EUROPEAN OPEN SCIENCE SPACE

Section: Geography, Geology and Geodesy

DOI 10.70286/EOSS-15.12.2025.005

NEW SYR DARYA RIVER DELTA IN THE NORTH ARAL SEA: ITS FORMATION AND PERSPECTIVE

Vladimir M. Starodubtsev
DrSci., Prof.
National University of Life and Environmental Sciences f Ukraine

Abstract: The formation history of the new Syr Darya River delta, which is forming in the northern part of the Aral Sea, is examined. The emergence of this relatively new type of river delta is linked to the catastrophic shallowing of the Aral Sea and the decline in its water level, which led to the division of the vast body of water into two unequal parts. It has been noted that a large southern part is subject to drying out and desertification, turning into a man-made desert, which has been given the local name "Aralkum". The northern part, called the Small Aral, receives residual water, solid and salt runoff from the Syr Darya River, gradually forming new relief features and wetlands with rich biodiversity.

Key words: Aral Sea, Syr Darya River, new delta, river flow.

Introduction. In August of the already distant 1986, while studying the soil cover of the modern Syr Darya delta, the author for the first time had the chance to see an empty riverbed of that big river. It was an absolutely astonishing sight. The wide and rather deep riverbed there was completely dry, with only a small stream of some brownish liquid, unlike river water, trickling along the very bottom. A major river that had flowed for centuries, suddenly ceased to exist (at that time, only temporarily). The well-known expression "man-made river" suddenly revealed its horrifying opposite meaning - we had destroyed a great river. Under this impression and thanks to the courage of the driver of our expedition vehicle, we made our way along the right bank of the river through the drying reed swamps to the sea lighthouse, once built at the mouth of the Syr Darya. And there we were met with an equally dramatic sight. The opposite shore of the Aral Sea was right in front of us, separated only by a strip of water a few hundred meters wide. The death throes of the Aral Sea's division into two parts began in the Berg Strait area. Although it continued until 1988, the prospects for the sea and the Syr Darya Delta were already visible. After all, the river's mouth opened onto the northern part of the dividing sea. However, the author of this article was able to trace the subsequent fate of the Syr Darya Delta after 1991 only through remote sensing data, while working in Ukraine.

Research materials and methods. The study focused on the formation of a new type of river delta, which began to emerge in the Small Aral Sea due to the Kokaral Dam dividing the Aral Sea into two parts and directing the Syr Darya River's flow

toward its northern part. The main research method was the analysis of remote sensing data from the region by Landsat (NASA) and Sentinel (ESA) satellites, as well as published results of the Syr Darya River runoff dynamics study in connection with its regulation. The study primarily relied on publications by Kazakh scientists, as well as books and articles written by the author based on previous research in Kazakhstan and Central Asia.

Results and discussion. After initial failed attempts to build an earthen dam and raise the water level in the Small Aral Sea, the Kokaral Dam was completed in 2005 with World Bank support, finally dividing the Aral Sea into the Small and Large Aral Seas [4]. The water level in the Small Sea is maintained at approximately 42 meters above sea level. At the same time, the water flooded the very mouth of the modern Syr Darya delta, which was exposed in the 60-80s due to the rapid decline in sea level. The southern part of the formerly united, enormous reservoir, which had first split in 1987-1988, continued to dry out, become saline, and desertified. The author of this article was able to study this dramatic process up until 1990 [13]. And the northern part (Small Aral) began to receive a catastrophically reduced amount of water, solid and chemical runoff. A new type of wetland has begun to form, which courageous Kazakhstan researchers [1] back in the early 2000s initially called the new Syr Darya “front-delta”. In fact, here, in accordance with the laws of litho-morphogenesis, soil formation and plant successions, a new river delta began to form (Fig. 1), flowing into a water body similar in its regime to dams (reservoirs). Therefore in 2017, we included this object in the list of “new river deltas flowing into regulated water bodies (dams) of the world” [17]. By that time, the author of this article was already working in Kyiv (Ukraine) and was developing the concept of “new river deltas flowing into large reservoirs(dams)” [15 -17] based on the materials of his previous research in Kazakhstan and Central Asia, as well as in Ukraine, using remote sensing materials. In 2018, such a landscape was also named the “new delta” of the Syr Darya [10].

