



SUSTAINABLE MANAGEMENT OF THE WOMANGUE WATERSHED IN LIMBE, CAMEROON: REDUCING THE RISK OF FLOODING AND LANDSLIDES



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GESCOD & GIRIN-LIMBE

Gescod is the multi-actor network of the Grand Est Region

It acts as a relay between the State, local authorities and civil society to encourage and strengthen the international openness of these actors in the Grand-Est region.

Within the framework of decentralized cooperation partnerships, Gescod supports actors from the Grand Est Region in numerous countries, mainly in Africa. The actions undertaken are co-constructed between regional actors and international partners keen to act together and in synergy around development programs. This sharing of skills and expertise enables cooperation projects to be carried out on a territory-by-territory basis. In Cameroon, Gescod has been working on behalf of local authorities for over 30 years.

The project "Sustainable management of the Womangue watershed in Limbé, CAMEROON: reducing the risk of flooding and landslides" started in June 2019. Working alongside the authorities and services of Limbe City Council, Gescod coordinated all the mobilized actors and piloted the activities. L'Agence française de développement funded the project, as well as l'Agence de l'Eau Rhin-Meuse (France) and the Limbe City Council.

| LIMB | E |
|---------------------------------------|-----------------------|
| 120 000 inhabitants (20 |)22) |
| O Vibrant economic secto | r |
| Strong anglosaxon cultu | ural identity |
| Urban perimeter hemm sloping hills | ned in by dense, |
| Highly permeable and f | ragile volcanic soils |
| Annual Rainfall : 4000 m | ım |

This project was lead within the institutionnal framework of a decentralized cooperation partnership established in 2007 between the City of Limbe and the City of Colmar (Colmar Agglomeration).











GIRIN







E-R-A











INSTALLATION OF DRAINAGE TRENCHES SYSTEM IN AN URBANIZED AREA UPSTREAM OF THE WOMANGUE RIVER WATERSHED



INNOVATIVE ASPECT



This is a contextual innovation. Drainage trenches are widely used throughout the world, but have never been tried out in Cameroon. A satisfactory result from the Girin-Limbé project could lead to the technology being extended through out Limbe and other areas of Cameroon.

STRUCTURE'S DESCRIPTION

The technology is being tested in a potential landslide zone with a steep slope of 45° upstream and 15° and 12° downstream, characterized by the porosity of the volcanic soil. The layout consists of a network of drains structured around a main watertight, open trapezoidal ditch 74 linear meters (74m) long, following the course of a natural talweg, connected to a network of eight (08) drainage trenches 228 m long.

This system aims to avoid water saturation of the soil by adopting the natural functionning of a river watershed. It enables rainwater drainage, and their flow to an outlet. The trenches permits the collection of rainfall water, inflitred into the ground or running off the surface thanks to the strainer pipes laid in a lined ditch and routed to the main drain, which in turn is connected downstream to a free outlet.

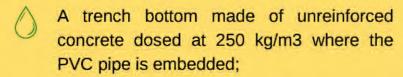
The trenches network formed a fishbone-like structure composed by the main drain, open and trapezoidal with concrete walls in the direction of the slope to be treated. It has been constructed in Limbé with the following dimensions:



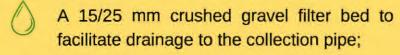
Width at base: 1 mWidth at crest: 2.5 m

Height: 1.5 m

A network of underground drains perpendicular to the slope connects to it. It forms the collection circuit. These drains are formed from:



A 160 mm diameter PVC pipe, cored at the top with 0.8 mm wide slots to facilitate water infiltration into the pipe;



A protective geotextile placed along the walls and above the gravel pack. This protects the gravel pack from the surrounding soil, preventing it from clogging;



Sigth of Limbé draining trenches network:

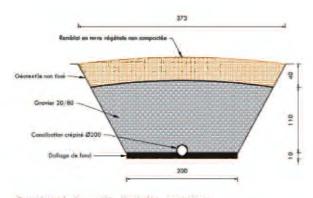
- Navy blue, the opened main drain
- Green, draining trenches
- Light blue, people's accomodation

A top layer of excavated material, consisting of topsoil, placed above the drainage layer;

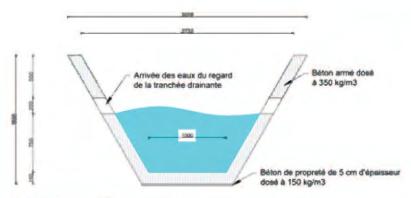
A reinforced concrete manhole at the drain outlet (dimensions I=0.7 x L=0.7 x h=0.9 m). It can be used to intervene in the event of a malfunction (blocked PVC pipe,);

A connection to the main drain to discharge drained rainwater.

SKETCHES



Sectional view of a draining trenches



Sectional view of the opened drain



CONSTRUCTION - STEP BY STEP



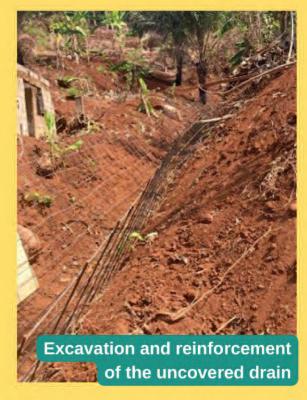
CONSTRUCTION OF THE MAIN DRAIN



View of the natural talweg before construction



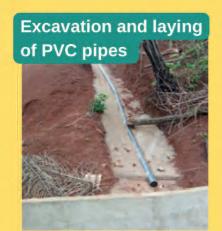
Formwork and reinforced concrete pouring by section







DRAINING TRENCHES CONSTRUCTION

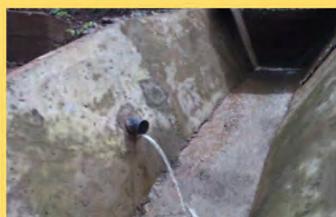






View of the service ladder and footbridge downstream of the main drain





Rainwater is collected by the in-ground drain and ispoured in the main drain



Aerial view of main drain and two trenches (right)



PROBLEMS ENCOUNTERED AND LESSONS LEARNED

Before the construction, geotechnical and topographical studies were used to combine the results obtained with hydrological data to draw up a landslide vulnerability map for the upstream slopes of the project area.

The place chosen for the draining trenches is located in a vibrant, anarchic, and dangerous urban zone where a deadly landslide took place in 2001. The pilote and innovating system in Cameroun answers to the unsatisfied need of stabilization of steep-sloped watersheds that are potentially exposed to landslide.



SOCIO-ENVIRONMENTAL ASPECTS



The presence of residential buildings and food crops on the perimeter led to negociations with local residents. Even though none of the five buildings concerned had received building permits from the city, the City mayor opted for dialogue and consultation. This approach was supported and facilitated by the project team. Thus making it possible to find an alternative to the initial need to relocate and rehouse the people affected. It was therefore agreed that the location of the structure would have to be adapted to the current state of occupation of the site, and that existing crops would have to be impacted by less than 20% of the occupied surface area. For crops such as bananas, some plants were simply moved a few metres out of the way of the drains. This approach has preserved the social and economic stability of the families concerned, and fostered strong social support for the project. No negative effects on the environment were noted during the construction phase.



The risk culture awareness campaign carried out in the project area has raised real awareness among the local population. As a result, some residents have voluntarily become involved in monitoring the areas marked as non-constructible zone. However, some people who had already invested in the purchase of plots of land in this risk zones continued to build their homes, driven by financial precariousness and the urgent need to get out of their status as tenants. On the drainage trench site, this attitude is no doubt also linked to the feeling that they now benefit from the protective effect of the system put in place.



TECHNICAL ASPECTS



The project had to be optimized during the preliminary design phase. It was therefore necessary to reduce the length of the structures, on the basis of the bills of quantities and estimates provided by the project management.



Some of the materials specified in the technical file proved unavailable on the local market.



Shortly after final handover, heavy rainfall hit Limbé, causing two fatal landslides and major flooding. The network of drainage trenches suffered severe erosion. Rainwater runoff, combined with the steep slopes, washed away the uncompacted backfill, which had not yet been stabilized by the regrowth of vegetation, exposing the geotextile and granulates. To remedy this damage, it was imperative to consolidate the area around the main drain by laying more than 1,000 bags of topsoil lined up along the impacted drains. An earthen ditch was also created to intercept transverse runoff and direct it towards the main drain through an opening in the drain wall. In the medium term, the re-establishment of natural vegetation on the site should reinforce the protection of the entire system and ensure that it functions in harmony with the site's natural hydraulic dynamics in wet weather.



Full concreting of the main drain is questionable, given the low flow rates collected. Spot treatment with rubble stone, for example, could be considered as a gentler, less costly solution, particularly at the connections between the drainage trenches and the main drain. For the rest of the route, vegetation would act as a flow velocity limiter.



The depth of the drain necessitated the construction of a ladle to access the bottom of the canal. Similarly, a culvert was installed to allow residents to move from one side of the drain to the other.



INSTITUTIONAL ASPECTS

- Urban development control operations were progressively transferred to the Limbe City Council's risk management service, with financial and logistical support from the project. These controls have gradually become laxer due to (i) the city's insufficient mobilization of human resources (only 1 agent mobilized) and (ii) the city's failure to use administrative and legal coercive means to deal with non-compliance with summonses to stop building.
- In order to obtain financial support from the State for the resettlement and compensation of people affected by the project, the Limbe City Council initiated a procedure for a Declaration of Public Utility. However, this proved to be too late, given the long lead times (2 to 3 years), which were incompatible with the project timetable. However, the city will have to continue this process in order to eventually relocate people living in the most vulnerable areas, where all construction is forbidden.

MORE INFORMATIONS

| Carrying out of the work | JZ SERVICES (local enterprise) |
|--------------------------|--------------------------------|
| Projet management | ERA Cameroun |
| Construction length | 4,5 months (2023) |
| Project manager | Gescod |
| Projet Manager Assistant | Sépia Conseils |
| Final beneficiary | Inhabitants and City of Limbe |
| Installation cost | 55 800 000 F CFA (85 000 €) |





CREATION OF A PILOT VETIVER NURSERY AND STABILIZATION OF THE URBANIZED WATERSHED AND CREATION OF TERRASSES PLANTED BY VETIVER.



INNOVATIVE ASPECT



This is a contextual innovation: the stabilization of the watershed has been used for years in Cameroon, especially on roadworks where vetiver enables not only the consolidation of steep slopes bordering roads but also on flood protection structures. However, it is the first time that this technique is used for stabilizing urbanized watersheds and for constructing terrasses in Cameroon.



