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Regional Comparison of Flood and Lowflow Characteristics in Southeast Asia and the Pacific

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Abstract

The specific discharges of the mean annual flood and the mean annual lowflow were compared in different rivers in Southeast Asia and the Pacific. It was found that the specific discharges of the mean annual floods have two groups, relatively high and relatively low while they as a whole show a decreasing trend with the size of catchment. Most rivers that belong to the relatively low group are under the influence of reservoir regulation upstream. The specific discharges of the mean annual lowflows have also two groups, one concentrated around 0.1-1.0$m^3/s/100k^2$ and the other below that range, both decrease slightly with the catchment area. They were found dependent on the dryness of the region and the reservoir regulation. Few unregulated rivers seem to show the influence of land cover such as forests, paddy fields and base rocks. A dryness index, m/n, the number of months that have the mean monthly rainfall less than 10mm and 30mm, was introduced and shown operational.
Key words: mean annual flood, mean annual lowflow, dryness index

1. Introduction

The mean annual flood $\bar{Q}max$ and the mean annual lowflow $\bar{Q}min$ are defined as the average of annual flood peak discharge series and the average of annual lowest discharge series, respectively, measured in instantaneous recording. They are the characteristic values of the hydrology of a basin that illustrate the integrated hydrological conditions necessary to be considered in water resources management of the basin. The river runoff, rainfall and other data were excerpted from "Catalogue of Rivers for Southeast Asia and the Pacific, vol. 1" published by UNESCO IHP Regional Steering Committee for Southeast Asia and the Pacific in October 1995. It contains the geographical, meteorological, hydrological and water resources data of the selected 25 rivers of the 11 countries in the region. Table 1 shows the data excerpted from the Catalogue for this analysis.

Rainfalls

Most rivers presented in the Catalogue of Rivers vol.1 are located in the wet or relatively wet climatic region with the mean annual rainfall between 1,000-2,500mm and the maximum mean monthly rainfall between 200-400mm. The rivers with the mean annual rainfall less than 1,000mm are only Jiyun-he of 594mm and the Burdekin of 670mm, while the largest mean annual rainfall is 3,820mm in Batang Rajang followed by 2,763mm in Song Thu Bon. As for the maximum mean monthly rainfall, the least is 144 mm of Mogami-gawa at Yamagata in July and the largest is 610mm of Song Thu Bon at Da Nang in October. Thus all rivers in the Catalogue have at least in some months a very wet season and experience floods. Therefore if the specific flood discharges are classified by climatic regions, no distinct regional differences may be detected.

The minimum mean monthly rainfall, on the other hand, varies a great deal by rivers as is indicated by a dryness index m/n in Table 1. A *dryness index* m/n is introduced to express the dryness characteristics of the basin as defined as:

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m: the number of months with mean monthly rainfall less than 10mm,
n: the number of months with mean monthly rainfall less than 30mm, and
the least mean monthly rainfall in mm: in case of m=n=0.
If two or more observation stations are available, an average is used.
It should be noted that the monthly rainfall data available in the Catalogue is not necessarily of a representative station of the basin and that the analyses to follow have the limitation in this respect. In case of m=n=0 (if all months have rain fall more than 30mm), instead of indicating simply 0/0, the least mean monthly rainfall is indicated by which the index can show the more precise information on the non-dryness of the basin.
The driest basin would be Jiyun-he with 5 months less than 10mm and 8 months less than 30mm. The least driest basin would be the Buller River with the driest month being 96mm.

2. Ranges of flow regimes

Figure 1 shows the ranges of the specific discharges of mean annual flood and the mean annual lowflow together with the mean annual flow of various rivers in the Catalogue, in a semi-logarithmic paper for rivers with the catchment area less than 6,000km^2 and in a logarithmic paper for those larger than 6,000km^2. The number on the top of the line is the dryness index m/n. The points indicated at the end of the broken lines are those before the major reservoir construction.

