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Research Article

CALIBRATION OF SEISMIC STATION CHANNELS IN GISSARAK AND TUPOLANG RESERVOIRS AND MONITORING OF SEISMIC EVENTS IN THEIR NEAR ZONES

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ABSTRACT

Testing of stationary seismic stations and seismic receivers used in the Gissarak and Tupolang reservoirs is necessary to ensure the reliability of seismometric information during engineering and seismometric researches. These studies are relevant in that the Gissarak reservoir is in a state of continuous operation and seismic monitoring on the Tupolang reservoir is carried out synchronously during the construction and operation of the facility. The basic features and operating conditions of the seismometric observation system in the Gissarak and Tupolang reservoirs remain unchanged. A variant of the method of harmonic calibration of the digital seismic channel was implemented in order to calibrate and test the performance of the channels of the seismic station, including seismic receivers. In the software environment, the submitted algorithm controls the amplitude-frequency characteristics of the channels. In the software environment, according to the presented algorithm, the amplitude-frequency characteristics of the channels, identity of the transition characteristics of the automatic digital converter, and other parameters are controlled. Investigation of the synchronicity of oscillations of the sides and foundations of the Gissarak and Tupolang reservoirs revealed that in the Gissarak dam during an earthquake occurring in the east-north-eastern segments up to 100 km, in the left and right parts of the sections of the dam and foundation oscillations occur with a slight excess of the left side, for the Tupolang dam during an earthquake occurring in the northern and southern directions, the oscillations of the sides and base occur with a slight delay to the starboard from the base.

Keywords: *Seismic Stations, Calibration, Amplitude, Frequency, Oscillation*

INTRODUCTION

The increased requirements for the measurement accuracy that are imposed on the recording systems for monitoring the seismicity of reservoir territories cannot be satisfied without reliable metrological certification and verification of the performance characteristics of the channels of seismic stations during their adjustment, as well as regular monitoring of the state of the equipment during operation (Khamidov, Artikov, 2018; Ibragimov, Khamidov, 2018).

To carry out digital registration of seismic waves during local observations, the Gissarak and Tupolang reservoirs measuring points are equipped with sensitive seismographs for recording local and nearby earthquakes of the SKM-3 and CM-3 type with an increase in channels depending on the background noise of the 1st kind from 10,000. Testing 12 measuring points are produced in a three-component mode. The working seismic station included an ELIOS 16-bit automatic digital converter, a Garmin-ELIOS GPS receiver, a NOVA 600AVR UPS, and an EBS-1363 industrial digitizer.

MATERIALS AND METHODS

Seismic monitoring in the territory of the Gissarak and Tupolang reservoirs was carried out mainly by the laboratory of Technogenic seismicity (now Local seismotechnogenesis) of the Institute of Seismology of the Academy of Sciences of the Republic of Uzbekistan (Khamidov *et al.*, 2021). At present, on the territory within a radius of up to 120 km from the Gissarak and Tupolang reservoirs, there are 3 seismic stations used to determine the epicenters and the scale of earthquakes (ShNK 2.06.11-04, 2006; Khamidov and Artikov, 2018; Khamidov *et al.*, 2021).

The first seismic station "Tupolang" (TPL) is located 1 km south of the section of the Tupolang reservoir and 77 km from the section of the Gissarak reservoir in the southeast direction. The second seismic station "Shabada" (SHBD) is located 76 km northwest of the section of the Tupolang reservoir and 1 km west of the section of the Gissarak reservoir. The third station, piecewise-stationary, is located 115 km west of the alignment of the Tupolang reservoirs and 72 km west of the alignment of the Gissarak reservoir, 300 meters from the left bank of the Pachkamar reservoir (PChK). At these stations from 2011 to 2021 operating digital seismic stations "SRS-KM/v-F" (Elius) operated. Previously, this type of digital stations from 1996 to 2007 successfully provided the compilation of regional catalogs of earthquakes in Uzbekistan based on registration in 22 Republican seismic stations as part of the Complex Experimental and Methodological Expedition of the Institute of Seismology of the Academy of Sciences of the Republic of Uzbekistan (Zakirov *et al.*, 2004). Also, for many years these stations have successfully provided seismometric information to the seismic monitoring systems of LUKOIL facilities up to 2020.

According to the operating conditions of seismometric equipment in the zones of the Gissarak and Tupolang reservoirs, the main characteristics of the recording tract are as follows: amplitude-frequency characteristics (AFC) of the channels; frequency response identity - full or partial - of the channels; amplitude characteristics of channels, their linearity and dynamic range; transient response of an automatic digital converter - ADC; mutual influence of channels; the price of the least significant digit; the position of the zero level of the ADC and its stability (Sokolov, Slovtsov, 2010). During operation, it is possible to quickly monitor the overall performance of the system, including seismic sensors (Zakirov *et al.*, 2004; Sokolov and Slovtsov , 2010; Khamidov *et al.*, 2021).

