VIỆN HÀN LÂM KHOA HỌC VÀ CÔNG NGHỆ VIỆT NAM

Tạp chí Khoa học và Công nghệ Biển

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GIẤY NHẬN BÀI

Tạp chí Khoa học và Công nghệ Biển xác nhận bài báo:

CLASSIFICATION OF HYDROGEOLOGICAL STRUCTURE ALONG THE RED RIVER IN HANOI AREA

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Xin trân trọng cảm ơn sự hợp tác của quý tác giả dành cho Tạp chí Khoa học và Công nghệ biển.

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TỔNG BIÊN TẬP

VIỆN HÀN LÂM KHOA HỌC VÀ CÔNG NGHỆ VIỆT NAM
TẠP CHÍ KHOA HỌC VÀ CÔNG NGHỆ BIỂN

GS. TS. TRẦN ĐỨC THẠNH

Classification of hydrogeological structure along the Red River in Hanoi area

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Abstract

Hanoi city has abundant groundwater, which is supplemented by the surface water (mainly Red River) all year round, and the extensive shallow aquifers, which are easily exploited by large diameter wells. In the Red River area with an open structure, there always exists some open hydrogeological windows; therefore, the groundwater has a strained hydraulic relationship with the Red River water system. Along the Red River from Ba Vi to the end of Phu Xuyen district, there are 9 regions with 3 types and 4 sub-types of different hydrogeological structure. In particular, the sub-type I-A of the groundwater has a tight hydraulic correlation with the Red River since the hydrogeological structure of the Red River bottom includes 3 aquifers: Holocene (qh), upper Pleistocene (qp_2), and lower Pleistocene (qp_1) that constructs a hydraulic system. The sub-type I-B is characterized by the hydrogeological structure at the Red River bottom including the aquitard in Vinh Phuc and 2 aquifers qp_2 and qp_1, which form a hydraulic system. The sub-type II-A is distinguished by the fact that the Red River crosses the aquifer qh; there are no aquitards between the aquifer qh and qp_2 so that can form a hydraulic system; the aquifer qp_1 is separated by the aquitard. The sub-type II-B is identified by the fact that the Red River crosses the aquifer qh; there is an aquitard between the aquifer qh and qp_2; there are no aquitards between the aquifer qp_2 and qp1 so that can create a hydraulic system. Type III has a solid existence of both aquifers and aquitards; thus, the hydraulic relationship between the Red River and the aquifers qp_2 versus qp_1 is inferior.

Keywords: hydrogeology, hydrogeological structure, groundwater, riverside

Introduction

Hanoi city is exploiting about one million cubic meters of groundwater per day for domestic and production purposes [1]. The large-scale exploitation works are mostly gathered inside the aquifer Pleistocene. Specifically, the long-term exploitation process with high volume and some expanded exploitation works system cause the lowering groundwater funnel to be reduced and its area to be increased. Due to the intensive exploitation in the South of the Red River, a gigantic lowering groundwater funnel over 300 km^2 has been formed. The groundwater, especially in the further areas from the Red River and the urban areas, has been much lowered because the location of the wells in some wells fields specifically and in the inner city generally has been designed and installed irrationally as their close distances, or the impropriety for the local hydrogeological condition. Besides, the wells located along the riverside such as Nam

Du, Luong Yen, Yen Phu, Cao Dinh, Thuong Cat, etc., are still operated and developed normally thanks to the direct supply from the Red River.

Therefore, the Red River has an important role in recharting to the groundwater. The recharting level is different along the river; it depends on certain factors, in which the hydrological structure is important factor. The result of the hydrological structure's division is vital to the efficient arrangement of the osmotic exploitation works in the riverside.

1. Methods

In order to determine and categorize the hydrogeological structure along the Red River in the study, the methods of indentification of the hydrogeological structure and determination of the spatial relationship between the Red River and the aquifers are used, as following:

1.1. Indentification of the hydrogeological structure

To identify the hydrogeological structure in the study, the authors proceed with the following steps:

- Analyzing the hydrogeological columnar section at the 50 boreholes along the Red River study area.
- Constructing hydrogeological 16 cross-sections perpendicular to the Red River and 1 hydrogeological cross-section along the flow direction of the study river.
- Examining the hydrogeological structure along the Red River concerning its direction of flow. In this step, the analyzers concentrate on clarifying the following information:

+ The existence of the aquifers and the aquitards
+ The distribution depth and the thickness of every aquifer and aquitard

According to the foundation of the above documents and procedures, with the results of building 16 hydrogeological cross-sections across the river and another along the river, by analyzing to determine the presence of the aquifers and the aquitards in the area, the authors divide the Red River into areas with different types and sub-types of the hydrogeological structure. In each field, the authors identify the depth of each aquifer and aquitard.

