Protection of recovery projects and developed areas from flooding

A Sherov\(^1\) and B Soliev\(^1\)

\(^1\)Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

sherov63@mail.ru

Abstract. The article discusses the formulation and solution of scientific, theoretical, and practical problems in the field of land reclamation of irrigated lands in general and, in particular, the protection of land reclamation facilities and the territory of cities and settlements from the effects of groundwater. In the Aral Sea basin, due to the intensive commissioning of new irrigated areas and various types of hydraulic structures (reservoir, village storage, canals, etc.), on a large scale, there is a violation of the natural laws of the regime and balance of groundwater. As a result of the hydrotechnical impact on water resources, the usual “losses” affecting the water balance and runoff, in the initial stage of their formation, cause processes such as flooding and flooding of adjacent territories, excessive wetting of non-irrigated lands and worsen the operation of reclamation projects. The open collector-drainage network existing around the land reclamation projects and cities does not provide a normal outflow of groundwater; its maintenance into a working and sanitary state requires large capital expenditures. High groundwater level with high salinity leads to the destruction of the basement of buildings and structures, the complete flooding of groundwater communications, the death of green spaces. According to some available data, losses incurred from exposure to aggressive groundwater in a number of cities in Uzbekistan range from 2.5 to 10 million dollars. The objects of reclamation control are established depending on the main factor determining the reclamation state of irrigated lands, on the degree of their natural drained. Essential criteria for determining the relationship of groundwater with soil – soils and their influence on the reclamation state of irrigated lands are the depth of groundwater table and the degree of mineralization, as well as their seasonal and long-term regime. The presented dissertation is devoted to the study of this insufficiently solved problem. Scientific and technical solutions to this problem are considered on the example of the built-up areas of irrigated areas of the Republic of Uzbekistan, where there are problems of engineering protection from the negative effects of groundwater.

1. Introduction

Environmental protection and rational use of water and land resources are the important scientific and practical tasks of land reclamation in the world. In this regard, the development of preventive and protective measures against flooding of reclamation facilities, cities, and towns located in the irrigated agriculture zone is of particular importance. In these areas, in developed countries, including the USA, Russia, Germany, the Netherlands, China, Italy, Japan, and other countries, due to the increase in infiltration processes, special attention has been paid to the prevention and maintenance of land reclamation systems under conditions of manifestation on irrigated lands soil degradation processes, violation of the natural regime of groundwater, salinization, shale, deterioration of soil physical
properties [2]. Particular attention in the world is paid to focus scientific and practical problems of solving land reclamation problems, high-quality design of improved engineering protection systems, taking into account reliable and highly effective technologies for the development of engineering protective measures to reduce the impact of groundwater [7]. In this regard, one of the important tasks is the development of new methods and technologies for protection against flooding, taking into account the use of engineering protection systems and land reclamation measures to improve the reclamation state of urban areas.

Currently, extensive studies are being conducted in the Republic of Uzbekistan aimed at studying the factors of the formation of groundwater flows on irrigated lands, including reducing their levels through the improvement of reclamation systems, to create and carry out the design of new drainage devices. The list of studies in this work includes solving land reclamation and drainage problems, studying waterlogging processes, assessing the reclamation state of urban areas, identifying areas of “technogenic” infiltration water flows, intercepting these flows from irrigated lands, large main canals, collecting, discharging and reusing them. The main attention is given to drainage systems, with the help of which the necessary reduction in water supply, the collection of water of irrigation origin, and the use of groundwater for the development of the region's economy in dry periods occur [2]. It is known that the main reason for flooding is the influence of water facilities on the environment, changes in the ecological balance as a result of human activities. As a result, more than 200 cities and towns, out of 7322 cultural and historical sites, 2050, or 28% of the Republic are under the negative influence of flooding [3].