Mean annual floods
It can be seen that in general the larger the areas are, the smaller the specific mean annual floods and the specific mean annual flows. Among them there are two groups, a relatively high discharge group and a low group. While the more than half fall in the high group, the low group includes Miho-chun, Citarum, Bengawan Solo, Kali Brantas, Prek Thnot, Jiyun-he, Ilong Pampanga, Song Srepok, Mae Nam Mae Klong and Mae Nam Ping. Some have obvious reasons of being low in the mean annual floods but some are not so obvious as illustrated below:

- Miho-chun at Seokwha: Miho Triples and two other reservoirs (total 46.5mcm) were built in 1981-88 about 30-40km upstream which reduced the maximum floods a great deal. (See Map 1)
- Citarum at Nanjun: Reason is unknown. The location of Nanjun is not precisely indicated in the Catalogue.
- Bengawan Solo at Jurug: Wonogiri Dam (730mcm) was built in 1981 about 30km upstream. (See Map 2)
- Kali Brantas at Jeli: Sutami Reservoir (343mcm) was built in 1972 about 60km upstream. (See Map 2)
- Prek Thnot at Anlong Touk: Deep and flat deciduous forest would result very low specific floods but the available length of data is too short to judge (6 years).
- Jiyun-he at Jiuwangzhuang: Yuqiao Reservoir (1,559mcm) was built in 1960 about 30km upstream.
- Ilong Pampanga at Arayat: Pantabangan Reservoir (3,000mcm) was completed in 1974 about 80km upstream and large paddy fields below.
- Song Srepok at Ban Don: 8 small reservoirs (total 51.3mcm) were built in 1976-86, 40km or more upstream.
- Mae Nam Mae Klong at Ban Wan Kha Nai: Srinagarind Reservoir (17,745mcm) in 1980 and Khao Laem Reservoir (8,860mcm) in 1985, which drastically reduced the flood peaks.
- Mae Nam Ping at Ban Tha Khae: Bhumibol Reservoir (13,462mcm) was built in 1964 about 50km upstream.

Mean annual lowflows
The mean annual lowflows also have two groups; one is concentrated around 0.1-1.0 centering in 0.2-0.5 m^3/s/100km^2 and the other has much smaller specific discharge. Both slightly decrease with the catchment area. The very small ones are the Pioneer River, Prek Thnot, Jiyun-he and the Burdekin River. Those observations may be interpreted by the dryness index and the human intervention as described below:

The mean annual lowflows differ greatly according to the dryness of the basin. All the rivers that have the extremely low mean annual lowflow have the high value of dryness index as Prek Thnot 2/3, Jiyun-he 5/8 and the Burdekin River 0.4/5. It is quite natural to have less than 10^{-2} - 10^{-3} m^3/s/100km^2 under such a long very dry season. But why the Pioneer River at Pleystowe Mill has also a low mean annual lowflows? Its dryness index is 0/2, which is not particularly large as compared with other rivers like Ara-kawa, Miho-chun, Geumho-gang, Song Ky Cung, Pyungchang-gang, Ilong Magat and Bengawan Solo that are in the range of 0/1-0/3 but show the mean annual specific discharge larger than 10^{-1}m^3/s/100km^2. This is because:

- Pioneer River at Pleystowe Mill: The Marian Weir built in 1952 less than 20km upstream of the observation station takes most of water for irrigation. In 1982, further 20km upstream at Mirani, the Mirani Diversion Channel was built for interbasin transfer of irrigation water to the Sandy Creek, an adjacent catchment. (See Map 3)

Unusual cases are those that, with a relatively high value of dryness index, still have the mean annual lowflow as high as 1m^3/s/100km^2. Such cases are Song Thu Bon and Kali Brantas. The reasons may be as follows:

- Song Thu Bon at Nong Son: Igneous rock formation with forests, grass lands and paddy fields.
- Kali Brantas at Jeli: Lowflow augmentation by Sutami Reservoir (343mcm) built in 1972 about 60km upstream.

Some rivers have relatively large dryness values but have relatively large mean annual lowflows in the order of 0.3-0.5m^3/s/100km^2. Such include Ilon Pampanga 2/3, Song Srepok 2/4, Song Ba 3/4 and Batang Rajang (monthly climatic data not available). The reasons would also be such as reservoir influence, paddy fields, forests and base rocks:

- Ilong Pampanga at Arayat: Pantabangan Reservoir (3,000mcm) and a large irrigation area seem to make the lowflows augmented.
- Song Srepok at Ban Don, Song Ba at Cung Son: As Song Thu Bon, the Central Vietnamese rivers have relatively high specific discharge during low flows considering the dryness factor. This would be because there are dense igneous rock formation and abundant groundwater.

