Terms of Reference for Consultant Firm
for
Provision of continuous engineering support to the
Somalia - Agro-Pastoralist Productivity and Resilience Project
The "Biyoole" Project
in Puntland

Introduction

From 2016 through 2018 the Government of Puntland implemented the Water for Agro-Pastoralist Livelihood Pilot (WALP) project. The project was also relatively short (2.5 years) and small (US$ 2 million), meant to tread lightly in the intervention of a precious resource subject both to cooperation and occasional conflict. Against this backdrop, an impressive amount was achieved, not only in terms of institutional strengthening and water provided to rural people and their livestock, but also the analytical work and tools that were tested and are now ready for scaling-up. Based on the successful implementation of the WALP project by Somali Government the World Bank has approved a scaled-up project called the Biyoole project.

Sectoral Context

Roughly half the Somali population lives in rural areas and derives their livelihoods from animal herding and crop cultivation. Despite the challenges of the past three decades, the livestock and crop subsectors remain the main sources of economic activity, employment, and exports. Half of the rural population pursues nomadic pastoralist livelihoods, while the other half pursues agropastoral livelihoods comprising a mix of settled crop production and livestock rearing.

In many African countries, groundwater sources from boreholes provide water for domestic use, livestock, and irrigation. In Somalia, however, groundwater sources are technically demanding to identify and exploit because aquifers are deep (more than half the boreholes are over 130 m deep with some over 400 m) and water within aquifers is often of low quality (salty or hard), which makes it unsuitable as drinking water or for irrigation. Costs for drilling and equipping these deep boreholes are high, ranging between US$0.5 million and US$1 million due to a combination of physical, market, and security conditions. In 2014, the Food and Agriculture Organization of the United Nations (FAO) mapped 3,700 water points across the country and identified a 40% failure rate. Only 2,200 were functional and perennial under normal non-drought conditions. Of these, only around 500, mainly deep borehole groundwater sources, were improved sources. This means that only 13% were fit for human consumption.

While boreholes can play an important role in ensuring water security for people, they are associated with environmental degradation. The yield of groundwater-fed boreholes is less vulnerable to short-term fluctuation in rainfall than other sources such as berkads, open dams, shallow hand-dug wells, and springs. This makes boreholes an important source of water in times of severe drought especially for

humanitarian response and particularly in non-riverine regions of Somalia. However, heightened pressures on pasture around these boreholes during drought events can cause long-term damage to the surrounding rangeland, creating so-called "sacrifice zones". Deep boreholes are also not a good solution for increasing agricultural productivity because their operation and maintenance costs are much higher than from shallow water sources and challenges related to water quality (for example, high salinity).

Based on recent experience, opportunities exist to enhance rural communities' access to water across Somalia's dry lands by deploying low-cost, small-scale water harvesting and storage technologies. Rivers in Puntland Somalia are ephemeral with water flowing for very short periods during the seasonal rains. Following seasonal rains, water infiltrates into shallow aquifers that last for only a few months of the year. Around these shallow aquifers, there is a small but growing horticultural production base selling vegetables to urban areas and improving rural incomes. Pilot projects in Puntland, including the WALP, have demonstrated that water harvesting and storage in these dry lands can be increased through investment in small dams such as sand dams, subsurface dams, and infiltration galleries. Sand dams, in particular, are experiencing a renovated interest because of their relative simplicity and their potential in enhancing the resilience of marginal dry-land environments.

The "Biyoole" Project

The World Bank is helping to build the capacity of Somali governments for planning and monitoring water and sanitation projects in arid, conflict prone environments by supporting the Biyoole Project. The Project Development Objective (PDO) is to develop water and agricultural services among agro-pastoralist communities in dry-land areas of Somalia. Biyoole focuses primarily on (a) improving access to multiple-use water resources (for human consumption, livestock, small-scale irrigation, and environmental services) in dry lands of Somalia; (b) land area under sustainable landscape management practices (number of hectares); (c) target beneficiaries (number) reached with agricultural services, share of which female (percent); (d) promoting the uptake of productivity enhancing innovations among target rural communities; and (e) strengthening the adaptive capacity of rural communities in Somalia and their resilience to the impacts of climate change.

