Anissimov, Leonid; Anisimova, Olga

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TRIBUTARY STREAMS IN THE VOLGOGRAD URBAN AREA: RISK ANALYSIS AND RECLAMATION PROGRAM

Leonid Anissimov, Olga Anisimova

Volgograd with a population of one million habitants is located on the west high riverside of the Volga River. It is stretched over 85 km along the Volga and numerous small tributary streams intersect the populated area. Every tributary composes a separate catchment basin opening to the Volga River. All official and nonofficial municipal and industrial landfills of the great city are located on the top parts and slopes of the ravines. Such a practice has been created due to social, economic and psychological reasons. Landfills disposed on the high elevation, on the week soils with gully erosion create environmental and sanitary problems. Contaminated surface and subsurface waters flow down to streams and, further, to Volga. In order to simulate the fate of these hazardous wastes in the environment, multi-media transport models have to be employed. The program to solve waste storage and contamination problems includes the reclamation of landfills, the water treatment using the biological ponds, and the reclamation of the flat-bottom valleys near the Volga riversides.

Keywords: tributary streams, landfills, contamination pathways, risk analysis, reclamation

1 Introduction

Soil, surface water and groundwater contamination on the urban territories is an important problem for great cites. Over the past decades, human activities have altered drastically the natural environment in the Volgograd district. Municipal and industrial construction, surface planning and filling of ravines are accompanied by growth of the solid waste volume. Populated area is divided into the private zone with one-store buildings and the municipal zone with multi-store buildings. Municipal zone has a regular sewage system as the private zone is forced to dispose their solid wastes and sewage waters to the nearest ravines. The human psychology is to find a hiding-place for wastes and it has been realized in a number of landfills in the upper parts of ravines around residential area. Landfills disposed on the high elevation, on the week soils with gully erosion create environmental and sanitary problems. Contaminated surface and subsurface waters flow down to streams and, further, to Volga. This process depends on the geological and hydrogeological setting of waste locations, migration paths and contaminant accumulation. Ravines of Volgograd are free and unpopulated area and they are very attractive to use them for parks and resting-places, especially, the flat-bottom valleys near the Volga Riverside. Reclamation of landfills, wastewater treatment and reclamation of great valleys around populated areas can solve many environmental and social problems.

2 General description

Volgograd City with a population of one million habitants is located on the high western Volga riverside. It is stretched on 85 km along the Volga River, as the width is to 10 km. Figure 1 shows the position of the principal relief elements and valleys with tributary streams, which intersect the residential area. Volgograd area has an arid climate with rainfall generally about 400 mm year^{-1} and surface evaporation more than 800 mm year^{-1}. Many valleys have temporal streams after snow melting but they are dry during the summer. The great tributaries (Mokraya and Sukhaya Mechetka, for example) have a permanent flow of water.

Study area can be divided into three parts: high plateau, river terraces and flood plain. High Plateau (Privolzhskaya and Ergeny Highs) creates the watershed between Volga and Don hydraulic basins. In the Volgograd area the watershed line is at a distance of 13-15 km from the Volga River. The topography varies from 140-150 m elevation above means of sea level on the north and towards southeast it goes down to 115-130 m. From the watershed line the elevations decrease to 80-90 m on the slopes of highs and to 30-40 m on the terraces of the Volga. The width of the terraces is 2-3 km. The flood plain of Volga is very wide, up to 30 km, in the Volgograd Region.

Geological cross-section of the Volga Valley is shown on the fig.2. The Quaternary sediments of different origin overlay the Neogene and Paleogene clastic sediments. Position of aquifers and groundwater level is given on the hydrogeological cross-sections across tributary valley (fig. 3) . The groundwater level is near the surface in the bottom of valley and in the head part of the terrace. These are the places of groundwater discharge. Filling of gullies caused decrease in erosion and consequently a spread of gully-ravine network decreased from 205 to 120 km. Decrease in gully erosion activity is accompanied by decrease of the area of drainage almost by one half. This caused the surface and subsurface runoff, groundwater afflux and sharp groundwater rise. After gully filling, groundwater rise reaches 16-18 m in some areas.

