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Original Research Paper

Calculation Method and Example Analysis of Landscape Environmental Water Demand for Medium and Small Rivers in the Northern Cities of China

Kebao Dong, Jing Zhang, Linfei Zhou and Junshi He†
College of Water Resource, Shenyang Agricultural University, Shenyang, Liaoning, 110866, China
†Corresponding author: Junshi He

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ABSTRACT

Meeting landscape environmental water demand is one of the necessary conditions for realizing the stability and sustainablity of landscape environment. According to the characteristics of medium and small rivers in the northern cities, based on the river function, the concept of landscape environmental water demand was proposed, also its calculation method is studied in this paper. The landscape environmental water demand for medium and small rivers in the northern area can be divided into two parts according to the river functional types: environmental water demand and landscape water demand. To environmental water demand, according to river function, hydrological characteristics and water resources in different periods, the method to calculate the water demand by stages is put forward in the paper. Then integrating with landscape water demand, the landscape environmental water demand is calculated. Taking Shenyang Pu River ecological corridor as an example, it is divided into 9 sections combined with practical application and the landscape environmental water demand is calculated by the partition and staging. The results show that the landscape environmental water demand of Pu River ecological corridor is 6749.56×10^4 m^3/year.

INTRODUCTION

River system is one of the most important ecosystems in nature, which has a variety of service functions for local population. At present, with the rapid development of China's economy, the problems of river water environment and water ecology are becoming a serious issue and its management objectives are also changed. Some countries are trying to restore the natural and cultural entertainment value that has already been destroyed in the river system (Willis et al. 1999). The river's main functions have been changed from providing the production and living water, flood control and drainage channel, to ecological environment and landscape entertainment through comprehensive consideration, which needs to meet their water demands at first.

There are many problems such as water shortage, limited supply of water resources, and uneven distribution of time and space in most rivers in northern China, especially the medium and small rivers which are mostly seasonal rivers and are often short of water in dry seasons. In the ecological management of urban inland river, in order to form a continuous view of the water surface, a large number of dams are built that leads to stagnant water after holding runoff, especially in dry seasons when river discharge is short or even none, and it aggravates water pollution and weakens water landscape benefits. This paper, taking the ecological corridor of Pu River as an example, presents the calculation method of water demand for medium and small rivers in the northern cities of China, and provides a scientific basis for water resources planning and rational allocation in similar areas.

CONCEPT AND COMPONENT

Concept: The study of ecological environment water demand was started in the 1940s, which arose some different concepts such as the minimum river water demand (O'Shea et al. 1995), the river environmental water demand (Karim et al. 1995) and so on. In 1996, Gleick put forward this to clear the basic framework gradually, "that the basic ecological water demand minimally changed the natural ecological system to provide a certain water quality and quantity for natural ecological environment, and to protect species diversity and integrity" (Gleick 1996).

As far as the recent researches shown, ecological environment water demand can generally be divided into two parts: ecological water demand and environmental water demand. The ecological water demand focuses on the amount of water, maintaining organisms' lives, but the environmental water demand focuses on the amount of water, improving research objects' overall functions (Xu et al. 2002). Landscape environmental water demand, which develops on the basis of ecological environment water demand, aims to maintain system composition, structural stability, functional maturation and healthy elegance of large scale landscape, and promotes landscape towards a positive developmental direction

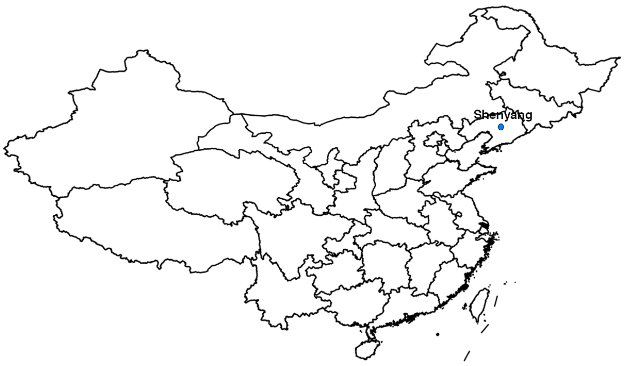

Fig. 1: Geographical position of Pu river.

