ГЕОДЕЗІЯ

GEODESY

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GEODESIC WORK OPTIMIZATION FOR DETERMINING LIKELY MARKS OF WATER LEVEL IN THE DIFFERENT SYSTEMS OF HEIGHTS

Purpose. There is a need for State leveling network reconstruction through the determination of Reineke – Tenberg mark in BS77 for optimization of geodetic works in marine industry, which will allow determination of BS zero mark in the State Height system BS77 at each water gauge station. The possibility permits the matching of the State Leveling system of the country with leveling systems of the neighboring countries which is expected within framework of fulfilling the UELN project. **Methodology and the results of the work.** By projecting, construction, and reconstruction of the marine industry objects after height system BS77 implementation, several difficulties arose connected with the use of GNSS – technologies, height network, polygonometry, created in BS, as well as marks of interval water levels at gauge stations. The outstanding difficulties as to heights arose by construction of narrow hydrotechnical objects of substantial amounts, considering the marks by contractions are interval water levels. The geodesist M. S. Zvyahina investigated the problem for the first time in 2006, and not hydrologist was employed. Any data on BS77 and even the name of system BS77 itself were absent in the beginning. Therefore, in the port cities the decisions on the values differences between the systems were not considered by the Department of UAGS (all-union astornomo-geodetic society). SE "CHORNOMORNDIPROEKT" as early as 1983 there were average differences throughout GUGK USSR for the many sea ports excluding those, which had differences from UAGS. However, it became necessary to collect the data as to difference in the height marks values of matched lines, changes of values within the time for different terrains, but in BS77. Then it became obvious, that new system did have its zero. The territories of different ports were searched for stability as well as for changes of values within time for the constant subsiding. The tables for approximations for some marksvary 70 years backward and forward. The researched behavior for the outstandingly subsiding territory – is port Poti and its water gauge station. Using the data of the Ukrainian scientist [Marchenko, Yarema, 2006] on the constant rate of rising level of the Black Sea was determined by the satellite altimetry level and average sea level, through the approximation of the marks of the working and control reference marks, matched to the BS as well as to BS77 for Poti area for the selected 2005 year. The level minus 5,6 cm against level 5,4 cm was determined (Fig. 3) out of [Marchenko, Yarema, 2006]. Our research and conclusions as to two different zeros BS and BS77 was confirmed by copying from the Instructions on office processing of measured exceedance data and induction of two groups of adjustments, after which the exceedances remain measured but ready for balancing. BS was implemented when the first group of adjustments was mastered, and BS77 – when both groups were used at the same time. Thus, these two independent systems, the relations between which should be determined by adjustment and gravity affection on the Kronstadt footstock, as well as on each point of the physical surface, in order to secure the transition to BS77, if there is a need to use earlier data and GNSS-technologies. **Academic novelty.** We state the system error as found, which can be easily computed on the Kronstadt footstock through the determination of its quasigeoid mark in BS, which allows the quasigeoid EGG97 to be easily transformed into adopted in Ukraine as well as in other Eastern European countries system *"Baltic 77"*. **Practical meaning**. This question now is very difficult due to the present situation in geodetic management, which except minors, has at all levels not geodesists, but specialist in other fields, which could study only essentials of geodesy. Those bureaucrats cannot insist or prove anything in the field of geodesy. However, until the instructions are not updated, until the BS77 zero appears on graphics, nobody has the right in any industry to change anything in their spheres of activity. If the huge and unnecessary expenses of marine industries where charged the accounts of the said bureaucrats, they could agree to sovereignty of geodetic science. We drew tables of determination of all derived system zeros, it will take SE “CHORNOMORNDIPROEKT” 2–3 years to match all the components, however at the beginning the State Geodetic service should get the funds for reliable determination of $d_{БС}$ for all 27 sea ports on the seacoasts as well as for areas near seaports on the large navigatable rivers (Danube, South Bug, Dnipro). We insist that it was not good to agree as to matching of geodetic and gravity surfaces – average level and quaisgeoid on the exit point (Kronstadt footshock).

Key word: Zero of Baltic 1977, height system, unified zero of sea post, seaport zero.

Introduction

Problem statement

Information on sea level, the average sea level and the depth of the waters, the approaching channels and domestic sea routes in derivative systems heights are based on observations and are necessary for the sea economy complex. They began to be taken simultaneously with the ports founding [DBN V.2.4-3: 2010]. These are systems – a Unified zero sea post (short – unified “zero”), port zero (“0” port) and average levels of sea for decades. These systems can not exist independently and should be matched to the state system of heights [Zvyagina, Kostetska, 2015, The Steering technical material. TsNIIGAiK, 1988] to ensure convertion between the systems and the transition to the next state system once apopted. The interval measurement of the gauge stations levels in the state system heights enables tracing the dynamics of fluctuation, to control reliability of water levels marks, which is important for both commercial activities of the ports, and for scientific analysis of geodynamic processes.

However, the state geodetic service did not provide the link between this law and regulatory framework at the time of introduction of the Baltic System 1977 (BS77) instead of the Baltic (BS) in Ukraine in the beginning of 1970s and has not explained the differences and features of the new system for its use in science and business and educational processes in universities for training of geodesist, hydrologists, hydrometeorologist, oceanographers and others. Even now, the features of BS77 are attributed to the “era” and not to the necessity of determining the BS77 zero on Kronstadt footstock.

We consider it necessary to give a chronology of implementation of Height systems and evaluation of periods of inaccurate or incorrect measurement of water levels at the gauge stations of the coast and the mouth of the great navigable rivers and alignment of such measurement’s results. The transition to the new system was accompanied by a loss of primary measurement data or height data of readout surface that were determined earlier.