3 Gully activity and waste disposal

The city area is in a zone of intensive gully-ravine activity. There are various reasons making for gullies occurrence and development: climate, relief features, rock composition forming the region and irrational human activity. Within the residential area ravines and gullies occupy about 5% (more than 240 gullies) of all the city lands. Density of erosive network in Volgograd area makes up 500-2000 m per 1 km^2, its entrenchment depth reaches 40-60 m though in average it is 10-20 m.

Gully development becomes active during the spring-summer period under the effect of flooding, snow melting and precipitation, especially showers. As a result, occurrence and growth of scours, sheetflood, suffusion is observed. The bed of gullies and ravines is divided into 3 parts: the top, where evacuation of material occurs; the middle, where material transportation prevails; and the low with material deposition observed. Flowing waters erode the slope from the mouth to the head. Erosion starts from the point at the slope foot, base level of erosion. In dealluvial loams gullies are formed by periodical collapse of columnar rock massif reaching in volume several tens of cubic meters. Light washout of loess-like loams results in high dipping scours occurrence 3-5 m deep and 10 m long in gully edges. Washout velocity of dealluvial deposits by common moisture abundance may reach 30 m during a strong long shower.

Many gullies within the residential area became places for spontaneous waste discharge. Official landfills are spaced at +80 - +120 m elevation and refer to watershed area attaching the gully-ravine network and on ravine slopes and branches. Uncontrolled discharge of waste waters to thalwegs of gullies and ravines causes pollutants discharge into the Volga River, activation of gully-erosion processes, cutoff of gullies and ravines slopes, brow recession.

Areas are poorly protected from surface pollution. Industrial discharge is stored together with such pollutants as oil products, emulsions, aniline, phenols, fatty substances and so on. Anthropogenic accumulations including construction and domestic wastes, wood, slag and above-mentioned pollutants are of great thickness (from 20 m and more). Embankment of settling basin dams is built with clay sands and slag inclusions. It should be noted that embankment, as a rule, is absent on landfills for solid wastes from ravine sides. It results in waste movement to the ravine bottom. Impervious screen is not provided and it is not surprising that the data of water composition available close to the landfills show that surface and groundwater are polluted by leachate.

Waste abstraction is not organized properly and habitants dispose their waste into branches of gullies. Melt waters and surface runoff are infiltrated through the landfill bodies. It causes direct pollution of groundwater and water of streams.

4 Risk analysis of the irregular waste disposal

The irregular waste management leads to economic, health and social losses of our society: we have no effective waste recycling programs, our landfills are located in the unsuitable places and the social losses are that our people lives in the media of sanitary and environmental problems. Risk analysis is required to assess the top-priority tasks to change the environmental and social situation in our populated areas. The toxicological risk analysis is one of the principal tasks to assess the health risk of a pollutant in the environment. According to the risk analysis practice the follow procedures are necessary:

- characterization of the pollutant source (landfill, composition of waste, biodecay chain);
- compartmentalization of the transport pathway of pollutants, i. e. a series of distinct but interconnected zones consisting of soil, vadose zone, groundwater, surface water and sediment compartments;
- quantify the dispersion of pollutant from the source to the various compartments along the pollutant pathway;
- quantify each human exposure pathway and assess the dose;
- estimate the adverse health effects bases on appropriate dose/response relationship.

Risk assessment according to this program is very complex and very expensive taking into account a number of pollutants in the municipal landfills, a number of landfills and, consequently, a number of pathways for the pollutants. The refinement of each compartment model will require more studies of intermedia mass transport processes and multimedia field data. A difficult task is to estimate a number of people and other environmental elements, likely to be exposed to toxic hazards. The best way to solve this problem is to take into account the experience of industrial states in the waste management and cleaning soil and surface water technologies.

