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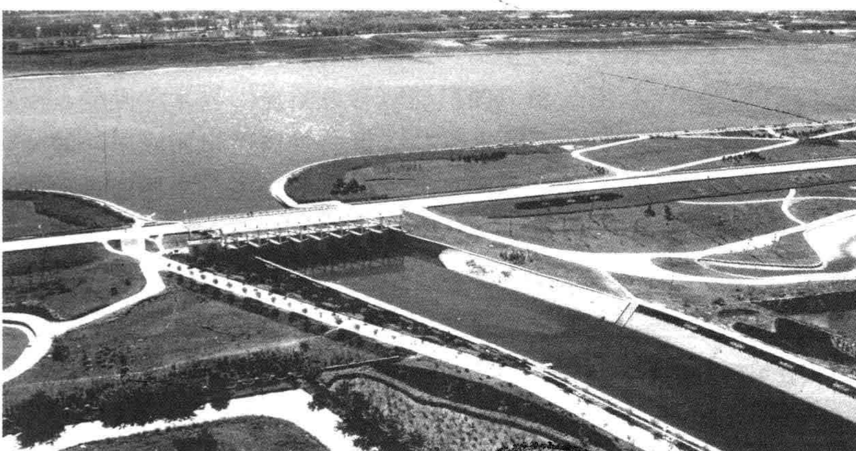

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SUMMARY 摘要

河岸植被缓冲带是指河岸两侧向岸坡爬升的由树木及其他植被组成的缓冲区域，其功能是防止由坡地地表径流、废水排放、地下径流和深层地下水流所带来的养分、沉积物、有机质、杀虫剂及其他污染物进入河溪系统。因而，**河岸植被缓冲带规划是河流水质保护的重要手段和前提条件**，对维系河流生态系统的健康有着重要的作用，受到学术界、建设和管理部门的广泛关注。

如何规划河岸植被缓冲带，主要取决于以下几个问题的回答：①如何考虑河岸植被缓冲带的空间布局？②河岸植被缓冲带的宽度如何确定？③在宽度确定的基础上，如何确定植物种类和植物组成？

本项研究首先对国内外相关研究进行综述、比较，并根据平原河网地区地势平坦、快速城市化的特点，基于GIS平台，筛选和建立了一套适合平原河网地区的河岸植被缓冲带规划技术和流程；同时，通过对上海地区河岸带植被的野外调研和数量分析，建立区域河岸植被缓冲带的参照系。以上海市滴水湖汇水区为实证研究对象，利用“3S”技术，建立空间数据库，定量模拟汇水区的面源污染负荷、汇流路径；在此基础上，确定河岸植被缓冲带的空间格局、宽度、植被种类和数量组成，最终实现区域河岸植被缓冲带的定量规划。论文的研究结论可以从规划方法和技术、实证研究两个方面进行概括。

规划方法和技术

（1）河岸植被缓冲带规划流程：应建立在“参照系构建-汇水

区划分-面源污染负荷计算和汇流路径分析”的基础上。河岸植被缓冲带规划主要包含两个方面：一是根据面源污染负荷及汇流路径确定河岸植被缓冲带的空间布局和宽度；二是在空间布局（位置）和宽度计算模拟的基础上，依据建立的河岸植被参照系，确定河岸植被的种类以及组成。

（2）参照系建立：本研究通过对上海地区河岸带植被的野外调研和数量分析，建立该区域河岸植被缓冲带的参照系。

（3）汇水区划分：针对传统的汇水区划分方法在平原河网地区应用的局限性，本研究提出了适合平原河网地区汇水区的划分方法。在河网地块内部，通过修正 Getirana 等人的 DEM 融合算法，提出了适合上海地区的 DEM 融合算法，基于修正算法通过距离偏移矩阵运算和高程偏移矩阵运算，将影响径流特征的地物要素（如道路、建筑、坑塘以及排水管网）叠加到原始的“伪”DEM 中，起到细化 DEM 的目的，提高平坦区域河网地块内河网提取和汇水区边界模拟的精度。在河网概化的基础上，在 MIKE11 中建立河网一维非恒定流水动力模型，依据水动力学模型模拟河道在水利控制设施（节制闸、出海闸以及翻水站等）调控作用下引水或排水期间河网的水位、流向以及水量等，确定各出水口所对应的范围，完成汇水区的划分。

