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PROMOTING CREATIVITY AND INNOVATION IN FLOOD PROJECTS BY VALUE ENGINEERING

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Abstract

This paper is trying to demonstrate that creativity is the key to coping with the flood related challenges in the 21st century and major technical jumps and innovations are essential for harmony with floodwaters. In this context based on worldwide experiences, Value Engineering, a systematic management technique encouraging creativity and teamwork can play a key role. Value Engineering is a process to open the mind to new ideas by breaking down constraints to visualization. It helps us break away from the old tried-and-true habit to develop new exciting methods, products and inventions to carry us into the future.

Intuitive Value Engineering can be achieved by few very intelligent and experienced experts but the profession cannot rely on a tiny part of the population for creativity and innovation. We should try to promote creativity by the synergy of teamwork. In this context the Value Methodology is a proven management technique that can greatly help the flood engineers in 21st century because in flood projects, finding the correct combination of various structural and non-structural measures has always been a great challenge. This is supported by many successful Value Engineering studies in flood management. A historical structure is presented a success story of creativity in flood management.

1. Introduction

Water-related extreme events, floods and droughts, are natural phenomena, which will continue to happen. The risk is likely to grow in the 21st century, heralded as the age of water scarcity, while flood losses also show a rising tendency. Recent climate variability and change seems to have adversely affected flood and drought hazards in several areas and this tendency is likely to continue (Obasi, 1997). Less developed countries do not have adequate financial and qualified human resources and cannot cope with hydrological extremes without foreign and international assistance. Increase of effective assistance to the less developed countries is badly needed (Frederiksen, 1996). While flood and drought protection is necessary to the present generation to attain a fair degree of freedom from extreme water-related events, it must be done in such a way that future generations are not adversely affected. According to the UK Environment Agency sustainable defense schemes should "avoid as far as possible committing future generations to inappropriate options for defense" (Loucks, 1995). There is no single universal remedy against water-related extremes and it is necessary to use a site-specific mix of measures, including structural and non-structural ones. This calls for more emphasize on creativity and innovations. A process to open the mind to new ideas by breaking down constraints to visualization is needed. This paper is trying to demonstrate that coping with the flood related challenges in the 21st century requires major technical jumps and innovations. In this context based on worldwide experiences Value Engineering, a systematic management technique encouraging creativity and teamwork can play a key role. A historical flood management structure, which symbolizes creativity, sustainability and intuitive Value Engineering, is presented as a success story of creativity.

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2. A Historical innovation in Flood Management

Figure 1 presents 73 historical dams located in Iran. As the Figure clearly indicates, the most important characteristic of Iranian historical dams is remarkable height. 20 historical dams higher than 15 m have been identified in Iran as shown in the figure. This is a world record in dam engineering. Spain with 10 and Slovakia with 9 historical dams higher than 15 m rank second and third respectively (Schintter, 1994).

The construction of three arch dams in the 13th in Iran (Kebar, Kurit and Abbasi) was the first application of this type of dam since Romans and Iranian constructed 3 true arch dams 2000 years ago (Schnitter, 1994). Abbasi flood-retarding dam also known as Abbasi arch was constructed 600 years ago near Tabas, in Northeast Iran. The dam is located 20 kilometers Northeast of Tabas (Figure 2). Tabas has a long history. The surface water from the surrounding mountains flows towards the city. It seems that this natural advantage was the main reason for the development of Tabas. In 13th century, the people living in Tabas, near the Great Dash Kavir and Kavir Lut desert (Figure 2), constructed ambitious water transfer projects for management of limited but vital water resources of the region. Due to the primitive technologies of the 13th century, the visionary people had to rely on their intuition, imagination, creativeness, hard work and courage to accomplish astounding achievements in water engineering. One of the mentioned water transfer systems consisted of 60 m high arch dam, which was the highest dam in world for 550 years till early 20th century, a Qanat and a 20 km long channel. The system regulated and transferred water from the Kurit dam site to Kurit village for irrigation. Considering the dimensions of the project, i.e., the length of the transfers system (26 km) and the height of the dam (60 m), it is evident that the construction of the project required astonishing qualifications and capabilities in the 13th century (Emami, Hematian, 2005). The achievements of the region in flood management are equally important.

