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THREE YEARS AFTER THE DISASTER BY DEBRIS AND MUDFLOWS IN VARGAS STATE, VENEZUELA.

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SUMMARY

In December 1999, a sequence of simultaneously debris and mudflows took place in the torrents of the center north costal area of Venezuela, that produced more than 20.000 deaths and economic losses of more than 3.000 millions American dollars. The amount of human and economic losses was greatly increased by a chaotic localization of houses, buildings, roads and weak bridges. The Ministry of Environment sought international expertise. Experts from Austria, France, Italy, Spain, Norway, China, and Japan came to Venezuela and developed with the local engineers a sound strategy and design criteria to tackle this problem. It was a very interesting experience. The implementation phase that initiated in the year 2000 has continued during 2002 and 2003. The intensity of execution has been limited due to the high cost of the engineering works and the low financial capacity of the government. In this paper, we present the results and obtained benefits, the implementation difficulties, the new problems raised and several recommendations to apply in similar cases in the future.

Key words: Risk mitigation, floods, Vargas Venezuela

BACKGROUND

Rains in the state of Vargas in December of 1999 caused the greatest hydrometeorological tragedy that Venezuela has ever known. The Maiquetia-Airport climatic station -serial 0503, registered 1207 mm in the first 17 days of the month, representing a value superior to the annual average, 510 mm. The amount of rainfall in the first 13 days was 296 mm, which totally saturated the soil porous space. The amount fallen during the 14th, 15th and 16th was 120, 381 and 410 mm, respectively, for a total of 911 mm (MARN, Environmental Commission for the Evaluation and Integral Treatment of the Torrential River basins of the State Vargas, March 2,000). On December 16th an intensity of 72 mm/hr was measured (www.corpovargas.gov.ve).

Most of the rivers and torrents of the Central Coast had simultaneous high peak discharges around the night of 15th and the morning of 16th. They deposited approximately 7.2 million of m^3

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(without including the torrent “Mamo”) (Report of the Japanese mission, mentioned by Salazar, 2,003), winning 1,020 has of land to the sea (www.corpovargas.gov.ve).

The debris cones and adjacent hills, in the majority of torrents were occupied by houses, buildings and tourist infrastructure, which were partially and totally affected by debris and mudflows (Fig 1).

The Institute for the Recovery and Development of the State of Vargas (CORPOVARGAS) indicated that 240,000 people, equivalent to 72% of the population of the state, were harmed. Eight thousand (8.000) houses were destroyed and a great number affected partially. Five small hospitals were damaged. The water supplies and sewage systems were damaged. 85% of the main road was destroyed. The port of La Guaira and the main airport of the country were paralyzed. 30% of the educative infrastructure was affected. At least fifteen thousand people died or disappeared, and the economic losses ascended to 3,000 million dollars (www.corpovargas.gov.ve)

Experts of countries with ample experience, technology and resources in “Torrent Control” like Austria, Italy, Japan, Spain, Norway and China, worked out projects looking for the risk reduction of the population that lived in the debris fan of fourteen (14) watersheds that were high-priority based on the magnitude of the happened damages. (Rivas 2,002). These projects were prepared at the request of the Bolivariana Republic of Venezuela with the participation of engineers of the Ministry of the Environment and Natural Resources (MARN).

The projects proposed the construction of a temporary retention dams, check dams, and channels throughout the populated zone. At this moment, CORPOVARGAS has constructed open dams, check dams, auxiliary dams and channels in six (6) torrents of the ones assigned to the foreign technical missions. In addition, it has built works in the torrents Curucutí, Alcantarilla and Anare, torrents that were incorporated after the original proposal.

Fig1: Debris cone in San Julian torrent, January 2000 (Source: UCV)

OBJECTIVES AND METHODOLOGY

The main objective of this paper is to know the progress of the torrent control program of the Central Coast, affected by the debris flow of December 1,999, and to evaluate the flood risk reduction by constructed works. The specific objectives are: a) To know the projects elaborated by the technical missions, b) To know the works and the strategies that are being developed by CORPOVARGAS and c) To evaluate the flood risk reduction associated with the constructed works.

For the attainment of the proposed objectives, a revision of the projects originally formulated, and studies published recently was made. Meetings with experts of the MARN main office and CORPOVARGAS were made. In addition, we made visits to the field for a detailed reconnaissance, took ground pictures and surveys to the population that lives in the zone.

THE ORIGINAL PROJECTS

The projects elaborated by the missions of Austria, Spain, Italy, Japan and Norway proposed for nine selected torrents the construction of 12 open dams. Furthermore, they proposed 8 check dams, 12 auxiliary dams, 1 opened dam with gallery, 1 horizontal grilled dam, 4 filtering dams, 3 mudflow breakers, 217 ms masonry revetment wall, 10,248 meters of fixed bottom channel, and 1,805 meters of channels with submerged sill (Table 1). As noted in table 1, the cost considered for the treatment of torrents was 57.50 million dollars. (Rivas 2,002).

