

Key Issues:

2- Hydrological Regimes

1-Biological Diversity

Climate Zone:

Cf : Temperate Humid Climate

Subjects:

- Discharging of Ecological Flow from Existing Dam



The Tsuga Dam

Effects:

- A remarkable increase in species of benthos in reduced flow river caused by diversion owing to the discharging of ecological flow.

Project Name: Tsuga Dam

Country: Kochi Prefecture, Japan (Asia) (N 33° 15', E 132° 58')

Implementing Party & Period

- **Project:** Sikoku Electric Power Co., Inc.
1944 (Completion of construction) -

- **Good Practice:** Sikoku Electric Power Co., Inc.
1989 (Commencement of operation) -

Key Words:

Ecological Flow, Reduced Flow River Caused by Diversion, Benthos

Abstract:

To check the effect of discharging the ecological flow in the Tsuga Power Plant, habitat conditions of benthos in the reduced flow river caused by diversion were investigated ten years after the start of discharging (1998/99) and results were compared with survey data collected before the start of discharging (1988). From the comparison, a remarkable increase of species of benthos after the start of discharging was confirmed. Comparison between the affected area and other areas of the main course and tributary streams also confirmed that there were no distinct differences in the number of species, the number of individuals, diversity, water quality and the like. The findings suggest that the present river environment in the reduced flow river caused by diversion is being improved or recovered by the effect of the ecological flow.

1. Outline of the Project

The Tsuga Power Plant (No. 1 and No. 2 power generators: 18,000 kW) is a dam and conduit type power plant opened in 1944. Water is taken from the Tsuga Dam, a concrete gravity dam built in the Yusuvara river, a feeder to the Shimanto river, through an about 5.7 km- long headrace tunnel. The dam gives an effective head of 96m.

While the Tsuga Power Plant had had a reduced flow river caused by diversion of about 22 km in total

length from the dam to the outlet of the plant, in 1989 when the water right was renewed, discharging an ecological flow was decided with the aim to improve or restore river environments in the area. In April 1998, modification work to change the outlet for the discharging from the dam spillway gate to the headrace tunnel directly below the dam was completed and the No. 3 power generator was put into operation for better use of the ecological flow (1.91 m³/s, effective head: 37.1 m).(See Table-1 and Figs.-1 and 2.)

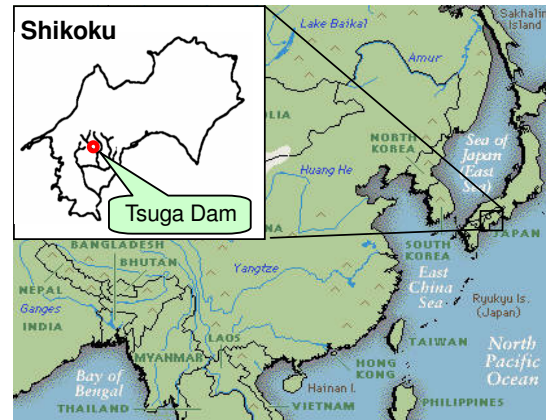


Fig.-1 Map of the basin of Shimanto River

Table-1 Particulars of Tsuga Dam

Item	Particulars		
River System	The Yusuhara river, a feeder to the Shimanto river of the Watari River System		
Catchment Area	381.0 km ²		
Power Plant	Name	Tsuga Power Plant power generators Nos. 1 & 2	Tsuga Power Plant power generator No. 3
	Maximum output	18,100 kW	550 kW
	Maximum water consumption	22.00 m ³ /s	1.91 m ³ /s
	Effective head	96.00 m	37.10 m
Dam	Type	Concrete gravity type	
	Crest height	45.5 m	
	Crest Length	145.0 m	
Reservoir	Total storage capacity	19.3 × 10 ⁶ m ³	
	Effective storage capacity	14.0 × 10 ⁶ m ³	
	Effective depth	15.0 m	

2. Features of the Project Area

The Shimanto River, in which the Tsuga Power Plant is built, has its source in Mount Funyu in the north of Higashituga Village on the boundary between Kochi and Ehime Prefectures. The river grows while winding its way by collecting water from a number of tributaries including the Yusuhara River and drains into the Bay of Tosa in Nakamura City. As it meanders much, the river flows in a variety of ways and benefits the fishery and forestry in communities along the course. The Shimanto River is also known widely as “the last limpid stream in Japan.”

