Key Issues:
4- Reservoir Sedimentation
12-Benefits due to Dam Function

Climate Zone:
Cf: Temperate Humid Climate

Subject:
- Sediment Control for Dam by Means of Bypass Tunnel

Effects:
- Securing Effective Reservoir Capacity on Long-term Basis

Project name: Miwa Dam
Country: Nagano Prefecture, Japan (Asia) (N35°49', E138°5')

Implementing Party and Period
- Project: Ministry of Land, Infrastructure and Transport
1959 (Completion of construction) -
- Good Practice: Ministry of Land, Infrastructure and Transport
2004 (under construction) -

Keywords:
Measures to Counter Sedimentation, Bypass Tunnel, Wash Load

Abstract:
A redevelopment project is currently underway at the Miwa Dam as a permanent measure to counter sedimentation of this multipurpose dam. The nature of the countermeasure, the first attempt in Japan, includes the development of technology for guiding the flow of sediment down from the dam and the implementation of such technology. The major installations are a flood bypass tunnel and a diversion weir, both of which were started in February 2001 with completion of construction slated for the end of FY 2004. The project is expected to provide a permanent measure to counter sedimentation.

1. Outline of the Project

The Miwa Dam is on the Mibu River, a tributary of the Tenryu, and is situated in Hase-mura and Takato-machi. Together with the Takato Dam (immediately downstream from it), meant exclusively for power generation, the Miwa Dam was given a position as a main installation in the "Mibu River Comprehensive Development Project", which had been under consideration since 1949 independently by Nagano Prefecture with the objective of countering repeated inundations in the Ina Valley and remedying the shortage of electric power, referring to TVA in the United States. Later, the Ministry of Construction (then) joined in and the project was started in 1952. The Miwa Dam, the construction of

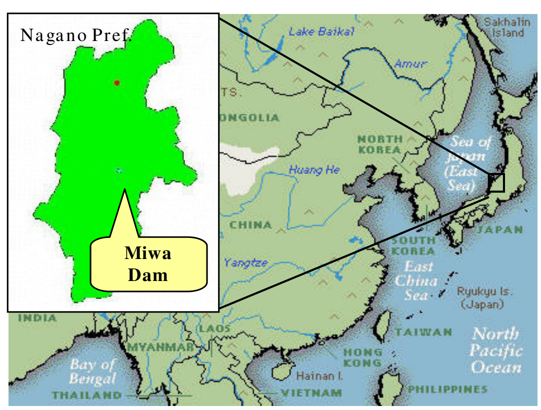

Fig.-1 Map of Miwa Dam Location

which was directly executed by the government, was completed in November 1959. Table-1 shows the particulars in the initial plan.

Its location and initially planned capacity distribution are shown in Figs. 1 and 2, respectively.

By the so-called first phase of the Mibu River Comprehensive Development Project, the safety degree of flood control along the river had improved dramatically and a stable supply of irrigation water was achieved, resulting in a remarkable increase in the agricultural water supply area from 1,200 ha to 2,500 ha. The prefecture launched electric power production at the Miwa and Haruchika Power Plants, the first case of such an undertaking. Electricity production at the two plants continues to play an important role, amounting to 40% of the total power output under prefectural management.

Table-1 Particulars of Miwa Dam in Initial Plan

Item		Specification
Date of Completion		November 1959
Name of River		The Mibu River of the Tenryu River System
Purposes		Flood control, power generation and irrigation
Position		Left bank: Katsuma, Takato-machi, Kamiina-gun, Nagano-ken Right bank: Oaza Himochi, Hase-mura, Kamiina-gun, Nagano-ken
Reservoir	Catchment area	311.1 km^2
	Reservoir area	1,789 km^2
	Total length of impoundment	5.2 km
	High water level when flooded	815.0 m
	Normal high water level	815.0 m
	Limited water level	808.0 m
	Minimum operating level	796.5 m
	Total storage volume	37,478,000 m^3
	Effective storage volume	25,544,000 m^3
	Flood control capacity	15,251,000 m^3
	Water use capacity	Flood period 14,003,000 m^3 Power generation Other than in flood period 25,544,000 m^3 Irrigation 4,000,000 m^3
	Sediment storage capacity	6,586,000 m^3
	Design flood volume	1,200 m^3/s
	Design discharge	300 m^3/s
	Design control volume	900 m^3/s
Dam body	Type	Gravity-type concrete
	Geological features	Kashio gneiss
	Crest elevation	817.6 m
	Height of dike	69.1 m
	Crest length	367.5 m
	Cubic volume of dam body	Concrete 285,700 m^3
Water use	Power generation	25.6 m^3/s 12,200 kW
	Irrigation	8.9 m^3/s About 2,700 ha
Total project cost: ¥3,160 million		

