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REGIME OF THE WATER LEVEL AND SHORE DEVELOPMENT OF THE DAM RESERVOIRS

Režim hladiny a vývoj břehů přehradních nádrží. — Na údolních nádržích jsou vzájemné vztahy mezi hydrologickými procesy na vlastních nádržích a geomorfologickými procesy na jejich březích. Procesy probíhající na povrchu vlastní nádrže závisí na režimu její vodní hladiny a mohou vyvolat značné a rychlé změny na pobřeží. Tyto změny zase zpětně působí na vodní režim nádrže. Intenzita procesů mění se v závislosti na různých podmínkách geografických, geologických, geomorfologických a hydrometeorologických a souvisí s manipulačním řádem a hospodařením vodou na té které přehradě. Na základě grafikonu četnosti výskytu vodních stavů lze na zaměřeném příčném údolním profilu posoudit intenzitu abraze a vypočítat objem abradovaného materiálu, kterým byl zanesen užitkový prostor nádrže. Podle výsledků několikaletého výzkumu a na základě studia změn na březích nádrží existujících, je možno sestavit prognozu vývoje břehů u nádrží plánovaných, což je pro projektanty a budovatele dalších přehrad neocenitelné.

The dams and the large dam reservoirs, the building of which made great progress all over the world especially during the last years, change the natural environments to a great extent.

The water forms together with the milieu a dialectic unity and it is not possible to study them separately. Therefore there is a very close correlation between the geomorphology and the hydrologic investigations (O. Dub 1957).

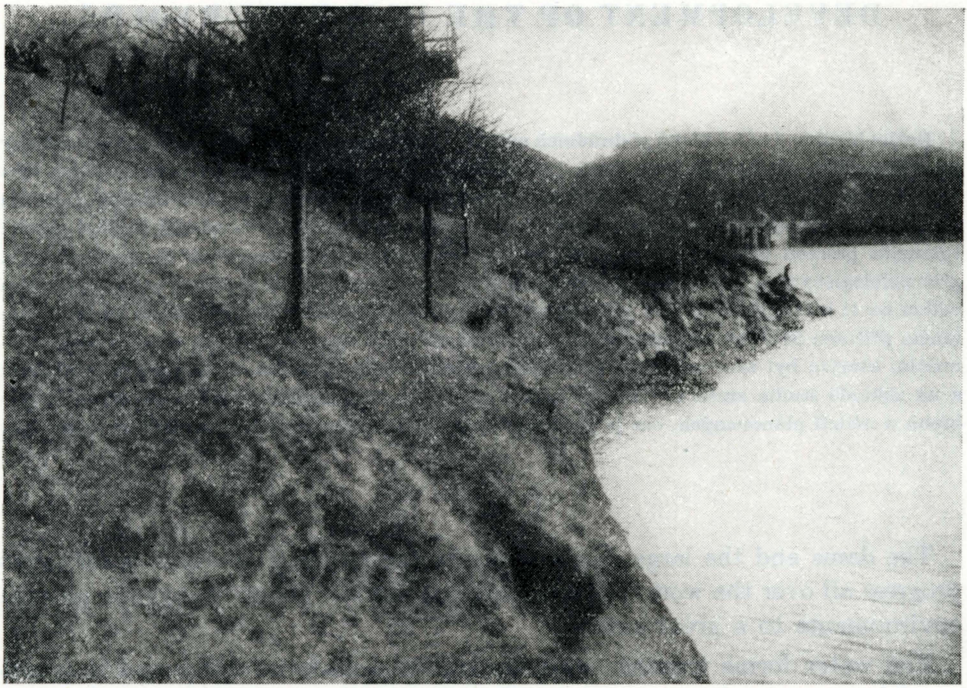
On the dam reservoirs there are mutual relations between the processes on the reservoirs on one side and the processes on their shores on the other side. The processes on the surface of the reservoir depend on the regime of its water level and cause considerable and quick changes on the shore. These changes affect the water regime of the reservoir retrospectively. The mutual activity and the intensity of the different processes does not appear on every reservoir in the same way nor on all its places. They change in dependence on the different geographic, geologic, geomorphologic and hydrometeorologic conditions and they depend on the manipulation order and on the water system of this or that dam.