Meanwhile, national consensus arose sometime around 1985 for the improvement of river environments. In 1988 the Ministry of International Trade and Industry (the present Ministry of Economy, Trade and Industry) and the Ministry of Construction (the present Ministry of National Land, Infrastructure and Transport) set the so-called “Guideline for Ecological flow with respect to River Right,” which makes it an obligation for power plants that fall under certain conditions to discharge appropriate ecological flows.

Under such circumstances, on the occasion of the renewal of this plant's water right, a movement requesting dam removal developed to become a newspaper topic. To deal with such a trend, Kochi Prefecture formed "the Tsuga Dam Review Panel" made up of persons of learning and experience and representatives of the national agencies concerned, the city, town and village interests as well as business entities, the prefecture itself serving as the secretariat. The council discussed technical matters concerning the dam, such as the discharging of ecological flow and the quality of water in the dam reservoir and an agreement was reached smoothly to take the steps for renewing the water right on the basis of the ecological flow as deliberated by the panel.

3. Major Impacts

For environmental protection in the reduced flow river caused by diversion, it was necessary to determine an ecological flow by giving comprehensive consideration to fishery, landscape, maintenance of underground water level, conservation of fauna and flora, keeping rivers clean and the like. As the level of underground water and cleanliness of rivers would be improved when an ecological flow was set, however, discussion went on mainly from the viewpoints of improvement of landscape and reservation of animals and plants.

For the improvement of landscape, aiming at the volume of water that would be visually satisfactory, a rate of flow that could form a continuous watercourse while maintaining a certain width/ depth, etc. was examined. For the reservation of fauna and flora, ayu fish was chosen as a typical aquatic because of its abundance and a water depth allowing it to live in and go upstream was examined.

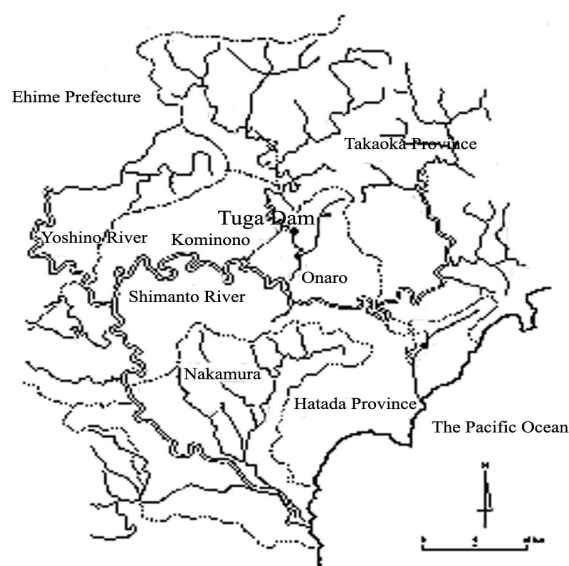


Fig.-2 The basin of Shimanto River

4. Mitigation Measures

"The Tsuga Dam Review Panel (December 1988 - February 1989)" confirmed in its deliberation that impact on landscape and aquatics should be considered mainly in determining an ecological flow and concluded as follows by referring to opinions of persons of learning and experience and the result of trial discharging.

- a) When $0.3 \text{ m}^3/\text{s}$ or so per 100 km^2 catchment area is discharged immediately below the dam, the stream regime up to the outlet would be improved and preferable effect on landscape and aquatics would be produced.
- b) In summer, sufficient desirable effect on the area from right below the dam to the outlet should be expected in view of the characteristics of "the limpid Shimanto." Therefore, it would be appropriate to raise the upper limit value of the guideline by a certain surplus.

Consequently, the ecological flow was set at $1.15 \text{ m}^3/\text{s}$ ($0.3 \text{ m}^3/\text{s}/100 \text{ km}^2$) and between April 1 and September 30 a surplus discharge of $0.76 \text{ m}^3/\text{s}$ ($0.2 \text{ m}^3/\text{s}/100 \text{ km}^2$) would be added to make the discharge

1.91 m³/s from April, 1989.

5. Results of the Mitigation Measures

Amid the society's increasing recognition of the value of river environment, R&D on techniques for the analysis/assessment of living environment for fluvial ecosystems is going on actively. In the following, how the reduced flow river caused by diversion in the Tsuga Dam changed in ten years from the start of discharging the ecological flow is discussed, mainly with respect to benthos by taking an ecosystem pyramid, the precision of the investigations and the like into account.