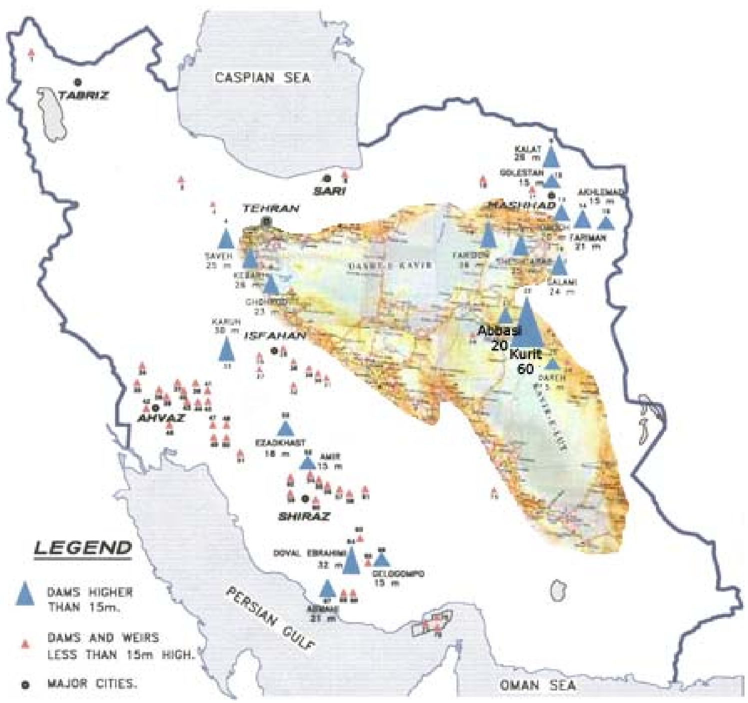

Figure 1: The historical weirs and dams of Iran
the deserts around Tabas are highlighted)

The Abbasi flood-retarding dam is an illustrating example of water wisdom of the builders (Figure 3). The dam has protected the city of Tabas from floods of Nahrain River for

600 years. To avert construction of diversion tunnel, Iranian used to construct the dams on a brick arch in narrow canyons. The lower part the dam would be constructed during a dry season. This creative scheme has been used in many historical dams in Iran. At Abbasi dam site, the lower part was not constructed, so during floods the outflow from the dam was automatically regulated. The scheme is so elaborate that most of the engineers visiting the site believed that the dam was uncompleted or it had suffered a wash-out because of the alluvium foundation (Schnitter, 1994). This is the first time that based on site visits by dam and flood experts and communications with the nearby villagers, the dam is called a flood-retarding dam. The dam site is located 100 m upstream of water springs that account for a considerable part of the base flow of the river. Consequently it is unlikely that the main function of the dam is water storage, otherwise they should have constructed the dam downstream of the springs. A historical document indicates that the main function of the dam is controlling the floods. Based on this document they did not construct the lower part of the dam in view of probable failure of the structures and risk to downstream. Although the area of the basin is just 200 km^2, the floods have large peaks as shown in Table (1).

