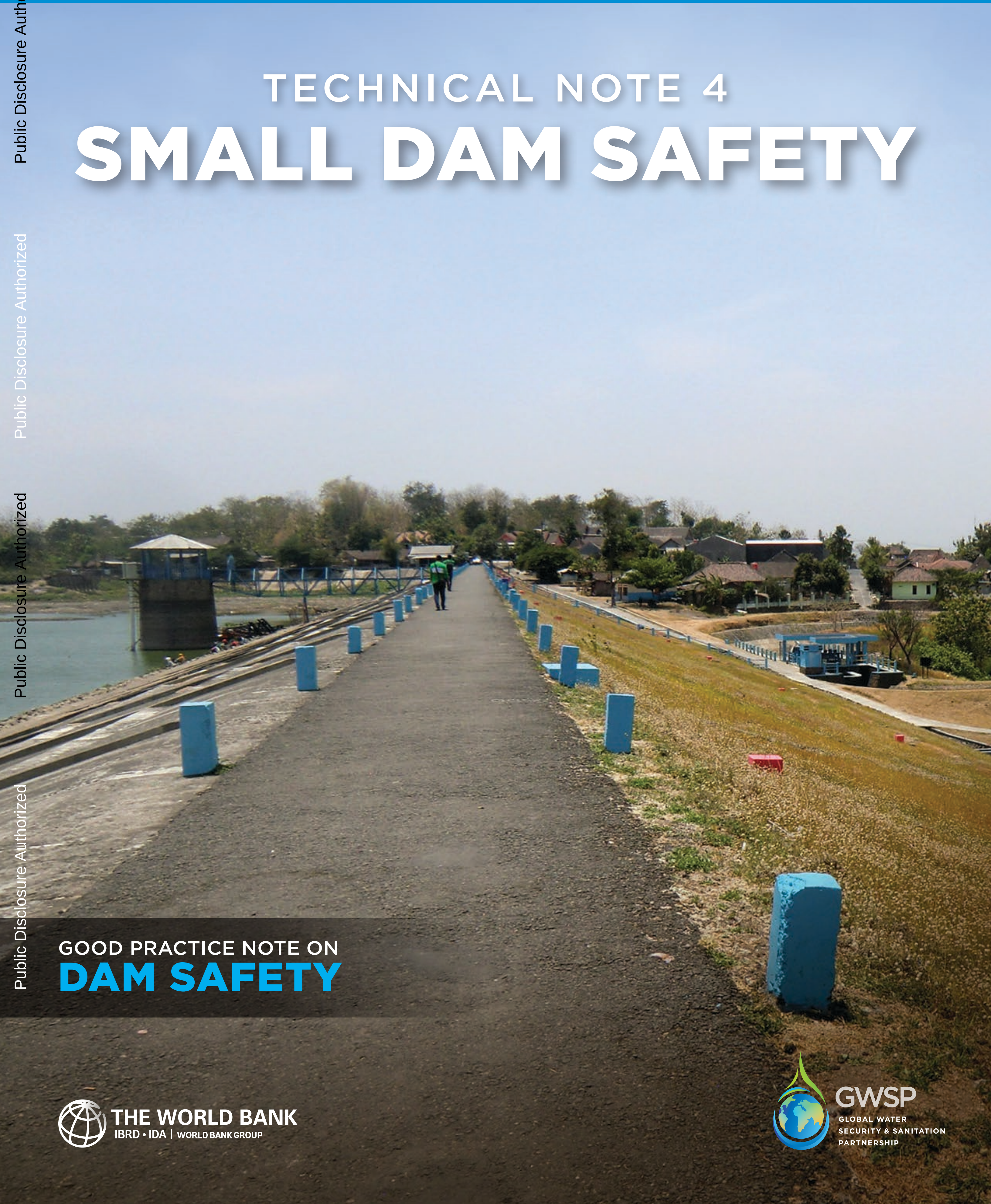
SAFETY OF DAMS AND DOWNSTREAM COMMUNITIES

TECHNICAL NOTE 4
SMALL DAM SAFETY



GOOD PRACTICE NOTE ON
DAM SAFETY

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Technical Note 4: Small Dam Safety

Contents

Objective and Scope of This Note

The objective of this Technical Note is to inform borrowers and World Bank task teams on safety aspects of small dams to support the application of the requirements of the Environmental and Social Framework (ESF) and on international experience with community[1] participation in management of irrigation systems and small dams.

The scope of this Technical Note covers small dams, which are defined as all retention structures other than large dams. The ESF defines large dams as dams:

(a) With a height of 15 meters or greater, from the lowest foundation to crest, or

(b) Between 5 and 15 meters impounding more than 3 million cubic meters.

This Technical Note provides guidance on the compliance requirements regarding small dams as per paragraph 5 of the ESF/ESS4/Annex 1 on Dam Safety. The guidance contained in this note is designed to enhance the quality of practice and should be regarded as complementary to, not a replacement of, the compliance requirements under the ESF.

The rest of the Note contains reference material on good international practice on planning, construction, and operation and maintenance (O&M) of small dams and irrigation systems. In particular, it provides detailed analysis and recommendation on community participation in irrigation water

1 Community includes water user associations (WUAs), water user groups (WUGs), irrigation districts (IDs), agriculture cooperatives, and other forms of community entities.

management and contribution to safety assurance of small dams.[2] Reference material is based on a review of relevant literature and 21 case studies, shown in Annex A.

This Technical Note aims in principle to provide guidance for small dam safety management and the possible contribution of communities to safety assurance along with required elements and steps. Hence, it does not deal with the entire set of the environmental, social, and institutional aspects, including the environmental and social impact assessment, stakeholders assessment, preparation of Stakeholder Engagement Plan and communication strategy, and so on. Some potential issues that need to be considered may include poor representation of minorities and women, domination of the community engagement process by powerful groups, distribution of land to elites, misuse of community funds, labor influx resulting in an increase in gender-based violence during construction works, and remedial and mitigation measures. These and other important aspects need to be carefully studied by the teams of irrigation and rural development projects in close coordination with the environmental and social specialists in line with the ESF, Environmental and Social Standard (ESS) 1 - Assessment and Management of Environmental and Social Risks and Impacts, ESS 10—Stakeholder Engagement and Information Disclosure, and other relevant ESSs.

ESF Safety Requirements for Small Dams

As the ESF provides more emphasis on potential risks and vulnerability of downstream communities, it has introduced risk assessment for certain small dams regardless of size or retention capacity. It applies the safety requirements of large dams to small dams, which

- could cause safety risks, such as an unusually large flood-handing requirement, location in a zone of high seismicity, foundations that are complex and difficult to prepare, retention of toxic materials, or potential for significant downstream impacts; or
- are expected to become large dams during their operating life.

If a dam does not fall into these two categories (large dams or small 'risky' dams), dam safety measures designed by qualified engineers in accordance with Good International Industry Practice (GIIP) will be adopted and implemented (see also section on Small and Low-Risk Dams in the main GPN).

The ESF requires small but risky dams to comply with specified dam safety requirements including: (a) reviews by an independent panel of experts on the investigation, design, and construction of the dam and start of operations; (b) preparation and implementation of detailed plans including a plan for construction supervision and quality assurance, an instrumentation plan, an O&M plan, and an emergency preparedness plan; (c) prequalification of bidders during procurement and bid tendering; and (d) periodic safety inspections of the dam after completion and implementation of measures required to address safety deficiencies.

However, as introduced by the ESF and elaborated by the Good Practice Note (GPN) on Dam Safety, the risks associated with a dam are design- and situation-specific and will vary depending on structural components, socioeconomic factors, governance, regulatory environment, and the surrounding

2 This Technical Note is prepared building on a consultancy report on small dams by an International Water Management Institute (IWMI) team led by Winston Yu and contributed by Mohamed Aheeyar, Olufunke COfie, Nishadi Eriyagama, Jonathan Lautze, IIsa Phillips, and Jean Philippe Venot (IWMI, 2019).

physical environment. The dam safety requirements will reflect those considerations and be proportionate to the size, complexity, and potential risk of dams.

Hence, in the case of small dams with less-demanding technical features, the suitable level of dam safety requirements, such as the required scope of dam safety plans and composition of the dam safety panel, should be discussed and agreed on in consultation with the World Bank dam safety specialists and other technical specialists such as social or environmental specialists. The suitability of requirements will consider specific site conditions, downstream consequences, and client capacity on dam safety management, among other factors.