The open dams have the purpose to break the debris flow energy and to generate temporary retention of heavy and ligneous material. Auxiliary dams avoid the toe scoring of the main check dam. The check dam stabilizes channels and slopes and the channels transport the total peak discharge in safe form.

Tab. 1: Works types for the high priority torrents.

	Torrent name*											
Type of work	M/P	PA	QS	QA	OS	Cr	SJG	EC	CCh	SJ	QSc	Total
Open dam	2	1			1	2	2		1	2	1	12
Open dam with gallery									1			1
Auxiliary dam		1			2	1			3	5		12
Training wall (meters)		67							50	100		217
Horizontal grilled dam		1										1
Filtering dam			1					3				4
Check dam	4								1	3		8
Mudflow breakers											3	3
Channel with fixed bottom (meters)	3000	1910	512	216			1200		420	2130	860	10248
Channel with submerged sill (meters)					565	540		700				1805
Cost ($10^6$$)	12,89	15,40			4,81	2,10	1,24	1,57	4,07	12,07	3,35	57,50

*M/P = Torrent Mamo, tributary Piache (Project by Noruega)
*PA = Torrent Piedra Azul; QS = Torrent Qda. Seca; QA = Torrent Qda. de Agua and QSc = Torrent Qda. Seca (Austria). *OS = Torrent Osorio; Cr = Torrent Cariaco (Spain)
*SJG = Torrent San José de Galipán; EC = Torrent El Cojo (Italia)
*CCh = Torrent Camurí Chico; SJ = Torrent San Julian (Japan)

The Cerro Grande torrent (assigned to the Republic of China), Naiquatá and Camurí Grande, were excluded from this analysis due to lack of information. The proposed strategies in general terms were the construction of selective retention dams in the upper zone, checks dams in the middle part of the watershed and outlet channel throughout the debris cones; proposals that in general were adapted by CORPOVARGAS in the definitive projects of execution.

The work developed by the missions was of great importance not only for the training of the Venezuelan engineers belonging to the Ministry (MARN), but also for other public and private institutions.

THE EXECUTED WORKS

The works have been executed by CORPOVARGAS, which belongs to the Ministry of Planning and Development. They have worked in nine (9) river basins: Mamo/Piache, Curucutí, Piedra Azul-Quebrada Seca, Osorio, Alcantarilla, San Jose de Galipán, Camurí Chico and Anare, for a total of 19 check dam, 7 opened dams, 11 auxiliary dams and 750 ms of channel of fixed bottom (Table 2). According to verbal information provided by CORPOVARGAS, approximately 36,000 m^3 have been constructed of gabion check dams in one and a half years (2002-2003). This means a high organizational and financial effort by the Corporation.

Tab 2: Works executed by CORPOVARGAS

	Torrent names*												
Type of work	**M/P**	**Cur**	**PA/QS**	**OS**	**Cr**	**Alc**	**SJG**	**EC**	**CCh**	**SJ**	**QSc**	**An**	**Total**
Open dam	1	1	3					1	1				7
Open dam with gallery													
Auxiliary dam			5				1	2	1			2	11
Training wall													
Horizontal grilled dam													
Filtering dam													
Check dam		2	2	9		2	1	1				2	19
Mudflow breakers													
Channel with fixed bottom (meters)							600	150					750 m
Channel with submerged sill (meters)													

*M/P = Torrent Mamo, tributary Piache;

*Cur = Torrent Curucutí;
*PA = Torrent Piedra Azul; QS = Torrent Qda. Seca;
*OS = Torrent Osorio; Cr = Torrent Cariaco;
*Alc = Torrent Alcantarilla: SJG = Torrent San José de Galipán; EC = Torrent El Cojo;
*CCh = Torrent Camurí Chico;
*SJ = Torrent San Julian;
*QSc = Torrent Qda. Seca.

The project for Guanape torrent, originally assigned to the Spanish mission, was elaborated and executed by CORPOVARGAS. It consists of an open dam and a fixed bottom channel of rectangular section, which has had problems of sedimentation.