DESCRIPTION OF THE PROJECT

It proposes a new approach adapted to the local context, a solution based on nature. The first goal is to demonstrate the relevance of the project before expanding its scale. The pilot site is particularly prone to run-offs and is located in a high risk, steeply sloping area. In fact, the main landslide of the deadly event of 2001 happened there.

The experimentation is also based on the stabilization of built-up terrasses, i.e. the development on the natural slope before building a home on it.

The vetiver is a grass from Asia used for soil stabilization by creating plants hedges perpendicularly to the slope. Nursery-raised plants, resulting from the division of mother plants, are planted in the field at 10 to 15 cm intervals in lines following the contour lines, themselves spaced 50 cm apart, to create, when mature, a slope-stabilizing device thanks to the vetiver's dense, deep, 3 to 4 metre root system.

By mutualizing information of scientific paper written by the geology department of Buea University with the results of the geotechnic campaign carried out for the project, we notice that most of landslides recorded to date in Limbé are translational and affect a relatively low soil thickness (2m on average, 4m maximum). This observation confirms that vetiver is the solution for landslide protection, thanks to its deep root system.

It was necessary to plant 44 000 plants on the area of 2001 landslide, a surface of 3 500 m², and 2 800 plants on two built-up terrasses, so a total of 47 000 plants.



CONSTRUCTION STEPS



CREATION OF THE PILOT PLANT NURSERY



Acquisition of mother-plants

The vetiver variety chosen was Chrysopogon zizanioides, a non-invasive variety and the most widely used in experiments in other countries. Part of the cuttings for the Limbe nursery were imported in part from Kenya, and supplemented by plants from the Maga locality in northern Cameroon, where vetiver is already used to protect several dykes.



Delivery of vetiver batches certified on the nursery

Plants certification

After inspection and appraisal, the supplier's batches of seedlings have been certified by the Regional Delegation of Ministry of Agriculture for the Littoral. This operation attests to the non-invasive nature of the variety used.



Setting up the tree nursery

After obtaining the certification, the provider had authorization to transfer the plants at the tree nursery. Before delivering the plants, the provider:

- acquired small tools needed for nursery work;
- prepared the area (clean-up and earthwork);
- recruited labor forces to work at the tree nursery.



Preparation of cuttings and nursery bags

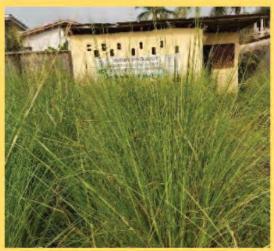
Once the nursery is ready, cuttings are transplanted into black 15x15 cm plastic nursery bags, pre-filled with topsoil and watered daily. After three months, these cuttings, now mother plants, were divided by splitting into daughter plants of three to four tillers each, which were then transplanted into nursery bags. Total production was thus 76,000 plants, as stipulated in the nurseryman's contract.



Watering plants after transplanting



Vetiver growing stage after a month



After 3 months



1

Preparatory activities

This step included cleaning-up the site, trimming of the trees that could shade vetiver, carrying out topographic surveys, and drawing up a planting plan.



The hedge lines are then planted inside the bins using string and calibrated templates. Hedgerow lines are spaced 50 cm apart, and the distance between two planting stations for cuttings on the line is 15 cm. Holes are drilled as the planting progresses. Each hole is about 15 - 20 cm deep.

Planting and harvesting



Planting

Daughter-plants are transported from the nursery to the site. The black plastic bag is removed, and plants are prepared for planting. The hole is filled up with dirt from the holes. After all, the entire area is watered.



Plants' preparation before planting



Planting on process



Size of upper part of leaves



Post-planting maintenance

Regular visits are made to the site to ensure that the plants are growing well and that the best environmental conditions are maintained. This makes it possible to plan weeding and leaf pruning activities to ensure optimum growing conditions. Dead plants are replaced.



Weeding plants



Views of the site 5 months after planting



STABILIZING BUILT-UP TERRASSES

The urbanization of the town of Limbé tends to progress rapidly towards the steep slopes of the hills surrounding the town. This phenomenon interferes with landslides in a number of ways. Houses are built on terrasses dug into the hillside, varying in size according to the size and standing of the desired dwelling. As a result:

- they are under threat from landslides occurring upstream,
- they aggravate the risk of landslides downstream and upstream of the terrace.

It is more dangerous if the terrasses are to be used as foundations for new buildings, because :



These terrasses are bounded on the upstream side by an excessively steep slope that is liable to propagate a landslide upstream.



When the terrasse is excavated, waste is evacuated downstream of the terrace in the form of a steep, unconsolidated slope, which is also liable to slide easily downstream.

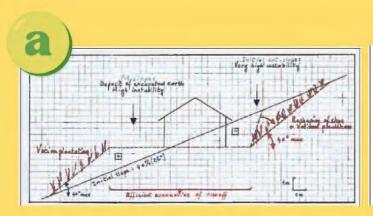


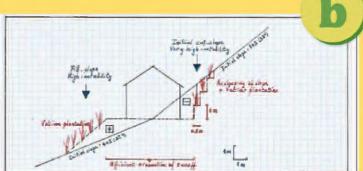
In most cases, terrasses are poorly sanitized. As a result, rainwater tends to stagnate on site, leading to increased seepage and a dangerous weighing down of the soil with increased interstitial pressures.

The protection of the two pilot terraces was based on the application of two principle schemes.

SKETCHES

Principle scheme (a) is recommended for terraces built on moderate slopes, and principle sch(b) is recommended for terraces built on very steep slopes.









View of protective plantings downstream of the terrace





View of protective plantings upstream of the terrace



PROBLEMS ENCOUNTERED AND LESSONS LEARNED

The choice of experimental site was also guided by the scientific assertion that areas affected by old or recent landslides are more susceptible to renewed movement in the event of new, heavy rainfall events. This is because the materials making up the soil have already been reworked, and are therefore destructured.



SOCIO-ENVIRONMENTAL ASPECTS

The development is on the site of the former landslide of 2001. Survivors whose homes were destroyed in the landslide have now left the area. Three new families have since settled on the site. As the resettlement process initiated by the city could not be completed within the project timeline, consultation and negotiation meetings were held with the beneficiaries to avoid any radical opposition to the project. A consensus was reached on adapting the layout of the hedge lines to the current state of occupation of the site, particularly in the lower, cultivated part. No negative environmental impact was noted during the construction phase.



TECHNICAL ASPECTS



When the project file was prepared, the surface area of the site was estimated at 1 hectare, which led to a planting requirement of around 70,000 cuttings. However, when the topographical survey was carried out prior to planting, the exact surface area was only 3,500 m², for a planting requirement of around 44,000 cuttings. The density is therefore much higher.



The execution of this contract did not allow the vetiver planting period to coincide with the rainy season. Planting began in January, in the middle of the dry season. This made access to water more difficult, especially as the area is not covered by the water network. The effect of the sun dried out several daughter plants, which had to be replaced from the nursery's existing stock.



It was not easy to recruit a contractor to supervise the deplanting and postplanting maintenance phases. Few firms were able to demonstrate sufficient competence and experience in this field. However, a consultancy firm specializing in environmental issues proved highly satisfactory.



No particular problems were identified during acceptance operations. The hedges' resistance to runoff generated by the heavy rains, which fell two months after planting, is an indicator of good planting execution - respecting slopes and contour lines - and good plant growth - anchoring roots well in the soil. However, the effectiveness of the protection system needs to be observed over time.



INSTITUTIONAL ASPECTS

The town of Limbe had no experience of projects requiring compensation or resettlement of people affected by the project. As the financing of compensation can quickly prove beyond the means of many urban communities, the Girin project has highlighted the need to anticipate the administrative process of declaring such projects to be in the public interest (Déclaration d'Utilité Publique). This anticipation is all the more important as the process from DUP to compensation decree can take between 2 and 3 years, or even longer.



MORE INFORMATIONS

| Carrying out of the work | Paradise Green (local enterprise) |
|--------------------------|-----------------------------------|
| Project management | Bureau d'études ENAG Conseils |
| Construction length | 14 months (2022- 2023) |
| Project Manager | Gescod |
| Final beneficiary | Inhabitants and City of Limbe |
| Installation cost | 19 500 000 F CFA (30 000 €) |





CONSTRUCTION OF REFUSE TRAPS IN THE UPSTREAM AREA OF THE WOMANGUE RIVER WATERSHED



INNOVATIVE ASPECT



The refuse trap is an innovation in Cameroon to overcome the inability of conventional mesh screens to retain the large masses and sizes of debris transported by watercourses during heavy rainfall.



STRUCTURE DESCRIPTION

The technology is being tested on the riverbeds of the streams that make up the upstream part of the Womangue river watershed. During heavy rains, the waters of these small affluents carry tree trunks and large boulders which increase the impact of flooding in the lower part of the watershed, by contributing to the blocking of water passages (particularly at bridges).

The purpose of log-jam traps is to stop tree trunks and boulders being swept down hillsides during intense rainfall events, whose accumulation in low-lying areas can aggravate or cause flooding. The principle of this technology is to allow small-diameter masses to pass through, while retaining larger ones.

Refuse traps are formed by an unit of triangular-shaped metal bars (IPN), spaced at 50 cm intervals, anchored in a concrete block and cast perpendicular to the riverbed. As part of the project, three refuse traps were installed on three upstream affluents of the Womangue river.

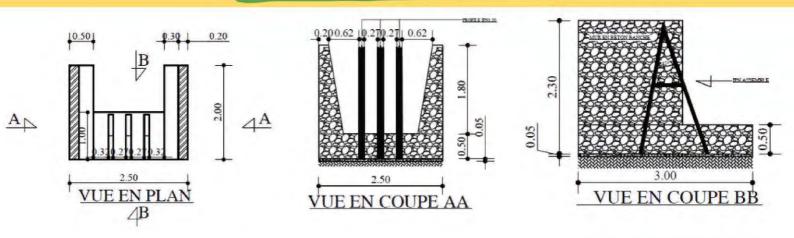
The logjam trap is composed by:

- A mass built perpendicular to the flow of water. Approximately 50 cm thick for the base of the structure, it is poured with simple water-repellent concrete whose compressive strength is reinforced by rubble stones between 5 and 10 cm in size and 5/15 gravel.

Metal connections consisting of 120 mm wide IPNs welded in a triangular shape and embedded in the concrete mass. The base of the joints is adjusted to the width of the river bed. The two bars considered as the sides of the triangle reinforce the stability of the unit (triangular), while the bar considered as the base of the triangle reinforces the strength of the trap. The number of units depends on the width of the watercourse. The interval between two joints is set at around 50 cm, based on testimonials from inhabitants. These joints are protected by an anti-corrosive coating.

