space Research Organization, and World Resources Institute, which are slightly different to each other. These codification systems directly address the need for numbering of natural landscape units, which is a focus of river basin management. Some of the existing codification systems are described below.

2.1 All India Soil and Land Use Survey (AISLUS)

Central Water and Power Corporation (CWPC) initially attempted to defined Indian River basins in 1949 under the intelligent guidance of A.N. Khosla, and ALS & LUC had developed the "Watershed Atlas of India" on 1:1 million scale following the stream order where the entire river systems of the country have been divided into 6 water resources regions, which has been further divided into 35 basins and 112

[1] *Paper JHER0205, submitted on 21/11/2014, accepted for publication after peer review and subsequent revisions on 14/12/2014*
[*] *Corresponding author may be contacted at kpareta13@gmail.com*

catchments, 500 sub-catchments and 3,237 watersheds (WAI, 1990). The delineation has been done in seven stages starting with water resource regions and their subsequent divisions and subdivisions into basins, catchments, sub-catchments, watershed, sub-watershed and micro-watersheds in decreasing size of the delineated hydrologic unit.

2.2 National Commission for Integrated Water Resources Development Plan (NCIWRDP)

The NCIWRD in 1999 prepared a comprehensive assessment of the water resource availability in India, which estimated the water resource to be 1969 billion m^3 (BCM) including surface and groundwater (NCIWRD, 1999). During the water resource assessment study, NCIWRD divided the entire country into 23 basins which included 13 major basins, and 10 composite basins.

2.3 Central Water Commission (CWC)

CWC defined river basins of India in 2002 during nation-wide data collection over 878 hydrological observation stations covering both classified and non-classified river basins. CWC has divided river basins of India into 15 basins, which have been further divided into 3 basins as classified, and other 12 basins as non-classified (CWC, 1989, 1997).

2.4 Central Ground Water Board (CGWB)

Central Groundwater Board prepared a "Watershed Atlas of India" at 1:250,000 scale using GIS techniques under the guidance of Saleem Romani in 2006. In this Atlas, the entire river system of the country has been divided into 34 basins, 94 sub-basins, and 3,448 watersheds. They have also generated various thematic layers significant to groundwater development/assessment on watershed basis and for Hydrological Information System (HIS).

2.5 Water Resource Information System in India (India-WRIS)

The "River Basin Atlas of India" was launched by Harish Rawat (Minister of Water Resources, India) on 1st November, 2012 (India-WRIS, 2012). It is a joint project "Generation of database and implementation of web enabled Water Resources Information System (India-WRIS) in the country" of Central Water Commission (CWC) and National Remote Sensing Centre (NRSC) of Indian Space Research Organization (ISRO). The India-WRIS Project national level watershed atlas has been prepared on 1:50,000 scale by using SRTM DEM data of NASA, having a spatial resolution of 90 meters, and has been divided into 25 major river basins and 103 sub-basins (STRM, 2006).

2.6 Watersheds of the World

The "Watersheds of the World" has been published by the World Conservation Union (IUCN), the International Water Management Institute (IWMI) (IWMI, 2001), the Ramsar Convention Bureau and the World Resources Institute (WRI) in July 2003. WRI for the first time presents and analyzes a wide range of global data at the watershed level, assessing 154 watersheds around the world. River basin boundaries have been delineated from ETOPO-5, 5 minute gridded elevation data, and USGS' 30 arc-second digital elevation model of the world (GTOPO30). WRI revised and checked basin boundaries by overlaying ArcWorld 1:3 million rivers, where rivers (except canals) crossed basin boundaries; the boundary was edited using a 1-kilometer digital elevation model.

WRI has also published "Primary Watersheds Map" that shows the location of 114 major watersheds of the world with international watershed code. It includes the world's largest transboundary watersheds and other small basins that are representative of a particular geographic area. They have delineated 20 major watersheds from Africa, 29 major watersheds from Europe, 19 major watersheds from North & Central America, 11 major watersheds from South America, 5 major watersheds from Oceania, and 30 major watersheds from Asia. Out of 30's Asian major watersheds, 10 major watersheds are situated in the Indian sub-continent area.

3. Data Used

As per Table 1, several types of data have been used for creations of international watershed, water division, water sub-division, basin, sub-basin, major watershed, and micro-watershed.

4. Methodology

In the present study, the river/drainage network has been generated from ASTER (DEM) data with 30m spatial resolution as well as Cartosat-1 DEM data with resampled 30m spatial resolution, and the river/stream names have been captured from topographic maps at 1:250,000 scales. Indian sub-continent largest transboundary watersheds, water divisions, and water sub-divisions have been extracted from Shuttle

Radar Topography Mission (SRTM) DEM Data, their watersheds boundaries have been also redesigned with the help of ASTER (DEM), and Cartosat-1 DEM data, and also the same data have been used for delineation of basins, sub-basins, watersheds, and sub-watersheds. Administrative boundaries and major locations of the towns have been obtained from administrative maps of Survey of India/National Informatics Center (NIC), New Delhi.

