8. Recommendations for future subsurface dam projects

The above-described results of the pilot study of the subsurface dam as the “Model Project to Combat Desertification” showed that the "subsurface dam technology" developed in Japan were applicable to West Africa, a region affected by desertification.

However, to construct operational subsurface dams adapted to the physical and social conditions of the region, sufficient attention should be paid to the following.

8-1 Selection of subsurface dam sites

(1) Evaluation of "fossil valley"

In this project, the subsurface dam was built using an existing fossil valley. Although water leakage from reservoir area occurred, it was confirmed that the construction of a subsurface dam using a fossil valley was possible.

It is said that there are many fossil valleys in the Niger River basin, and there may be many possible sites for the construction of subsurface dams.

It should also be noted that the fossil valley is often accompanied by shallow groundwater, and in general, by a wide area of flat lowland. Therefore, fossil valleys seem places with high potential for the development of irrigation or livestock farming. It is desirable to examine the distribution of fossil valleys and their characteristics not only for the construction of subsurface dams, but also from this viewpoint.

(2) Geological structures other than fossil valleys

Although the surveys for the subsurface dam site in this project were carried out targeting “ring-shaped landforms” and “bottleneck-shaped landforms” as well, proper geological structures from these landforms except “fossil valleys” were not found. However, more detailed surveys would make it possible to find proper dam sites from geological structures other than “fossil valleys”, even if these surveys require enormous effort.

(3) Difficulty in estimating exploitable groundwater

In selecting the subsurface dam site, it is necessary to estimate the volume of groundwater to be stored. However, estimating the "water to be stored", which is relatively easy in case of a surface dam, encounters the following difficulties in case of a subsurface dam:

1) Because the water storage layer of a subsurface dam is formed under ground, it is difficult to precisely determine its form and volume.

2) The water storage capacity of a subsurface dam depends on the effective porosity of the geological strata. Determining the effective porosity of all parts of the water storage layer requires a significant survey effort.

3) It is difficult to precisely estimate the recharge of groundwater into the water storage layer.

4) It is difficult to detect water leakage points from the water storage layer, and to forecast the volume of water leakage.

In future subsurface dam projects, it is advisable to carry out more detailed surveys to estimate more precisely the volume of water to be stored. Nevertheless, even with such an estimate, it is impossible to completely avoid fairly large error. This should be taken into account in selecting subsurface dam sites and in making plans for using the reserved water.

(4) Selection of dam site from a socio-economic viewpoint

In this project, taking into account its experimental character, priority was given to the hydrogeological conditions in selecting the subsurface dam site. In future subsurface dam projects for practical purposes, socio-economic factors should be taken into account as well.

In general, using the reserved water by the subsurface dam requires "water-pumping facilities". If the subsurface dam is located far from where the reserved water is used, large "water-supply facilities" are also required. In some cases, the cost of the installation of these facilities may be higher than that of the construction of the subsurface dam.

Therefore, in selecting the subsurface dam site, the following factors should be taken into account for better cost-effectiveness:

- Population that will use the reserved water
- Possibility of developing irrigation or livestock farming using the reserved water

In addition, note that if polluted water enters the reservoir area of a subsurface dam, it takes an enormous amount of time to restore the water quality due to slow water circulation. Therefore, precautions against water pollution by agricultural chemicals, for example, should be taken when using the land within the reservoir area.

8-2 Survey methods

(1) Use of aero-photographs

Most of the study area for this project was very flat, so the use of aero-photographs was essential for the field exploration. The use of aero-photographs is effective in general in field exploration in areas with huge peneplains such as in Africa. It is thus desirable to disseminate the technique of using aero-photographs to African engineers engaged in geomorphological and geological studies.

(2) Points to be noted in observing groundwater

It was revealed that there were some perched water bodies in the fossil valley sediment at the subsurface dam site in this project, and the existence of this perched water strongly affected the results of the observation of groundwater level. It is thus necessary to note that it is possible to overestimate seasonal fluctuation in the groundwater level due to the presence of perched water.

In general, perched water may not only be in fossil valley sediment, but also in basement rock.

(3) Importance of hydrological observation (rainfall, rate of streamflow, groundwater level, etc.)

The surveys and the evaluations in this project encountered difficulties due to a lack of existing hydrological data on rainfall, rate of streamflow, groundwater level, etc.

