# Flood Control Using Urban Underground Space

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## Kanda River / Loop 7 Underground Regulation Pond

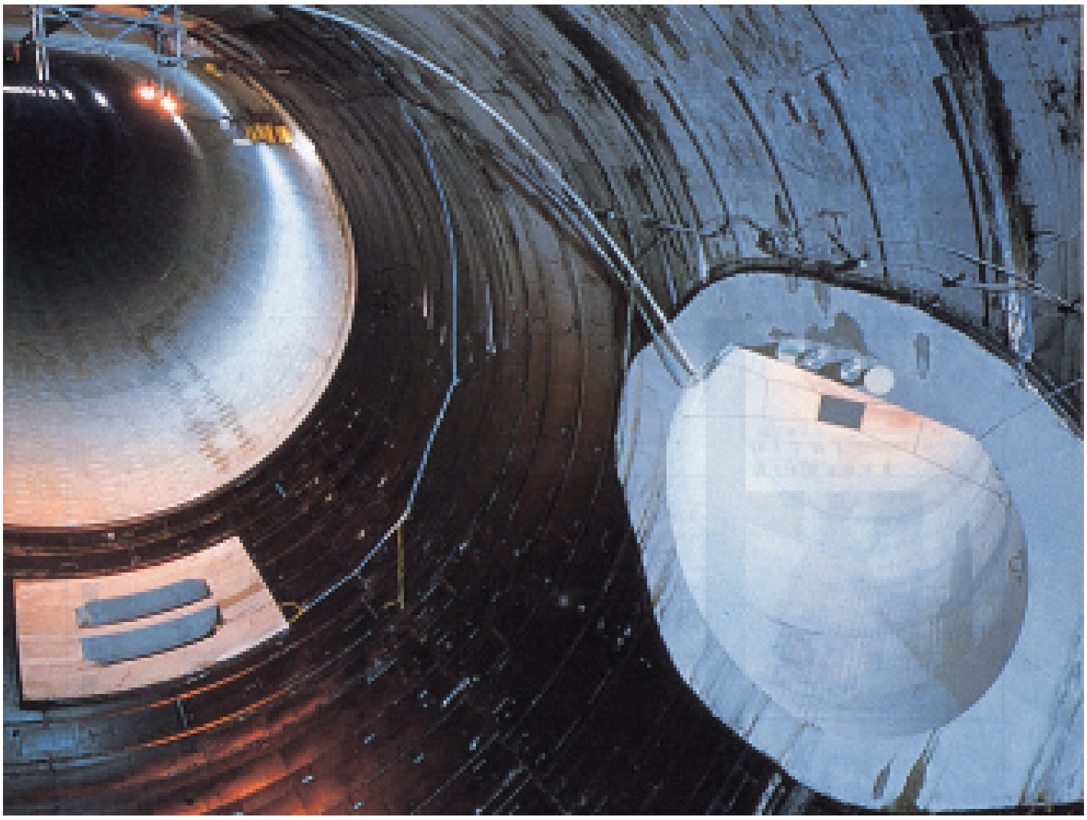

Photo 1 Completed Kanda River/Loop 7 Underground Regulation Pond and Aqueduct

### PARTIALLY COMPLETED UNDERGROUND REGULATION RESERVOIR

The Loop 7 ring road encircling Tokyo sees extremely heavy traffic round the clock, yet about 40 m below street level a huge underground tunnel measuring 12.5 m in inside diameter has been completed. (Photo1) This 2.0 km-long underground cavern was constructed by the Construction Bureau of Tokyo Metropolitan Government as Phase I of the Kanda River/Loop 7 Underground Regulation Pond, which is designed to hold back and regulate floodwater in the middle reaches of the Kanda river. Frequent floods have been caused by the Kanda river in the past. The project, which commenced in fiscal 1988, consists of a shield departure shaft in Umezato Park, an underground regulation pond in the form of a tunnel extending from Umezato 1-chome to Izumi 1-chome in Suginami Ward and with a capacity of 240,000 $m^3$, and a facility for introducing water from the river. Although delays occurred during the course of construction due to problems with land acquisition, the regulation reservoir was completed and brought into service in March 1997.