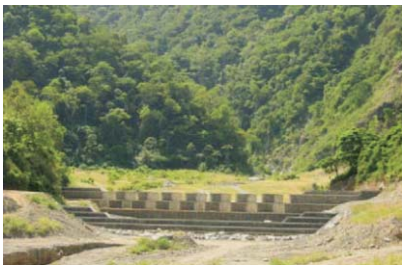

Fig2: Open dam in Piedra Azul torrent. (2003)

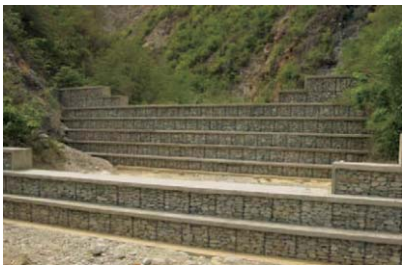

Fig3: Dams in Alcantarilla torrent. (2003)

The original projects were reformulated by CORPOVARGAS due to their high cost and the currently limited budgetary resources of the country. The decision to use gabion as construction was in order to decrease costs and generate an important amount of labor hand in a zone with high unemployment and to take advantage of the excessive amount of rocks that were transported by different torrents. Additionally, they indicated the necessity to take quick actions due to the social pressure of the affected population. Time was passing away without proper actions.

CORPOVARGAS has used the more resistant metallic meshes in the market to avoid the damage by the flood impact of rocks. However, it is necessary to develop a detailed program of inspection and maintenance in order to keep the gabion in optimal conditions.

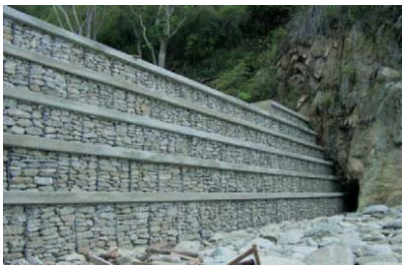

Fig4: Dam in torrent El Cojo. (2003)

Fig5: Dam and channeling, torrent San José de Galipán. 2003. (Source: CORPOVARGAS)

RESULTS

It is difficult at this moment to evaluate the effects of works, because is too early and the projects are still in progress. Nevertheless, some conclusions can be obtained by means of fieldwork, review of previous papers and surveys of the inhabitants.

Flood risk mitigation.

The flood risk evaluation is difficult because of the uncertainty and complexity of the phenomenon. Another difficulty is the lack of information about relevant impact indicators. Nevertheless, it is possible to make estimations on the magnitude in which the floods risk in the debris cones has been reduced in association with the effects of the control work program that has been built.

We will use as indicators of the flood risk mitigation, the volume of retention produced by the constructed dams. A low risk mitigation is considered when the torrent has a retention volume smaller than 10,000 m^3; between 10,000 and 60, 0000 m^3 the reduction is medium; between 60,000 and 120,000 m^3 is high and greater than 120.000 m^3 the mitigation is very high. Additionally we will use information about the level of houses expropriation located in risk areas.

Tab. 3: Potential storage volume retained by dams and its relation with flood risk mitigation.

Torrent name	Area (Km^2)	Constructed check dams (number)	Storage retention capacity (m^3)	Protected community (name)	Risk Mitigation (value)
Piache	4,50	1	9.500	El Piache	Low
Curucutí*	1,33	3	67.500	Curucutí	High
Piedra Azul-Q.Seca**	21,93	5	107.500	Maiquetía El Rincón	High
Osorio***	4,70	9	6.000	Casco Histórico La Guaira	Low
Cariaco	1,25	0	0	Cariaco	None
Guanape	4,22	1	3.000	Punta Mulatos	Low
Alcantarilla	1,50	2	31.500	Macuto	Medium
San José de Galipan	14,98	1	6.000	Macuto	Low
El Cojo	6,49	2	19.000	Punta El Cojo	Medium

Camuri Chico	10,21	0	0	Camurí Chico	None
San Julian	21,29	0	0	Los Corales	None
Qda. Seca	3,00	0	0	Qda.Seca	None
Cerro Grande	25,39	0	0	Tanaguarena	None
Anare	24,80	2	8.000	Anare	Low

* In the Curucutí torrent, there was a check dam previous to the event of 1,999, which was deposited with sediment. After the catastrophe, two (2) check dams and one (1) open dam for selective retention were constructed. ** In the tributary Quebrada Seca that drains to Piedra Azul two (2) open dams of selective retention were constructed with capacity of 20,000 m^3 each one. *** In the Osorio torrent there are two (2) dams, 4 meters tall, with low capacity of retention. In addition, seven (7) low check dams have been constructed.

Based on the results shown in table 3, and with the scale of conversion we have developed the levels of risk mitigation, which appear in figure 1. This information allows us to classify the torrents in five groups according to the flood risk mitigation: 1) Very high reduction, 2)High, 3) Medium, 4) Low and 5) Null reduction to the risk.

In the first type, the torrents are Piedra Azul-Qda Seca, Curucutí and Uria.
In torrent, Piedra Azul one open dam and two check dams with theirs auxiliary dams have been constructed. In addition, in the tributary Quebrada Seca two open dam were built, that altogether offers a retention volume higher than 100,000 m^3. In the Curucutí torrent, three dams assure retention of 67,500 m^3. In the Uria torrent, the risk has been reduced to a minimum level in association with expropriation of houses.

