MINISTRY OF ECONOMY AND FINANCE OF THE REPUBLIC OF UZBEKISTAN

RESULTS OF THE FINAL EXPEDITION ON THE DRIED BED OF THE ARAL SEA

Executive Summary

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EXECUTIVE SUMMARY

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CONTENTS

LIST OF ABBREVIATIONS

UNDP	United Nations Development Programme
GIS	Geographic Information System
OP	Observation Point
IFAS	International Fund for Saving the Aral Sea
SIC ICWC	Scientific-Information Center of the Interstate Commission for Water Coordination of Central Asia
GPS	A device, a satellite navigation system that provides distance, time and location measurements in the WGS worldwide coordinate system.
GTZ	German Technical Cooperation (GTZ)

INTRODUCTION

This study was carried out within the framework of the UNDP Joint Programme: “Empowering Youth towards a Brighter Future through Green and Innovative Development of the Aral Sea Region” with financial support from the UN Multi-Partner Human Security Trust Fund for the Aral Sea Region in Uzbekistan.

The area of the dried seabed of Uzbekistan is 3 million hectares. UNDP supported two scientific expeditions to the dried bed of the Aral Sea covering an area of 1.2 million hectares in 2019-2020.

The next 2 expeditions to the dried seabed were implemented in two phases: in May and September 2023. This enabled the completion of a full study of the remaining 1.5 million ha of the dried seabed.

The project objective is to organize monitoring to identify the condition of the Amu Darya River delta and the dried bottom of the Aral Sea through space surveillance and ground expeditions to assess changes in the sea and the Aral Sea region to improve the ecological condition and efficient use of water supplied.

In addition, monitoring will allow to identify surface transformation, exclude (or add) areas subject to radical improvement of natural

Figure 1: Overview of the dried bottom of the Aral Sea, 4th expedition.

Figure 2: Review of expedition routes.

Figure 3: Dried bed of the Aral Sea.

conditions with the help of vegetation, which will contribute to the improvement of water regime – phytomelioration[1].

Based on expeditionary surveys of a comprehensive nature, including soil, hydrological studies, survey and geobotanical description of plant cover taking into account satellite imagery data, there was:

- identified risk zones and unstable ecological zones on the dried bed of the Aral Sea to draw up risk maps;
- made soil maps and classification of soils on the dried seabed;
- conducted scientific research and field studies on forest vegetation states. This was conducted based on the collected data and GIS maps developed using GPS;
- determined the methods of retrospective analysis of satellite images and thematic territorial GIS maps were prepared;
- compared changes in landscape classes and risk zones

Furthermore, monitoring of the dried seabed showed that aside from the disturbance of the natural ecological processes› stability, there is also a human-induced factor linked to anthropogenic activity.

The updated data presented will further help develop recommendations to stabilize the territory.

[1] Phytomelioration is the process of using the natural transformative function of vegetation to optimize terrestrial ecosystems.

MONITORING RESULTS

ORGANIZATION OF THE WORK

The routes taken by the expeditions were determined using space images of the territory. In total, the routes spanned approximately 10,350 km and covered around 2.7 million hectares of land. The teams laid 105 soil sections, performed over 1,500 soil and water analyses, examined 76 wells and boreholes, and provided detailed descriptions of 2,800 surface points.

