

The Architectural-landscape Organization of Urban Areas in Flooded and Waterlogged Territories (Prospects of Astana City)

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Abstract Urban construction in flooded and waterlogged areas has a centuries-old history. Of the repeatedly used water treatment systems, the most effective turned out to be a water-channel system that allows groundwater or atmospheric water to be diverted to the water body closest to the development area or located inside it. In most cases, the channels allow solving some of the problems in the field of passenger and freight transport, complementing or duplicating overland transportation by waterways. The best examples from world practice show the possibility of organizing highly comfortable buildings on sites with both road and water-channel communication. The Astana city was historically formed on the right bank of the Yesil' River, where geological and hydrological conditions did not have dominant factors in the form of flooding and waterlogging due to precipitation and groundwater. At the end of the last century, the intensive growth of the city, which became the capital of Kazakhstan, led to the urban development of the left bank of the Yesil' River. In this area (especially in the southwestern part), there are many water bodies and a very high groundwater level, which both independently and in combination with flood waters and precipitation periodically forms flooding of vast areas. Sporadically carried out measures to drain

overflowing water bodies, the construction of wells and drainage outlets only partially solved the annually escalating problem. In these circumstances, it seems advisable to use the experience of the United States, where a developed canal system has been formed in the Miami city. These channels eliminated the danger of flooding of the territory, provided convenient water transport links to various areas, formed commercially attractive areas with private access for individual development, as well as comfortable recreational areas. The proposed water-channel system for the city of Astana has a relatively complex spiral-arc configuration. This is proposed due to terrain peculiarities of the landscaped area and the location of existing water bodies. This system is linked to the riverbed of the Yesil' River and ensures the flow of excess water into it downstream of the river outside the city limits. As a result, many sites with convenient street-road and water-channel connections to the existing urban area become available for active urban development.

Keywords An Urban Development, Architectural Organization of Landscapes, Flooded Areas, Wetlands, A Water Transport, An Integrated Transport

1. Introduction

Ensuring the successful functioning and sustainable development of Astana city determines constant attention to adequate compensation for several problems of natural and anthropogenic origin. Among them are high groundwater levels (including those with access to the surface), flooded and waterlogged areas.

Flooding of the city territory creates difficulties during construction, and is also the reason for the deterioration of the environmental situation in the Astana city. In addition, the problems of foundation construction in conditions of seasonal freezing of soils characterized by frost heaving are relevant. Particular attention is paid to the behavior of the soil in the spring, when snow melts or rains start, since at this time the soil receives a large amount of moisture, thereby may not have the best effect on the performance of foundations.

In addition, groundwater (due to its chemical composition) causes corrosion of metal and concrete structures. The storm sewer system available in the city does not fully solve the existing problem. Some territories are still periodically flooded by both groundwater and flood waters. Protection from flooding of the Astana city is the most important task for the further development of the city. The long-term practice of diverting surface water using storm sewers has proved to be insufficiently effective. There is a need for new solutions, for new ways to eliminate the existing problem.

As the experience of foreign countries shows, the development of swampy and flooded areas (similar to the territory of the Astana city) is carried out in many cities around the world. Cities in such territories have been successfully existing for centuries. The solution to the problems in such cities was the introduction of canal systems. This technology has been practiced for centuries and remains relevant. The presence of channels allows solving some of the problems in the passenger and freight transport system.

In general, the list of authors who have studied the design features of cities and districts in flooded areas is quite large. However, it is worth noting that this problem is new in Kazakhstan's science and practice, since the natural and climatic features of Kazakhstan, in principle, are not predisposed to the problem that has arisen, in this case in the Astana city. And this phenomenon has not been studied in depth before in Kazakhstan.

The problem of flooding in cities is constantly in the field of attention of specialists from various countries. The problem was reviewed by C.P. Konrad [1] and A. Kocornik-Mina, Th.K.J. McDermott, G. Michaels, F. Rauch [2]. The resilience of cities to floods, using the example of Naples, was studied by C. Vitale, S. Meijerink, and F.D. Moccia [3]. The consequences of the 2021 flood in Central Europe were summarized by F. Lehmkuhl, H. Schüttrumpf, J. Schwarzbauer, C. Brüll, M. Dietze, P. Letmathe, C. Völker and H. Hollert [4]. L. Junger, S.

Hohensinner, K. Schroll, K. Wagner and W. Seher examined the features of land use in the zone of periodic flooding in the example of Austria [5]. The specifics of rain flooding were analyzed by Zou, L., Wang, Z., Lu, Q., Wu, S., Chen, L., Qin, Z [6].

In this context, it is important to study the impact of floods on road infrastructure (T. Papilloud, V. Rählisberger, S. Loreti, M. Keiler [7]). The progress achieved in flood research was summarized by C. Agonafir, T. Lakhankar, R. Khanbilvardi, N. Krakauer, D. Radell and N. Devineni [8].