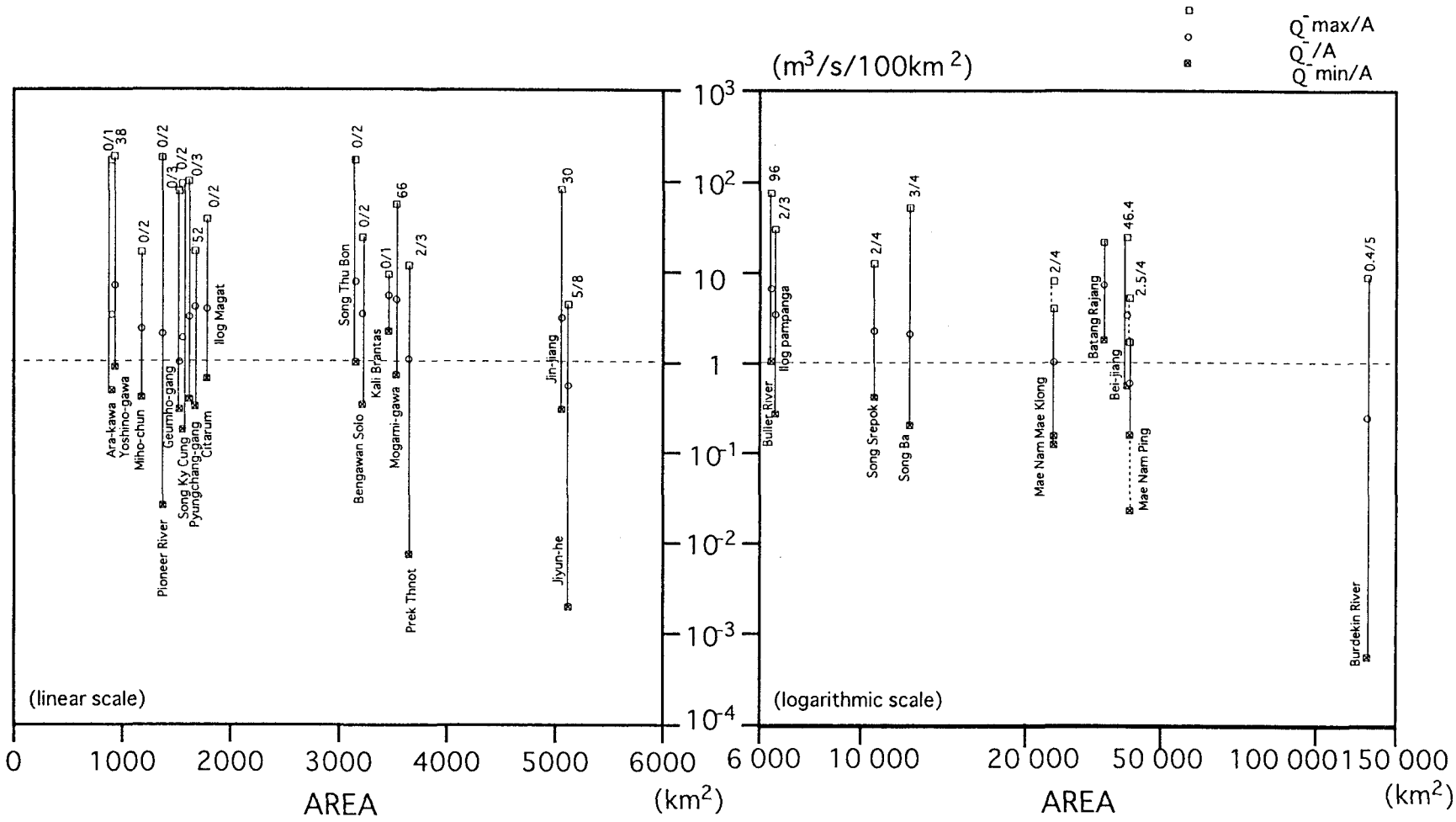
As is seen in Mae Nam Ping, the lowflows are in general highly augmented if there is, in upstream, an irrigation reservoir and the irrigated paddy fields. Two exceptions are the cases of irrigation intake in the Pioneer River mentioned above and interbasin transfer in Jiyun-he. In Jiyun-he, large inter-three-basins transfer lines are developed from Panjiakou in the northern basin through the Yuqiao reservoir (1559mcm) built in 1960 in the Jiyun-he basin to Tianjin City in the southern basin. The reservoir Yuqiao does not contribute to the lowflow augmentation of the downstream of Jiyun basin.