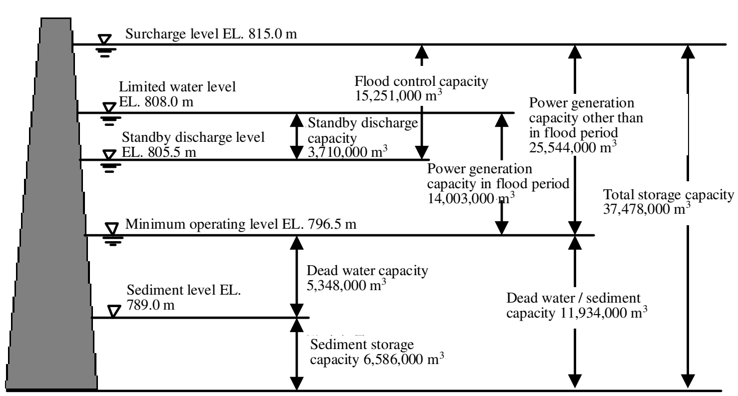

Fig.-2 Initially Planned Capacity Distribution

2. Features of the Project Area

The Tenryu River, nicknamed the “Wild Tenryu,” is one of Japan’s largest rivers. Its catchment area, 5,090 km^2, and the total length of its main watercourse, 213 km, respectively rank 12th and 9th of the 109 river systems managed by the Ministry of Land, Infrastructure and Transport. It is famous for its rapids with a bed slope of nearly 1/200 in its upper stream (in Nagano Prefecture).

From the source in Mt. Akadake of the Yatsu range, it flows into the Ina Valley through Lake Suwa and then runs south to Ina City where it is joined by the Mibu, the largest of its tributary rivers. Thereafter, together with the Koshibu, the Matsu and other rivers, it enters Shizuoka Prefecture through the Tenryu gorge, a well-known sightseeing and boating spot, and continues to flow south. In Hamamatsu City, it reaches the Sea of Enshu.

Yearly average precipitation in the catchment area ranges from 1,300 mm in the Suwa basin to 3,000 mm in the mountain areas of the Central and South Alps. Taking advantage of its abundant water and sharp slope, a number of dams were built in very early days, namely, the Yasuoka Dam (completed in 1936; Chubu Electric Power Co.) and the Sakuma Dam (completed in 1956; Electric Power Development Co.), which has the largest reservoir capacity (327,000,000 m^3) in Japan. Nevertheless, both of these dams face a problem with sedimentation.

On the other hand, the Mibu River has its source in Mt. Senjo, called the Queen of the Southern Japan Alps. After following a complicated watercourse traveling south, west, north and west, the Mibu joins the Tenryu in Ina City. The river has a catchment area of 481 km^2, a total watercourse length of 60 km, and a bed slope of 1/100, that is, its stream is faster than that of the Tenryu. In Ina City, it turns into a typical alluvial fan river. Fig.-3 is a map of the catchment area of the Tenryu and Fig.-4 is a rainfall contour map of the area.