The regime of the water level consists of a series of factors, which the oscillation of the water level and the changes caused by the wind activity, by the flow and by the freezing of the water level, belong to.

The oscillation of the water level depends on the general balance equation of the reservoir:

$$V_p + P + S + W_z + L + K = O + W_k + E + L_v + V_k ,$$

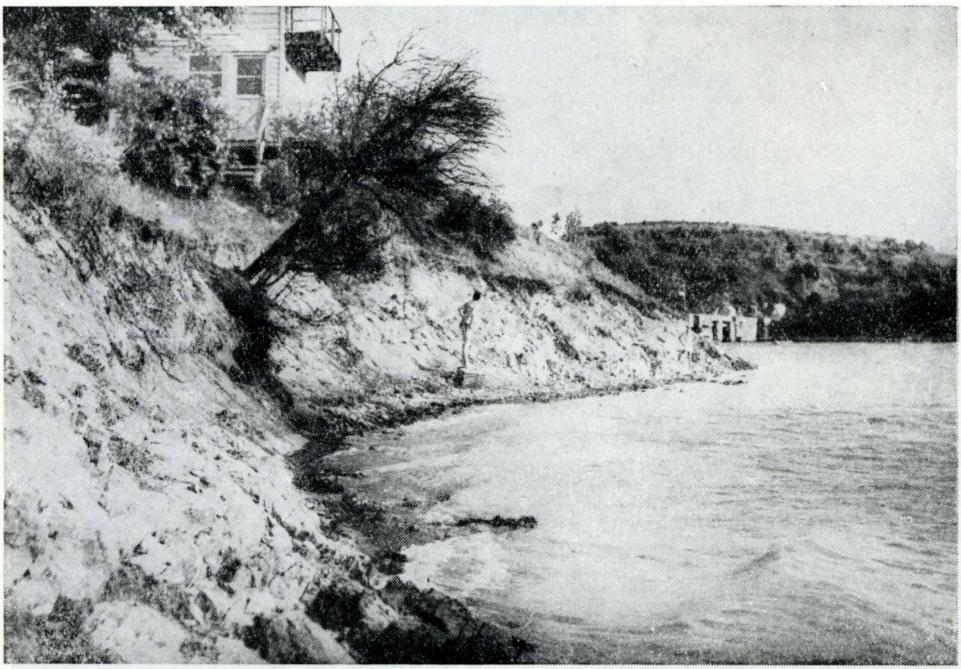
where V_p means the capacity of the reservoir on the beginning of the balanced period, P the water quantity, which flowed into the reservoir, S the quantity



1 Shore abrasion on the Kníničky-dam near Brno. State in 1958.

of the precipitations fallen down on the water surface, W_z the water quantity returned by the sluice into the reservoir, L the melting ice and snow, K the quantity of moisture formed by the condensation on the reservoir surface, O the water quantity flown away through the turbines, by the dewatering orifice and over the dam, W_k the water quantity delivered to the water gangs and channels, E the evaporation of the free water surface, L_v the water volume in ice, V_k the final capacity of the reservoir. The members of this equation form on one hand the decisive factors, on the other hand the supplementary ones. The supplementary factors, e.g. the condensation, can be neglected due to their smaller importance. The infiltration in the inflow and discharge is not mentioned separately, though the ground water inflow may be of importance in some reservoirs. At dam reservoirs with the seasonal storage the water plane

reaches the same level every year, at the reservoirs with the carryover storage the maximum level can be even some meters below the normal backwater. The amplitude of the oscillation of the water plane varies usually about 2—3 m reaching in a series of cases 6—7 m and cases were established in Czechoslovakia, where the draw-down was up to 15 m (J. Linhart 1956) during one year. By the building of the cascade of dams on one water course, the oscillation