5 Mokraya Mechetka Valley reclamation program

The Mokraya Mechetka River has drainage area about 170 km^2 at a length of 16 km. Its head presents a number of major fan-shaped gullies. In lateral section its

valley is almost symmetric about the flat wide bed and high slopes. Thalweg altitudes were equal to 100-110 m, today thickness of filled-up ground (domestic wastes) reaches 15-20 m. Geology of the landfill area is represented by the Quaternary loams, the Neogene white fine-grained sands, to the lower part of which subsurface waters are confined. Underlying rocks are dark-grey clays with interlayer of the Maikopian (Paleogene) light silt serving as aquitard. Constant stream flows along the bed, 2-3 in width and 1 m in depth. In the lower part, near the Volga River, the valley is widened and reaches 400-600 m.
Valleys of Mokraya Mechetka Rivers appeared in the Middle Quaternary. Later, during Early Khvalynian transgression, there observed slope transformation and the Khvalynian terrace shaping in ravines mouth due to the marine clays filling up to 20-25 m. In that way trough-shaped profile of ravines downstream was formed. This caused sliding deformation of slopes being sometimes sizable. Besides, mud-streams in the blanket deposits on slopes are widely met.

The Mokraya Mechetka River has undergone great changes along its whole length. Domestic wastes accumulator is located in the ravine thalweg, there is an earth-fill dam in its lower part. The bottom and slopes are not shielded. Liquid wastes are stored into artificial hollows embanked around. On the Mokraya Mechetka slopes, particularly in pre-mouth areas of lateral ravines, there are a lot of springs but their number decreases due to waste discharge from building and metallurgical enterprises. Uncontrolled use of fertilizers, irregular watering, unauthorized dumps on the slopes result in relief change, hazardous substances waterlogging and transport into Volga. Two dams were constructed in the middle and lower parts of Mokraya Mechetka watercourse. The dams have channels for water passage. Many gullies running into the ravine are filled up with anthropogenic ground. The slopes are occupied with garages and other constructions and wastes are dumped there.