3. Conclusions

1. Flow regimes of rivers in the Catalogue, vol.1 show extensive human intervention to the natural regime. Reservoir construction and its flow regulation give the largest disturbance to the extremes of the flows. Miho-chun, Bengawan Solo, Kali Brantas, Mae Nam Mae Klong, Mae Nam Ping are the cases of reservoirs reducing floods and augmenting lowflows. The Pioneer River is the case of irrigation water use which decreases the lowflows downstream. Jiyun-he is the case of interbasin water transfer which does not contribute for the lowflow augmentation downstream.
2. Some rivers seem less disturbed by reservoir regulation and show the influence of land use and base rocks. The three Central Vietnamese rivers, Song Srepok, Song Ba and Song Thu Bon seem to show the effects of rich groundwater during lowflow season due to dense distribution of igneous rocks.
3. The specific discharges of the mean annual floods have two groups, relatively high and relatively low while they as a whole show the decreasing trends with the size of catchment. Most rivers of the relatively low group show the influence of upstream reservoirs regulation.
4. The specific discharges of mean annual lowflows have also two groups, one concentrated around 0.1-1.0m^3/s/100k^2 and the other below that range, both decrease slightly with the catchment area. They were found dependent on the dryness of the region and the reservoir regulation. But some are highly disturbed by reservoirs and weirs showing either augmentation or loss. Few undisturbed rivers seem to show the influence of land cover such as forests, paddy fields and base rocks.
5. The dryness index m/n was introduced and found, with limitation in the representativeness of basin rainfall, well correspond with the mean annual lowflows as long as the human intervention by reservoirs is not overwhelming.

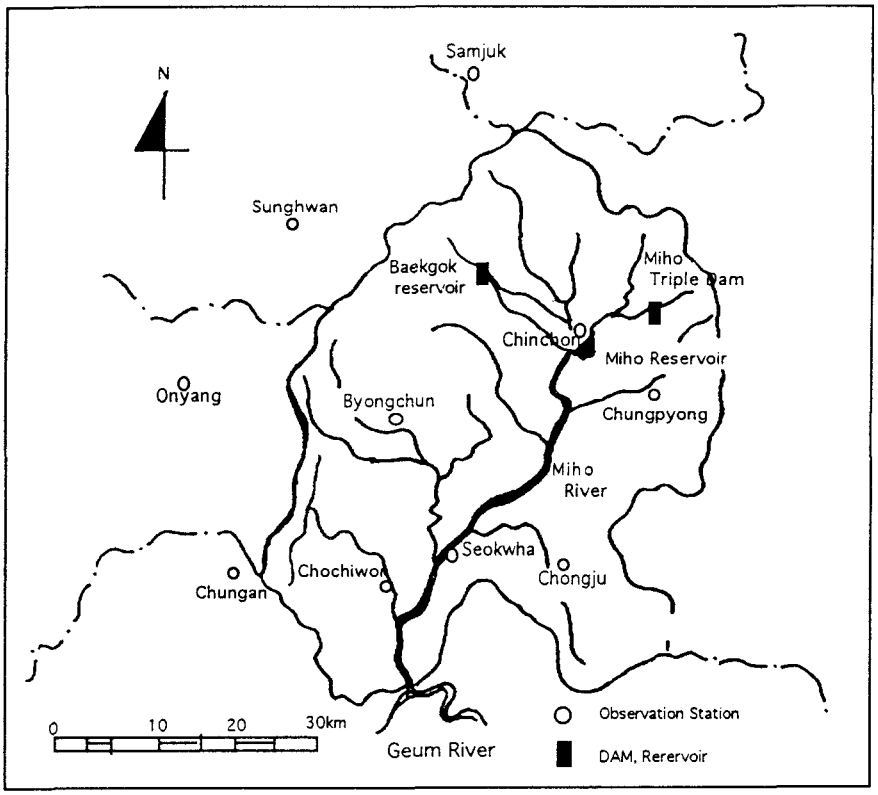
Reference

Takeuchi, K., A.W. Jayawardena and Y. Takahasi (ed.) (1995) Catalogue of Rivers for Southeast Asia and the Pacific, vol.1, UNESCO IHP Regional Steering Committee for Southeast Asia and the Pacific