Currently, for different geofiltration conditions for the formation of a new technogenic regime and balance, according to the composition of the structure of aquifers, scientific research on the development of methods for predicting flooding and flooding is carried out in research centers and higher educational institutions abroad, including United States Geology Survey – USGS, ESRI inc. (USA), German Research Center for Geosciences (Germany), Advanced Industrial Science and Technology (Japan), Indian Institute of Remote Sensing (India), Academy of Geological Sciences (China), General Directorate of Minerals Research and Exploration Institute of Turkey (Turkey), All-Russian Research Institute of Hydrogeology and Engineering Geology (Russia), Industrial Research Institute for Engineering Surveys in Construction (Russia), Tashkent Institute of Irrigation and Agricultural Mechanization Engineers (TIIAME), Scientific Research Institute of Irrigation and Water Problems (SRIIWP) (Uzbekistan) [5].

As a result of studies conducted in the world on the development of integrated measures for land reclamation, a number of scientific results were obtained, including the development of methods for hydraulic and chemical land reclamation, rationing of moisture and air in the soil pores, including the theoretically skeletal composition of physical land reclamation (American Society of Engineers and Builders, USA). It should be noted that reclamation methods are used throughout the history of mankind [2]. For example, swamps occupy large areas of the lands of Bangladesh and the Netherlands, and methods for draining land have been developed (International Institute of Hydraulic and Environmental Engineers, Netherlands). At the same time, the latest polymeric materials were used to create drainage devices for urban planning (Technical University, Berlin, Germany), the degree of the environmental impact of water facilities based on the criterion of negative impact on land reclamation-hydrogeological conditions of the city territory (Scientific Research Institute of Irrigation and Water problems, Uzbekistan) [2, 3]. Based on these studies, certain results have been achieved in assessing the reclamation state of urban areas.

Currently, in the world to study the natural, reclamation-hydrogeological conditions of the territory of cities, in several priority areas, research is being carried out, including the development of methods for calculating the impact of water management measures on the flooding process, the study of the natural regime of groundwater, based on the assessment of water and salt balance factors that change the general reclamation state, the construction of a map of urban flooding, taking into account their infrastructure, the development of mathematical methods for calculating the forecast of flooding,
assessment of the effectiveness of the drainage, measures to prevent flooding and to create modern and advanced protective structures.

In Central Asia authors I.P. Aidarov, V.A. Baron, F.E. Rubinova, K.M. Aripov, N.N. Khadzhibaev, A.V. Lebedev, S.Sh. Mirzaev, F.M. Rakhimbaev, N.I. Parfenova, N.M. Umarov, B.D. Abdullaev, E.V. Mavlyanov, A.S. Khasanov, L.Z. Sherfedinov, Ya.U. Isamuhammedov and others studied the changes in the natural regime of groundwater as a factor in changing the overall reclamation state and certain results were achieved. Initial reclamation studies of the water balance are summarized in the works of N.A. Kenesarina, M.M. Krylova, A.A. Azizova, R. Alimova, H.A. Akhmedov, M.A. Shmidt, V.V. Poslavsky, D.M. Katz, A.A. Rachinsky, B.S. Serikbayev, N.M. Reshetkina, A.R. Ramazonova, A.T. Salokhidinova, M.Kh. Khamidova, R.K. Ikramova, E.K. Kurbanbaeva, E. Zh. Makhmudov, Kh.I. Yakubov, M.O. Yakubov, etc. scientific works, much attention is paid to the reasons for the rise in groundwater levels, at the same time, their influence on the processes of formation of flooding and secondary salinization of land [4; 5]. In this regard, regional studies on the prevention of flooding and secondary salinization were performed on 46 sites in the laboratories of the State Enterprise Institute of Hydrogeology and Engineering Geology HYDROINGEO, Tashkent National University, in more detail in 20 cities and towns in TIIAME and scientific research laboratories of SRIIWP. The results of the research were the solution of the theoretical problems of the causes and factors of flooding, the forecast for assessing the increase in the GWL lifting standards by modeling methods, and also the effectiveness of existing drainage systems was determined within urban areas [6; 7; 8].