Two side blocks that extend the base to the upper limits of the river banks. They are also made of simple, water-repellent concrete, reinforced with rubble stone.

SKETCHES







CONSTRUCTION STEPS





Formwork for casting the assembly anchoring mass on site 1



View of the completed 4-joint logjam trap on site 1



Assembling IPN in the workshop



Sealing of IPN assemblies in the massif on site 2



View of the completed 3assembly logjam trap at site 2 (after a rain)





Upstream and downstream views of the logjam trap at site 3 after a heavy rainfall



> PROBLEMS ENCOUNTERED AND LESSONS LEARNED

To be effective, refuse traps need to be positioned as far upstream as possible on all affluents of the main watercourse, to capture the maximum number of refuses as they flow downstream. The three main affluents have been treated. Technical and organizational feedback will enable the City of Limbe to decide whether or not to extend the project.



SOCIO-ENVIRONMENTAL ASPECTS



Ideally, the sites chosen for the creation of refuse traps are located on hillsides, on steep slopes, in order to intercept tree trunks and rocks torn from them as far upstream as possible. Unfortunately, this ideal is hampered by Limbe's rapid urban expansion, with residents occupying the slopes and immediate banks of the watercourses. This situation means that compromises have to be made when it comes to siting the traps.



The rapid buildup of logjams during rainstorms can sometimes result in the submergence of the nearest homes, leading to strong reservations about the social acceptance of such systems. This raises the question of the rapid, virtually real-time removal of refuses in such cases.



TECHNICAL ASPECTS



The project had initially planned to build five logiam traps in five tributaries of the Womangue, but only three structures were actually beld, due to various constraints:

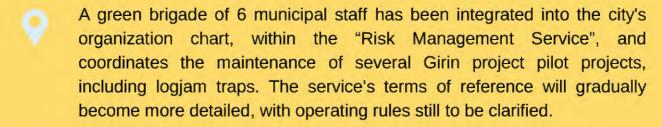
- at the request of inhabitants, one site was moved to an upstream area
 of the river that was wider and required more IPN assembly, resulting in
 the removal of one trap,
- · the company's difficulties in working on watercourses,
- the inexperience of the company involved poor workmanship, misunderstanding of the system.

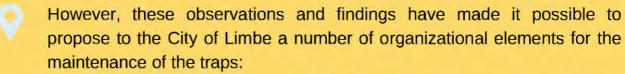


It was noted that one of the refuse traps had collapsed due to severe erosion of the riverbed during the rainy season. Although no faults were identified during the acceptance phase, the functionality of the system needs to be monitored over time, so that feedback can be used to improve the construction of future traps.



INSTITUTIONAL ASPECTS





 the formalization of service regulations specific to the green brigade, which will enable teams to work on-call in order to respond effectively to the need to quickly clear waste from the traps during the rains, to avoid "dam effects" that could lead to overflows;

- implementation of a refuse trap maintenance organization involving volunteer inhabitants and the green brigade;
- the mobilization of environmental protection associations for contracted management of structures, in conjunction with local community relays and under the supervision of the green brigade.

MORE INFORMATIONS

| Carrying out the construction | TK Consult (local enterprise) |
|-------------------------------|-------------------------------|
| Project management | ERA Cameroun |
| Construction length | 3 months (2023) |
| Project manager | Gescod |
| Project manager assistant | Sépia Conseils |
| Final beneficiary | Inhabitants and City of Limbe |
| Installation cost | 11 000 000 F CFA (16 750 €) |





CONSTRUCTION OF ECO-FRIENDLY TOILETS



INNOVATIVE ASPECTS



Numerous ecological toilet models have been tested in Cameroon. The models selected for the Girin project take account of environmental vulnerability factors. They propose viable technical solutions that protect human health through the quality of ground and surface water and the aquatic environment, while taking into account the risk of flooding. The technology selected is suitable for flooding.



STRUCTURE'S DESCRIPTION

The technology has being tested with a focus on differentiating between water-saturated flood-prone areas at the bottom of the watershed or at river level, and non-flood-prone areas in the upper parts of the watershed, generally on slopes with highly permeable volcanic soils. In this vulnerable context, conventional sewage treatment facilities are unsuitable. A diagnostic study revealed that populations in the project area mainly use traditional latrines (non-watertight pits) and barrel latrines (excreta are discharged into waterways when it rains). These types of latrines contribute to the pollution of surface and ground water, greatly increasing exposure to the risk of water-borne diseases, while at the same time weakening the life of aquatic species still present in waterways.

To meet the needs of the field, two models, each comprising a shower cubicle and a toilet cubicle, have been developed as part of the Girin project, thanks to the experience capitalized on by ERA-Cameroon.



Model 1: ventilated double dry pit toilets adapted to non-flood



Model 2: cubitainer toilets adapted to flood zones

These two toilet models are alternative solutions that take into account the environmental conditions in Limbe (floodable and non-floodable zones) and offer appropriate measures for preserving the environment and protecting human health, as well as the possibility of reusing the by-products (hygienized urine and faeces).

Their operating principle is based on maintaining a "dry" storage pit to avoid contamination of groundwater and surface water. This principle is adapted to suit different areas:



In flood-prone areas, maintaining dry conditions in the storage system requires :

- separate evacuation of faeces and urine/grey water;
- · the use of watertight cubitainers (which act as pits);
- raising the level of the storage system (cubitainers) to match the high-water level during periods of flooding.



In non-flood-prone areas, the separation of faeces and urine/grey water is sufficient to maintain a conventional concrete dry pit.

These models were tested with the construction of 42 ecological latrines in the various neighborhoods of the Girin project area, by training local craftsmen using a "learning by doing" approach. Working in close collaboration with neighborhood leaders, a dozen craftsmen from various trades (masons, plumbers, carpenters) were identified and trained in the specific features of the two models. This was followed by a "field school" phase involving the construction of the first 10 ecological toilets. The craftsmen with the best technical skills were then invited to contract with the Girin project for the remaining 32 toilets. The necessary materials and equipment were purchased directly by the project from local hardware stores.

Twelve craftsmen were trained, including 9 masons, 2 plumbers and 1 carpenter, who will then be able to distribute the two toilet models adapted to the Limbe context on request, or provide technical assistance to beneficiaries.

In the end, 12 Model 1 toilets and 30 Model 2 toilets were built in the various districts along the Womangue river.



Elements specific to model 1: non-flood zone

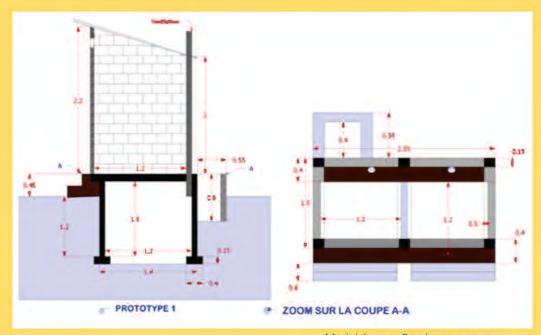
- A pit consisting of two compartments. The two compartments are used alternately, one in use and the other on standby. The cabin above the waiting compartment is used as a shower, with grey water draining to an external sump, and the other cabin as a WC. When the WC compartment is full after an estimated 8 to 12 months of use, the household will have to reverse the use of the two pits, which requires a technical intervention for which it can call on trained craftsmen. The use of the second compartment gives the faeces accumulated in the first compartment time to be hygienized, so that when the compartment in use is full, the user can reverse the slabs again, after having removed the contents of the hygienized compartment. The advantage of the two compartments lies in the extended use of the superstructure and the possibility of agricultural reclamation of the hygienized faeces.
- Two slabs, each located above one of the pit compartments. They are removable to allow access to the compartments for the emptying of hygienized faeces, and to reverse the use of the compartments. One compartment houses the toilet seat, while the other is equipped with a shower drain.
- A collection manhole to collect urine in a 20-liter container located at the outlet of the collection circuit.
- A sump to collect grey water for infiltration into the natural ground.
- A ventilation system consisting of 100 mm diameter PVC pipes fixed to the rear face of the superstructure, facilitating aeration of the two compartments and evacuation of humidity from the pits. An anti-mosquito screen at the pipe outlet prevents insects (flies, cockroaches, etc.) from entering the compartments.
- Cabin ventilation holes, located at the top of the superstructure facade, facilitate ventilation of the pit by the air circuit generated.
- Framework and roofing: the framework is built of wood (laths) and the roofing is made of corrugated sheet metal.



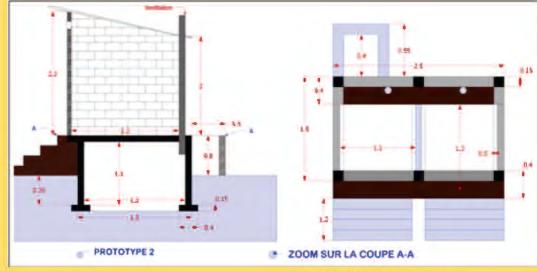
Elements specific to model 2: flood zone

This model comprises the same elements as Model 1, with the difference that the pits are made up of two 1,000-liter plastic cubitainers. The superstructure enclosing the cubitainers is raised above the natural terrain to remain out of the water during flood episodes, which may require the installation of several steps to access the cabins.

SKETCHES



Model 1: non-flood-prone area



Model 2 : flood-prone area



Diagnostic study of sanitation in the project area

This preliminary phase took the form of a survey of households in the project area. The method used combined field observation and interviews with heads of households. On the one hand, a visual and technical database was compiled. On the other hand, quantitative and qualitative information was collected on the basis of a questionnaire providing various items of information on each of the households surveyed, whose type of sanitation was deemed inadequate from the outset. The information collected concerned the size of the household, the availability of a space and its surface area for the construction of a toilet, the family's use of a field, the family's willingness to use urine as fertilizer, the family's willingness to transport building materials and participate in staining work, etc.

Model proposal for adapted toilets

The data collected enabled ERA Cameroun to work on the design and sizing of two toilet models, taking into account the context and environmental constraints of the project area. Then the proposed models were presented to the inhabitants of the project area during a meeting organized at the Limbe City Council hall, chaired by the City mayor. The aim of this presentation was to give local residents the opportunity to understand the relevance of the proposed technology, and to express their interest in adopting/using it.

Selection of beneficiary households

In view of the high demand and the limited number of latrines set by the project's budgetary constraints, it was necessary to select the households benefiting from the 42 toilets on the basis of objective criteria. To this end, priority was given to households whose traditional latrines were located too close to the watercourse. Other criteria derived from the questionnaires administered during the diagnostic phase were also taken into account.