5.1 Investigation Items

The benthos chosen as subjects to be investigated were general flatworms (Turbellaria), eelworms (Nematoda), mollusks (shellfish), annelids (Oligochaeta, Polychaeta and Hirudinea) and arthropods (Arachnida, Crustacea and Insecta). (Fig.-3)

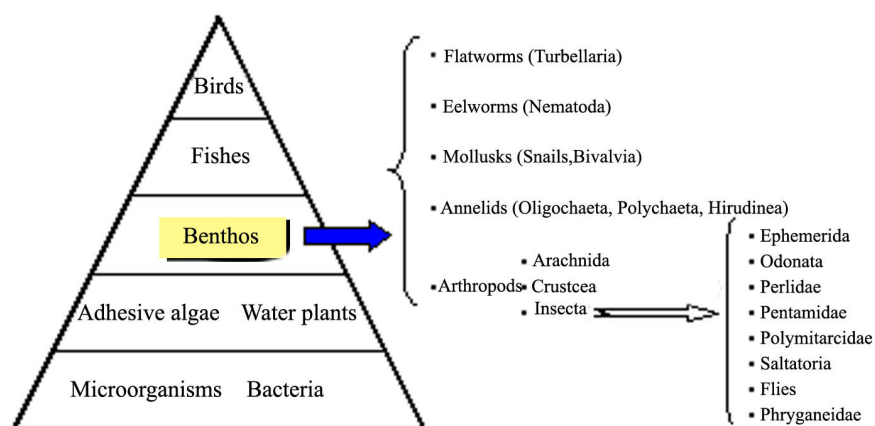


Fig.-3 Conceptual diagram of River Ecosystem Pyramid

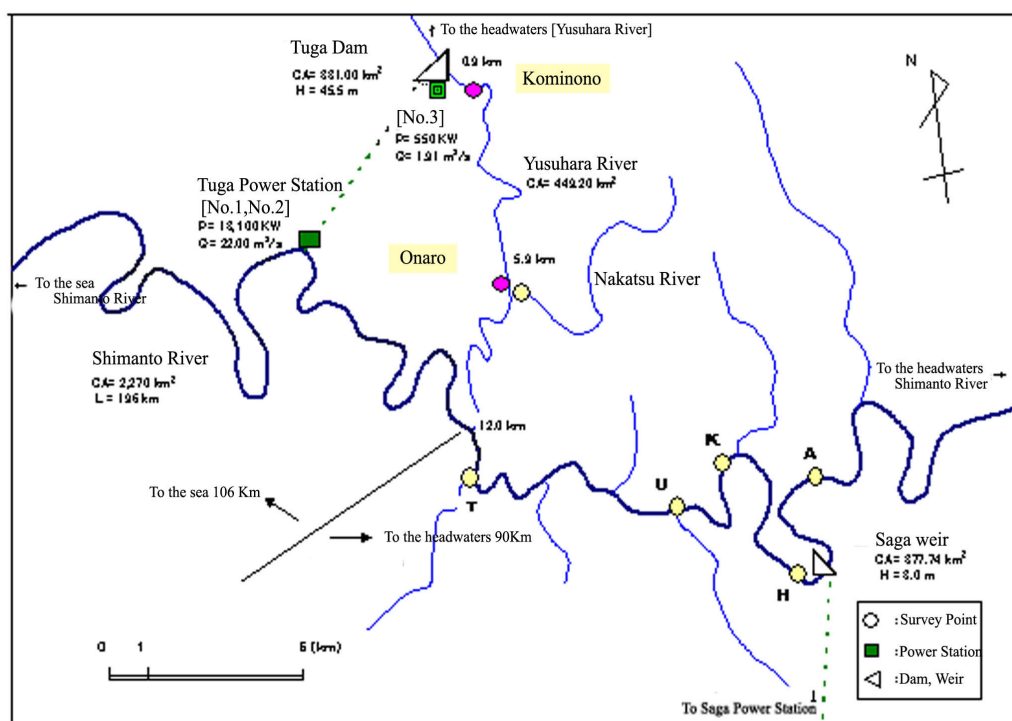


Fig.-4 Locations of Benthos Investigation Points

5.2 Investigation Sites

In the reduced flow river caused by diversion, two sites were chosen, namely, the “Kominono” site, about 1km downstream of the Tsuga Dam, and the “Onaro” site, which is almost in the middle between the Tsuga Dam and the junction with the Shimanto and about 6km downstream of the dam. The latter was the place where similar investigations had been carried out in the past. As controls for comparing with the reduced flow river caused by diversion, six points, of which five were in the main course of the Shimanto and one in the Nakatsu, a tributary of the Yusuvara, were investigated