(Shang et al. 2011). Given the river, its landscape environmental water demand aims to maintain river landscape ecosystem's structure and function to be not destroyed (Yu et al. 2005).

The characteristics of medium and small rivers in the northern cities of China are under shortage of water resources. Because of serious human interference, it is not possible, for these rivers, to recover to the structural and functional status as before, even through ecological management. Rivers in cities should exert not only environmental function, but also landscape function. Therefore, this article believes that the landscape environmental water demand refers to the water demand, which displays the rivers expected environmental and landscape function. Landscape environmental water demand is based not only on the water demand of ecological environment, but also different from it, which includes two meanings, one refers to maintaining the water requirement of ecological environment around rivers, known as environmental water demand, the other refers to meet the water requirement of water sight and entertainment, known as the landscape water demand. The allocation between environmental water requirement and landscape water requirement should be reasonable and sustainable.

Component: According to the concept of landscape environmental water demand for small and medium rivers in the northern cities, it includes two parts: environmental water demand and landscape water demand. The environmental water demand includes the river ecological water demand and the ecological water requirement of the surrounding environment (such as vegetation water demand). The river ecological water demand can be divided into several forms by different ecological environment function (Wang et al. 2007), such as the ecological basic flow, diluting and self-cleaning water demand, water demand for sediment transport. Therefore, environmental water demand consists of ecological base flow, self-cleaning water demand, water demand for sediment transport, water demand of riparian vegetation, water demand of river surface evaporation and seepage. Landscape water demand can be divided into landscape water demand and recreational water demand according to its concept.

Minimum landscape environmental water demand: For rivers, the landscape environmental water demand is not a fixed value, but a range. Under normal circumstances, there are two thresholds about the minimum and the maximum. Considering the water resources' shortage of most rivers in Northern China, the research on minimum water demand has more significance in practice (Zhang et al. 2005). Therefore, this article only studies the river minimum landscape environmental water demand and the environmental landscape water demand refers to the minimum water demand.

CALCULATION METHOD

Calculation interval division of environmental water demand: Ecological water demand of the seasonal rivers also has the special seasonal characteristics (He et al. 2013). The water resource of the medium and small rivers in north is mainly composed of the runoff and drainage. When the rainfall of flood season is high, the water body is mainly composed by runoff. However, in the non-flood season, various types of drainage take a larger proportion in the water body, including the sewage and the treated water, which has become an important providing source for small and middle rivers (Tang et al. 2014). In addition, a large number of dams along the river are usually built to control the limited water resources, forming the linear lake wetland system, in order to maintain the surface area of the urban river landscape. With a view to the above characteristics of small and medium rivers in the north, the environmental water demand should be calculated separately for flood season and non-flood season.

Calculation method of environmental water demand: There is more precipitation, more adequate water supply, and higher flow rate, larger variation of water levels, and more obvious river characteristics of the flood season. Water supply is the main runoff, so water quality should not be as a control factor in the water demand calculation. The water demand should be calculated by its water requirement. Water demand consists of river ecological base flow, water requirement for sediment transport, riparian vegetation, river water surface evaporation and leakage, then take the bigger one from river ecological base flow and the water requirement for sediment transport, plus water demand for vegetation, evaporation and leakage, as the environmental water demand in the flood season. The calculation formula is as follows:

$$Q_{flood} = \sum_{i} [\max(Q_{river,i}, Q_{\text{sediment},i}) + Q_{\text{vegetation},i}$$