Then, other criteria resulting from the exploitation of questionnaires administered in the diagnostic phase were taken into account. Four criteria prevailed in the selection: availability of a minimum area of 6m², possession of a field for small subsistence agriculture, availability to experiment with the use of urine as fertilizer, availability to transport materials and ensure water supply to the site. Field visits to all the households that applied enable the verification of the effectiveness of the information given during the survey. The accessibility of the site and the head of household's gender were also criteria that allowed to narrow the selection.

At the end of the selection, the result was made public in the various neighborhoods, and the recipients were invited to sign tripartite agreements for the construction of toilets (beneficiary/ City of Limbe/ Gescod).



STAGES OF CONSTRUCTION

Local craftsmen's training



Group picture at the end of the school phase

In order to ensure the full appropriation of the technology proposed by the local technicians, the identified craftsmen were trained in the specificities of the two toilet models during a theoretical training session.

This was followed by a "school" practical phase with the construction of the first 10 ecological toilets under the close technical supervision of ERA Cameroon engineers. Right after, the project contracted with "leader' artisans who demonstrated the best technical capabilities during the 'school' phase to build the remaining 32 toilets.



Group picture at the end of the training session

Synopsis of the stages of construction of the two models of the eco-friendly water closets toilets

| Implementation steps | Method | Sizes |
|---|--|---|
| Setting out of the structure | Traditional layout method : based on the squaring of the different angles | Model 1 : 3 x 1.6 x 1.2 m3 Model 2 : 2.5 x 1.6 x 0.4 m3 |
| Mansonry of the pit for type 1 and installations of the tank for type 2 | Squaring of the pit Levelling of the elevation Ensuring the vertically of the poles | Pit 1: 2.85 x 1.5 x 1.5 m3 Pit 2: 2.4 x 1.4 x 1.5 m3 Footings: 0.4 x 0.4 x 0.15 m3 Poles: 1.5 x 0.15 x 0.15 m3 |
| Chaining of the pit | Front projection of the views Reservation for slab | Chaining 1 : 2.85 x 1.5 x 0.15 m3 (two compartments) |
| Wall elevations | Levelling the walls Crossing of the hollow blocks on the corners of the walls | Front view : heigth 2.20 m Rear view : heigth 2.0 m |
| Construction of stairs | Stabilization with volcanic arsh | Type 1:1 à 2 steps Type 2:5 à 7 steps (Depending on the known water heigth) |
| Plumbing | Separate collection system from the defecation seat (urine and wastewater) The two collection circuits flow into the manhole (urine is collected in a small plastic tank and the wastewater is discharged onto a filter bed at the bottom of the manhole) | |
| Preparing the collection manhole | Place the filter bed at the bottom of the manhole Place the urine collection container | 0.45 x 0.4 m2 (Internal dimensions) |
| Fitting the defecation seat | Upgraded Turkish seat | 58.5 x 43 x 9 cm3 |



TEACHING BENEFICIARIES HOW TO USE TOILETS CORRECTLY.

ERA Cameroon provided the beneficiaries of the toilets with a practical guide during an awareness session on toilet use and maintenance before they were given the keys, in the presence of officials from the City of Limbe.

| USAGE | | |
|-------|---|--|
| 1 | 1. Defecation hole: clean the hole with a small amount of water and a broom | |
| 2 | 2. Urine collection siphon: avoid clogging the siphon strainers | |
| 3 | 3. Cabin n°1 Cleaning Water Collection Siphon | |
| 4 | 4. Collection of bath water in cabin compartment n°2 | |
| 5 | 5. Collection of waste water from cabins n°1 and n°2 6. Urine collection: urine can be stored and used as fertilizer in agriculture after 45 days of fermentation (sanitization process) | |
| | | |

NB: Always keep the door closed to avoid the presence of flies in the cabins Do not pour much water into the defecation hole to maintain dry conditions

VIDANGE



Interior view of pit n°1 and



- Pour ash or dust into the pit when Cab n°1 is full.
- Break the light layer of mortar over the slab of cabins n°1 and n°2
- Carry the toilet seat from Booth n°1 and secure it in Booth n°2 while connecting the urine collection hose
- Redo a light layer of mortar above the slab of the cabins and resume use
- Wait for feces to decompose in Booth n°1 pit; decomposition time is approximately 8 months
- After 8 months, remove the dalette from cabin n°1 and extract the remaining waste after decomposition.
 This waste can be used as compost in agriculture
- · Repeat the process whenever the lavatory is full.

NB: After eight (08) months of decomposition the feces are transformed into compost easily manipulated without risk of contamination and without taboos. It is a good fertilizer in agriculture



ILLUSTRATION OF CONSTRUCTION'S STEPS

Model 1: view of the pit under construction

Model 2: Pit chaining on process

Model 1: view of the pit under construction











Models 1 and 2: installation of the urine separator seat and installation of the cabin cleaning wastewater collection system



Model 2: Raised toilet with

six stair steps





Model 2 toilet completed



Models 1 and 2: view of urine and wastewater collection



Models 1 and 2: rear view of latrine and ventilation pipes



PROBLEMS ENCOUNTERED AND LESSONS LEARNED

Prior to this project, ERA-Cameroon carried out a diagnostic study to assess the state of basic sanitation in the project area, combining social, technical and environmental indicators. This diagnosis guided the proposals for ecological toilet models presented above, based on local constraints.



SOCIO-ENVIRONMENTAL ASPECTS



There are around 3,500 households in the Womangue catchment area, yet only 42 ecological toilets have been built for 42 households. Initial feedback suggests that the proposed models have been well received, and the Limbe City Council has received numerous requests for toilets from residents of the project area and beyond.



The specificities linked to the use and maintenance/operation of the toilets (inversion of compartments, hygienization) require long-term support for the beneficiary households. This task should be entrusted to Limbé's sanitation department. Similarly, to facilitate the appropriation of the toilets by the households, the heads of household must be involved from the construction phase onwards, to improve their understanding of how the toilet works.



The plan was for households to participate in the work by mobilizing available manpower. In practice, this proved difficult to implement for a number of reasons:

- i) lack of available manpower, one-woman households, presence of young children;
- ii) scheduling of work periods incompatible with the diaries of a head of household, particularly in the rainy season.



TECHNICAL ASPECTS



After adjusting the quantities of materials required to build the two toilet models, it turns out that their construction costs are similar (close to 1,250,000 Fcfa per unit, or 1,900 euros).



The high cost of the technical models proposed raises the question of their reproducibility, offering a technology optimized for man and his environment, but beyond the financial reach of the targets that need it most (excluding subsidies).



The "Turkish" toilet seat has been adapted to ensure separation of urine and faeces. However, a number of reports from the field point to difficulties in use, particularly for people who prefer an "English-style" seat. This solution can be envisaged, but it imposes the constraint of regular cleaning with water, which can compromise the operation of a dry pit.

MORE INFORMATIONS

| Carrying out of the work | Craftsmen trained by ERA-Cameroun |
|-----------------------------------|--|
| Project management | ERA Cameroun, project partner assisted by the technical services of the Limbe City Council |
| Construction length | 04 month (2023) |
| Project manager | Gescod |
| Final benificiary | Inhabitants from the project area |
| Installation cost of a one toilet | 1 250 000 F CFA (1 900 €) |





CLEANING AND DEEPENING OF THE MINOR BED OF THE DOWNSTREAM SECTION OF THE WOMANGUE RIVER



INNOVATIVE ASPECT



This action is not particularly innovative - either in terms of context or technique - as the reprofiling and recalibration of a watercourse is standard maintenance work that is often carried out. The work carried out on the Womangué involved both municipal staff, whose skills had to be reinforced, and rolling stock owned by the city. However, a particular feature of this work is that it gave rise to interesting and constructive technical consultations between international experts mobilized by the project as project management assistants, the project management and the engineers from the Limbe City Council. Discussions focused on :



the complex case of the hydraulic behaviour of the Womangué during flood periods, combined with tidal variations which affect the confluence with the Djenguele river;



the challenge of finding a solution to reduce the risk of flooding based on an alternative approach to all-concrete development, giving priority to taking into account and dealing with natural and social constraints.

This situation is typical of the downstream part of the Womangue watershed. The solution of regular, methodical cleaning of the river is considered sufficient and effective to maintain optimal hydraulic operating conditions for the river during flood periods, while helping to preserve the aquatic biotope.



STRUCTURE DESCRIPTION

The method is being tested on 1,122 ml of the Womangue river, from the confluence of the Womangue and Djenguélé rivers to 150 ml upstream of Bridge n°4 - Manaman Bridge. The reprofiling and recalibration work aims to facilitate the flow of rainwater and thus limit the impact of flooding, by

- · removing obstructions and other obstacles in the minor bed;
- · increasing hydraulic flow by deepening the minor bed.





WORK ORGANIZATION AND EXECUTION



MATERIAL RESOURCES DEPLOYED



One excavator



3 dumper truck



One vehicle



Small tools (shovels, pick axes, wheel barrow...)



LABOR DEPLOYED

| FUNCTION | ROLE DURING CONSTRUCTIONS |
|---|---------------------------|
| Technical Services Manager | Works manager |
| Urban Development Manager | Monitoring engineer |
| Head of risk management and fire-fighting department | Environmental monitoring |
| Risk Management Office Manager | Site manager |
| An excavator operator and an assistant | Machine operator |
| Three truck drivers and three assistants | Truck driver |
| A dozen labourers recruited from neighbourhoods in the project area | Maneuver |

CONSTRUCTION SITES ORGANIZATION



Preliminary organization

Visit to the landfill site: determine the route to be taken by the trucks to unload the landfill products.



Amobilization of Limbé city staff: distribution of roles.

Reconnaissance of the machinery and vehicles mobilized by the Limbe City Council and technical assessment.

Recruitment of laborers and guards for the excavator in the neighborhoods, at the suggestion of the neighborhood chiefs.

riangle Development of tools for managing logistics and personnel during the works :

- · incident report form
- breakdown declaration form
- worksite attendance sheet
- weekly pay slip
- rolling stock fuel consumption monitoring sheet
- preparation of a plan for drafting site meeting minutes
- adoption of weekly meeting frequency

2 Setting-up

Getting the excavator to the site.

A Milestones set by topographers.

A Clearing the banks of the watercourse.

3 Execution

Briefing of teams on the execution file by the project manager

A Mechanical and manual cleaning operations.