The GPN introduces risk classification concepts and examples for both construction of new dams and rehabilitation of existing dams.[3] Annex C of the GPN also provides information on a classification system for small dams from ICOLD (2016).

General Information on Small Dams

Small dams play an important role in the provision of many kinds of benefits, such as drinking and irrigation water supply, flood control, small/mini hydropower generation, fishing, and so on. They are particularly important in rural and agricultural areas. Agriculture remains an engine of rural growth and poverty reduction in developing countries. Agricultural water management (AWM) can change the lives of millions of people by improving yields, reducing risks linked to climate variability, and increasing income for farmers (Giordano et al. 2012). Central to AWM is the role that water storage, including small dams, can play in providing timely and reliable irrigation water supplies. Water storage can serve as insurance for farmers, allowing off-season crop production (with irrigation) and livestock watering at all times (Payen, Faurès, and Vallée 2012; Rautanen, van Koppen, and Wagle 2014).

The demand for water storage is increasing as farmers and rural communities are more frequently facing water shortages for their crops and livestock (McCartney and Smakhtin 2010; Payen, Faurès, and Vallée 2012). This demand is in part driven by climate change and increasing variability and scarcity observed around the globe.

Since the 1990s, there has been a significant interest in developing small dams (Venot, Andreini, and Pinkstaff 2011). This interest is, in part, a reflection of the challenges associated with minimizing environmental and social impacts and the challenges of financing large water infrastructure. Thus, the importance of small dams in development and specifically for small-scale irrigation has increased and will continue to do so. Global estimates for the number of small dams are difficult to determine but could be on the order of millions. The interest in developing small dams is also consistent with research suggesting that small-scale farmer-led irrigation has significant positive impacts on livelihoods (for example, see Martin and Yoder 1986 for South Asia).

Small dams may be owned by a central or local government or some larger private farmers. In some cases, small dams and associated irrigation or water supply infrastructure is handed over to community

3 The classification system (size, hazard, or combined) significantly varies among countries and jurisdictions; for a comprehensive review of definitions, see Wishart et al (2020).

organizations. Regarding the community management of small dams, substantial research has been undertaken over the past several decades on its effectiveness. Venot and Krishnan (2011) summarized the current debates regarding opportunities and limitations of small dams (table 1). This Note provides some lessons on how to address the challenges of small dam management with participation of community groups and effective government support for them.

TABLE 1: Perceived Opportunities and Limitations of Small Dams and Small-Scale Irrigation

Opportunities/stated advantages	Limitations/stated drawbacks
Planning	
• Viable/practical alternatives to large projects	• Multiple approaches/lack of benchmarking
• Compatibility with local farming systems	• Low visibility and limited funding
• Easy adaptability to local conditions and involvement of population in the siting/design • Quicker/higher returns than large-scale projects at local level	• Planning processes similar to those of large-scale projects • Lack of attention to complexity of intervention • Lack of involvement of diverse stakeholders in planning phases; lack of oversight/guidance
Infrastructure/development	
• Low costs (absolute value)	• High costs relative to benefits
• Simple technology	• Inconsistent commitment by governments/donors
• Large scope for development (area, region)	• Difficulty to replicate (context specificity)
• Substantial aggregate areas	• Need for/lack of attention to proper feasibility studies
• Spreading of benefits spatially/reaching remote areas	• Lack of capacity (engineering)/low quality of construction, including resulting from use of general contractors without specific experience with dams
Management	
• Easy to maintain and manage	• Low management capacity (community/extension agents)
• Compatible with local culture and knowledge	• Need for/lack of attention to training
• Amenable to participatory management	• No sustained interest for participatory management • Lack of empowerment/ownership • Complexity of institutional (land and water) arrangements
	• Lack of maintenance/low performance
	• Local power structures impeding equitable access
Impacts	
• Multiple uses (irrigation, livestock, fisheries)	• Weak forward/backward links (market/inputs)
• Substantial impacts on economy (diversification)	• Conflicts
• Generation of employment opportunities	• Capture by local elites
• Buffer against climate variability/change	• Sensitivity to extreme events (droughts, floods, earthquakes)
• Promotion of local entrepreneurship	• Health (malaria) and environmental (pollution) issues
• Limited migration and related negative impacts	• Susceptible to rapid silt-up
• Limited social and environmental externalities	

Source: Adapted from Venot and Krishnan (2011).

Failure of small dam, can result in fatalities, destruction of property, and environmental damage. Some literature suggests that, in developing countries, higher risks are associated with small, rural dams rather than large, better-engineered dams. From 1993 to 2018, the rate of small dam failures per year reached 10^{-3} or one in 1,000, which is about 50 times that of large dams (ICOLD 2018).

There is a wide range of "small" dams. Across different regions and countries, small dams may take different forms and have different names, including, among others: small reservoirs, farm, and fish ponds (photo 1), silt retention dams, microdams, tanks, and anicuts (South Asia, photo 1), petits barrages

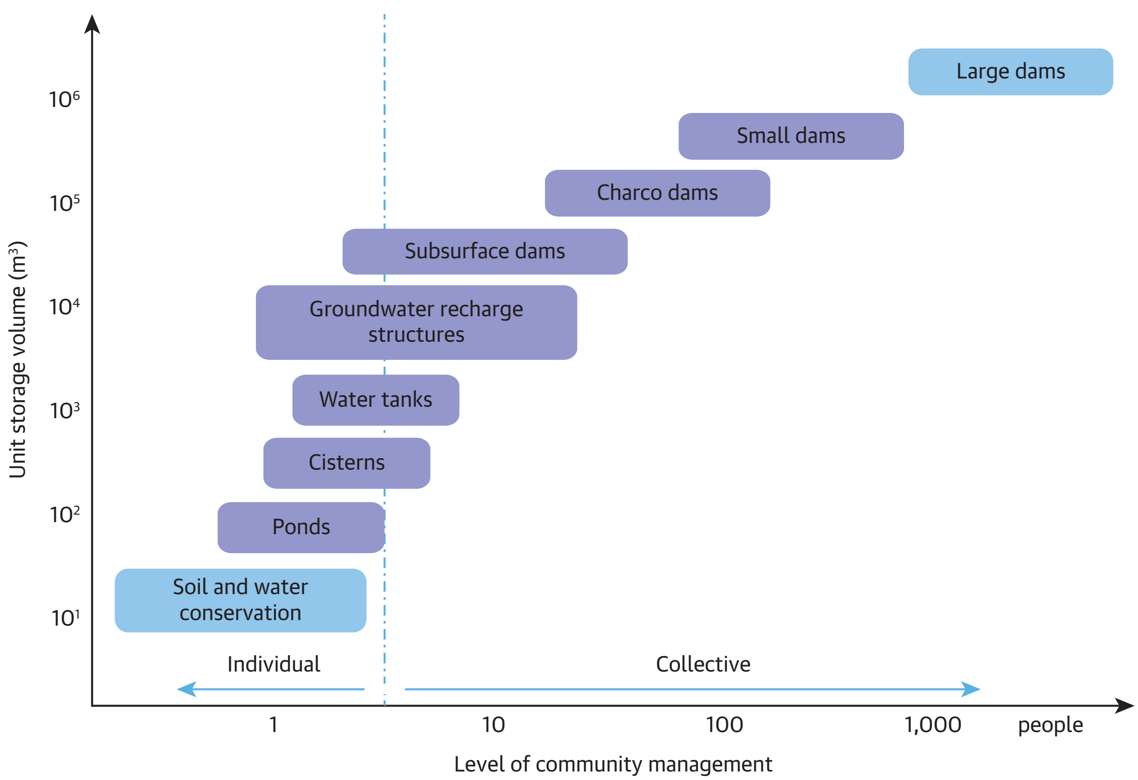
PHOTO 1: Examples of Small Dams

Sources: Photos courtesy of IWMI 2019; Nissen-Petersen 2006; Payen, Faurès, and Vallée 2012.
Note: (Upper left) Hafir in Kordofan, Sudan; (upper right) Charco dam in Tanzania; (middle left) Tank in Tamil Nadu, India; (middle right) Farm pond in Thailand; (lower left) reregulating small reservoir, California (courtesy of Charles Burt); (lower right) hillside dam, Kenya (Nissen-Petersen 2006).

(Sub-Saharan Africa), açudes (Brazil), charco dams (East Africa, photo 1), microdam (Ethiopia), sand dams (Limpopo), hillside dams (Kenya, photo 1), berkads (Somalia), hafirs (Sudan, photo 1), check dams (West Africa), valley dams, and subsurface sand dams.