1.2. Determination of the spatial relationship between the Red River and the aquifers

To determine the spatial relationship between the Red River and the aquifers in the study based on the documents about hydrogeology and morphological characteristics of the Red River, the authors proceed with the following steps:

- Constructing the topographic cross-sections of the river bed at 95 cross-sections in the study.
- Overlapping the river bed topographic cross-sections onto 16 hydrogeological cross-sections.
- Analyzing the spatial relationship between the Red River and the aquifers in the study area. In this stage, the analyzers need to concentrate on clarifying the following information:

+ The aquifers and aquitards are distributed above the river bottom.

+ The cutting level of the river into the aquifers and aquitards includes the cutting width, cutting depth, cutting area, and the cutting proportion.
+ The existence of the aquifers and aquitard at the river bottom.

In order to clarify the hydrogeological structure and the relationship between the groundwater system and the Red River study area, the authors examine the hydrogeological stratigraphy at some boreholes along the river and also evaluate the investigation result of the cross-sections' measurement (95 river cross-sections were implemented by the Red River - Thai Binh Hydrological Survey Team in 2000 [5]). In addition, the authors construct 16 hydrogeological cross-sections across the river and another along the Red River from Ba Vi to Phu Xuyen. The fundamental of building 16 hydrogeological cross-sections across the Red River is based on the stratification outcome of 259 boreholes in the area were performed through research projects and projects on groundwater from 1993 to present, especially 50 studied boreholes at 16 cross-sections. The authors observe the morphology of the Red River bottom through the prospection and measurement results of 95 river cross-sections. The position diagram of 16 cross-sections across the Red River in the study area is shown in figure 1.

To build the hydrogeological cross-sections along the Red River from Ba Vi to Phu Xuyen, based on the stratification results at the riverside boreholes, especially at 16 cross-sections, the authors interpolate the layers' depth at the river bottom (the deepest position is on the cross-sections). The Red River bottom's morphology on the longitudinal cross-section is based on the river cross-section's measurement result at 95 cross-sections by observing the deepest position at the river bottom on each measuring line. The hydrogeological cross-section along the Red River in the study area is demonstrated in figure 2.