 $\stackrel{\textstyle extstyle 2}{\scriptstyle extstyle 2}$ Consolidation of stream walls and embankments in places with earthbags.



MAIN RESULTS OBTAINED

The cleaning and deepening work was carried out in successive stages, from downstream (where the Womangué and Djenguélé rivers meet) to upstream.



Reprofiling and deepening over 1122 ml from the confluence of the Womangué and Djenguélé rivers to 150 ml after bridge no. 4 (man-na-man bridge).



Transportation of 3,000 tonnes of cuttings by trucks and storage on the site of the landfill identified by the city services.



Clean-up of easements and house surroundings clogged with excavated material.



Creation of 1,122 linear meters of riverbank lanes.



Erection of earthbag banks to stabilize riverbanks at critical points (bridges, sharp bends).



Manual cleaning under the 4 bridges along the treated route.



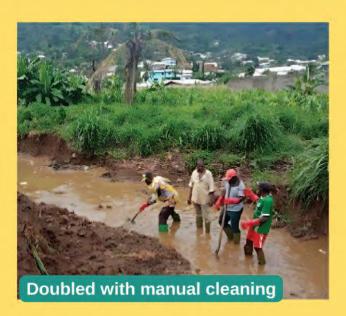
Capacity-building for the city's technical services in logistics management and the technical management of drainage works.

PICTURES















View of impacted earthbags after heavy rains, without being washed away by the flood.



> PROBLEMS ENCOUNTERED AND LESSONS LEARNED

The recalibration and deepening of the Womangue was preceded by technical guidelines recommending a depth of excavation of 50 cm at the base of the minor bed, and specific treatment of the foot of the bank. Despite the mobilization of a topographical brigade, this method came up against the performance limits of the logistics available to accomplish the task. The "régie" approach adopted for this work necessitated the use of an excavator, the manoeuvrability of which staff were unable to fully master. This meant that the work could not be carried out under optimum conditions.



SOCIO-ENVIRONMENTAL ASPECTS



Completion of the work coincided with the start of the rainy season. The drainage work carried out enabled water to flow normally during the first rains, which were moderate in intensity, giving rise to a feeling of satisfaction and relief among the population. Unfortunately, the rains increased in intensity shortly afterwards, turning into an exceptional event not seen for the last five years (more than 120 mm of rainfall in 1 hour, with rainfall sequences lasting more than 4 hours). These heavy rains, combined with the tidal phenomenon, caused major flooding in low-lying areas, demonstrating their extreme vulnerability. It would appear necessary to undertake large-scale stormwater drainage works on the scale of the two interconnected watersheds of the Womangué and Djenguélé rivers, with the aim of optimally reducing this vulnerability in a context of climate change.



It is advisable to think in terms of global technical solutions, combined with urban planning regulations that give priority to :

- the allocation of specific zones dedicated, for example, to the storage of rainwater (buffer basin), pending its natural discharge to the outlet,
- prohibiting construction in high-risk areas, etc.



TECHNICAL ASPECTS



The equipment available was not suited to the approach used, which was based on compliance with the recommendations of the topographical studies and the instruction to treat only the foot of the bank. The excavator was not equipped with a level to measure the bottom of the excavation, nor with a bucket suitable for treating the foot of the bank without destabilizing the entire bank.



The option implemented by the technical services of the Limbe City Council systematically recalibrate the riverbed has altered the configuration of the banks. The unfortunate coincidence of the work with the rainy season meant that the natural vegetation did not have time to recolonize the new banks, which would undoubtedly have given them greater stability and resistance to strong currents.



The accentuated erosion of the hillsides calls into question the relevance of river cleaning alone. Filling time is very short in this very gently sloping area.



Stabilization of the banks by targeting critical points and creating earthbag embankments was hampered by the high speed of the currents - and consequent erosion - and the stagnation of water after the floods. In the end, the banks were damaged by the exceptional rainfall, but were not destroyed.



The work was carried out in two phases. The first phase took place at the start of the rainy season, when the entire program of works was carried out (recalibration, deepening, manual cleaning under the bridges) and part of the banks, particularly in line with the bridges and in the bends, were stabilized using rustic materials (earth bags). Following an exceptional rainfall event shortly after completion of the work, flooding and strong currents caused erosion of the banks, and sediment and other debris once again filled in the riverbed and blocked the passage of water at certain bridges. This unexpected situation obliged the project to schedule a second phase of cleaning to restore the hydraulic capacity of the bridges and remove the sediment accumulated in the riverbed.



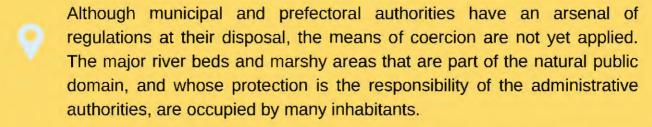
The project's Technical Monitoring Committee has proposed that a specific study be carried out, of the "Limbé rainwater drainage master plan" type, integrating the Djenguélé river watershed. One of the issues at stake in this study would be the requalification of a low-lying area - marshy in any case - as a natural space enabling:

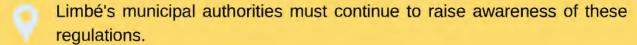
- temporary storage of rainwater before discharge into the ocean
- achieve one of the Girin project's objectives, which is to preserve the aquatic ecosystem in the project area.

The release of these areas will necessarily be accompanied by a plan for the evacuation / resettlement of the occupants of this zone.



INSTITUTIONAL ASPECT





MORE INFORMATIONS

| Carrying out the construction | Technical Service of the Limbe City Council |
|-------------------------------|---|
| Project Management | ERA Cameroun |
| Construction length | 3 months (2023) |
| Project Manager | Gescod |
| Final beneficiary | Inhabitants and City of Limbe |
| Installation cost | 16 400 000 F CFA, equals to 25 000 € |





TRAINING AND EQUIPPING THE WATERCOURSE MAINTENANCE AND LANDSLIDE PREVENTION "GREEN BRIGADE



INNOVATIVE ASPECT



This organizational innovation is based on the structuring of a department that previously did not exist in the organizational chart of the City of Limbé. It responds to the contextual need for a team dedicated to monitoring watercourses and maintaining the pilot schemes built as part of the project, in order to ensure their sustainability.



SERVICE'S DESCRIPTION

The Limbe City Council's green brigade was created in October 2022 by municipal decision. Recommended as part of the project proposals, its operationalization will contribute to better management of the city's waterways (reporting of landfills, active monitoring of the proper flow of water, etc.), as well as ensuring the proper functioning and durability of the structural improvements made. The Green Brigade is part of the Risk Management and Fire Fighting Service. Therefore, it is an important tool in the City of Limbe's organizational structure for strengthening its natural hazard prevention capabilities.

The brigade is staffed by a permanent brigade leader and temporary personnel who can be mobilized from the workforce constituted each year by the City to carry out various manual tasks. The project has supported the operationalization of this service by helping to define its missions, provide it with equipment, and initiate training for its members.



ITS DUTIES



Monitoring and maintenance of watercourses

- Inspection of watercourses after rainfall / flooding (landfills and various obstacles)
- Removal of garbage from watercourses and other obstructions
- Pruning and removal of vegetation along watercourses



Supervision and maintenance of project facilities

- Cleaning/purging of refuse traps and waste disposal
- · Monitoring the operation of drainage trenches
- Monitoring and maintenance of vetiver hedges



SERVICE'S STRUCTURATION



BRIGADE'S EQUIPMENT



One tricycle

· Waste and logjams' transportation



One chainsaw

 Cutting tree trunks trapped by refuse traps to facilitate removal



PPE - boots and leggings

 Protection of crews when working in the river, especially during floods



Motorcycle

Inspection of facilities and river conditions



Small equipment - shovel, pitchforks, gloves, axes, machete

Miscellaneous work

Logjam traps

Draining trenches' system monitoring

- Regular inspection of structures once every three months in the dry season.
- Systematic inspection during and after heavy rainfall.
- Purge traps in the event of refuses.
- Regular inspection of the structure - once every three months in the dry season.
- Visit weekly during the rainy season.
- Make a systematic visit in the event of a major rainfall event.

During inspections, the condition of the structure is checked for any anomalies visible on the surface, i.e.:

- Above buried trenches: presence of erosion, dangerous human activity, etc.
- At manholes: make sure there are no foreign bodies or suspicious deposits.
- · During rainfall, check that drained water flows into the main drain.
- · Look for any cracks in the walls or bottom of the main drain.
- · Check that there are no obstructions downstream of the main drain.



PROBLEMS ENCOUNTERED AND LESSONS LEARNED

The sustainability of the crisis and emergency management system will depend to a large extent on changes in the behavior of local actors and populations, and on a form of collaboration between the authorities and the population in terms of prevention. The collaboration also aims to build a new model of inclusive governance that takes the participation of the population seriously.



SOCIO-ENVIRONMENTAL ASPECTS



The cleaning of refuse traps is an important point of vigilance. Residents are well aware of the risk of water overflow in the event of obstruction. Given the still inadequate deployment of the green brigade, some local residents have spontaneously taken on the task of cleaning out logiam traps, but in return are asking the town to provide them with the appropriate equipment (wheelbarrow, pitchfork, machete).

Other, more radical, local residents have called for the refuse traps to be dismantled. It is therefore essential that a dialogue between the City and the populations concerned leads to a form of collaboration favorable to both parties.



TECHNICAL ASPECTS



The temporary staff recruited by the Limbe City Council are at the disposal of the head of the sanitation service, who assigns them on a daily basis to various manual tasks scheduled throughout the city. Those made available to the green brigade are not easily mobilized, often unreachable by telephone, unavailable for personal reasons or already assigned to a task by the head of the hygiene service at the time they are called upon. This type of organization calls for better coordination between services, and greater anticipation. For the same reasons, it was not possible to carry out the site visits scheduled as part of the staff training program, due to the unavailability of temporary staff.



The green brigade training planned in the project was not fully carried out, as the expert initially identified was no longer available. Training in watercourse maintenance was not carried out. The project team was nonetheless able to mobilize the city's engineers and those of the project management team to organize briefings for the head of the green brigade on how to maintain the drainage trenches and refuse traps. For the vetiver plantations, reference was made to the maintenance document drawn up by the service provider as part of its contractual obligations.



During heavy rains, the green brigade was unable to organize the cleaning of the logiam traps, which provoked the anger of inhabitants following the overflow of water at one of the sites. Further support is needed for the Green Brigade to define an effective and realistic operating protocol, taking into account the need to involve the local population in the maintenance of these structures. This is urgently needed to avoid further incidents during the next rainy season.