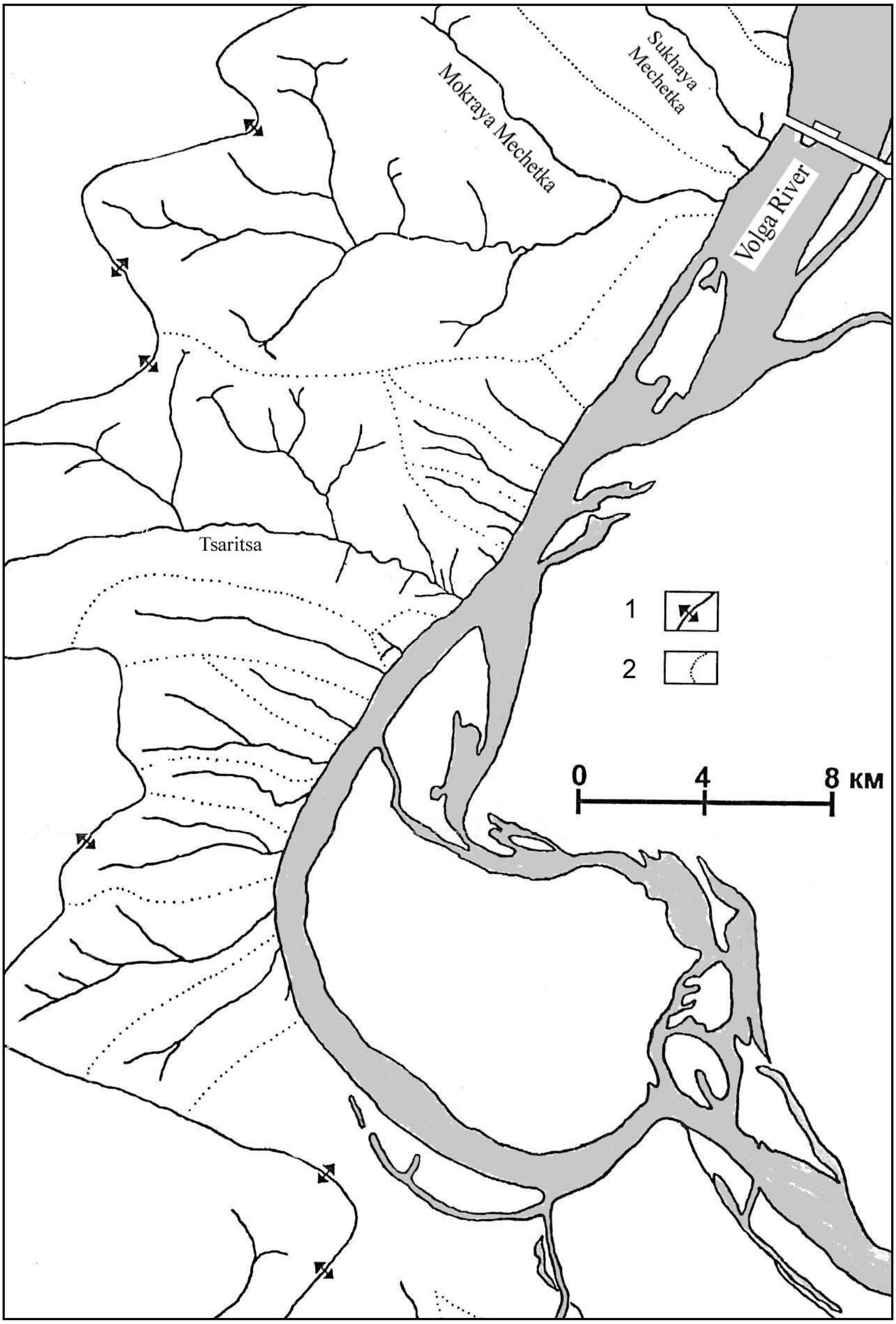
The Mokraya Mechetka river divides the northern district of the city into two parts: the old industrial area and the residential settlement Spartanovka with a population of 100 000. There are no developed parks in the district. In this region the flood plain of the Mokraya Mechetka River has a trough-shaped profile and is divided into three parts: a low one living flood plain, flooded during high water of the Volga River, the middle part, fossil flood plain between motor dams, and upper part with narrow valley (Fig.4). Every part demands a special approach for the reclamation program. The upper part is suitable to place biological ponds to clean contaminated water from the catchment area with landfills and other sources of pollution. The middle part is the best place for the park attractions and, at last, the low one is suitable for the ecological park. This program has to include the objects for the ecological education.

6 Conclusion

Surface and ground water protection of a great city begins from the protection of every tributary stream in the catchment area. Neighborhoods around the principal metropolitan area with untreated domestic sewage and the inadequate collection and disposal of urban solid wastes can create the environmental and sanitary problems for the whole region. All the contaminants return to the residential area and to the Volga River and the success of environment protecting depends on the active involvement of both public and authorities in implementing proper waste treatment schemes with a scientific basis.

Professor Leonid Anissimov
VolgogradNIPImorneft,
Lenin Av. 96,
Volgograd 400005,
Tel.: 7 8442 341310
Fax: 7 8442 345751
E-mail: vmorneft@vlink.ru

Olga Anisimova,
Saratov State University,
Astrakhanskaya 83,
Saratov 410026,
Russia



1 – position of the Volga – Don watershield
2 – positions of tributary stream watershelds