Table 1 Data used and sources

S.No.	Data Used	Sources
1.	India and Pakistan Topographic Map @ 1:250,000	Series U502, U.S. Army Map Service, 1955 http://www.lib.utexas.edu/maps/ams/india
2.	Shuttle Radar Topography Mission (SRTM), DEM Data @ 90m Spatial Resolution	NASA, & USGS EROS Data Center, 2006 http://glcfapp.glcf.umd.edu:8080/esdi
3.	ASTER Global Digital Elevation Model (GDEM), DEM Data @ 30m Spatial Resolution (GDEM, 2009)	Japan Space Systems (J-space systems) Japan, cooperation with US, 2009 http://gdem.ersdac.jspacesystems.or.jp/search.jsp
4.	Cartosat-1 Digital Elevation Model (CartoDEM), DEM Data @ 30m Spatial Resolution (CartoDEM, 2008)	Indian Earth Observation, National Remote Sensing Centre (ISRO), 2008 http://bhuvan.nrsc.gov.in/data/download/index.php
5.	Watersheds of the World	http://www.wri.org

5. Proposed Watershed Codification System

The system proposed here for the delineation and codification of the Indian River Basins is established upon concepts, first articulated by the A.N. Khosla with the Central Water and Power Corporation (CWPC), published by All India Soil and Land Use Survey "AIS&LUS" (WAI, 1949), and Watersheds of the World published by IUCN, IWMI, RCB, & WRI in 2003 (WRI, 2003). It is a common framework based upon topographic control of regions drained on the earth surface and the topology of the ensuing hydrographic system.

WRI just extracted the 114 international watersheds with international watershed code. As per A.N. Khosla the watershed outline has been done in seven stages beginning with water resource regions (represent 1 to 6) and their resulting separation and subdivisions into basins (symbolize A, B, C,..., Z), catchments (represent 1, 2, 3,..., 9), sub-catchments (represent A, B, C,..., Z), watershed (represent 1 to 9), sub watershed (represented with small English alphabets as a, b, c,..., z) and micro-watersheds (characterized by numerals as 1 to 6) in decreasing size of the outlined hydrologic unit. For example '2C2C5h1' codes connote '2' - water resource region (Ganga), 'C'- basin (Yamuna), '2' - Betwa catchment, 'C'- Betwa-Dhasan (Upper Dhasan) sub-catchment, '5'- Karawan watershed, 'h' - Garhpehra sub-watershed, and '1' - micro-watershed code. The beauty of this code is that it represents a national code to be useful for the easy study of the Indian river system, but due to lack of international code and detailed information of basin, it does not represent a realistic information of the basin.

After the detailed study of watershed codification, this paper suggests a "New Watershed Codification System" for Indian River Basin, which will be more useful for the study of systematic river basin planning, watershed management, etc., and this code should represent any micro-watershed in an international stand.

5.1 Indian Sub-Continent Largest Transboundary Watersheds

The existing international watershed code for 10 watersheds has been taken from the "Watersheds of the World" published by IUCN, IWMI, RCB, & WRI in 2003, and this paper has suggested some additional international watershed code for the remaining river (12 Watersheds) in India, which has been used for generation of new watershed codification system for Indian river basins. Table 2 and Figure 1 show the existing and proposed international watershed code for the Indian River basins.

5.2 Water Divisions

On the basis of drainage flowing into ocean and other basins, three water divisions have been suggested. The water division code has been used as A for all drainage flowing into the Arabian sea, B for all drainage flowing into the Bay of Bengal, and X for other rivers draining into other basins. The details of water divisions are (see also Figure 2): (i) All Drainage flowing into Arabian Sea (A); (ii) All Drainage flowing into Bay of Bengal (B); and (iii) Other River Draining into Other Basin (X).

5.3 Water Sub-Divisions

On the basis of drainage flowing into ocean from north India, and south India, each water division has been divided into water sub-divisions. The water sub-division code has been used as 1 for North India, and 2 for South India. The details of six water sub-divisions are shown below and in Figure 2.

(i) All Drainage flowing into Arabian Sea from North India (A1)
(ii) All Drainage flowing into Arabian Sea from South India (A2)
(iii) All Drainage flowing into Bay of Bengal from North India (B1)
(iv) All Drainage flowing into Bay of Bengal from South India (B2)
(v) Other River Draining into Other Basin from North India (X1)
(vi) Other River Draining into Other Basin from Indian Island (X2)

Table 2 International watershed code, watershed/ basin name for India river basin (WRI, 2003) with modification