Sokolov and Slovtsov presented the basis of the software for the calibration of seismometric channels "SRS-KM / v" (Sokolov, Slovtsov, 2010). According to this requirement, the software for the calibration of seismometric channels of the seismic workstation "SRS-KM / V" EL 108.00.00 (hereinafter referred to as the station) and the primary information processing (hereinafter referred to as the software) is installed on a personal computer running Windows XP (Sokolov and Slovtsov, 2010). During the calibration work, the computer is connected to the station via the USB interface.

Testing of seismic stations and seismic sensors used in objects in real time is presented to the company "ELIUS" LLC. In the future, from 2007 to 2019, all factory metrological assessments and checks of seismic stations installed in the Gissarak and Tupolang reservoirs were made on the basis of the algorithm below.

To calibrate and check the operability of seismic station channels, including seismic receivers, a variant of the harmonic calibration method of a digital seismic channel has been implemented. In this case, the response of the system was processed on a personal computer (PC) when a given signal from the generator was applied directly to the working input of the channel and test pulses to the damping coil of the seismic receiver.

The frequency response was calculated for three channels of each station in turn based on digital records of sinusoidal voltage fluctuations from an external generator for a set of specified frequencies (periods). An external sine frequency generator is connected to one of the three inputs of the test signal of the station conversion device. The following generator frequencies fg (in Hz) are set sequentially: 33.0; 20.0;

15.0; 10.0; 7.0; 5.0; 3.3; 2.0; 1.5; 1.0; 0.7; 0.5; 0.33; 0.2; 0.15; 0.1 on a logarithmic scale (Sokolov and Slovtsov, 2010; Shevchenkova and Yakovenkova, 2020; Khamidov *et al.*,2021).