Determining the places of flooding taking into account the city’s infrastructure on the map requires a lot of time and money. For this reason, the specialists of the State Unitary Enterprise: Yu.D. Magrupov, B.R. Zhuraev, G.I. Khadzhibaeva, A.B. Primov, Sh.N. Yusupov, A.T. Abdreimov (Uzbekistan) Eijkelkamp Soil & Water (Netherlands) N.I.rosimovich-Ivelin, N. Peters, Jos von Asmus, Leon von Hamersveld, Alfred Getenbeek, R. Rudolph, Erwin Wonk (Sweden) developed a program for automatic calculation of water balance (IAS MPV-1733) for the city of Urgench based on planned modeling in on-line mode and obtained important results. According to the results, one of the causes of flooding is the scale of water management that had a noticeable negative impact on the reclamation-hydrogeological and engineering-geological conditions of irrigated lands and a negative impact on the environment: the rise of groundwater, the salt composition of groundwater and flooding of urban areas and settlements. At present, in the Republic of Uzbekistan, one of the main causes of flooding of urban lands is the cultivation on adyrs and pebble-covered lands of hygrophilous crops - cotton, alfalfa, corn, etc. - for which high irrigation rates are applied during the growing season, most of which go for deep filtering and subsequent pinching out to the lower located built-up urban areas.

Employees of the SRIIWP NGO (currently SRIIWP) T.U. Bekmuratov, A.U. Usmanov, V.A. Umarov, A. Ganiev based on many years of field studies evaluated the direction of reclamation processes, the degree of drainage of the lands of Ferghana, Andijan, and Namangan regions. The development and irrigation of adyrs and pebble lands, their irrigation negatively affects the productivity of the downstream lands, worsening their reclamation condition. Significant losses of a large volume of irrigation water for depth filtration, combined with an imperfect irrigation technique, undoubtedly contribute to the flooding of the underlying territories. In this regard, at present, the study of these tasks to achieve economic efficiency and the use of drainage systems is comprehensive: protection of built-up areas, collection of industrial water, lowering water supply, full consideration of the possibility of using groundwater. In this regard, at present, the study of these problems makes it possible to make up the solution to the problems of protecting land reclamation projects and land reclamation of built-up territories.

The research objective is the development of methods and technologies for solving the prevention and protection of flooded land reclamation facilities and territories of cities and settlements, identifying the causes of flooding and eliminating the effects of groundwater infiltration and the use of perfect drainage structures.

Research objectives include:
Study of natural and anthropogenic factors in the formation of flooding processes and related negative phenomena;

Improvement of mathematical methods for predicting the groundwater level regime at land reclamation facilities and territories of cities and towns.

Development of a method of zoning the territories of cities and settlements according to the conditions of flooding, depending on the natural and economic and hydrogeological conditions;

Assessment of the reclamation efficiency of existing vertical drainage wells (SVD) at research facilities;

Development of the design of new types of drainage: combined, mine and absorption wells, the possibilities and conditions for their use.

2. Methods
In the research process, an assessment of the reclamation state of cities was used, based on the analytical processing of field experimental research data, system and logical analysis, zoning theory, statistical processing of experimental results, methods of mathematical and hydrodynamic modeling, as well as the application of component methods (simplification) in their design:

based on the application of research methods for the water, natural and hydrogeological conditions of cities and settlements, by assessing the reclamation state, prevention measures and engineering protection methods against flooding have been developed;

methods for mathematical calculations of predicting the groundwater level regime in cities and towns under conditions of a waterproof horizon lying close to the earth’s surface have been improved, and a mathematical model of the process of exchanging water vapor with air in the aeration zone has been compiled [9; 10.];

Improved in the cities of Kokand, Rishtan, and Ferghana to design a vertical drainage option: a shallow “shallow” combined with “deep” drainage;

recommendations were developed on the use of mine wells in the Lagansky massif of the Ferghana region, and the city of Gulistan - absorbing wells.

3. Results and Discussion
To solve the theoretical problems of the flooding process, the multi-year and seasonal water treatment regimes were conventionally divided into three phases: local water recovery, the formation of inflow of irrigation water from large areas and water logging of land reclamation projects and urban areas, as a result of the water supply [11; 12].