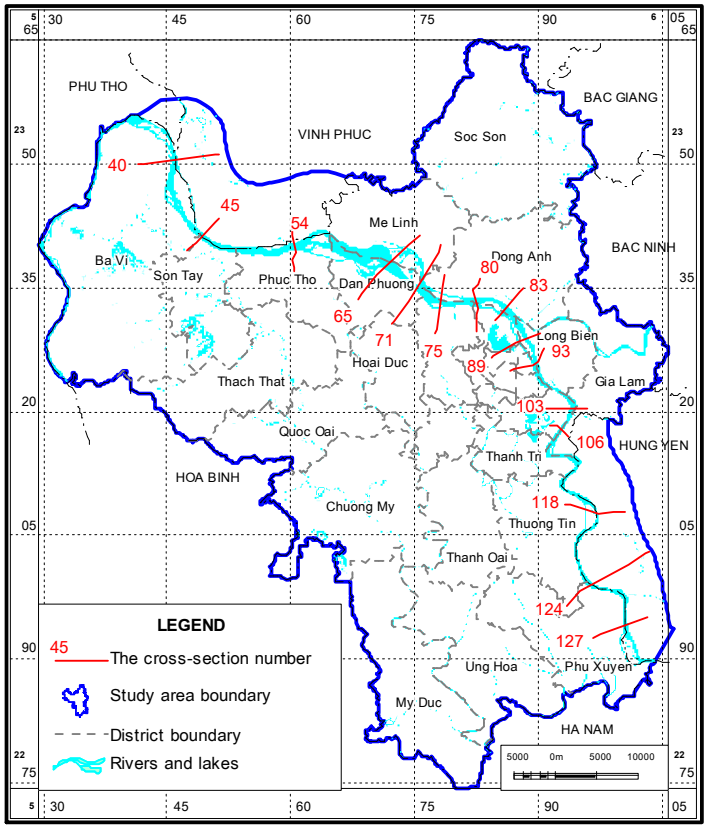

Figure 1. Location of hydrogeological cross-section

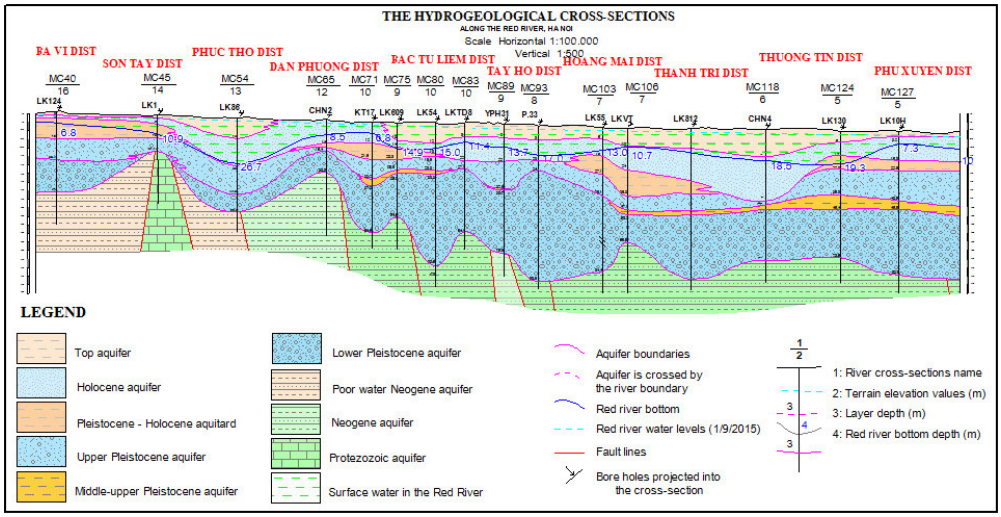

Figure 2. The hydrogeological cross-sections along the Red River in the study area

2. The hydrogeological regionalization results in the area along the Red River

The indentification results of 16 hydrogeological cross-sections across the river and a hydrogeological cross-section along the river in the study area gives the information that a full hydrogeological cross-section in the riverside area contains 3 aquifers and 3 aquitards in the quaternary sediments (see table 1).

Table 1. A full hydrogeological cross-section along the Red River

No	Layer Sign	Aquifers and Aquitards
1	Layer 1	Weak surface aquitard
2	Layer 2	Pore-aquifer in the Holocene sediments (qh)
3	Layer 3	Aquitard Pleistocene - Holocene
4	Layer 4	Pore-aquifer in the upper Pleistocene sediments (qp_2)
5	Layer 5	Aquitard in the middle- upper Pleistocene
6	Layer 6	Pore-aquifer in the lower Pleistocene sediments (qp_1)

The hydrogeological structure analysis leads to a comprehensive presence of the pore-aquifers in the quaternary sediments (qh, qp_2, qp_1) and the discontinuous distribution of the aquitards (layers 1, 3 and 5). The regions from Ba Vi to Son Tay, from Dan Phuong to Bac Tu Liem, from Hoang Mai to Thanh Tri, and Phu Xuyen display the full existence of the aquifers and aquitards (known as a closed structure). The areas Phuc Tho, Tay Ho, and Thuong Tin present the aquifers thoroughly; however, the aquitard Pleistocene - Holocene (layer 3) is completely eroded forming hydrogeological windows between 2 aquifers (known as an open structure). Particularly in the Thuong Tin area, although there is a hydrogeological window between aquifers qh and qp_2, however, between the aquifers qp_2 and qp_1, there exists an upper middle aquitard Pleistocene (layer 4) about 3m thick, which is distributed continuously. Therefore, the aquifer qp_1 could be considered as a closed structural area.

The analyzing result of a spatial relationship between the Red River and aquifers shows that the Red River bottom cuts into almost the aquifer qh but neither the aquifer qp_2 nor qp_1. In many places, there exists a hydrogeological window between the aquifer qh and qp_2, qp_2 and qp_1.

According to the hydrogeological structure analysis and the spatial relationship between the Red River and the aquifers examination, the authors divide the Red River into areas with different structural types and sub-types. In each area, we synthesize and analyze to clarify the following information:

+ The parameters showing the river bed's characteristics in each area are the river's width (minimum, maximum, average) and the river bottom's depth (minimum, maximum, average).

+ The parameters showing the hydrogeological structure in each area are the aquifers and aquitards' thickness (minimum, maximum, average), the depth of the river bottom cutting into layers (minimum, maximum, average), the width and the area cutting into the average layer, and the proportion (%) of cutting into layers regarding the cutting area and the cutting depth.