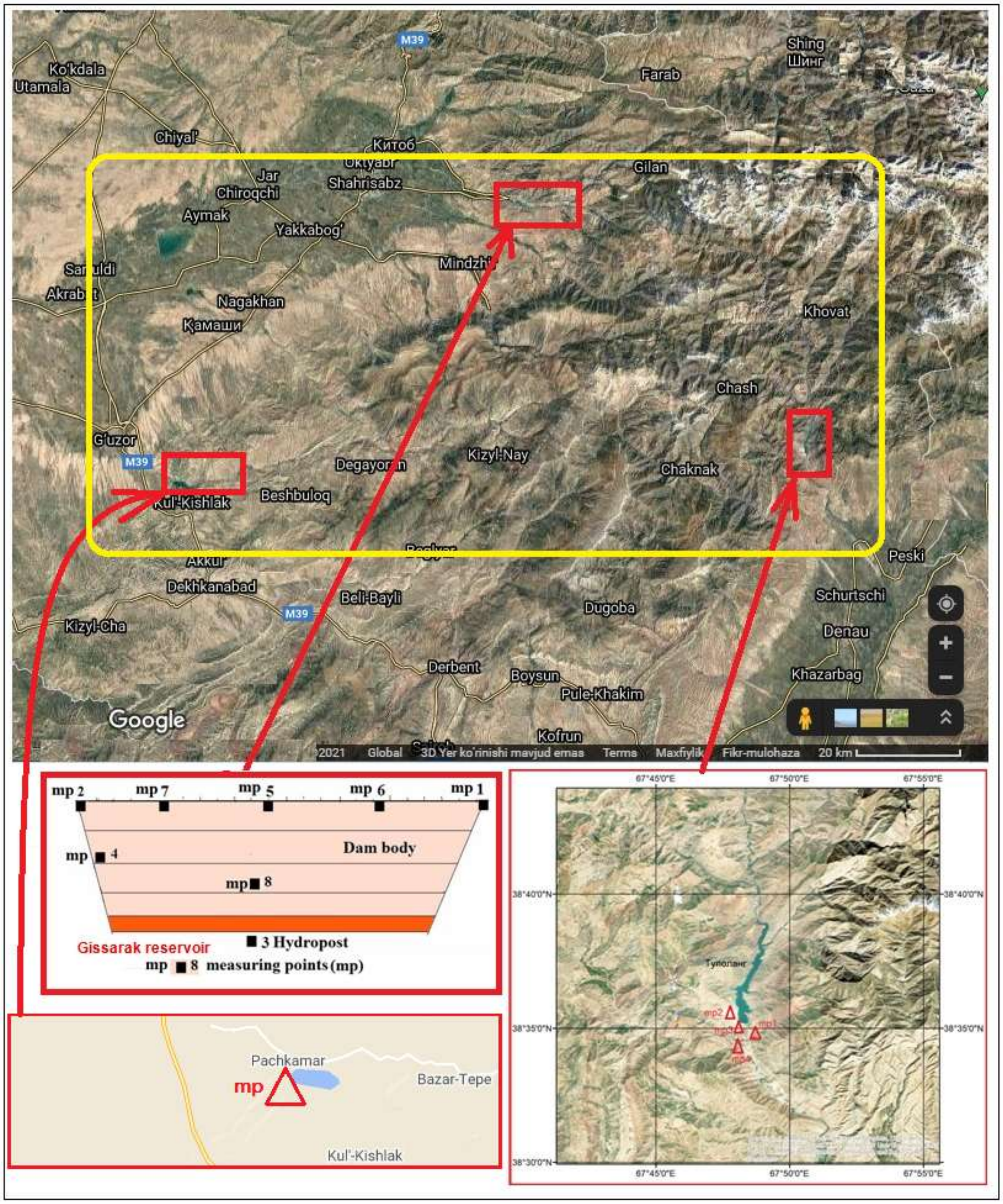


Figure 1: Layout of measuring points on the dam the coastal slopes of the Gissarak and Tupolang reservoirs

The amplitude value of the voltage at the generator output at all frequencies was maintained at a level of 30 mV with an accuracy of 1%. Files of digital vibration records for a given set of frequencies from an external generator for each of the three channels of the SRS station have been generated. The recording duration is five to seven periods of the generator signal. Using files of digital records in each selected interval (window) for each frequency of the generator according to the given formulas, the following are determined: arithmetic mean value of the amplitudes A_ω **:** $A_\omega = \sum A_i / N$ [mV], where: Ai [mV] - amplitude values of the recorded signal in selected interval, taken modulo; N - is the number of amplitude values in the selected interval according to (Shevchenkova and Yakovenkova, 2020).

The calculated results for all three channels are listed in the summary table. For automated verification of the main parameters of the channel, a program unit for comparing the current digital response from a pulse with the same parameters T_{imp} and U_{imp} with the calibration one, created in, was used.

Below is an example of calibrating the channels of seismic stations and seismic sensors used in the Gissarak and Tupolang objects. Channel calibrations were made in 24 channels of recording weak earthquakes of 8 seismic stations operating in the zones of influence of these reservoirs.

In the area of the Gissarak and Tupolang reservoirs, seismic receivers are located both on the surface and on the pit benches (Fig. 1), and in wells 5-10 m deep drilled behind the upper contour of the dam. The distance between the seismic receivers is about 100-200m, while the observations covered the volume of rocks with a maximum transverse dimension of 400-1100m. The base of the dam of the Gissarak reservoir is located in a single tectonic block, and in zones with seismicity of 7 and 8 points. The base of the Tupolang reservoir dam is located in not a single tectonic block, and in zones with a seismicity of 9 points. In general, during the research period from 2011 to 2021, 8 three-component measuring points operated at the facilities - mp (24 channels) in Gissarak and 4 (9 channels) in Tupolang (Fig. 1).

RESULTS AND DISCUSSION

Mp 3 and mp 4 worked to localize local fluctuations. Basically, more than 143 records were made on these mps of which 28 were related to high-frequency ones from nearby earthquakes. The synchronous recording was carried out on mp 5 on the ridge. A variation according to the scheme from Figure 1 mp 3 with translation according to the established time scale to mp 7, mp 5, mp 6, and mp 1 was carried out when processing mp 2 and mp 4 of the grounds. The study of the spectra and their parameters in 2018 for mp5, mp8 and mp3 showed that the spectrum curves for the left and right sides have a certain difference within the permissible 15%. Figures 2, 3, 4 and 5 show comparative estimates of displacements for different measuring points of velocities at the near source.

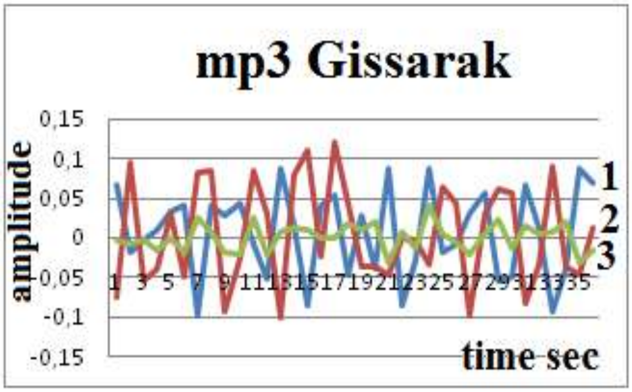


Figure 2: mp3 speed displacements at near hearth (1- EW; 2-NS; 3-Z)

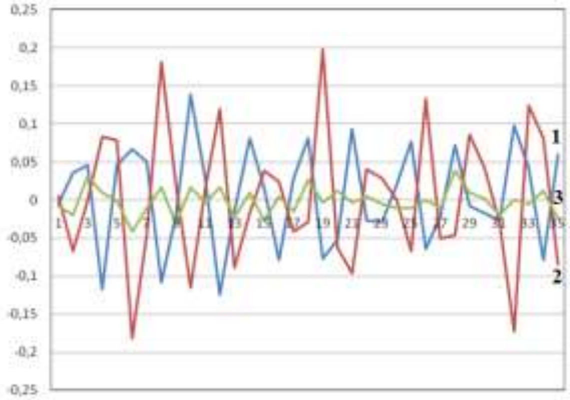


Figure 3: mp5 speed offsets near hearth

Two distinct $S_{\max}$ were identified. With an increase in the epicentral distance, the position of the S_{max} maximum on all components shifts to the low-frequency region. Figures 2, 3 and 4 show the change in velocity components in three channels in mp7 measured from non-stationary surveys.