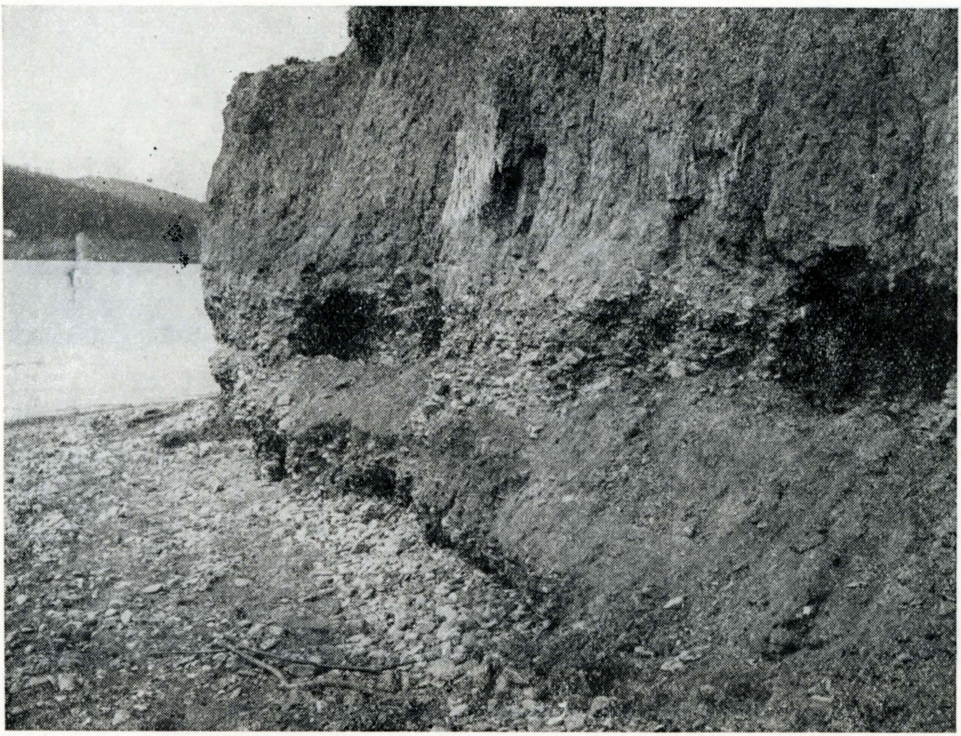
2 The same part of the shore as on the fig. 1, in 1963.

of the water level became in the water reservoirs downstream considerably more moderate.

In addition to the oscillations of the water level caused by the water balance of the reservoir, the oscillation conditioned by the more considerable difference of the atmospheric pressures in the various parts of the reservoir can occur in larger reservoirs. These are rhythmical oscillative movements at which the whole water plane passes from the horizontal position to the tilted one, alternately on one and the other side (seiches).

To the changes caused on the water level by the wind activity the wave motion belongs first of all. Its intensity depends on the force and on the duration of the wind, on the length of the free water plane on which the wind wave may take a run and on the depth of the reservoir. On large basins in SSSR wind waves were observed during strong storms surpassing 2,5 m in height

(A. V. Živago—K. O. Lange 1959) and on the reservoirs in ČSSR the author registered at a very strong wind (6—8 Beauf.) the height of waves up to 1,5 m. The steepness of the waves given by the ratio of their height to their length is on the large dam lakes greater than on the sea, but their period is considerably smaller than on the sea. The wind causes besides the wave motion even the water mass movement near the shore. In the direction of the wind, the flow develops



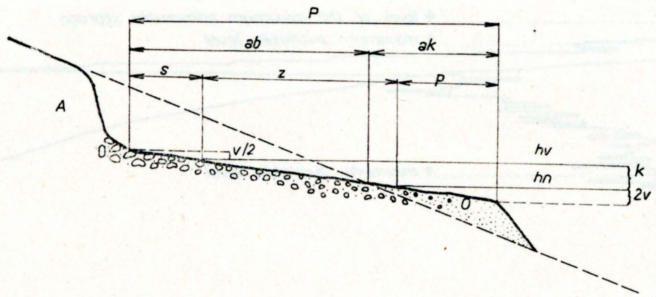
3 Niches in the abrasion cliff in the gravel terrace with a loess cover on the Knínički-dam.