A number of studies are devoted to the assessment and management of flood risks, for example, I. Escuder-Bueno, J.T. Castillo-Rodríguez, S. Zechner, C. Jöbstl, S. Perales-Momparler, G. Petaccia [9], F. Klijn, P. Samuels, A.V.Os [10]. Measures to protect territories in Canada and Slovakia from floods based on risk assessment were considered in their works by E.A. Bogdan, M.A. Beckie, K.J. Caine [11] and L. Soló [12]. This issue is important in the context of climate change and this was emphasized by D.-H. Kang, D.-H. Nam, S.-J. Jeung, B.S. Kim [13].

Various aspects of the problem of swamping of territories are considered in the works of S. Alikhani, P. Nummi, A. Ojala [14], F. Liu, X. Liu, T. Xu, G. Yang, Y. Zhao [15], R. Quan, M. Liu, M. Lu, L. Zhang, J. Wang, S. Xu [16]. An interesting feature of the problem is the dependence of the possibility of waterlogging on the structure of the urban landscape (J. Wu, W. Sha, P. Zhang, Z. Wang [17]).

In the context of the problem considered in the article, it is of interest to study the features of urban passenger and freight water transport: as a system (H. Cheemakurthy, M. Tanko, K. Garme [18]), in the field of sustainable development (Z. Aziz, I. Ray, S. Paul [19], B.S. Hoyle [20]) and logistics (E. Divieso, O. Fontes Lima Junior, H.C. de Oliveira [21], P. Iamtrakul, I. Raungratanaamporn, J. Klaylee [22], M. Janjevic, A.B. Ndiaye [23], D.M. Utomo, I. Mateo-Babiano [24], R. Vergnani and others [25]). The partial interaction of road and water transport systems was considered using the example of Miami and Dubai by S.E. Salimbayeva [26, 27].

These studies allow us to assess the problematic situation in the Astana city and propose an innovative approach to solving it. To study the current situation in the Astana city and identify possible ways to solve the existing problems of flooded territories, a widespread general scientific method of selecting analogues, analyzing design and implemented measures, and choosing solutions adequate to the current situation was used. There are many methods of protection from groundwater, which include drainage systems, lowering screens, and many other options. Drainage systems with wells and drainage pipes are silted up and require periodic technologically complex cleaning. Water-reducing screens are effective only for small areas. However, if there is a river, lake or sea next to the wetland, canals are the most effective solution for large areas.

Cities of Amsterdam, Bangkok, Sankt-Petersburg are vivid examples of the fact that the channel system method has been working for centuries. However, in European cities, the road transport infrastructure is organized along embankments, essentially duplicating canals. Accordingly, for example, residential complexes do not have private access to waterways. In Bangkok, the canals have independent transport significance. They were originally laid with the aim of creating new transport routes, and during operation, they gradually began to build up along the shores. However, at present time, most of the canals that cut through the city have been filled in for the construction of highways.

Built in 1928, the Ala Wai Canal in Honolulu eliminated swamps and regulated the flow of several streams, redirecting them directly to the ocean. This made it possible to obtain drained territories for promising urban development, which became a major tourist center of Waikiki. The canal itself is often used by locals and tourists for convenient rowing boats.

In several promising areas of Dubai for urban development at the end of the last century, the groundwater level rose significantly due to various reasons. The problem was gradually solved by the construction of residential and public complexes with isolated channel-type reservoirs, providing additional opportunities for movement within these complexes (the Jumeirah Al Qasr, the Emirates Hills and the Jumeirah Islands districts, for example –Figure 1). The problem was completely solved in the 2010s by the construction of the Dubai Water Canal.

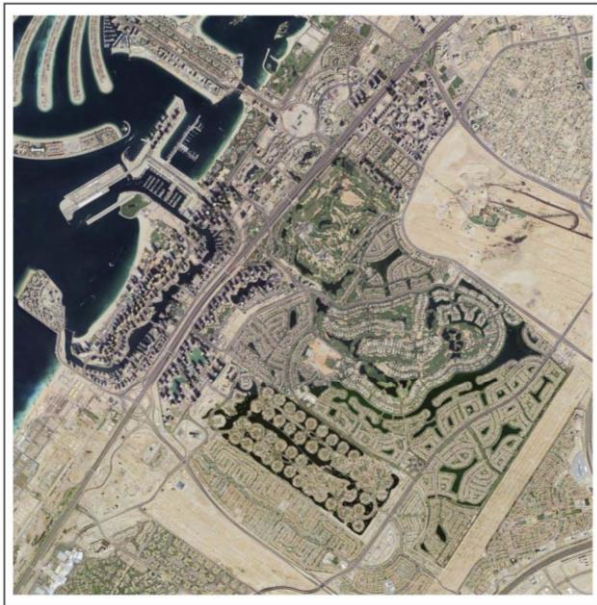


Figure 1. The Emirates Hills and the Jumeirah Islands districts, the Dubai [30].