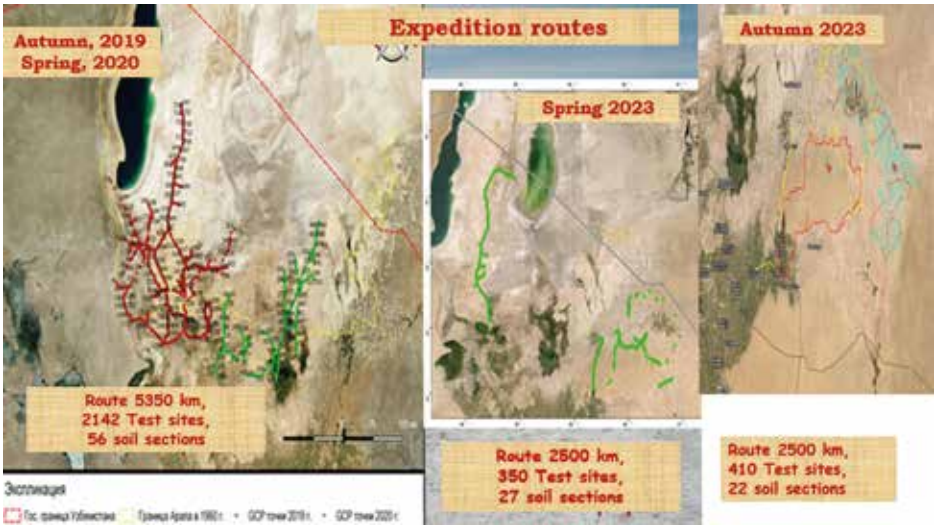

Figure 4: Route maps of 4 expeditions.

The hydrogeologists, soil scientists, geobotanists, geographers, forest specialists and ecologists participated in the expedition. The collected samples were processed for research purposes, including laboratory studies.

GEOBOTANICAL RESEARCH

During the field expeditions, the following activities were conducted:

- collection of botanical specimens;
- geobotanical description of vegetation;

Figure 5: Collecting Desert Plant Samples.

Figure 6: Determination of land cover change.

- collection of herbarium specimens and assessment of the states of forming plants;
- identification of conservation plants, changes of dominant species in huge formations or dominant vegetation species and their migration; identification of hotspots cenopopulation[2] of medicinal and useful plant species growing in certain habitats;
- based on more than 2,800 observation points, 90 species of higher plants belonging to 58 genera, 26 families, as well as plant communities determined by the majority of vegetation formations were identified;
- determination of the order of vegetation change during the drying process;
- vegetation-soil complexes, plant associations, formations of dominant plant species depending on their relation to soil salinity were determined;
- It has been established that the area covered by plants on saline soils increases due to natural patterns that determine the replacement of halophilic plants[3] that live in high salinity conditions and are able to survive in particularly harsh climate

[2] Cenopopulation (from the Greek κοινός – "general" and Latin populatio – population) is a collection of individuals of a species within one phytocenosis, occupying a specific habitat.

[3] Halophytic plants are plants that easily adapt to existence on saline soils with high salt tolerance

Figure 7: Kandym plant.

conditions by representatives of psammophilic plants[4] – plants of shifting sands with a developed root system that ensures high survival.

The results of geobotanical studies contribute to a better understanding of the fundamental mechanisms of plant adaptation to stressful environmental factors, as well as the development of a strategy for periodic seeding of prospective forms and species of plants in the area of the dried Aral Sea bed to stabilize the sand-dunes and saline soils.

An approach has been developed for phytoremediation efforts[5] aimed at enhancing the ecosystem and land reclamation. This will be achieved by introducing vegetation into the desiccated regions of the Aral Sea bed, utilizing plant species that are capable of stabilizing the moving sands and saline soils. Additionally, the potential for using plants in this region as a foundational resource for the development of the republic's pharmaceutical industry has been identified.

[4] Psammophytes are plants of sandy soils (species of saxaul, juzgun, ephedra, astragalus, sand acacia, holly willow, willow, and Caspian willow). Psammophytes are widely used for artificial fixation and afforestation of shifting sands.

[5] Phytomelioration work is a system of measures to improve natural conditions through the regulated use of communities, the creation of pasture protective forest belts, curtain plantings, grass sowing, etc.

HYDROGEOLOGICAL RESEARCH

The objects of the study were the basins of free-flow water of the Right Bank Nizhneamudarya deposit and pressurized groundwater of the South Aral artesian basin, and the groundwater sites and areas within the desiccated portion of the Aral Sea that have been impacted by human activities. In particular, two hydrogeological sections were observed. These Sudochye-Adzhibay site (19 wells, 9 observation points NP), Aral-Bozgul site (28 wells, 17 NP), as well as 29 tube wells and dug wells in the Kyzylkum pasture zone.