near the surface and causes at movements towards the shore a flow of an opposite direction on the bottom. The shore being plain and flat, the coarseness at the bottom is in relation to the depth of the water considerable, the velocity decreases at the bottom and therefore the inflow to the shore is greater than the discharge, water is accumulating here and the water level raises. It is the other way round, when the wind blows from the shore, when the greater discharge cannot be compensated by the slowed up inflow and therefore the water level is sinking at the shore. On the dam reservoir of Rybina in SSSR a difference in height of the water level at the west and east shore was establishe1 to be even 1 m (J. Linhart 1961a), when the wind was strong.

The changes caused by the water flow reflect only in the upper part of the

reservoir and exceptionally even in the middle one, which will have only at greater inundations the character of a river.

The changes connected with the origin and the end of the coherent ice cover in the basin depend on its geographical position, on the atmospheric conditions and on the physical properties of water. The surface of the water level freezes from the shore towards the centre of the reservoir. The thickness of the ice



1 Origin of the abrasion cliff and development of the shore platform

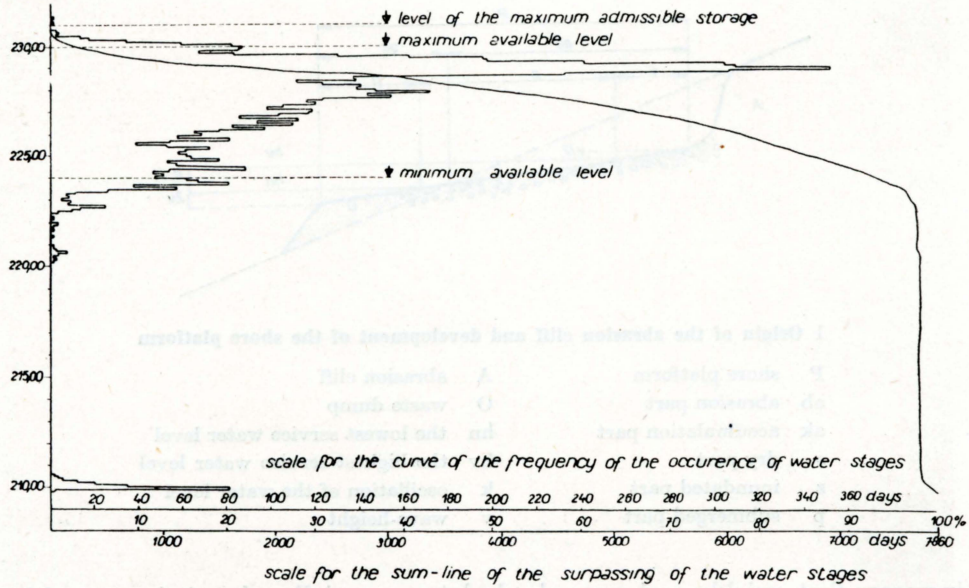
P	shore platform	A	abrasion cliff
ab	abrasion part	O	waste dump
ak	accumulation part	hn	the lowest service water level
s	dry part	hv	the highest service water level
z	inundated part	k	oscillation of the water level
p	submerged part	v	wave-height

increases first quickly and more slowly later, especially when it is covered by a layer of snow, which has a small conductivity of heat. According to the observations, the solid ice cover in the reservoir lasts about a fortnight longer than in the flowing river below the dam. The greatest thicknesses of the ice cover on the dam reservoirs in ČSSR were measured in the value of 70 up to 100 cm (S. Kratochvíl 1961).