The Miami city with adjacent settlements forms a large agglomeration. Most of the areas are located in swampy and often flooded areas. At the beginning of the last

century, the construction of several canals began to solve the problems of optimal urban development of the territory (Figure 2). This solution made it possible to create a highly comfortable two-part independent transport infrastructure with street and water access to the main points of urban gravity. Moreover, in most areas, using the “waterways” system, unlike the street and road network, it is much faster to get to the city center or to the city beaches. At the same time, the problem of restricting unauthorized pedestrian access to private land ownership zones was solved, since it practically eliminated the need to erect fences on the outer boundaries of individual residential buildings. The building has acquired a promising appearance from the point of view of investment attractiveness. And every plot with mansions or multistorey complexes has access to waterways. In addition, the condition of the water pool allows you to organize private or group water activities directly near the residential area.



Figure 2. The Imperial Point district, the Miami, FL [31].

The purpose of the presented work is a proposal to improve the territory of the Nura district in terms of the prospects for its active urban development. This area has a high groundwater level and is prone to periodic seasonal flooding. The formation of a channel system allows you to regulate a chaotic natural drain. At the same time, this will improve the system of passenger and freight traffic between this area and the central part of the Astana city.

2. Research Methods

The methodology of the research is based on the widespread method of collecting factual material, analyzing the current situation, identifying the main problems, determining the way to solve them, taking into

account the world practice of solving such problems. In accordance with this, extensive material on the development of the city of Astana was collected and analyzed. The problems associated with seasonal flooding of territories that limit the active urban development of vast areas within the city boundaries have been identified. Attention was also drawn to the insufficient level of development of transport infrastructure. This leads to a significant slowdown in traffic flow, corresponding losses in the field of logistics and significant pollution of the air basin. Based on the study of the world experience of building in flooded areas and the formation of a combined water-channel and street-road transport network, a proposal that corresponds to the specifics of the city of Astana has been formulated.

3. Research Area

The capital of the Republic of Kazakhstan, the Astana city, is located on a steppe plain. The relief of the territory occupied by him is represented by the low floodplain terraces of the Yesil' River. The modern territory of the city is located inside a closed circular bypass road with plots extending beyond its boundaries, and with separate, isolated plots setting aside for the city's Cemetery and the Pantheon. In conditions of intensive urban development and population growth, the need for energy and water resources, transportation, and housing and communal services is objectively increasing. The main architectural and urban planning idea of the new Master Plan is to form an expressive image of the Astana city, as a comfortable city for life, one of the centers of cooperation and interaction between the countries of the Eurasian continent [28]. One of the actively developing parts of the city is the Nura district, which has not yet become an area of active urban development due to difficult hydrological conditions (Figure 3).

The modern set of water bodies in the Astana city consists of permanent, temporary watercourses and reservoirs of natural and artificial origin: Yesil', Nura, Karasu, Kozykosh, Sarkyrama rivers; Akbulak, Sarybulak streams; Maybalyk, Buzykty, Kushagyn, Taldykol' lakes; a group of five Small Taldykol's lakes; the Nura-Yesil' canal; the Astana's reservoir; drainage reservoirs-rainwater. Spread of water bodies over the territory of the city of Astana is shown in Figure 4. The total area of water areas within the city is 5808.6 hectares (with the prospect of reducing to 5512.2 hectares by 2035 [29]).

Groundwater plays an essential role. According to the level of groundwater occurrence in the Astana city, there are three types of territories: flooded area (75% of the built-up area of the city) with a groundwater level up to two meters from the ground surface; swampy area (10% of the flooded area); an area with a groundwater level of more than 2.0 m from the surface of the earth. Groundwater formation occurs mainly due to filtration of winter-spring

precipitation and partly due to infiltration of surface runoff of temporary watercourses. The aquifer of alluvial lower Quaternary-modern deposits is widespread in the valley of the Yesil' River. Moreover, on the left bank, it occupies the entire interfluvium of the Nura River and the Yesil' River. On the right bank, it is much less widespread and is observed along the bank of the Yesil' River in a strip 0.5-1.0 km wide. In the spring flood, there is a sharp rise in the surface water level, which leads to a rise in the groundwater level due to their entry into the alluvial aquifer. At the same time, the adjacent low-lying areas are flooded. The main collectors of groundwater in the city are: the aquifer in the undifferentiated alluvial sand-gravel quaternary sediments of the valley of the Yesil' River; and the aquifer fracture zone of Ordovician rocks.

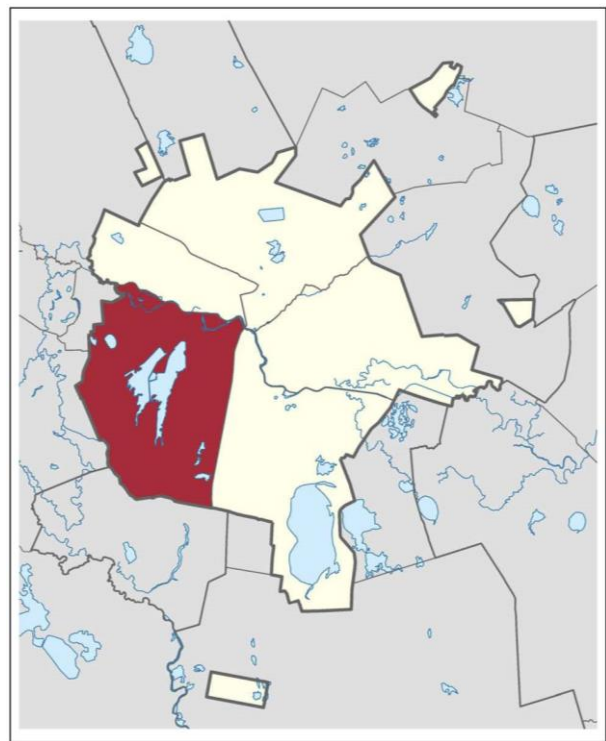


Figure 3. The Nura district in the structure of the Astana city [32].