By collecting the analyzing results of the hydrogeological structure along the Red River from Ba Vi to Phu Xuyen, the authors divide the study area into 9 regions with 3 structure types (see figure 9) as follows:

- Type I: including 4 layers divided into 2 sub-types, which are sub-type I-A and I-B

+ Sub-type I-A: including 4 layers (1,2,4, and 6) distributed in 2 regions (area 2 and 5)

Area 2: From Le Loi, Son Tay town to Tho An, Dan Phuong district with a length of 11.4 km.

Area 5: From Phu Thuong, Tay Ho district to Thanh Luong, Hai Ba Trung district with a length of 13.7km

In both areas, the Red River cuts into layer 1 utterly and layer 2 partly. At that time, the layers at the river bottom are layers 2,4, and 6.

A typical hydrogeological cross-section of this sub-type is shown in figure 3.

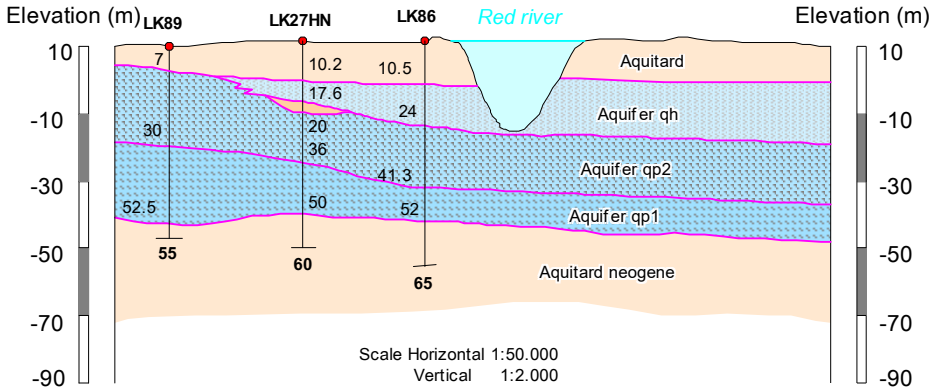

Figure 3. A hydrogeological cross-section of route 54 (Van Phuc – Phuc Tho)

+ Sub-type I-B: including 4 layers (2,3,4, and 6) distributed in 2 regions (area 1 and 3)

Area 1: From Phu Cuong, Ba Vi district to Le Loi, Son Tay town with a length of 17.6 km. In this area, the Red River cuts into layer 2 entirely and layer 3 partly. At that moment, the layers at the river bottom are: layer 3,4, and 6.

A typical hydrogeological cross-section across the Red River in this area is shown in figure 4.

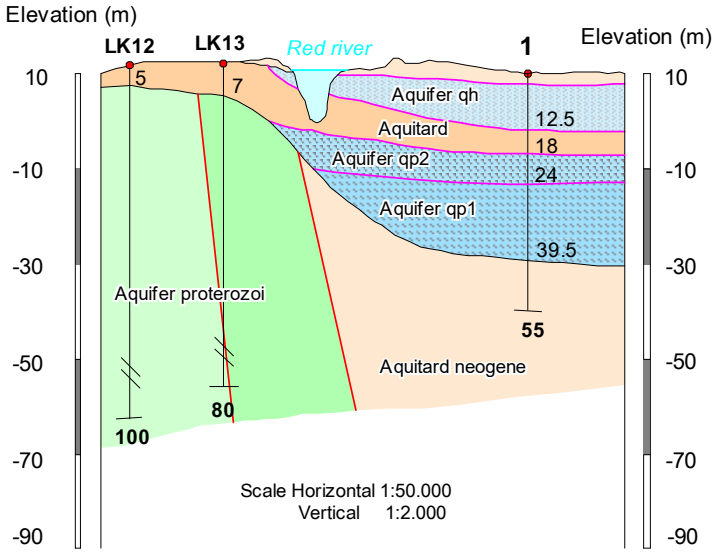

Figure 4. A hydrogeological cross-section of route 45 (Duong Lam – Son Tay)

Area 3: From Tho An to Lien Hong, Dan Phuong district with a length of 8.4 km. In this area, the Red River cuts into layer 2 partially; meanwhile, the layers at the river bottom are layers 2, 3,4, and 6.

A typical hydrogeological cross-section across the Red River in this area is shown in figure 5.