Table 1: The flood peaks at Abbasi dam site

Return Period (Year)	5	10	20	50	100	1000	10000	PMF
Flood Peak (CMS)	49	92	161	286	375	632		993

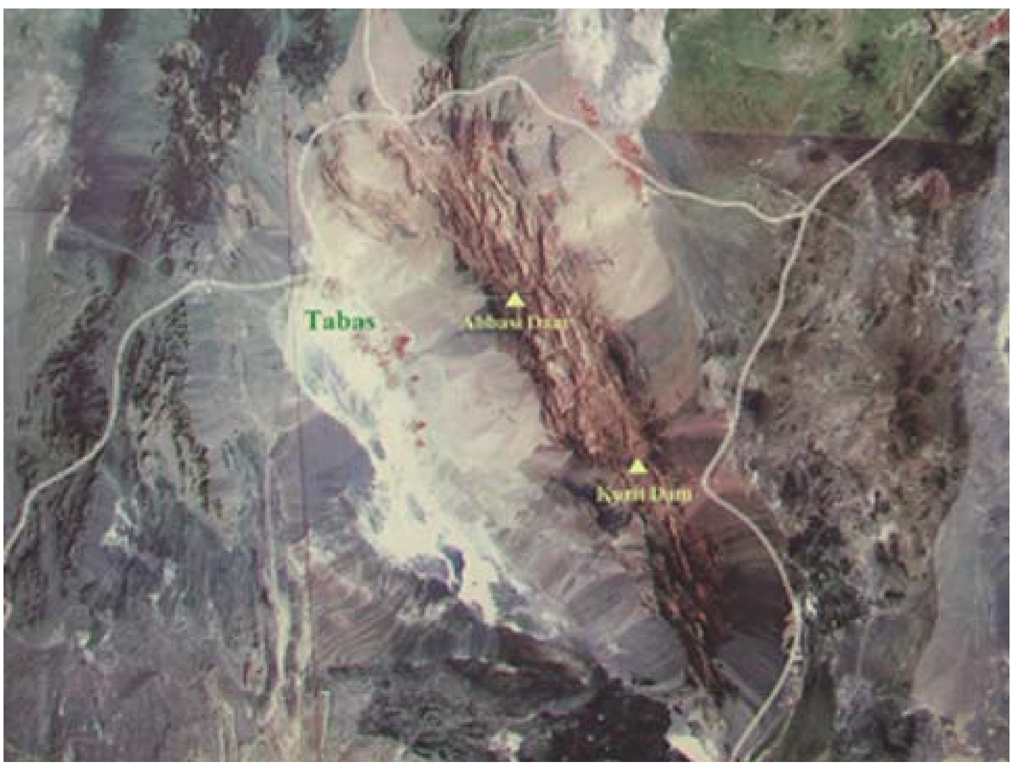

Figure 2: An aerial photo of Tabas region

Figure 3: 25 m high Abbasi flood-retarding dam

3. Retarding basin for flood Control

There are two basic types of flood-mitigation reservoirs - storage reservoirs and retarding basins - differing only in the type of outlet works provided. The discharge from a storage reservoir is regulated by gates and valves operated on the basis of the judgment of the project engineer. Storage reservoirs for flood mitigation differ from conservation reservoirs only in the need for a large sluiceway capacity to permit rapid drawdown in advance of or after a flood.

A retarding basin is provided with fixed, ungated outlets that automatically regulate the outflow in accordance with the volume of water in storage. The outlet usually consists of a large spillway or one or more ungated sluiceways. The Pinay retarding basin in France consists of two wing dams partially closing the river but with a gap between them for discharge the type of outlet selected depends on the storage characteristics of the reservoir and the nature of the flood problem. Generally the ungated sluiceway functioning as an orifice is preferable because its discharge equation [$Q = C_d A(2gh)^{1/2}$] results in relatively greater throttling of flow when the reservoir is nearly full than would a spillway operating as a weir . A simple spillway is normally undesirable because storage below the crest of the spillway cannot be used. However, a spillway for emergency discharge of a flood exceeding the design magnitude of the outlets is necessary in any case.

As a flood occurs, reservoir fills and the discharge increases until the flood has passed and the inflow has become equal to the outflow. After this time, water is automatically withdrawn from the reservoir until the stored water is completely discharged.