Component 1: Support Development of Multiple-Use Water Sources. Based on detailed basin-level hydrology assessments, micro-watershed action plans, and groundwater investigations, this component will finance investments in key water management infrastructure for harvesting, storing, and delivering water for people, livestock, and agriculture. The infrastructure will be designed to deliver both improved human health outcomes and water for productive uses (mainly agricultural production and agroforestry services for landscape restoration), thereby making the targeted communities more resilient to droughts and floods (restored landscapes suffer less from erosion and are thus more resilient to flooding).

Subcomponent 1.1: Construction of New Community Water Points. This Subcomponent will support the construction of existing water infrastructure and small works. The menu of water infrastructure investments will include small sand and subsurface dams in dry river beds (wadis), surface water storage

infrastructure (for example, berkads and hafir dams), area infiltration interventions such as semicircular bunds or soil bunds, and rock catchments. As explained in paragraph 14 in the Project Appraisal Document (PAD), sand dams are particularly effective at enhancing the resilience of marginal dry-land environments by helping sustain vegetation biomass during drought periods. The improved vegetation biomass and soil management, combined with the increased water availability derived from these various infrastructure investments, will facilitate agricultural activities and food production. These will, in turn, increase the targeted communities' resilience to droughts and floods. Solar units will lift water and then use gravity to feed auxiliary structures such as cattle troughs, water points for human use, and so on. In addition, if no other options are feasible, the component will support construction of boreholes for groundwater extraction. Boreholes are an important source of water during severe drought, especially for humanitarian response, and particularly in non-riverine regions of Somalia.

Subcomponent 1.2: Rehabilitation of Community Water Points. This subcomponent will finance the rehabilitation of existing water infrastructure and small works including boreholes. The Sub component will also finance associated infrastructure to provide multiple-use water services (zero-emission standpipes or shallow wells with hand or solar pumps and watering troughs for livestock). Selected project sites can include multiple interventions to ensure adequate water through periods of drought and for multiple purposes: high-quality water for domestic use and moderate quality for livestock and agricultural uses. These investments will be the anchor assets around which other project activities in each selected sub-catchment will seek to capitalize and manage. The diversification of water sources based on the WET, extensive ground truthing, and groundwater assessment will increase the supply of water and therefore mitigate the risk of droughts and climate change.

Wadi Development Potential Studies

To help support the preparatory phases of both the WALP and Biyoole two complementary studies (one macro level and one micro level) on the development potential of Wadis in Puntland were undertaken by the World Bank in the first half of 2015. The macro level study identified possible sites for wadi development across Puntland, using a newly developed wadi evaluation tool (WET), and the micro-level study examined the social, environmental and economic impacts of wadi development helping to understand the potential winners and losers where water resources are developed.

The macro study defined the hydrological principles that should be followed for improved planning, operation, maintenance and management of water resources in ASALs including the production of a set of baseline maps for the siting of wadi developments based on an interpretation of remote sensing data, including geology, soil and geomorphology, land use and vegetation and a detailed topography allowing for 3D interpretation of the regional geology and fluvial drainage. Hydrological models for application in wadi development were investigated and reviewed and recommendations were provided for a WET to aid decision-making by analyzing fluxes, change and trends in water and land resources.

The micro level study focused on the micro-level social, environmental and economic impacts of wadi development, and the development of a rational method for site selection. The positive and negative

impact of existing water infrastructure interventions in wadis were evaluated and a method with rational criteria for future site selection was proposed, premised on an evaluation of the socio-economic drivers of rural water infrastructure in the project area.

Objectives of the Consultancy

The objective of the consultancy that this Terms of Reference refers to is to support the Puntland Government of Somalia, by providing backstopping engineering and construction support for site selection and water source construction monitoring. A total of 40 water points will be constructed/rehabilitated.