Based on the selected earthquake records, first of all, the length of the analyzed section of the seismogram was determined. This length was determined from the moment of arrival of the "*S*" wave until the moment when the amplitude of the oscillation is equal to about 1/6 of the maximum amplitude and averages from 2 to 8 (rarely up to 10) sec. The frequency response characteristics of the measuring points (according to Fig. 4) are presented in Figures 5 to 6 and Table 1 below.

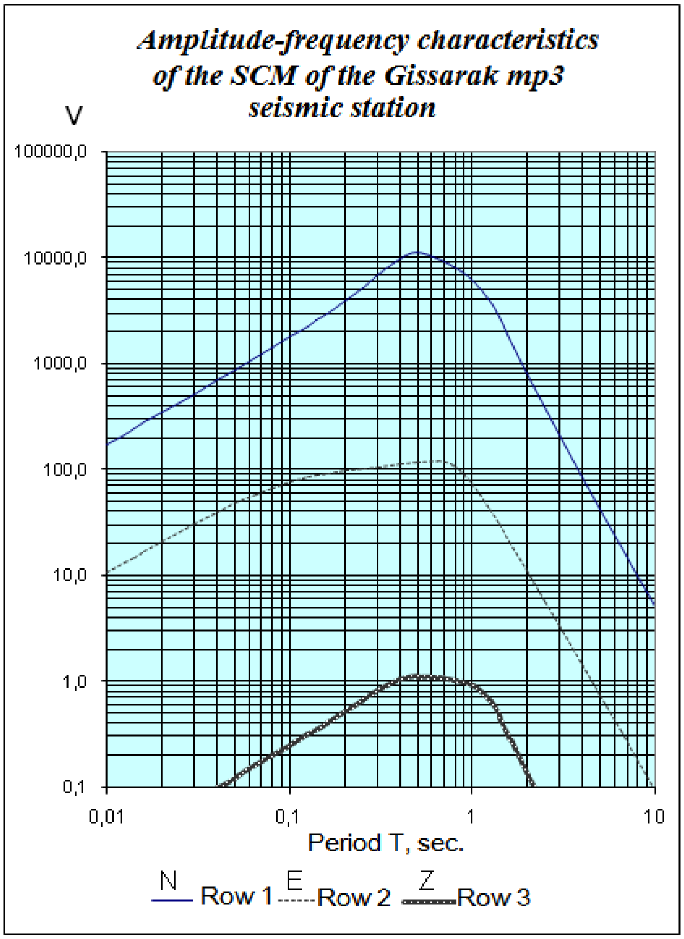


Figure 4: AFC characteristics of SCM channels of seismic stations Gissarak mp3

Changes in the values of the parameters of the spectral curves at the points located on the port and starboard sides: the prevailing phase frequency (in terms of displacement and velocity) for the starboard side is always higher than for the port side and the base of the canyon. By displacement f_p - from 0.51 to 2.4 Hz in speed, by horizontal components from 0.31 to 5.52 Hz. The spectrum width at the level of $0.74S_{max}$ is from 0.31 to 2.85 Hz for the starboard side and from 0.42 to 4.06 Hz for the port side.

On the basis of the digital system ISSS Gissarak and Tupolang, the main characteristics of the recording paths have been tested: AFC - amplitude-frequency characteristics of the channels; frequency response identity - full or partial - of the channels; amplitude characteristics of channels, their linearity and dynamic range; ADC transient response; mutual influence of channels; the price of the least significant digit; the position of the zero level of the ADC and its stability.