The second phase of the project consists of a further departure shaft along the Myoshoji river, a 2.5 km-long underground regulation pond with a capacity of 300,000 $m^3$ under Loop 7, and a facility for taking water in from the Zenpukuji river, and this has already been commenced. When both phases are complete, a reservoir totaling 4.5 km in length and with a total capacity of 540,000 $m^3$ will safeguard an area extending from Yodobashi bridge to the confluence with the Zenpukuji river against an hourly rainfall of 50 mm, which can be expected about once in three years.

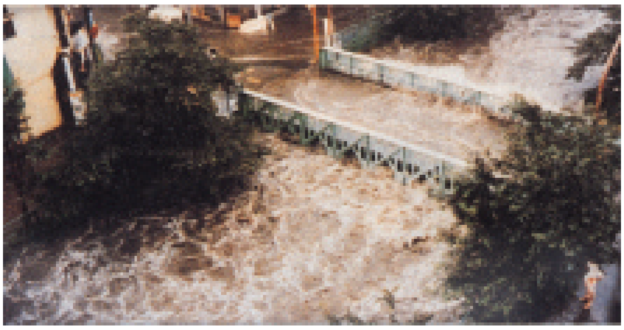

Photo 2 Kanda river in flood after heavy downpour (July 22, 1981)

Photo 3 Umezato launch shaft and underground tunnel-shaped regulation pond

**UNDERGROUND RIVER PLAN**

Flooding is the most common type of natural disaster to strike Tokyo, one of the world's biggest cities. Increasing coverage of the ground with asphalt and concrete pavement causes the Kanda river system to frequently burst its banks and inundate properties along its path. (Photo 2) Widening the river or raising higher levees is impractical, because the urban areas along such medium and small waterways as the Kanda river are densely built up. Accordingly, the Tokyo Government decided to construct underground rivers under the two major ring roads, Loops 7 and 8, to give protection against an hourly rainfall of about 75 mm, which has a return frequency of once in 15 years. The river to be built under Loop 7 will be 10.0-12.5 m in inside diameter and extend for a total of 30 km. The aim is to collect floodwater from four river systems and 10 rivers, including the upstream areas of the Shirako river as well as the Shakujii, Kanda, and Meguro rivers, pumping it into Tokyo Bay with a pumping station. The budget for this project is limited, however, so it seems unlikely to see early completion.

The project described here is the Kanda River/Loop 7 Underground Regulation Pond, which is the 4.5 km-long Kanda river section of the river. This section was particularly urgently needed and was designated for early implementation and interim use as a regulation pond. Completion of this reservoir not only protects property in the section of the river between Loop 7 and Yodobashi bridge (across the lower reaches of the river), which was in serious danger of flooding if hourly rainfall exceeded 50 mm, but also allows improvement of the river upstream of Loop 7, which has till now been impractical.

**DEPARTURE SHAFT AND TUNNEL-SECTION REGULATION POND**

The departure shaft for the shield tunnel was a cylindrical reinforced concrete shaft reaching to a depth of 60.1 m and measuring 28.2 m in diameter. It was constructed with a 1.2 m-thick cast-in-situ diaphragm wall around the perimeter as a sheathing wall. (Photo 3) A shield machine was lowered down into the shaft for use in excavating the tunnel. The shaft also served as the entry point for shield segments and the muck removal point.

