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Studies of Influence of Lithological Composition of Overburden Rock on Colmation Process in Open-Type Infiltration Basins

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Abstract

The article presents a study on overburden deposit rock in Southeastern Kazakhstan, focusing on the lithological composition and water-physical properties of cover sediments in infiltration basins for artificial groundwater replenishment. Analysis at pit No. 5 revealed sediment layers affecting dynamic infiltration: the uppermost layer (0–0.5 m) consists of fine-grained, micaceous sand; sandy loams (0.5–1.4 m) exhibit good permeability; dark brown impermeable clays (1.4–1.7 m) act as a barrier; a second sandy loam (1.7–2.4 m) and medium-grained sands (2.4–2.8 m) provide high permeability; and mixed-grain sands (2.8 m and below) show minimal capillarity and emerging water-bearing properties at 3.5 m. These findings confirm that surface infiltration basins can effectively enhance groundwater reserves with minimal surface runoff. The study's practical significance lies in its scientific basis for designing and optimizing groundwater replenishment systems, allowing precise site selection and contributing to predictive models for assessing infiltration rates. Overall, the results strengthen water management practices in arid and semi-arid regions, demonstrating the suitability of these basins for artificial groundwater replenishment in Southeastern Kazakhstan.

Keywords: Infiltration basin; Lithological composition; Hydro isobath; Artificial replenishment of groundwater; Water recovery; Groundwater recharge; Water management.

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1. Introduction

Formation and extent of colmation largely depend on lithological composition,[1–3] properties of soils composing flanks, and base of open-type infiltration basins.[4–6] In this regard, studies of lithological composition and characterization of water-physical properties of overburden rock in the bases of infiltration basins,[7–9] as well as an assessment of their permeability and filtration characteristics, which influence the intensity of colmation processes,[10,11] their impact on colmation, are integral part of both feasibility study and detailed design of artificial groundwater replenishment systems (hereinafter artificial groundwater replenishment systems (AGWRS)).[12–15] For this purpose, point studies of lithological composition and water-physical properties of overburden rock in the bases of infiltration basins of proposed water intake structures of AGWRS systems were carried out.[16–18] With that, at selecting experimental research sites, main criteria of hydrogeological zoning of South-Eastern Kazakhstan territory for AGWRS were used, with linkage to rural settlements in urgent need of high-quality drinking water.

Geomorphologically, the territory belongs to flat accumulation plain between Aksu - Lepsy rivers, genetically represented by hilly ridge terrain on alluvial and lacustrine-alluvial modern and upper Quaternary deposits. From hydrogeological point of view, aquifers of alluvial modern and Upper Quaternary deposits are interconnected and represent single hydrodynamic system, differing in section by filtration properties of water-bearing rock, their lithofacies composition and thickness.[19,20] The long-term efficiency of the infiltration method in AGWRS is determined by several critical factors that affect the rate of colmation and the sustainability of infiltration capacity over time. The accumulation of fine particles, organic matter, and microbial biofilms within the pore space of infiltration basins leads to the formation of a low-permeability layer. The speed of this process depends on the composition of the infiltrating water, sediment properties, and the frequency of basin maintenance.

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The longevity of infiltration basins depends on routine maintenance, including desilting, surface scraping, and controlled drying cycles. These measures help restore permeability and prevent the progressive decline in infiltration capacity caused by colmation. Microbial biofilms that develop in the infiltration zone contribute to pore clogging and reduced permeability. While biofilms initially enhance contaminant removal, their excessive growth can create impermeable layers that hinder long-term infiltration performance.

By addressing these factors through proactive management and regular maintenance, it is possible to extend the operational lifespan of infiltration basins, ensuring the continued effectiveness of AGWRS and sustainable groundwater replenishment. Colmation, a key factor affecting the long-term efficiency of AGWRS, is the process by which fine particles, organic matter, and microbial biofilms accumulate within the pore space of infiltration basins, leading to a gradual reduction in soil permeability. The formation and progression of colmation are influenced by a complex interaction of physical, chemical, and biological processes. These processes can be broadly categorized into mechanical colmation, physical-chemical colmation, and biological colmation.

On drawing near basis of erosion, sands of various grain sizes, sandy loams with interlayers of clays and loams begin to prevail in the sediments. Thickness of deposits is 50-100 m. Depending on lithological composition of water-bearing rocks, their filtration properties also change. Water transmissibility of sediments ranges from 700 to 1500 m2/day, in apparent dependance with lithofacies composition of water-bearing rock. To study lithological composition and water-physical properties of overburden sediment rock, engineering and geological pits were passed along pilot insets in middle reaches and coastal part of Aksu and Lepsy rivers (Fig. 1), simulating average depth of infiltration diurnal balance basins (usually 3 meters), considering gravel backfilling (0.5 m).[21-25]

Prior studies on AGWRS have primarily focused on theoretical modeling and laboratory experiments, often using homogeneous lithological compositions to estimate filtration parameters and predict colmation effects.[26-28] However, these approaches frequently fail to account for the heterogeneous nature of sediments found in real-world environments, leading to inaccuracies in assessing long-term infiltration efficiency.