An outstanding example of the use of retarding basins in the United States is the reservoir of the Miami Conservancy District in Ohio. Retarding basins were selected for this project because the small streams rise so rapidly that it would be difficult to operate storage reservoirs effectively. Moreover, the retarding basin assures the drawdown of the reservoir after a flood and prevents use of the reservoir for conservation purposes at the expense of flood control.

The planning of a system of retarding basins must assure that the basins will not make a flood worse by synchronizing the increased flow during drawdown with flood peaks from tributaries. When the entire drainage area is small, such an event is unlikely. However, separate tributaries within a large basin may be subjected to independent storms and the probability of synchronizing is greater. Hence retarding basins are preferable for relatively small streams and storage reservoirs are preferable for large streams.

4. The advantages of the present alternative

To control the floods of the river, there are other alternatives involving storage structure at Abbasi Dam site. One of the alternatives is a dam with overflow outlet (overflow alternative). Undoubtedly the alternative of creative builders (bottom outlet alternative) has great advantages in comparison with the overflow alternative as follows:

Initial reservoir Elevation:

In overflow alternative reservoir may be partially full at the beginning of the flood. Consequently the routing of the peak of incoming flood in this alternative would be less than the bottom outlet alternative. Similarly retarding of the flood peak would be less in this case. Surprisingly the alternative constructed matches closely with modern criteria for retarding dams as motioned above.

Sedimentation

The bottom outlet alternative enjoys considerable advantage in terms of sustainability and sedimentation. A survey of the reservoir clearly indicates that there is virtually no sedimentation in the reservoir after 600 years of operation. As the Abbasi Dam has been stable in many extreme events such as the Great earthquake of 1978 with maximum horizontal acceleration of 0.75g, it is virtually a sustainable dam. Very few dams in world enjoy such an advantage. On the other hand the maximum useful life of the overflow alternative would have been 50 to 100 years. Fortunately Abbasi Dam is the only historical dam in Iran that has not been threatened by construction of a modern dam. It is hoped that many generations would have the privilege of visiting this outstanding human heritage than would be a source of inspiration for many engineers for centuries to come.

Risk to the downstream

As it was mentioned Tabas is located downstream of the dam near the river. Accordingly the failure of the dam would have disastrous consequences for the city. In the overflow alternative the total time that dam is full or nearly full is much more than the other alternative. So the total risk to the downstream is much less in the bottom outlet alternative. A historical document indicates that they did not construct the lower part of the dam in view of probable failure of the structures.

Overtopping Frequency

Evidently the frequency of overtopping is much lower for the bottom outlet alternative. Figures 3, 5 and 6 clearly indicate that the dam structure is intact after 600 years. With increased overtopping frequency and duration, the probable damages to dam would have been more severe.