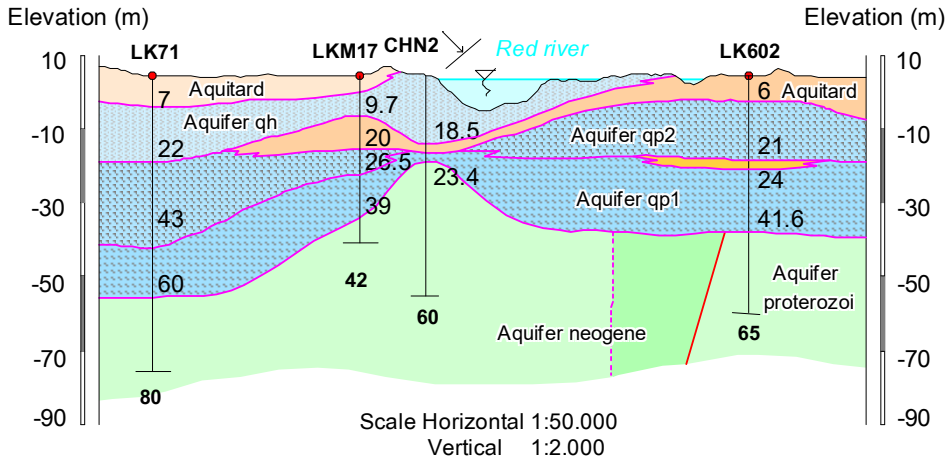

Figure 5. A hydrogeological cross-section of route 65 (Hong Ha – Dan Phuong)

- Type II: including 5 layers divided into 2 sub-types, which are sub-type II-A and II-B

+ Sub-type II-A: including 5 layers (1,2,4,5 and 6) distributed in 1 region (area 8)

Area 8: From Hong Van to Le Loi, Thuong Tin district with a length of 9.7 km. In this area, the Red River cuts into layer 1 completely and layer 2 partly. At the same time, the layers at the river bottom are layers 2,4,5 and 6.

A typical hydrogeological cross-section across the Red River in this area is shown in figure 6.

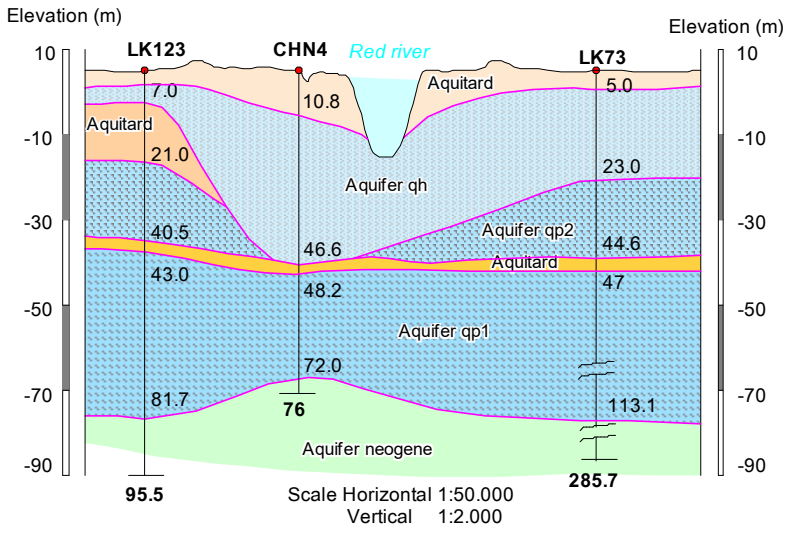

Figure 6. A hydrogeological cross-section of route 118 (Tu Nhien – Thuong Tin)

+ Sub-type II-B: including 5 layers (1,2,3,4 and 6) distributed in 1 region (area 6)

Area 6: From Thanh Luong, Hai Ba Trung district to Linh Nam, Hoang Mai district with a length of 9.7 km. In this area, the Red River cuts into layer 1 completely and layer 2 partly. At the same time, the layers at the river bottom are layers 2,3,4 and 6 (see figure 7).

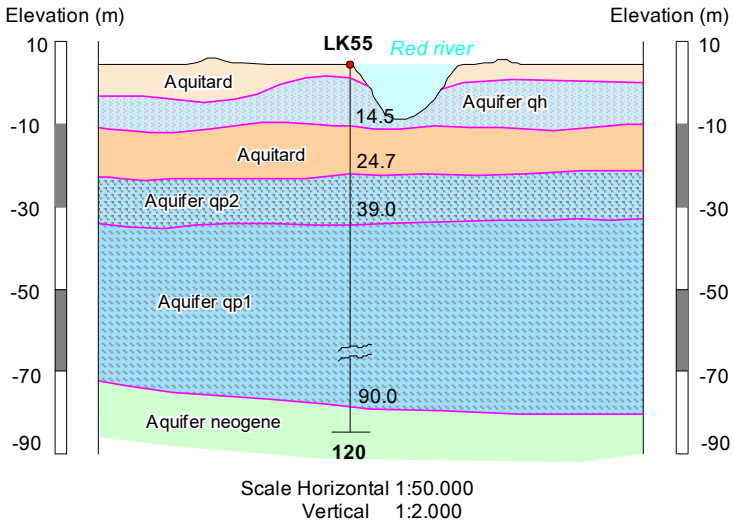

Figure 7. A hydrogeological cross-section of route 103 (Linh Nam – Hoang Mai)