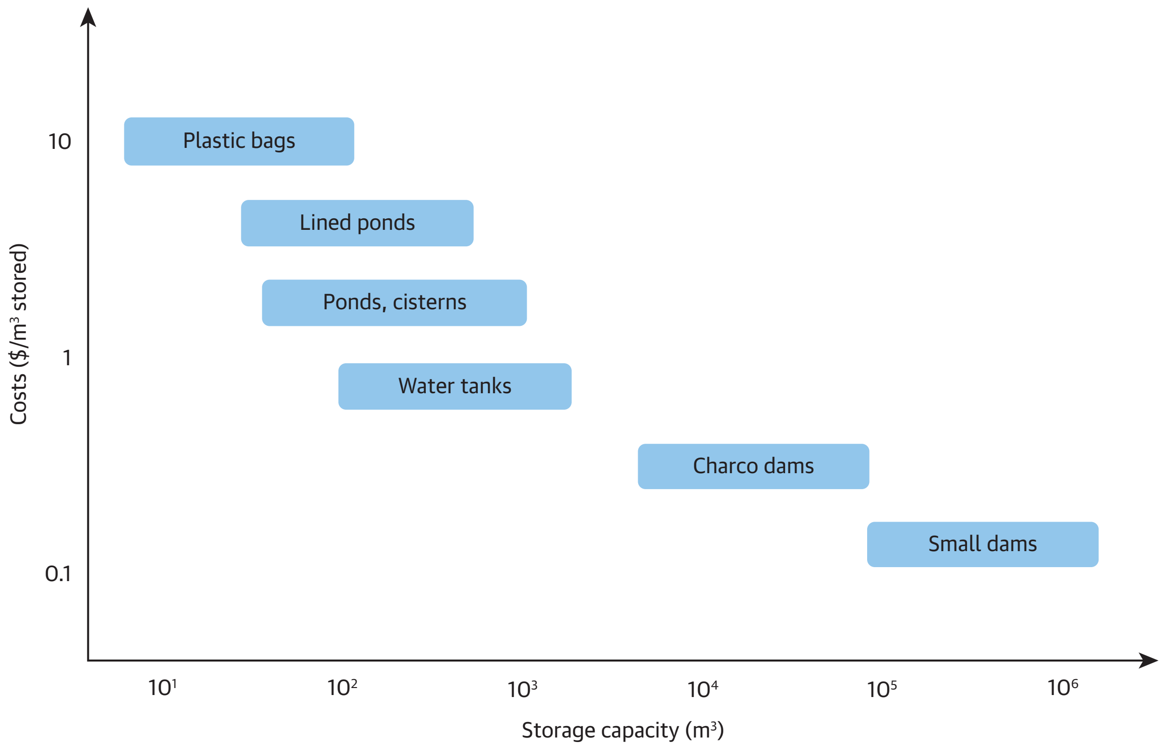
There are likely other terms used as well (especially in local languages). The technical dimensions of these structures will differ by storage volume, embankment height and length, construction material (for example, earth, rocks, or concrete), outlet types (for example, spillway, undershot gate, or sluice), and so on. The case studies in this report show this variety. Moreover, uses of the infrastructure, cost of construction, degree of community management and planning, level of surveillance/ O&M, and number of stakeholders involved can vary extensively from place to place (Payen, Faurès, and Vallée 2012). Figure 1 shows different water storage options against the level of community management required, and figure 2 shows the investment costs of different storage alternatives.

FIGURE 1: A Range of Water Storage Options



Source: Payen, Faurès, and Vallée 2012.
Note: m^3 = cubic meters.

FIGURE 2: Comparing Average Unit Costs for Different Water Storage Structures



Source: Payen, Faurès, and Vallée 2012.
Note: m^3 = cubic meters.

Legal and Regulatory Aspects of Management of Irrigation Systems and Small Dams

The case studies in Annex A demonstrate that in most situations small dams fall under existing local-level irrigation or agriculture department legislation (through issued guidelines, ordinances, circulars, manuals, and so on) and treated as "irrigation" infrastructure. In some cases, local irrigation departments may have dam safety divisions and associated guidance documents. For example, the Sri Lanka Irrigation Department has a separate division for dam safety and associated circulars[4] related to inspections to ensure dam safety. Note that this applies only to those small and large dams that remain under the direct responsibility of the Irrigation Department. The Ghana Irrigation Development Authority (GIDA) supports water users' associations (responsible for small irrigation dams) with dam safety manuals. In Japan, the Ministry of Agriculture and Forestry provides an Irrigation Pond Management Manual to the land improvement districts responsible for irrigation water management including small dams/ponds that are not subject to the national dam safety regulation. In the China case, the local water management bureau provides technical advice and training (including various procedural documents for farmers).

4 See http://www.irrigation.gov.lk/images/pdf/downloads/circular/id4_2013.pdf.

Case studies show that, although some governments, such as in Nigeria and Sri Lanka, retain the ownership and management responsibility of small dams, in others, there is legislation that deals with the transfer of a broad range of responsibilities for local irrigation assets (including small dams) to a community organization. These can take the form of water user associations (WUAs), water user groups (WUGs), village groups, or other user organizations. It is often difficult for government staff to regularly visit small dams in remote locations because of resource constraints. This is one of the main reasons for the transfer of some management responsibilities of irrigation systems and small dams to local communities. There are ample examples of legislative frameworks across the globe for community management of local-scale infrastructure, such as irrigation canals network (Hodgson 2003). The World Bank and other multiple development banks (MDBs) and bilateral institutions have long been involved in supporting these decentralization efforts and legislative frameworks in client countries.

Some of these frameworks define the detailed process for establishment of WUAs, WUGs, and their internal administrative structures, roles, and responsibilities in relation to their members, and local infrastructure management procedures (including fee structure and collection modality, voting procedures, conflict resolution procedure, and so on). Garces-Restrepo et al. (2007) review 43 country cases and identify key institutional elements of WUAs found in these frameworks (table 2).

The case studies in this report reveal that the legislative frameworks may not be explicit in the specific maintenance and inspection requirements of local infrastructure. The frameworks also do not provide guidance on a community organization's specific responsibilities for record-keeping, scheduled inspections by a professional engineer, and the development of emergency action plans for those small dams

TABLE 2: Institutional Elements of Water User Association Legislation

Element included in Institutional framework	Number of countries
WUAs have clear right to use and maintain irrigation infrastructure	32
WUAs have legal status to obtain credit and enter into contracts and to enforce sanctions against members who break rules	29
Arrangement for settling irrigation-related disputes, including process of appeal	26
Arrangement to extend technical advisory service to WUAs	24
Legal water right for WUAs	20
A policy to reorient the mandate of the irrigation agency	18
A policy to redeploy agency staff previously assigned to O&M	14
Legal water right for individual water users	14
WUAs have legal right to develop businesses and make profits	12
Organizational link for the WUA to water basin management	7
Almost no specific policies or legal framework for IMT/WUAs	5

Source: Garces-Restrepo et al. 2007.
Note: IMT = Irrigation Management Transfer; O&M = operation and maintenance; WUA = water user association.

with a high hazard rating. However, some of these technical details may be captured in individual O&M plans developed by the community organizations (for example, see the India case study).

Given that the protection of people and property is the ultimate responsibility of government, all aspects related to dams (for example, design, construction, rehabilitation, modification, operation, monitoring, maintenance, repair, abandonment, and removal) should rely on a legal framework that establishes rights, responsibilities, and duties for both the government and dam owners.[5] However, The legislative frameworks for community participation may not always be explicit with respect to public safety and accountability of community organizations.

Technical Requirements for Small Dams[6]

Safety of Small Dams

Various aspects of a small dam's management have been improved over the years to adapt the design standard, construction method, and O&M procedure to local contexts to minimize the potential risks of small dams. Design and construction procedures of small dams are sometimes simplified to maximize the use of local labor and to accommodate small local contractors.

Nonetheless, the safety standards and practices of small dams should be commensurate with their potential risks. There are small dams whose downstream consequence in case of dam failure is high. It is critical to ensure a balance between safety and economic/financial considerations and not to compromise the safety of downstream communities.

However, the technical and financial capacity of small dam owners and implementation entities are, in general, limited, and often tend to focus on cost saving, which can lead to the acceptance of higher risks. It is critical to provide adequate safety assurance and technical support through all phases from planning, design, and construction to O&M of small dams. The capacity assessment of key entities should involve national and local governments (the regulator or owner of the dam), designers, contractors, operators, community organizations, and so on.