（4）面源污染负荷计算及汇流路径分析：本研究通过修正的 SCS 模型和 PLOAD 模型对单场次降雨条件下的面源污染负荷做了计算，并模拟了面源污染的汇流路径。

（5）河岸植被缓冲带规划：基于面源污染途径确定河岸植被缓冲带的空间布局；通过对时间模型和水文模型进行修正，计算得到河岸植被缓冲带所需的最小宽度；依据参照系确定植物种类和数量组成。

实证研究

（1）参照系建立：通过对上海地区河岸带植被的野外调研，利用 SPSS 软件进行聚类分析得到 8 种河岸带植被类型。分别对 8 种河岸带植被调查数据进行统计分析，确定了不同植被类型的参

照值。

（2）汇水区划分：通过对汇水区内各出口水闸的开启状态进行分析，发现各出口水闸的开启状态会随着内河水位的变化而变化，河网水流方向也呈周期性变化，滴水湖汇水区的范围是一个动态范围，伴随着出水口的改变而改变。滴水湖的汇水区范围共有三种方案，其中非引水期间（模式 1）的汇水区范围最小，为 $76.15km^2$，此汇水区存在的持续时间最长，达到 282d，引水期间（模式 3）汇水区范围最大，面积为 $233.5km^2$，持续时间为 80d，处于两者过渡状态（模式 2）的汇水区范围持续时间最短，为 3d，面积介于两者之间，为 $92.29km^2$。

（3）面源污染负荷计算及汇流路径：从面源污染负荷计算结果来看，在汇水区划分模式 2 下的面源污染的空间分布与模式 1 类似，产生 NH_3-N、TN、TP 和 TSS 总量最大的区域主要位于滴水湖的东北侧，紧邻滴水湖的西侧区域产生的 NH_3-N、TN、TP 和 TSS 总量较少。而汇水区划分模式 3 下产生 NH_3-N、TN、TP 和 TSS 总量的区域主要集中在滴水湖的东北侧和西侧，东北侧区域内的面源污染较为集中，都集中在 2 号河网地块，与之相对应的是滴水湖西侧的面源污染呈散点状分布，各地块均有分布，且集中在河网地块中心位置。汇水区划分模式 3 下产生的面源污染产生的区域最广，对滴水湖水质的影响作用最大，对该模式下的面源污染防治也显得尤为关键。对面源污染的汇流路径进行分析，发现 NH_3-N、TN、TP 和 TSS 的汇流路径均以 B1（坡面径流-沟渠-1 级河流）为主，其次为 B2（坡面径流-沟渠-2 级河流）和 A1（坡面径流-1 级河流），通过三种路径排放的面源污染负荷量占到面源污染排放总量 70%以上，河岸植被缓冲带的空间布局和后续的河岸植被缓冲带建设应重点考虑这些区域。

（4）河岸植被缓冲带规划：设置了情景模式 1（基于河流两侧现状土地利用类型）和情景模式 2（基于河流两侧土地利用类型为林地），模拟这两种情景模式下河岸植被缓冲带的宽度和空间布局。在规划情景模式 1 中，河岸植被缓冲带宽度在 9～74.5m 之间变

化，宽度主要集中在17.1～42.4m之间。在规划情景模式2中，河岸植被缓冲带宽度在9～56.4m之间变化，宽度主要集中在13.3～29.8m之间。此外，在宽度确定的基础上，选择人民塘、随塘河及其支流作为代表性河段，以植被参照系为依据，对这些河段的植物种类与组成做了定量研究。

论文创新点

（1）对国内外相关研究进行综述、比较，并根据平原河网地区地势平坦、快速城市化特点，基于GIS平台，筛选并建立了一套适合平原河网地区的河岸植被缓冲带规划技术和流程。