In addition, while earlier studies have highlighted the impact of sediment grain size and permeability on colmation, they often lacked an in-depth analysis of how lithofacies transitions at different depths influence water transmissibility and overall infiltration dynamics. This research bridges this gap by providing empirical data on how lithological changes within infiltration basin profiles impact colmation formation and permeability variations over time. These findings build upon and refine the existing body of knowledge, offering a more robust framework for designing and managing AGWRS in regions with complex hydrogeological conditions.

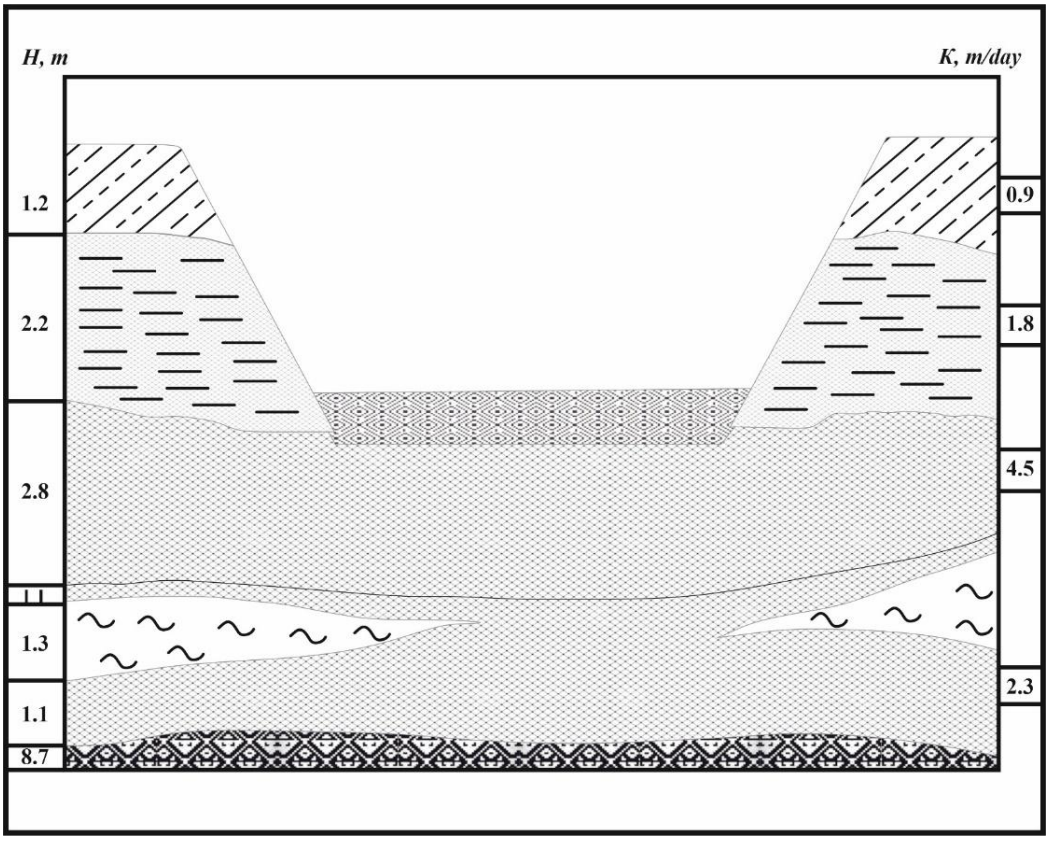


Fig. 1: Typical schematic geological and lithological section of infiltration basins of trapezoidal section.

2. Materials and methods

To characterize the lithological structure and assess the suitability of overburden sediments for artificial groundwater recharge, a comprehensive granulometric analysis was conducted using a set of established methods in soil science and engineering geology. The selection of methods was based on the complex lithological heterogeneity of the study area, located within the alluvial and alluvial-proluvial plains of Southeastern Kazakhstan, and tailored to the needs of optimizing the performance of AGWRS.

2.1 Granulometric analysis approach

Granulometric composition was determined using a combination of sieve, hydrometric, and pipette methods, depending on the type and grain size distribution of the sediment.

For coarse-grained and sandy soils, as well as for the coarse fraction of pulverized clay soils, the dry and wet sieve method was employed, which serves as an intermediate between direct micrometric and indirect sedimentation methods. Dry sieving was performed using sieves with mesh openings of 10, 5, 2, 1, and 0.5 mm. Wet sieving (with water rinse) utilized additional meshes of 0.25 mm and 0.1 mm to accurately differentiate fine and powdery sands. This method allows for precise separation and quantification of particles larger than 0.1 mm, which is critical for analyzing water permeability, pore structure, and susceptibility to colmation in infiltration basins.

To determine the content of particles with diameters less than 0.1 mm, the hydrometric method was used. This technique involves measuring the density of a soil suspension at specific time intervals using a hydrometer, allowing for the calculation of the diameter and proportion of suspended particles. It provides key data for assessing fine-grained particle migration, which directly impacts the colmation potential of recharge structures.