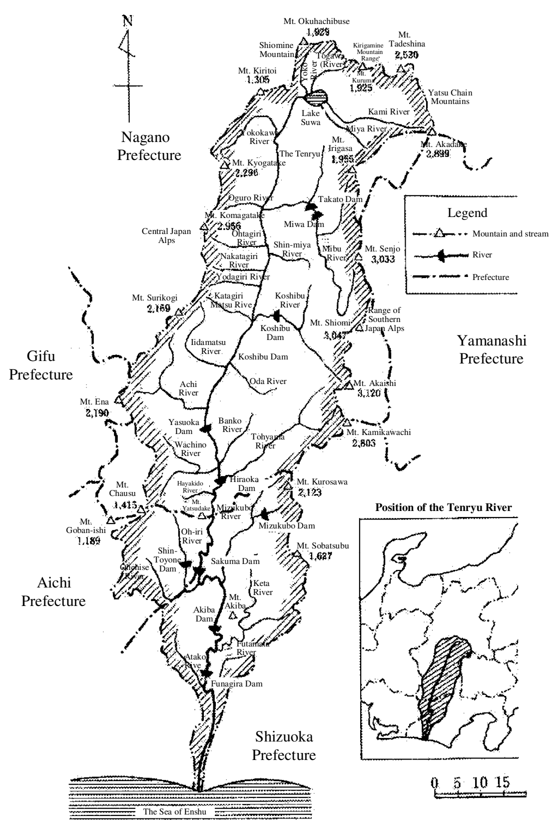

Fig.-3 Map of the Catchment Area of the Tenryu

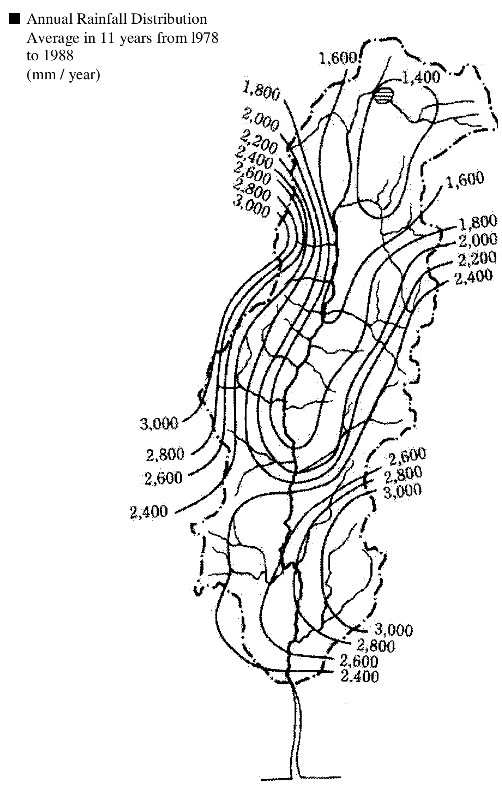

Fig.-4 Rainfall Contour Map of the Tenryu

In its approximately 200-km course from Lake Suwa to the Sea of Enshu, the Tenryu describes almost a straight line. The peculiarity of the area is apparent even from the map. In this section, the river is sandwiched in between the Central Japan Alps and the Southern Japan Alps which rise on the west and east sides of it. A group of faults runs under the latter and includes the "Chuo Tectonic Line," which is one of the world's representative faults and the largest in Japan, and the Tenryu flows almost in parallel with the Southern Japan Alps. The Chuo Tectonic Line dates back about 70 million, possibly even 100 million years. Long after its origin, or between 20 and 15 million years ago, affected by the diastrophism that produced the Itoigawa-Shizuoka Tectonic Line, commonly called "Fossa Magna," the Northern, Central and Southern Japan Alps still continue active orogenic movement. The Southern Japan Alps in particular have the highest uplift speed, reportedly 4 mm a year.

In reality, the mountains rise at a higher speed and the figure is understood to be a result balanced with sediment run-off due to weathering and erosion. This could very well be related to the occurrence of floods containing a large amount of sediment, thus the nickname, "Wild Tenryu." Fig.-5 is a geological map of its catchment area (in Nagano Prefecture).