（2）通过对上海地区河岸带植被的野外调研和数量分析，建立区域河岸植被缓冲带的参照系。

（3）针对传统的汇水区划分方法在平原河网地区应用的局限性，本研究提出了适合平原河网地区的汇水区划分方法。

关键词： 河岸植被缓冲带；平原河网；汇水区；流域；面源污染；滴水湖

Abstract

Riparian vegetation buffer strip refers to the buffer area along the river. Its function is to prevent nutrients, sediments, organic matter, pesticide and other pollution from entering the river system brought by sloping surface run-off, waste water release, groundwater and deep groundwater flow. That is why it has always been an important instrument in river protection. It plays an important role in maintaining the health of water ecosystem, and has been paid attention by not only the academic circles, but also the construction and administration departments.

How to plan an effective riparian vegetation buffer strip for water quality conservation? Before answering this question, we need to dress the following questions: ① How are we to deal with the spatial distribution of the riparian vegetation buffer strip width? ② How are we to determine the riparian vegetation buffer strip width? ③ On the basis of the width, how are we to regard the species and composition of the vegetation?

This study, in the first place, reviewed and compared relative studies at home and abroad. Next, the plain river network area is characterized by its plain topography, and rapid urbanization. Based on GIS software, a set of suitable procedure and methodology for the planning of riparian vegetation buffer strip is established. Meanwhile, the reference conditions are set up, via extensive field investigation on the riparian vegetation species, and data analysis. Thirdly, take Shanghai Dishui Lake as an example, using "3S" technologies; the special database is built up. Fourthly, Quantitative model non-point source pollution loads and runoff routes, and define the width, pattern, vegetation species and

quantity of the buffer. All these lead to the accomplishment of the quantitative planning of regional riparian vegetation buffer strip. The results and conclusions are as follows:

Procedure and methodology:

(1) The planning of riparian vegetation buffer strip shall be studied under the framework of "watershed division-measurement on non-point resource pollution load and rainfall path-establishment of community reference condition-riparian planning". The planning mainly includes two aspects. Firstly, locate and gain the breadth of the buffer based on non-point source pollution load and runoff pathway. Secondly, according to the established riparian vegetation reference condition, and with the modeling of special location and width, define the species and composition of the vegetation.

(2) Establishment of the reference condition: The reference condition is set up, via extensive field investigation on the riparian vegetation species, and data analysis.

(3) Watershed division: In plain river network, it is difficult to divide a watershed because of the disturbance of rainfall path caused by closed river network structure, plain topology, water conservancy facility regulation and intensive human activities. Aiming at such condition, this study, divides the watershed through two angles, that is, within the river network and between the two river networks. In polygonal river networks areas, watershed delineation is the first step in many hydrological projects. In rapidly urbanized plain river network areas, some landcover features can't be shown in DEM, which caused errors in drainage patterns due to low density of elevation value. Poor landcover features representation in DEM has frequently caused the error of drainage patterns due to the lower precision of the height source or elevation values. To avoid these problems, a new

approach, using the digital landcover features (e.g. roads, buildings, ponds, and pipe drainage systems) as ancillary data are added into DEM, has been developed. To avoid detrimental changes in DEM, distance transformation concepts are used to determine the elevation offset distribution in the plain river network areas. The new approach supports the application in small-scaled plain river network areas by modifying two newly added scenes (landcover features are added in DEM and landcover features are burned in DEM). As for inter-sectional river network areas, considering the influence to water volume and direction led by the regulation of dams or other water conservancy facilities, make clear the outlet of the relative network and finish the division work.

(4) Measurement on non-point resource pollution load and rainfall path: This study borrowed the modified SCS model for reference, to calculate the runoff yield based on the data of rainfall-runoff was also given. In the same way as the calculation of runoff yield, this study borrowed PLOAD and EMC (event mean concentration) for reference, to calculate the total non-point source pollution loads of the watershed at one single rainfall event. The pollution load of the buffer runoff is then derived. The modeling of the pollution flow path is further done in ArcGIS Hydrology tools.