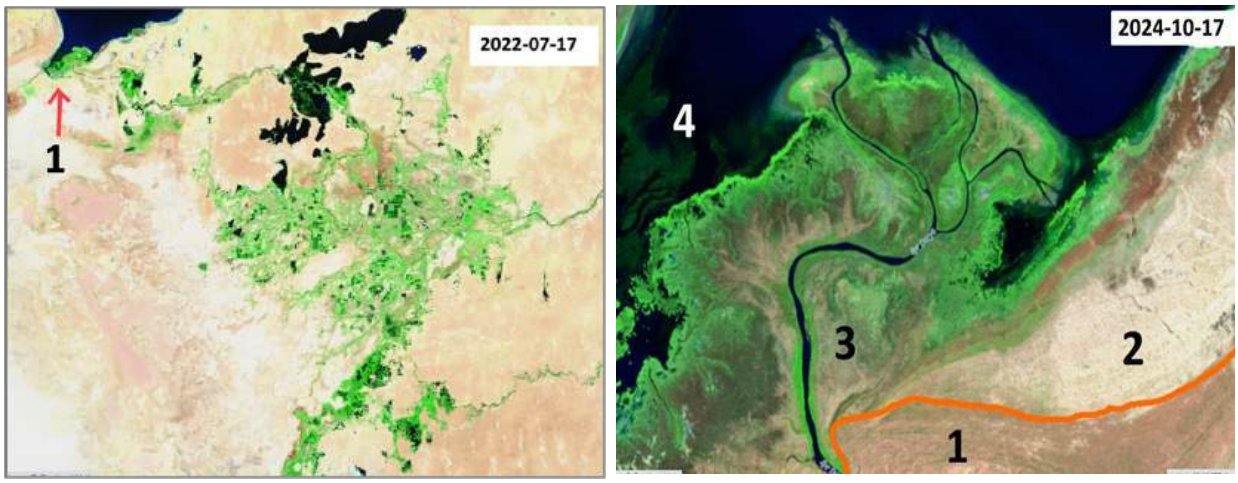

Fig. 1. The modern Syr Darya delta (left) with a new delta forming (indicated by the arrow) and an enlarged image (right) of the new delta: 1 – part of the desertified modern delta, 2 – dried seabed, 3 – landscapes of the new delta, 4 – water surface of the Small Aral Sea. Sentinel-2 (ESA) space images.

What flow of the Syr Darya River forms this emerging new delta? Changes in the hydrological and hydrochemical characteristics of the river flow under the influence of irrigation in its basin from ancient times to the period of modern socio-economic transformations that began in 1991 have been studied by many prominent scientists in Central Asia and the entire Soviet Union [8, 9, etc.]. A brief schematic overview of these changes was made by us earlier [11,12]. In recent decades, this problem has been the subject of a huge number of works by hydrologists, hydrochemists and water management specialists from Kazakhstan and other countries in the Syr Darya basin, as well as foreign countries. A detailed analysis of these publications is not the subject of this short article. We will only note some works related to the issue of the new (modern-?) Syr Darya delta formation [2; 4; 5;18;19 and others].

According to the latest publications, the inflow of the Syr Darya to the delta (Kazalinsk hydropost) in the conditionally natural period (early 60s of the last century) was estimated at 14.3 km^3/year [18]. And by the 1980s it had decreased to 2-4 km3/year in low-water years and to 6-8 km^3/year in high-water years [12]. During the growing season, the flow along the Syr Darya River periodically ceased altogether. This is precisely the situation we observed in August 1986. It should also be noted that the water inflow to the Kazalinsk ("Kazaly") hydrologic station is not equivalent to the inflow into the Aral Sea, as is sometimes incorrectly assumed. After all, the losses of runoff in the modern delta due to the watering of wetlands and irrigated fields of rice systems are not taken into account. This was confirmed by the creation of a additional hydrographic post Karateren closer to the mouth of the river and the hydrometric data obtained there [5]. The author of the article also had the opportunity to observe back in the 1986s how, just before the mouth of the river, the water was directed by a water divider on the riverbed not into the sea, but into depressions in the terrain to irrigate hayfields and pastures. As a result, the actual inflow of water from the Syr Darya into the Aral Sea was lower than declared. Overall, data on the Syr Darya's lower reaches published in regional scientific literature since 1991 varies greatly and requires comparison. The prevailing information is that from 3.5 to 10.1 cubic km of water flowed to the head of the modern delta (Kazalinsk) between 1993 and 2018, depending on the year's water content and releases from reservoirs. And to the mouth part of the channel (Karateren) - from 2.1 to 9.2 cubic km, respectively [5]. The smallest inflow was recorded in 2022 - 0.82 km^3 [6]