- Type III: including 6 layers (1,2,3,4,5 and 6). This type is not divided into sub-types, and is distributed in 3 regions (area 4,7, and 9)
+ Area 4: From Lien Hong, Dan Phuong district to Phu Thuong, Tay Ho district with a length of 10.6 km.
+ Area 7: From Linh Nam, Hoang Mai district to Ninh So, Thuong Tin district with a length of 13.1 km.
+ Area 9: From Thong Nhat, Thuong Tin district to Quang Lang, Phu Xuyen district with a length of 18.2 km.

A typical hydrogeological cross-section across the Red River in this area is shown in figure 8.

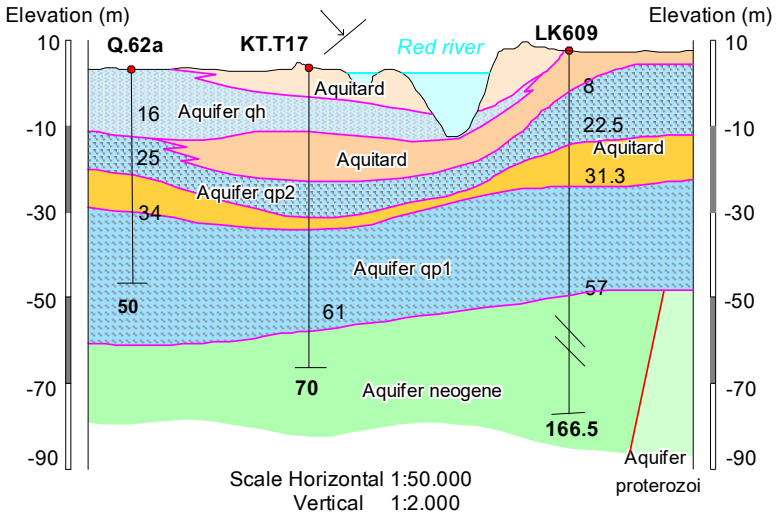

Figure 8. A hydrogeological cross-section of route 75 (Lien Mac - Bac Tu Liem)

In all 3 areas, the Red River cuts into layer 1 totally and layer 2 partly while the layers at the river bottom are layers 2,3,4,5 and 6.

Table 2 demonstrates the regionalization result of the Red River's structure with different types and sub-types.

Table 2. Synthesis result of the Red River's structural regionalization in the study area

No	**Type**	**Sub Type**	**Bottom-river layers relationship area**					**Layers presence**
			2;4;6	**3;4;6**	**2;4;5;6**	**2;3;4;6**	**2;3;4;5;6**	
1	I (4 layers)	I-A	Area 2					Layers 1,2,4,6
			Area 5					
		I-B		Area 1				Layers 2,3,4,6
						Area 3		
2	II (5 layers)	II-A			Area 8			Layers 1,2,4,5,6
		II-B				Area 6		Layers 1,2,3,4,6
3	III (6 layers)						Area 4	Layers 1,2,3,4,5,6