Survey research in Brazil revealed that the failure of small dams was a result of overtopping (65 percent of cases), piping (12 percent), slope failure (12 percent), and other causes (for example, human error, improper construction, and poor operations) (12 percent) (ICOLD 2016). Many of these dam failures occurred during periods of severe flooding because small dams are mostly of the embankment type. Also, because small dams are usually located upstream of communities, their safety is directly linked to the safety of people and property in downstream communities. Furthermore, given the large number of small dams that may exist within a catchment and as part of a larger cascade—a common feature in South Asia (see the India and Sri Lanka case studies in Annex A)—their cumulative impacts from a system perspective may be significant and should be carefully evaluated.

5 Wishart et al (2020) provides detailed analyses of the legal and institutional aspects of dam safety assurance, including the roles and responsibilities among regulators, owners, and other entities with a wide range of models.

6 The following sections largely come from ICOLD (2016). Another excellent reference is CEMAGREF (2002).

Some differences (in comparison to large dams) to consider when evaluating the dam safety risk of a small dam (ICOLD 2016) include:

- Especially for small dams, decisions are often made in the context of budget constraints. This approach could lead to design criteria and construction methods with higher risk and more maintenance problems.
- The effort required by engineers for small dam design and construction monitoring is not much less time consuming than for large dam activities. However, because of resource constraints, significantly less time is devoted to technical services by clients of small dams. This circumstance leads to cost savings in investigation, design, and site monitoring, which lead to substandard designs and construction quality.
- Foundation and construction materials investigations are normally limited because of budget constraints. This limitation may result in additional costs and unreliable performance of the structure.
- Flood hydrology studies are sometimes inadequate.
- Sediment accumulation is particularly critical for small dams because of the limited storage capacity; useful life is consequently much shorter. This fact is often not taken into appropriate consideration in the planning phase.
- Normal seepage rates may affect the yield of small dams, and low water depth makes small reservoirs more sensitive to evaporation. Design should balance the cost of seepage control measures with expected water losses.
- Inexperienced small contractors are often employed to construct small dams. These contractors have limited resources and may not always construct high-quality structures.
- Small dam failure may cause large consequences[7] even though they are smaller in size because of the lower water head and water volume than large dams.
- One small dam failing in a cascade of small dams in a river system may cause the other downstream small dams to fail.

It is in this context that care must be given to ensure that reliable designs are prepared, the construction period is adequately monitored, and quality assurance and quality control are done properly. Adequate site investigation, design, construction supervision and quality control, and O&M tailored to the specific dam site condition and construction materials are important for small dams. Table 3 lists some conditions and influences affecting the safety of small dams and possible consideration for ensuring dam safety.

Ensuring proper design, construction, and quality assurance may require in-depth discussions on how responsibilities should be shared among central government, local government, and community

7 For example, failure of the Situ Gitang dam in Indonesia caused around 100 casualties.

TABLE 3: Typical Small Dam Safety Issues and Possible Safety and Resilience Enhancement Measures

Condition	Effect on safety	Possible safety and resilience enhancement measures
Inadequate spillway capacity (dam flood-handling capacity) caused by an undersized spillway, heightening of the spillway crest by owners not aware of the hydrological risks, insufficient freeboard, or obstructions in spillway (for example, tree growth)	Embankment can be overtopped and breached.	Appropriate flood hydrology study and assessment of the adequacy of the spillway size, including the freeboard and erosion control structures in the discharge channel Possible armoring (using roller compacted concrete, soil-cement, and so on) of downstream slope for critical sections to enhance resilience against overtopping erosion
Backward erosion of unlined open channel spillways adjacent to the embankment dam	Erosion of the spillway channel would reduce its discharge capacity and jeopardize its contact with the embankment core and eventual breach.	A concrete sill defining the spillway level and providing some protection against erosion. Lining (using soil cement and so on) and other erosion-control structures may be needed depending on the erodibility of the materials.
Uneven crest of embankment (which may be constructed uneven or settle); cattle footpath providing low point on crest of embankment	Embankment can be overtopped and breached because of a concentration of water in the low crest areas.	Adequate construction quality control; secure adequate camber Add compacted material to level crest Setting up a regular surveillance mechanism with local groups and an awareness-raising program
Wet areas or seepage through the embankment or foundation, as identified on the downstream face or in an area downstream of the embankment	Saturated conditions in the downstream shell can cause slope failure. Piping failure of the embankment can occur.	Setting up regular surveillance mechanism with local groups Sufficient cutoff system and core trench excavating down to the foundation with targeted permeability; no permeable layers left in the foundation Place inverted filters.
Obstruction of the internal drainage system	The phreatic surface may raise in the dam body.	Sufficient design/width of drain and filters Enhanced surveillance and periodic inspection to detect potential issues Monitoring of seepage records and analysis of its correlation with the reservoir water level and its long-term trends Add drainage berm at downstream toe.

table continue next page

TABLE 3: continued

Condition	Effect on safety	Possible safety and resilience enhancement measures
No internal drains and filters provided, especially for embankments constructed with dispersive clays	Piping failure can occur, most commonly during the first reservoir filling.	Proper design with drain and filters (chimney, blanket, or at least a large toe drain) and quality control of construction materials Undertaking appropriate soil and geotechnical investigation to identify and avoid problematic construction materials and ensure a selection of suitable materials for respective zones Adequate monitoring for the first filling
High seepage water along or into an outlet pipe; conduit pipes that may crack as a result of settlement, or the pipe materials that may degrade (for example, wooden pipes exposed to air and water).	Piping failure of embankment along the bottom outlet can occur.	Provision of the outlet pipe encasing and use of suitable quality pipe Avoiding placing outlet pipes inside and over the embankment structures and excavating trench foundation and backfill with suitable materials to the top of the encasement Proper design, construction, supervision, and quality control for the core/concrete contact Add downstream filters.
Piping (or internal erosion) at the interface of an embankment and retaining wall for the spillway control section and discharge channel	The embankment can breach at that point.	Proper design and construction quality of the earth/concrete interface. Special care is required in placing earthfill against concrete structures. The spillway excavation can start where the embankment crest level meets the natural ground level, eliminating the need for a reinforced concrete retaining wall.
Embankment cracks or slope failures	An embankment breaching failure can occur.	Proper compaction of embankment materials Suitable zoning (core, general fill, filter zones, and so on) because homogenous fill would give the contractor no indication of where to place suitably selected materials
Tree growth on embankments—roots damaging the embankment especially when dead	Piping failure of the embankment can occur.	Regular surveillance and maintenance work program with a local group Awareness-raising program
Burrowing animals that excavate tunnels in the embankment	An embankment slope failure or seepage failure may occur.	Regular surveillance with a local group and an awareness-raising program

table continue next page

TABLE 3: continued

Condition	Effect on safety	Possible safety and resilience enhancement measures
Compaction of earthfill not meeting standard	Uncompact embankments experience settlement, seepage, and slope failure problems.	Enhancement of construction quality control: material compaction at the optimum moisture (avoid saving of moisture conditioning or constructing a dam in wet season) Placement of embankment material (avoid too thick layers to speed up construction)
Damage to the upstream slope of the embankment because of wave action	This damage may cause upstream slope instability and erosion of the crest with wave water overtopping and breaching of the embankment.	Provision of suitable upstream slope protection, such as ripraps with rock materials that do not disintegrate during the life of the dam
Ineffective downstream slope protection ; erosion of slopes of embankment by storm water	Slope surface erosion may occur.	Use of some geosynthetic mats to maintain grass cover; surface drain and berm to control surface runoff erosion; placement of ripraps with suitable rock materials, and so on
Absence of monitoring devices.	The behavior of the embankment and associated structures spillway cannot be monitored.	Installation and maintenance of a minimum set of essential and basic monitoring instruments, such as reservoir water level gauge, v-notch seepage measure, standpipe piezometer, and survey monuments
Siltation of reservoirs	There may be clogging of bottom outlets for discharge and possibly reduced flood attenuation function of reservoirs .	Periodic sediment deposit excavation, catchment management, and so on (see Annex D for more details)

Sources: CEMAGREF (2002); Hagen, Anderson, and Hattingh (2018); ICOLD (2016).

organizations, especially in cases in which capacity constraints are a motivating factor in the delegation of responsibility from government to community organizations. Consideration should also be given to the potential application of remote sensing and communication engagement in the detection of potential problems where applicable.