Scope of Works

The following tasks in this scope of works are to be carried out by a firm which will be made up of a joint venture between an international engineering consultancy firm partnering with a state level local engineering consultancy firm) and include:

Task 1: Lessons Learned from WALP and WET Refresher Training:

As a pilot project, the lessons learnt were as important as the infrastructure and institutional outcomes achieved. The key lessons from the WALP project included: Implementation through country systems was possible and effective but required strong implementation support. Political decision-makers should be provided with a broad set of technically sound options for dam locations from which they can select final sites. Water-truckers present a significant threat to the sustainable development of sand dams. Local markets for goods and services were better than expected but the market for works was limited and quality highly variable. The focus on sand and sub-surface dams constrained the options for action especially where political and equity considerations overrode technical considerations: The Wadi Evaluation Tool (WET) is a useful tool to assist the site selection process. Government's willingness to solve problems was not matched with their ability to solve problems. Cross-ministerial participation is key for proper site selection as well as rapidly identifying and addressing problems with the water points. Greater emphasis should have been put on hydrological monitoring as an input to the designs. An environmental and social impact assessment is an important component of understanding the dams' success.

The WET is a decision support tool for water harvesting infrastructure based on a broad spatial scale and is operated in an open source QGIS environment under no commercial license. The model concept is based on the spatial analysis of available remote sensing data and the spatial overlay of up to 30 different thematic data layers including an analysis that considered numerous complex boundary conditions. Data was combined into one suitability map that can show all possible sites within a defined region of interest and rank these sites according to their water harvesting potential. The WET model has very high flexibility, and for example can already be run with two layers only. Suitability maps and reports for

Puntland and Somaliland were produced for WALP and ahead of Biyoole the WET was upgraded and used to undertake feasibility studies in Galmudug and South West States.

Objective for Task One the consultants will take the PIUs through the lessons learned from WALP and provide training in use of the WET application. These workshops will be carried out in the State capital.

Task 2: Site Selection and appropriate technology identification

Site selection is the most crucial point in the project. Sites are selected initially through remote sensing using the WET developed under WALP and then ground truthing field visits to confirm suitability. The Biyoole preparation is in an advanced stage of site selection. In Puntland, 21 potential sites were identified for World Bank support under the Special Financing Facility for Local Development Emergency Response to the 2016 drought. The World Bank is supporting HydroRam water resource modeling training and the Puntland GIS Specialist has prepared water catchment maps showing these 21 locations. Whilst the projects preferred option is to harvest water from sand by constructing sand or subsurface dams this is not always the most suitable technology, and as such, based on experience and analysis, a menu of suitable water technology options was included in the Biyoole project PAD.

Objective for Task Two. Drawing from the options described above, the consultancy will support the selection of sites, this includes assessment of the sites already identified and selection of new sites:

Defining Project Site Parameters: Utilizing the WET tool and drawing from the recommendations in the micro study (chapter 11) work with the PWDA/PIU to confirm sites listed above, and identify new sites, and prioritize interventions and appropriate technologies. The WET can prioritize using weightings criteria, some examples of parameter weightings are: **i)** focus purely on sub basin hydrology, **ii)** focus on accessibility, **iii)** focus on locations of importance or **iv)** focus on site suitability. Although final decisions need to be validated on the ground, the model can to be used to find the most promising areas for water harvesting. Of primary interest to the Biyoole project is the definition of sub-basin and site parameters including; geometry parameter layers, climate and hydrology parameter grids, soil parameter grids, site requirement layers and site suitability layers. Each of these primary layers have drop down boxes in which priority weightings can be set.

Project teams have indicated that their priorities in terms of component one is, in specific order, access to water for humans, livestock and agriculture. Under **task 2** the consultants will work closely with the project teams to guide them in inputting these parameters into WET helping to determine the most appropriate wadis and locations in wadis for potential water harvesting or alternatively to wadi development identify other sites and water technologies. In total 40 sites should be identified and an initial batch of ten 2 pager rapid assessment Site Pre-Feasibility Option Reports done.