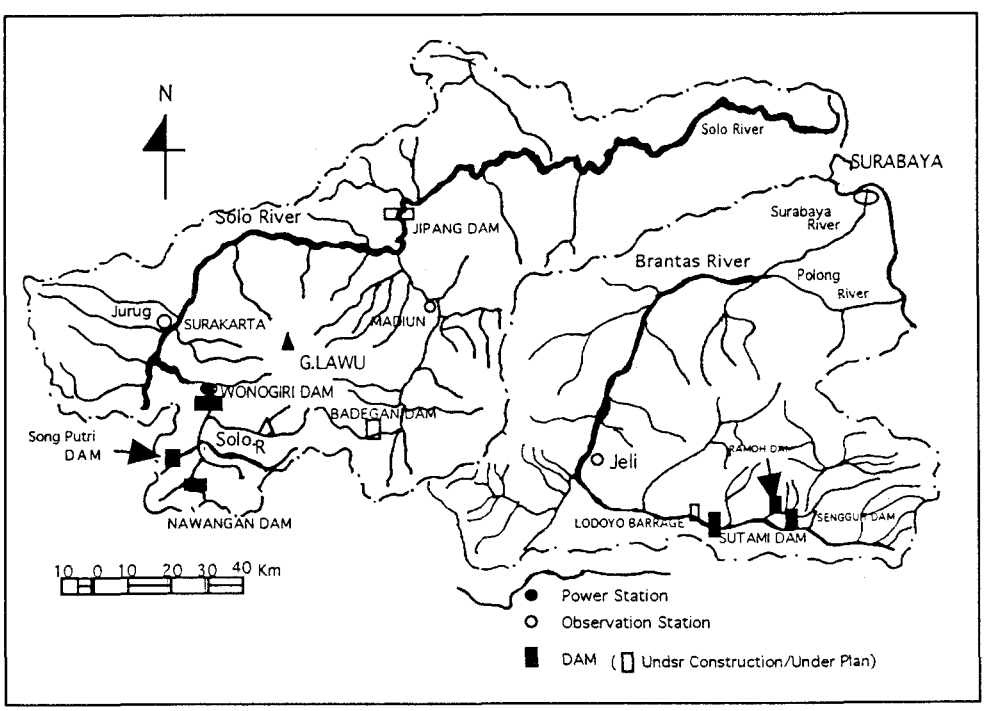


1) m/n: The number of months that have the mean monthly rainfall less than 10mm/that less than 30mm. Number: In case of m=n=0, the least mean monthly rainfall in mm.
2) Points at the outer end of broken lines indicate the data before the construction of major reservoirs.

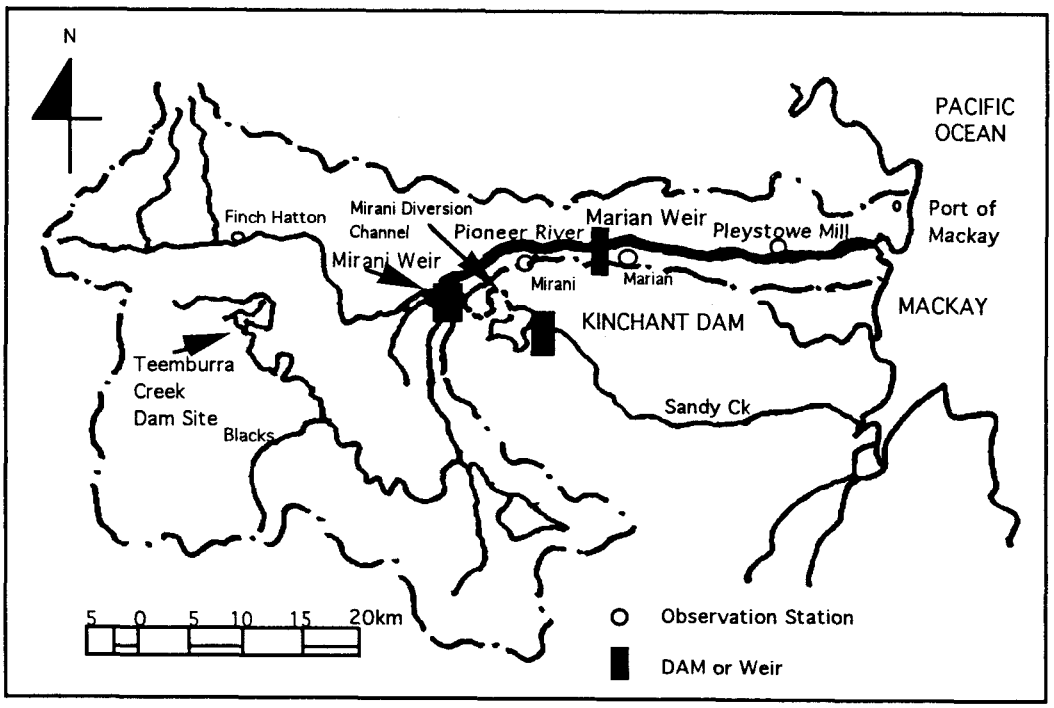
Fig.1. Ranges of the specific mean annual flood, the specific mean annual flow and the specific mean annual lowflow in Southeast Asia and the Pacific rivers.