A distinctive feature of the hydrography of the city is the relatively large number of temporary watercourses operating only during the periods of spring snowmelt. River runoff is spent mainly on evaporation, saturation of alluvial deposits and partially replenishment of lake reserves. By origin, the lakes are hollow. The depth of the lakes ranges from 1.0 to 2.0-3.0 meters. On the territory of the city, the hydrological situation is determined by the water regime of the Yesil' River, which largely depends on snowmelt and connection with the Nura River, from which underground (channel) waters bifurcate into the floodplain of the Yesil' River.

The Yesil' River flows into the city in its eastern part, flows through all districts and through the city center, flows out in the northwestern part. The length of the river

within the administrative boundaries is 59158 m. The average depth is 3.0 m. Within the city, the river is characterized by low water content with sections of an artificially formed riverbed. The flow in which during the year, with the exception of the spring flood period, is supported by releases from the Astana reservoir. A retaining waterworks has been built in the western district of the city, which maintains the width of the river (from 80.0 to 150.0 m) and its depth necessary for the recreation of citizens within the city.

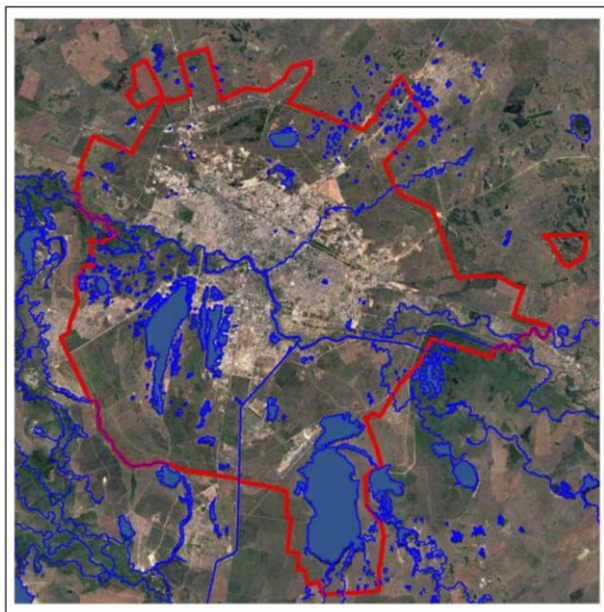


Figure 4. The totality of water bodies on the territory of the city of Astana (figure based on the source materials of Google Earth Pro, 2024).

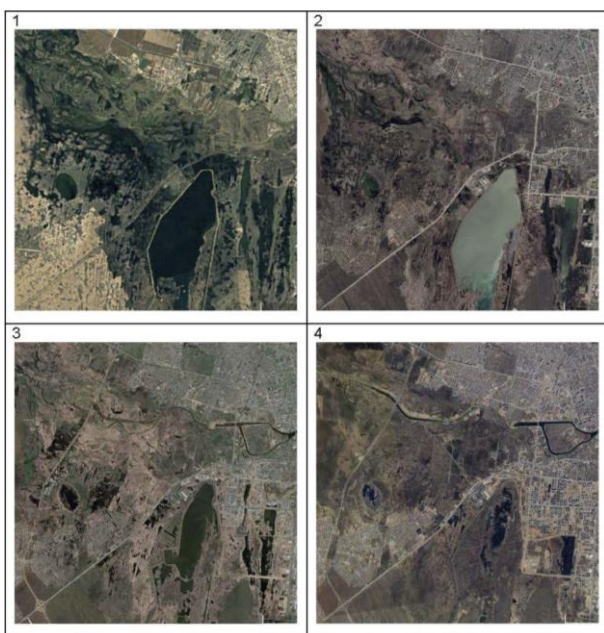


Figure 5. Water bodies in the Nura district, the Astana city [33]: 1 – the situation in 2004; 2 – the situation in 2016; 3 – the situation in 2020; 4 – the situation in 2023.

The Nura River is of significant importance. Since in the area of convergence with the Yesil' River, water flows over the surface (in high water) and along ancient channels (in other periods of the year) into the floodplain of the Yesil' River. Along the aquifer of sandy deposits under loams, the pressure waters of the Nura River are discharged and the lakes are recharged.