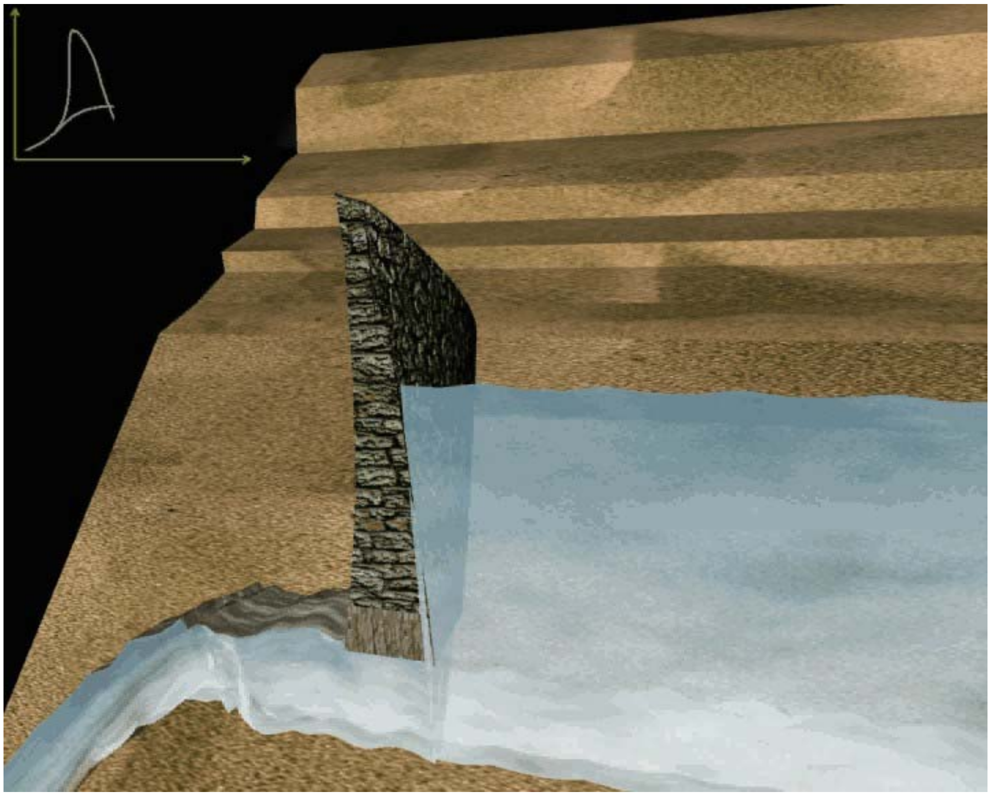

Figure 4: Flood Attenuation in Abbasi retarding Dam

Figure 5: Downstream view of Abbasi retarding Dam

Passage of people

In the overflow alternative the passage of villagers is blocked because there is virtually no other way in the gorge. Still the bottom outlet alternative has allowed the passage of villagers.

Throttling of flood peak

For retarding dams the ungated sluiceway functioning as an orifice is preferable because its discharge equation results in a relatively throttling of flow when the reservoir is nearly full than would a spillway operating as a weir. The deep understanding of dam and flood hydraulics by ancient Iranian is very surprising, but it should be remembered that their survival depended on efficient water resources and flood management.

In addition to the above discussion the overtopping resistance of the masonry arch dam and application of arch, which is a superior structural element, should not be overlooked (ASCE, 1995).

Figure 6: A view of the arch of Abbasi Dam from underneath

5. Role of Creativity and Value Engineering in Flood management:

Creativity is the means to advance civilization into the future. The Abbasi Dam is a symbol of creativity and can be considered as a technical jump. In the view of flood and drought challenges of 21st century, many technical jumps are vitally needed. Accordingly creativity should be promoted in flood management projects so that appropriate solution can be tailored to the particular site-specific conditions. Large flood projects are always unique and therefore engineers should "invent" unique solution for them. The Value Methodology (also called value engineering, value analysis or value management) is a powerful problem-solving tool that can reduce costs while maintaining or improving performance and quality requirements. It is a function-oriented, systematic team approach to providing creative solution for a project or a product or service. The value methodology provides motivations and creative atmosphere so the team can strive for excellence and synergy. In this context a Job Plan is used in Value Engineering studies. The organized and systematic approach of the Value Engineering Job Plan is the key to success of the study. The Value Engineering Job Plan follows the steps used by inventors when they develop new ideas and procedures. Engineers and contractors are inventors- their designs and methods of construction are the result of original thinking. Table 2 shows a comparison of steps of inventors and VE Job plan (Zimmerman, 1988). Based on the above discussion, inventors may be considered as intuitive Value Engineers who could invent without the need for the teamwork synergy. Abbasi Dam can be regarded as a symbol of intuitive Value Engineering.

According to a survey conducted in the United States (Park, 1999):

- 75 percent of the people are neither eager to present new ideas nor they can develop it.
- 12 percent can present new ideas but they do develop them;
- 12 percent can develop a new idea if they are given one;
- 1 percent can present new ideas and develop them.