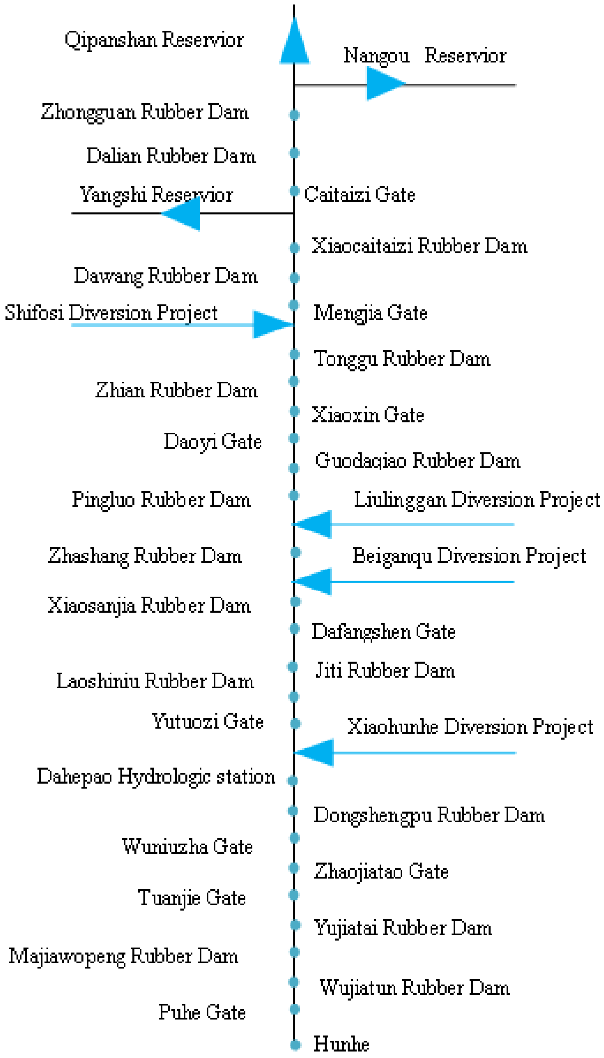

Fig. 2: Node diagram of water conservancy project in Pu river ecological corridor.

$$+Q_{evaporation,i}+Q_{leakage,i}] \quad ...(1)$$

In this formula, Q_{flood} is the environmental water demand in flood season, $Q_{river,i}$ is the river ecological base flow in the i_{th} month, $Q_{sendiment,i}$ is the water requirement of sediment transport in the i_{th} month, $Q_{vegetation,i}$ is the vegetation water demand in the i_{th} month, $Q_{evaportion,i}$ is the water requirement for evaporation in the i_{th} month, $Q_{leakage,i}$ is the water requirement for leakage in the i_{th} month, i is the month in flood season.

There is a less precipitation, insufficient water supply, a slower flow rate, a lower water level, and more obvious characteristics of lake wetland in the non-flood season. Because of the small runoff and large proportion of various drainages in the water supply, water quality index, as the control factor of water demand, should also be calculated by both quantity and quality of the water requirement. Water demand consists of the self-cleaning water demand, water requirement for vegetation, evaporation and leakage, and then as environmental water requirement in non-flood season. The calculation formula is as follows:

$$Q_{non-flood}=\sum_j[Q_{self-cleaning,j}+Q_{vegetation,j}$$
$$+Q_{evaporation,j}+Q_{leakage,j}] \quad ...(2)$$

In this formula, $Q_{non-flood}$ is the environmental water demand in non-flood season, $Q_{self-cleaning,j}$ is the self-cleaning water demand in the j_{th} month, $Q_{vegetation,j}$ is the vegetation water demand in the j_{th} month, $Q_{evaporation,j}$ is the water requirement for evaporation in the j_{th} month, $Q_{leakage,j}$ is the water requirement for leakage in the j_{th} month, j is the month of non-flood season.