The most important indicator for the formation of a new delta and its relief is the solid runoff and the dynamics of its flow into the lower reaches. It is the influx of sediments that primarily determines the intensity of litho-morphogenesis processes during the formation of riverbed ridges and the cellular relief of the delta. And together with vegetation, it forms the soil cover, penetrating the alluvial deposits with its roots, enriching the resulting soils with organic matter, creating a layered profile of such soils, consisting in the early stages of alternating layers of silt and dying roots and plant remains of varying degrees of decomposition and humification. However, the rate and intensity of the vertical profile formation in such soils of the new Syr Darya delta is

low compared to the ancient and modern deltas due to the small amount of mineral sediments brought by the residual flow of the river. After all, if between the Tyumen-Aryk and Kazalinsk hydroposts, due to the deposition of solid runoff in reservoirs and fields, the accumulation of sediments even over the period from the 60s to the 70s decreased from 3.1 million tons to 0.4 million tons/year [12], then it can be assumed that at the Karateren hydropost it is even less by now (at this last hydropost on the river there is no data on suspended sediments). In general, the formation of the soil cover of the new delta differs from the scheme developed earlier by Karazhanov K.D. [3] based on the materials of studies of the ancient delta of the Syr Darya by the significantly smaller role of flood inundations in litho-morphogenesis (Fig. 2 - 4).