According to the results of the survey, we cannot rely on a tiny part of the population for creativity and innovation. We should try to promote creativity by the synergy of teamwork. In this context the Value Methodology is a proven management technique that can greatly help the flood engineers in 21st century because in flood projects, finding the correct combination of various structural and non-structural measures has always been a great challenge.

Table 1: Comparison of inventors steps and VE Job Plan

INVENTORS STEPS	VE JOB PLAN	DESCRIPTION
INSPIRATION DATA GATHERING ANALYSIS OF KNOWN FACTS	*Information phase: Function Analysis Phase:*	Information and background on the subject matter are sought so that patterns and combinations of ideas can be formulated. The required functions of the inventor's quest are broken down and identified.
EXPERIMENTATION. NEW COMBINATIONS	*Creative phase:*	Ideas, ideas, and more ideas are formulated to hopefully arrive at the right formula.
ANALYZE AND JUDGE DATA	*Judgment phase:*	The inventor needs a place to start, so he begins judging and evaluating his idea, trying to arrive at the best combination.
DEVELOP DESIGN	*Development phase:*	The inventor's dream nears the point of success as he begins building. He fails and tries again, each time learning by his mistakes and other people's suggestions.
SELL TO PUBLIC	*Recommendation:*	His new invention is complete and ready to go, only to meet with the reluctant supervisor, who sets every roadblock imaginable. He overcomes these roadblocks and feels the true meaning of success.

6. A Similar Creative Scheme for Harmony with Floodwaters in Japan

The flood-retarding scheme of Abbasi Dam has been used for solving flood control and environmental conflicts in Muko River in Japan (Hata, 2005). One of the biggest issues in the discussion on dams is the interception of biological continuity by a dam. On the other hand, it is necessary to keep the discharge less than the flow capacity of downstream. To satisfy both conditions the following measures could be suggested. The Muko River in the Hyogo prefecture runs through the highly developed urban areas and also crosses the Japanese main road and railway, and flows into the Seto Inland Sea (Figure 7).

The river authority of Hyogo prefecture planned in 1983 to construct flood control dam in the valley at the middle stream to protect this important urban areas. However, as the place is famous for the beauty of the valley and is known as a scenic area, people who love the place have been against the plan for more than 20 years. The re-examination of the river plan including the design flood from the Zero Base has started in the Muko River Basin Committee where the author also belongs. The Prefecture River Authority proposes a type of dam with orifices like a retarding basin without control gates at the outlets as shown in Figure 8 (A).

Under a certain value of the design flood comprehensive flood management may be possible without dam construction. However, when we must find an agreement between the two groups of different opinions on dams in case there is no choice but the dam construction. The following type of a dam may be a solution in these cases.