Calculation method of landscape water demand: Landscape water demand should be able to meet the river landscape's service function, including water demand for water landscape and entertainment. To river water whose functions are landscape and entertainment, water demand for river landscape and entertainment has been a priority to meet, as long as the river water quality can reach the corresponding standards. To the river water which takes the landscape and entertainment as a part of the function, the quantity of water demand will be a main index, its water demand can be calculated according to the requirements of functional targets, because the water quality for river landscape and entertainment is not very high (Ni et al. 2002). Water demand for river water landscape can be calculated in accordance with the requirements of functional targets, such as the river surface area, water level and flow etc., to determine the water demand for water landscape. Recreational water demand is mainly used to meet water recreation (such as boating, rafting, swimming, etc.). Generally speaking, as long as the landscape water demand is met, the water demand for entertainment is met.

Integration of landscape environmental water demand: The purpose of landscape environmental water requirement integration is mainly to solve the repeat calculation between different types of landscape environmental water demand. Considering the compatibility between environmental water demand and landscape water demand, the integration should follow accumulation principle and maximum principle. Landscape water demand, ecological base flow, water requirement for sediment transport and self-cleaning, which belongs to non consumptive water requirement, follow the maximum principle. Water requirement for vegetation,

Table 1: Ecological base flow of Pu River ecological corridor in flood season 10^4 m³.

Month	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII	Section VIII	Section IX
Jun.	42.34	12.69	62.93	74.24	80.43	26.68	84.48	140.84	7.41
Jul.	132.47	39.70	196.88	232.28	251.64	83.47	264.31	440.65	23.19
Aug.	178.03	53.36	264.60	312.19	338.20	112.18	355.23	592.23	31.17
Sep.	58.75	17.61	87.31	103.02	111.60	37.02	117.22	195.43	10.29
Total	411.59	123.36	611.72	721.73	781.87	259.35	821.24	1369.15	72.06

Table 2: Dilute self-purification water demand of Pu River ecological corridor in non-flood season 10^4 m³.

Month	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII	Section VIII	Section IX
Jan.	1.67	0.50	2.48	2.92	3.16	1.05	3.32	5.54	0.29
Feb.	1.56	0.47	2.32	2.74	2.97	0.98	3.12	5.20	0.27
Mar.	6.26	1.88	9.30	10.97	11.88	3.94	12.48	20.81	1.10
Apr.	11.52	3.45	17.12	20.20	21.89	7.26	22.99	38.32	2.02
May	8.53	2.56	12.69	14.97	16.21	5.38	17.03	28.39	1.49
Oct.	10.21	3.06	15.17	17.90	19.39	6.43	20.37	33.96	1.79
Nov.	6.21	1.86	9.23	10.89	11.80	3.91	12.39	20.66	1.09
Dec.	2.76	0.83	4.10	4.84	5.25	1.74	5.51	9.19	0.48
Total	48.72	14.61	72.41	85.43	92.55	30.69	97.21	162.07	8.53

Table 3: Water requirement for water surface evaporation of Pu River ecological corridor 10^4 m³.

Month	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII	Section VIII	Section IX
Jan.	2.42	1.29	3.83	0.79	0.70	1.69	3.40	2.81	0.19
Feb.	4.45	2.37	7.04	1.44	1.28	3.01	6.07	5.03	0.34
Mar.	8.27	4.40	13.09	2.68	2.39	5.65	11.41	9.44	0.64
Apr.	14.21	7.56	22.49	4.64	4.14	9.93	20.06	16.57	1.12
May	18.74	9.97	29.65	6.13	5.46	13.12	26.50	21.89	1.48
Jun.	6.96	3.70	11.01	2.46	2.19	6.09	12.31	10.04	0.68
Jul.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct.	4.02	2.14	6.36	1.39	1.24	3.30	6.66	5.45	0.37
Nov.	3.36	1.79	5.32	1.12	1.00	2.51	5.06	4.17	0.28
Dec.	1.69	0.90	2.68	0.56	0.50	1.26	2.55	2.10	0.14
Total	64.12	34.13	101.48	21.21	18.92	46.54	94.02	77.50	5.23

Table 4: Leakage water requirement of Pu River ecological corridor 10^4 m³.