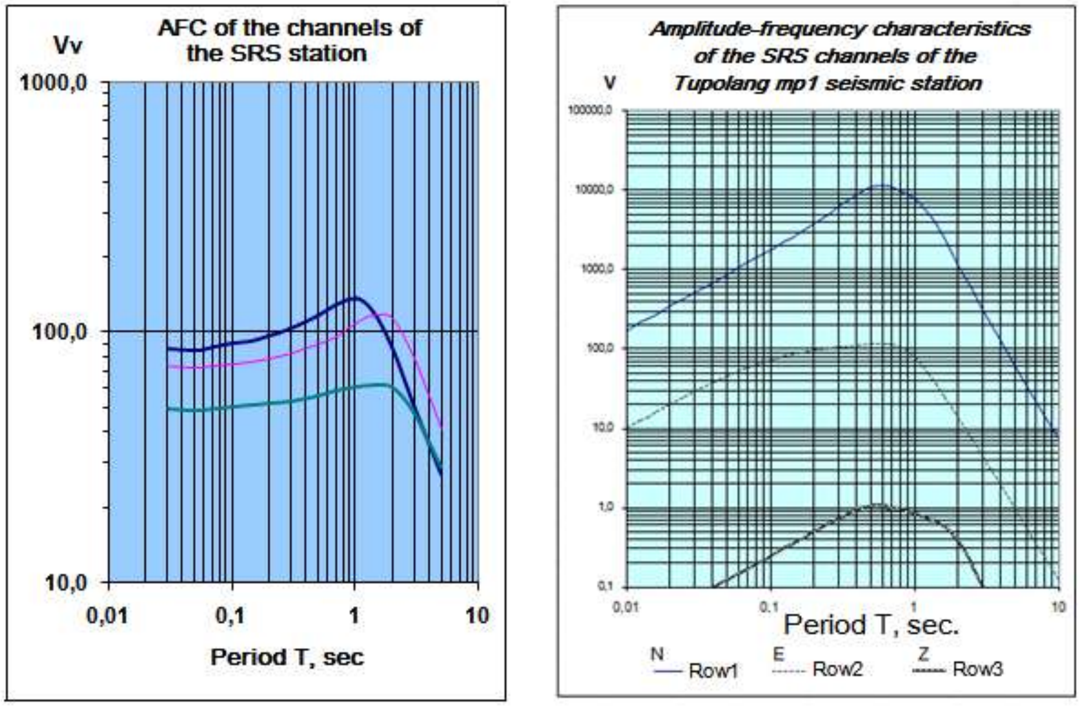


Figure 5: AFC characteristics of SRS channels of Tupolang mp1 seismic stations

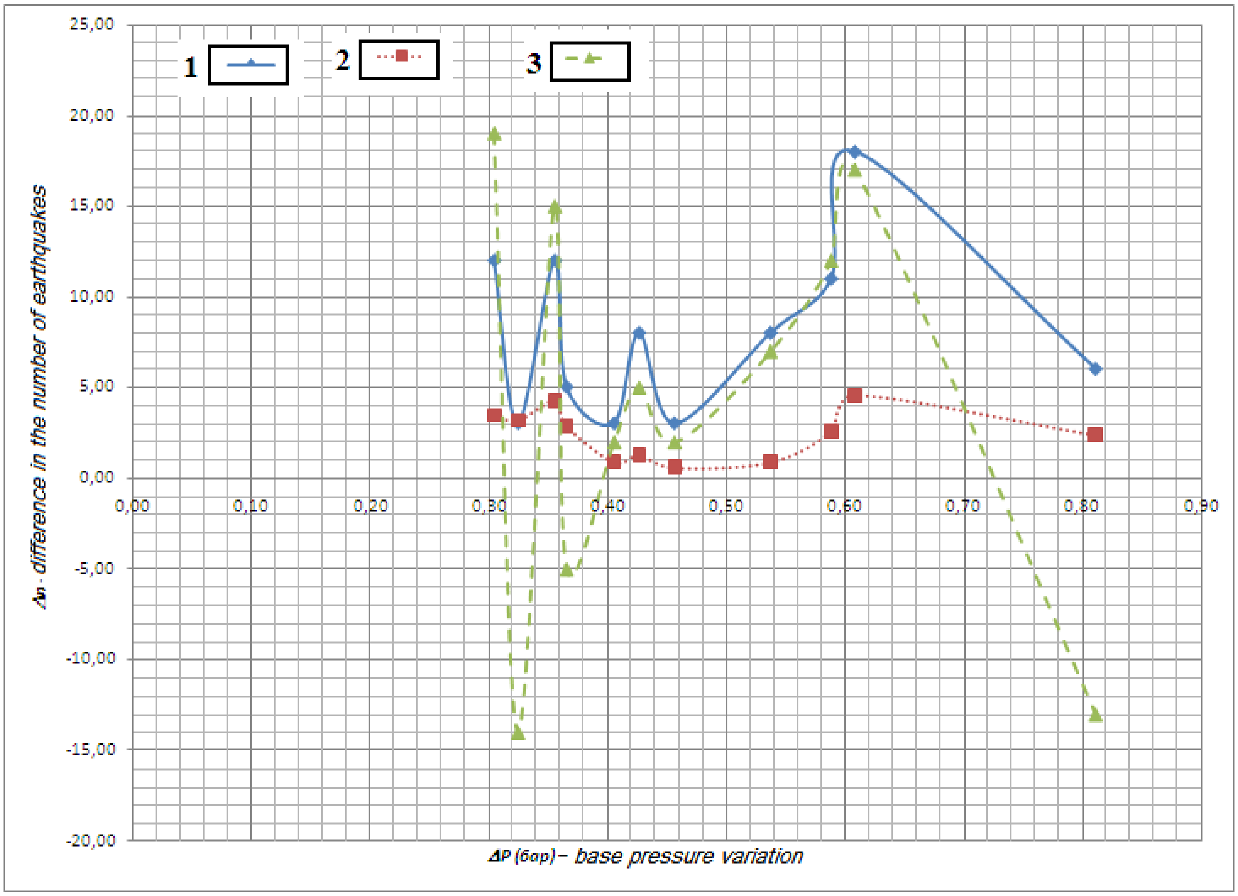
Weak earthquakes in the near zone of the Tupolang reservoir