The Black and Azov coast gauge stations became operational from 1874 in the local systems heights. In 1946–1949 along all the coast the Baltic state system the heights were introduced. Along with the formation of the state network of I class level lines, the level lines of I or II class were undertaken for vertical positioning to gauge stations.

First class netwrok particulars were the lines, which did not create closed landfills in the south and had a great length. For example, the Lomonosov – Sevastopol Line is 2288 km long, Moscow – Brest – 1136 km, Brest – Odessa – 1064 km. II class level lines were employed to bind gauge stations and end points.

BS marks were attributed to local systems bench marks, zero of gauge stations, which were selected 0.5 meters below the lowest water levels and the top rail, which was used as a bench mark and control of gauge station stability. It made possible to determine the BS marks for interval observations, month averages and annual averages, and minimum and maximum levels. As of 01.01.1961 a unified zero post of the sea was implemented thoughout USSR with a chosen mark minus 5,000 meters in BS , and the levels were defined in centimeters. Without binding on all gauge stations to zero BS, the system could not function.

Task definition

The research results outlined here summarize previously published work [Zvyagina, Kostetska, 2008, 2010, 2013, 2015; Kostetska, Zvyagina, 2013] and offer optimization techniques to geodetic surveys to determine probable water level marks in various systems of heights, including derivatives, for the purposes of marine economy and science.

Purpose

A comprehensive study of the problem allows one to show the ability to define BS zero mark value for each gauge station in the State BS77 Heights System and explore the need for reconstruction of the State height system through determining of value of Reineke – Tenberg mark in BS77.

This will allow taking into account the recommendations of the European subcommittee "International Association of Geodesy (EUREF), namely [Dvulit, Smelyanets, 2014]:

– develop the main basis of heights taking into account the recomendations of EUVN (European United Vertical Network) and EVRS (European Vertical Reference System);

– to link the State network with the leveling networks of neighboring European countries in the framework of the project UELN (United European Leveling Network). The correcting of the height network may involve Poland and the Baltic countries.

There was a need to singularly set the difference of Height systems BS and BS77, and to determine the zero in each of their derivatives in gauge stations, and determine marks in both state systems of all marks of linked traverse of gauge stations levelling I and II classes at the date of the introduction of BS77. There was an urgent need to establish a new regulatory framework and training of specialists, who are to optimize the needs of geodetic science, of marine economy, and supply the users (hydrologists, hydrometeorologists, oceanographers and others) with accurate geodetic data.

It is necessary to align the skewed data of long-term observations of water levels on gauge stations that need to be defined in the derived Height System of **unified zero sea post**, which is notdetermined for gauge stations as per BS77, nor as a zero mark for Kronstadt footstock as per BS77. Moreover within BS77 for the last 39 years it us impossible to estimate at a particular guage station the zero of the other derived system – **zero of the port**, which is used while projecting hydrotechnical infrustructure. There is no answers to questions about long-term average sea levels on the gauge stations either to their value nor to the system heights.

Methods and results of work

The degree of stability of the areas where there was even movement of the earth's surface can be established only after repeated levelling in the state system and comparing the marks obtained.

Hydrotechnical projection is made from port zero, that is from the set average value out of minimal levels. This minimum readout horizon also linked through BS, and through the mark of the upper rail, the mark in the lower part of the rail might be set, which corresponds to the value of port zero. Since the minimal values during the storms are fixed from term obeservations as an average value out of three pairs of readings of wave tops and bottoms, a-priory port zero should be located above the rail's zero provided the rail has the capacity to measure the bottom of the wave. Unfortunately, the different directories on the principle scheme shows the rail's zero mark only 20–30 cm below BS zero.

Since 01.01.1961 p. Hydrometeorologic service of USSR has set for all the seas within USSR territory except for the Aral and Caspian seas, a unified readout horizon at a mark of minus 5,000 m in BS – a unified zero of sea post. The exceptional unified zeros for the Aral and Caspian seas were set as plus 51,494 m and minus 28,000 m respectfully. By this the zeros of gauge stations, which functioned since 1947 in BS, were cancelled in 1961 though the implementation of unifies zero sea post.

The marks of zeros of gauge stations were valuable data to be lost provided the controlled computing of interval levels from local systems and from BS to the system of unified zero while corresponding of this zero to the state system BS7, which were implemented in 1972 in Ukraine. If the term or average level has the mark minus 0,30 m in BS, and the mark 470 in the unified zero system, then the marks minus 0.30 m and 470 cm in BS77 should have altered somehow, and in first step there was a need to obtain reference marks to compute readout surfaces in BS77: "0" of BS, unified "0", "0" ports and computed from local system to BS or set anew in BS an average sea levels at gauge stations for drawing navigation maps.

However, it is not allowed to file the reference marks in the unified zero system to the Catalogue of leveled heights as they are unchecked. At this time the State Authority specialists file such data.

Let us draw in Fig. 1 the chart of dependence of marks of readout surfaces of gauge stations, computed by matching to the State Height network. If a working reference during control leveling (two times a year and after storms) receives a new mark, then the mark in the unified zero system will be changed by the same value, whereas the place of zero in BS and unified zero remains unchanged.

In the article "The Theory of Earth and gravimetry" of Geodesist' Directory, Publishing House Nedra, 1966 B. P. Shymbirev wrote: *ge-potential is a field of gravity. The potential of gravity equals to of potentials of the sum of the force of gravity and centrifugal force.*

To compute geopotential ... is not a possible task now, because we do not know the exact law of density variations in the Earth. Therefore, the task of determining the external geopotential must be solved using methods of mathematical physics.