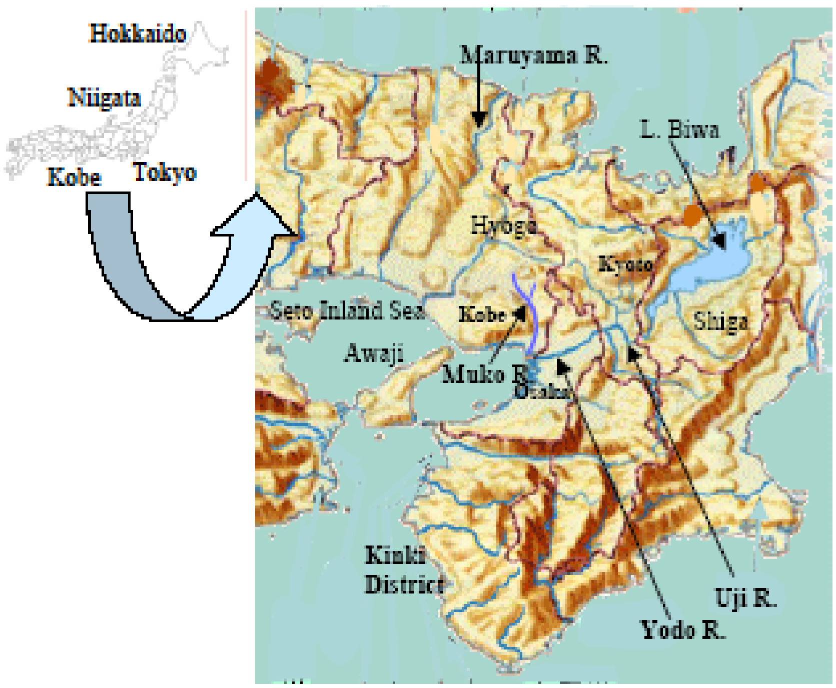

Figure 7: Some main rivers in Kinki district in Japan

The objective of these flood control dams is to decrease the discharge rate less than the flow capacity of the downstream. On the other hand the main problem of a dam is the interception of biological continuity as mentioned above. Therefore, a solution of this problem will be to enlarge and open the outlet of a dam along the riverbed, and preserve the continuity of the river flow (**Figure 8**(B)). If the orifice is enlarged to the size that maximum discharge rate becomes the flow capacity of the downstream, it will make it possible to keep the continuity of sediment and the migration of fishes through the dam. The structure may be similar to the historical Abbasi dam (Emami, et al., 2005) in Iran. It seems to be important to keep the continuity of flow especially for the dam aimed for flood control. It might also be necessary for a newly planned small-scale dam for irrigation to make it empty once a year like sometimes making the irrigation pond empty. Though it is not an effective water use of a dam, it will make more nature oriented water use of the river.