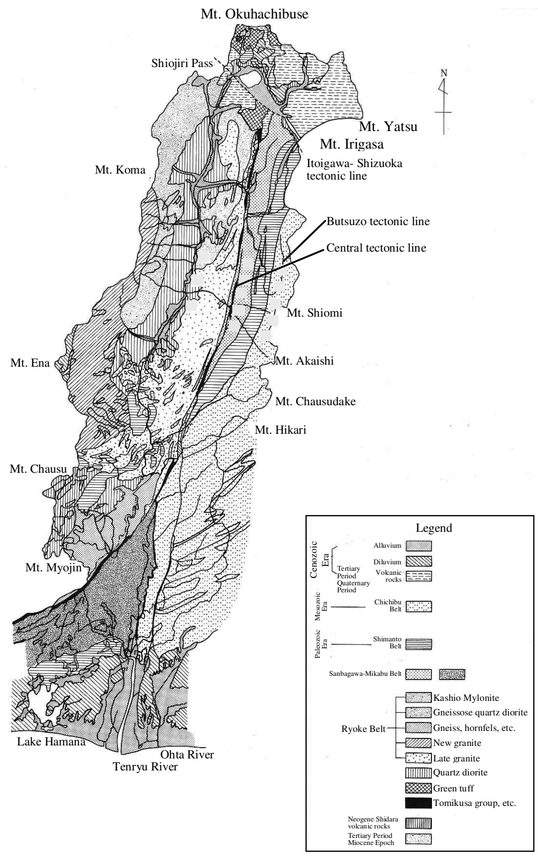

Fig.-5 Geological Map of the Tenryu Catchment Area

3. Major Impacts

At the time when the Miwa Dam was under construction, flood control was planned to prevent the Mibu and the main stream of the Tenryu from flooding on the assumption of a maximum inflow of 1,200 m^3/s and a maximum discharge of 300 m^3/s during a probable flood over a period of 100 years. In the design sediment, about 6,600,000 m^3 for 40 years was secured through coordination with Nagano Prefecture, the power generation utility.

However, in August 1959, just before completion of the work, a flood equivalent to the design high water discharge at a maximum flow rate of 1,182 m^3/s occurred. With this as the start, sediment of about 6,800,000 m^3, exceeding the design volume, flowed in for only three years to the "3-6 Calamity" deserving special mention in the history of disasters in Ina Valley. Of the above volume, 4,400,000 m^3 was deposited in the effective reservoir capacity to deteriorate the flood control function. To counter the situation, the reservoir capacity distribution plan was changed in 1966 on the basis of the results of sounding carried out in 1963. The capacity distribution diagram that was calculated when the plan was revised in

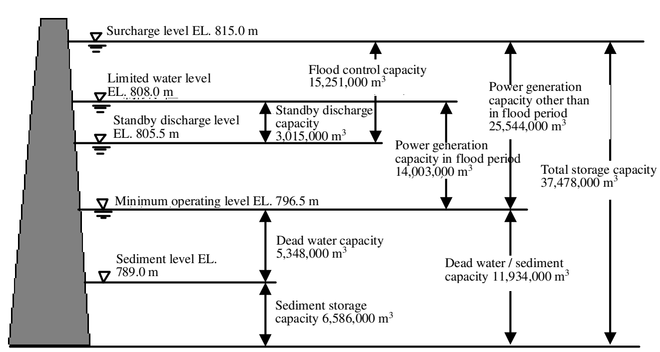

Fig.-6 Revised Planned Capacity Distribution

1966 is shown in Fig.-6.(Note) The contents of the revised plan are as follows.

1) Flood control plan

The flood control capacity is to be changed to a value that could maintain minimum EL. 805.5 m as of 1963. With a new flood control capacity set by using two significant floods around the time when the dam was completed, namely, a typhoon-type one in August 1959 and a front-type one in June 1961 as references, an optimum dam discharge system was restudied and the design discharge was changed to 500 m^3/s.

2) Water utilization plan

The water utilization capacity is simply changed to the value secured as of 1963, but without reviewing water rights in volume.

3) Plan to Cope with Sedimentation

The dead water capacity is changed to empty space capacity as of 1963, but the sediment storage capacity is not changed. There are no fundamental changes such as a review of the design volume of yearly average sediment.

The revision of the plan in 1966 is believed to have been an emergency measure against abnormal sedimentation. Thereafter, it was decided to systematically remove gravel as a temporary measure to counter sedimentation with the intention to maintain and secure effective storage capacity.
Nevertheless, the volume of sediment continued to increase and an inundation in 1972 brought the actual volume of sediment to a peak of 9,500,000 m^3. After this, fortunately without the occurrence of any large floods, digging to remove gravel amounting to 450,000 m^3/year maximum was continued and a decrease to 7,700,000 m^3 was attained by 1981. In order to radically improve such an unstable situation, a full-scale investigation for redevelopment was started in the same year. Ironically, the Mibu River swelled to its highest (i.e., 1,321 m^3/s in the Miwa Dam, exceeding the design high water discharge) in 1982, the following year, and in this one-year period, 4,300,000 m^3 was newly deposited. Furthermore, flooding in 1983 added about 1,600,000 m^3. The secular change in the volume of sediment and longitudinal change in the sediment rise are shown in Figs. 8 and 9, respectively. The state of sediment in 1989 is shown in Fig.-7.