Map.1 Miho-chun Basin in Republic of Korea



Map.2 Bengawan Solo and Kali Brantas Basins in Indonesia



Map.3 The Pioneer River Basin in Australia

Table 1. List of river data analyzed

	River	Country	Latitude	Station	AREA	Q¯	Qmax	Q¯max	Q¯min	Max two-month rain	Dryness I.	Period
					(km²)	(m³/s)	(m³/s)	(m³/s)	(m³/s)	(mm)	10mm/30mm	
1	Ara-kawa	Japan	N35-36	Yorii	905	30	5512	1534	4.4	344	0/1	1952-93
2	Yoshino-gawa	Japan	N33-34	Toyonaga	933	66	9801	1750	8.3	486	38	1958-90
3	Miho-chun	Korea(Rep. of)	N36-37	Seokwha	1180	28	11425	193	4.8	516	0/2	1970-92
4	Pioneer River	Australia	S21-22	Pleystowe Mill	1375	29	9840	2490	0.3	700	0/2	1917-81
5	Geumho-gang	Korea(Rep. of)	N35-36	Dongchon	1529	15	2434	1165	4.6	426	0/3	1960-92
6	Song Ky Cung	Vietnam	N21-22	Lang Son	1560	29	4520	1437	2.8	502	0/2	1958-90
7	Pyungchang-gang	Korea(Rep. of)	N37-38	Hoopo	1621	52	3924	1607	6.3	596	0/3	1976-85
8	Citarum	Indonesia	S05-07	Nanjung	1675	69	455	279	5.4	532	52	1918-31,74-91
9	Ilog Magat	Philippines	N16-17	Bayombong	1784	70	1541	673	11.7	780	0/2	1959-79
10	Song Thu Bon	Vietnam	N14-16	Nong Son	3155	242	10100	5358	31.3	974	0/2	1977-92
11	Bengawan-Solo	Indonesia	S06-08	Jurug	3220	110	1152	762	10.8	520	0/2	1969-92
12	Kali Brantas	Indonesia	S07-08	Jeli	3464	188	522	318	75.9	652	0/1	1951-93
13	Mogami-gawa	Japan	N37-38	Shimono	3534	174	3807	1929	25.6	282	66	1964-90
14	Prek Thnot	Cambodia	N11-12	Anlong Touk	3650	39	500	426	0.3	492	2/3	1964-69
15	Jin-jiang	China	N24-25	Shilong	5060	159	8020	4100	15.2	554	30	1950-66
16	Jiyun-he	China	N39-40	Jiuwangzhuang	5120	28	572	225	0.1	444	5/8	1930-80
17	Buller River	New Zealand	S41-42	Te Kuha	6350	426	8500	4780	66.6	308	96	1963-present
18	Ilog Pampanga	Philippines	N14-16	Arayat	6487	226	4735	1962	17.7	666	2/3	1946-79
19	Song Srepok	Vietnam	N11-13	Ban Don	10700	246	2400	1352	45	592	2/4	1977-92
20	Song Ba	Vietnam	N12-14	Cung Son	12800	273	10500	6680	26.3	460	3/4	1977-92
21	Mae Nam Mae Klong	Thailand	N13-16	Ban Wang Kha Nai	26449	273	3561	2137	32.8	534	2/4	1965-76
22					26449	273	2377	1079	41.4	534	2/4	1982-91
23	Batang Rajang	Malaysia	N01-03	Kapit Wharf	34053	2510	10799	7432	621.7			1971-92
24	Bei-jiang	China	N23-25	Shijiao	38363	1324	14900	9485	217	510	46	1924-80
25	Mae Nam Ping	Thailand	N15-19	Ban Tha Khae	38862	234	4760	2054	9.1	448	2.5/4	1952-61
26					38862	234	1447	669	60.2	448	2.5/4	1966-91
27	Burdekin River	Australia	S18-25	Clare	129500	322	36000	11600	0.7	400	0.4/5	1951-92