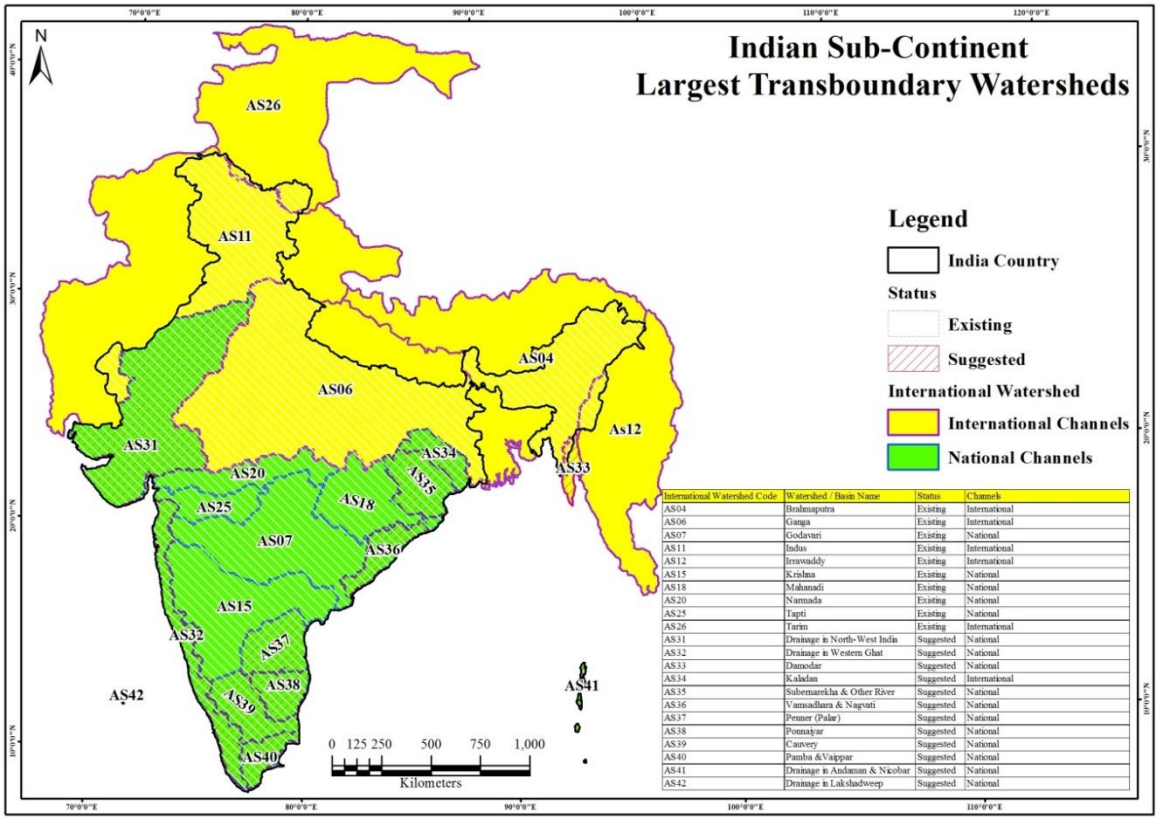
Watershed Code	Watershed / Basin Name	Status	Country
AS04	Brahmaputra	Existing	China, Nepal, India, Bangladesh
AS06	Ganga	Existing	India, Nepal, Bangladesh
AS07	Godavari	Existing	India
AS11	Indus	Existing	Pakistan, India, China, Afghanistan
AS12	Irrawaddy	Existing	Myanmar, India
AS15	Krishna	Existing	India
AS18	Mahanadi	Existing	India
AS20	Narmada	Existing	India
AS25	Tapti	Existing	India
AS26	Tarim	Existing	China, India, Soviet Union
AS31	Drainage in NW India	Suggested	India
AS32	Drainage in Western Ghat	Suggested	India
AS33	Kaladan	Suggested	India, Myanmar
AS34	Damodar	Suggested	India
AS35	Subernarekha & Other River	Suggested	India
AS36	Vamsadhara & Nagvati	Suggested	India
AS37	Penner (Palar)	Suggested	India
AS38	Ponnaiyar	Suggested	India
AS39	Cauvery	Suggested	India
AS40	Pamba &Vaippar	Suggested	India
AS41	Drainage in Andaman & Nicobar	Suggested	India
AS42	Drainage in Lakshadweep	Suggested	India

5.4 Basins

The basin boundaries have been marked as the same boundary of Indian sub-continent largest transboundary. The basin codes are indicated by suffixing alphabets to the water sub-division code as "Nm" for Narmada, "Gn" for Ganga, etc. The details of 22 basins with code and basin name are shown in Table 3.

5.5 Sub-Basins

Total 72 sub-basin boundaries have been delineated as the partition of basin boundary. Each basin has been divided into a number of sub-basins, which connect to main tributaries or individual streams. The sub-basin codes are designated again by suffixing alphabets to basin code as "(NMD)" for Narmada, "(CMB)" for Chambal, "(LGN)" for Lower Ganga, and "(DSN) for Dhasan, etc. The details of sub-basin code with name are shown in Table 3. Figure 3 shows the Indian River basin, and sub-basins boundary with respective codes.