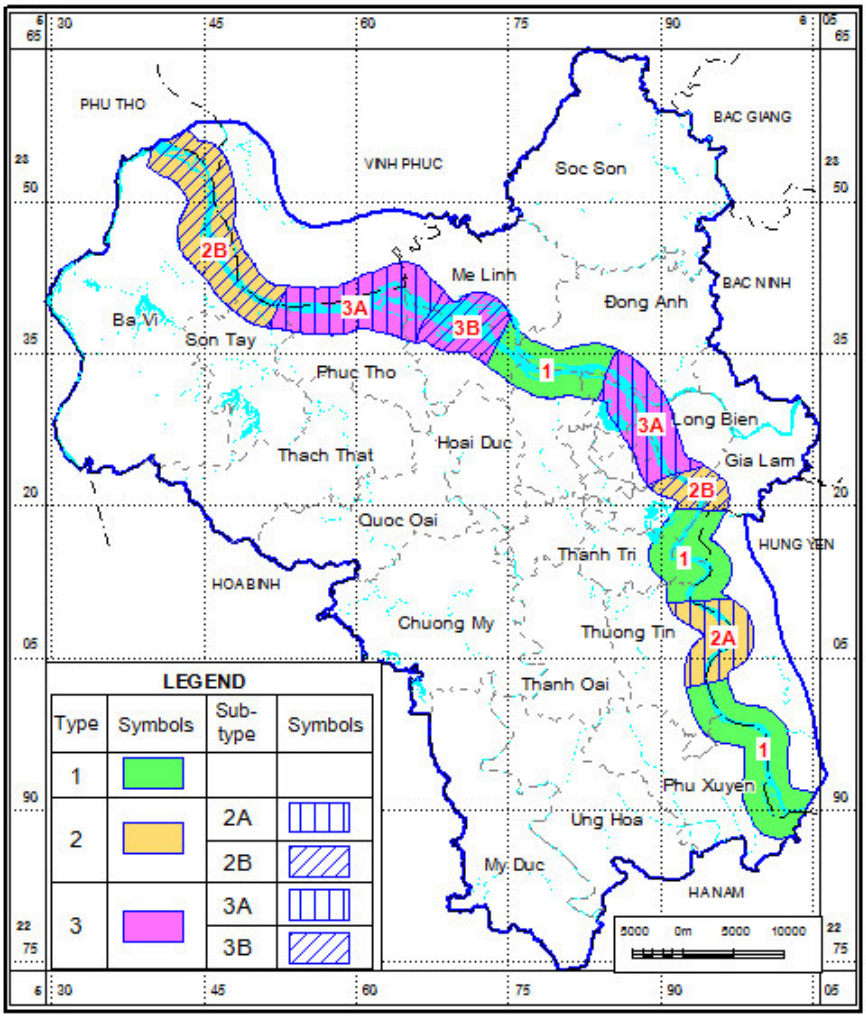

Figure 9. The structural regionalization of the Red River in the study area

The morphological characteristics of the river bed and the layers in each area is synthesized in detail in Table 3.

Table 3: Summary of the Red River's characteristic and hydrogeological structure in the study area

No	Type		Area	Length (km)	Red river bed characteristics						Hydrogeological structure										
					Width (m)			Bottom river depth (m)			Layer	Layers thickness (m)			Cutting into layers depth (m)			Cutting width (m)	Cutting area (m2)	Cutting proportion (%)	
					min	max	avg	min	max	avg		min	max	avg	min	max	avg			Area	Layers thickness
1	I (4 layers)	I-A	Area 2	11,4	320	1.900	1.110	10,9	26,7	18,8	Layer 2	9	16	12,5	9	14,7	11,9	850	10.073	73%	95%
											Layer 4	10,5	16,8	13,7							
											Layer 6	8,5	10,4	9,5							
			Area 5	13,7	500	1.200	850	11,4	17	14,2	Layer 2	6	14	10,0	3	9	6,0	325	1.950	23%	60%
											Layer 4	4	16,7	10,4							
											Layer 6	37,1	66,9	52,0							
		I-B	Area 1	17,6	400	1.780	1.090	6,8	10,9	8,9	Layer 3	8	12	10	2,8	5,9	4,4	220	957	9%	44%
											Layer 4	8,1	12,4	10,3							
											Layer 6	0	18,6	9,3							
			Area 3	8,4	900	3.100	2.000	8,5	16,5	12,5	Layer 2	12	19	15,5	6	16,5	11,3	1100	12.375	40%	73%
											Layer 3	2,4	8	5,2							
											Layer 4	2	10,5	6,3							
											Layer 6	14,4	29,5	22,0							
2	II (5 layers)	II-A	Area 8	9,7	400	600	500	17	21,5	19,3	Layer 2	15,5	26	20,8	2,5	8,5	5,5	330	1.815	17%	27%
											Layer 4	2,4	10,5	6,5							
											Layer 5	2,6	6	4,3							
											Layer 6	29,3	33	31,2							
		II-B	Area 6	9,7	300	900	600	13	17	15,0	Layer 2	10	12	11,0	7	9	8,0	350	2.800	42%	73%
											Layer 3	5	11,1	8,1							
											Layer 4	9	12	10,5							