Fig.-7 Sediment in the Miwa Dam (March 1989)

(Note) A subsequent review found an error in calculation for the residual capacity obtained from the result of sounding in 1963. Therefore, the numerical values in Fig.-6 are different from those in Fig.-8 "Secular Change in Miwa Dam Sedimentation."

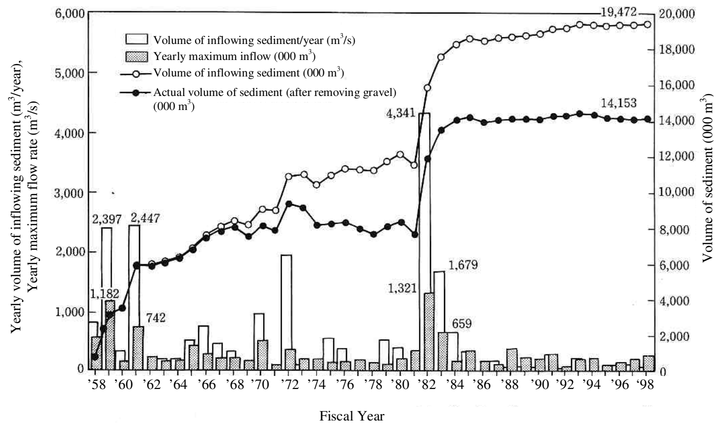

Fig.-8 Secular Change in Miwa Dam Sediment

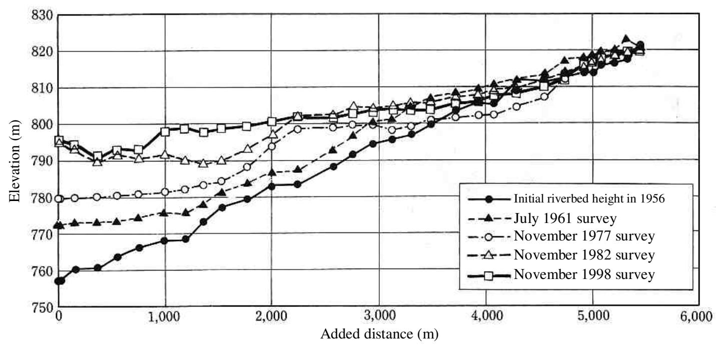

Fig.-9 Longitudinal Change in Miwa Dam Sediment Rise

4. Mitigation Measures

4.1 Outline of Plan for Redevelopment Project

The Miwa Dam redevelopment project had been carried out independently from 1981 but was combined with the project for building the Tokusa Dam upstream, which was adopted in 1988, and the Mibu River Comprehensive Development Project was adopted in 1989 as a construction project. An outline of the plan for the Miwa Dam Redevelopment Project is described in the following section. Fig.- 10 is the arrangement plan for the installations of the redevelopment project and Fig.-11 shows the capacity distribution upon completion of the redevelopment project.