After the filling of the dam reservoir the remodelling of the original valley slopes and of the bottom begins. The earths are saturated by water, their real weight decreases by the effect of the uplift pressure, but their load above the water level does not change. Due to the change of the equilibrium the old already calmed landslides on the valley slope can be enlivered. By the oscillation and the persistence of the water plane on a certain level the system of step-like abrasion terraces is formed. They do not keep long in loose soils, for they are washed out by water at the iterative rise of the water level. At a sudden draw-down the fine parts of the soil use to be washed out of the slope to the bottom of the reservoir and the change of the physical properties, the disturbance of the stability of the shores and the landslides set in.

The results of the existing research showed that the main factor of modelling

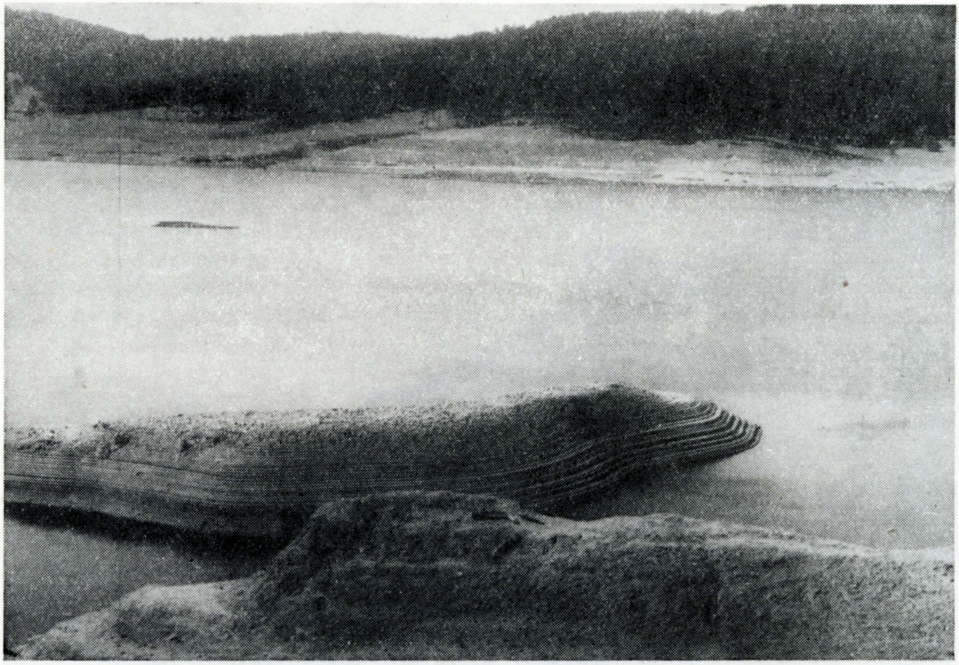
is the waved water level of the reservoir. The steep shores are wavecut and the abrasion cliffs are formed on them. If they consist of less resistant rocks, they are retreating relatively quickly and leave an abrasion terrace sloping gently to the water level; of this terrace a larger or narrower shore platform successively develops. The shore retreats most quickly in loess loams. On the large dam reservoirs in SSSR the back-wearing of the abrasion cliffs up to



2 Water basin of the Kníničky-dam near the town Brno
Curve of the freguency of the occurrence of water stages and the sum-line of their surpassing from 25. 6. 1940 till 31. 12. 1961

100 m in one year was established in the first phase after their filling (S. L. Vendrov 1953) and the height of these cliffs reached up to 20 m. On the dams in ČSSR e.g. on the Kníničky dam on the river Svratka near the town Brno, the shore retreats in sections formed by terrace gravel with loess in the overlying rock on average yearly by 1 m. The initial quicker retreat got slower, from the filling of the basin the 25. 6. 1940 till 31. 12. 1961, that is in 7860 days, the shore retreated here on some places by 22 m. On the base of the graphic frequency chart of the occurrence of the water stages and of the establishment of their duration of surpassing, it is possible to judge on the measured profile the abrasion intensity and to compute the volume of the abraded material, which caused the aggradation of the useful capacity of the reservoir. The building of the dam on the upper Svratka river in Vír was finished in 1957 and the water passage was improved so, that in the basin of the Kníničky dam

on the middle Svratka river the most frequent level of the water plane increased from the altitude 227,90 to the height 228,90. This means, the shores to be now disturbed most often by the effect of the wave activity in a stripe situated by 1 m higher than it was before. In the measured profile the upper part of the shore over the height 228,90 in the years 1958—1961 retreated by 3,5 m and 14 m^3 of loess were abraded here on one running meter of loess.