International Watershed Code	Watershed / Basin Name	Status	Channels
AS04	Brahmaputra	Existing	International
AS06	Ganga	Existing	International
AS07	Godavari	Existing	National
AS11	Indus	Existing	International
AS12	Irrawaddy	Existing	International
AS15	Krishna	Existing	National
AS18	Mahanadi	Existing	National
AS20	Narmada	Existing	National
AS25	Tapti	Existing	National
AS26	Tarim	Existing	International
AS31	Drainage in North-West India	Suggested	National
AS32	Drainage in Western Ghat	Suggested	National
AS33	Damodar	Suggested	National
AS34	Kaladan	Suggested	International
AS35	Subernarekha & Other River	Suggested	National
AS36	Vamsadhara & Nagvati	Suggested	National
AS37	Penner (Palar)	Suggested	National
AS38	Ponnaiyar	Suggested	National
AS39	Cauvery	Suggested	National
AS40	Pamba &Vaippar	Suggested	National
AS41	Drainage in Andaman & Nicobar	Suggested	National
AS42	Drainage in Lakshadweep	Suggested	National

Figure 1 Indian sub-continent largest transboundary watersheds

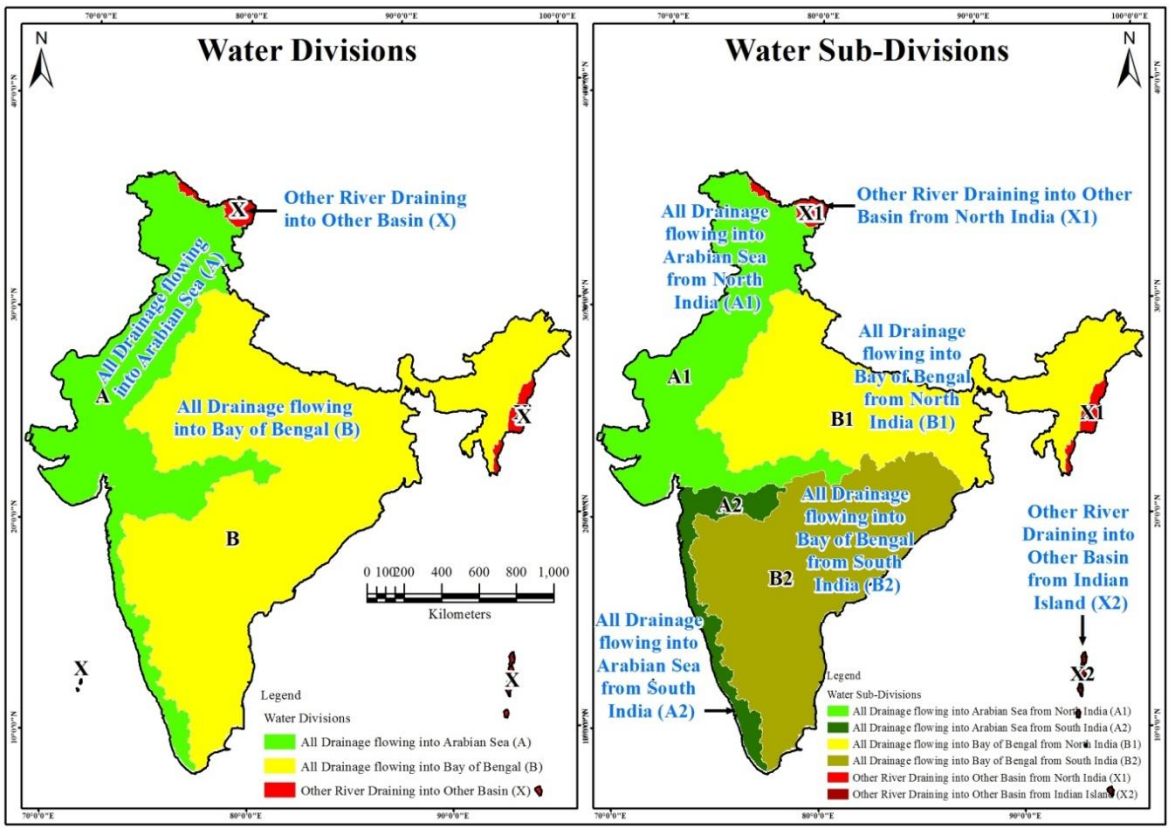


Figure 2 Water divisions and water sub-divisions

5.6 Watersheds

Each sub-basin is further divided into watersheds, in which sub-tributaries and streams are taken up for delineation of watersheds. Total 814 watersheds have been delineated from the 72 sub-basin boundaries. Watershed code represented by numerals suffixed to sub-basin code as 1, 2, 3, …, 40. The details of watersheds codes are shown in Table 3. Basin boundary, sub-basin boundary, and major watershed in India with watershed code in Dhasan sub-basin are shown in Figure 4.

5.7 Sub-Watersheds

Each watershed has been divided into sub-watershed based on main tributaries and streams extracted from Cartosat/ASTER (DEM), and each sub-watershed code represented by small English alphabets as a, b, c, …, z, which is suffixed to watershed code. Comprehensive code for a sub-watershed is "AS06B1Gn(DSN)11k" as example of a sub-watershed of Dhasan sub-basin.