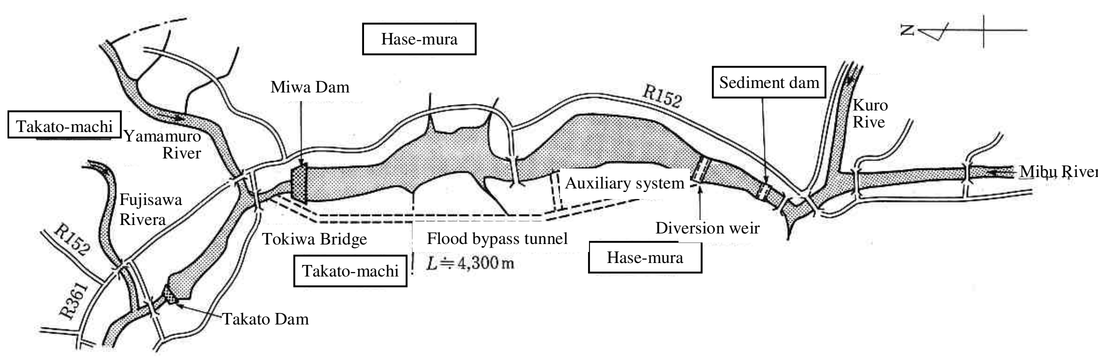

Fig.-10 Arrangement Plan for Installations of the Miwa Dam Redevelopment Project

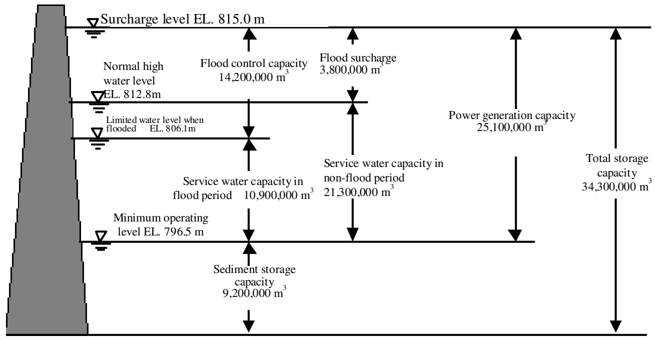

Fig.-11 Miwa Dam Capacity Distribution after Completion of Redevelopment Project

4.2 Permanent Measures to Counter Sedimentation and Removal of Deposited Earth and Sand

1) Basic Concept of Permanent Measure to Counter Sedimentation

The basic concept of a permanent measure to counter sedimentation is as follows.

Earth and sand in a far larger amount than the yearly average volume of inflowing earth and sand estimated when the initial plan was worked out in the 1940s flowed into the Miwa Dam and resulted in the risk of function impairment.

Subsequently, from an examination based on the actual earth and sand inflow after the completion of the construction and physical properties such as grain size, it was revealed that about 3/4 of the deposited earth and sand, called wash load, was of fine particles, 0.017 mm in average diameter, which barely existed in the material composing the river bed and usually flowed down in the state of being dissolved in water during a flood occurrence. Accordingly, in order to prevent these fine particles of earth and sand from settling while retained in the dam lake, the following design was worked out based on the concept of guiding the particles together with the water via a flood bypass tunnel to detour the dam lake as shown in Fig.-12 Conceptual Drawing of Permanent Measure to Counter Sedimentation. Fig.-13 shows the yearly average volume of inflowing