Task 3: Geophysical Studies

Due to the enormity of task three this stage will be phased in four batches of 6 sites each. Once sites have been selected and ground truthing for feasibility concluded the consultant is expected to carry out field investigations and a topographic survey for each proposed site to acquire geometric, geological and

hydrogeological information necessary for the dam design. The field investigations should include general surveys (geo-morphological and hydrogeological) extended in a radius of 300-500 m from the center of the dam and site studies localized in the stream and nearby zones (mostly the river banks), the latter is subject to a high variability due to a wide range of situations and dam solutions (sand or subsurface).

Annex one provides the full detail of the tasks involved. The consultant should note that although these tasks are focused on sand dams the process also applies to other water technologies.

Objective for Task Three - Construction Investment Reports (CIR) – Based on (a) to (g) detailed in annex one provides a short (no more than 10-pages) feasibility report per site on design options with recommendations on which to proceed with. The report shall provide summary information justifying the need for the construction of the dam. Specifically, the report should define the targets for the construction of the dams. Targets are listed as follows:

1) definition of water use
    i) for agriculture
    ii) for watering livestock
    iii) for domestic uses
        (a) definition of beneficiaries
        (b) definition of water demand
        (c) definition of period supply
            (i) continuous water supply
            (ii) seasonal water supply

Further to that, the report shall provide information summarizing the results of the field investigation. Specifically, it should report the following results of the survey:

(d) geological appraisal of the dam site area and related surroundings

(e) estimation on the potential accumulation of alluvium

(f) appraisal on run-off, frequency and quantities

(g) estimation on the potential water retention capacity

Finally, the report should provide results of the costs/benefits preliminary analysis or, more in details:

(h) estimate the investment, running and maintenance costs at preliminary level

(i) draft the preliminary ripening curve and the curves of water availability compared to the water demand.

Task 4: Development of Detailed dam designs, BOQs and bidding documents

Detailed dam design – develop detailed drawings including dam depth, spillway height and width. The detailed design should include all necessary civil, structural, architectural, mechanical, geo-technical and foundation designs including specification of quality and amounts of required materials needed for construction. While preparing design documents, eligible contractors should follow standard bidding document from the World Bank as well as Eurocodes (http://eurocodes.jrc.ec.europa.eu/home.php)

Detailed multiple-use design of water reservoirs in the sand dam, abstraction, storage and distribution mechanisms– Depending on the intended multiple uses (for people, livestock and agriculture) of the water storage capacity at the dam site, design appropriate mechanisms for abstracting the water from the wadi to reservoirs and distribution systems out of the wadi for each purpose. The solutions should put an emphasis on the life-cycle costs of the infrastructure, its operation and maintenance. The designs should also be realistic about the local technical capacity to operate and maintain the system including the availability of spare parts. The detailed design should include all necessary civil, structural, architectural, mechanical, electrical, geo-technical and foundation designs.

Bidding Documents (including Specifications and Drawings). Document all work associated with the designs and field investigations in (a to g) above including maps and drawings at suitable scales, design criteria and guidelines, design memoranda, design calculations, equipment catalogues and other pertinent information. Bidding will conform to World Bank procurement standards. Prepare a consolidated bidding package which includes:

- complete set of bid documents according to World Bank procurement standards;
- tender drawings for the architectural, civil, structural, electrical, mechanical, disciplines to appropriate scales as required for construction of the works;
- technical specifications for the work in accordance World Bank procurement standards;
- bills of quantities as the basis of contractor payment adopting an international recognized standard such as the Civil Engineering Standard Method of Measurement of the British Institution of Civil Engineers or the Eurocodes.
- in a separate report marked confidential, an Engineer's cost estimate for all works to within +/- 10%
- Proposed criteria and procedures for the evaluation of contractors' bids for construction packages in accordance with current Government of Puntland procurement procedures, for use by the Client during the procurement process.

Questions and queries: Respond to any queries raised by the authorities and for making any amendments to the designs/calculations/drawings requested by the Government or the World Bank.