For clay-rich soils, the pipette method was applied in combination with sieving. This method is based on Stokes' law, using sedimentation velocity in calm water to fractionate particles. Samples were extracted at regular time intervals and depths, then dried and weighed to determine the mass of each fraction. This method enables high-resolution identification of colloidal clay fractions (<0.005 mm), which are major contributors to pore clogging during artificial recharge operations.

3.2 Particle size classification

For the classification of particle sizes, the following system was applied:

Gravel: Coarse (10–5 mm), Fine (5–2 mm)

Sand: Very coarse (2–1 mm), Coarse (1–0.5 mm), Medium (0.5–0.25 mm), Fine (0.25–0.10 mm), Very fine (0.10–0.05 mm)

Silt (Dust fraction): 0.05–0.005 mm

Clay: <0.005 mm

In field conditions, a simplified assessment of lithological types (clay, loam, sandy loam) was performed by estimating the percentage of four main particle size groups:

1 mm (coarse sand)

~0.05 mm (fine sand)

0.05–0.005 mm (dust/silt)

<0.005 mm (clay)

3.3 Sample preparation and separation procedure

To isolate sand fractions (≥1 mm), washing techniques were employed:

A soil sample was placed in a graduated glass vessel with water and vigorously shaken.

After settling of coarser particles, suspended water containing fine clay and silt was decanted.

The process was repeated until the water became clear, after which the volume of sandy residue was measured.

The relative mass of each fraction, expressed as a percentage of the total oven-dried soil mass, was defined as the grain size distribution. This parameter is essential for evaluating soil permeability, filterability, and long-term infiltration performance.

3.4 Relevance for AGWRS design

Grain size distribution is a key indicator in determining:

The potential for colmation (clogging of pore spaces),

The efficiency of infiltration, and

The required scale of preventive and maintenance measures to ensure stable operation of AGWRS infrastructure.

The analysis showed that fine clay and silt particles (up to 42.7% in loamy horizons) may accumulate in infiltration basins, leading to a gradual reduction in recharge efficiency over time. Therefore, the granulometric characteristics obtained are critical for:

Selecting suitable sites for artificial recharge, Designing filtration and sedimentation pre-treatment stages, and predicting colmation potential and ensuring long-term efficiency of infiltration basins.

The presence of alternating permeable and low-permeability layers, as revealed in pit profiles, further underscores the importance of site-specific lithological modeling for effective AGWRS planning in the alluvial plains of Southeastern Kazakhstan.

The sieve method was selected due to its high accuracy and efficiency in determining the granulometric composition of coarse-grained, sandy, and the coarse fraction of pulverized clay soils. This method is widely used in engineering geology and soil science due to its ability to:

Accurately separate and quantify different particle size fractions by passing the soil sample through sieves with standard mesh sizes. Provide reliable data on the distribution of particle sizes larger than 0.1 mm, which is critical for assessing water permeability and predicting colmation processes. The hydrometric method provides critical data for understanding the contribution of fine-grained particles to

colmation processes, as these particles are primarily responsible for clogging infiltration basins. The pipette method was chosen for determining the granulometric composition of clay soils due to its ability to:

Accurately separate and quantify fine clay particles based on their sedimentation rate in calm water. Over time, fine-grained fractions, such as clay and silt particles (up to 42.7% in loamy deposits), may migrate and accumulate in pore spaces, contributing to gradual colmation and a decrease in infiltration capacity.

The granulometric composition of overburden sediments at the studied sites demonstrates a favorable initial environment for infiltration processes but indicates a moderate to high potential for colmation over extended periods. The presence of fine fractions in the lower horizons, combined with mixed-grained sediments, suggests the need for continuous monitoring and maintenance to sustain optimal performance of infiltration basins. The granulometric analysis results provide a solid foundation for developing site-specific management strategies aimed at prolonging the lifespan of AGWRS in the studied regions of Southeastern Kazakhstan.

3. Results and disscussion

The first lithological layer of overburden deposits from the surface in pit No. 5 is fine-grained, clay, light yellow, micaceous sand; characterized by either an equal ratio of siltstone and sand particles (35-40%), or some predominance of particles with size of 0.05-0.25 mm; layer thickness 0.5 m.

Further along the section, in the range of 0.5–1.4 m, sandy loams were opened and tested, they are light gray, light, weakly plastic, in dry state have sufficient adhesion. They are stable in dry and wet conditions, as they combine positive qualities of sand (high internal friction and good water permeability) and clay (adhesion in dry state) particles. Sediment thickness is 0.9m.

Dark brown, dense clays lie under sandy loams. They are practically impermeable, characterized by high adhesion, great plasticity, stickiness and swelling. The thickness of the layer is 0.7 m.

In the range of 1.7–2.4 m, sandy loams are light gray, of medium density, slightly plastic, and have sufficient adhesion in dry state. They are stable in dry and wet conditions, as they combine positive qualities of sand (high internal friction and good water permeability) and clay (adhesion in dry state) particles. Sediment thickness is 0.7 m.