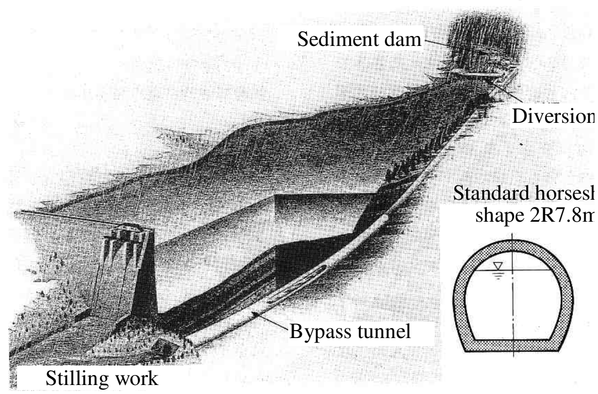

Fig.-12 Conceptual Drawing of Permanent Measure to Counter Sedimentation

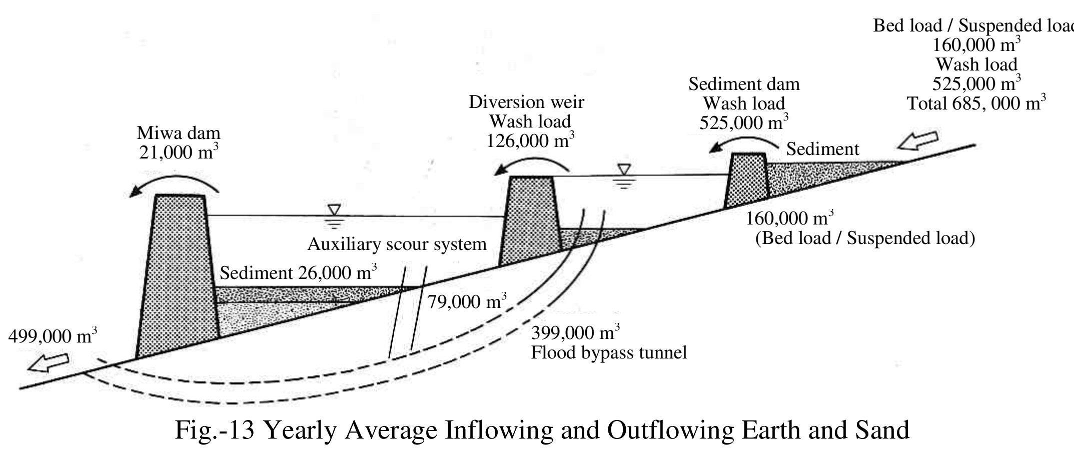

Fig.-13 Yearly Average Inflowing and Outflowing Earth and Sand

and outflowing earth and sand. The numerical values in the drawing are those estimated on the basis of the actual volumes of earth and sand that flowed into the Miwa Dam during the ten years from 1976 to 1985.

a) Wash Load

The Miwa Dam flood bypass tunnel having a design discharge of 300 m^3/s removes 399,000 m^3/year on average. When the inflow to the Miwa Dam exceeds 300 m^3/s, a wash load amounting to 126,000 m^3 /year on average goes over the diversion weir and together with the storm flow, flows into the dam lake. Of this inflow, 100,000 m^3 in total, that is, 21,000 m^3 from the flood spillway of the dam body and 79,000 m^3 from the auxiliary scour system, is discharged during a flood. Additionally, 26,000 m^3 deposited in the dam lake while retained is dealt with by securing the 10-year sediment storage capacity of 2,600,000 m^3 to EL. 796.5 m or less.

So as to maximize the wash load discharge capacity during a flood, the passage capacity of the flood bypass tunnel was set at 300/s, the same as the design discharge of the Miwa Dam after the completion of the Mibu River Comprehensive Development Project.

b) Bed Load / Suspended Load

A yearly average of 160,000 m^3 of bed load / suspended load flowing down toward the dam is caught by the sediment dam (interim completion: March 1994) with a capacity of about 200,000 m^3 and removed by gravel collection operation for effective use as construction material. During a heavy flood, the sediment dam is filled with sand, which is prevented as much as possible from flowing into the dam lake by making use of the approximately 520,000-m^3 capacity of the diversion weir built downstream

2) Contents of Construction Work

The contents of main works to be executed in the redevelopment project are as follows.

a) Permanent Measure to Counter Sedimentation

- As a system for guiding a wash load, which flows down together with a flood, to detour the dam lake and for discharging it to the lower course, the construction of a flood bypass tunnel with a length of 4.3 km and a passage capacity of 300 m3/s plus a diversion weir for discharge control.
- With a flood exceeding 300 m3/s, which cannot be removed by the above system, earth and sand flow and are deposited in the dam lake. The construction of an auxiliary system to discharge the sediment into the flood bypass tunnel. (The auxiliary system is presently being examined, for example, by performing verification tests, with the goal of putting it to practical use.

b) Removal of Deposit

- To secure the capacity required for the redevelopment project, 9,500,000 m^3 of deposited earth and sand is removed from the dam lake. This is the sum of the existing sediment of 6,900,000 m^3 and 2,600,000 m^3 of new earth and sand expected to flow in while the work is underway.

5. Technological Ground for Mitigation Measures

The examination including the estimate of yearly average volume of earth and sand flowing in and out of the dam lake (Fig.-13) was carried out under the guidance of sediment hydraulics experts (Dr. Ashida, emeritus professor of Kyoto University, and others).

In designing the diversion weir, hydraulic model experiments were performed. The form of overflow, the shape of the section connected to the flood bypass tunnel, the height of a trap weir to prevent the suspended load from flowing into the flood bypass tunnel were determined on the basis of the results of the experiments.

6. Further Information

6.1 References

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2000
2) Yokomori, M., Sonohara, K., Hukumoto, A.,: Design of diversion weir and flood bypass tunnel for Miwa Dam redevelopment project, Dam Engineering No.187, Japan Dam Engineering Center, April 2002

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