The tunnel, with an outside diameter of 13.7 m and inside diameter of 12.5 m, was constructed 34-43 m under Loop 7 using shield machinery of the largest scale. Before executing the work, a review of conventional shield technology was carried out, indicating a need to develop new techniques for the work. Consequently, a large-diameter slurry shield machine weighing about 2,800 tons and measuring 11.8 m in length was developed. As a result of transportation limitations, the machine was broken down into 120 components for delivery to the site, where it was assembled successfully with great accuracy. To reduce the danger inherent in assembling the heavy tunnel segments, each of which weighed 7.4 tons, in such close quarters and at considerable elevation, an automatic process was developed for carrying out the various stages of segment assembly work from segment supply to bolt tightening. These various technological developments contributed to the successful completion of this large-scale tunnel. (Photo 4)

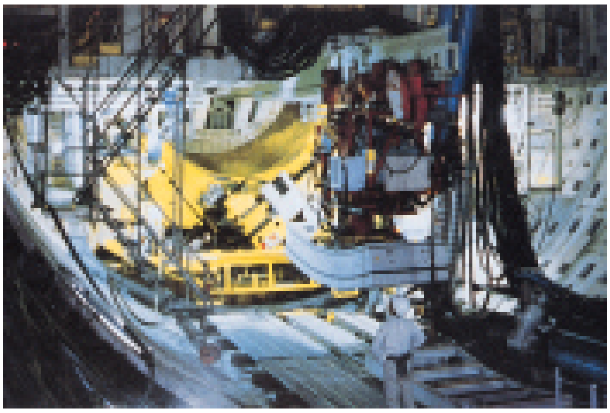

Photo 4 Automatic segment assembly system

## DESIGN OF WATER INTAKE

The water intake collects floodwater from the Kanda river and directs it into the regulation tunnel. (Fig. 1) To cope with sudden downpours, the intake weir is of the overflow type; this design was selected on the basis of a hydraulic experiment. (Photo 5) Water that flows over the weir passes along a conduit and through a silt settling basin before swirling downward through the water intake shaft to an energy dissipation basin. From there, it enters the tunnel-shaped reservoir through an aqueduct. The shaft is placed adjacent to Loop 7 on the left bank of the river. To minimize the transmission of noise and vibration to the environment and minimize the entrainment of water into the shaft as the water falls through about 50 m, various shaft designs were compared and a model experiment was carried out. As a result, a tangential vortex design was adopted for the first time in Japan. This type of shaft allows a water intake of limited size to handle flow rates of up to 50 $m^3/s$.

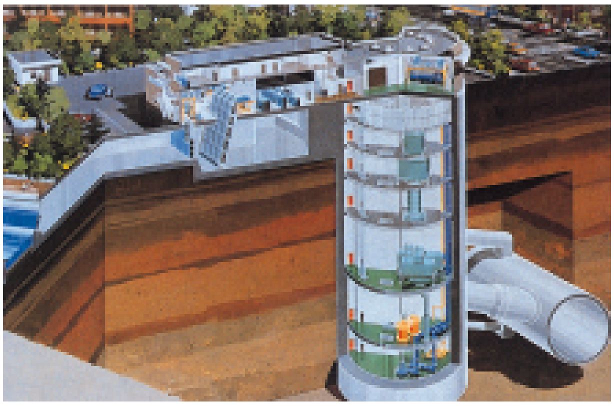

Fig. 1 Perspective of water intake facility

Once the threat of flooding has passed, floodwater is pumped back into the river. To ensure preparedness for another flood within three days, the main drainage pump with a capacity of 50 $m^3/min.$ is placed under automatic control. The turbid water held in the pond is treated in a manner compatible with environmental concerns, using settlement and aeration before discharge into the river.

## CONSTRUCTION OF WATER INTAKE

A great deal of effort went into constructing the water intake. In constructing a 1.2 m-thick cast-in-situ diaphragm wall in the highly permeable sandy ground to a depth of 108 m around the shaft, excellent water tightness was required. Close attention was paid to the stability of the wall after excavation as well as to ensuring proper filling with concrete through control of the casting speed in response to concrete lateral pressure. To prevent the entry of artesian ground water, an impervious layer was built around the bottom of the wall by a chemical injection method. The injection of chemicals into the sandy layer was carried out in two steps with adjustments made between the two stages. The result was an artificial homogenous, impervious layer with excellent water cut-off characteristics. While excavating the shaft, the work was protected against artesian ground water and subsidence (due to excessive falls in ground water level) by controlling deep wells drilled around the perimeter of the shaft such that artesian ground water pressure was reduced in response to changes in artesian ground water level.