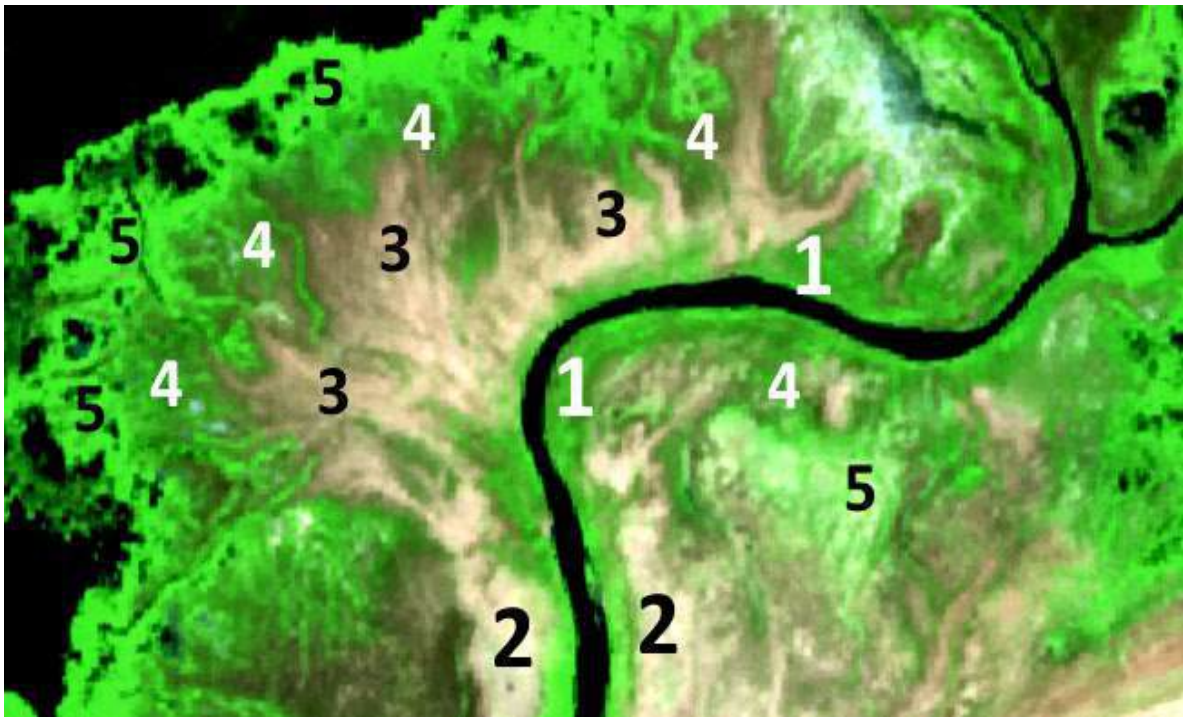

Fig. 2. Formation of the floodplain (1), first-order (2) and second-order (3) riverbanks (levees), bog-meadow soils (4) and subaqueous soils (5).

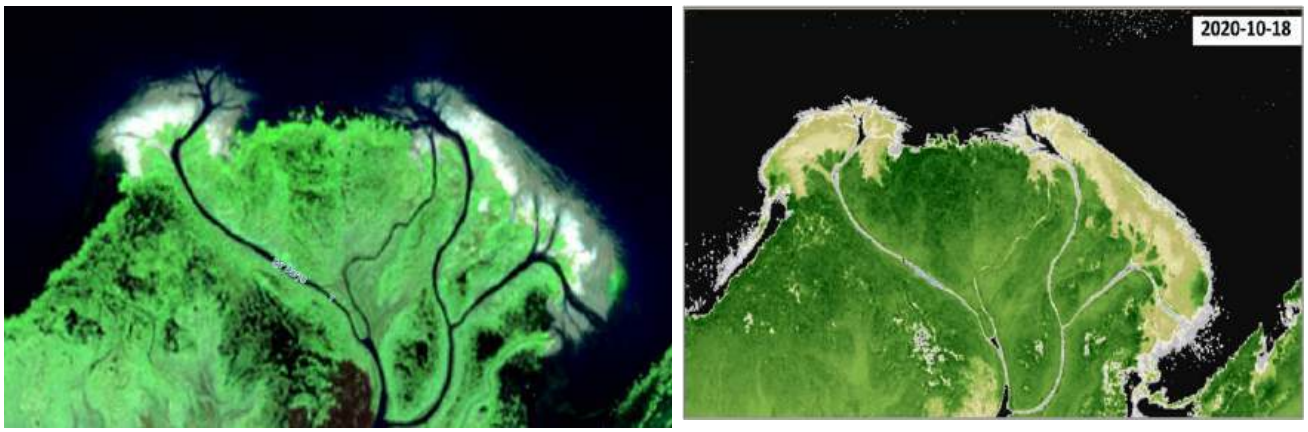

Fig. 3. Formation of new silt deposits (left) and their overgrowth with meadow vegetation (right).

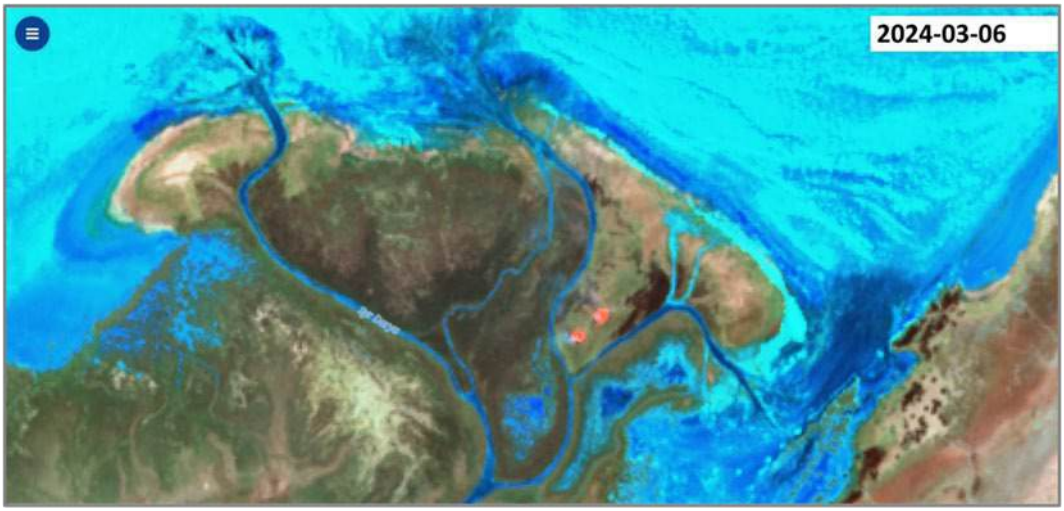

Fig. 4. View of the new delta after the death of coastal aquatic vegetation in winter.