In the article "Leveling" of the same directory M. E. Piskunov proves that because of the influence of centrifugal force at each setting leveling sighting beam being horizontal, deviates from the original tier surface, causing different angles and heights of points at summaries of the measured exceedances does not make the distance from these points to the starting tiered surface, i.e. does not create a unified system of heights and gives Fig. 3.

The possibility of amending for the unparallel of level surfaces allowed to create the State Baltic system of heights (BS). The concept of creating a single high-altitude network was developed by scientist – geodesist MS Molodenskiy, by which the geodetic height of the whole-earth ellipsoid is

$$H = H^{\gamma} + \xi,$$

whereas H^{γ} – normal height, ξ – a deviance of height, which equals to the height of quasigeoid [Kalinic, 2005].

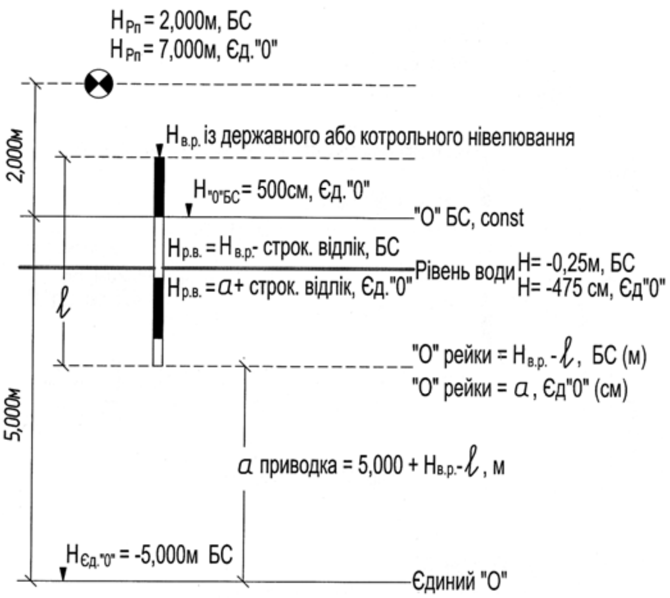

Fig. 1. Chart of networked unified zero in BS system

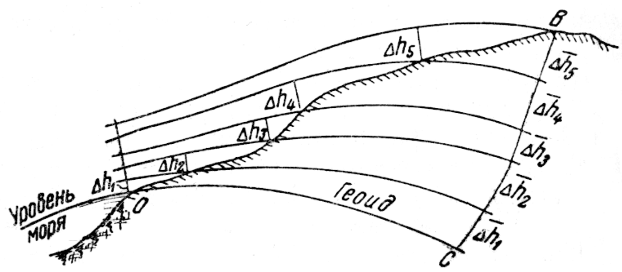

Fig. 2. Determination of point B mark in relation to Kronstadt' zero relative footstock (by N. E. Piskunov)

The determination of normal height, as a part of theoretical formula of Molodensgkiy, using the method of geometrical leveling, allowed creation of the BS from 1946 to 1949.

Level surface which cross the mark Reineke-Tenberg, during BS implementation was taken as a readout surface both for geodesy and gravimetry.

Chiseled at granite foundation of Blue Bridge the horizontal mark was decorated, replaced by the plates, then was additionally equipped with a protective frame and named Kronstadt footstock. Thus, the readout of leveled heights in old and modern Russia is taken from the average level of Baltic Sea, drawn by M. F. Reyneke during the period of his observations from 1825 to 1840.

For BS the average value of the acceleration of gravity at the interval temporal line BC (Fig. 2) was practically not defined, and the average value of normal acceleration of gravity on the interval H_q^B can be precisely computed through the value of normal acceleration of gravity, which is taken from charts with argument latitude φ of point B.

That means, that for any two points of the same level surface, the normal heights are equal, if the points lay on the same parallel, and normal heights are different, if the points lay on the same meridian.

In the article "Leveling" of new edition of *"Geodesist' Directory"* published in 1975, M. E. Piskunov stipulates the possibility of determining geopotential with the following words: "***The complex shape and u wedge angles (non-parallelism) of surfaces of references, crossing the points of the physical Earth surface, are determined by the density distribution inside the Earth, its shape and by the influence of centrifugal*** $P = w^2r$***, which equals zero at the poles and increase to the equator proportionally to the distance r from the point on Earth's surface to the rotating axe of Earth*"**.

That, what after refers to as "The complex shape are determined by the density distribution .. its shape" means that the gross masses of enormous concentration are distributed inside the Earth's body absolutely chaotic and randomly and at different distances from different parts of the surface. Their influence leads to deviation of direct leveling line from the geocenter, at the same time the datum line brought to the horizon batter level remains tangential to the displaced vertical center line, and the readout of leveling rod includes the error of the batter level rake. That leads to the situation, when in the BS even the normal heights on the same parallel of points of the same leveling surface and after induction of adjustment for wedge angles remains uneven.

As of 1 January 1961 in the maritime economy instead of zeros of gauge stations the unified zero of sea post (Unified Zero) was inducted, which was selected in BS at a level of minus 5.000 m. Another deviation zero – sea port zero was also linked to the State height system, was computed up to millimeter, fixed in meters, whereas the zeros of gauge stations were not used any more.

All the data of interval observations on gauge stations, including the data converted from local systems to BS, were converted further to the system of unified zero and were fixed in centimeters (BS zero at sea post equated to 500 cm).