The analysis of the studies carried out in the last period showed that the influence of changes in the hydrological regime on the earth's crust during the operation of the Tupolang reservoir is mainly associated with a change in pressure created by a change in the volume of water (Ramana *et al.*, 2015; Khamidov *et al.*, 2019). Using the results of calculations for modeling (Telesca *et al.*, 2012; Ramana et al., 2015; Khamidov *et al.*, 2017), processing data on displacements of coastal slopes when changing the volume of water in the reservoir (Khamidov *et al.*, 2017; Khamidov *et al.*, 2019), using materials from literary sources (Tetelmin, Ulyashinsky, 1990; Gupta, 2002; Singh *et al.*, 2008) and based on the results of the author's research (Khamidov, 2017; Khamidov, 2016; Khamidov *et al.*, 2020) compiled a table showing changes in the parameters of pressure and seismicity in the zones of several reservoirs in Uzbekistan (Table 1).

Table 1: Changes in pressure and seismicity parameters of reservoir zones

№	A	ΔH	ΔP	ΔT	n	N_{fon}	N	Δn
1	Tupolang (Uzbekistan)	38	0,365	2	5	24	2,9	- 5
2	Gissarak (Uzbekistan)	40	0,405	3	3	11	0,9	2
3	Andijan (Uzbekistan)	43	0,426	2	8	18	1,3	5
4	Charvak (Uzbekistan)	50	0,537	2	8	16	0,9	7

Symbols on table 1: *A*-reservoirs; ΔH (m) - averaged variation of the water level for Δt (month); ΔP (bar) - pressure variation based on; ΔT - is the average amount of pressure variation during operation; n is the average number of earthquakes with an energy class of $9 \leq K \leq 15$ until the next volume variation where $K = LgE$ (*E*-earthquake energy); N_{fon} - is the average local background of the number of earthquakes per year, within a radius of 50 km from the object; *N* - long-term average background number of earthquakes per 10-year allotment; Δn - is the difference in the number of earthquakes from year to year.



1-the average local background of the number of earthquakes per year, within a radius of 50 km from the object;
2-year average background number of earthquakes per 10 year allotment;
3- the difference in the number of earthquakes.

Figure 6: Dependence on the total pressure N fon, N and Δn

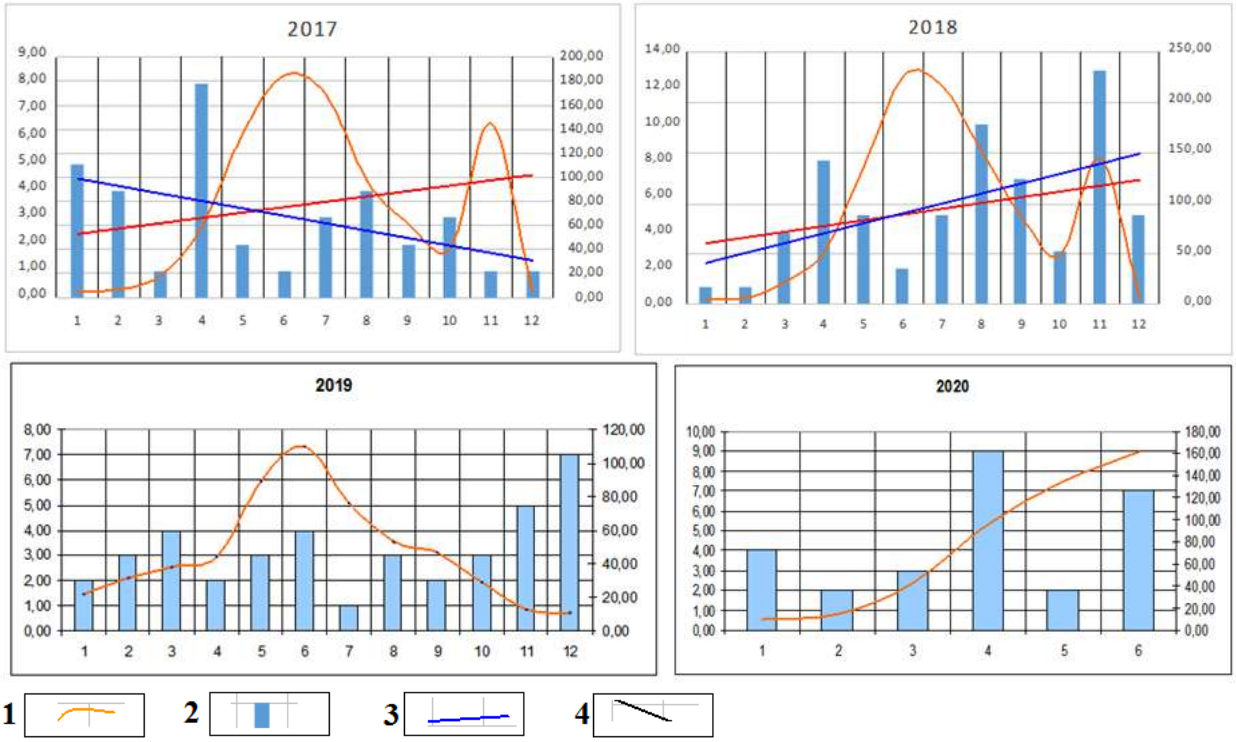
Figure 6 shows the relationship between N_{fon} (average local background of the number of earthquakes per year within a radius of 50 km from the object), *N* (long-term average background number of earthquakes, per 10-year allotment) and Δn (difference in the number of earthquakes) during the operation of eleven high-pressure reservoirs. The dependence shows that reservoirs with moderate base pressure up to *11.5* bar are operated at a higher frequency than reservoirs with base pressure up to *14.0* bar.