Operation and Maintenance Requirements

Generally, small dams have fewer physical O&M requirements compared with large dams. These requirements include monitoring and operation of inflows and outflows from the structures, maintenance of hydraulic control structures and the small dams, monitoring of sedimentation, and general safety management. Though they may be minimal in scope and level of effort, regular surveillance (that is, inspection) and maintenance of small dams remains an important practice to ensuring the long-term safety and operation of the small dam.

Most of the case studies in which these responsibilities for small dams were transferred to community organizations revealed very few cases of regular technical inspections. This is a training, resource, and staffing issue. The Ingomar Reservoir case study (in California), in contrast, presents a good example of an effective professional irrigation district (supported through membership fees and service delivery fees—both a fixed amount based on area irrigated and a variable amount based on water usage) that generates sufficient funds to undertake regular O&M. Similarly, in Japan, the land improvement districts (LIDs) also generate sufficient funds to undertake the required O&M of small dams under local community responsibility. The Sri Lanka Irrigation Department, which retains ownership of small dams, assigns a division engineer to visually inspect the dams and other equipment monthly and critical sections of the small dams weekly during the rainy season. Monthly inspection reports are produced as required in the dam safety circular. In other cases, a distinction is made between "major" and "minor" (for example, canal cleaning) maintenance, with major maintenance still the responsibility of the government (for example, see the Gum Selassa Ethiopia case). Good practice would include regular visual inspections using simple equipment and techniques—for example, regular and close examination of the entire dam surface and its immediate surroundings; appropriate measurements of cracks, surface erosion, and soil transported by leakage; and keeping concise and accurate records of observations.

Careful surveillance and inspections can provide important clues to the behavior of the structure. Embankments should be examined for any evidence of displacement, cracks, sinkholes, springs, or wet spots. Any of these conditions may be in a developing mode and lead to failure if not corrected. Visual observation along the line of the embankment roads, parapet walls, utility lines, longitudinal conduits, or other lineaments parallel or concentric to the embankment axis can help to identify surface movements. The crest should be examined for depressions and crack patterns that could indicate sliding settlement or bulging movements. Embankments should be examined for any signs of bulging, depression, or other variances. Cracks on the surface may indicate potentially unsafe conditions. Openings or escarpments on the embankment crest or slopes can identify slides. Surface cracks near the embankment abutment contact can be an indication of settlement of the embankment. The downstream face and toe of the dam should be examined for wet spots, depressions, sinkholes, or springs, which may indicate concentrated or excessive seepage through the dam and abutment. Finally, drainage systems should be inspected for increased or decreased flow and for any obstructions. Obstructions such as trees and bushes brought into a reservoir after floods should be cleared immediately, a practice that, unfortunately, is far from being generally applied.

By routinely monitoring the conditions and performance of the small dam and its surroundings, necessary maintenance can be identified to avoid the development of potential hazards. For continuity and consistency of approach, it is recommended that the same person or team should normally carry out each type of inspection, and when necessary, an experienced engineer brought in to inspect or advise about particular problems. This professional engineer should have experience in design and familiarity with construction, operation, and maintenance of dams. If such individuals are not routinely available, then at least obtaining the services of an engineer to set up the first program of inspection, using a simple pro-forma checklist to record observations, is recommended (see Annex B).

The case studies reveal that although community organizations may be expected to contribute to the O&M of small dams, they often face challenges in obtaining required technical support as described earlier, especially in the context of remote rural locations. The local government departments should provide critical support—in addition to the local irrigation departments, local agriculture departments and extension officers may be a source of support. As such, all projects should be designed to include such technical provisions (both staff and resources), and efforts should be made to ensure that adequate government budgets are allocated in the longer term to support these communities on technical matters.

Surveillance and Monitoring of Small Dams

Surveillance and monitoring should provide the means to detect anomalies and evaluate how fast they are occurring. Parameters to monitor include reservoir water level, leakage and seepage measurement (both visually for any cloudiness or fines in the seepage water and for unusual changes in flow rates), and displacement measurements such as settlement. Measurement of uplift and pore water pressures is usually not critical for small dams, but it may be necessary in special cases in which there would be need for expert guidance at the design level. Nonetheless, some minimum level of instrumentation is needed for proper dam supervision. In all cases, regular surveillance by staff with basic training is necessary. It *is important to keep in mind that a small dam with no instrumentation should not be a dam with no surveillance*. As a benchmark, ICOLD (2016) recommends the following types and numbers of devices (table 4) for small dams with a high (level III) potential hazard classification (ICOLD 2016), which is also covered with a classification matrix and diagram in Annex C of the GPN. CEMAGREF (2002) also provides some useful guidance on monitoring instrumentation.

ICOLD (2016) also suggests that the use of standpipe piezometers is recommended given that monitoring maintenance may be limited. Moreover, it is important to install one or more weir gauges to monitor the leakage. Further, guidelines on placement and installation are given in ICOLD (2016). Note that in the case studies, very little of such monitoring is taking place. Even basic hydrological flow gauging at the small dam sites is minimal. This is important for understanding and monitoring the inflows into the small dam. All projects should make provisions to include such instruments as part of the construction contracts (costs are minimal for these devices).

TABLE 4: Recommended Types and Numbers of Instruments for Small Earthfill or Rockfill Dams

Instrument (parameter)	Location	Normal geology	Special geology
Piezometer (uplift water pressure)	Right abutment	2	5
	Central section	3–5	6–8
	Left abutment	2	5
Weir gauge (seepage water)	Right abutment	—	1
	Central section	2	2
	Left abutment	—	1
Benchmarks (displacements)	Crest	Lc/50	Lc/20
	Berm (eventual)	Lb/50	Lb/20

Source: ICOLD (2016).

Note: Normal geology refers to when it is enough to monitor only one foundation layer with piezometers and special geology refers to when more than two levels of foundation need to be instrumented. — = usually not required; Lb = length of the downstream berm (meters); Lc = length of the crest (meters).

Improving Construction Quality

The challenges associated with quality assurance during construction are not unique to small dams and can be found across a wide range of rural infrastructure investments (for example, rural roads). The capacity and capabilities of local contractors vary. As such, obtaining knowledge about the local construction market is a useful exercise (during project preparation) in setting the qualification criteria for procurement (for example, equipment availability or volumes of material excavated). Proper testing is also needed during construction (for example, mechanical characteristics of soil and compaction quality) at regular intervals with the issuance of relevant certificates. A qualified engineer needs to supervise this testing.

However, the capacity for government officers and engineers to supervise and manage contracts can also vary. Thus, to minimize the likelihood of poor construction, project activities may also consider (a) training administration and project teams on procurement and contract management; (b) improving the preliminary costing of works; (c) applying strict prequalification criteria for contractors; (d) strengthening the capacity of the engineering supervisors; (e) enforcing contractual clauses on delays, penalties, and so on; and (f) systematically opting for design options that are simpler to construct.

Moreover, based on the World Bank-financed project experiences, mobilization of third-party quality-assurance monitoring consultants may be considered during the construction period. These consultants essentially provide additional staffing resources to the line department to support construction supervision and undertake supplemental quality-assurance tasks. Some challenges may exist in practice, which should not be underestimated (for example, acceptance of consultants by local engineers and departments).

Engaging local communities with construction supervision also shows some promise. This is particularly relevant when these small dams (either new or rehabilitated) will be transferred to local communities for future management and O&M. Though local communities may not have the requisite engineering skills, technical support can be brought in to ensure coordination and interactions between the contractor and the final users or owner of the small dam. For example, tank user groups in Karnataka under the World Bank-financed India Karnataka Community Based Tank Management Project were involved in signing and confirming with field engineers the data measurement book. This book was then used as the basis for the issuance of payment certificates to contractors. "OK cards" were also used by the tank user groups to certify the completion of individual items from the bill of quantities. Building community engagement with surveillance of dam safety requires the development of new tools to make information and practical tools on monitoring dam safety more readily available to a wide variety of audiences.

Also, mobile phones and web-based georeferenced information and communication technology (ICT) can be instrumental in collecting and analyzing feedback from community members and gauging community awareness of dam safety plans; as such, tools have been applied for several water supply and sanitation projects, and so on.[8] This kind of citizen feedback can help monitor the quality of

8 For example, the Water and Sanitation Program for Pimpri Chinchwad Municipal Corporation in India.

construction works and service delivery in remote places, and such a possible arrangement should be considered.