Table 3 Basin/sub-basin name with code, & number of watersheds for India river basins

S. No.	International Watershed Code	Water Division	Water Sub-Division	Basin Name (Code)	Sub-Basin Name (Code)	International Sub-Basin Code	No. of WS	Total No. of WS
1	AS11	A	1	Indus (Id)	Gilgit (GGT)	AS11A1Id(GGT)	1	65
2					Shyok (SYK)	AS11A1Id(SYK)	11	
3					Indus (IND)	AS11A1Id(IND)	12	
4					Jhelum (JHM)	AS11A1Id(JHM)	4	
5					Chenab (CNB)	AS11A1Id(CNB)	12	
6					Ravi (RVI)	AS11A1Id(RVI)	8	
7					Beas (BAS)	AS11A1Id(BAS)	1	
8					Sutlej (STJ)	AS11A1Id(STJ)	9	
9					Barmer (BMR)	AS11A1Id(BMR)	7	
10	AS31	A	1	Drainage in NW India (Nw)	Ghaghar (GGH)	AS31A1Nw(GGH)	10	110
11					Chautang & Other (CTG)	AS31A1Nw(CTG)	4	
12					Churu (CRU)	AS31A1Nw(CRU)	26	
13					Luni (LUN)	AS31A1Nw(LUN)	35	
14					Saraswati (SWT)	AS31A1Nw(SWT)	7	
15					Sabarmati (SMT)	AS31A1Nw(SMT)	7	
16					Mahi (MHI)	AS31A1Nw(MHI)	10	
17					Drainage in Rann (RAN)	AS31A1Nw(RAN)	7	
18					Bhadra & Other (BDR)	AS31A1Nw(BDR)	3	
19					Shetranjuli & Other (SJO)	AS31A1Nw(SJO)	1	
20	AS20	A	1	Narmada (Nm)	Narmada (NMD)	AS20A1Nm(NMD)	32	32
21	AS32	A	2	Drainage in Western Ghat (Wg)	Bhatsol and Other (BTS)	AS32A2Wg(BTS)	9	37
22					Vasishti and Other (VSO)	AS32A2Wg(VSO)	10	
23					Nagvati & Other (NGO)	AS32A2Wg(NGO)	11	
24					Varrae and Other (VRO)	AS32A2Wg(VRO)	3	
25					Periya and Other (PRO)	AS32A2Wg(PRO)	4	
26	AS25	A	2	Tapti (Tp)	Tapti (TPT)	AS25A2Tp(TPT)	16	16
27	AS04	B	1	Brahmaputra (Bp)	Brahmaputra Right Bank (BRB)	AS04B1Bp(BRB)	27	70
28					Brahmaputra Left Bank (BLB)	AS04B1Bp(BLB)	35	
29					Barak & Other (BRK)	AS04B1Bp(BRK)	8	
30	AS06	B	1	Ganga (Gn)	Upper Ganga (UGN)	AS06B1Gn(UGN)	22	204
31					Lower Ganga (LGN)	AS06B1Gn(LGN)	30	
32					Ramganga (RGN)	AS06B1Gn(RGN)	8	
33					Ghaghara (GGR)	AS06B1Gn(GGR)	14	
34					Gandak (GDK)	AS06B1Gn(GDK)	2	
35					Kosi (KSI)	AS06B1Gn(KSI)	4	

36					Mahananda (MHD)	AS06B1Gn(MHD)	9	
37					Gomti (GMT)	AS06B1Gn(GMT)	4	
38					Yamuna (YMN)	AS06B1Gn(YMN)	24	
39					Banas (BNS)	AS06B1Gn(BNS)	12	
40					Chambal (CMB)	AS06B1Gn(CMB)	18	
41					Kali Sindh (KSN)	AS06B1Gn(KSN)	3	
42					Parbati (PBT)	AS06B1Gn(PBT)	2	
43					Sindh (SND)	AS06B1Gn(SND)	2	
44					Betwa (BTW)	AS06B1Gn(BTW)	7	
45					Dhasan (DSN)	AS06B1Gn(DSN)	11	
46					Ken (KEN)	AS06B1Gn(KEN)	8	
47					Tons (TNS)	AS06B1Gn(TNS)	9	
48					Son (SON)	AS06B1Gn(SON)	15	
49	AS34	B	1	Damodar (Dd)	Damodar (DMD)	AS34B1Dd(DMD)	9	9
50	AS35	B	2	Subernarekha & Other River (So)	Subernarekha (SNK)	AS35B2So(SNK)	4	14
51					Baitami & Brahmani (BHM)	AS35B2So(BHM)	10	
52	AS18	B	2	Mahanadi (Mn)	Mahanadi (MHN)	AS18B2Mn(MHN)	40	40
53	AS07	B	2	Godavari (Gv)	Weinganga (WGN)	AS07B2Gv(WGN)	13	78
54					Penganga (PGN)	AS07B2Gv(PGN)	12	
55					Indravati (IRV)	AS07B2Gv(IRV)	17	
56					Godavari (GVR)	AS07B2Gv(GVR)	36	
57	AS36	B	2	Vamsadhara & Nagvati (Vn)	Vamsadhara & Other (VDO)	AS36B2Vn(VDO)	3	9
58					Netravati and Other (NTO)	AS36B2Vn(NTO)	6	
59	AS15	B	2	Krishna (Ks)	Bhima (BMA)	AS15B2Ks(BMA)	19	56
60					Krishna (KSN)	AS15B2Ks(KSN)	29	
61					Tungabhadra (TBD)	AS15B2Ks(TBD)	8	
62	AS37	B	2	Penner (Palar) (Pn)	Palar and Other (PLO)	AS37B2Pn(PLO)	14	14
63	AS39	B	2	Cauvery (Cv)	Cauvery (CVR)	AS39B2Cv(CVR)	22	22
64	AS38	B	2	Ponnaiyar (Py)	Ponnaiyar and Other (PNO)	AS38B2Py(PNO)	16	16
65	AS40	B	2	Pamba & Vaippar (Pv)	Pamba and Other (PMO)	AS40B2Pv(PMO)	6	12
66					Vaippar and Other (VPO)	AS40B2Pv(VPO)	6	
67	AS26	X	1	Tarim (Tr)	Shaksgam (SKG)	AS26X1Tr(SKG)	1	2
68					Sulmar (SLM)	AS26X1Tr(SLM)	1	
69	AS12	X	1	Irrawaddy (Iw)	Mangpui Lui & Other (MLO)	AS12X1Iw(MLO)	6	6
70	AS33	X	1	Kaladan (Kd)	Karnaphuli & Muhury (KPM)	AS33X1Kd(KPM)	3	3
71	AS41	X	2	Dr. in Andaman & Nicobar (An)	Drainage in Andaman & Nicobar (AMN)	AS41X2An(AMN)	1	1
72	AS42	X	2	Drainage in Lakshadweep (Ld)	Drainage in Lakshadweep (LKD)	AS42X2Ld(LKD)	1	1
	22	**3**	**6**	**22**	**72**			**817**