Sandy loam is underlain by a layer of medium-grained light-yellow sands spread over the area; they are characterized by good water permeability, low capillarity, deposits are almost incompressible; thickness of the layer is 0.4 m.

From a depth of 2.8 m, discovered sands are or various grain size, light gray, up to 30% fine gravel; from 3.50 m, they were slightly water-bearing. They are characterized by relatively high water permeability, absence or very low capillarity; thickness of the layer is 0.9 m.[29]

Studies and obtained results obtained are supplemented by materials from studies of water–physical properties at a representative site of the AGWRS, right bank of Karatal River near Kishi-Tobe village as part of more fundamental research works in river basin, themed: "Developing method for artificial replenishment of groundwater reserves and research of prospects for its use for drinking water supply in Southeastern Kazakhstan."

First layer: Fine-grained clayey sand with admixture of mica. The high content of clay particles gives it plasticity and cohesiveness. The presence of mica may indicate certain conditions of sediment formation (*e.g.*, proximity to crystalline weathering zones).

Second layer: Loam. The optimal combination of sand and clay properties makes this layer resistant to various external influences. The absence of significant plasticity indicates a relatively low content of clay particles.

Third layer: Clay. Practically a waterproof rock, which makes it a good water-support. High plasticity and stickiness are characteristic of clay and are due to the presence of colloidal particles.

Fourth and fifth layers: sandy loam and sand. The repetition of sandy loam layers indicates possible cyclic sedimentation processes. The underlying sands are characterized by good water permeability, which may indicate an older age and a long period of exposure to groundwater.

Six layer: Multigrained sands with gravel. The presence of gravel indicates more vigorous depositional conditions, possibly near an ancient riverbed. Weak water-bearing capacity may be related to depth and lithologic composition.[30-34]

Results of granulometric analysis of soils for greater clarity, as well as facilitating corresponding calculations, in addition to the above Table 1, are reflected in constructed graph, where grain composition of soils is depicted as a total curve (accumulation curve, or cumulative curve). In this case, ordinates of total curve do not correspond to content of individual functions, but to sum of fractions of particles less than a certain diameter. To construct a curve along ordinate axis, total percentage (from 0 to 100) of fraction content is set aside, and along abscissa axis, logarithms of particle diameters are set. Several curves for different types of soils, clay, loam and sand are applied to the same grid that is most common in the context of overburden deposits at experimental research sites.

According to total curve, it is possible to find so-called effective diameter of soil particles (d10, mm), which accounts for less than 10% of particles in the soil. This conditional value is used in calculations of so-called contaminant capacity, which directly affects formation of silty film in the bases of infiltration basins, and therefore magnitude of colmatation processes.[35-39]

Some difficulties in determining grain composition of clay soils (for example, adoption of spherical particle fall rates and

Table 1: Granulometric composition of rocks in undifferentiated alluvial-proluvial modern and Upper Quaternary deposits at experimental research sites.

Lithological composition of rock	Granulometric composition of fractions, %						
	7.0-5.0	5.0-2.0	2.0-1.0	1.0-0.5	0.5-0.05	0.05-0.005	Less than 0.005
Alluvial deposits of predominantly modern Quaternary age, middle course of the right bank of Aksu river, Matai village, pits No. 3,4							
Sand with various grain size, up to 30% fine gravel	-	15.2	21.7	-	34.4	14.8	14.8
Medium-grained sand	-	40.0	41.0	1.5	6.2	5.1	6.2
Fine-grained, micaceous sand	-	-	-	-	87.1	6.8	4.1
Sand with various grain size with lenses of medium-textured loam	-	-	59.6	12.8	2.1	3.6	12.5
continued							
Sandy loam	-	-	-	15.5	35.5	30.8	24.2
Loam with medium-grained sand lenses	-	-	9.8	16.5	9.0	31.2	42.7
Clay loam	-	-	-	-	56.0	32.2	11.8
Loamy and dense clay	-	-	-	-	41.4	38.3	20.3
Alluvial-proluvial deposits of predominantly modern and Upper Quaternary age, middle course, left bank of Lepsa river, Zhanalyk village, pit No. 5							
Sand with various grain size, up to 30% fine gravel	-	22.2	17.7	11.0-	28.4	19.8	9.8
Medium-grained sand	-	20.8	51.0	12.0	4.1	7.0	5.1
Sand with various grain size with lenses of medium-textured loam		2.5	48.6	24.8	3.0	2.6	14.7
Light sandy loam	-	-	-	25.5	35.5	20.8	16.5
Dense clay	-	-	-	-	32.6	48.9	20.3
Alluvial-proluvial deposits of predominantly modern and Upper Quaternary age, middle course, right bank of Karatal river, Kishi-tobe village, pits No. № 1, 2							
Gravel sand	-	15.2	21.7	-	34.4	14.8	14.8
Coarse-grained sand	9.5	5.3	21.1	1.7	29.9	1.6	0.8
Medium-grained sand	-	43.0	43.0	0.1	5.6	4.9	3.4
Fine-grained sand	-	-	-	-	97.1	0.8	2.1
Sandy loam	-	-	-	-	45.1	33.6	21.6
Sandy loam	-	-	-	-	6.1	51.2	42.7
Loamy clay	-	-	-	-	43.6	36.3	20.1