Thus, by the time of unified zero system induction, its readout surface along with the reference surfaces – sea port zeros and average sea levels in the area of gauge stations were cleared from error influence on account of wedge angles (non-parallelism) of those surfaces of references with BS surface of references.

The State leveling network was created in Ukraine in the beginning of 1970s, in which the normal heights got the adjustments on account of gravity field influence. This is Baltic System 1977 (reference point – Kronstadt). This high-precise leveling network has got approximately 13000 km of leveling line of I class and 11800 km of II class line, based on one point of reference, and does not have outside control and is balanced as a free system [Dvulit, Smelyanets, 2014].

The meaning of the system was not cleared up by the above quote. During Zvyagina's study in MIIGAiK during 1968–1974, no accent on difference and the name of system itself was made: M. E. Piskunov as a lecturer and a Thesis supervisor had not explained this focuss either.

At gauge stations reference surfaces BS and BS77 (zeros of those systems) were not matched and had different values $d_{БС}$ (Fig. 3). In order to understand their differences, we will cite the data from "Instruction on adjustments of leveling of I and II classes, 1988".

COMPUTING OF ADJUSTMENT B EXCEEDING FOR TRANSFERRING TO THE DIFFERENCES OA NORMAL HEIGHTS

§ 74. Compensation computations of leveling of I and II classes, as well as III class, carried in the mountain and high-mountain regions, can commence only after induction of adjustments on account transition to the differences of normal heights to the measured exceedance. The exceedance, computed on results of field observations, after inductions of the above exceedance into them, during the compensation computations should be computed as an immediately measured values.

Thus, for each to consequent reference marks I and K it should be computed

$$H_{qk} - H_{qi} = h_{ik} + f,$$

Whereas, H_{qk} and H_{qi} – normal heights of reference marks K and I; h_{ik} – measured exceedance of reference mark K over reference mark I; f – adjustments to the transition to the differences of normal heights (in the "Instruction on adjustments of leveling of I, II, III and IV classes", pub. 1966, the adjustment f is called the adjustment for the wedge angles (non-parallelism) of the leveling surfaces.

Adjustment f is being computed as:

$$f = -\frac{1}{\gamma_m}(\gamma_{0k} - \gamma_{0i})H_m + \frac{1}{\gamma_m}(g-\gamma)_m h_{ik},$$

wherease γ_m – approximate value of normal gravity, taken as a constant for the whole territory of the country equal to 980000 milligal; γ_{0k} and γ_{0i} – the values of normal gravity on the readout ellipsoid in the points Kand I, selected from the charts (Annexure 18) as per argument B; H_m – the average height of reference marks I and K; g – measured gravity; γ – normal gravity; $(g\text{-}f)_m$ – direct average of gravity anomalies in the points I and K.

According to this Instruction the measured exceedances are corrected by the adjustment group on account of wedge angles (non-parallelism) of the leveling surfaces and deviation of plumb-in line from geocenter towards incorporated high-density masses, after which the exceedances are taken as immediately measured, however free from the influence of leveling directions and gravity filed and prepared for the network alignment. Thus, the exceedances in BS are alighted by adjustments on account of wedge angles (non-parallelism) of the leveling surfaces, whereas in BS77 those adjustments in the measuring of the exceedances the group of adjustments on account of deviation of plumb-in line are added. Taking into account that not a single gauge station has the matching marks in BS and BS77 systems, the global ocean as a whole cannot be undisturbed, then while leveling the mark of Reineke-Tenberg of Kronstadt foostock from the posts – its backups, BS zero in this footstock in BS77 also was computed by unknown value thought the adjustment on account of gravity influence.

Imported to the Fig. 1 the addition related to the BS77 system, its connection through the value $d_{БС}$ to BS, World Geodetic System WGS84 and Amsterdam footstock zero in the system EYRF2000, makes Fig. 3.

The source of new data is a Fig. 4, and those data can be merged with the figure 2 only through "0" of BS77. This readout surface is constant for each gauge station.

The records on point Kronstadt 17.5 cm and Black Sea 22.9 cm in the European System of Heights related to Amsterdam footstock by the end 2005 reflected on Fig. 4 forced the authors to find the extend of conformance of our researches presented in [Marchenko, Yarema, 2006] to the date not only mark-wise, but also Black Sea high-speed rising – 12 mm per year.

The most comprehensive data are accumulated in SE "CHORNOMORNDIPROEKT" on city Poti. Taking into account that Georgia has cancelled classifying of its geodesic data, moreover – not a single part of its object of polygonometry has survived till now, we can analyze actual data.

Two reference marks of class I from the Directory of 2003 of Geodesy Department of Georgia do not correspond to the Catalogue [Catalogue of observations on the Black and Azov Seas, 1990]. Those certificates allowed drawing a chart of average annual gradient of those changes. Even earlier, in 1983 the certificate was obtained from the Enterprise #4, which allowed based on the leveling data of I class of 1969 to obtain the marks of two reference points in the systems BS and BS77 and to figure out the difference dБС for the transition from one system to another.

In the archive SE "CHORNOMORNDI-PROEKT" we can also find a drawing from Research project of 1955–1956, presented on the Fig. 5.