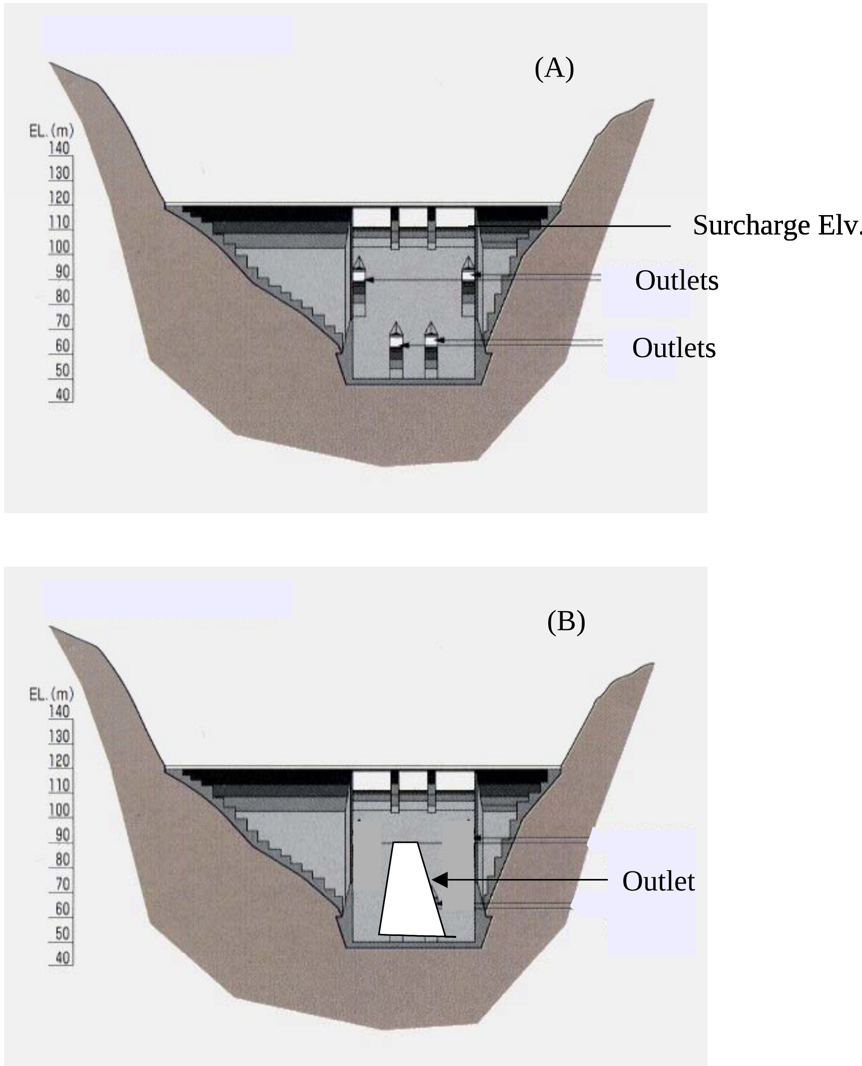

Figure 8: Modification of flood control dam
(A: Planned dam by Hyogo Prefecture B: Modified one)

As the stored water by the dam is quickly discharged after controlling the discharge rate, the damage to the plants will not be great. By designing the shape of the orifice the dam may harmonize with the surrounding as a well-designed bridge fits the landscape. It might be important to design a large aperture of orifice and the shape of it according to the calculated discharge to conserve ecological and sediment continuity and to decrease the damage to the landscape. The delay of runoff by the storage in the dam gives the time of warning and evacuation even in the case of exceeding the design flood when overflow of the dam crest happens and the danger of overtopping the downstream levee impends.

7. Summary and Conclusions:

1. There is no single universal remedy against water-related extremes and it is necessary to use a site-specific mix of measures, including structural and non-structural ones. This calls for more emphasize on creativity and innovations. This paper is trying to demonstrate that creativity is the key to coping with the flood related challenges in the 21^{st} century and major technical jumps and innovations are essential. In this context

based on worldwide experiences Value Engineering, a systematic management technique encouraging creativity and teamwork can play a key role.

2. While flood and drought protection is necessary to the present generation to attain a fair degree of freedom from extreme water-related events, it must be done in such a way that future generations are not adversely affected.
3. Abbasi retarding dam that symbolize creativity and sustainability and can be regarded as a technical jump is presented as a success story of creativity. Through creativity and persistence, the visionary builders of the structure succeeded in construction of an effective, safe, low cost and sustainable dam that has successfully achieved the main function of the project for the last 600 years. It is likely that the dam would attenuate the floods of Nahrain River for many centuries to come. The successful use of flood retarding scheme of Abbasi Dam in the MuKo River Dam is another illustration of the vital role of creativity in solving the conflicts of flood management and environmental values.
4. Value Engineering is a process to open the mind to new ideas by breaking down constraints to visualization. It helps us break away from the old tried-and-true habit to develop new exciting methods, products and inventions to carry us into the future.
5. Intuitive Value Engineering can be achieved by few very intelligent and experienced experts but we cannot rely on a tiny part of the population for creativity and innovation. We should try to promote creativity by the synergy of teamwork. In this context the Value Methodology is a proven management technique that can greatly help the flood engineers in 21st century because in flood projects, finding the correct combination of various structural and non-structural measures has always been a great challenge.
6. The author has been involved in Value Engineering studies of many flood management structures in Iran such as:
    - VE studies of Marun Regulating Dam Spillway (Emami et al., 2003);
    - VE studies of diversion system Marun Regulating Dam Spillway (Emami et al., 2003);
    - VE study of the spillway of the Gavoshan Dam;
    - VE study of the spillway of Vanyar Dam (Emami et al., 2004);
    - VE study of the spillway of Ghaleh Chay Dam;
    - VE study of Karun-4 Cofferdams.

Based on the results of the above-mention VE studies, the author believes that VE is very effective in flood management projects by enhancing safety and reducing the cost and construction time. This has been made possible by creative solutions encouraged by the team work systematic approach of Value Engineering.

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