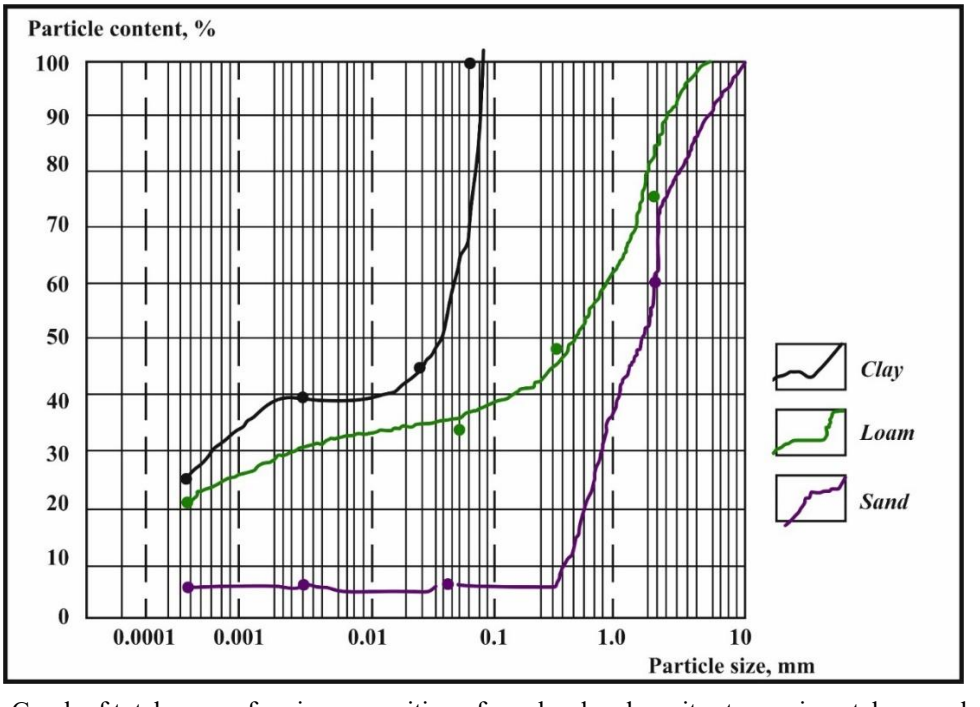


Fig. 2: Graph of total curve of grain composition of overburden deposits at experimental research sites.

average particle density for calculations), as well as high dependence of grain composition analysis results on method of preparing a soil sample for analysis, reduce practical importance of classifications based only on data from grain composition analyses.

Thus, engineering and geological works made it possible to determine lithological and granulometric composition and give a positive characteristic to overburden rock at experimental sites recommended as promising objects for creation of small AGWRS systems (Fig. 2). Experimental research site located in the middle reaches of the right bank of Aksu River, 550 m northeast of Matai station.

Studies were carried out in pits No. 3.4; 200 m apart along the length of proposed infiltration basin; research interval 0.0–3.8 and 3.9 m, taking into account description and documentation of all lithological differences in overburden rock. It is represented by alluvial deposits of modern quaternary age (alQ IV). In terms of distribution area and lithological composition, it is composed of heterogeneous, low-power weakly-permeable and impermeable overburden deposits of medium density.

The first lithological layer of overburden deposits from surface in pit No. 1 is a light gray sandy loam, light, weakly plastic, in dry state it has sufficient adhesion, dust formation is insignificant. These soils dry out quickly, do not swell and do not have stickiness. They are stable in dry and wet conditions, as they combine positive qualities of sandy (high internal friction and good water permeability) and clay (adherence in dry state) particles; thickness of the layer is 0.6 m (Fig. 3).

Further along the section, in the range of 0.6–1.2 m, light yellow, sandy loam, medium density clays are deposited; they are practically impermeable, characterized by high adherence, have great plasticity, stickiness, and swelling. Capillary properties of clays are less pronounced than those of loamy and dusty soils; thickness is 0.6 m.[40-44]

Under the clays, in the range of 1.2–1.5 m, there are interlayers of light gray sandy loam, with characteristics described above; thickness of interlayers is 0.3 m. In the range of 1.5–2.3 m, dark brown, heavy loams with numerous interlayers and lenses of clay sand were found; in the dry state they have significant adhesion and density. They dry out