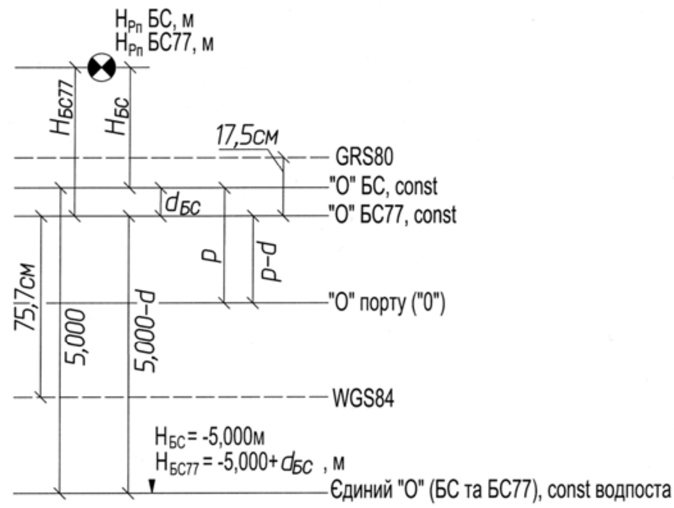

Fig. 3. The connection between zeros of height system BS, BS77 at gauge stations and unified zero according to systems GRS80 and WGS84 (the fragment of figure 9 of [Marchenko, Yarema, 2006])

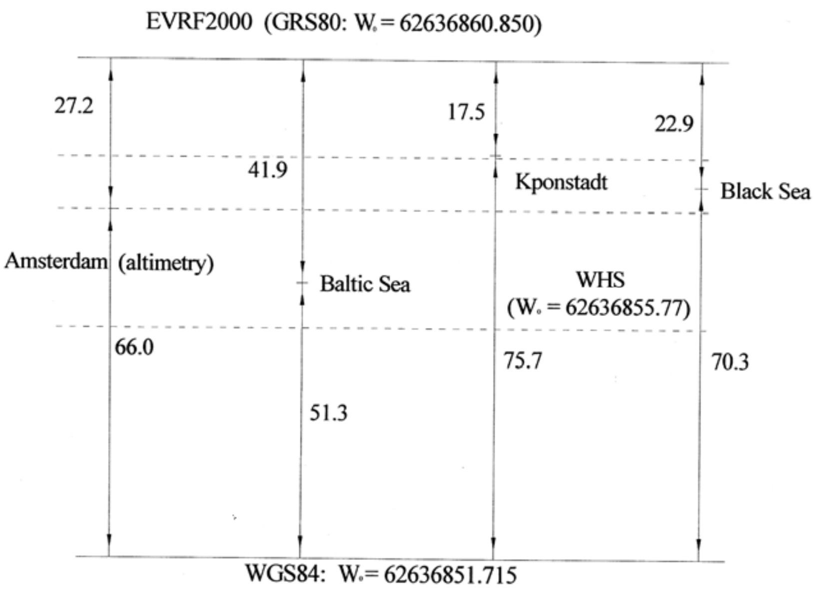

Fig. 4. The differences between the levels (in cm) of Black sea, Baltic sea, Amsterdam (NAP) and Kronstadt in the systems EURF2000 and WGS84 according to the data of satellite altimetry [Marchenko, Yarema, 2006] (1992–2005)

Table

Reference mark data and details of their vertical shifting

Benchmark name	Leveling class	BS77 datum, m		Datum migration, mm	Annual datum migration, mm per year
		Year 1947	Year 1969	For 22 years (1969–1947)	For 22 years
Ст. реп. 402	I	1.867	1.669	198	9.00
Ст. реп. 1675	I	1.967	1.788	179	8.14
Ст. реп. 6349	I	2.792	2.580	212	9.64
Mark 8370	I	3.262	3.070	192	8.73
				Average annual gradient	8,88

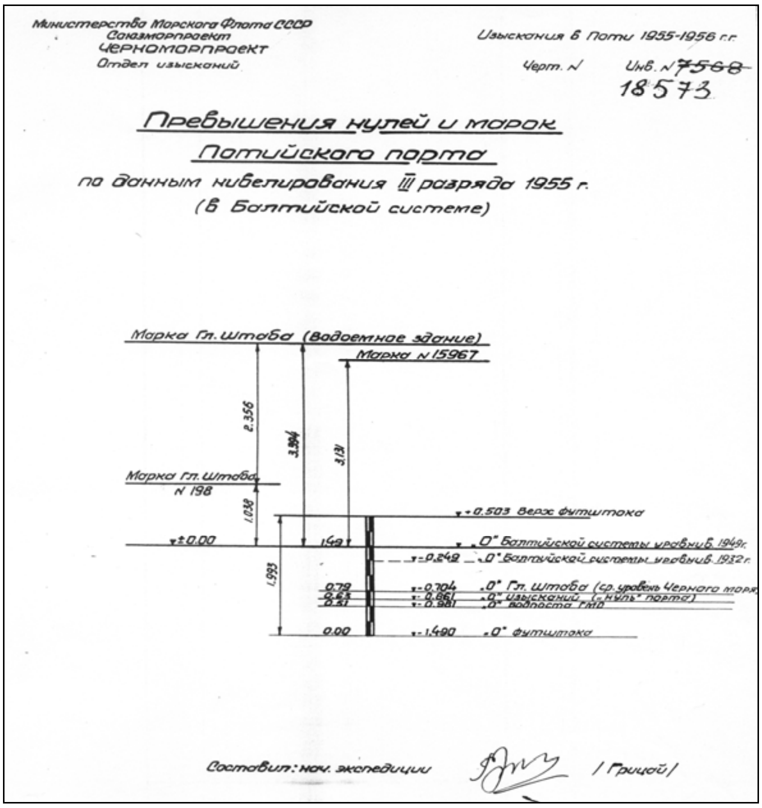

Fig. 5. The exceedance on zeros of readout surfaces and marks of Poti port (from the Research project 1955–1956)

On the Figure we can find *mark БГШ*, which was located on water-reservoir building and had the same mark as in the certificate of 2003 based on the leveling of I class of the year 1947. Thus, the mark still existed in 1955, however soonafter it was lost.