The task was to monitor the state of groundwater in order to study patterns of changes in level, chemical composition and conditions affecting their regime as a result of a decrease in the level of the Aral Sea.

In particular, the following were identified and implemented:

- The depth of groundwater occurrence varies from 0.5 to 10 and more meters in space, which is related to the natural or currently acquired relief of the seabed, as well as to the depth of occurrence of water-bearing and water-proof horizons.
- The hydrogeological conditions of the drying seabed are dynamic due to the continuing decline of the Aral Sea level and the expansion of the bottom land belts.
- Groundwater mineralization varies from 1.5 – to 100-2 and more g/l. The composition of salts includes sulfates and chlorides.
- The groundwater level regime changes from south to north. With the removal of the reservoirs left after the retreat of the sea towards the modern and inland water bodies, groundwater is gradually approaching the ground surface.
- The groundwater regime is influenced by the state of inland water bodies, these are lakes Sudochye, Dzhiltyrbas, Muynaksky and Rybachiy, watercourses South Karakalpak drainage collector, Akchadarya, Toguzarkan channel, etc. Wells located in the southern part near watercourses and lakes show an increase in water levels ranging from 0.2 to 0.5 meters, accompanied by a decline in water mineralization. Nearer to the current shoreline of the sea, the influence of

discharges diminishes, leading to changes in the groundwater level regime primarily driven by the natural decrease in sea level.

- Groundwater in the Aral Sea region, especially in the western part, is characterized by a high degree of mineralization – from 35 to 75 g/l and higher; the chemical composition of water: chloride, sodium.
- On the territory of Karauzyak district the depth of groundwater level was 0.6 -1.6 m, in Takhtakupyr district – above the ground surface, in Muynak district – 7.7 – 17.5 m.
- The flow rate of wells at self-discharge in Karauzyak district was 0.18 – 2.5 l/s, in Takhtakupyr district – 6.0-7.0 l/s, pumping flow rate of wells was 0.2 – 12.5 l/s at low 5.2 – 17.39 m, specific flow rates were 0.08-1.94 l-s/m.
- Underground waters of the Cretaceous horizon[6] at the depth of 470-490 m. are less brackish and they can be promising for use in irrigation. However, it is recommended to use for drinking water only with the use of desalination station.

In general, the obtained information on the groundwater conditions of the studied territories can be used for making long-term forecasts.

Recommendations:

- to establish a complete database on all water sources and their interrelationships;
- rationally use water from existing self-flowing wells for distant-pasture cattle rearing, forestry, etc.;
- to develop a program of step-by-step equipping self-flowing wells with water regulating devices (gate valves), assigning specific responsible user to oversee wells and establishing a water use regime. At the same time, it is necessary to consider the possibility of using wells only in the spring and summer period;

[6] The Cretaceous aquifer is a source of drinking water.

Figure 8: Measuring groundwater conditions.

Figure 9: Self-flowing well.

- to increase the number of distant-pasture cattle rearing farms with water supply from groundwater by drilling new wells to the Cretaceous aquifer with mineralization of 2-3 g/l;
- to consider the possibility of creating small reservoirs for fish farming under the State forestry agencies for experimental purposes as well as providing incentives for forestry employees;
- to conduct a detailed study of balneological features of thermal waters. To prepare their classification and recommendations on use;
- due to intensive changes in the Aral Sea coastline, it is advisable to extend the Akkala transect towards the sea to study groundwater level and hydrochemical regimes

FOREST GROWING CONDITIONS ON THE SEABED OF THE ARAL SEA

Creation of protective plants that grow in deserts of the Aral Sea region and the drained bottom of the sea is an effective method of combating salt-transfer, fixation of sands, rehabilitation of ecological situation, creation of a stable base for distant pasture cattle breeding.