The mineralization of the river water flowing into the Small Aral is also important for the formation of a new delta. At the beginning of the 20th century, the water of the Syr Darya River had a mineralization from 250 mg/l in the upper reaches to 500-600 g/l in the lower reaches and was distinguished mainly by its hydrocarbonate-calcium composition. In the following decades, the water mineralization in the upper reaches (Uchkurgan gage station) changed little. After the Syr Darya entered the Fergana Valley, its water was diverted for irrigation, and the return flow increased, exceeding 10 km³/year in the 1980s. As a result, the mineralization of water began to increase and the maximum values in the Fergana Valley near the Kal hydropost in the 1980s reached 1200-1400 mg/l, and near the Akjar hydropost – 1600-1800 mg/l (Starodubtsev, 1985). In its middle reaches, the river continued to be enriched with salts coming from the irrigated lands of the Hungry (Golodnaya) Steppe, but was diluted by the low-mineralized waters of the Chirchik, Akhangaran and Keles rivers. Therefore, the annual range of mineralization here was large – from 800-1000 to 1400-1600 mg/L. In the lower reaches of the Syr Darya in the 1980s, average annual mineralization values reached 1500-1700 mg/L at the Tyumen-Aryk hydrologic station, and 1700-1800 mg/L at Kazalinsk. The highest individual mineralization values near Kazalinsk exceeded 3000 g/L (Fig. 5). The ionic composition of the river water became sulfate-sodium, and the chloride ion content increased significantly. Since 1991, the use of water for irrigation has decreased and runoff into the delta and the sea has increased. Therefore, its mineralization decreased in the lower reaches – to 1200-1600 g/l. And only at the turn of the year 2000, trends of increasing mineralization of river water began to emerge again, interrupted by releases from the Toktogul reservoir for hydropower purposes [19].

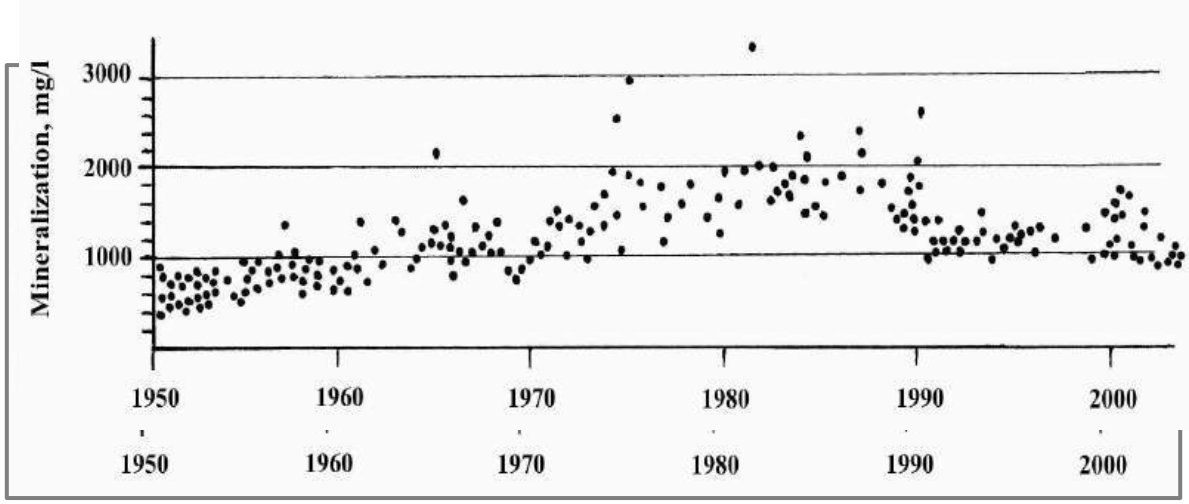

Fig. 5. Mineralization of water in the Syr Darya River in the lower reaches (Kazalinsk g/p) in 1950-2004 (Starodubtsev, 2007), [14].