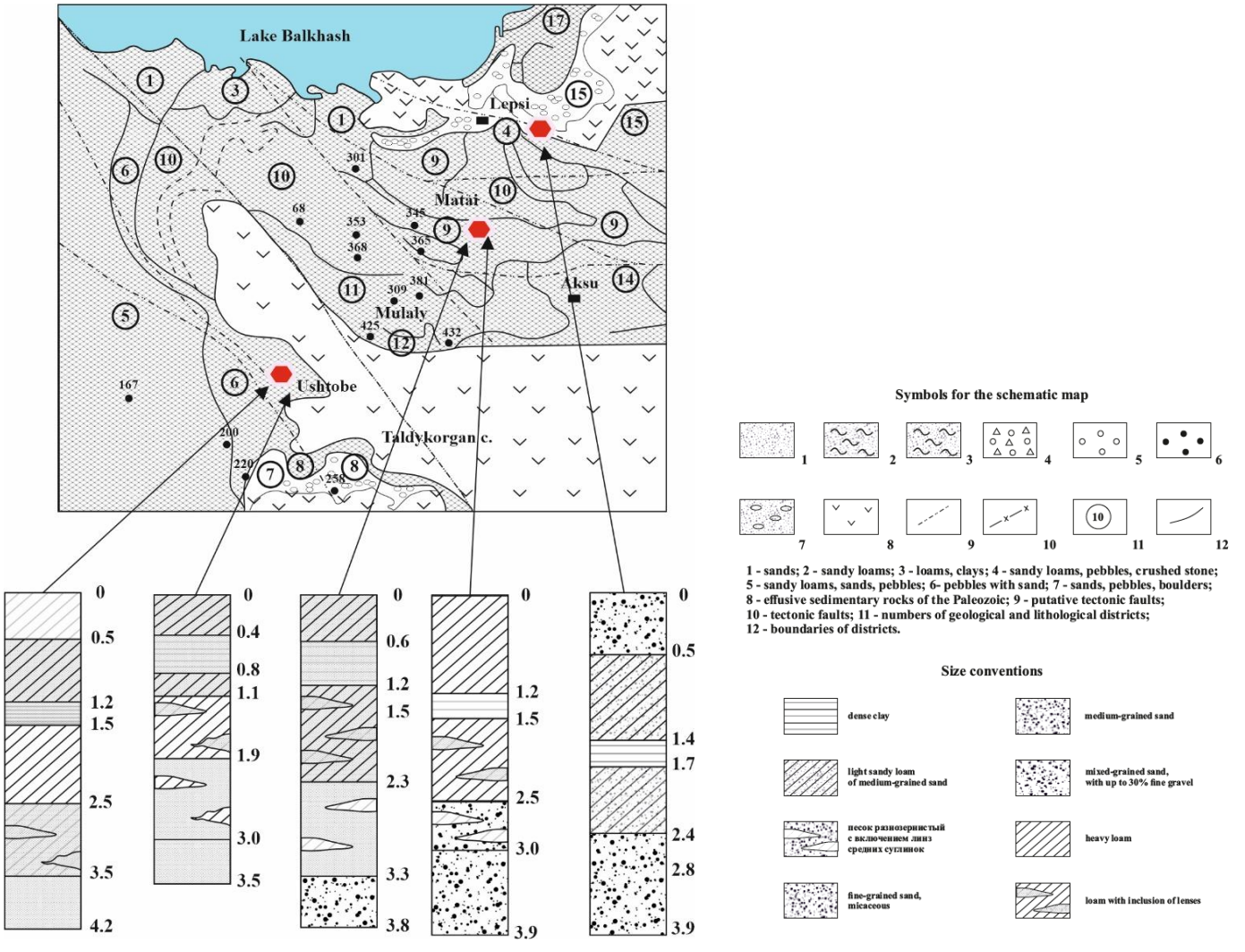
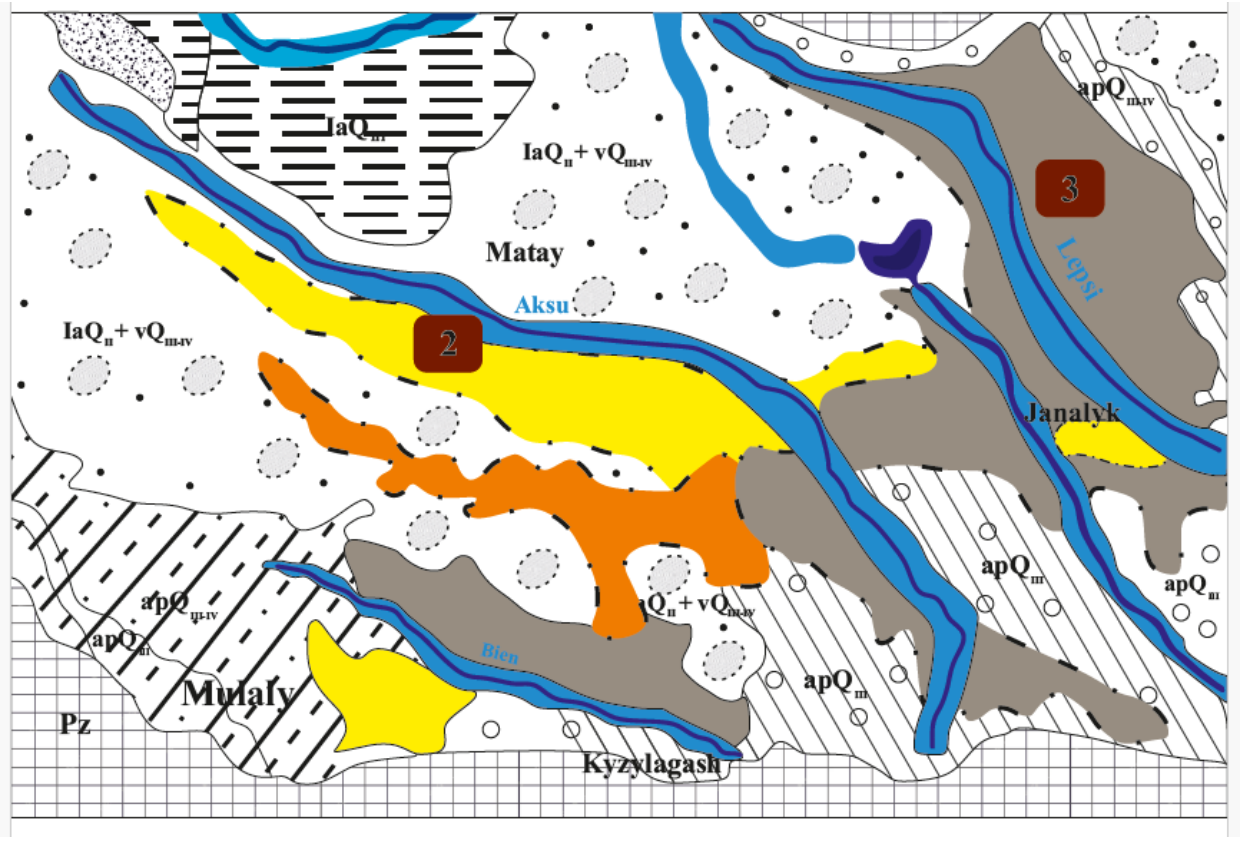