5.8 Micro-Watershed

Micro-watershed can be defined as natural hydrological element that covers a particular extent of terrestrial surface from which the precipitation, and runoff flows into a well-defined river, stream, drainage, or channel at any specific point. Micro-watershed (MWS) boundary has been delineated based on the stream ordering system (Strahler, 1952); it has defined on each of 3rd order stream, but limited to starting of the 3rd order stream, with the area from 100 hectare to 300 hectare (Pareta, 2004; Pareta and Pareta, 2012). MWS code has followed the similar system as proposed above, MWS code represented by numerals suffixed to sub-watershed code as 1, 2, 3, ..., n. The completed code for a micro-watershed is "AS06B1Gn(DSN)11k13" as example of a micro-watershed of Dhasan sub-basin.

5.9 Mini-Watershed

Mini-watershed (Mini-WS) boundary has been demarcated on each of 2nd order stream, but limited to starting of the 2nd order stream, with the area of less than 100 hectare (Pareta and Pareta, 2011). The completed code for a mini-watershed with nine digits is symbolized as "AS06B1Gn(DSN)11k13b", as an example of a mini-watershed of Dhasan sub-basin (Figure 5), where "AS06" represents Indian Sub-

Continent Largest Transboundary, "B" for Water Division, "1" for Water Sub-Division, "Gn" for Basin, "DSN" for Sub-Basin, "11" for Watershed, "k" for Sub-Watershed, "13" for Micro-Watershed, and "b" for Mini-Watershed.