Having good understanding that mark datum n/n was determined in 1947 in the same was as a sea level, however this is the only document, which fixes average sea level by leveling of I class), we have drafted a chart of approximation of mark n/n datum towards the past as well towards the future, that we took into account the migration of mark datum in BS as on 1955, which was not available as knowledge with the researches in 1955.

Also it was taken into account that in order to determine of this average sea level near Poti port it was necessary to use the data of average annual levels of sea for 12 years, i.e. from 1935 to 1947, and approximation of the datum as on 1935 for correct benchmarking of gauge station rail. For those twelve year it was taken into consideration, that during the falling of the sea by 8,88 mm per year × 12 = 107 mm sea level has not decreased, but leveled-up due the Law of the communicated vessels. From that level onwards during 1935 to 2005 included, the level increased by 71×12 mm per year = 852 mm and equaled by the end 2005 – minus 5.6 cm. And this is practically with data minus 5,4 cm of the source [Marchenko, Yarema, 2006], where the sea level is computed based on the data of the satellite altimetry. The average annual level of 1947 matches the Catalogue [Catalogue of observations on the Black and Azov Seas, 1990] data only for the indicated year.

To foresee level increases for the year 2005 based on the catalogue [Catalogue of observations on the Black and Azov Seas, 1990] data and the certificate of Hydrometeobureau Sevastopol for the Black Sea ports Kerch and Feodosia is impossible due to the shift BS and BS77 zeros, which automatically increaseseveral interval levels in BS77. Those researches are given in [Kostetska, Zvyagina, 2013]. The catalogue data are not suitable for the computing of science prognosis.

We also studied the source [Spank, 1929] edition in Teflis, which gave evaluation of "*List of height marks*" of 1915 edition and "*Catalog of height marks*" 1926 edition, and the year of Poti gauge station set up is not mentioned.

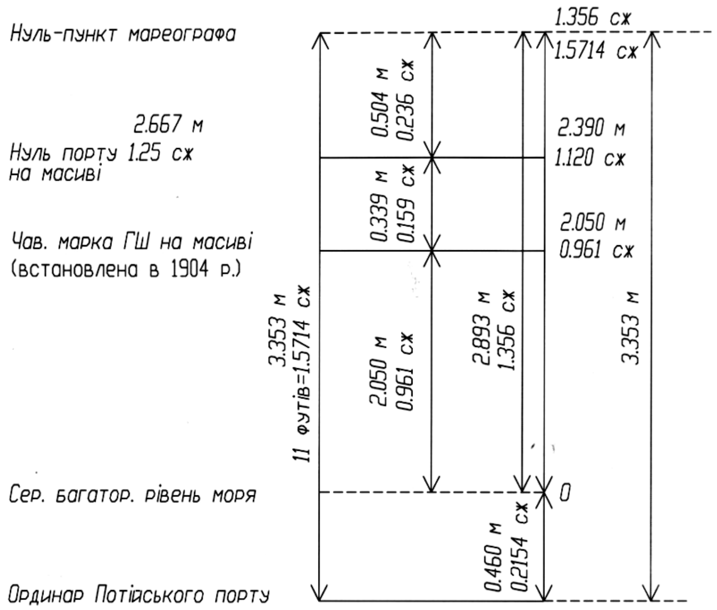

Fig. 6. Set up of functioning of local vertical system of gauge station (copied from [11])

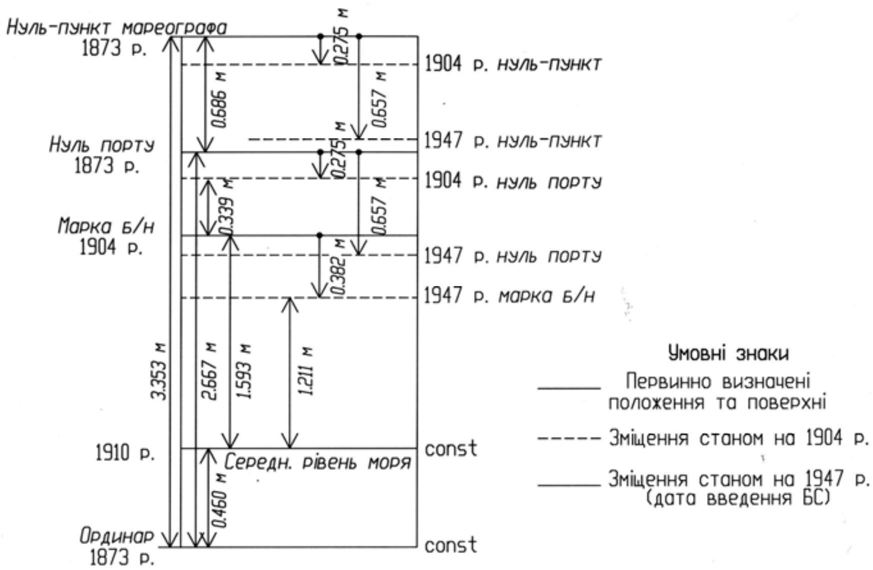

Fig. 7. The changes of high-altitude position of gauge station equipment during period from 1874 to 1947

Fig. 6 presents the precise data copy from [Spank, 1929] in fathoms and is simultaneously converted to meters. The set up of the gauge station functioning is approximately 350 m away from the sea on an upper surface of concrete massive, the marble shield has the chiseled mark "1.25 fathom" (this is the distance from the zero-water level – on Fig. 6 indicated on the left side), which was taken as the port zero. In 1904 on the same concrete mass, the mark n/n was set by General HQ and it was understood, that the distance from the zero-water level to the port zero is not 1.25 fathom, but 1.120 (see Fig. 6 on the right side) with the difference 0,130 fathom, or 0.275 m. Applying the gradient, which we computed of annual mark migration as 8.88 mm/ year, we determined that this difference took place between the years 1873–1904. Actually, in the catalogue [Catalogue of observations on the Black and Azov Seas, 1990] the interval observations in Poti were given as of the beginning of 1874.