5.3 Method of Investigation

Study was carried out by comparing the numbers of species and individuals in the reduced flow river caused by diversion between before and after the discharging of the ecological flow and the reduced flow river caused by diversion was also compared with other areas of the main course and the tributaries. The investigation data before the discharging were taken from “The Shimanto River, its Nature and Life” listed in the bibliography.

1) Method of Investigation

For the collection of benthos, a combination of the collection for quantitative determination (the number of species, the number of individuals and the input) in rapids by means of a server net with coderat and the collection for qualitative determination (the number of species) in shallows and slow currents by means of a landing net (the D type frame net) was employed. On each point, collection was carried out on two points. The coderat was 50cm×50cm in size and the server net and the landing net were 60.5mm in mesh size.

2) Frequency of Investigations

The field investigations after the discharging of the ecological flow were performed twice, in August 1998 and January 1999.

5.4 Result of Investigations

5.4.1 Comparison between before and after discharging the ecological flow

Fig.-5 and Table-2 show a comparison of compositions of benthos species in the reduced flow river caused by diversion between before and after discharging the ecological flow was started.

The number of benthos species identified in the Kominono site about 1km downstream from the Tsuga Dam was 88, an increase by 68 over the time of investigation (1989) before the start of discharging the ecological flow. Even when a change in the method of classification is taken into account, the increase is remarkable enough. In the Kominono site, the species of aquatic Insecta

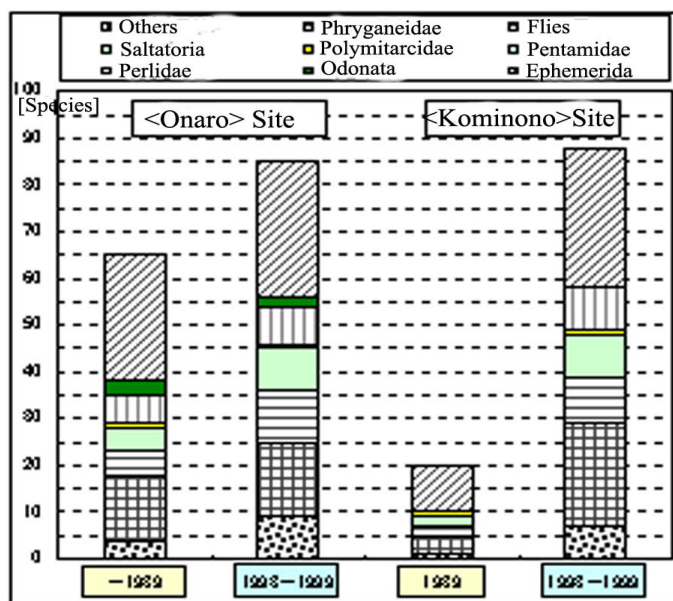


Fig.-5 Comparison of Composition of Benthos Species

increased by 62 and others by 6. In particular, the dayfly, stone fly and caddis fly increased conspicuously.

The species of benthos found in the Onaro site totaled 85 (in two investigations), a 20 increase over 65 species in the previous six investigations. Aquatic Insectra increased by 15 and others by 5.

Table-2 Table of Comparison of Benthos Species Compositions

Item		The Yusuvara River			
		Downstream from Tsuga Dam (Onaro)		Flow Directly below Tsuga Dam (Kominono)	
		~1989	1998~1999	~1989	1998~1999
Number of Investigation Points		2	1	1	1
Total Number of Investigations		6	2	1	2
Insectra	Ephemera	27	29	10	30
	Odonata	3	2	0	0
	Perlidae	6	8	0	9
	Pentamidae	0	0	0	0
	Polymitarcidae	1	1	1	1
	Saltatoria	5	9	2	9
	Flies	5	11	2	10
	Phryganeida	14	16	4	22
	Subtotal	61	76	19	81
Other than Insecta		4	9	1	7
Total		65	85	20	88