Until 2018, the Taldykol' lake was used as a reservoir of conditionally treated domestic and industrial wastewater of the city. Upon completion of the reconstruction of sewage treatment plants, the treated wastewater was redirected to the Yesil' River. The area surrounding the lake is a lake-alluvial plain with numerous lake-marsh depressions. Currently, due to the influence of the accumulator, the lowered parts of the relief are swamped. A natural factor causing an increase in the groundwater level in the floodplain of the Yesil River, where the Taldykol reservoir is located, is the inflow (bifurcation) of groundwater and surface waters from the Nura River into the Yesil River, since the absolute relief mark on the edge of the Nura River is 10-14 m above the water level of the Yesil River. The change in the situation with the size and location of water bodies in the Nura district in 2004-2023 is shown in Figure 5. However, currently, due to the large amount of precipitation in the winter of 2023-2024, previously drained water bodies are again filled with surface and groundwater (as it was shown in Figure 4).

In general, the hydrographic and hydrological conditions of the Astana city and especially the Nura district are very complex and require a radically balanced approach when carrying out urban planning and landscaping. For example, plans for the development of the city involve various measures to lower the groundwater level in an area of about twenty thousand hectares. It is supposed to protect more than twenty-five thousand hectares from flooding. The length of the protective structures will be 64.1 km.

The Draft Master Plan [29] provides for lowering the level and organizing groundwater monitoring by consistently performing the following works: conducting a hydrogeological study of the aquifer sands of the Nura-Yesil' interfluvium by drilling engineering and geological wells with experimental pumping; drilling of water-reducing wells; sinking of drainage trenches into the cross of the channel of aquifers and sinking of drainage trenches along ancient channels; drilling of monitoring wells. The pumped water will be used to irrigate green spaces and divert into the Yesil' River.

Constant pumping of water, periodic technologically complex cleaning of silted drainage pipes – all these measures do not solve the complex of engineering-geological and hydrological problems of the territory under consideration.

4. Discussion

The main problem with lakes formed by groundwater is

that if you fill these lakes with soil, then the level of pressure groundwater on the entire left bank will begin to rise, which will lead to flooding of an even larger territory. Based on the analysis of the current situation in the Astana's Nura district, it seems advisable to build a canal with branches that ensure the interception of water from all existing reservoirs and streams formed by groundwater coming to the surface, as well as atmospheric precipitation. The arc-shaped configuration of the proposed channel is due to the existing relief, while at the same time having a certain aesthetic significance. The rectilinear configuration of the channel did not allow for a solution to the problem due to the peculiarities of the relief and the mutual location of numerous reservoirs of various sizes. Graphical analysis has shown that the rectilinear configuration of the channel does not adequately solve the problem, since the length of the rectilinear channels will be one and a half to two times longer. In addition, a much larger amount of work will be required to change the existing terrain.

The canal will provide a regulated flow of surface atmospheric and groundwater into the lake area on the west side of the city. Most of the atmospheric and groundwater from the surrounding areas flowed into these lakes. These lakes have a natural flow into the Yesil River. Accordingly, the water balance of the existing lake and river system in the city and suburbs will not be disrupted. The proposed canal in the Nura district in the context of water bodies in the territory of Astana is shown in Figure 6.

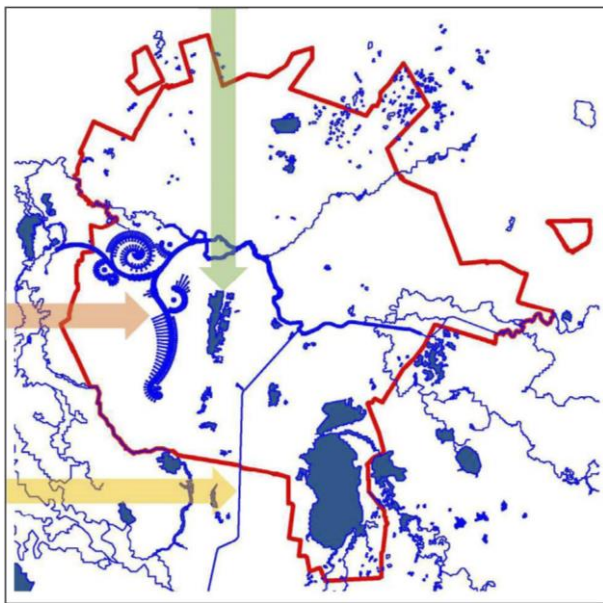


Figure 6. The proposed Canal in the Nura district (the orange arrow), the existing Nura-Yesil' canal (the yellow arrow), preserved Small Taldykol's Lakes (the green arrow) in the context of water bodies on the territory of the Astana city.

The lakes group Small Taldykol', located on the east side of the Nura district, is not part of the proposed Canal system. Based on public discussions, relevant decisions of the Leadership of the Republic of Kazakhstan and the

Administration of the Astana city, the group of lakes Small Taldykol' is preserved within its natural boundaries. To exclude the possibility of flooding of the territory, conservation of biodiversity, and preservation of an ecologically significant landscape, the total area of the open water surface of the Small Taldykol Lakes is maintained at 130 hectares. A park area is being formed around this water body.