Fig. 3: Schematic map of engineering and geological workings on representative research sites with lithological sections of overburden sediments.



Symbols

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to geological and lithological schemes and maps of research sites on the water content and turbidity of rivers in Southeastern Kazakhstan as sources of IWRM for drinking water intakes in rural settlements

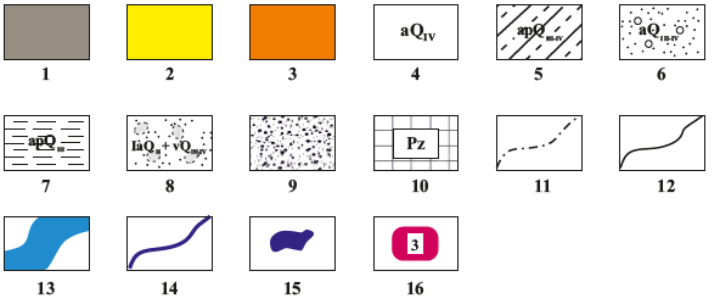


Fig. 4: Geological and lithological map of research site for water content and turbidity of Aksu and Lepsy rivers as a source of AGWRS for drinking water intakes in rural settlements of South-Eastern Kazakhstan. 1 - most promising sites for AGWRS according to all defining criteria for practical use as a full-fledged source for agricultural water supply of settlements. 2 - medium prospects for practical use as a source for agricultural water supply in settlements. 3 - Areas of limited prospects for AGWRS located in areas of limited sources and resources of drinking water supply.4 - Alluvial deposits of predominantly modern Quaternary age (water-bearing rocks are lithologically represented by gravel, crushed stone, sands, gravel-pebbles, boulders). 5 - Alluvial deposits of predominantly modern and Upper Quaternary age (mixed-grained sands, sandy loams). 6. Alluvial-proluvial deposits of modern and Upper Quaternary age (mixed-grained sands with pebbles). 7 - Alluvial-proluvial deposits of Upper Quaternary age (mixed-grained sands, light loams with pebbles). 8 – Undifferentiated lacustrine-alluvial deposits of Middle Quaternary and fluvioglacial deposits of modern and Upper Quaternary ages (boulder-gravel-pebbles with sandy aggregate, sands, sandstones, gravelites). 9 - Undifferentiated lacustrine-alluvial deposits of Lower Quaternary and fluvioglacial deposits of modern and Upper Quaternary ages (boulder-gravel-pebbles with sandy aggregate, sands). 10 - Rocky and fractured rocks of Paleozoic age (sandstones, conglomerates, effusions and their tuffs). 11 – Isolines of plot boundaries according to perspective zones for practical use as a source for agricultural water supply of settlements. 12 – Isolines of boundaries for different age sediments. 13 - floodplain part of rivers. 14 - isolines of rivers.15 – lakes. 16 - location and number of sites for studying water content and turbidity of rivers in South-Eastern Kazakhstan.

slowly after moistening, but have increased water permeability due to interlayers of clay sand; plasticity, stickiness, swelling, moisture capacity and capillary properties are clearly expressed in these soils; thickness of the layer is 0.8 m.