Objective for Task Four. Development of Detailed dam designs, BOQs and bidding documents

Task 5: Real time monitoring. Construction Status Reports and post construction hydrological monitoring study to monitor hydro flows in the wadis

Lessons learned during WALP showed how advantageous it is for PIUs to have readily available real time engineering advice and regular formalized construction assessment done per site. For task five the consultants will avail an engineer to be available on phone, WhatsApp or email and to travel to the field site if necessary, to provide real time advice and guidance. Two formal documents in the form of Construction Status Reports, should be done per site during construction. Construction Status Reports should provide an assessment and have the following sections: project status, observations, areas of concern and possible solutions. These should be presented as one consolidated report with an overall challenges and lessons learnt per engineering support mission. The PIUs do not have the capacity yet to undertake the hydrological monitoring required to establish the impact of the wadi developments on **i)** down-stream water needs of both by people and the environment **ii)** shallow ground water reservoirs and **iii)** deeper ground water recharge, and the consultancy will be required to review, and adjust if necessary, the Hydrological Monitoring process developed for the WALP project, thereafter to train PIUs in hydrological monitoring and oversee the implementation of the process including ongoing monitoring .

Objective Task Five. Provide two Construction Reports (consolidated per mission) per site and monitor hydro-flows before and after the wadi developments are commissioned and produce a report.

a) Key Consultant Personnel

For the above tasks, the firm should field the following caliber of personnel:

Core Staff

Team Leader and Organizational Specialist: Master's degree in GIS, remote sensing or mapping, economics, engineering, international development, public policy management or related subject. At least 10 years of international development experience, including fragile states, along with experience in water supply and sanitation sector, first-hand experience of working with Governments to monitor projects. Proven ability to lead international missions and convening of workshops and meetings in multi-cultural situations, strong understanding of working in fragile and conflict affected states. Proven ability to lead teams working in highly insecure contexts. Proven ability of report writing.

Water and Sanitation Specialist/Engineer: Masters' degree in subject related to Engineering, Public Health, Sociology or Anthropology. At least 10 years' experience of working with government implementing water projects in rural Somalia. Proven ability to engage in international missions and convening of workshops and meetings.

Staff periodically contracted in

Technical Expert: Master's degree in Surveying, Remote Sensing, land information and mapping or related field. Experience in wadi development, use of the Wadi Evaluation Tool (WET) and ability and willingness to work with Somali government staff to define project parameters and to identify project sites. Experience in ground truthing. At least five years international development experience, including fragile states. Proven ability undertakes localized engineering assessments and to produce high quality feasibility assessment reports.

Monitoring and Evaluation specialist: Master's in Advanced Development Studies or MSC in International Development. Three years' experience in development of and wadi management research; both qualitative and quantitative. Extensive experience in training and managing field teams of national researchers in FCAS and for supporting governments in, and documenting, local level community socio-economic discussions. Experience in M&E research methodologies. Experience of working with governments to develop monitoring frameworks as inputs to resilience planning. Experience in Impact Assessment Reporting. Experience in Geo-tagging and Drone technology for M&E.

The firm can use both international and national personnel, as relevant to the tasks, provided that the combined competency requirements are fully met. Firms are encouraged to associate and to form joint ventures with national Somali consultancy firms and to work closely with government staff. The estimated period for this contract is four years from approximately May 2020 – May 2024.