Finally, careful attention needs to be given to the construction period and the schedule of works. Work planning is critical to ensure that construction is done properly and not expedited (beyond what is reasonable) as a result of a short construction period or limited budget, because that may increase the likelihood of poor-quality outcomes. The quality assurance can be complemented by using ICT applications that allow communities to share visuals with experts located off-site for remote monitoring. Also, consideration should be given to minimizing disruptions to the current irrigation practices.

Lessons Learned for Community Participation in Irrigation Management and Small Dam Safety

Although most reviewed literature deals with broader institutional and social aspects of irrigation water management, 21 case studies more specifically reviewed the institutional aspects of small dam management and useful lessons and challenges.

In many developing countries, the government agency responsible for water infrastructure (both large and small) often faces financial and staffing challenges with the effective and efficient operation, management, and maintenance (OMM) of such infrastructure. Large infrastructure tends to be prioritized by the government, often leaving institutional gaps for OMM of irrigation delivery systems (for example, tertiary-level canals and hydraulic works) and other small infrastructure. As such, most MDBs and bilateral institutions providing support in the irrigation sector have assisted in modernizing the irrigation sector through efforts to decentralize OMM responsibilities of local infrastructure to community organizations (Johnson, Svendsen, and Gonzalez 2004). These institutional reforms have also contributed to modernizing the local governments, including reorienting these irrigation departments to be more customer-focused.

Though specific legislative frameworks may differ across countries and regions, community organizations (for example, WUAs or tank user groups) have increasingly been given the responsibility for OMM of local infrastructure, such as irrigation systems, including the tasks of setting and collecting user fees, performing regular maintenance, delivering services to their members, and resolving conflicts across users. Ample evidence exists that communities will undertake collective action to maintain communal infrastructure (Meinzen-Dick, Raju, and Gulati 2002) and that performance of the infrastructure is enhanced when communities are involved (Venot, de Fraiture, and Acheampong 2012). The Mexico case is often touted as a successful example of this transfer of responsibilities (Garces-Restrepo et al. 2007; Kloezen, Garces-Restrepo, and Johnson 1997). Many other positive examples exist, to varying degrees (for example, Albania, Armenia, Kyrgyz Republic, Portugal, Spain, and Turkey). For a general review, see Garces-Restrepo et al. (2007) and Playan, Sagardoy, and Castillo (2018). In general, greater success has been observed in Asia compared with Africa (Mutambara, Darkoh, and Atlhopheng 2016).

The spatial scale that these organizations cover may vary (for example, tank catchment, hydraulic boundaries, or watershed). These organizations are in a good position to understand their own physical and social environments and use their local knowledge effectively to solve problems. It is increasingly recognized that communities should also be involved in the siting, planning, design, and construction of irrigation systems. Common ownership of the water source by a wide range of beneficiaries (and customers) helps ensure that the infrastructure is operated and maintained properly. Community members will also be more likely to be engaged in future calls for help in repair and maintenance work (for example, removal of sediment from the small ponds) (Nissen-Petersen 2006). Pisaniello and McKay (2015) argues that in the developing country context, the quality of small dam safety assurance can be achieved only if the local communities who are exposed to the threat of dam failure are empowered and involved in local dam safety management and preparedness. However, given the diversity of complex social environments and of potential divergence between the interests or space for negotiation and collaboration between downstream and upstream communities (for example, in countries affected by conflict or where minority ethnic groups may be less engaged in community structures), it is important to seek independent engagement of both communities in the vicinity of the dam and those most likely to be affected downstream by failure.

The case studies illustrate the diversity of approaches and varying levels of small dam management among community groups, such as WUAs and WUGs, and national or provincial governments. In some cases, the “owner” of the small dam remains with the government. For example, in the case of Nigeria, dams are operated under the government water supply corporation, and the community notifies the government if an issue of safety or environmental quality arises. In the China case, the local township is the owner and the village is given responsibility for OMM. In the Sri Lanka case studies, two dams are owned and operated by the irrigation department of the national government, and one dam is managed by a farmer group under the provincial council and national government.[9] In the Vietnam case studies, all eight dams[10] are owned and managed by state-owned irrigation management companies with hiring of local farmers for some basic works. In other cases, more-traditional water users’ organizations (for example, Ghana, India, Sri Lanka, Burkina Faso *Handi*, U.S. irrigation districts, and Japan land improvement districts) and even “cooperatives” (for example, see Burkina Faso rice cooperative and the Ethiopia irrigation cooperative) are used. The experience with community management of small dams varies across these cases, with some successful cases in California, Sri Lanka, Japan,[11] and so on. In any case, it

9 North Western Provincial Council and Department of Agrarian Development. The demarcation of these two governmental entities is unknown.

10 This was confirmed for all eight cases initially studied. Eventually, two of the eight dams were selected for developing case sheets included in the folder of small dam case studies. The Ministry of Agriculture and Rural Development in Vietnam confirmed that it is challenging for community groups to properly operate and maintain even small dams that needed to be transferred back to state-owned irrigation management companies at a meeting in January 2020.

11 Under the Land Improvement Act (LIA), the national government, prefecture, municipalities, and LIDs are responsible for implementing some agricultural and rural development projects including O&M of drainage and irrigation facilities. Approximately 60 percent of essential irrigation facilities, including dams, canals, and drainage built by the Ministry of Agriculture, Forestry and Fisheries (MAFF), and prefectural governments, are transferred to LID for O&M. Also, more than 70 percent of 210,000 “tameike” or irrigation ponds are managed by villages and WUAs. Farmers in the LID are obligated to participate in the O&M works. LIDs are composed of at least five board members and collect fees from the member farmers as per the LIA. This system instills a sense of responsibility in the community for maintenance of the facilities. The MAFF and prefectural governments conduct audit and inspection of LIDs to ensure proper administration and financial management as per the LIA.

is important for governmental regulators to provide periodic oversight and technical support for safety assurance of those small dams.

What all these case studies demonstrate is the challenge of fully empowering these community organizations and building sufficient capacity to collect funds and undertake full OMM of these small dams. Collection of funds to support maintenance was mixed across the cases, with most community organizations collecting fees on either a seasonal or an ad hoc basis. Members will be more inclined to contribute when the structure and community organization are able to provide an improved service to its members (see Mclean dam in the Ghana case). Although the oversight and technical support roles of local government are also often inadequate, there are some positive examples, such as the Ghana Irrigation Development Authority, which provides oversight responsibility over water user associations, and in the China case, in which the local municipality provides partial budget to support the two farmer dam safety operators. In Vietnam, challenges with community ownership have resulted in transferring back the ownership and management responsibility from water user groups to state-owned irrigation management companies.[12] Moreover, across these cases, limitations are observed when a narrow view of the users of the small dam is adopted (for example, Ethiopia cases, Ghana nonlandowners, and Burkina Faso upstream versus downstream [Fraiture et al. 2014]). These cases illustrate the importance of having a broad view on the "users" and "uses" of the small dam and undertaking a careful stakeholder analysis; doing so from the beginning of the reform process will help minimize conflicts. It is thus important to undertake proper stakeholder assessment with guidance from social and institutional specialists from the beginning of project preparation.

The capacity of these community organizations, especially newly created ones, is not limited in just these cases but is an observed common challenge worldwide (Payen, Faurès, and Vallée 2012). The performance and effectiveness of these organizations has been widely investigated with (not surprisingly) mixed results (Acheampong, Ozor, and Sekyi-Annan 2014; Nikku 2006; Nkhoma 2011; Playan, Sagardoy, and Castillo 2018; Suhardiman and Giordano 2013; Umamheshwara 2009; World Bank 2012). For example, Umamheshwara (2009) demonstrated low participation in established tank user groups in Karnataka, India in the Haveri District. This is despite the observation that those who participated in the tank user group showed greater crop yields and annual incomes. Low participation rates among community group members undermines their ability to recover its costs and be financially sustainable. This is in contrast to the professional Irrigation Districts in the United States and LIDs in Japan that successfully raise funds to provide services to its community members.