(5) Planning of riparian vegetation buffer strip: The study applied a width variable calculation method. Based on time models and hydrology models created by different researchers targeting protection of riparian, with comprehensive consideration of physical and chemical properties of soil, topology, landcover, and other special environmental factors, calculate the variable width of the riparian. On the basis of extensive investigation, the riparian

vegetation species on different habitats are defined. The reference indicators and frames are separately created based on all kinds of vegetation types. These laid a solid foundation for the species selection and community construction of the riparian.

A case study in Lingang:

(1) Establishment of reference condition for riparian vegetation community: Based on extensive field investigation on the riparian vegetation community in Shanghai, eight habitats are gained using the cluster analysis of SPSS. The investigation data of riparian vegetation under eight habitat conditions are analyzed statistically. Reference values of vegetation species, richness indicator, diversity indicators, and ratio of local species, vegetation coverage and the number of community vertical structures are defined under different vegetation types.

(2) Watershed delineation: The analysis of sluices at each outlet within the watershed show that, during the year, the on and off status of each sluice changes with the change of water level of inner lakes. The flow direction of the river network varies periodically. The Dishui Lake watershed is a dynamic area. It alters along with the outlet, is quite different from the traditional one. There are three scenarios about the watershed area. During the non-diversion period, it is the smallest, covering an area of 76.15km^2. Such watershed lasts the longest, up to 282d. When Dishui Lake is drawing water from other rivers, the area becomes the largest, of 233.5km^2, lasting for 80d. Between the two circumstances, is the middle one with an area of 92.29km^2, and will last for only 3d.

(3) Measurement on non-point resource pollution load and rainfall path: In the aspect of the special distribution of non-point source pollution in the watershed, regions producing NH_3-N, TN, TP and TSS mainly concentrate at the north-east and the west of

Dishui Lake. The non-point source pollution in the north-east is mostly centralized in network No. 2. However, the pollution in the west scatters, distributes in every block, and centralized in the sole of every block. The analysis shows that these regions are mainly paddy fields and dry lands in land use. The study proves that agriculture is the main cause of non-point source pollution through modeling.

The analysis on the non-point source pollution release routes shows that NH_3-N, TN, TP and TSS are mainly following the route of B1 "buffer runoff-ditch- 1st class stream", and then goes to B2"buffer runoff-ditch- 2nd class stream" and A 1"buffer runoff- 1st class stream". These three routes account for over 70% of the total non-point source pollution release volume.

(4) Planning of riparian vegetation buffer strip: Two profiles are separately set, based on the current situation of the landuse of both sides of the lake, and the simulation situation as woodland. An analysis was carried out to compare the riparian buffer width and location under these two profiles. In planning profile No. 1, integrating the simulating results from both time model and hydrology model, it shows that, riparian buffer width ranges from 9m to 74.5m. Among that, riparian buffer width mainly ranges from 17.1m to 42.4m, In planning profile No. 2, integrating the simulating results from both time model and hydrology model, it shows that, riparian buffer width ranges from 9m to 56.4m. Among that, riparian buffer width mainly ranges from 13.3m to 29.8m. On the foundation of such, two sets of riparian vegetation species and specific community parameters are chosen based on the site condition around the river and the frame of reference condition.

The innovations in the dissertation are as bellow:

(1) Based on previous study results made by other researchers, a framework and a set of procedure of the planning of riparian vegetation buffer strip are addressed, and the techniques and the methodology are established.

(2) Based on previous study results on establishment of reference condition, a procedure of the establishment of reference condition is discussed and a set of reference condition of riparian vegetation buffer strip for Shanghai is established.

(3) Automated watershed delineation from DEM is the key step when conducting any spatially distributed hydrological modelling. For rapidly urbanized flat area, it fails to provide a realistic drainage structures and watershed boundary from conventional DEM processing methods. A new method was proposed for watershed delineation in urbanized plain river network.

Key Words: Riparian buffer zone, Plain river network, Watershed, Basin, Non-point source pollution, Dishui Lake

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