From 2018 to 2023, forest reclamation work was carried out on the dried bottom of the Aral Sea on an area of 1,730 million

Figure 10: Stop to describe the area.

Figure 11: Saxaul plant.

hectares. The survival rate of new forest crops is uneven and varies depending on the method of planting (airplane, hang glider, agricultural machinery), type of soil, level and mineralization of groundwater, as well as compliance with silvicultural work.

Muynak zone. On slightly and moderately saline soils of 25-30%, the survival rate of forest plantations here is 55-64%. At early plantings of 2018 – 2020, it was observed natural regeneration of saxaul trees.

Forest-forming species – saxaul, tamarisk, solas and calligonum. These trees have an average height of 1.2-1.7 meters, average crown diameter of 0.5-0.8 meters, on those areas where reclamation works have been carried out.

In “Tiger’s tail” area, the 1982-1985 Silvicultural Fund was preserved. There are seedlings of saxaul, tamarisk, astragalus and small-sized saxauls.

Akpetkey zone. The “Akpetkey” zone contains old saxaul trees, which were planted under the joint project of IFAS, GTZ and Forestry Agency of the Republic of Karakalpakstan. Saxaul row planting in some places with application of mechanical protection method. The states of plants with herbs is good, average height 3.5-4 meters, average diameter 2-2.5 meters, there is regeneration between rows. Height 1.5-2 meters, average diameter 0.8-1.2 meters, density 500-800 thousand pieces per 1 ha.

Figure 12: Consolidation of sand dunes.

About 500 thousand hectares of forest reclamation works[7] were carried out under the "Yashyl qoplama" program. Manual and mechanical sowing of saxaul and tamarisk on sandy and sandy loam soil with coquina and small knobbly dunes was carried out. The states of plants are in good condition.

Seeds of saxaul and desert plants were sown by airplane and tractors. The survival rate is 65-70%. No pest infestation of forest plantations was observed during the expedition. There were wild animals such as fox, jackal, wolf, and various birds, even desert eagle.

This means that life exists on the dried bottom of the Aral Sea and new species appear owing to the diversity in flora and fauna. A wildlife preserve has been organized on the territory of the Akpetkey island system.

Pasture territories of Kyzyl Kum. Planting activities are carried out in the territory. However, the survival rate of forest plantations is only up to 20%. This requires the use of various mechanical and aerial sowing technologies for large-scale forest planting works. In the northern area and northeast to the border with Kazakhstan, it is necessary to carry out works for sand-dune stabilization along the Chinese channel (South Karakalpak drainage collector).

The following promising plant species are of great importance for forest reclamation in the dried Aral Sea bed area:

[7] Forest reclamation works are activities, mainly the creation of forest crops and protective forest plantations, one of the types of reclamation.

Figure 13: Black saxaul.

- Black saxaul – Haloxylon aphyllum
- Hispid tamarisk – Tamarix hispida
- Salt cedar – Tamarix ramosissima
- Halostachys belangeriana
- Climacopter – Climacoptera aralensis
- Climacoptera lanata
- Nitrebush – Nitraria schoberi
- Russian box thorn – Lycium ruthenicum
- Saltbush – Atriplex pratovii
- Five-horn smotherweed – Bassia hyssopifolia
- Saltwort – Salsola richteri.

Since 2008, the naturally grown vegetation in the area surveyed by the expedition team has increased by 160 thousand hectares and amounted to 393 thousand hectares in 2020. Such overgrown area allows saving about $170 million for future forest planting works.

Recommendations:

- take measures to combat diseases and pests of desert forests;
- to establish two research stations for laboratory research and ecological risk assessment on the dried Aral Sea bed;
- to conduct large scientific expeditions in spring-autumn period (2 times a year), with an interval of 3-4 years in order to study changes in the state of soil, groundwater, vegetation cover,

as well as to analyze the dynamics of forest plantations by soil types and locations;

- determine areas where it is possible to sow seeds of halophyte[8] and xerophyte[9] plants, taking into account the results of experimental survey work on the resistance of these plants to soil salinity conditions.