In the second block are classified the torrents San Jose de Galipán, Alcantarilla and El Cojo.
In San Jose de Galipan there is an important work related to a long outlet channel and a check dam with low retention storage, and a significative number of houses expropriation bordering the channel. In torrents Alcantarilla and El Cojo, two check dams, each one of them with theirs auxiliary dams, offer a significant retention of material.

In the torrents Osorio, Guanape, El Piache and Anare have been a “low flood risk reduction”, since the storage of sediment retention in each one is smaller than 10,000 m^3.

In the torrents Cariaco, Camurí Chico, San Julian, Quebrada Seca and Cerro Grande retention works have not yet been built.

Fig6: Level of flood risk mitigation (houses close to the torrents) in torrents that have been worked on in Vargas State, Venezuela. Indicators: storage volume retained by dams and level of houses expropriated.)

Flood risk mitigation.

Torrent name	1 (none)	2 (low)	3 (medium)	4 (high)	5 (very high)
Piedra Azul- Qda. Seca					
Curucutí					
Uria					
Alcantarilla					
El Cojo					
San José de Galipán					
Osorio					
Guanape					
El Piache					
Anare					
Cariaco					
Camurí Chico					
San Julian					
Qda. Seca					
Cerro Grande					

Situation in 1999

Situation in 2003

Public opinion

Fifty percent of the interviewed people think that the protection against floods is greater now than before. The others indicated disappointment in the fact that the check dams were constructed in gabions and the concrete offered greater security. In addition, they are worried because in some cases the works are paralyzed awaiting budgetary allocations. The anxiousness is greater for those people that live in areas where no protective works have been constructed.

The surveyed inhabitants recommend to have greater respect for laws, decrees, etc., that govern the zoning for the construction of houses. They affirmed that these events would repeat themselves. Some of them thought that every 50 years an event like this would happen, which is an empirical appreciation that does not correspond with the scientific technical knowledge. They recommend that the population learn more about these natural phenomena. They must be aware that the zone where they live is at risk, requiring contingency plans to take safe actions at the time of appearing an extraordinary flood event.

Other obtained benefits

The construction of 36,000 m^3 of gabions has generated approximately 18,000 labor days that has a valuable effect in the economic recession situation. In addition, it has allowed Venezuelan engineers to acquire experience in the solution of problems of great complexity in the field of hydraulics and torrent control. The works have contributed to diminish the threat on the main road, favoring economic reactivation, especially the tourism.

Operative difficulties and new problems

The great magnitude of the flood events and the limited resource allocations has made difficult the total execution of the projects. In many cases, the inhabitants reject accepting the relocation proposals. Problems of public security have appeared that prevent the activities of planning, construction and supervision of works. In some torrents, the inhabitants have been relocated in their old houses located in affected sites by the 1999 floods. Also the inhabitants have built houses in lofty and steep slopes, problems that must quickly be tackled by CORPOVARGAS or the State government.

CONCLUSIONS

In the first place, it is worth emphasizing the organizational and financial effort of CORPOVARGAS. They have constructed a considerable volume of works. They have worked in nine torrents in a period (2002-2003) for the flood risk abatement to the population that lives in the debris cone.

Having generated 18,000 labors days is a valuable benefit due to the situation of economic recession in the area. . The dams and channels have diminished the threat on the main road, favoring the economic reactivation, especially the tourism.

Venezuelan engineers have acquired experience in the solution of problems of great complexity in the field of hydraulics and torrent control. The constructed works such as open dams, closed

check dams, outlet channels and submerges sill, constitute a significant technical advance in the discipline of the torrent control in Venezuela and Latin America.

The works resulted of the adaptation that CORPOVARGAS has made to the proposed by the technical missions, which could not be executed due to the high cost and the difficult economic situation of the country.

In torrents Piedra Azul-Quebrada Seca and Curucutí the dams has produced a "high flood risk reduction". The same has occurred in Uria due to the expropriation program. In the torrents San Jose de Galipán, Alcantarilla and El Cojo, the flood risk reduction is medium; and low in the torrents Osorio, Guanape, the Piache and Anare. On the other hand, in the Cariaco, Camurí Chico, San Julian, Quebrada Seca and Cerro Grande mitigation works have not been undertaken.

RECOMMENDATIONS

We highly recommend the elaboration of maintenance plan for all the dams and channels built in gabion. In that, respect a coordinated actions should be design between CORPOVARGAS and the Ministry of Environment in order to improve the strategies and design of future dams based on the observations on constructed works.

CORPOVARGAS must manage its financial resources to conclude paralyzed works and indispensable complementary works to assure a greater protection in all treated torrents. At the same time is urgent to find resources to build the works in the torrents: Cariaco, San Julian, Quebrada Seca and Cerro Grande due to the very high population density. CORPOVARGAS should take into account the strategies, designs and construction material, proposed by the missions of Austria, Italy, Japan and Spain.

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