b) Deliverables, Time Line and Payment Schedule

Table 1: Deliverables, timelines and payments

Tasks	Deliverables	By when	Payment schedule	Approximate billing date
	Signing contract		**10%**	Jun 2020
Task One	1.1 WET refresher training report	Aug-20		
	1.2 Lessons learned workshop report			
Task Two	Site Selection Report			
	2.1 Pre-Feasibility Options Report for 6 sites	End Sept 2020		
	2.2 Pre-Feasibility Options Report for 14 sites	End Mar2021		
Task Three	3.1 6 Construction Investment Reports	End Sept 2020		
	3.2 14 Construction Investment Reports	End Mar 2021		
Task Four	4.1 6 Detailed dam designs, BOQs and bidding documents	End Oct 2020	Tasks - 1.1, 1.2, 2.1, 3.1 & 4.1 **20%**	Nov 2020
	4.2 14 Detailed dam designs, BOQs and bidding documents	End Jun 2021		
Task Five	5.1 6 Construction Status Site Reports consolidated into one report	End Feb 2021	Tasks 2.2, 3.2, 4.2, 5.1, 5.2	
	5.2 6 Hydro-flow monitoring reports	End Feb 2021	**50%**	Mar 2021
	5.3 14 Construction Status Site Reports consolidated into one report	End Jun 2021	Tasks 5.3 & 5.4	
	5.4 14 Hydro-flow monitoring reports consolidated into one report	End Dec 2021	**15%**	Dec 2021
	5.5 14 Construction Status Site Reports consolidated into one report	End Dec 2022	**5%**	Jan 2023
	5.6 14 Hydro-flow monitoring reports			
			100%	

c) Key Consultant Qualifications

The assignment will be undertaken by a firm with at least eight years' experience in providing back stopping technical assistance and advisory engineering support in fragile states contexts. Experience in Somalia and in wadi exploration and development is essential, as well as proven ability to work with Government staff and commitment to institutional capacity building.

d) Contract Management

The Puntland Government of Somalia will lead and supervise project implementation and ensure quality control. The firm's primary reporting links will be with the Puntland Water Development Agency (PWDA). The firm will also work closely with the World Bank task team, the Puntland Biyoole Project Coordinator and the National Project Coordinator in the Federal Government. It is important to be clear that the purpose of this consultancy is one of technical assistance and advisory support. This is in line with the overarching capacity and country systems building principle that Biyoole is designed to promote. As such the firm contracted will be there to guide PWDA through every step in the construction process, however ultimately it is the PWDA Senior Water Engineer who is responsible for final engineering decisions and sign off of works, and payment certificates approval will be made by the GM of PWDA.

Type of contract

This will be a lump sum contract for fees. The fees will be paid on percentage basis for stages of defined outputs. The reimbursables will be paid on actual basis, based on a proposed budget. The total cost proposed fees plus reimbursables will be considered in awarding the contract. The Government envisages the need for continuity for downstream work as this is a phased assignment.

Facilities

Transport – The firm will be responsible for all air and surface transport costs for their staff. . Firm to provide security strategy at point of contract signing.

Per diem and accommodation costs – Government will cover the costs of perdiems and accommodation for government staff. The consultant is responsible for firm staff.

Communications and printing costs – The firm will be responsible for all communications and printing costs.

Desk study resources

- Policy documents
- Project Paper and results framework– WALP
- ESMF - WALP

- Wadi Development Micro Study
- Wadi Development Macro Study
- WALP Endline Survey
- Assessment of Water Resources for Priority Areas in Puntland
- Assessment of Water Resources for Priority Areas in Puntland
- Assessing Potential for Small Dam Developments in Somalia: Galmudug and South West States
- WALP Pre-Feasibility Option Papers (for each of the 8 sites)
- Biyoole Project Appraisal Document (PAD)
- Biyoole Project Operations Manual (POM)

Security

Operating in Somalia presents immense security challenges. The firm contracted will be responsible for all their own security arrangements and will be required to recognise the risks involved in working in the Somali context and to acknowledge that these risks are borne independent of the Government of Puntland. The firm will be required to provide a detailed security plan as part of their proposal.

e) Appendix One – Detail of Geophysical Studies

Note – the detail below relates specifically to sand / subsurface dams and will need to be modified for other technologies.