No	Type		Area	Length (km)	Red river bed characteristics						Hydrogeological structure										
					Width (m)			Bottom river depth (m)			Layer	Layers thickness (m)			Cutting into layers depth (m)			Cutting width (m)	Cutting area (m2)	Cutting proportion (%)	
					min	max	avg	min	max	avg		min	max	avg	min	max	avg			Area	Layers thickness
											Layer 6	45,3	56	50,7							
3	III (6 layer)		Area 4	10,6	900	1.400	1.150	6,8	15	10,9	Layer 2	4	12	8,0	3	6,8	4,9	420	2.058	22%	61%
											Layer 3	1,9	9,9	5,9							
											Layer 4	6,1	11,3	8,7							
											Layer 5	2,1	4,1	3,1							
											Layer 6	25,6	53,6	39,6							
			Area 7	13,1	400	900	650	10,7	17	13,9	Layer 2	10	23,5	16,8	0,7	7	3,9	95	366	3%	23%
											Layer 3	11,1	15,3	13,2							
											Layer 4	7,8	12	9,9							
											Layer 5	2	3,1	2,6							
											Layer 6	16,3	36,5	26,4							
			Area 9	18,2	400	600	500	7,3	21,5	14,4	Layer 2	8	13,6	10,8	4,1	8	6,1	300	1.815	34%	56%
											Layer 3	6,1	8	7,1							
											Layer 4	14,8	17,6	16,2							
											Layer 5	5	8,6	6,8							
											Layer 6	28,2	38,4	33,3							

Conclusion

Hanoi city is favored by the nature to receive abundant water resource; besides, the groundwater has a solid hydraulic relationship with the Red River, which provide a frequent and stable supply to the groundwater system. The regionalization result of the hydrogeological structure in the Red River Hanoi has a significant meaning in orienting riverside infiltration works construction, as well as determines the Red River's role in supplementing the groundwater in the quaternary sediments.

The results of this study can be use for boundary classification of Red River in groundwater flow model to assess and ascertain the river's role to the aquifers in the quaternary sediments in Hanoi.

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Phân loại cấu trúc địa chất thủy văn ven sông Hồng khu vực Hà Nội

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[4]Viện Địa chất & Địa vật lý biển, VAST

Tóm tắt:

Thành phố Hà Nội có trữ lượng nước dưới đất (NDĐ) phong phú và được nước mặt (chủ yếu là sông Hồng) bổ cập quanh năm, các tầng chứa nước (TCN) nằm nông và phân bố rộng rãi, khai thác dễ dàng và thuận tiện bằng các giếng khoan đường kính lớn. Ở vùng ven sông Hồng có cấu trúc hở, liên tục tồn tại các cửa sổ địa chất thủy văn nên nước dưới đất có quan hệ thủy lực chặt chẽ với nước sông Hồng [**Error! Reference source not found.**]. Dọc theo sông Hồng từ Ba Vì đến hết huyện Phú Xuyên được phân chia thành 9 vùng với 3 kiểu, 4 phụ kiểu cấu trúc địa chất thủy văn (ĐCTV) khác nhau. Trong đó, phụ kiểu I-A nước dưới đất có quan hệ thủy lực chặt chẽ với sông Hồng, đặc trưng bởi cấu trúc ĐCTV đáy sông Hồng gồm 3 tầng chứa nước Holocen (qh), Pleistocen trên (qp_2) và Pleistocen dưới (qp_1) tạo thành một hệ thống thủy lực. Phụ kiểu I-B đặc trưng bởi cấu trúc ĐCTV dưới đáy sông Hồng gồm lớp cách nước hệ tầng Vĩnh Phúc và 2 tầng chứa nước qp_2 và TCN qp_1 tạo thành một hệ thống thủy lực. Phụ kiểu II-A đặc trưng bởi sông Hồng cắt vào tầng chứa nước qh, giữa tầng chứa nước qh và TCN qp_2 không có lớp cách nước nên tạo thành một hệ thống thủy lực, tầng chứa nước qp_1 được ngăn cách bởi lớp cách nước. Phụ kiểu II-B đặc trưng bởi sông Hồng cắt vào tầng chứa nước qh, giữa tầng chứa nước qh và TCN qp_2 tồn tại lớp cách nước, giữa tầng chứa nước qp_2 và TCN qp_1 không có lớp cách nước nên tạo thành một hệ thống thủy lực. Kiểu III đặc trưng bởi sự có mặt đầy đủ các tầng chứa nước và các lớp cách nước ngăn cách giữa các tầng nên mức độ quan hệ thủy lực giữa sông Hồng với tầng chứa nước qp_2 và TCN qp_1 kém hơn.

Từ khoá: Địa chất thủy văn, cấu trúc địa chất thủy văn, nước dưới đất, vùng ven sông.