As rainfall sometimes shows an extreme difference even between relatively close points, it is

advisable to arrange rainfall stations more densely in areas where there is a shortage of water resources as in the Sahel. In addition, as variation in river water is closely related to the exploitation of river water and groundwater, it is preferable to measure the rate of streamflow as at many points as possible, even in the same river system. As for the groundwater level, although the observation data collected during the excavation of deep wells were relatively well preserved, the data of the groundwater level in shallow wells and the data of seasonal and interannual fluctuation in the groundwater level were limited. These data are necessary for any exploitation of groundwater resources. The establishment of systems for such observation and data-keeping is thus desirable.

(4) Surveys in the reservoir area

As described in Section 8-1-(3), form, volume, hydraulic characteristics and possibility of water leakage of the reservoir layer of the subsurface dams are not easy to determine. Surveys to determine these parameters for the construction of a subsurface dam are thus important.

8-3 Methods of construction of a subsurface dam

(1) Disadvantages of a "subsurface earth dam"

The method of construction adopted for this project was to install an "earth dam" (earth dike) under ground. This method poses the problem of "water springing" during construction. In this project, there was little “water springing” from the excavation face of the fossil valley sediment and special measures were not necessary. However, when there is a lot of shallow groundwater and stopping “water springing” is difficult, it sometimes becomes impossible to continue construction.

It should be noted that a subsurface dam to be constructed very deep under ground requires a great quantity of excavation and backfilling, with corresponding costs. The risk of water springing also increases.

(2) Material of the dam body

In this project, the dam body was built with materials extracted from a place away from the dam site. However, surplus soil produced by excavation at the dam site proved usable as the dam material later on.

The reuse of the surplus soil produced by the construction of a “subsurface earth dam” eliminates the need to use material from other places, and thus can reduce the negative impact on the environment. This process should be considered in planning “subsurface earth dam” projects.

(3) Introduction of a "cut-off wall by an underground diaphragm wall”

In this project, the method of constructing the "subsurface earth dam" was selected to use materials available in Burkina Faso. However, the principle of the subsurface dam is the same as that of the "cut-off wall" that is generally used for construction work, and the “cut-off wall” is applicable to the subsurface dam. Especially when, as described above, there is a risk of a large amount of “water springing” during excavation work, or when the dam is to be built very deep under ground, or when shortening the construction period is necessary because work can only be carried out in the dry season, the “cut-off wall method” is better than the “underground earth dam”.

West African countries such as Burkina Faso have recently been advancing the effective use of limited urban space, represented by the construction of high-rise buildings, for example. From now on, this "urban development" will probably extend to the "exploitation of underground space". The “cut-off wall by an underground diaphragm wall (e.g. soil-cement mixing wall method)” was developed as a construction method for such " exploitation of the underground space". Therefore, this method and the necessary machinery will be introduced sooner or later in West Africa.

From this viewpoint, the applicability of the method using a "cut-off wall by underground diaphragm wall" to the construction of a subsurface dam is increasing in West Africa.

8-4 Costs

In this project, the direct costs of the construction of subsurface dam and installation of water-pumping and supply facilities were as follows:

- Construction of the subsurface dam 108,595 thousand yen
- Installation of water-pumping and supply facilities 24,900 thousand yen (part of which is an estimate)

The direct costs of installation of the associated facilities were as follows:

- Facilities for groundwater observation 4,160 thousand yen
- Small-scale surface dam with water gates 16,933 thousand yen
- Pilot farm 2,570 thousand yen

The personnel costs for the Japanese engineers who supervised the entire construction work of the subsurface dam are not included in the costs indicated in this section.

8-5 Management and maintenance system

In this project, when the water-supply facilities started service, the villagers in Kombangbedo Village to which the water was supplied organized a "Committee for the management of the water-supply facilities". This committee collected the water tax, and organized “rotation for cleaning the facilities” as well.

On the other hand, facilities with sophisticated devices such as solar power stations cannot be maintained by the local people alone. It would thus be necessary to set up a system for longer-term management and maintenance with, for example, the assistance of the government of Burkina Faso.

It should be noted however that the solar power station installed in this project was not equipped with "batteries for night storage", which tend to break down.

Thus, ownership by local people and local authorities is essential for the management and maintenance of water resources, including subsurface dams. It is desirable, based on the principle of the participation of local communities and local people, to establish ownership by them from the planning stage of the project.