1. **For each dam site:**

   a. **Carryout soil investigation** within the vicinity of each proposed dam site in order to locate suitable material for dam construction.

   b. **Topographic survey:** the topographic survey shall be carried out in each location of the 40 sites selected, by means of total station or precision GPS. A precision up to 10 cm is required. The survey shall include **i)** a transversal profile to the stream on each dam axis proposed which shall extend for 50 m beyond each river bank (a point each 5 m), **ii)** a longitudinal profile from 500 m upstream of the selected location up to 200 m downstream (a point each 10 m), **iii)** the contour of the dam upstream zone of influence, mapping a point each 10 m along both banks up to 300 m of distance upstream and 100 m downstream of the dam site, **iv)** in the same area and on the banks all the rocky outcrops shall be mapped. The data shall be presented in: **v)** a cross-section along the dam layout as described at the point "i") above, **vi)** longitudinal cross section as described to the point "ii)" above, **vii)**, perpendicular to the stream axis cross-sections roughly spaced each 50 m from bank to bank including the banks top edge, **viii)** a map in AutoCAD format with the location and the elevations of all the points, outcrops banks and elevations contour lines 0.5 m spaced, **ix)** excel worksheet with all points coordinates and elevations.

   c. **Develop profile drawings (longitudinal and cross-sectional) of the riverbed.** This should be based on longitudinal profiling or 'probing' to assess the extent of the sand reservoir, the existence and continuity of the impermeable bedrock layer, the height and consistency of the banks, and, slope of the wadi.

   d. **Measuring the storage capacity of the sand reservoir** to locate the most cost-effective location for constructing wells and the subsurface, weir or sand dams identify the largest sand reservoir of the wadi and hence where the maximum amount of water can be stored for the lowest costs given different dam placements.

   e. **Measuring the volume of extractable water from the sand reservoir -** estimate the maximum extractable volume of water (yield) from the planned sand reservoir by calculating the rate at which water can be extracted from the sand. Two to three sand samples were collected at different depths from each probed wadi. The samples should be fully saturated with water in buckets with a fixed volume and the total water that is abstracted reported as a percentage of volume of sand.

   f. **Carry out detailed geotechnical and geophysical investigations** to confirm the suitability of the:

      i) Dam axis for the dam foundation and dam abutment in the wadi/river embankment;

      ii) The depth, continuity and consistency of the impermeable bedrock layer – testing it for permeability, estimating losses and proposing mitigation measures if any;

      iii) Stability of the upstream wadi embankment

More information about each component of this part of the investigation are detailed as follows:

Geo-Morphological survey: The geological survey shall be carried out in an area of 500 m of radius from the center of the dam layout. The geological formations with particular attention paid to the rocky basement and fracture's degree, to the presence of possible faults and to the extension and grain size of the alluvial deposits on the wadi bottom and banks are described in a geological report. The main morphological features (escarpments, stream diversion or convergence, erosions of any type, farms) should be outlined on a separate map or on the same geological map). The results will be shown on two maps, one based on the topographic map described at the point "**b.*viii)"*** above and one reporting geo-morphological features in the enlarged area (500 m of radius) based available high-resolution satellite images. During the geological survey the consultant shall extend the survey to the nearest site where construction materials (stones) are available. If there are not suitable locations in a radius of 500 m the survey is extended to the nearest accessible site. In the geological report, as a part of the final technical report, the Consultant shall evaluate the suitability of the bedrock with regard to the dam foundations, to the possible leakage caused by fractures or by an unconsolidated semipermeable layer and a description of possible mitigation measures.

Geophysical survey: the proper methodology to verify the presence and the pattern of an impervious rocky basement (where appropriate) is the refraction seismic. The lines (or bases) are carried out perpendicularly to the stream axis, spaced of 50 m each other, starting from the dam layout. A continuous longitudinal line is carried out from 50 m downstream to 300 m upstream. Each line is made with layouts of 12-24 geophones with a spacing of 2 to 5 m according to the width of the stream section covered by alluvial deposits. In the case that the contractor is not able to supply the seismic equipment the survey can be done with VES (vertical electrical soundings). The VES shall be carried out with parallel to the stream axis layout only where a thickness of alluvial deposits beyond 3 m is expected or where the distance between near outcrops exceeds 30 m. The maximum AB/2 spacing (semi-distance between the current electrodes) is 50 m. The maximum AB/2 is reduced where an outcrop is present along the layout: no VES shall be done on outcropping rocks. The number of VES to be carried out on each side shall be defined by the contractor as part of his technical offer. An indicative number of VES is given in Annex 1 to this ToR. The same criteria should be applied to test pits, probing roads and porosity test described below. VES coordinates, data, curves and interpretations are delivered to the end of the interpretation and enclosed to the report. The VES centers or the seismic lines shall be mapped on Google Earth images and on the topographic map. All the indications given above can be adapted in the technical specifications supplied for each site.

