Industrial Technology Facilitation for the Dredging of Highland Placers

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Abstract. As the reserves of alluvial placers in river valleys are getting depleted, the importance of highland placers increases. In some cases, it is possible to use dredging for their development. Dredging is successfully applied to develop a highland placer of the Yakh-Suyskoye deposit located in northwestern Pamir at the altitude of 2000 m or more. A 380-liter dredge is used there. This deposit faces specific problems. They include steep slopes and narrowness of the valley, unevenness of the placer bedrock with lots of sharp bumps and dips, lots of boulders and dredging waste in the placer, adverse hydrogeological conditions that hamper the development and the maintenance of the water level. Due to this, the dredge operated in the semi-bank mode. Besides, the dredge aft was regularly displaced to dispel dredging wastes, which decreased the dredge performance while not being able to eliminate the bottom break hazard and the accumulation of dredging wastes in the pontoon. All of the above calls for the development of a new placer development technology that would prevent negative impacts. Based on the previous research, we developed and introduced a placer development technology stipulating the increase of the water level by 7 m. To this end, we constructed a dam on the waste piles below the dredge. The dam was 10 m high and 120 m wide. Since the permeability coefficient of the river Safet-Dora rocks is 75-80 m/day and that of the dredging waste piles is 500 m/day, the dam was equipped with polyethylene film sealing screens. This new dredging technology with a 7.5 m water level increase allowed us to process the site in one bank; eliminate the accumulation of dredging wastes at the pontoon aft and the risk of pontoon breakage on the bedrock bumps; increase the dredge operation time by 1.3 h/day; prevent river pollution; acquire significant economic benefits. Thus, we developed and introduced a relatively simple and efficient dredging technology for highland placers, which can be recommended for further use.

1. Introduction
Highland placers can be found in the mountains of Central Asia, North Caucasus, the Sayans, Altai, northern Buryatia, Transbaikal, and some regions of Yakutia at altitudes of up to 2000 m above the sea level (sometimes even higher).

Highland regions feature at least four placer groups. The first one comprises slope eluvial-diluvial placers, as well as diluvial-proluvian-colluvial and colluvial-alluvial placers; the second group comprises alluvial proper and glacifluvial lake placers; the third one comprises highland residual eluvial placers of relic watersheds, highland residual alluvial placers of uplifted and bridged river valley placers, and highland terraced placers; and the fourth one comprises terraced placers of deep-incised mountain river valleys in their mid-higher reaches [1,6,8].
Highland placers are formed under high-velocity sloping, mostly physical weathering, when only large particles of mineral resources, including gold, can be extracted relatively easily. The transportation of gold here mostly occurs through inclusions in psephitic and, to a lesser extent, psammitic materials. Free gold can only be transported if released during the intensive melting of glaciers or heavy rains on steep slopes. The destruction of quartz fragments containing gold inclusions takes place in colluvial and proluvial sediments due to the frost and bacterial weathering involving the entire bacterial community, especially cryophilic species and their strains [5,7]. Due to the regular washing-out of the highland alluvium due to the temporary increase of the water flow and current velocity, relatively light psammitic and gravel rock debris and light minerals can be easily washed away. Therefore the natural washings that are formed are rich in heavy minerals, including gold. Nevertheless, mineral resources are not significantly released in the valleys of the higher reaches of rivers, and they are mostly contained in the psammitic or psephitic materials. Their significant release and thus the formation of placers rich in mineral resources and their stocks occurs only in stope-out equilibrium valleys. Those are, however, typical alluvial placers [2,3,4].

Highland regions are characterized by the extreme continental climate and, as a consequence, often and rapid changes in water flow intensity and velocity. In periglacial areas, the seasonal temperature changes bring the changes of the water phase factors in the intensive frost weathering leading to the release of mineral resources from quartz veins and other mining formations.

2. Mining and geological conditions of placer dredging
Dredging can be applied to any types of placers, probably except the slope diluvial-proluvial-colluvial ones. It is difficult to dredge those because of their relatively small size, as well as the problems with creating a reservoir for the dredger to operate in and maintaining the required water level in it.

In some cases, dredgers operate in the mountains at up to 2000 m above the sea level (Tajikistan) under very complicated operational and mining conditions. Thus, highland dredging technology must be improved to achieve a successful operation.

Placer mining in highland regions comes with additional problems. These mostly include steep slopes of the deposit developed, narrow valleys (and gorges in some cases), uneven bedrock with sharp bumps and dips, lots of boulders and dredging wastes in the placer, adverse hydrogeological conditions that hamper the maintenance of the required water level in the dredging site and the selection of the tailings locations, which impacts the safety of works. Therefore, the dredging bank is processed using special methods, such as semi-bank operation and regular aft displacement to dispel dredging wastes, which significantly reduce dredger performance and do not prevent bottom breakage and the accumulation of wastes at the pontoon aft [9,11].