Almost the second and third phases, these are the phases of flooding: the rise and the close proximity of the water surface to the surface in a stationary state. As a criterion for a potential flooded zone (territory), the ratio of the layer of complete saturation of the aeration zone to the depth of the water level at the end of the fall is taken:

\[ K_n = \frac{A + h}{h_{a}} \]

(1)

Where:

\( h_{a} \) is zone of saturation of capillary moisture to the maximum moisture capacity, m;

\( h_{a} \) is aeration zone, moisture transit layer from the critical boundary to the earth’s surface, a variable moisture-air sphere.

In Figure 1 Changes in the parameters of the seasonal regime of GL are shown.
Figure 1. Scheme of changes in the quantitative indicators of the seasonal regime of groundwater in the conditions of flooding.

The graph shows that the depth in the first phase \(H_1 > H_{kr}\) (1–5 months) is not a state of flooding, because the water level is below the critical level \((h_{cr} > 3\, \text{m})\) and the preliminary state will be expressed:

\[
H_1 = h + h_i
\]  
\(2\)

Where:
- \(H_1\) is the height of the layer of flooding and saturation, m
- \(h_i\) is the thickness of the surface of the earth, m

A dense cover layer of soil for land improvement projects or in urban conditions occupies a large area (asphalt, buildings, structures), which are not permeable and limit the evaporation process and do not allow moisture and atmospheric water to pass, as a result of the rise of water supply, the second phase begins (with increasing air temperature) \(H_2 < h_{cr}\) (Figure. 1; 6–9 months), the air – capillary zone is displaced by drops of moisture and a saturated aeration zone is formed, and capillary saturation is observed for a short period [13, 14]. After vegetative irrigation, an increase in the water level occurs, i.e. during flooding, there is a process of transition from the first to the second phase, i.e., full saturation to the maximum moisture capacity of the entire aeration zone to the earth's surface and \(H_2 = h\), that is:

\[
H_2 = A + h_{zsc}
\]  
\(3\)

To solve the problems of flood forecasting, long-term changes in the mode of average annual levels have been studied associated with the period of the transition from the first phase to the second associated with the rise in the water level from \(H_{max}\) to \(H_{min}\), which is characterized by the amplitude of groundwater fluctuations over the year:

\[
A = H_1 - H_2 = H_{max} - H_{min}
\]  
\(4\)

At the beginning of the flooding in the aeration zone, the change in the maximum depth \(H_1\) to the minimum \(H_2\) is equal to the height of saturation. Therefore, by dividing the graph of the oscillations of the GWW into parts, then set the boundary parameters, we can determine the period of occurrence of flooding:

\[
H_1 = A + h_{zsc} + h_{zsc} = A + h
\]  
\(5\)

With the approach of the water surface to the surface in the absence of a surface coating, the parameters \(h_i = h_i + h_e = 0\), this increases the evaporation of moisture, occupying the pores of the soil-air vapor [15, 16]. During irrigation, the reverse process occurs, the pores are filled with water.
droplets, then the GL rises higher than the critical depth, $H_2 = H_{\text{min}}$. For urban lands in the formula (1), the coefficient of potential flooding $K_n$ is determined by the following dependence:

$$K_n = \frac{A + h}{h_{cr}}$$

(6)

Where:

- $h_{cr}$ is a critical groundwater depth is recommended (1.5–2.0 m for irrigated lands, 2.5–5 m for cities and regional centers; 5–12 m for land reclamation projects).

By quantitative indicators, for zoning purposes, depending on the range of $K_n$ values, the degree of flooding of certain territories is established: for $K_n > 1$, the areas are not subject to flooding; $K_n \approx 0 - 1$ - slightly flooded, prone to seasonal flooding; $K_n < 0$ - areas constantly flooded when the water level is higher than the critical depth ($H_2 < 3.5$ m). These indicators depend on the seasonal change in the water level, as well as on the geomorphologic, hydrogeologic and geological conditions of the land.