SOIL COVER OF THE BOTTOM OF THE ARAL SEA

Very diverse conditions of soil formation are formed on the young territory, which predetermines multidirectional development of the primary soil cover although there is general tendency to desertification.

The exposed bottom sediments are marine, river and mixed genesis sediments. Following the retreat of sea level, primary soil formation processes were immediately emerged on the dried part of the seabed. The study of the soil cover shows that the exposed soils can be considered as intrazonal soils[10] with their specific features.

These features consist in the dynamism and direction of development of the soil-forming process, both in space and time, in the underdevelopment and weak differentiation of the soil profile, and the specificity of the water-salt regime of young soils. The development of soils over time under the influence of changing hydrogeological conditions and arid climate occurs progressively from hydromorphic[11] to automorphic[12]. In closed hollows and lagoons “shors” or otherwise salt marshes[13] are formed.

[8] Halophytic plants are plants that easily adapt to existence on saline soils with high salt tolerance.

[9] Xerophytic plants of dry habitats that can tolerate prolonged drought.

[10] Intrazonal soils are formed under special conditions. They are considered atypical for their natural and climatic region. They are particularly influenced by one or two specific soil formation factors.

[11] Hydromorphic soils are soils formed under the influence of constant capillary moisture as a result of the close occurrence of groundwater.

[12] Automorphic soils are well-drained soils that are not subject to waterlogging due to the influx of ground or surface water.

[13] Salt marshes, also known as “sors” or “shors,” are devoid of vegetation and form at the bottoms of drying salt lakes where highly mineralized soil and groundwater are located close to the surface

Figure 14: Process of soil transects.

Figure 15: Study of soil cover.

In order to study the soil process and classification of soils, 105 soil transects were laid down, genetic horizons were described, samples were taken from each horizon, and chemical and physical properties of soils were determined. A soil map (GIS) was created.

The following varieties of coastal soils have been identified and described: semi-hydromorphic solonchaks, hydromorphic solonchaks, semi-automorphic solonchaks, automorphic solonchaks[14], desert-sandy soils, sands fixed to varying degrees.

There was a significant decrease by 15.1% of hydromorphic salt marshes by 15.1% from 1990 to 2023 due to the aridization process. This increased the automorphic salt marshes by 14.6%, sands by 3.5% and most importantly it increased the desert-sandy soil coverage by 5.7% that demonstrated fertility signs.

The soil properties, especially the surface layers were evaluated and there were identified zones of possible dust and salt transfer. Medium and strong ecological hazard accounts for 47% of the total area. Ecological hazard is associated with a light granulometric composition[15] of soils often ends with the formation of aeolian erosion-accumulative relief.

[14] Semihydromorphic soils formed under conditions of periodic waterlogging by surface or soil-ground waters with signs of gleying. Hydromorphic soils – soils formed under the influence of constant capillary moisture as a result of the close occurrence of groundwater

[15] Particle size distribution – the relative content of particles of various sizes in soil, rock or an artificial mixture (regardless of their chemical or mineralogical composition)

Figure 16: Study of landscape changes on a drained seabed.

Recommendation

When implementing forest reclamation measures, it is necessary to use differentiated approach to soil conditions for selecting crops. As per the research findings, the existing relationship between vegetation and soil allows recommending the step by step development of the drained bottom i.e., starting with planting more salt-tolerant plants before planting woods and shrubs.

RESULTS OF REMOTE SENSING OF THE DRAINED BOTTOM AREA AND PRESENTATION OF CARTOGRAPHIC MATERIALS FOR ENVIRONMENTAL RISK ASSESSMENT

The purpose of the expedition is to collect ground data to obtain information about the state of the environment and vegetation cover of the dried seabed, study plant communities with the study of tree and shrub vegetation, study soil cover, decipher and map the landscapes of the dried Aral Sea bottom using satellite imagery (remote sensing) data.