Changes in these pressures on the foundations create those displacements that practically create an additional deformation field (Khamidov, 2016; Khamidov *et al.*, 2020). Most earthquakes have occurred at depths of less than 10 km; the centers are located closer to the area where the reservoir depth was greatest, and some hypocenters coincided with the intersections of seismically active faults in this area.

These analyzes also include an increase in the seismic activity of geodynamic changes, also noted during the filling of the Tupalang reservoir.

Studies have shown that a gradual increase in loading-unloading from reservoirs as a percentage of the total volume on average with a 5% decrease in volume corresponds to a pressure drop of 0.05 bar. 6% corresponds to a decrease of 0.1 bar; 7% corresponds to a decrease of 0.15 bar. In reality, it corresponds to the variation in water pressure.

The pressure on the base of the reservoirs at the maximum operational limit can be chosen as the ratio $P = F / S^2$, where F is the force of gravitational weight and S^2 is the area of the base where this force acts. The deformation bending of the base ζ_i at the current pressure P, was chosen by us partly from the literature data and partly from the empirical connection $\zeta_i, = 0{,}044 \cdot e^{0{,}222P}$, with a standard deviation: $R = \pm 0.855$ (Gupta, 2002; Khamidov *et al.*, 2020). Deformation variations $\Delta\varepsilon_{\zeta}(\zeta_i) \cdot 10^{-5}$ - calculated in relation to a depth of *5-15 km*. the crust of the base of the Tupolang reservoirs (in averaged values). It is at these depths in the above radius that the seismogenic layer is distinguished, where the main foci of local earthquakes are located. Figure 7 below shows the variation in the displacement ζ_i of the base of the Tupalang reservoir and the number of earthquakes n_i in its near zone for the period from 2017 to 2020.



1 - change in the volume of water in the reservoir; 2-number of earthquakes; 3-trend of volume variation per year; 4- trend of variation in the number of earthquakes.

Figure 7: Variations in the displacement ζ_i of the base of the Tupalang reservoir and the number n_i of earthquakes in its near zone for the period from 2017 to 2020 by months

An analysis of the results obtained in the near zone of the Tupalang reservoirs in comparison with others showed that during the operation of large reservoirs, its base and thicket are in constant compression and tension loads of the corresponding intensity of the base bending amplitudes from the volume variation.

CONCLUSION

The study of the synchronicity of the oscillations of the sides and the base of the Gissarak dam showed the following. From earthquakes occurring in the east-north-east segments up to 100 km, in the left and right parts of the sections, the dam and foundation vibrations occur with a slight excess of the left side from the mp3 base. From earthquakes located to the south of the object, the lag of the left side from the base is much more noticeable than from the opposite side. With an increase in the magnitude of earthquakes, the difference in the arrival of the phases of the waves increases, but does not exceed more than 1.2-1.5 sec; The established changes in the sign of the oscillations of the same phases in mp3 in comparison with other points mp8 and mp5 are observed in 5 cases out of 9 experiments.

The study of the synchronicity of the oscillations of the sides and the base of the Tupolang dam showed the following. From earthquakes occurring in the northern and southern parts of the site, fluctuations of the sides and base occur with a slight delay to the starboard from the base. From earthquakes located to the east of the object, the lag of the starboard side from the base is much more noticeable than from the opposite side. With an increase in the magnitude of earthquakes, the difference in the arrival of the phases of the waves increases, but does not exceed more than 1.1-1.4 s; The established changes in the sign of the oscillation of the phases of the same name in IT1 in comparison with other points mp2 and mp3 are observed in 4 cases out of 7 experiments. The change in the sign of oscillations of the phases of the same name in both objects has not yet been explained by the difference in such parameters as epicentral distance, magnitude, azimuth of arrival of waves, and others.