This consequent line of event allowed us to determine approximation of exceedance of gauge station elements over the selected readout surfaces from the one given in Fig. 6 to the described on Fig. 7.

However, by observation on gauge stations in the local systems it is not possible to take into account the even decrease of the land, thus it is impossible to check the stability of height marks and places of readout surfaces during either time.

It was underpinned, that the original materials of observation from the beginning of gauge stations functioning till 1985 included were handed over to the Sevastopol department of the State Oceanography institute for the drafting of Catalogue [Catalogue of observations on the Black and Azov Seas, 1990], published in 1990, and was never given back.

Academic novelty

Taking into account the above mentioned in preparing of the materials of the field researches to the adjustment, and namely that the each height mark after the introduction of BS77 through the exceedance will get the adjustment for the bringing of the vertical line on it to Earth geocenter, it was necessary to introduce the second group of adjustment on the Kronstadt footstock as well. This is a system error in computing the height of rail Reineke – Tanberg in BS77, as will as for all the State height network by the one and same value.

Since this mark is located on the selected readout surface of BS, the wedge angles (non-parallelism) of leveling surfaces amendment can not be used.

The evaluation of the circumstances during the set up of the Amsterdam footstock, the influence of vertical line deviation could also not be computed due to unsolved peripherian tasks that lay beyond the scope of this Thesis, yet it would be taken into account. Itis also does not state about the evaluation of influence of system component (sliding, tilting etc) in the geoid height [Kalinic, 2005]. Only after mitigation of above mentioned shortcomings of BS 77, quasigeoid EGG97, which belongs to the ellipsoid GRS80 and to the system of horizontal coordinates WGS84 and is connected with the United European Leveling Network UELN, which is connected to the Amsterdam footstock, without any additional problems can be converted into Baltic 77 system adopted in Ukraine and other Eastern countries.

Practical meaning

The major problem is seen in the fact that the acting regulatory framework does not foresee evaluation of $d_{БС}$ value (Fig. 3) on the height marks of I and II class leveling. Thus, there is no place for the BS77 zero either on Kronstadt footstock, nor on the gauge stations, and the idea to induct this is unusual for scientists, let alone the specialists. Its induction will require the creation of a new regulatory framework, however the link between different systems will be possible as well as transition to new ones, if required. The derived height system of the marine industry will have precisely determined zeros.

Practically, with the aim of neutralization of system compound influence, it is necessary to evaluate $d_{БС}$, for this BS77 zero set lower than “zero of Kronstadt footstock”.

Our researches used the satellite altemetria data [9], which match a lot with the data obtains with the GNSS technologies. However, while comparing altimetry data with the data taken from gauge stations by geometrical leveling in BS77, the mismatch is approximately equal to the doubled difference $d_{БС}$. Even after transferring of gauge stations to the reference marks, determined by leveling by I or II classes in BS77, the interval water levels are determined as overestimated, the depths are dug lower than projected due to underestimateв port zero. The financial losses from the underestimated depth of the overhaul digging by 10 cm, at the cost of 50 uah for the digging and transportation to the underwater bank of one cbm of ground for the channel of width 150 m and length 1 km, will make 1.5 mio uah. The digging is done twice a year. The internal sea channels of ports have lengths from 5 to 20 km. The liability to maintain the projected depth is laid on the seaports [DBN V.2.4-3: 2010].

Conclusion

In the works [Zvyagina, Kostetska, 2008, 2010, 2013, 2015; Kostetska, Zvyagina, 2013] it was researched in detail, that the Catalogue [Catalogue of observations on the Black and Azov Seas, 1990] does not reflect the dynamics of level changes in neither of the sea ports – and in 90 or 130 years the annual data will practically coincide with the date for 30 years. The legislation and regulation framework requires the update of instructions as to geodesic securing of scientific and commercial activity of the country, not only referring to determination of BS zero mark in BS77 and functioning of gauge stations, and then – to changes of guidelines in oceanology and hydrography. A sample of principal scheme of matching of height marks of gauge stations (sea level) [Catalogue of observations on the Black and Azov Seas, 1990] and recommendations to the State services to do the survey of multi-billion constructions in the ports without geodesic securing – in the conditional height system [The Steering technical material. TsNIIGAiK, 1988] is totally unacceptable.

All the problematic aspects in the articles [Zvyagina, Kostetska, 2010, 2015; Kostetska, Zvyagina, 2013] were considered, and analized [Zvyagina, Kostetska, 2010; Kostetska, Zvyagina, 2013], and the relations worked and matched to the zeros of derivative systems and graphics are compelled in the standard form [Zvyagina, Kostetska, 2013]. They will not have miscalculations and will allow correcting of all the data as of 1986, which should be kept at gauge stations, as well as all data of the observations stating as beginning from the functioning of the new port which were not included into the Catalogue [Catalogue of observations on the Black and Azov Seas, 1990].