More than 2800 samples were collected to interpret and map landscapes of the drained bottom of the Aral Sea, determine the ecological risk zones from satellite imagery (remote sensing) data as points for land classification. These points include coordinates,

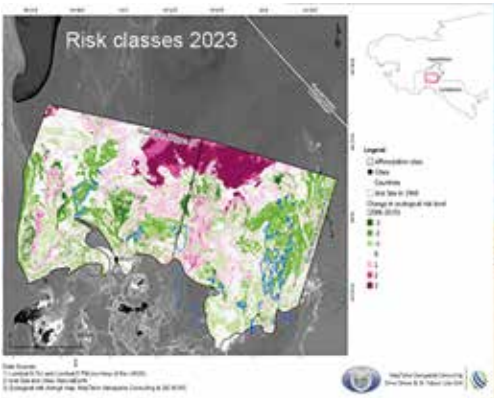

Figure 17: Environmental Risk Map.

Figure 18: Expedition Camp.

vegetation type, dominant species, plant layers, soil morphology and other environmental data.

The Cameral work was conducted in ArcGIS 10.8 program, and all photos were geo-referenced to GPS point coordinates. Interpretation of Landsat 8 OLI satellite images, generalization of field observations of geobotanists, ecologist and soil scientist specialists for each GPS navigation points were carried out to build a map of environmental hazard and assess the direction of processes.

Expeditions from 2019 to 2023 determined that due to self-overgrowth, vegetation covered 10% of the drained bed area.

Conclusion

As a result of expeditions in the field, ground data was collected to obtain information on the state of the environment. Studies covered plant communities, including the distribution of trees and shrubs; the soil cover was examined; and the landscapes of the drained Aral Sea bed were decoded and mapped based on satellite imagery (remote sensing). Based on this, environmental risk maps for the years 2019–2023 were made, facilitating an assessment of the evolving changes in coverage according to risk categories over time.

As part of this study, a methodology was developed based on Earth observation from space to map and quantify the land cover condition in different years. The proposed method is novel in so far as it improves existing mapping strategies in Aralkum by utilizing machine learning algorithms and multi-temporal remote sensing data as inputs.

Based on the tasks set by the Government on the basis of the initiatives of the President Sh.M. Mirziyoyev, the top priority task is to manage the territory of the dried seabed and the Aral Sea area.

Therefore, it is advisable to entrust the Government of Karakalpakstan with general management of the designated territory, ensuring appropriate control over licensing and monitoring activities.

FUTURE ACTIVITIES

For many years a large amount of knowledge, statistical, cartographic, satellite and ground-spatial data on the Aral Sea has been accumulated, and there is a need and opportunity for further use in a systematized approach. In this regard, it is necessary to unite this information and data into an information portal.

To this date, there was:

- conducted 13 complex expeditions
- 2.7 million ha of drained seabed studied.

The results of the study have:

- a practical value and they serve as a basis for decision-making on process management
- scientific novelty – they provide information about unique processes occurring at the present moment which may not happen again in the future.

What have we got?

Full understanding of the object of study

- large amount of data, including satellite images
- methodological basis for environmental risk assessment.
- risk classes.

Objectives of the future

• database.
• interactive map of dried seabed and Aral Sea area condition.
• strategy for studying forest coverage.

For further consideration

Subproject. Creation of the “Geoinformation System” platform**.**

“Drained bottom of the Aral Sea».

Objective – development and creation of “Geoinformation system”

“Drained bottom of the Aral Sea”.

Main objectives:

1. Collection and baseline analysis
2. Development of GIS system structure
3. Creation of the database
4. Development of program interface
5. Creation of a geographic information platform
6. Preparation of a manual for application of the GIS platform
7. Conducting trainings

Rationale:

In the last two decades, a number of research expeditions have been conducted to monitor and study landscape changes on the dried Aral Sea bottom. At the same time, a large amount of knowledge, literary, statistical, cartographic, satellite and ground-spatial data has been accumulated during these years. The collection and systematization of this data requires a special approach for further use. In this regard, it is an urgent task to unify and combine this information and data into a single structure by creating a geo-information portal. In this way, ministries, agencies and other stakeholders will have access to geo-information resources of the Aral Sea for operational review, situation analysis and development of short-, medium– and long-term measures.