The procedure for constructing a map model is reduced to a breakdown of the initial set of regionalization objects into certain types, i.e. their classification according to the available set of signs of the location of settlements. Based on the typification of the province and the region (geological), land reclamation construction objects and built-up areas are identified according to the following categories of flooding, the main indicators of which are the depth of the water table: I - not flooded - more than 5 m; II – slightly and moderately flooded - 3-5 m; III - flooded - 1-3 m; IV – highly flooded, less than 1-2 m [17, 18, 19]. In the developed map of scale M 1: 2500000, typical schemes of eight geomorphologic regions are compiled, within which protected objects and built-up areas are located, as models of environmental conditions, they are affected by water management measures: District I: 1 a – removal cone; 1 b – foothill plain; II district: 2 in – dividing massif; 2d – closed and semi-closed troughs; III district: 3 d – alluvial terraces, etc. According to the proposed typification, irrigated lands and built-up territories are located in identical geomorphologic conditions - on river flow cones, on alluvial river terraces (of different ages and lithological structures), etc. The analysis of the results of incoming articles of the water balance of the flooded territories of settlements and typical objects, by applying the method of expert assessments, made it possible to establish the presence of three main factors that most affect the formation of the process of flooding of the studied areas.

The first factor. As a result of the infiltration of water from irrigated lands, which has strong ties with all the analyzed characteristics, it is interpreted as the main factor “the influence of the regional inclination of the earth’s surface on the formation of the process of land flooding and salinization as a result of runoff of infiltration waters”. They can be considered regional flows of “irrigation groundwater” (IGW) and which is equal to an average load of 63.2%. The input factors of this type account for up to 91% (Turtkul) of the horizontal flow of the total variance of balance items.

The second factor is these are “local causes” of the flooding process, in the zone of irrigation influence, in urban conditions from losses due to filtration from irrigation and municipal wastewater, it forms groundwater and with vertical flowing “from top to bottom”.

The typification of cities and settlements according to flooding factors is presented in table 1.

| Area | Index | Hydro geological zone | The number of settlements in the zone / specific gravity, % | The total area of the city or n.p., ha | Volume of income items, mln. m³ / year | Infiltration m³/ha/year | Factor loadings |
|------|-------|-----------------------|--------------------------------------------------------|--------------------------------------|----------------------------------------|------------------------|----------------|
| I A  | Stem cones | Kokand. 2500 Pakhtakor. 300 | 9/6.4 | 34.33 | 13732 | 5.24 | 25.3 | 69.5 |
| I B  | Foothill plains | 26/18.6 | 3.292 | 10973 | 44.78 | 39.8 | 5.32 |
For example, the share of groundwater inflow into the territory of Pakhtakor is 39.8%. Similarly, as a result of anthropogenic factors, on the Lagan massif, starting in 1983, the GL from a depth of 20 meters rose almost to the surface of the earth. The depths of the groundwater cover for the 30th year of observations at the experimental site were completely subordinate to the irrigation regime, in the zone of command of the sprinkler and the water canal channel, they had values of 1÷2 m, with a distance of 2÷3 from the central part of the channel and 3 ÷ 4 m from the periphery of the experimental section [20].

The calculations were made according to the computer program "Statistics" and the following results were obtained:

\[ R = -0.8183 \] correlation coefficient; \( N_{byn} \) are the billing year numbers;

\( n = 20, 16, 14 \) etc. the depth of the groundwater table.

The correlation dependence of the depths of the GWG over the years has the form (Figure 2)

Mark: \( GL = 18.2181 - 1.1272 N_{byn} + 4.356, m \) (12).

![Figure 2. Change in the multi-year regime of the groundwater level by well number 586 and at the observation site of the gardening farm "Lagan" of the Ferghana region.](image)

where: 18.2181 and 1.1272 – constant members of the coupling equation; \(- 4.356\)–confidence interval.

The third factor oppositely affects the formation of the process under the influence of pressure water from the underlying horizons. It manifests itself from deep aquifers through "hydrogeological
windows" in the form of local zones of local focal points of overflow. As an example, one can imagine that in the city of Kokand, the underground inflow is equal to 69.5% of the constituent balance of groundwater. An analysis of the values of this factor showed that, up to the Quaternary period, as a result of tectonic dislocations, linear ducts of mountain sais of the Tashkent geological age of the rocks were formed, which were further filled with alluvial deposits of the Sokh period, i.e., younger structural-forming processes. The presence of such a linear dislocation of rocks (under the bed of ancient sais) as a result of erosion allows us to draw the following conclusions: according to the sequence of the geological age, “hydrogeological windows” formed, causes of flooding (factors 1 and 2), paths and layers of groundwater runoff over deep underground canals serve as the main storage for the accumulation of pressure groundwater (3 factors) [17].