4 Steps of the abrasion terraces on the Batak-dam in Bulgaria developed in the sandy banks by the sinking of the water level in 1962.

The height of the water level 228,90 was reached or surpassed in the whole period of observation (1940—1961) during 353 days and the whole half of this value falls on the last 4 years. The retreat of the abrasion cliffs will stop, as soon as they will get out of the reach of the waves, the power of which is suppressed on the shore platform growing below the cliffs. The wave activity is then limited only on the abrasion and the levelling of the inundated and submerged surface of this platform. The depth at which the waves begin to modell the bottom more considerably and at the same time to lose their power, equals the double wave-height (V. P. Zenkovič 1946). The correctness of this fact was confirmed by the research, for the depth of the margin of the submerged part of the sandy shore platform is equal to the double height of the wave. It may be seen, that the waves do not affect the greater depth of the bottom.

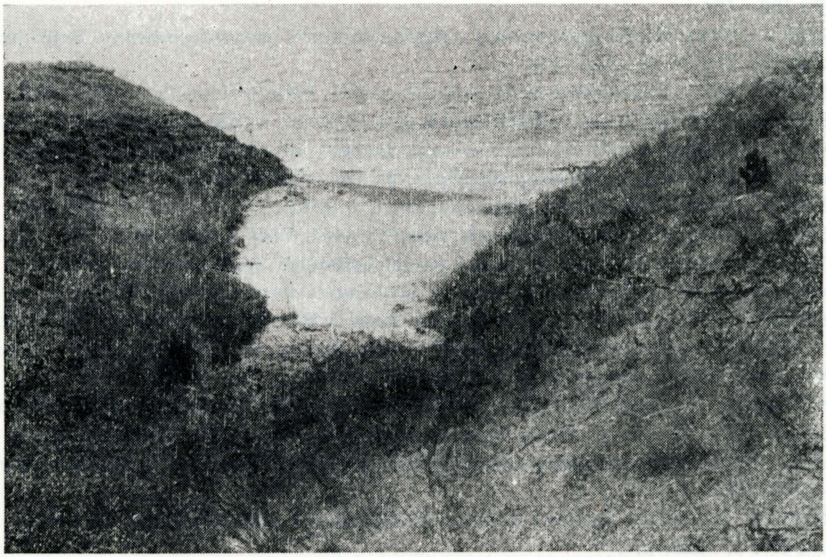
The shore platform begins consequently in the depth equal to the double height of the wave below the lowerst service water level and it has its end below the abrasion cliff in the height equalling approximately the half of the wave-height above the most frequent service water level. The wave activity continues then on the shore platform by the classification of the material so, that the coarser material remains in its upper part and in the direction to the basin

5 Roots of the stubs stripped by the effect of the swell in the slope débris on the shore of the Orava-dam.

it grows finer and finer. On the gulf shore the abrasion passes more intensively on the capes. The abraded material is deposited by the waves on the margin of the cape, where the sandy beach grows successively. At the opposite direction

of the wind the beach grows even on the second side of the cape, they become allied after a certain time and the cape changes into a liman closed by the beach. The vegetation seizes on it successively and so the shore line gets levelled gradually.

The lateral erosion observed in the upper part of the reservoir due to the effect of the running water contributes to the destruction of the shore. The



6 Development of sandy beaches and limans on the shore of the Cimljansk-dam in Soviet Union. All photographs by Jaroslav Linhart.

destructive effect is increased by the frazil ice during the spring melting and by the floating blocks of ice.

On the base of the long range observations and of the study of the changes on the shores of the existing reservoirs, it is possible to elaborate the prognosis of the development of the shores of the planned basins, what is of great importance for the projectors and for the builders of further dams.

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