Month	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII	Section VIII	Section IX
Jan.	3.77	1.42	2.74	0.06	0.06	0.01	0.03	0.11	0.01
Feb.	3.77	1.42	2.74	0.05	0.06	0.01	0.03	0.10	0.01
Mar.	3.81	1.44	2.81	0.22	0.24	0.04	0.12	0.42	0.02
Apr.	3.87	1.45	2.89	0.40	0.44	0.07	0.23	0.77	0.04
May	3.84	1.45	2.85	0.30	0.32	0.05	0.17	0.57	0.03
Jun.	4.17	1.55	3.35	1.48	1.61	0.27	0.84	2.82	0.15
Jul.	5.07	1.82	4.69	4.65	5.03	0.83	2.64	8.81	0.46
Aug.	5.53	1.95	5.37	6.24	6.76	1.12	3.55	11.84	0.62
Sep.	4.34	1.60	3.59	2.06	2.23	0.37	1.17	3.91	0.21
Oct.	3.85	1.45	2.87	0.36	0.39	0.06	0.20	0.68	0.04
Nov.	3.81	1.44	2.81	0.22	0.24	0.04	0.12	0.41	0.02
Dec.	3.78	1.43	2.76	0.10	0.10	0.02	0.06	0.18	0.01
Total	49.60	18.42	39.48	16.14	17.49	2.90	9.18	30.62	1.61

evaporation and leakage, which belongs to consumptive water requirement, follow the accumulation principle. The calculation formula is as follows:

$$Q = \sum_i [\max(Q_{river,i}, Q_{sendiment,i}, Q_{landscape,i}) + Q_{vegetation,i} + Q_{evaporation,i} + Q_{leakage,i}]$$
$$+ \sum_j [\max(Q_{self-cleaning,j}, Q_{landscape,j}) + Q_{vegetation,j} + Q_{eaporation,j} + Q_{leakage,j}] \quad ...(3)$$

In this formula, Q is the annual landscape environmental water demand, $Q_{landscape,i}$ is the landscape water demand in the i_{th} month of flood season, $Q_{landscape,j}$ is the landscape water demand in the j_{th} month of non-flood season, other symbols have the same meaning as Eqs. 1 and 2.

EXAMPLE ANALYSIS

General situation of the study area: Pu River, located between Liao River and Hun River, is the largest tributary of Hun River on the right bank. It lies in the east longitude of 122°40'48' ~ 123°56'32' and the north latitude of 41°21'53' ~ 42'4'15' (Fig. 1). This river originated from Xianger Mountain, Hengdaohezi town, and enters the territory of Shenyang in Gulazi village. It runs through Qipanshan development zone, Shenbei new district, Yuhong district, Xinmin city and Liaozhong county. The basin area is 2248 km^2, total length is 205 km, and the length in Shenyang is 179.7 km (He et al. 2011).

Shenyang municipal government has been implementing the comprehensive renovation project of Pu River since 2010, including pollution control, river regulation, river sides greening, water resources control and other key projects. Pu River ecological corridor construction is divided into 4 sections according to the district, which are Shenbei, Yu Hong, Xinmin and Liaozhong section. There are 26 water related buildings on the river channel and 4 water diversion works have been completed (Fig. 2). The scope of this study is Pu River ecological corridor, total length is 161.8 km, from Qipanshan reservoir to the department entrance of Hun River.

CALCULATION PARTITION

Comprehensive consideration of geology, geomorphology, hydrology, meteorology and other natural conditions, river function, water resources planning, and also the consistency of managed space units, the acquisition of hydrological data, the distribution of water retaining, storage structures and diversion projects, based on the administrative area, Pu River ecological corridor has been divided into 9 sections. The specific divisions from the upstream to the downstream are:

(1) The Qipanshan reservoir ~ Caitaizi gate, called section I
(2) Caitaizi gate ~ Xiaocaitaizi rubber dam, called section II,
(3) Xiaocaitaizi rubber dam ~ Daoyi gate, called section III,
(4) Daoyi dam ~ Zhashang rubber dam, called section IV,
(5) Zhashang rubber dam ~ Laoshiniu rubber dam, called section V,
(6) Laoshiniu rubber dam ~ Dahepao hydrologic station, called sectioneVI,
(7) Dahepao hydrologic station ~ Tuanjie gate, called section VII,
(8) Tuanjie gate ~ Puhe gate, called section VIII,
(9) Puhe gate ~ Hun River, called section IX

ENVIRONMENTAL WATER DEMAND CALCULATION

Considering the meteorological and hydrological conditions of the Pu River basin that rainfall mainly concentrates in June to September, June to September is determined to be the flood season, October to May in the next year is determined to be the non-flood season in the landscape and environmental water demand calculation.

In the calculation of water demand, in view of the functional localization of Pu River ecological corridor and the actual situation that water demand for sediment transport is small, it is considered that the river ecological water demand will be satisfied, as long as the water demand for sediment transport is met.

Ecological base flow: This study, using the Tennant method, takes 40% of the 1975 ~ 2011 month average flow rate for years as the ecological basic flow rate in the channel (Tennant 1976). Calculation results are shown in Table 1.

Dilute self-purification water demand: This study, using an average flow rate of the driest months method for the near decade, takes average month minimum runoff volume from 2002 to 2011 as dilute self-purification water demand, calculation results are shown in Table 2.

Water requirement for water surface evaporation: According to the precipitation and evaporation data from 1975 to 2011, the annual average evaporation in Pu River Basin is more than the annual average precipitation, but the monthly mean evaporation less than the mean precipitation from July to September. This study uses formula (4) to calculate the water requirement for water surface evaporation, calculation results are shown in Table 3.

$$Q_{evaporation} = \begin{cases} A(E-P), E > P \\ 0, E < P \end{cases} \quad ...(4)$$

In this formula, $Q_{evaporation}$ is water requirement for water surface evaporation, A is the surface area, E is water surface evaporation, P is precipitation.

Leakage water requirement: Based on the river landscape

Table 5: Riparian vegetation water demand of Pu River ecological corridor 10^4 m³.

Month	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII	Section VIII	Section IX
Apr.	3.28	2.15	4.71	3.90	5.61	3.61	5.65	14.22	2.12
May	3.28	2.15	4.71	3.90	5.61	3.61	5.65	14.22	2.12
Jun.	3.28	2.15	4.71	3.90	5.61	3.61	5.65	14.22	2.12
Jul.	3.28	2.15	4.71	3.90	5.61	3.61	5.65	14.22	2.12
Aug.	3.28	2.15	4.71	3.90	5.61	3.61	5.65	14.22	2.12
Sep.	3.28	2.15	4.71	3.90	5.61	3.61	5.65	14.22	2.12
Oct.	3.28	2.15	4.71	3.90	5.61	3.61	5.65	14.22	2.12
Total	22.96	15.06	32.98	27.27	39.24	25.27	39.53	99.53	14.87

Table 6: Landscape water demand of Pu River ecological corridor 10^4 m³.

Month	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII	Section VIII	Section IX
Jan.	1.19	0.48	2.25	1.08	0.61	0.85	2.94	4.43	0.08
Feb.	1.11	0.45	2.11	1.02	0.57	0.79	2.76	4.15	0.08
Mar.	4.44	1.83	8.43	4.07	2.29	3.18	11.04	16.62	0.31
Apr.	8.18	3.37	15.52	7.50	4.22	5.85	20.33	30.61	0.57
May	6.06	2.50	11.51	5.55	3.12	4.34	15.06	22.68	0.42
Jun.	30.07	12.41	57.06	27.55	15.49	21.51	74.72	112.50	2.07
Jul.	94.08	38.83	178.53	86.19	48.46	67.31	233.77	351.98	6.49
Aug.	126.43	52.19	239.94	115.84	65.13	90.46	314.18	473.05	8.73
Sep.	41.72	17.23	79.18	38.23	21.49	29.85	103.67	156.10	2.88
Oct.	7.25	2.99	13.76	6.64	3.73	5.19	18.02	27.13	0.50
Nov.	4.41	1.82	8.37	4.04	2.27	3.15	10.96	16.50	0.31
Dec.	1.96	0.81	3.72	1.80	1.01	1.40	4.87	7.34	0.13
Total	326.90	134.93	620.38	299.51	168.39	233.88	812.31	1223.08	22.56