5.4.2 Comparison with main stream and tributary after discharging

Findings of comparative study of benthos, which were collected during the same period with the investigation of the two sites on five points in the main stream of the Shimanto and one point in the Nakatsu river, a feeder to the Yusuvara, are outlined in the following. Of these points, the point in the Nakatsu river and the point A of the Shimanto river are believed to be least affected by artificial changes of the stream regime. (Fig.-6 and Table-3)

- The numbers of species which appeared on these points in August 1998 and January 1999 were respectively 45~58 and 44~73. The numbers did not seem to be particularly small. On two control points, larger numbers than an average of species were confirmed.
- Average numbers of individuals on each point in August and January were about 3,130/0.5m² and 7,875/0.5m² respectively, showing that in January individuals are more than twice as many as in August. The same trend was observed for all the points investigated but there was none which was thought to have an extremely small number of individuals in both occasions of the investigation.
- Monthly averages of inputs for August and January were about 6.77 and 19.08g/0.5m², that is, the average for January was nearly three times as much as that for August. The same tendency was seen on all the points except one. Nevertheless, there was none which was thought to have an extremely small input in both instances of the investigation.
- Diversity indices (Simpson's diversity index) for the investigation points in August and January fell

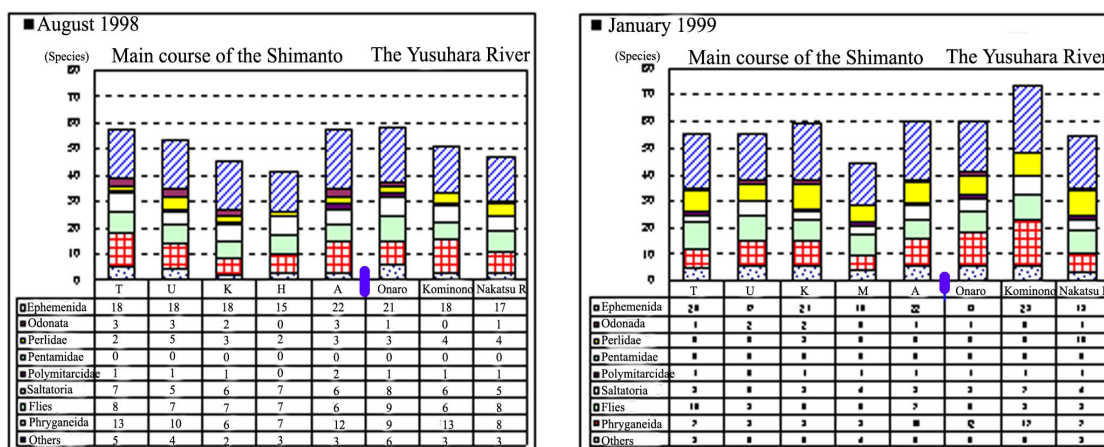


Fig.-6 Comparison of Composition of Benthos Species in Individual Investigation Points

Table-3 Result of Investigation of Benthos Species on Each Investigation Point

■ August 1998

Name of Investigation Point	Main River of the Shimanto					Yusuhara River			River Average
Item	T	U	K	H	A	Onaro	Kominono	Nakatsu	
The number of Species	57	53	45	41	57	58	51	47	51.1
The number of Individuals per 0.5m ²	1,561	2,545	6,348	6,901	4,247	1,306	972	1,238	3,140
Input (g/0.5m ²)	6.99	19.43	6.78	7.11	5.36	2.41	4.20	1.86	6.77
Diversity Index 1-1/SID	0.89	0.93	0.86	0.82	0.83	0.74	0.89	0.90	0.86
Pollution Index PI	1.35	1.60	1.43	1.47	1.34	1.19	1.30	1.50	1.40
Rate of Carniphaga (% , the number of individuals)	3.8	3.2	1.0	0.9	0.3	8.9	7.1	9.8	4.4
Coefficient of Net-weaving Types (% , input)	41.3	30.0	9.4	15.2	23.6	29.8	65.8	28.7	30.5