If the irrigation supply of groundwater through the aeration zone is schematized by the nature of their supply, distribution, and volume of infiltration water in the planned area, then they are divided into linear and area filtration sources. The duration of the period of formation of the flooding process before mapping from various natural causes and anthropogenic factors is presented in Figure 3.

![Figure 3](image)

**Figure 3.** The duration of the formation of the flooding process from various causes and factor loads:
1 is as a result of runoff of infiltration water;
2 is the vertical overflow "from top to bottom";
3 is the pressure in the underlying layer in the form of local zones of "foci" of overflow "bot-tom-up".

Based on the collected factual material on 140 cities and towns, zoning was carried out in three stages: the first typification of cities and towns by geographic location; the second is based on theoretical materials and the results of field experimental studies of hydrogeological parameters, which made it possible to regionalize into categories of flooded conditions. In the last third stage, a map of the reclamation state of the territory of cities and settlements was developed taking into account the naturally drained irrigated areas on a scale of 1: 2500000 typological zoning.

Methods of protection against flooding are divided into 2 groups:
- Irrigation and drainage (preventive) methods. These are passive methods, for various water management conditions according to the complexity of the formation of flooding, the manifestation of a new technogenic regime is being studied and the balance is being eliminated, their external causes of flooding. They consist of 8 ways: improving the operation and maintenance of the inter-farm and on-farm irrigation network; struggle with filtering from channels and hydraulic structures; strict standardized water use; transition to the trained methods of watering; organization of the catchment and disposal of rain and melt water; construction of barrier drains; creation of forest land improvement zones and zones; replacing moisture-loving crops with less moisture-loving ones.
- Protective drainage (active methods). Various types and designs of drainage structures are used to lower the water level within the city [5].
In conditions of flooding and water scarcity, the main objective of research is the creation of such innovative protective drainage systems that, on the one hand, would intercept the infiltration flow of groundwater from external sources, and secondly, they would serve as an irrigation source or for the city's water supply.

4. Conclusions
Based on the research, the following conclusions are presented:
1. The main causes of flooding, changes in the long-term and average annual levels are established and the following stages of the rise of groundwater and their phases are determined:
   - 1 phase - GL rise from a depth of 15–20 to 5–8 m as a result of changes in the water-salt balance of irrigated areas from the effects of natural and anthropogenic factors in increasing water losses for infiltration over a period of 30 to 45 years;
   - 2 phase - complete saturation of the aeration zone as a result of the merging of infiltration water with groundwater, the GL rise rate for a relatively short period (7-10 years) was from 0.7 to 1.5 m/year and reached a critical depth of 2.5-3 m;
   - 3 phase - flooding of the territory of cities as a whole. UGV from the surface of the earth stabilized at a depth of 0.8 - 2.5 m. The income and expenditure items of the water balance of the territory of cities, due to the operation of KDS and the evaporation mode, are stabilized.
2. As a result of solving the forecast problems of the flooding process, in the conditions of close confinement, a constant exchange of water vapor with air in the aeration zone over large areas has been established, the effect of drainage depends on the impact of pressure water of aquifers: more or less, and with a large decrease in the water level in the central well (8-10 m), a standard of water supply reduction (2.5 -5.0 m) around the drainage is provided within 100-120 m of its radius of influence, based on the relationship between flow and radius influence. The determination results for this relationship gave reliable results.
3. In conditions of water supply and drainage of settlements to divert water outside the city, a land reclamation zoning map on a scale of 1: 2500000 was made, which included the criteria for potential flooding: $K > 1$ - week and unfrozen lands; $K_p = 0-1$ - prone to seasonal flooding; $K_p < 0$ - constantly and heavily flooded territories. These parameters are variables - they depend on the long-term and episodic changes in the GL and UNF, and are also generalized depending on the geomorphological, hydrogeological, and geological-lithological conditions of the built-up territories. The results gave reliable estimates of the reclamation state of urban areas.

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