INSTITUTIONAL ASPECTS

The political choice to integrate staff under precarious contract into the Green Brigade is guided by the fact that the missions assigned to the brigade do not require the mobilization of permanent staff to be salaried. However, this does not allow the brigade manager to secure the loyalty of a team. As a result, this system requires the organization of short training sessions each year, whenever a new response team is formed. This choice needs to be reconsidered to guarantee the efficiency of the service provided by the green brigade.







ELABORATION OF A FLOOD AND LANDSLIDE RISK PREVENTION PLAN



INNOVATIVE ASPECT



The Flood and Landslide Risk Prevention Plan is an urban planning document that is not included in the register of officially prescribed planning documents for use by decentralized local authorities in Cameroon. Therefore, its development in the local context is an institutional innovation. Indeed, it is the result of the initiative of a municipality and seeks to respond to a real and urgent need to have an urban planning and natural risk prevention tool for the City of Limbe.



DESCRIPTION OF THE IMPLEMENTATION APPROACH

The flood and landslide risk prevention plan measures and prevents the risks incurred in urban areas in the event of flooding or landslides. Risk is the result of a hazard (natural phenomenon) meeting a stake (people and property). It enables us to rationalize the urbanization of areas prone to flooding or landslides, as well as to ensure the safety of people and property in such areas.

This pilot document has two objectives:

- einforce Limbe's capacity in terms of urban planning and management of areas at risk from natural hazards;
- Propose a strategy for reinforcing regulatory tools that are enforceable against third parties in terms of urban planning control.

The approach to developing a flood and landslide risk prevention plan is based on the same requirements as those observed for the development of recognized planning tools in Cameroon. Broadly speaking, it involves carrying out a study according to a methodology that includes documentary analysis, the collection of additional data and improvements to the existing database, as well as the preparation of deliverables. These phases are described below.



DRAWING UP ROUGH ZONING MAPS BY CROSSING HAZARDS/ISSUES



Study scoping meeting

The scoping meeting marks the official start of the mobilization of the study teams. It enables them to ensure that they fully understand the project owner's expectations, and to carry out a final validation of the methodology and timetable for the study. This stage marks the beginning of the organization of the working synergy between the team in charge of the study and the managers of the Limbe City Council services involved and/or concerned by the study.



Organization of the study kick-off er workshop

The study kick-off meeting brings together all the stakeholders identified in the methodology. Its purpose is to take stock of available data, identify relevant information on current structuring projects and gather suggestions from stakeholders. This important stage also enables the experts to explain how the study will be conducted and the specific contributions expected from the various stakeholders. This initial contact then ensures that relations remain fluid throughout the rest of the process.

In the case of this study, in addition to the stakeholders from the City of Limbe, the following players were invited to the kick-off meeting and/or consulted at various stages of the process:

- Fako Prefecture
- Ministry of the Environment, Nature Protection and Sustainable Development
- Ministry of Housing and Urban Development
- · Heads of the 10 neighborhoods in the project area
- Women's representatives from project-area neighborhoods
- · Youth representatives from project-area neighborhoods

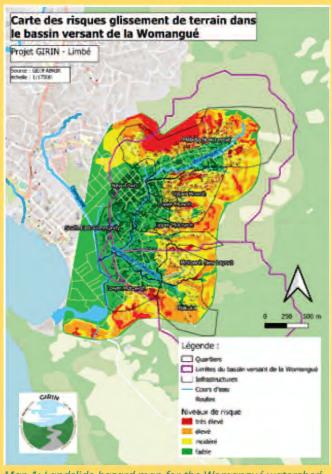


Compilation and analysis of available datas

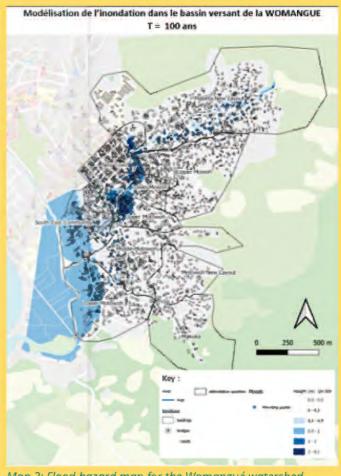
The Limbe City Council initiated the elaboration of a Master Plan in 2009, which was not completed. At the time the Girin project was launched, the city had no urban planning document. The studies carried out as part of the Girin project led to the drafting of a master plan to combat flooding and landslides. During the project, a georeferenced natural risk management database was created through the development of a Geographic Information System (GIS) for mapping flood and landslide risks. The GIS also produced summary hydraulic models.

These reference documents, along with some fifteen other general and technical documents mainly compiled as part of the project, were used by the team in charge of the study, thus building up a substantial documentary base that is essential for structuring the technical stages of the flood and movement risk prevention plan project. This stage will enable the team to determine what additional data and information is required as part of the methodological approach to be developed during fieldwork.

Watershed-scale flood and landslide hazard maps



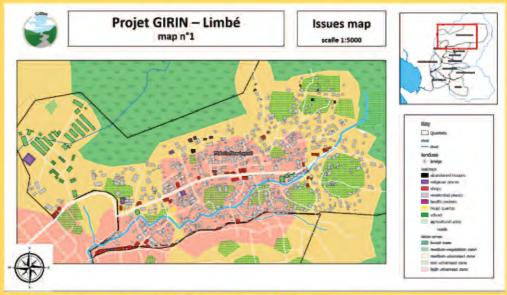
Map 1: Landslide hazard map for the Womangué watershed.



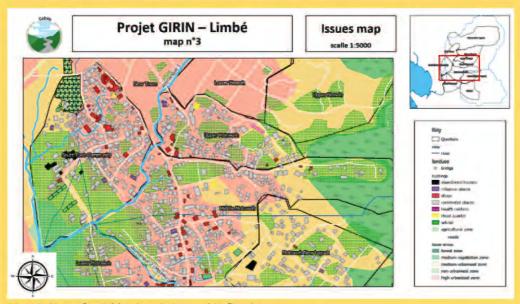
Map 2: Flood hazard map for the Womangué watershed.

Zooms in on the issues maps for a few neighbourhoods in the project area

The issues at stake concern the economic assets and social facilities associated with the buildings and surface areas. The maps also distinguish between non-urbanized areas (agricultural, natural), densely urbanized areas and moderately urbanized areas.



Map 3: Map of issues in the Mabéta district, located in landslide-prane areas



Map 4: Map of neighborhoods located in flood-prone areas

These reference documents, along with some fifteen other general and technical documents mainly compiled as part of the project, were used by the team in charge of the study, thus building up a substantial documentary data base that is essential for structuring the technical stages of the flood and movement risk prevention plan project. This stage enables the team to determine what additional data and information is required as part of the methodological approach to be developed during fieldwork.

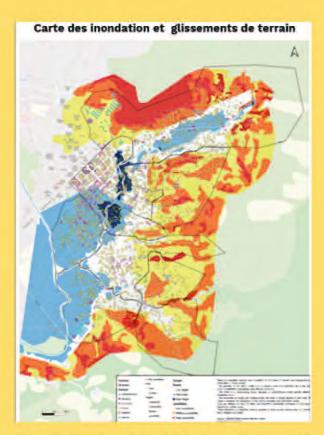


Drawing up a first version of the "hazards" and "issues" maps (rough zoning)

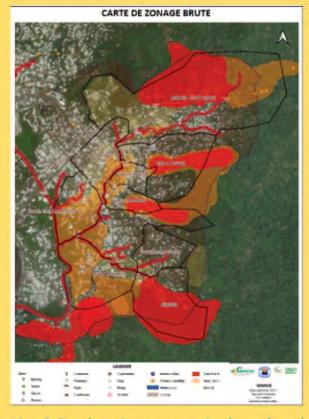
These and some fifteen other reference documents were used by the study team. This was followed by the creation of a substantial document base, essential for structuring the technical stages of the flood and landslide risk prevention plan project.

This stage established the initial knowledge of the issues involved in the study. Thanks to the studies already carried out as part of the creation of the risk management GIS, the experts were able to enhance the flood and landslide hazard maps, as well as the map of issues identified in the project area.

The raw zoning established will form the basis for the consultations to be organized during phase 2 with stakeholders, in particular the population of the project area.



Map 5: Flood and landslide hazard map with watershed-wide issues



Map 6: Rough zoning map crossing hazards and issues at the watershed scale

Gross zoning notice

- The red zone represents the maximum risk zone, subject to major restrictions on nonconstruction and/or demolition of existing buildings.
- The orange zone represents the intermediate risk zone and is subject to medium restrictions on non-construction.
- The **yellow zone** represents the minimum risk zone and is subject to routine restrictions (remediation, regulated construction, etc.).



Design of the methodological data collection guide and database architecture

The aim here was to design the appropriate tools for collecting the data that had been missing during phase 1, and which were deemed important for the purposes of the study. Two sets of data were therefore collected by the experts, in addition to those made available by the project owner:

- Updated data on the geolocation and impact of recent landslides and floods (2022-2023)
- Building regulations in the Womangue basin

Two tools have been developed for this purpose:

- · A flood and landslide survey form combined with a geolocation procedure
- · A grid for calculating the constructibility index applicable to zoning.

2

Collection of missing data and participatory survey

The teams in charge of the study, accompanied by agents from the Limbe City Council, criss-crossed the neighbourhoods in the project area to collect data using a participatory approach, in particular the organization of focus groups mobilizing participants representative of the various sociological components of the neighbourhoods in the project area. Survey questionnaires were also administered during the tours, and the necessary GPS coordinates recorded.



Surveying GPS coordinates using a smartphone in the Mabéta district

This stage is essentially marked by local consultations, which enable us to compare the rough zoning maps with inhabitants perceptions of the risks (flooding and landslides) and their impacts.



Consultation session with neighbourhood leaders in the presence of city representatives

During the consultative surveys, discussions with participants in groups will enable precise readjustments to be made to the zonings produced on the basis of the observations made. The recommendations and proposals arising from this activity have led to a precise, consensual description of each neighborhood and its exposure to risk.



Séance de concertation avec des jeunes du quartier Middle Motowoh

At the end of these consultations, the design team proceeds with the following steps:

- consolidation of the database developed;
- refinement of risk zone maps (synthesis of participatory survey results with raw risk maps) and digital data;
- integration of the final risk maps into the Limbé GIS.