Figure 1. Tributary streams in the Volgograd urban area

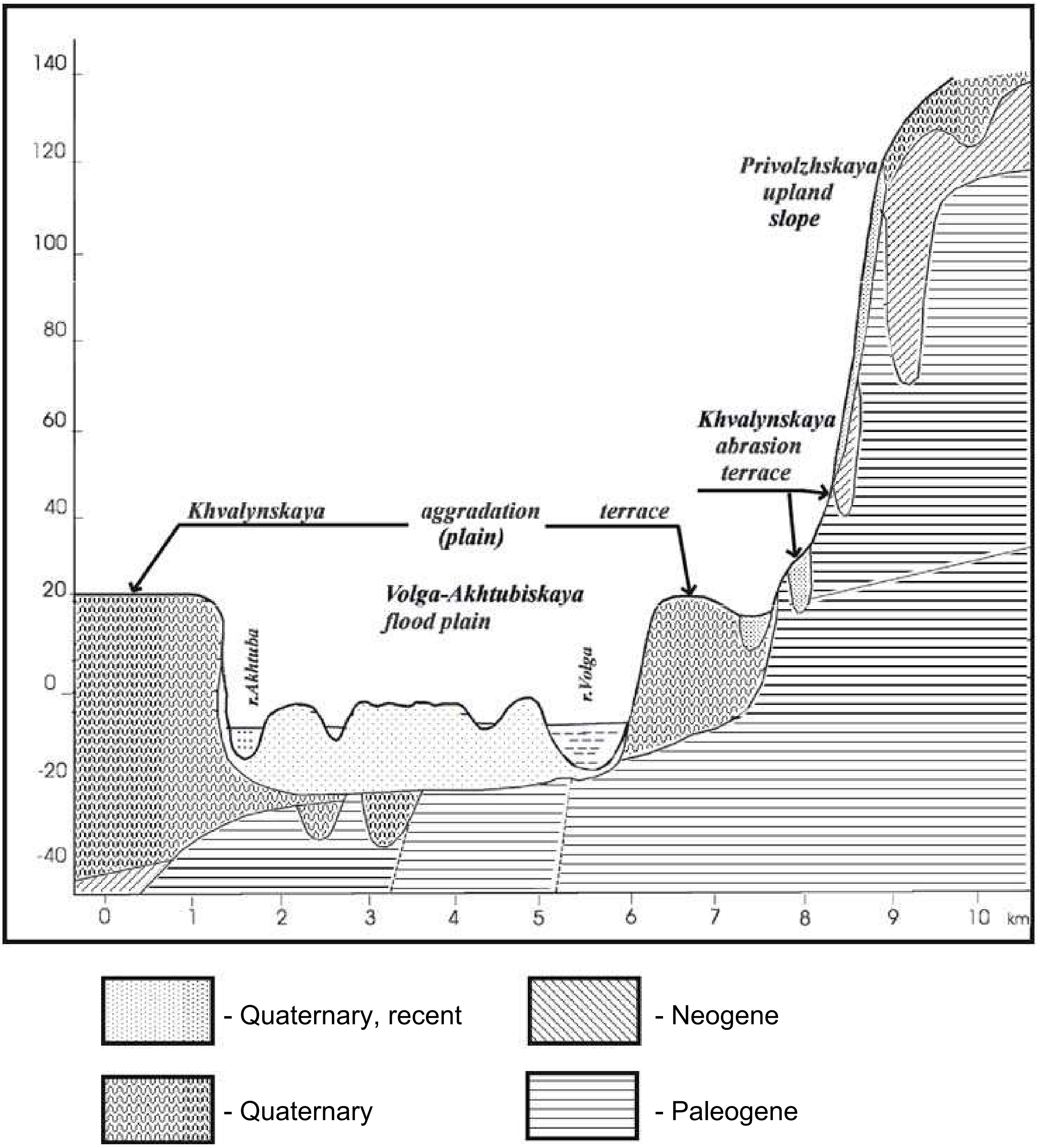


Figure 2. Geological