Table 7: Landscape environmental water demand of Pu River ecological corridor 10^4 m³.

Month	Section I	Section II	Section III	Section IV	Section V	Section VI	Section VII	Section VIII	Section IX
Jan.	7.85	3.21	9.05	3.77	3.93	2.75	6.76	8.47	0.49
Feb.	9.78	4.26	12.10	4.23	4.31	4.00	9.22	10.33	0.62
Mar.	18.34	7.72	25.20	13.87	14.52	9.63	24.02	30.67	1.75
Apr.	32.87	14.62	47.21	29.15	32.07	20.87	48.92	69.88	5.30
May	34.39	16.13	49.90	25.29	27.61	22.16	49.35	65.07	5.13
Jun.	56.75	20.09	82.00	82.08	89.83	36.65	103.28	167.92	10.36
Jul.	140.82	43.67	206.28	240.82	262.28	87.91	272.60	463.68	25.78
Aug.	186.84	57.47	274.68	322.33	350.57	116.91	364.43	618.29	33.92
Sep.	66.37	21.36	95.62	108.97	119.44	41.00	124.04	213.55	12.62
Oct.	21.36	8.80	29.12	23.54	26.62	13.40	32.88	54.31	4.32
Nov.	13.38	5.09	17.36	12.23	13.03	6.46	17.58	25.24	1.39
Dec.	8.23	3.16	9.55	5.50	5.85	3.02	8.11	11.46	0.63
Total	596.99	205.57	858.07	871.79	950.07	364.74	1061.17	1738.86	102.30

water demand by statistics, this study uses formula (5) to calculate the leakage water requirement, and determines the permeability coefficient, by experience, according to the types of soil. Calculation results are shown in Table 4.

$$Q_{leakage} = k \cdot Q_{landscape} \quad ...(5)$$

In this formula, $Q_{leakage}$ is the leakage water requirement, K is permeability coefficient, $Q_{landscape}$ is the landscape water demand.

Riparian vegetation water demand: According to the green belt area outside river and the green water quota of Shenyang, this study uses area quota method to calculate the riparian vegetation water demand by formula (6), and the calculation results are given in Table 5. Because of the Shenyang area in November to March of the following year during vegetation withering period, so in the meantime without considering the vegetation water demand.

$$Q_{vegetation} = \psi \cdot F \quad ...(6)$$

In this formula, $Q_{vegetation}$ is the riparian vegetation water demand, ψ is green water quota, F is the green belt area.

Landscape water demand calculation: According to the Pu River's ecological management planning objectives, water system management should become an ecological landscape zone, which water runs through and is connected to each other. Therefore, the river landscape water demand is the sum of water storage at each gate and dam in the river channel, and water demand that can keep water flowing and continuous water surface of the channels between every gate and dam. Each section's landscape water demand by statistics is distributed in every month according to the ratio of mean monthly runoff and annual runoff. The results are presented in Table 6.

Integration and analysis of landscape environmental water demand: According to the integration method of landscape environmental water demand as above, monthly and annual landscape environmental water demand of each section in Pu River ecological corridor can be calculated by formula (3), calculation results are given in Table 7.