The Nura-Yesil canal, located in the southeastern part of the city, can also be included in the system of urban personal, public and freight transport. The canal was built in 1971 and was designed to transfer part of the flow of the Nura River into the Yesil River in order to supply Astana with industrial water and irrigate the lands adjacent to the canal. The head of the canal is located on the right bank of the Nura, 20 km from the southwestern outskirts of Astana. The mouth of the canal is located on the left bank of the Yesil River in the southeastern part of Astana. Within the city limits, it has a length of about ten kilometers. However, to do this, it will be necessary to redo bridges at intersections with highways (there are five such places). The height of the existing bridges practically does not allow sailing under them, even on light-engine boats.

The main bad of the canal adjoins the riverbed of the Yesil' River in the dam area. This will make it possible to organize the movement of individual and public passenger and cargo water transport through the entire city, significantly reducing the traffic load on the Astana's street-road network (Figure 7). The Astana City Development Project [28, 29] provides for an increase in the length of navigable sections on rivers from the current 6.0 km to 19.5 km. The proposed channel will significantly improve this parameter. It is possible to organize competitions in water-motor sports and rowing both in individual sections and across the City. The proposed Canal with branches may become part of a project to increase the capacity of the riverbed and strengthen the banks with protective dams. A significant improvement will be provided by straightening the riverbed. This will dramatically reduce the risk of flooding of territories.



Figure 7. The prospect of connecting the existing riverbed of the Yesil River (dark blue) and the proposed new channel (light blue) is in order to ensure the functioning of water transport in the Astana city (the drawing based on the Google Earth Pro source materials, 2024).

Territories that are no longer flooded become suitable for active urban development – the construction of various residential and public buildings, the formation of park and recreational areas for active and passive recreation. The corresponding new street and road network of the Nura district are being formed in conjunction with the existing street and road network of adjacent districts of the Astana city, being its continuation and development (Figure 8).

The layout of the territory and development along the proposed canal (total length 29.0 km) implies ensuring free access of residents to individual and public automobile and water transport by combining dead-end arrivals (width 12.0 m) with turning circles (diameter 36.0 m) running from the main street (width 45.0 m) and dead-end water branches (width 38.0 m) with U-turns circles (diameter 60.0 m) connected to the main channel (width 60.0 – 80.0 m). Depending on the location, the branches from the canal and the main streets have different lengths (from 100.0 to 1100.0 m). The total number of branches is 231.

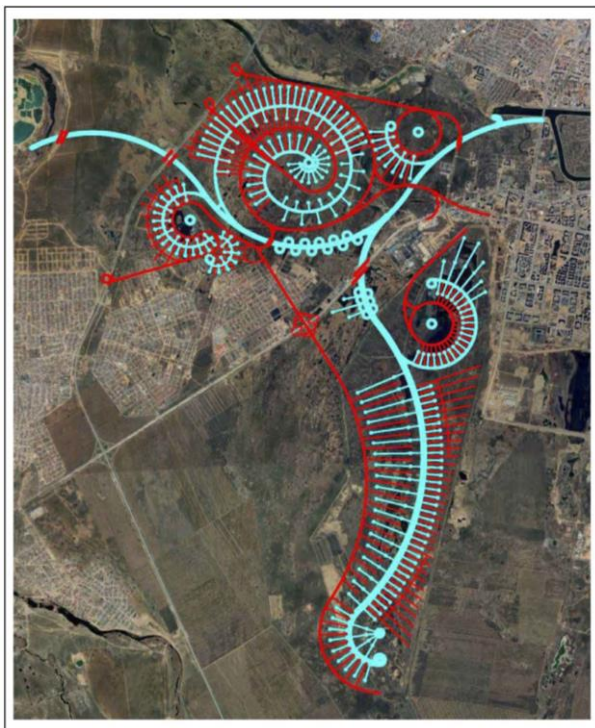


Figure 8. The proposed new channel (light blue) and new highways (red) are in the context of the existing Astana city road network (the drawing based on the Google Earth Pro source materials, 2024).

The banks of the canal and branches are made of gabions. This design allows you to preserve the natural soil conditions and unhindered filtration of groundwater into the channel. Taking into account the current urban planning regulations, the building line is located at a distance of 35.0 m or more from the banks of the canal and branches.

The dimensions of water branches from the main channel are taken from the standpoint of taking into account the possibility of forming berths for boats along the shores and free two-way traffic along the axis of the

branch. The solution implemented in the Dolphin Isles district in the Miami is used as an analogue (Figure 9). As an addition, it is proposed to perform a turning circle for boats at the end of the branch.