DRAWING UP REGULATIONS APPLICABLE TO LAND USE AND RECOMMENDATIONS FOR REDUCING VULNERABILITY TO HAZARDS

Public consultation

As residents' proposals for appropriate measures to reduce the vulnerability of their neighborhoods to flooding and landslides had been collected during the consultative surveys, the team of experts focused discussions during this stage on gathering proposals from officials of the Limbe City Council and officials of certain deconcentrated State services, notably the Divisional Delegation of Housing and Urban Development.

Following these consultations, and by cross-referencing these proposals with the established regulatory possibilities, the study team proceeds to format the regulatory notice on land use and formulates practical recommendations for reducing vulnerability (e.g. prohibition of deforestation, building on terraces, building on waterways, etc.) applicable within the framework of the flood and movement risk prevention plan according to the different zones that can be

affected.

Discussions with the

Discussions with the Departmental Delegation of Housing and Urban Development.



Discussion with the Go Secretary of Limbé City



Workshop to present study results and consult with all stakeholders

The workshop to present the results of the consultations enabled the zoning maps for each district and the regulatory notice to be submitted to the stakeholders for final validation. This workshop was organized in the form of sub-groups for each district, followed by a plenary session.

The presentations are followed by discussions between the experts, neighborhood representatives and city officials. A summary is then drawn up at the end of the debates and submitted to the participants for approval. The final flood and landslide risk prevention plan document is then drawn up on the basis of this summary.



Work in sub-groups



Presentation of the sub-group work



Preparation of the recommendations and sustainability plan

The recommendations leaflet is based on the regulatory zoning, and sets out the rules to be observed to achieve a sustainable reduction in vulnerability to hazards. The various zones identified are coded by a combination of letters and numbers, providing the following information:

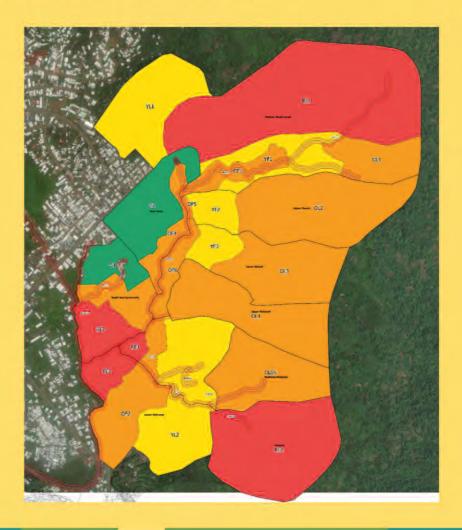
- · Risk intensity:
 - · Red for high-risk
 - Orange for medium intensity
 - Yellow for moderate intensity
 - Green for absence of risk up to date
- · Nature of the risk

L: Landslide

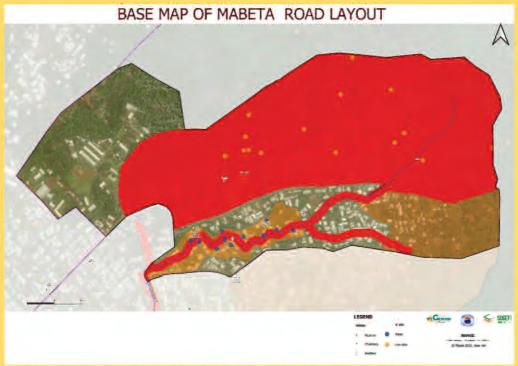
F: Flood

 The position of risk zones in relation to each other, with reference to an origin and then to a clockwise numbering system. In our case, the Middle Motowoh district acts as the "point of origin".

Regulatory zoning in the Womangué watershed



Example of regulatory zoning for each neighborhood



Medium-intensity flood risk along the first confluence: red zone - minor bed & orange zone - major bed

This fairly large district is located at the northern end of the Womangué watershed. It is a peripheral district, because while the urbanization is moderately dense in its central and southern parts, the eastern and northeastern parts are practically devoid of any urbanization whatsoever. This is where the Womangué river rises. The district is also characterized by its contrasting topography, with a series of steeply-sloping hills framing the district to the east and north.

Overall, the risk of flooding in this area is of medium intensity. It is mainly concentrated downstream of the first confluence (red zone along the minor bed and orange zone for the major bed).



PROBLEMS ENCOUNTERED AND LESSONS LEARNED

Although the flood and movement risk prevention plan is an unfamiliar document for the management of high-risk areas in Cameroon's regulatory context, it was quickly perceived as a pertinent response to the City of Limbé's need to equip its urban planning departments, and especially its newly-created risk management and firefighting department, with a tool that could guide the City's action in high-risk areas.



SOCIO-ENVIRONMENTAL ASPECTS

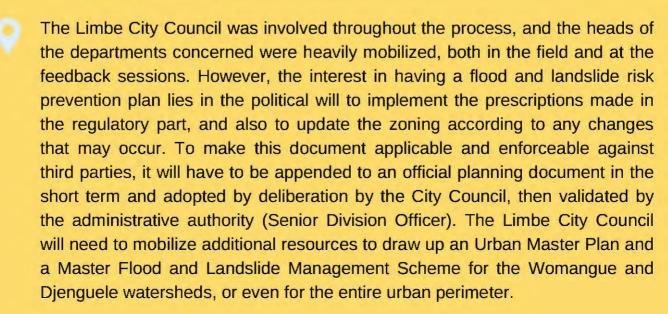


The flood and movement risk prevention process, as proposed to the local population, was quickly understood, and the interactive data collection tools used helped to encourage their participation.

People living in areas at risk are genuinely keen to contribute to the search for sustainable solutions to reduce the impact of hazards on their quality of life. However, their readiness to get involved is often accompanied by a certain impatience to see high-impact solutions implemented to stem the problem of flooding.



INSTITUTIONAL ASPECTS



MORE INFORMATIONS

| Carrying out the construction | SOGEFI Cameroun |
|----------------------------------|--|
| Construction length | 08 month (2023) |
| Project manager | Gescod |
| Assistant of the project manager | Technical experts of the Grand-Est Region (France) |
| Final beneficiary | City of Limbe |
| Installation cost | 9 840 000 F CFA (15 000 €) |



Interview with residents of the South East Community changed neighbourhood by the study's head of mision





ORGANIZING AND IMPLEMENTING AN EARLY WARNING AND CRISIS MANAGEMENT SYSTEM INVOLVING LOCAL AUTHORITIES AND RESIDENTS



INNOVATIVE ASPECT



The Girin project aims to set up a participatory early warning system in Limbe, involving the authorities and the population, together with a local action plan for participatory crisis management in the event of an exceptional rainfall event. This approach, unprecedented in the Cameroonian context, represents an institutional innovation, since it is being implemented by a decentralized local authority.



DESCRIPTION OF THE APPROACH

The first part of the approach involves the organization of a participatory early warning system based on

- a flood forecasting protocol based on hydrological modeling supported by rainfall monitoring;
- a water level monitoring network involving the local population, particularly volunteers.

This organization is managed and coordinated by the Risk management and firefighting service, a new service created within the Limbe City Council.

The second part of the approach was to set up a multi-actor crisis management framework, bringing together the authorities, the local population and the civil protection actors, with the City of Limbé as the driving force, capable of mobilizing its material and human resources for the first response.



SETTING UP A PARTICIPATORY ALARM SYSTEM

The implementation of this component was based on the prior installation of a network of high-tech measuring equipment set up to perform instant modeling and signal the risk of the river overflowing at predefined alert thresholds.

The technical and organizational constraints associated with the operationalization of this model have prevented its development. Only the river observation-based warning system has begun to be implemented as part of the project.

Nevertheless, a network of measuring instruments equipped with automatic transmission technology has been installed in the watershed by a competent expert mobilized by the project. The technology of the equipment installed thus leaves scope for the future development of a predictive model based on automatic, computerized data processing. For this, the availability of competent expertise in the field and the City's ability to organize and formalize specific service regulations for staff dedicated to hydraulic monitoring within the risk management service are prerequisites to be organized.

In the meantime, risk management service staff have been trained in the operation of the measuring stations installed, and are now responsible for collecting and storing the rainfall (intensity, duration, frequency) and hydrometric (water level) data required for hydrological studies and the design of wastewater treatment facilities.

The training provided focused on the following four key points:

- Equipment knowledge (components, operating principles, etc.)
- · Equipment upkeep and maintenance
- The data collection/retrieval procedure
 - rain gauges
 - pressure sensors
- Reading water level gauges

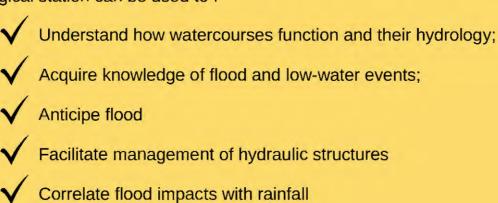
Installation of measurement equipment

A network of measuring instruments consisting of two rain gauge stations and four hydrological stations has been set up in the Womangué watershed. Rainfall measurements are provided by two rain gauges, and hydrological measurements by four limnimeters, each coupled to a pressure sensor. The rain gauges are installed upstream of the two main branches of the Womangué river, while the hydrological stations are located at four bridges, providing the best possible spatial coverage of the river network and enabling data to be collected at key points.

Installed equipment is sold with archiving and data management software:

- Automatic rain gauges are mounted on a metal mast, with the rain gauge at
 the top connected by cable to the data acquisition unit, which is protected by a
 box that records and stores the data. The data is transferred via the data
 acquisition unit's modem. The device is powered by an autonomous system
 consisting of a solar panel and a battery that takes over in the event of a solar
 panel malfunction.
- The pressure sensors consist of a submerged module connected by a cable of variable length (between 15 and 20 meters) to a central unit located on the bank. They automatically measure water level data. The device is powered by locally available, replaceable batteries.
- Limnimetric scales enable manual measurement of water levels. These are plates graduated from 0 to 1 meters, superimposed and fixed to bridge piers by means of metal bars.

The pressure transducer and water level gauge are installed together to form a hydrological station. The control software is OTT Water Logger. Data from a hydrological station can be used to:



Set up an early warning system

2 Pictures







Installation of a pressure transducer central unit and view of the connection cable to the submerged module



Staff training in field data collection



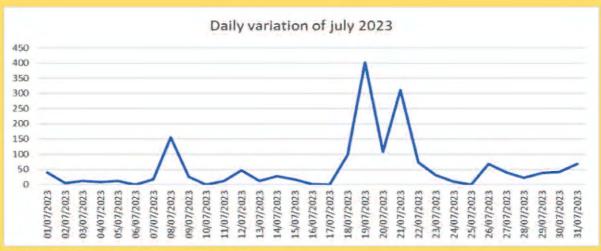
View of a water level station and the cable connecting the submerged pressure sensor module to the central unit installed on the bank.