The purpose of this geo-information platform “GIS-Aral Sea” is to collect, aggregate, analyze and provide access to spatial data

and materials from previous and current expeditions of SIC ICWC, governmental and other organizations monitoring the results on the state of the Aral Sea and the dried Aral Sea bed.

The main directions are:

- providing a metadata directory for searching geoinformation resources by subject, keywords, location and other criteria;
- automated metadata exchange with other open geoportals;
- providing a software interface and developing principles and methods for rapid visualization of geographic information layers (geoinfographics);
- integration with GIS software packages by integrating the necessary set of scripts for working with the system into geoinformation Internet portals (for instance, Google EarthEngine);
- developing guidelines and organizing trainings on the application of GIS platform.

Research Methodology. The research includes collection and processing of geospatial data, materials and information from internal and external sources. Review of literature, cartographic data.

- field research analysis
- database design and development
- programming

Subproject implementation

The “GIS-Aral Sea” geo-platform is an important and efficient tool for using geoservices (search, visualization, editing, analysis, etc.) and will work as a web portal to access distributed network resources.

The geoportal will serve as a platform to assess the implemented measures to mitigate the consequences of the Aral Sea disaster in the future, which is in line with the concept of environmental protection of the Republic of Uzbekistan until 2030, adopted by the Decree of the President of the Republic of Uzbekistan No. PD-5863 dated October 30, 2019.

Systematized geospatial data are also necessary for the State Forestry Committee to assess the effectiveness of measures to create protective forests “green covers” on the dried Aral Sea bed within three years as part of the approved scope of work and roadmaps by the Resolutions of the Cabinet of Ministers of the Republic of Uzbekistan No. 132 dated 15.02.2019, No. 1031 dated 24.12.2019 and No. 745 dated 25.11.2020. This activity will be implemented by SIC ICWC experts and German company “Map Tailor”

FINDINGS

1. The desiccated seabed is an unstable ecological system that poses a threat to the environment and public health. Therefore, it is necessary to conduct continuous monitoring to understand the actual condition of the desiccated seabed to help make management decisions.

2. Opposite processes take place simultaneously on the dried seabed. On the one hand, there are aridization, desertification, destruction of the surface layer by heavy machinery, aeolian deflation, formation of salt centers. On the other hand, there are the processes of natural growth of plants, and formation of desert sandy soil.

3. Human impact consists of both destructive actions, disturbance of the landscape by subsurface exploration, and intensive afforestation to establish ecological balance.

4. Groundwater and its characteristics determine the ecological state of the dry seabed. A permanent groundwater monitoring system is organized on the dry seabed through a network of monitoring drilled wells and wells dug by hand.

5. Soil cover develops from salt marshes to desert sandy soil with signs of fertility and ecological stability. This is contributed by sowing seeds and planting of vegetation.

6. The change in natural vegetation occurs from migratory to stabilizing, from halophytes growing on wet salt marshes to psammophytes on saline sands.

7. Drained bottom of the sea is a resource base for pharmaceutical development.

8. Observations from space and field measurements of land cover conditions in different years determine the dynamics of the processes. An innovative mapping method and strategy has been developed. There is an ecological hazard map reflecting the real picture of the dried seabed surface.

9. The organization of the Sudochye-Akpetki nature sanctuary was the implementation of the project recommendations based on the results of the expeditions.

Figure 19: Team of the 4th expedition (autumn 2023).

10. In order to collect a large amount of information on the state of the dried Aral Sea bed, it is necessary to structure it, create a database and a geo-information platform that will enable the management of the natural environment of the drained bottom of the sea.