The improvement of highland placer dredging technology can be illustrated by the Yakh-Suyukoye deposit (Tajikistan) that is developed using a 380-liter deep-digging dredge, which has all of the problems mentioned. The pay wash lies in the ancient concealed valley of the river Safet-Dara, a left tributary of the Yakh-Su river located in the foothills of the Darvaz Range of the Pamirs at the altitude of about 2000 m. The valley incline is 0.01-0.06. The bedrock is plicated and slated.

The area features a temperate climate. The yearly average temperature is +9С with the highest value of +35С and the lowest of -14С. The yearly average precipitation is 855.7 mm, mostly snow. The snow cover sets by the end of November and persists until mid-April. The depth of ground freezing is 0.2-0.5 m. Rivers break up in April with torrential floods.

The placer is characterized by a significant presence of boulders (17% on average) and dredging wastes (up to 20%). The proportion of fine-grained 0.005 mm suspension in the dredging quarry producing stable water turbidity is 8.85%.

The alluvial sediments of the placer carry a lot of water and feature a large influx of groundwaters. There are several waterbeds that have a significant influence on the supply of water into the dredging quarry.
The permeability of the Safet-Dara river rocks is 75-80 m/day. After panning, dredging tailings have 22% of +200 coarseness class boulders. Simultaneously, the permeability of pebble tailings reaches 500 m/day. The water is supplied to the dredger using a closed-circuit arrangement. Due to the high permeability of the tailings used in dam construction (upslope placer development), it is difficult to maintain the required water level in the quarry, which leads to a significant accumulation of wastes in the dredger, the necessity to regularly displace the aft to dispel the wastes, and the processing of the placer in two semi-banks. Besides, industrial wastes are not treated to fit the standards.

3. Technological solutions for the development of highland placers

To mitigate the negative impacts related to uphill locations, we developed a placer development technology stipulating the increase of the water level in the quarry by 7=10 m using a dam constructed on the tailings below the dredge based on the previous research [10,12]. Due to the high water permeability of the rocks and especially the tailings, the dam must have efficient sealing and comply with the following requirements:

- Maintaining sufficient water permeability;
- Resilience against filtering deformations throughout the operating life;
- Minimum possible construction costs and inputs with maximum efficiency of excavation equipment.

The increase in the water level shall yield the following results:

- Quality treatment of the process water in the settlement pond;
- Preventing the accumulation of dredging wastes at the pontoon aft;
- Access to resource deposits;
- Safe operation of the dredger;
- Dredger operation without aft displacement.

![Figure 1. Process flow chart for highland placer development.](image_url)

These actions shall improve the working conditions and the productivity of the dredger.

The 120-meter long and 10-meter high dam featuring a polyethylene film sealing screen and a cut-off wall driving of 1.5 m in the dredging waste pile was constructed using an ESh-10/60 excavator and a bulldozer (Figure 1). To protect the film (reduce the damage it receives during the laying on the pebble tailing), we used bulldozers to dump a 0.5 m protective layer of dredging waste and overburden rocks on the quarry slope of the dam. The overlapping double-laying of the 3-meter wide 108-02-020 polyethylene film on the quarry slope and the cut-off wall of the dam took 16 man shifts. This required 1 ton of the film. Afterwards, the bulldozers were used to create a protective layer of dredging wastes.
and overburden rocks. The thickness of the protective layer calculated for a 10-meter high dam was 1 m.

![Figure 2. Sealing screen dam layout.](image)

The introduction of this technology at the dredging quarry helped increase the water level by 7.5 m, which led to the following results:

1) The quarry can be processed in single banks instead of semi-banks;
2) The freeboard of the placer was reduced;
3) The problem of dredging waste accumulation at the pontoon aft was solved, and thus the aft displacement to dispel wastes across the bank became redundant;
4) The dredger operation became safer (we eliminated the risk of pontoon breaking on the bedrock bumps);
5) The working hours of the dredger increased by 1.3 hours per day, which led to the increase of daily output by 7.2%;
6) We prevented the pollution of the river with discharge flows;
7) The introduction of this technology had a significant economic effect.

4. Conclusion
The research conducted and the industrial introduction proved this simple and efficient highland dredging technology efficient. The unique feature of this technology is that the dam is constructed directly on the pebble tailing using its outsloping, creating a protective layer of overburden rocks and dredging wastes, film laying, and protective layer filling.

5. References
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