The annual landscape environmental water demand of Pu River ecological corridor is 6749.56×10^4 m^3, among them, the water requirement in flood season is 5521.21×10^4 m^3, which is about 82% of the total annual water demand, and the water requirement in non-flood season is 1228.35×10^4 m^3, which is only 18% of the total annual water demand. Seasonal river features are obvious. Non consumptive environmental water demand is 5784.29×10^4 m^3, landscape water demand is 3841.94×10^4 m^3. The former is larger than the latter, so obviously, the landscape water demand is satisfied automatically as long as the environmental water demand is met, which also further indicates that the Pu River ecological corridor construction has not been excessively developed to use landscape water.

CONCLUSIONS

Due to the shortage of water resources, in the northern region of China, the medium and small rivers in urban area usually form a unique characteristic of a linear lake wetland system through ecological management. In light of different functions, hydrological characteristics and water constitute in different periods of its system, it is not suitable to adopt the same calculation method for the whole year for computing the landscape environmental water demand. Therefore, this article proposes a method of staging calculating environmental water demand, which uses different calculation methods in different periods of the year and then integrates with the landscape water demand to obtain the landscape environmental water demand.

In 50% and 75% frequency years, the water quantity of Pu River ecological corridor is , respectively, 18710.70×10^4 m^3 and 10141.60×10^4 m^3, the amount of production water extracted from watercourse are 6974.70×$10^4$$m^3$ and 10439.87×10^4 m^3. Considering the water requirement of the landscape environment, the total water demand is, respectively, 13724.26×10^4 m^3 and 17189.43×10^4 m^3. These data show that the water quantity of Pu River ecological corridor can meet the water demand in 50% frequency year, but in 75% frequency year its water shortage is 7047.83×10^4 m^3, which needs to be made up by strengthening the water reuse, utilizing diversion projects and so on.

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REFERENCES

Gleick, P. H. 1996. Water in crisis: paths to sustainable water use. Ecological Applications, 8(3): 571-579.

He, J. S., Zhang, G. T. and Wang, W. S. 2011. Utilization of rain and flood resources and river ecological restoration in Pu River basin. China Water & Power Press, Beijing, pp. 14.

He, J. S., Zhou, F. and Zhang, J. 2013. Ecological regulation divided by seasons in main Liaohe River based on river health. Resources and Environment in the Yangtze Basin, 22(5): 657-662.

Karim, K., Gubbels, M. E. and Goutler, I. C. 1995. Review of determination of instream flow requirements with special application to Australia. Water Resources Bulletin, 31(6): 1063-1077.

Ni, J. R., Cui, S. B. and Li, T.R. 2002. On water demand of river ecosystem. Journal of Hydraulic Engineering, (9): 14-19.

O'Shea, D. T. 1995. Estimating minimum instream flow requirements for Minnesota streams from hydrologic data and watershed characteristic. North American Journal of Fisheries Management, 15(3): 569-578.

Shang, C.J. and Hao, Z.B. 2011. Study on water conservancy scenic area landscape environmental water demand. Yellow River, 33(3): 46-48.

Tang, L. 2014. Study on water ecological characteristics and main evaluation factors of medium and small rivers in North Area. Environmental Protection Science, 40(1): 41-45.

Tennant, D.L. 1976. Instream flow regimes for fish, wildlife, recreation and related environmental resources. Fisheries, 1(4): 6-10.

Wang, X.Q. 2007. The theory, method and application of river ecological water demand. China Water & Power Press, Beijing, pp.72.

Willis, K. G. and Garrod, G. D. 1999. Angling and recreation values of low-flow alleviation in rivers. Journal of Environmental Management, 57(2): 71-83.

Xu, X.Y. and Yang, Z. F. 2003. General discussion on ecological environment water demand. China Water, 3: 12-15.

Yu, Z. B. and Long, T. Y. 2005. Wang, D. Q. 2005. Study on calculation method of ecological water demand for the landscape. Journal of Chongqing University of Architecture, 27(1): 71-75.

Zhang, Y., Yang, Z. F. and Wang, X. Q. 2005. Computing method of divisional ecological and environmental water requirement for river channel and its application to the Yellow River basin. Acta Scientiae Circumstantiae, 25(4): 429-435.