Base deformations can correspond to the limiting tectonic focal deformations, which directly affect the regular stress-strain state and background movements of the nearby seismogenic layer of the earth's crust (within the zone of active influence of reservoirs). Apparently, these deformations are the main causative agent of non-background seismic events in tectonic structures, at least in the band of low energy classes.

REFERENCES

Khamidov HL, Artikov FR (2018). Monitoring of technogenic seismicity in the reservoir zones of Uzbekistan. *XIX Ural Youth Scientific School of Geophysics*, pp. 182-184. Available: https://www.elibrary.ru/item.asp?id=37019346

Ibragimov AKh, Khamidov KhL (2018). Assessment of fluctuations in the dams of the Gissarak and Tupolang reservoirs of southern Uzbekistan. *Tenth International Scientific and Practical Conference on the Problems of Reducing Natural Hazards and Risks,* pp. 52-57. Available: https://www.elibrary.ru/item.asp?id=36404160

Khamidov L, Turapov M, Mahkamov S, Artikov F, Suyunov Sh (2021). Tracking the local seismicity level in the active influence zone of the southern Uzbekistan reservoirs. *E3S Web of Conferences 264, 02043*. doi: 10.1051/e3sconf/202126402043.

Zakirov MS, Sokolov MV, Bakhriddinov S (2004). Monitoring of seismicity of the territory of the Republic of Uzbekistan. *Problems of seismic hazard assessment, seismic risk and earthquake forecast*, pp. 84-94.

ShNK 2.06.11-04 (2006). Town planning norms and rules. Construction in seismic areas. Hydraulic structures. Official edition. State Committee of the Republic of Uzbekistan for Architecture and Construction, Tashkent. -103 p.

Sokolov MV, Slovtsov NO (2010). Software for the calibration of the seismometric channels of the station "SRS-KM/v" and the primary processing of information. *Feasibility study of the system "ELIUS."*

Sadikov FS, Ibragimov AKh, Alimukhamedov IM (2010). The network of digital seismic stations in Uzbekistan and its development. *Bulletin of the NNC RK* **3** 23-25.

Shevchenkova YuV, Yakovenkova VV (2020). Earthquake class by code. *Volcanology and seismology* **2** 69-78, doi: 10.31857/S0203030620020078.

Ramana DV, Pavan Kumar J, Singh RN and Chadha RK (2015). Co-Integration Models for Koyna and Warna Reservoirs. *India International Journal of Geosciences* **6** 1173-1178, doi: 10.4236/ijg.2015.610092.

Khamidov LA, Artikov FR, Khamidov HL (2019). Empirical relationship between the amplitude of displacements of coastal slopes with the filling level of reservoirs. *“Tenth scientific readings in memory of Yu.P. Bulashevich. "Deep structure, geodynamics, thermal field of the Earth, interpretation of geophysical fields."* pp. 262-266.

Telesca L, Shafey R, Bary Fat, Amin Mohamed, Gabry M (2012). Analysis of the cross-correlation between seismicity and water level in the Aswan area(Egypt) from 1982 to 2010. *Nat. Hazards Earth Syst. Sci.* **12** 2203-2207, doi: 10.5194/nhess-12-2203-2012.

Khamidov LA, Artikov FR, Khamidov HL (2017). Possible mechanism of occurrence of earthquakes in zones of active influence of reservoirs. *Ecological Bulletin of Uzbekistan* **1** 20-21.

Gupta HK (2002). Review of Recent Studies of Triggered Earthquakes by Artificial Water Reservoirs with Special Emphasis on Earthquakes in Koyna. *India Earth-Science Reviews* **3-4** 279–310, doi: 10.1016/S0012-8252(02)00063-6

Singh C, Bhattacharya PM and Chadha RK (2008). Seismicity in the Koyna-Warna Reservoir Site in Western India. *Fractal and b-Value Mapping. Bulletin of the Seismological Society of America* **98** 476-482, doi:10.1785/0120070165.

Tetelmin VV, Ulyashinsky VA (1990). Technogenic impacts and processes in the rocky foundations of the dams. *Energoatomizdat* 160 p.

Khamidov LA, Alimukhamedov IM, Artikov FR, Khamidov KhL (2020). Parameters of the local geodynamics of the near zones of reservoirs. *Problems seismology* **1** 64-80.

Khamidov LA (2016). Steady state of the geological environment in the zones of large reservoirs. *Reports of the Academy of Sciences of the Republic of Uzbekistan* **3** 85-90.

Khamidov LA (2017). Determination of the stress-strain state of the geological environment in the zone of influence of reservoirs. *Geology and Mineral Resources* **3** 106-113.