Under the loam in the range of 2.3–3.3 m there is light gray sand, multi-grained, medium density with lenses of medium-textured loams; soils are characterized by low adhesion and low water permeability. Plasticity, stickiness, swelling and capillary properties manifest themselves to a noticeable extent, especially with an increase in the number of clay particles; thickness of the layer is 1.0 m.[44-49] Below down the section, layer of sand with various grains, light gray, with up to 30% fine gravel was uncovered; from 380 cm mark, it is slightly water-bearing. It is characterized by good water permeability, absence or very low capillarity 4 thickness of the layer is 0.5 m.

The first lithological layer of overburden deposits from the surface in pit No. 2 is a dark gray loam, heavy; in dry state it has significant connectivity and density. It dries slowly after humidification and has very low water permeability. Loam is characterized by plasticity, stickiness and swelling; thickness of the layer is 1.2 m.[50-54] Thin interlayers of dense dark brown clays were uncovered below the section; they are characterized by pronounced plasticity, stickiness and swelling; thickness of the interlayer is 0.3 m.

In the range of 1–2.5 m, dark brown, heavy loams with numerous interlayers and lenses of clay sand were found; in the dry state they have significant adhesion and density. They dry out slowly after moistening but have increased water permeability due to interlayers of clay sand; plasticity, stickiness, swelling, moisture capacity and capillary properties are clearly expressed in these soils; thickness of the layer is 1.0 m.[55-59]

Below down the section, main sedimentary rock is mixed–grained sands with lenses of medium-textured loams, in the range of 2.5-3.0 m; density of sands is 2.66 g/cm3, they are characterized by good water permeability, absence or very low capillarity, deposits are almost incompressible; thickness of interlayer is 0.5 m. In superincumbent bed of overburden deposits, in range of 3.0 -3.9 m, there are sands of with various grain size, light gray, up to 30% fine gravel; from the 370cm mark, they were slightly water-bearing. They are characterized by relatively high-water permeability, absence or very low capillarity; the thickness of the layer is 0.5 m.

The experimental research site is located in the middle reaches, left bank of Lepsy river, 350m north of Zhanalyk village.[60-64] Research was carried out in pit No. 5; research interval is 0.0–3.9 m, taking into account opening and description of all lithological differences in overburden rock. It is represented by alluvial-proluvial deposits of predominantly modern and Upper Quaternary age (apQ III-IV). According to distribution area and lithological composition, it is composed of heterogeneous, thin, weak- and medium-permeable overbuden deposits with different densities.[65-68]

Engineering and geological work made it possible to determine lithological and granulometric composition and give differentiated characteristic of overburden rock at the experimental sites recommended as promising objects for creation of small AGWRS systems. They served as main taxonomic units for zoning water basin territories of Karatal, Aksu and Lepsy rivers according to perspective of practical use as source of AGWRS for drinking water intakes in rural settlements of South-Eastern Kazakhstan. Karatal river as a source of AGWRS for drinking water intakes in rural settlements of South-Eastern Kazakhstan (Fig. 4).

The results of the experimental studies conducted in Southeastern Kazakhstan, particularly in the Aksu, Lepsy, and Karatal river basins, provide a solid foundation for optimizing artificial groundwater replenishment systems (AGWRS) in regions with similar hydrogeological and climatic conditions. These findings can be extrapolated and adapted for use in other arid and semi-arid regions characterized by heterogeneous lithological composition, intermittent surface water sources, and a high risk of water scarcity.

4. Conclusion

Studies of the lithological composition and water-physical properties of overburden rocks in experimental areas of Southeastern Kazakhstan have confirmed their significant influence on colmatation processes in the foundations of infiltration basins. The obtained full-scale characteristics of the physical properties of the rocks of the aeration zone and sediments of the water-bearing stratum made it possible to identify the patterns of formation of colmatants and assess their impact on the effectiveness of artificial replenishment of groundwater reserves.

The analysis of the granulometric composition of the overburden showed a high heterogeneity of the studied soils, which requires a differentiated approach to the design of artificial groundwater replenishment systems. In particular, it was found that sandy loams and medium-grained sands have the best permeable characteristics, contributing to the effective functioning of infiltration basins, while the presence of clay and loamy interlayers increases the risk of colmatation.

The research results are of practical importance for the design and operation of AGWR systems. They can be used in the development of measures to prevent coloration and improve the efficiency of infiltration basins. The conducted engineering and geological work has confirmed the prospects of the selected sites for the creation of small systems of artificial replenishment of groundwater reserves.

Therefore, an integrated approach to the study of the lithological composition and water-physical properties of overburden rocks makes it possible to ensure the scientifically sound design and operation of AGWR systems, minimize the impact of colmatation and increase the efficiency of using surface infiltration basins to replenish water resources.

Future research should focus on long-term monitoring of changes in groundwater quality at infiltration sites, including chemical and microbial indicators, to assess possible impacts of colmatation and infiltration dynamics over time. In addition, studies incorporating numerical modeling of infiltration under various climatic scenarios would help optimize the spatial and temporal design of AGWR systems in response to climate change. The integration of remote sensing technologies for continuous assessment of land surface and vegetation dynamics around infiltration basins may further enhance system performance and sustainability.

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Conflict of Interest
There is no conflict of interest.

Supporting Information
Not applicable.

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