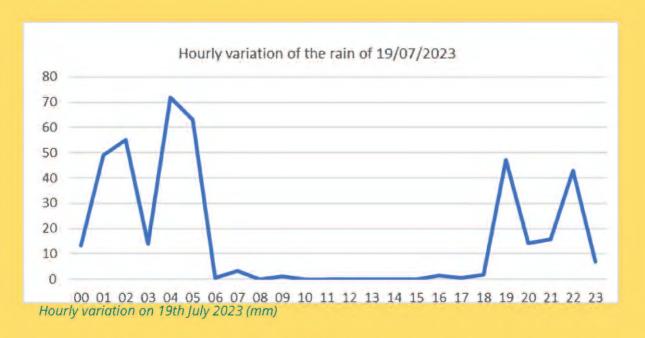


Some station' measurements

Prior to the installation of rain gauges in the Womangue watershed, rainfall data for hydrological and hydraulic studies in Limbé were virtually non-existent. Thanks to the equipment installed, Limbé now has a reliable rainfall and hydrometric database. The stations have provided invaluable information on the devastating rainfall in Limbé in July and August 2023. As a result, the extent of the flooding caused by these rains was better explained to the Limbé authorities and the local population.



Daily rainfall variation in July 2023 (mm)





Alerts tested as part of the project



→ Alert by observation of rising water levels in the river

This approach is based on the experience of local residents, who have been able to observe and identify specific points during successive floods in their neighborhoods that indicate that the river is beginning to overflow its banks. The rise in water levels at these well-known points is interpreted by local residents as a sign that the flow of water at the outlet is slowing down. Residents therefore believe that by observing these first signs of rising water, they can give an early warning of the risk of flooding in the event of heavy downpours before the river begins to overflow its banks. This empirical approach can now be used to draw up a warning protocol and install beacons, exploiting the data available thanks to hydrometric measuring instruments (materialization of thresholds, taking into account the response time of the watershed to flooding).

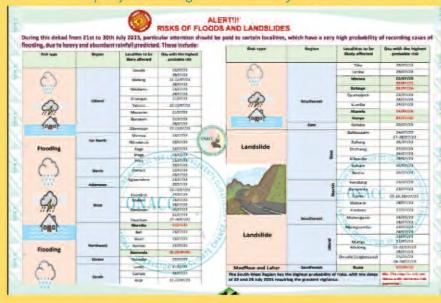
Distribution of warning bulletins from the National Observatory of Climate Change (ONACC)

In June 2022, the project's Technical Monitoring Committee invited divisional officials from the Ministry of Transport to discuss the definition of a warning system. The officials present suggested that the Limbe City Council approach the National Meteorological Department (DMN), which regularly publishes regional and divisional weather forecasts, to discuss how to produce a rainfall forecast bulletin for the City of Limbe. It was not possible to finalize these arrangements within the framework of the project.

The project also experimented with the dissemination of warning bulletins issued by the ONACC. These bulletins provide information on the risk of flooding and landslides at city level, with precise dates of high vigilance, and cover periods of 10 days. The City of Limbé's risk management service distributed them on the project's participatory WhatsApp monitoring system, which brings together the heads of the 10 districts of the City of Limbé. Below are the alert bulletins for July 21-30, 2023 and August 1-10, 2023. The City of Limbe actually experienced intense rainfall from July 18 to August 30, 2023, with major flooding and five landslides, two of which were fatal.



Example of two warning bulletins issued by the ONACC



This experiment deserves to be continued, and if possible, systematic access to alert bulletins could be the subject of a partnership between the town of Limbe and the ONACC. This would make it possible to draw up specific protocols for the town of Limbe, formalizing alerts in a more comprehensive way: day, level of vigilance, instructions.

Finally, a list of instructions has been drawn up by the project's Technical Monitoring Committee, with the participation of the district chiefs, for use by the risk management service:

| Flood risk | Landslide |
|--|---|
| Warning instructions | Warning instructions |
| Unplug your electrical appliances. Put your valuable and sensitive belongings up high. Stay at home. Go home if no one is home. Get to a safe place if possible. Make sure your children are safe. Take care of the elderly. Take care of the disabled. | Leave your home! Get to a safe place! |



ORGANIZATION OF A LOCAL CRISIS MANAGEMENT PLATFORM

Implementation of the second component, relating to the creation of a participative crisis management platform involving the authorities and the population, took place in three stages:



Identifying local civil protection actors;



Creation of a participatory crisis management platform;



Joint preparation of a local crisis management plan.

The identification mission enabled us to draw up an initial list of stakeholders involved in or concerned by civil protection, particularly in response and rescue operations:



- Senior Divisional Office
- Red Cross
- Firefighters
- · Decentralized local authority

Some of these actors responded to the invitation to take part in the specific work of the project's Technical Monitoring Committee, with a view to improving the organization of local crisis response. Several of the meetings organized within this framework were attended by representatives of the local population, as well as structures producing meteorological information, notably the Regional delegation of the Ministry of Transport for Fako.

It soon became clear that mobilizing such a wide range of actors would be a challenge in terms of management. In addition, participants noted the need for the project and the Limbe City Council to first take official administrative steps with their hierarchies and administrative supervisors to legitimize their mobilization. A lack of expertise also limited the progress made in implementing this component, which unfortunately failed to produce convincing results. Nevertheless, the willingness of the players mobilized to participate in a local crisis management synergy was clearly expressed.



PROBLEMS ENCOUNTERED AND LESSONS LEARNED

The organization of an early warning system, as envisaged and initiated within the framework of the Girin project, responds to a real need to improve the response of local actors to crises, as a complement to civil protection. Thinking about early warning must go hand in hand with answering the question of what to do once the alert has been given. Indeed, a participatory warning system will only be fully effective and relevant for populations if the actions to be taken are clearly defined and effectively implemented (thresholds for evacuation and refuge zones, assistance for disaster victims, etc.).



SOCIAL ASPECTS



Extended consultations with the heads of the ten neighbourhoods in the project area led to the development of a matrix cross-referencing the alert level according to the type of hazard (flood or landslide) and the instructions to be communicated to the population. These instructions were not sufficiently disseminated as part of the project's communication initiatives, due to a lack of time. They need to be made more widely available to the general public.



The project explored the idea of setting up river monitoring by volunteer residents at characteristic points identified on the basis of their empirical knowledge of the precursory signs of probable river overflow. However, simulations could not be organized to test this method. The Limbe City Council's risk management service should be supported in its experimentation with this method, drawing on data collected by hydrometric stations to rationally define the critical thresholds to be marked on monitoring beacons.



The principle of mobilizing neighborhood chiefs to relay warning messages and instructions to the local population was adopted. This involvement, like that of local residents volunteering to monitor the watercourse, is often accompanied by the question of compensation for their commitment. This raises questions about the community's ability to meet these expectations, and the reliability of their involvement over time. The solution of transmitting messages directly to the population should be explored more seriously in the future.



TECHNICAL ASPECTS



The organization of an early warning system based on flood forecasting using hydrological modelling requires a number of important prerequisites. Analysis of the local context and consideration of the project's inherent limitations (tight schedule, limited financial resources) soon led to the realization that these prerequisites, if not available, could not be met (high cost, lack of expertise and trained/competent personnel, complex organization of on-call duty during the rainy season, etc.).



These constraints/limitations have also led us to consider the need for the local authority to define its scope of action in terms of civil protection. It could focus primarily on preventive actions (raising public awareness, better management of urbanization, strengthening planning tools, etc.) and on establishing strategic partnerships with institutions and organizations specialized in weather forecasting. The latter could provide rainfall warning bulletins specific to Limbe's urban perimeter, to be relayed to the population.



The risk management service staff responsible for operating the installed stations have discovered a "trade" that does not fall within their initial skills. The training provided as part of the project by the expert mobilized was well received and appreciated, but deemed insufficient by those concerned. Further capacity-building measures are therefore required to ensure a real sense of ownership. The option of outsourcing equipment maintenance is also being considered. The Limbe City Council could sign a contract or enter into a partnership with a specialized structure (university, research organization). Such a partnership could also extend to assistance with data collection and processing (e.g. student internships). In the same vein, it would be interesting to carry out studies/modeling of exceptional events to generate cartographic data useful for raising awareness and political decision-making.



INSTITUTIONAL ASPECTS

- The monitoring of an early warning system by a municipality's services implies a specific organization of the dedicated service, computer equipment and qualified personnel on call (24 hours a day) to monitor the modeling performed by the computer software and relay the alert to the neighborhoods. This kind of organization can be "cumbersome" for a local authority to set up, which is why it is essential to carry out a proper needs analysis from the outset, and to assess the capacity (human, financial), or even question the appropriateness, for a local authority to invest in such a mission. We also need to ensure that the right expertise is available to implement such a technology.
- The dissemination of ONACC weather alert bulletins to neighborhood chiefs via the WhatsApp group created as part of the project has been a success. It would be advisable to continue this experiment and to organize the transmission of bulletins to the population by the district chiefs, monitored directly by the Limbe City Council risk management service.
- Thanks to the Girin project, the City of Limbé has acquired modern resources and tools for managing flood and landslide risks on its territory, particularly in terms of prevention:
 - · creation of a GIS for flood and landslide risk management;
 - setting up a municipal firefighting unit;
 - · installation of hydrological and hydrometric measuring stations;
 - drawing up a flood and landslide risk prevention plan.

It would be advisable to strengthen the capacity of city's services to optimize these tools in order to implement preventive actions. Drawing up a local crisis management action plan based on the guidelines of the national contingency plan would provide a strategic crisis response document shared by all local stakeholders (government departments, local authorities, the Red Cross, populations living in risk areas, etc.).

MORE INFORMATIONS

| Carrying out the project | Technical services of the Limbe City Council |
|---------------------------|---|
| Construction length | Spread on two years (2022-2023) |
| Project Manager | Gescod |
| Project Manager Assistant | Setec-Hydratec and and technical expert of the Grand Est Region (France) |
| Financial beneficiary | City of Limbe |
| Equipment acquisition | 12 200 000 F CFA (18 600 €) |
| Installation cost | 3 215 000 F CFA (4 900 €) |



Identification of the observation point at bridge N°4





In Cameroon

Nouvelle route Bastos Face Ambassade d'Allemagne BP 4280 Tél. +237 698 17 51 58 camerounegescod.org

In France

Siège: Espace Nord-Sud 17, rue de Boston 67000 Strasbourg Tél. +33 3 88 45 59 89 gescodegescod.org

www.gescod.org