Photo 5 Completed water intake weir

The water intake shaft is a complex concrete structure that includes space for equipment. (Photo 7)

Concrete was cast in several stages to a height of 5.1 m per lift. Pipes were installed at three locations for this purpose. To prevent the formation of cold joints during these operations, concrete casting operations were controlled by adjusting the casting time and retarding the setting time.

The most reliable protection against artesian ground water is freezing, and this method was adopted in constructing the aqueduct. A cutoff wall was constructed by chemical injection, since this method can cope with fast ground water flows, diverting the water away from the frozen section and minimizing the effect of the work on residential wells in the area.

Both environmental concerns and the needs of neighborhood residents were taken into account during construction work. The site was surrounded with a soundproof enclosure reaching a maximum height of 14 m to prevent noise escaping, while trees were planted and panels giving an outline of the project were displayed. In addition, every effort was made to speed up the project and enhance work efficiency in just about every area of the work. Examples of this are the adoption of a vertical belt conveyor for shaft excavation, improved work efficiency by drilling horizontal holes for freezing using large-scale suspended platforms, and a review of structure configuration leading to reduced work volume.

## COMMENTS AND OUTLOOK

The urban areas of major cities are now densely built up. In making efforts to improve living conditions and reduce the threat of natural disaster, major cities are being driven to use previously undeveloped space, such as the space beneath our feet. The underground regulation pond described here was built more than 40 m below the surface so as not to constitute an obstacle to future infrastructural improvements in the underground space. The project pioneered the use of underground space at great depths in urban areas.

The experience gathered through this project will help provide valuable data for the future use of underground space in other major cities in the future. However, there are more than a few technical issues remaining unsolved, of which the most crucial is the cost of construction. To further the overall underground river plan of which this project forms a part, it will be necessary for the administration to join with citizens in considering what level of expenditure is appropriate in the cause of reducing disaster damage.

In conclusion, the author expresses great respect for all parties who contributed to completion of this unprecedentedly large construction project for an underground regulation pond. Though deep under a road and under a tight schedule, the work was completed in safety and without inconveniencing traffic on the major road above. This can be attributable to taking the proper steps to deal with the situation and drawing up detailed plans while paying careful attention to the surroundings.

Assistance in collecting materials for this report from:
Construction Bureau, Tokyo Metropolitan Government
Joint venture between Shimizu Corp., Nishimatsu Construction Co., Ltd., Fujita Corp., Dai Nippon Corp., Nissan Construction Co., Ltd., and Sanko Construction Co., Ltd.

Photo 6 Cast-in-situ diaphragm wall under construction

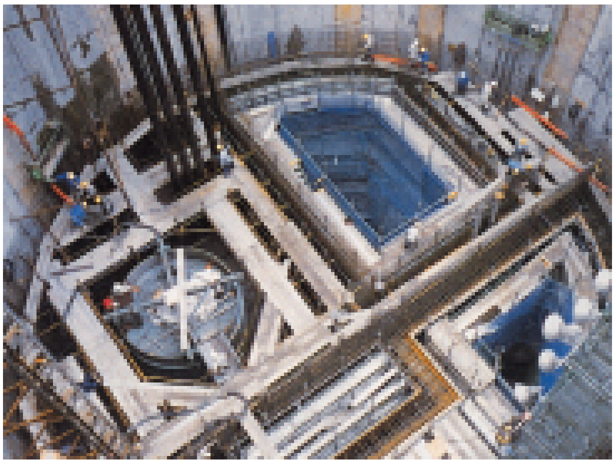

Photo 7 Water intake shaft under construction