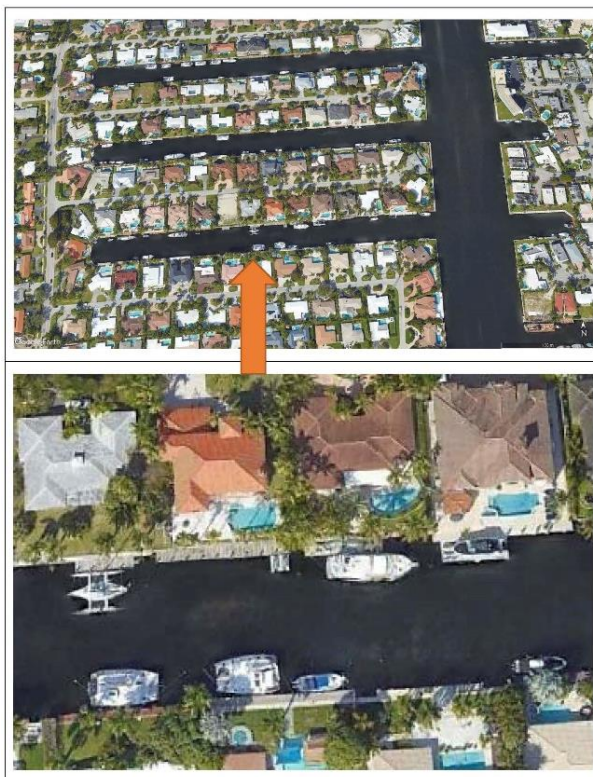


Figure 9. An example of a solution for the development of individual residential buildings with berths for boats along the water canal (the Dolphin Isles district, the Miami city, FL [34]).

In the areas of individual residential buildings (Figure 10), each site provides for the presence of a garage on the side of the passage and a personal berth for personal small vessels on the side of the backwater. In addition, berths for passenger cruise ships are located on the main channel. Parking pockets and public transport stops are located along the main street. Accordingly, a pedestrian passage to the embankment of the main canal is provided from the end of the passage, and a pedestrian passage to the sidewalk along the main street is provided from the end of the backwater.

In the areas of multi-apartment multi-storey linear and tower residential buildings with passageways (Figure 11), an entrance to each section from the passage side and access to the adjacent territory to individual berths for individual small vessels along the backwater and to a common berth for passenger cruise ships along the main channel are provided. The driveway on both sides has parking areas. Parking pockets and public transport stops are located along the main street. Accordingly, a pedestrian passage to the embankment of the main canal is provided from the end of the passage, and a pedestrian passage to the sidewalk along the main street is provided from the end of the backwater. The courtyard of the residential building is

provided from the side of the branch from the main channel. It includes a standard set of landscaping elements: recreation areas, children's playgrounds, sports and gymnastics grounds, and utility areas. The collection sites for household waste are located so that it is possible to take out garbage by both road and water transport.



Figure 10. An example of a solution for the individual residential buildings development along the proposed new canal in the Astana city, providing residents with access to water and road transport.

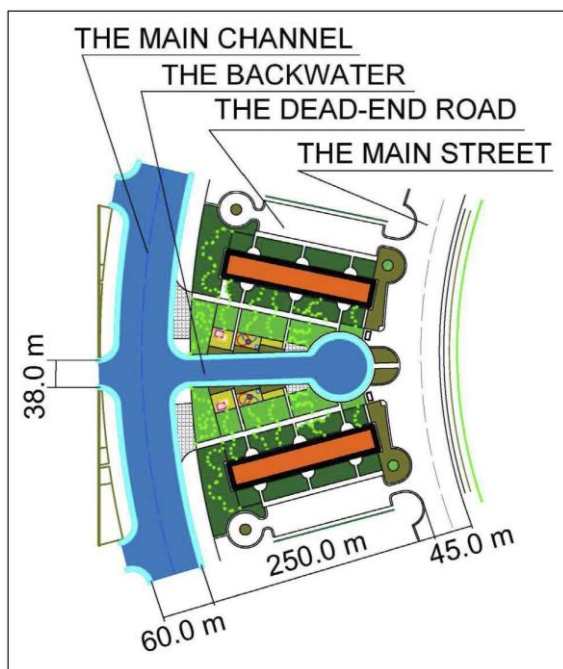


Figure 11. An example of a solution for the development of multi-apartment, multi-storey residential buildings along the proposed new canal in the Astana city, providing residents with access to water and road transport.

Public buildings of various functional purposes and types are also located taking into account the possibility of free access using road and water transport (Figure 12). For example, the building of the district administration is located in the area between two driveways connected at the ends. Small park areas separate these driveways from branches from the main canal. The main access for citizens using water transport is carried out directly from the berths on the main channel and the circular backwater. Citizens using motor vehicles enter the square in front of the building from parking areas and public transport stops along the main street.

Similarly, access for adults accompanying children to a preschool has been resolved. The complex of this institution is located in an isolated fenced area between the connected driveways. This complex includes the institution building itself with independent entrances for each children's group, outdoor playgrounds with small pavilions for each group, auxiliary and utility buildings. An independent entrance is provided from the kitchen and food block to the main building.