cross-section across the Volga Valley

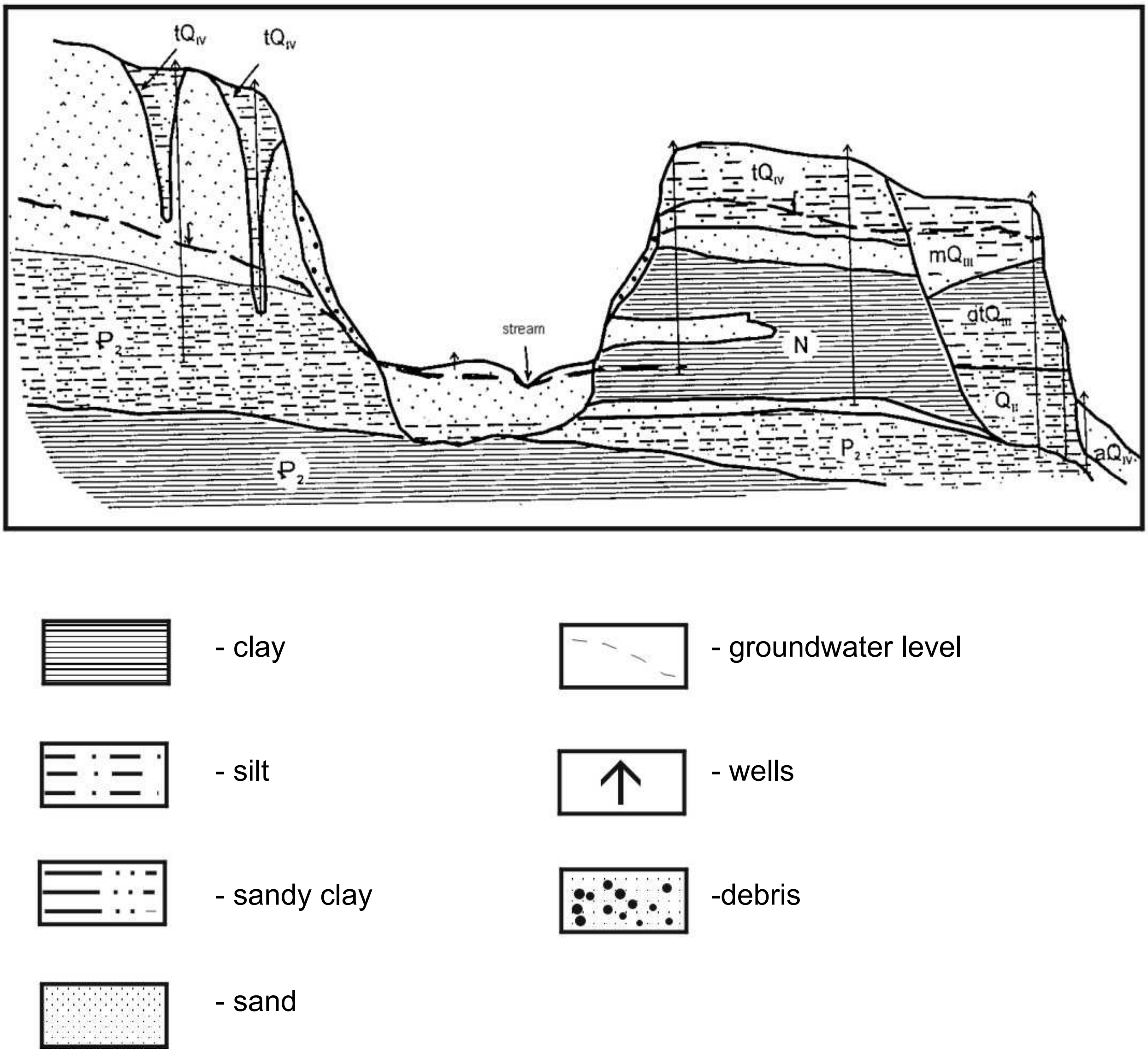


Figure 3. Hydrogeological cross-section across the