■ January 1999

Name of Investigation Point	Main River of the Shimanto					Yusuhara River			River Average
Item	T	U	K	H	A	Onaro	Kominono	Nakatsu	
The number of Species	55	55	59	44	60	60	73	54	57.5
The number of Individuals per 0.5m ²	5,518	2,733	8,857	16,693	14,069	3,245	9,228	2,657	7,875
Input (g/0.5m ²)	13.94	5.95	14.64	17.20	30.16	13.10	51.10	6.54	19.08
Diversity Index 1-1/SID	0.86	0.85	0.81	0.82	0.68	0.93	0.73	0.55	0.78
Pollution Index PI	1.34	1.34	1.65	1.60	1.35	1.62	1.28	1.14	1.42
Rate of Carniphaga (% , the number of individuals)	1.0	0.6	3.3	0.5	0.3	13.1	3.5	0.5	2.9
Coefficient of Net-weaving Types (% , input)	21.9	22.4	26.3	4.7	9.3	45.2	60.0	8.9	24.8

respectively in ranges from 0.74 to 0.93 and from 0.68 to 0.93. In the two instances of investigation, none of the points showed a small index, nor was believed to be conspicuously poor in diversity.

- e) The pollution indices (the Pantel-Buck system) of the investigation points in August and January fell respectively in ranges from 1.19 to 1.60 and from 1.28 to 1.65. The values indicate that the

biological quality of water approximately ranged between the low saprobic and β medium saprobic, which means that there would be no problem with the biological quality of water in any of the points.

- f) The rate of carniphaga as a measure indicating the diversity and the stability of ecosystem, and the coefficient of net-weaving type as a measure indicating the degree of climax and symbiosis of benthonic swarms were calculated. The result showed that the two investigation sites, Kominono and Onaro, gave considerably higher values than those of the other points. Particularly, it was confirmed that the coefficient of net-weaving type of the Kominono site was very large.

5.5 Conclusion

To confirm the effect of discharging the ecological flow in the Tsuga Power Plant, results of investigations of benthos before the discharging and ten years after the discharging were compared. On the site, which was in the reduced flow river caused by diversion and about 1km downstream from the dam, 88 species were confirmed. This representing an about 4-fold increase over the investigation before the discharging, it was known that the species of benthos rose remarkably. Further, the reduced flow river caused by diversion was compared with other points in the main course and a tributary. There were no significant difference between them in the number of species, the number of individuals, the diversity index, biological quality of water an the like. Thus, it was assumed that the environment of the reduced flow river caused by diversion was improved or restored to a similar degree to six points in the main stream and a tributary, which were believed to be little affected by the artifact.

6. Reasons for Success

In the process of determining the ecological flow at the time of renewal of the water right, “the Tsuga Dam Review Panel” composed of persons of learning and experience, the local interests such as those from the cities, towns and villages concerned and the business interests, was formed. Local representatives’ views and requests were listened to carefully and with the recognition of the panel, which attached importance to emphasis on transparency and openness, an agreement was reached in favor of the renewal of the water right.

In deciding the ecological flow, an investigation plan was developed on the basis of guidance and advice provided by persons of learning and experience and trial discharging was carried out. These were referred to in preparing an assessment report.

7. Outside Comments

July 1987	Representatives of Taisho-cho and others formed a countermeasure council. - Whether the dam should be continued or not began to be discussed. -
Feb. 1988	Yusuhara-cho's and Higashitsuno-cho's town assemblies submitted to the prefecture a written request for removing the dam.
Mar. 1988	Six cities, towns and villages in the basin of the river formed a joint countermeasure council. - Administrative measures acceptable to inhabitants were sought. -
July 1988	Shikoku Electric Power Co. Inc. formally requested the renewal of the water right.
Aug. 1988	A sign-collecting campaign for removing the dam, organized by inhabitants' bodies, fishery cooperatives, etc. went on actively. - The issue was covered by newspapers and television news programs day after day.
Oct. 1988	The Yusuhara and Higashitsuno town assemblies and inhabitants shifted the position from "removal" to "negotiation with Shikoku Electric Power."
Dec. 1988	The first meeting of "the Tsuga Dam Review Panel" was held.
Jan. 1989	Trial discharge was carried out. - The object of trial discharging, the volume of discharge, etc. were explained.
Feb. 1989	The Tsuga Dam Review Panel submitted its final report to Governor of Kochi Prefecture. - The ecological flow as well as the safety of the dam was reported. - When the negotiation on the renewal of water right with the cities, town and villages concerned reached a conclusion, the application for the renewal of the water right was filed. - "Clean Stream of the Shimanto Returns" (headlines that appeared in various newspapers and magazines.) -

8. Further Information

8.1 References

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8.2 Inquiries

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