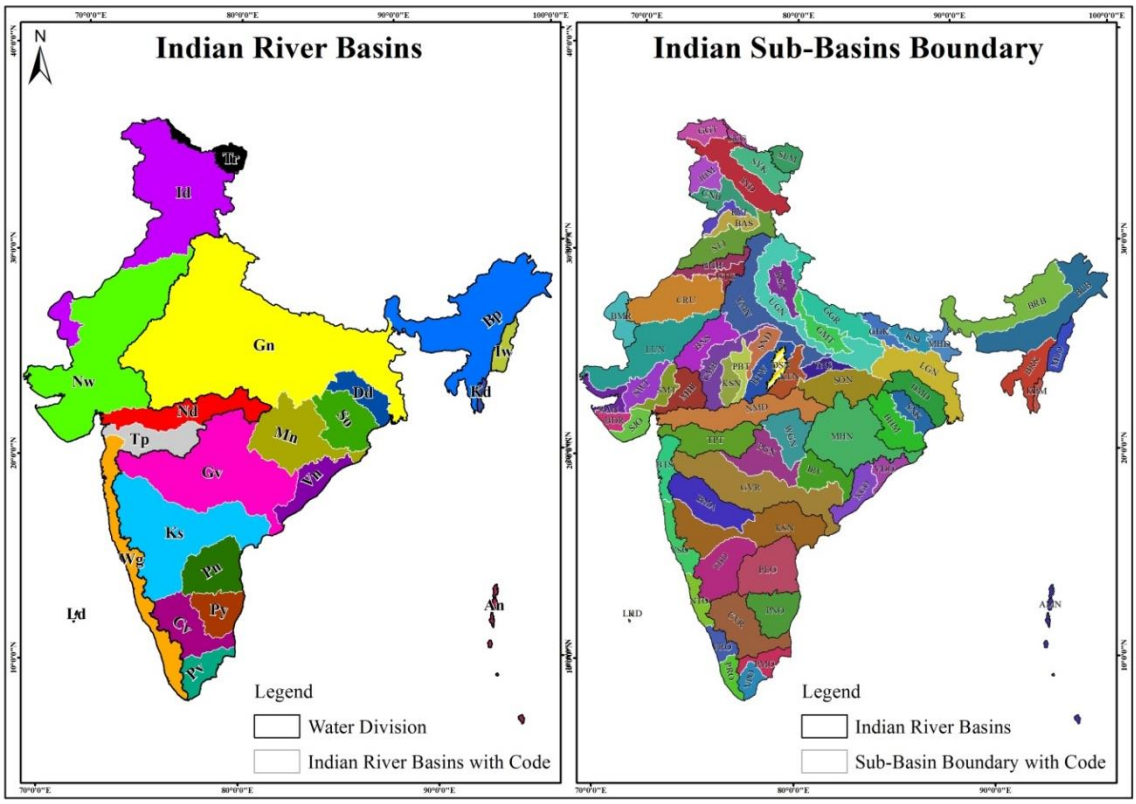


Figure 3 Indian river basins and sub-basins boundary with code

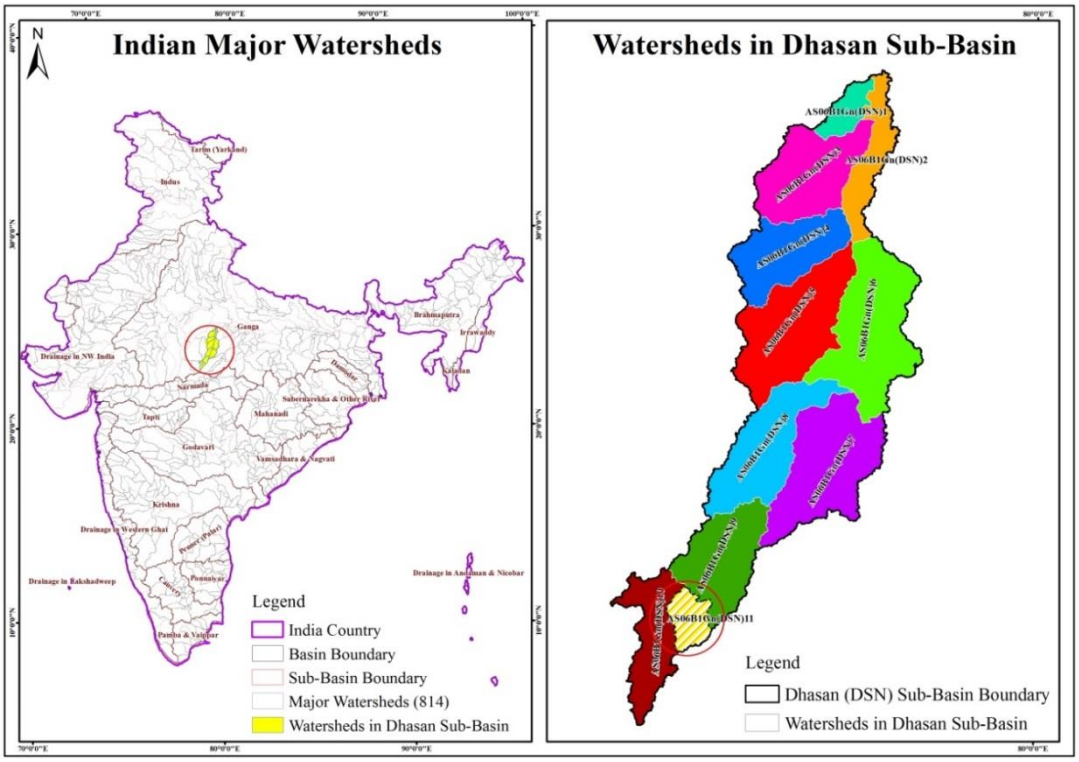


Figure 4 Indian major watershed and watershed code in Dhasan sub-basin

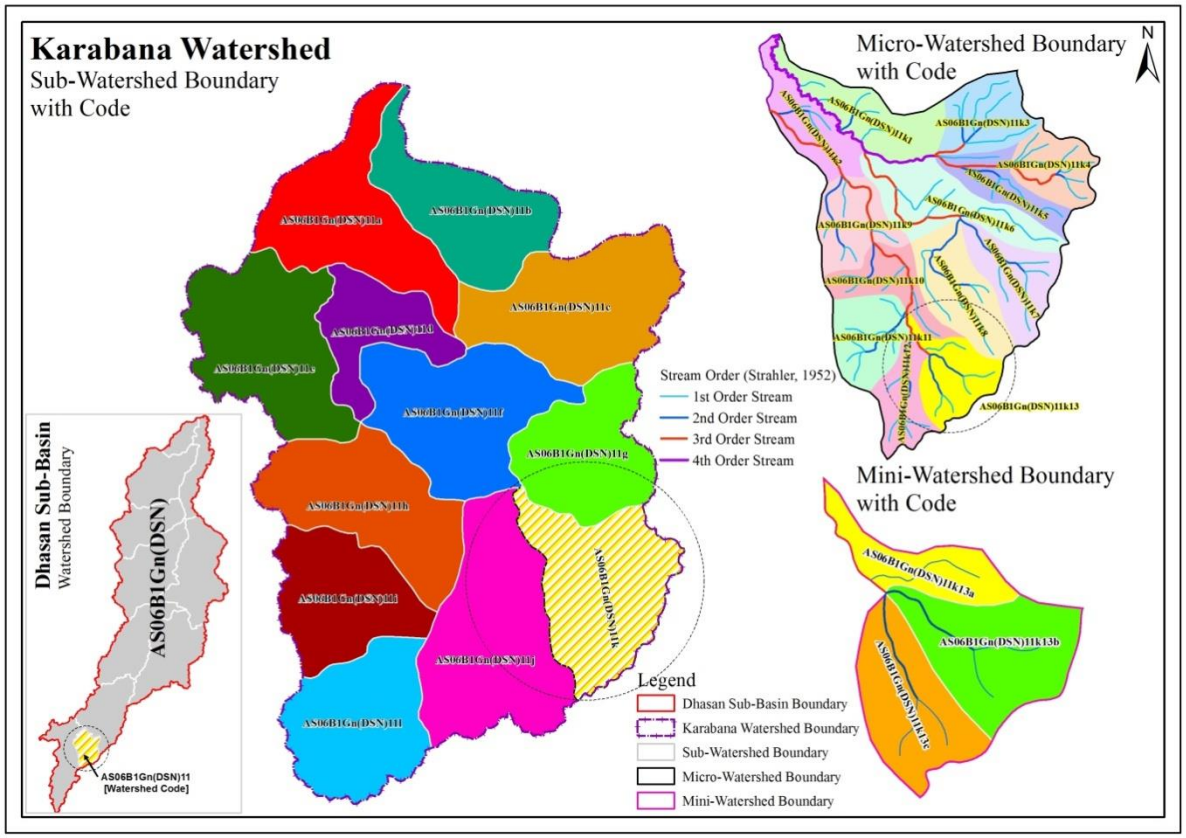


Figure 5 Watershed, sub-watershed, micro-watershed and mini-watershed boundary with code

6. Conclusion

The codification systems of river basins are different in different countries. Consequently, the river basin/watershed boundaries do not match with each other internationally. To overcome this limitation, a comprehensive uniform categorizations and codifications are proposed for Indian River basins. A series of single nine-digit code is sufficient to uniquely identify mini-watershed (mini-WS). This paper suggests this codification system as an essential spatial framework that can be used to reconcile the data and information from a variety of scales for better water resource management, river basin planning, and sustainable water resource development.

7. Acknowledgement

We are profoundly thankful to our Guru Ji Professor J. L. Jain, who with his unique research competence, selfless devotion, thoughtful guidance, inspirational thoughts, wonderful patience and above all parent like direction and affection motivated us to pursue this work.

References

CartoDEM (2008). Cartosat-1 Digital Elevation Model (CartoDEM). Indian earth observation, National Remote Sensing Centre (ISRO): http://bhuvan.nrsc.gov.in/data/download/index.php, India.

CWC (1997). India River Basin Atlas. Central Water Commission (CWC), New Delhi, India.

CWC (1989). Major River Basins of India - An Overview (1989). Central Water Commission (CWC), New Delhi, India.