Playan, Sagardoy, and Castillo (2018) and Garces-Restrepo et al. (2007) reviewed the international experience and summarized some common problems to the transfer of irrigation management to local community organizations. These problems include resistance from government officials and farmers themselves. Government agencies may resist reform because there is lack of political support for decentralization, it requires new expertise within the government agency, and decentralization implicitly

12 At the provincial level, all large and medium-size dams are managed by provincial irrigation management companies (IMCs), whereas small dams are entrusted by IMC to local communities for O&M (IDA Dam rehabilitation and safety improvement project PAD 2015).

means a downscaled role for them. Farmers may also resist simply because they are suspicious of government and reluctant to adopt new responsibilities. Changing from existing practices and norms will only be possible if the new approach can demonstrate tangible value to both the community (and its members) and the government departments. Also, in many cases, not enough is done to spread information to farmers about the details of the reform and the benefits. Other common challenges include weak legal frameworks (for example, lack of clarity regarding water rights), poorly designed construction rehabilitation projects (for example, lack of community involvement), transfer of degraded irrigation systems, weak technical and managerial capacity of community organizations, inadequate collection of funds for cost recovery, and interference between community organizations and other entities (for example, government and agricultural cooperatives). These issues are seen across the case studies.

Finally, a key finding from the cases and the literature is that historically in many places, community participation to irrigation water management was already the norm (for example, India [Reddy, Reddy, and Palanisami 2018]; Burkina Faso [Annemarieke et al. 2011]). That is, in many places where irrigation systems including small dams are planned or existing and will be rehabilitated, it is likely that rules and agreements already exist for the common property resource (especially in Sub-Saharan Africa). Failures with new community organizations can be attributed to insufficient recognition of these preexisting land and water rights and customary uses (Payen, Faurès, and Vallée 2012). Aubriot and Prabhakar (2011) observe, for instance, in Tamil Nadu, India, that WUAs (to manage tanks) were created without considering the existence of customary institutions and their ways of managing tanks, and thus the WUAs either ran parallel to the latter, led to their decline, or ensured continuity with them. In the end, the success of these community organizations often will lie in the hands of the local elite. As such, the existing social and cultural norms of local groups need to be carefully considered when "new" local water management-focused institutions are being introduced.

It should also be noted that when new community organizations are being introduced, they create a complicated landscape involving many new stakeholders. Venot, de Fraiture, and Acheampong (2012) demonstrated a wide variety of actors typically involved in the governance of small reservoirs (table 5). Overall success in part depends on being able to coordinate and integrate across these different user and social groups regarding a single common dam resource.

In summary, building a functional long-lasting community organization with the responsibility for OMM of irrigation systems including small dams takes time (many years at best). It also requires significant support and training from the government and other entities. Provisions for this support needs to be included in irrigation projects including small dams. Expectations should be set appropriately. Some essential ingredients for successful community irrigation water management are provided in the Recommendations section.

Environmental and Social Impacts

The range and types of environmental and social issues that may arise from a small dam are likely not that different from a large dam. Although the environmental and social impacts of a small dam are likely to be

TABLE 5: Division of Responsibilities in the Management of Small Reservoirs

	Line ministries	Donors	Contractors	Local government	Traditional authorties	User committees/WUA	Community	Farmers	Others
Construction	**39%**	5%	**30%**	6%	3%	2%	4%	2%	3%
Major maintenance	**41%**	13%	6%	18%	2%	8%	4%	3%	3%
Minor maintenance	4%	0%	0%	5%	4%	**34%**	**46%**	6%	3%
Setting of management rules	4%	0%	0%	4%	23%	**40%**	23%	6%	2%
Implementing, monitoring rules	5%	0%	0%	4%	12%	**47%**	24%	6%	4%
Relation with other actors	14%	1%	0%	10%	11%	**39%**	19%	3%	5%
Conflict resolution	6%	0%	0%	9%	**60%**	22%	13%	1%	2%
Environmental protection	9%	0%	0%	4%	9%	**33%**	**34%**	10%	3%
Extension role	**69%**	2%	0%	2%	2%	5%	2%	0%	6%
Agricultural practices and marketing	12%	0%	0%	1%	4%	12%	13%	**49%**	6%

Source: Venot et al. 2012.

significantly less, a proper environment and social assessment should be undertaken to assess the impacts and associated risks, including those related to potential failure of the small dam, on local communities and assets. When multiple small dams are constructed within one catchment, the cumulative effect could be significant and should be carefully assessed. It may be useful to assess the role of national or regional agencies in charge of hydromet monitoring including other nongovernmental entities such as academia, civil society organizations, and so on for possible timely provision of hydromet data. It is also important to assess how representatives of local committees manage irrigation systems and dams in a participatory manner, and whether they have proper tools and incentives to work with those using land around the dam in both upstream and downstream areas and to shift behavior and reduce potential areas of conflict. It is important to consider these kinds of issues, following the ESF, including ESS1 to ESS10, relevant Guidance Notes for Borrowers and GPNs and seeking guidance from the environmental and social specialists.

Recommendations

The original International Water Management Institute study reviewed broad dimension of community participation in irrigation water management (IWMI, 2019), and this Technical Note draws on its extensive literature review to provide a high-level overview for irrigation water management. In many cases, small dams in rural areas are part of the irrigation system and planned, designed, and constructed under broader irrigated agriculture or rural development projects.

As a matter of principle, regardless of whoever owns small dams—national or local governments, WUAs/WUGs, or other forms of communities—it is important to ensure dam safety in planning, design, construction, and O&M phases. Despite a small scale in height and reservoir capacity, downstream potential consequence in case of dam failure could be high, but the technical and financial capacity of the owners and operators of small dams are often limited. It is thus critical to ensure adequate quality assurance at all phases of small dam construction and management by various stakeholders in the most effective manner with due consideration to the limited resources generally available.

Community participation can be useful and effective for enhancing the operation, maintenance, and safety assurance of small dams as part of broader irrigation water management. The community organizations in the form of WUAs, WUGs, or others can play a critical role for basic surveillance, O&M, emergency notification and action, and so on of small dams as part of the irrigation network management in coordination with and under the guidance of governments. Thus, involving the community in siting, planning, design, construction supervision, O&M, and surveillance is essential for maximizing and sustaining the benefit of small dams. It also increases the likelihood that a community organization will undertake the responsibility of operation, management, and maintenance of the irrigation system/small dams. Building the capacity for community organizations and community participation for irrigation system/small dam management requires dedicated training. Provisions for this support must be included in the project components.

Based on the case studies and literature review, some key factors that are needed or desired for successful community participation in irrigation water management, including irrigation networks and small dams, are summarized as follows (a summary of good practices is listed in Annex D):

Build high-level political support. To change the status quo (for both government and communities), commitment at the highest possible government level is needed for a sustained period. Experience in the World Bank projects shows that this is understandably difficult to obtain and sustain. Nonetheless, as is evidenced in the successful case of Mexico and elsewhere (Garces-Restrepo et al. 2007), teams will need to make concerted efforts to build a broad range of political support to build the foundation for reform. As demonstrated in the case studies and literature, transferring OMM to community organizations does not mean there is no longer a role for the government agency. In fact, government involvement is essential to overall success. Government plays an important role in supporting the decentralization process and helping to empower and build the technical and managerial capacity of community organizations and community participation. This role could be helpful if the existing government agencies support this process and work hand in hand with community organizations as part of broader irrigation sector reform. Government can also support community organizations in other ways, including where there is a need for mediation between upstream and downstream communities or where social structures inhibit inclusive community engagement that can prevent fulfilment of dam safety responsibilities.

Put in place a regulatory framework for community participation and collection of funds. The establishment of regulatory framework enabling community participation in planning, design, construction, and O&M of irrigation system/small dams would be instrumental in enhancing the safety management and maximizing the benefits of small dams. The regulatory framework is recommended to offer a provision that community organizations may collect funds to support the O&M of their infrastructure. The respective roles of the national and local governments, along with a community organization and its members for safety management of small dams as part of the irrigation system management, should be assessed. Careful attention should be given to addressing critical regulatory gaps that may be constraints to community contribution to irrigation system/small dam management.

Fill legal gaps for both community organizations and government agencies. Even if legislation on community management is in place, further adjustments and amendments may need to be made. Practically, it is not straightforward to legislate all aspects of irrigation governance including, among others, financial transparency, equity in water allocation, dispute resolution, collective decision making, equity in cost allocation, and the relationship between the community organization and government department. New problems will often reveal themselves during implementation of the reform process (see the India case study and budget flow issues requiring further changes to the legislative framework). This scenario is common across the World Bank-funded irrigation projects. In parallel, restructuring of the local government departments is needed because the existing bureaucracies are unlikely to initiate nor see the need for reform of the sector (Nikku 2006). This restructuring includes a reorientation toward supporting community organizations in terms of both technical and management capacity building, including considering the existing social and cultural norms of local groups when establishing new community organizations. Government should provide regulatory oversight of small dams and technical guidance/support for community organizations. Gaps in the legislation should be addressed to prevent the discrediting of these community organizations in the early years of implementation.