Test Pits: the pits are located along the dam layout, where alluvial deposits cover the basement, with a 5 m spacing; where the layout length exceeds 50 m the spacing will be 10 m. Three additional pits will be excavated along the stream axis upstream of the layout spaced 100 m each other, the first 100 m upstream of the dam layout. It is expected a maximum depth of 5 m but mostly they shall reach the impervious basement before the 3 m of depth. If the excavation is made by hand a dewatering pump shall be used in case water is met before the basement is reached. It is suggested the use of a small excavator for the task. For each pit a stratigraphic column will be done illustrating the variations of grain size and color and the presence and the type of the bedrock at the bottom. A lithological cross-section will be presented as elaboration. During the excavation samples of the alluvial sediments are taken for the or porosity tests.

Probing rods survey: Where appropriate this type of investigation is made by iron rods of small diameter to be infixed in the ground and hammered down up to the rocky basement or to the point where it is impossible to

proceed for the presence of too compact materials or stones (pebbles, blocks). The profiles are done with a 5 or 10 m spacing (with the same spacing suggested for the pits along the dam layout) for each test, along lines perpendicular to the stream axis. Each line or profile is spaced 100 m from the previous, from 100 m downstream of the dam axis, moving upstream. It is suggested to execute the probing rods survey before the pits excavation to verify the reliability of the methodology and to find out possible basement depressions. In the case of sandy banks tests are done horizontally in the banks, to find the basement distance from the bank flank and on the bank top as specified for the single areas.

Porosity tests: on samples taken during the test pits excavation are done rough porosity tests finalized to evaluate the effective porosity of the sediments. This type of test can be applied only to get rough information since the sample are not in their natural state but deeply disturbed when taken away from the pit walls. Normally the test results give higher values of porosity since the sample material, once removed from the ground shall have a larger volume of voids. The test is made filling a bucket with sample then saturating it with measured volume and water. Once the saturation is reached (new water is not being absorbed) a seal near the bucket bottom is removed and water can freely drop in a cup. After one hour the quantity of water in the cup is measured and the ratio between the volume of the output and the input water is measured. If the bucket is graduated, also the volume of sand can be measured, and a rough effective porosity can be calculated. In the case of fine deposits (fine sand or silty sand) the test is extended until when the output water flow is almost negligible. In the description of the test results is given a description of the sample grain size and the volumes of the sediments and of the input/output water. In the technical report the Consultant shall estimate the maximum volume of extractable water from the sand reservoir and the daily rate (yield) with which it can be extracted. The calculation should be done on the base of the data obtained from the porosity tests and considering the possible recharge of the artificial aquifer. It is suggested that the test id done for each site on five samples taken in the pits excavated at the center of the dam layout and along the stream axis, following the instruction given at the point '**f.3'** listed above. The samples shall be representative of the material found in the excavation.

Hydrogeological survey: in a radius of 300-500 m from the dam layout center the Consultant shall map (with precision GPS) all the existing water points (springs and hand dug wells). If water point does exist, then the target is to have a minimum of 4-6 water points at different distance and position (upstream, downstream, on the banks) that shall constitute the core of the monitoring network. The consultant shall take measurements of the well depth and radius, of the SWL (static water level) and EC (electrical conductivity) and shall estimate the production (by inquiring the owner or the utilizers). Also, in the inquiry is collected information about the perennial or seasonal character of the aquifer and the seasonal variations between maximum and minimum SWL. These data are then summarized in an excel sheet enclosed to the final report.