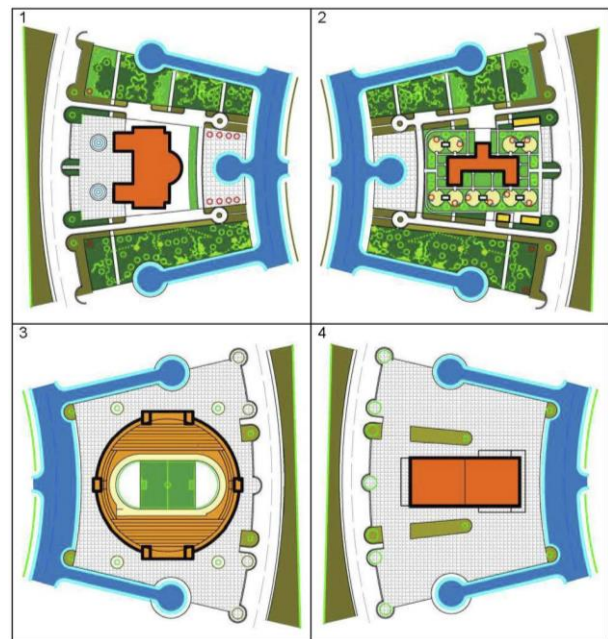


Figure 12. An example of the placement of public buildings along the proposed new canal in the Astana city, ensuring access for citizens using water and road transport: 1 – a District administration building; 2 – a Children's preschool educational institution; 3 – a Stadium; 4 – a Shopping center.

The stadium is located in an almost completely open area, providing free access to each of the six entrances to the indoor stands of the sports arena. The arena provides for the possibility of holding football matches and athletics competitions. The circular shape of the arena allows you to observe the optimal location of the stands and free access at any spatial position of the site. Along the main channel, a local extension is provided for the entire length of the site, ensuring convenient use of the pier during the mass arrival

and departure of fans using water transport. Parking areas for vehicles are located in the appropriate pockets along the main street.

Also, in an almost completely open area, there is a shopping center building. Along the main canal, a local extension is provided for the entire length of the site, ensuring convenient use of the pier during mass arrivals and departures of buyers using water transport. Parking areas for vehicles are located in the appropriate pockets along the main street. Additional parking spaces are provided on the sides of the building. The main entrance is provided from the main street. Platforms for loading goods and garbage collection are located on the side of the berths on the main channel, but they also have free access for trucks.

The placement of other public buildings (administrative and memorial buildings, schools and children's leisure centers, polyclinics and hospitals, entertainment and garden complexes, etc.) can be decided on the basis of previously considered examples.

5. Conclusions

Territories with high groundwater levels coming to the surface and zones of episodic flooding of rivers and lakes are a widespread phenomenon in areas of intensive urban development. The most common methods of solving the problem of flooding are water reduction and the construction of dams.

The Miami city is one of the rare examples of an adequate urban planning approach to the formation of a settlement that takes into account and adapts planning and infrastructure concepts to the natural and climatic conditions of the region, as well as turning existing engineering and geological difficulties into a factor of a multidimensional justified provision of a more advanced urban planning system. As a result, the traffic flow redistributed along the street and the single-channel network forms a significantly lower volume of pollutant emissions into the environment, while maintaining highly comfortable living conditions.

Using the experience of the Miami city, in the case of Astana city, there is an opportunity for adequate architectural, landscape, technical and technological use of the specifics of the city's territories by turning constantly chaotically formed reservoirs of various sizes into purposefully formed channels to solve infrastructure and transport issues and increase the level of urban improvement. This allows you to get an additional 200 sites that are promising from the point of view of development, and comfortable from the point of view of privacy. Water transport will become part of the integrated urban transport system.

The proposed solution allows solving a complex of problems in the field of improving the lives of citizens, hydrology of the urban area and important environmental

aspects. The transport infrastructure is formed by a combination of highways and water channels forms an alternative in the field of movement around the city of Astana, which allows you to choose a convenient type of public or personal transport in a particular situation.

In the Astana city, as a result of the high level of motorization and insufficient development of road transport infrastructure, a significant load is formed on the street and road network during the peak period, which leads to a decrease in the average speed of traffic flow to 10 km/h. In this regard, the formation of the transport framework of Astana city, including waterways, will prevent the likelihood of a transport collapse on the roads of the capital and ensure transport accessibility of residential complexes and social facilities.

The redistribution of passenger and freight traffic flows with the transfer of part of the traffic to water channels reduces the load on the city's road network. This will lead to a significant reduction in the traffic congestion that constantly occurs in the city of Astana on the streets. And as a result, there is a significant reduction in travel time around the city and a reduction in harmful emissions from the operation of internal combustion engines in cars.

The proposed canal system will allow balancing the movement of water and a critical increase in its volume in numerous water bodies in the Nura district. This will prevent the occurrence of critical situations with seasonal flooding of the territory and pollution of water bodies due to the chaotic movement of meltwater.

In the future, a ten-kilometer section of the Nura-Yesil' canal located within the city boundaries may be included in the Astana water transport system. But for this, it will be necessary to partially rebuild the bridge structures at five points where this canal intersects with highways.

A comprehensive solution to the tasks of eliminating the threats of seasonal flooding of territories by straightening the Esil riverbed, strengthening the banks, developing a drainage system (this is provided for by the General Development Plan of the Astana city) and the development of the Canal system (proposed by the authors of the Article) will have a positive impact on solving issues of sustainable development of the territory.

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