GDEM (2009). ASTER Global Digital Elevation Model (GDEM). Japan space systems (J-space systems) Japan, cooperation with US: http://gdem.ersdac.jspacesystems.or.jp/search.jsp.

GoI (Government of India) (1999). Integrated water resources development. A plan for action, Report of the commission for integrated water resource development, Volume I. New Delhi, Ministry of Water Resources, India.

India-WRIS (2012). Water resource information system in India (India-WRIS): http://www.india-wris.nrsc.gov.in.

IWMI (2001). IWMI climate and water atlas. Colombo, Sri Lanka: IWMI CD-ROM.

NCIWRD (1999). Water requirement for various uses. National Commission on Integrated Water Resources Development, Government of India.

Pareta K (2004). Hydro-geomorphology of Sagar district (M.P.): A study through remote sensing technique, Proceeding in XIX M. P. Young Scientist Congress, Madhya Pradesh Council of Science & Technology (MAPCOST) Bhopal, India.

Pareta K, Pareta U (2011). Hydromorphogeological study of Karawan watershed using GIS and remote sensing techniques, *International Scientific Research Journal*, 3(4), 243-268.

Pareta K, Pareta U (2012). Quantitative Morphometric Analysis of A Watershed: Based on digital terrain Model and GIS, LAP Lambert Academic Publishing, Germany.

Strahler AN (1952). Dynamic basis of geomorphology, Bulletin of the Geological Society of America, 63, 923-938.

STRM (2006). Shuttle Radar Topography Mission (SRTM) 90m Digital Elevation Model: CGIAR (2006). http://srtm.sci.cgiar.org.

WAI (1990). Watershed Atlas of India (WAI). All India Soil and Land Use Survey (AISLUS), Ministry of Agriculture, New Delhi.

WRI (2003). Watersheds of the world. International Union for Conservation of Nature (IUCN), International Water Management Institute (IWMI), Rasmar Convention Bureau (RCB), and World Resources Institute (WRI), Washington, DC.