Mokraya Mechetka valley

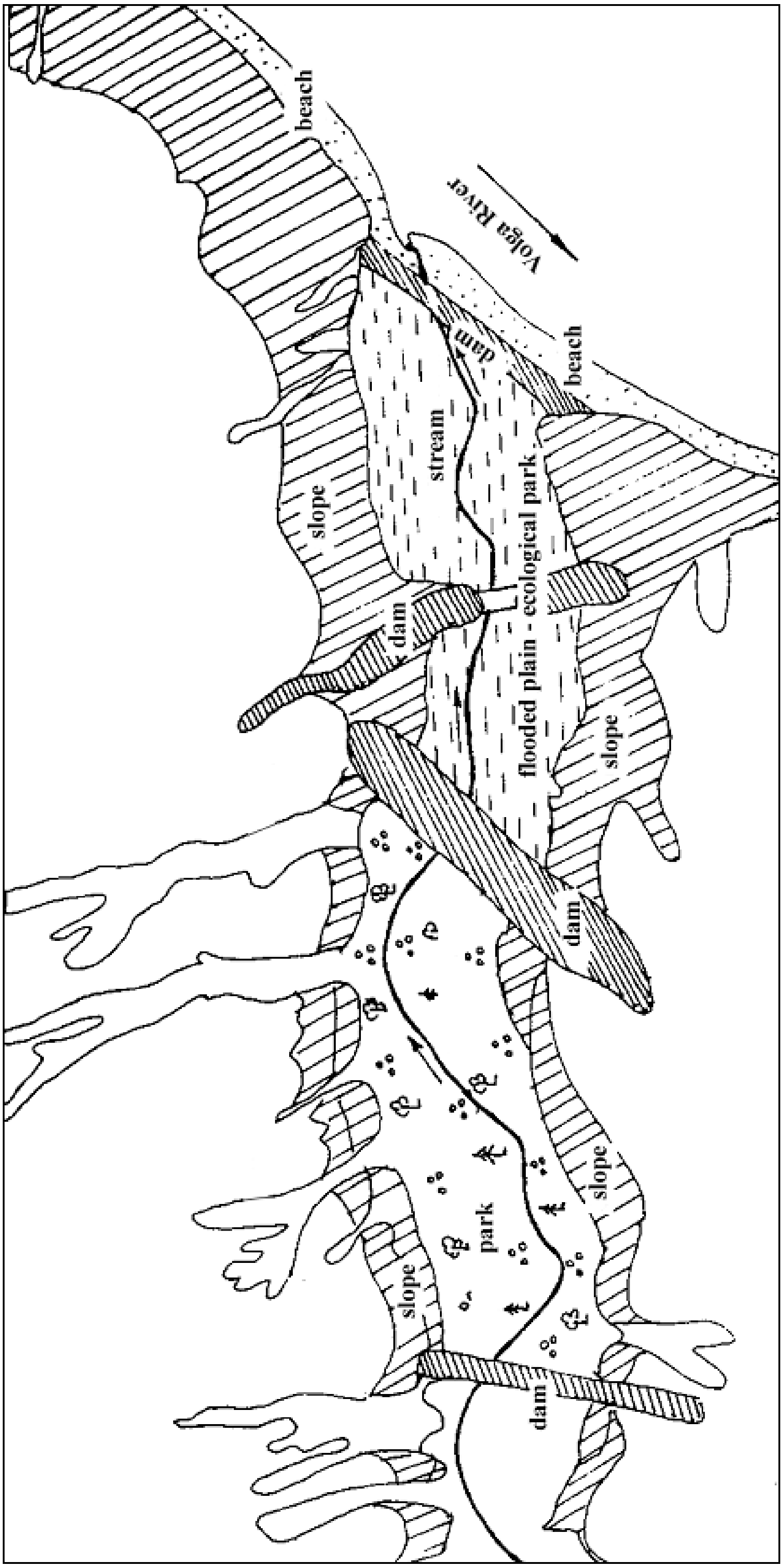


Figure 4. Reclamation program of the Mokraya Mechetka valley