With such mineralization of river water and an average salinity of the water of the Small Aral of about 10,000 mg/l, the danger of strong salinization of the new delta soils should not be expected, in contrast to the highly saline soils that formed during the retreat of the Large Aral [13, 14]. This is facilitated by the close location of the river mouth and the dam outlet, as a result of which active water exchange is maintained here.

Conclusion. At the confluence of the Syr Darya River and the Small Aral Sea, a new type of delta landscape, typical of large reservoirs, is emerging. The morpho-elements typical of such deltas form slowly due to the small amount of sediment and significant fluctuations in the water level of the reservoir. The area of this delta exceeds 3 thousand hectares, but it is very variable precisely because of the water level regime, especially in extremely high-water and low-water years. The delta is distinguished by significant biodiversity [1, 7], which has been remarkably researched and published by a team of Kazakhstan scientists [1]. At the same time, the delta's ecosystems will undergo significant changes following the completion of the Kokaral Dam reconstruction and a rise in the water level of the Small Sea by approximately 2 meters.

References

1. Bioraznoobraziye vodno-bolotnykh ugodiy avandel'ty reki Syrdar'ya. (2012). Pod redaktsiyey: Ospanova M.O., Stamkulovoy K.Zh. Avtory: Dimeyeva L.A. i dr. (8 chelovek). [Biodiversity of wetlands of the Syr Darya River delta front. Edited by: Ospanova M.O., Stamkulova K.Zh. Authors: Dimeeva L.A. et al. (8 persons)]. Almaty, 2012. - 65 p. (in Russian)
2. Burlibaev M., Murtazin E., Bultekov N. U. (2004). Sostoyanie zagryazneniya okruzhayushchej sredy v Kazakhstane [The state of pollution of the environment in Kazakhstan]. Hydrometeorology and Ecology, - Pp. 192–208. (In Russian)
3. Karazhanov K.D. (1977). Evolyutsiya i transformatsiya pochv sovremennoy del'ty Syrdar'I [Evolution and transformation of soils of the modern Syr Darya delta]. - Izvestiya AN KazSSR. Ser. Biol., 1977, No. 3, pp. 69-72. (In Russian)

4. Micklin P. (2014). Introduction to the Aral Sea and its region. The Aral Sea. Springer Earth System Sciences. Vol. 10178. P. 15–40. https://doi.org/10.1007/978-3-642-02356-9
5. Mustafaev Z. S., Kozykeeva A. T., Sagaev A. A., Alimbaev E. N. (2019). Formirovanie gidrologicheskogo rezhima v nizov′jah reki Syrdarii. [Formation of hydrological regime in the lower reaches of the Syrdarya River]. Questions of Geography and Geoecology, No 3, 2019, 57-67. (In Russian)
6. Narbayeva K., A. Tairov, M. Leman, A. Tolekova, D. Abdibekov. (2025). Assessment of water supply in the Aral-Syrdarya basin based on statistical analysis. Tashkent, 2025, 100-103. https://doi.org/10.5281/zenodo.15458446
7. Resource Characteristics of Common Reed (Phragmites australis) in the Syr Darya Delta, Kazakhstan, by Means of Remote Sensing and Random Forest (2025). / Azim Baibagyssov, Anja Magiera, Niels Thevs, Rainer Waldhardt. Plants. DOI: ZENODO10.3390/plants14060933
8. Rubinova F., Kuropatka L. (1980) Solevoj stok Syrdar'i i ego izmeneniya pod vliyaniem khozyajstvennoj deyatel'nosti [Salt runoff Syr Darya and its changes under the influence of economic activity]. Hydrological Research in Central Asia. – P. 97–10. (In Russian)
9. Shiklomanov I.A. (1979). Antropogennyye izmeneniya vodnosti rek. [Anthropogenic changes in river water content]. L., 1979. 302 p. (In Russian)
10. Shinkarenko S.S., Solodovnikov D.A. (2018). Formirovaniye novoy del'ty Syrdar'i [Formation of a new Syr Darya delta]. Modern problems of remote sensing of the Earth from space. Vol. 15. No. 2. P. 267-271. (in Russian) DOI: 10.21046/2070-7401-2018-15-2-267-271
11. Starodubtsev V.M., Bogachev V.P.(1983). Meliorativnaya otsenka stoka reki Syrdar′I [Reclamation assessment of the drainage of the Syrdarya River]. Soil Science, No12, Moscow. P.90-101. (In Russian)
12. Starodubtsev V.M. (1985). Vliyanie orosheniya na meliorativnye kachestva rechnogo stoka [The impact of irrigation on the meliorative qualities of river runoff]. Nauka Publishing House of the Kazakh SSR. Alma-Ata. 168 p. (In Russian)
13. . Starodubtsev V.M. (1990). Zasoleniye pochvogruntov obsykhayushchego dna Aral'skogo morya u vostochnogo poberezh'ya [Salinization of soils of the drying bottom of the Aral Sea near the eastern coast]. Problems of Desert Development, No. 5. Ashgabat. P.45-50. (In Russian)
14. Starodubtsev V.M., Petrenko L.R. (2007). Soil Desertification in River Deltas. Part II. The Syrdarya River. Kyiv: MAUP Publishers. - 90 p.
15. Starodubtsev V.M., Bogdanets V.A. (2010). Formirovaniye novoy del'ty reki Ili v Kapchagayskom vodokhranilishche. Aridnyye ekosistemy. - t.16. - № 4 (44). - S.49-53 / Starodubtsev V.M., Bogdanets V.A. (2010). Formation of a new delta of the Ili River in the Kapchagay Reservoir. Arid Ecosystems. - Vol.16. - No. 4 (44). - P.49-53. (In Russian)