Also it's become obvious to cancel forced alignment of the two systems on the Kronstadt footstock, then the imbalance of levels on the Baltic, which are frequently touched by many authors, will not be materialized (the tilt of sea can not be kept for long). The submergence of the south coast of the Baltic Sea may have other reasons, one of which is the indetermination of BS77 zero place and the submergence of the land.

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ОПТИМІЗАЦІЯ ГЕОДЕЗИЧНИХ РОБІТ ДЛЯ ВИЗНАЧЕННЯ ЙМОВІРНИХ ПОЗНАЧОК РІВНІВ ВОДИ В РІЗНИХ СИСТЕМАХ ВИСОТ

Мета. Для оптимізації геодезичних робіт у морській галузі досліджено необхідність реконструкції Державної нівелірної мережі через визначення позначки риски Рейнеке–Тенберга в БС77, що дасть можливість отримувати на кожному водомірному посту значення позначки нуля БС у Державній системі висот БС77. Очікуємо на можливість ув'язати Державну нівелірну мережу країни з нівелірними мережами сусідніх європейських країн у межах виконання проекту UELN. **Методика та результати робіт.** Під час проектування, будівництва і реконструкції об'єктів морегосподарського комплексу після введення системи висот БС77 виникли великі складнощі із використанням ГНСС-технологій, висотної мережі полігонометрії, створеної в БС, та позначок строкових рівнів води на водомірних постах. Особливі складнощі у висотному відношенні виникали під час будівництва вузьких гідротехнічних споруд великої довжини, коли позначками є дані строкових рівнів води. З'ясувати проблему вперше доручено в 2006 році не гідрологу, а геодезисту М. С. Звягіній. Відомостей про БС77 та навіть назви системи БС77 спочатку не було, тому в портових містах рішення про величину різниці між системами іноді приймали відділення ВАГО (Всесоюзного астрономо-геодезичного товариства). ДП "ЧОРНОМОРНДІПРОЕКТ" ще у 1983 р. через ГУГК СРСР отримав середні різниці для багатьох морських портів, за винятком тих, що мали різниці від ВАГО. Але стало необхідним зібрати дані щодо різниці позначок висотних знаків прив'язних ходів, зміни позначок у часі для різних територій, але вже в БС77. Тоді стало зрозуміло, що нова система має свій нуль. Досліджено території різних портів на стабільність, а також на зміни позначок у часі для постійно осідаючих територій та складені таблиці апроксимацій знаків приблизно на 70 років у минуле і майбутнє. Відстежена поведінка рівнів для особливо осідаючої території – це місто Поті та його водомірний пост. Скориставшись даними українських вчених [Марченко, Ярема, 2006] про постійну швидкість підвищення рівня Чорного моря, визначену методом супутникової альтиметрії та середню позначку рівня моря на 2005 рік, через апроксимацію позначок робочих і контрольних реперів, приведених як до БС, так і до БС77, для району Поті на цей 2005 р. визначено рівень мінус 5,6 см порівняно з рівнем 5,4 см (рис. 4) із [Марченко, Ярема, 2006]. Наші дослідження та висновки щодо двох різних нулів систем БС та БС77 підтвердилися випискою з Інструкції про камеральне опрацювання даних виміряних перевищень та введення двох груп поправок, після чого перевищення залишаються виміряними, але підготовленими до врівноваження. БС введено, коли навчилися отримувати першу групу поправок, а БС77 – коли почали вводити обидві групи сумісно. Отже, це дві незалежні системи, зв'язок між нулями яких належало встановити через поправку за вплив гравітаційного поля як на Кронштадтському футштоці, так і в кожній точці фізичної поверхні, щоб забезпечити перехід до БС77 за потреби використання попередніх даних та ГНСС-технологій. **Наукова новизна.** Вважаємо знайденою системну похибку, яку легко визначити на Кронштадтському футштоці через визначення на ньому позначки квазігеоїда в БС, що дасть змогу квазігеоїду EGG97 легко трансформуватись у прийняту в Україні та в інших східних європейських країнах систему "*Балтийская 77*". **Практична значущість**. Це питання поки що дуже складне у зв'язку з побудованою владною вертикаллю у сфері геодезії, що за маленьким винятком на всіх рівнях керівниками є не геодезисти, а фахівці інших професій, які могли вивчати тільки початкові ази геодезії. Ці чиновники не можуть наполягати чи щось доводити у сфері геодезії. Але доки не будуть оновлені інструкції, доки на графіках не з'явиться нуль БС77, ніхто не має права в жодній галузі щось змінювати у своїх сферах діяльності. Зокрема, беручи до уваги думку геодезистів, можна було б уникнути величезних і не потрібних втрат морської галузі. Ми склали графіки визначення всіх нулів похідних систем, ДП "ЧОРНОМОРНДІ-ПРОЕКТ" за 2–3 роки ув'яже всі складові, але спочатку Державна геодезична служба повинна отримати кошти на безпомилкове визначення $d_{БС}$ для всіх 27 морських портів на морських побережжях та в районі морських портів на великих судноплавних річках (Дунай, Південний Буг, Дніпро). Наполягаємо, що не можна було домовлятись щодо суміщення на вихідній точці (Кронштадтський футшток) геодезичної та гравітаційної поверхонь – середнього рівня та квазігеоїда.

Ключові слова: нуль Балтійської 1977 р. системи висот; єдиний нуль поста моря; нуль порту.

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