16. Starodubtsev V.M. (2017a). Formation of new delta-like subject in Kapchagai reservoir of Ili River. Water resources, - V.44, # 1, P.12-15.
17. Starodubtsev V.M. (2017б). New deltaic landscapes formation in large water reservoirs: global aspect. Naukovi dopovidi NUBIP, - № 1(65). 17 c. http://journals.nubip.edu.ua/index.php/Dopovidi/article/view/8107.
18. Tairov A. Z. (2015). Ob izuchenii ionnogo stoka reki Syrdarii v yeye nizhnem techenii. Voprosy geografii i geoekologii, № 1, s. 67-72. / A. Z. Tairov (2015). On the study of the ionic flow of the Syrdarya River in its lower course. Issues of Geography and Geoecology. - No. 67-72. (In Russian)
19. Tairov A.Z., M. Leman, A. Tolekova, D.U. Abdibekov, T.E. Sorokina. (2025). Hydrochemistry and ion flow dynamics of Syr Darya transboundary river within Kazakhstan. News of the National Academy of Sciences of the Republic of Kazakhstan. Series of Geology and Technical sciences, - Vol. 2. 470. Pp. 290–306. https://doi.org/10.32014/2025.2518-170X.456

ВИКОРИСТАННЯ GNSS-ТЕХНОЛОГІЙ У МОДЕРНІЗАЦІЇ ВИЩІЙ ГЕОДЕЗІЇ ТА ІНЖЕНЕРНИХ ВИШУКУВАННЯХ

Доброходова Ольга
канд. техн. наук, доцент
Кириленко Аліна
здобувачка
Кафедра земельного адміністрування та геоінформаційних систем
Харківський національний університет міського господарства
ім. О. М. Бекетова, Україна

Анотація. У статті висвітлено роль GNSS-технологій у сучасній вищій геодезії, зокрема в побудові та розвитку державних геодезичних мереж [1, 5]. Розглянуто принципи роботи глобальних навігаційних супутникових систем, методи визначення координат, особливості застосування референц-станцій і сервісів мережевих корекцій.

Ключові слова: безпілотні літальні апарати, БПЛА, інженерно-геодезичні вишукування, лінійні споруди, інтеграція з ГІС, Leica Aibot, цифрові моделі рельєфу, ортофотоплани, профілі трас, моніторинг будівництва, нормативно-правове регулювання дронів в Україні, просторові дані, сезонні фактори, технології знімання.

Введення. Глобальні навігаційні супутникові системи забезпечують можливість отримання координат у глобальних системах, що робить їх ключовим елементом сучасної геодезії [5]. На відміну від класичних методів, які