Recognize multiple users and objectives. Stakeholder consultations and analysis is needed during project preparation to understand the multiple users, multiple objectives, and multi-governance arrangements. In many cases, the small dam's pool is a common resource, meaning that there are multiple beneficiaries making use of the resource. For small dams, these are usually the communities living near the dam, such as farmers, irrigators, livestock owners, and domestic water users. These groups would need to be represented in the community organization responsible for the OMM of the irrigation system/small dams. Rules and procedures will need to be clear to manage what may be conflicting users (for example, see the Burkina Faso and Ethiopia case studies). Moreover, farmers must receive economic benefits from the irrigation system/small dam to ensure their participation. As such, this means ensuring that this infrastructure is linked to the broader rural system. Many projects focus on the construction aspects of irrigation system/small dams and fail to explore the relationship between the infrastructure and the broader agriculture systems.

Undertake institutional analysis and awareness campaigns. If there are existing organizations that can take on the responsibility of OMM of irrigation systems/small dams, such as WUAs and WUGs, the assessment of those entities' current capacity, which often depends on high participation rates, is important. Enhancement of existing organizations is critical, and if such entities do not exist, new management organizations may need to be set up. As such, it is important to understand the existing institutional landscape of both formal and informal organizations. Significant attention and care should be given to define who is included in the "community." Care should be taken to identify and involve all potential stakeholders (formal and informal) of small dams in connection with irrigation system management, including women who in some countries represent a significant majority of clients yet who may not be allowed to own land and thus are excluded from decision making,. Communities may be more engaged when wider objectives and uses of small dams are considered (for example, better links to agricultural and rural development systems). It is also important to assess potential adverse impacts on formal/informal land tenure, gender implications, and both national- and local-level governance environments, and so on seeking guidance from social specialists.[13] In any reform process, it will be critical that future members of a community organization are aware of the reform process and the benefits it will bring to the community. Finally, the government office is also an important stakeholder. It is important to assess the institutional mechanism and capacity of the government office so that they can periodically provide sufficient oversight and technical support for community groups. Delegation to a third-party agency may also be considered. It is also instrumental to facilitate building or enhancing the relationships between the government field staff and the community organizations (much like the agriculture extension officer and farmer relationship).

Early involvement of beneficiary community organizations in planning, design, construction, and O&M of irrigation system/small dams. Experience demonstrates that involving community and end users early in project design increases the chances of future engagement with the maintenance of local infrastructure. Community participation will increase localized benefits and more-acceptable and -sustainable outcomes. By engaging with users in the design of the system, those issues of the most concern will come forward and can be accounted for in project design. To this end, FAO (2010)'s requirement is a good practice: "All designs and installations must be completed with the full participation of the end users to ensure that they are appropriate and sustainable.". In the case of infrastructure management transfer, it is crucial for community organizations to receive functioning infrastructure and that the community organization can provide an improved service to its members/farmers. This is essential to establish legitimacy of community organizations. At the same time, beneficiaries' financial or in-kind contribution could improve maintenance of small dams. Community engagement in construction supervision also increases the likelihood of better-quality construction outcomes. Participation in O&M could contribute to enhancing the safety of small dams through basic surveillance and monitoring and emergency preparedness. It is worth noting that, in practice, engaging users means engaging women because they make up more than 40 percent of farmers. Inactivity of farmers is often a result of the production of nonprofitable crops, subsidies in the form of food or other commodities, or completely degraded infrastructure and soil conditions.

Ensure financial support. Local governments or relevant authorities should empower community organizations to collect funds to support the O&M of irrigation systems and small dams. Funds may be

13 In several cases, including those in areas with significant levels of indigenous populations, when small dams are associated with newly introduced small-scale irrigation, the institutional reorganization can be associated with a movement toward increased formalization of land title. In several cases, it prompts a shift away from de facto control over land use according to different roles within the family farm or under indigenous practices, toward consolidating sole legal control to the man of the household, who is more often the recipient of formal titles.

collected on a seasonal or area basis but should be regular. In more-advanced situations, fees would be collected based on use (for example, a volumetric irrigation service fee). In some areas, collecting funds is usually a challenge and therefore in-kind contribution (for example, labor) is an acceptable alternative. In cases in which government retains ownership of the irrigation system/small dam, local communities may be hired (or provided grain, inputs, and so on) for maintenance work. It is also important to secure funds for safety management of small dams in addition to the O&M of the irrigation network because the benefit of dam safety is sometimes more difficult for local farmers and beneficiaries to appreciate than that of irrigation systems.

Monitor and evaluate community organizations. To support a continual improvement process, monitoring and evaluation of the performance of community organizations against a set of key indicators will be critical for success. Benchmarking of irrigation systems/small dam management among community organizations would be useful in terms of O&M, basic surveillance, reporting, and so on to learn main issues, lessons, and so on for one another and provide motivation for better performance. Developing a communication strategy for community organizations, and upstream and downstream users, is critical to engage with them meaningfully throughout the project cycle.

Consider community contribution to broader dam safety management. Given major challenges with cataloging and inventorying all small dams,[14] communities and civil society actors with an interest in sustainable water use can play an important role for supporting the development and upkeep of an inventory of small dams.[15] The communities could also provide support for the land use conservation and restrictions in the upstream catchment areas for sediment management.

Perform quality assurance of small dam design and construction. This task is important and should address the following:

- It is critical to provide adequate safety assurance mechanisms throughout the process from planning, design, construction, and O&M phases commensurate with the risk of small dams. A dam risk classification system is covered in this Note and the main GPN, which would provide the basis for discussing the required level of quality assurance.
- The project team and borrowers should consider and agree on the required safety assurance mechanism, such as the scope of works of design and construction supervision consultancies and their qualification, and the contents and levels of dam safety plans with due consideration to the risk of small dams. The team should consult with dam safety specialists for reviewing technical documents related to dam safety and providing recommendation on required measures for borrowers.

14 Pisaniello, Dam, and Tingey-Holyoak (2015) found that in Vietnam, which has thousands of small dams, there is no national record of small dams or their problems. This included no systematic data on dam type and size, hazard rating, conditions, or history of dam failures.

15 If there are no such inventories of existing dams, the use of remote sensing tools could be useful in identifying such structures. Annex E provides some relevant information on such tools. The inventory of dams and subsequent identification and prioritization of high-risk dams could also be instrumental in discussing the future dam safety management system for the entire nation of borrowers. These points can be discussed and incorporated into the project design.

- The Legal section on and Regulatory Aspects of Management of Irrigation Systems and Small Dams provides typical safety issues of small dams and practical recommendations based on the ICOLD technical bulletins and other guidelines and literatures. Those references would be useful for assessing the overall quality of a small dam's design and construction quality.

It is important to continually assess the quality of design and construction works and the capacity of the government office, dam owners, community organizations, designers, contractors, and so on and ensure that required support is to be provided to fill gaps.

Provide training and technical support. This training and support includes both community organizations and the government agency. The change in the roles of government officials and farmers requires new capacities. Community organizations will need to build a broad range of skills (technical, financial, and administrative) to be effective and to ensure adequate maintenance and management of small dams and other irrigation infrastructure. Technical support from the government to community organizations is important and should be adequately accounted for in project design. Mandatory education, awareness building, and preparedness training is needed for communities so that they understand their future role in dam management. Identification of specialized institutions with experience in community mobilization will also be essential. During the training, it is important to ensure that community members, especially women, have access to information and training sessions because there are data to suggest that they tend to receive less access to these types of services. Other community members are also typically excluded from owning land and from being part of decision making, so it is important to ensure that their voices are reflected. Because some dams may cut across different ethnic or political groups, care needs to be taken to fully identify all relevant stakeholders and to encourage early engagement across these lines. Training of governmental staff, as regulators or owners of small dams, should also be provided based on their capacity assessment. The World Bank experience shows that government-allocated budgets are usually insufficient, so this training should always be built into the project design. Study tours could also be an effective training tool for both government officials and community organizations. Moreover, for community organizations, other models of training may be considered (for example, peer-to-peer, "on the job" support).

Conduct a safety assessment of associated existing dams to the World Bank–funded projects. If construction of new dams, rehabilitation of existing dams, or safety assessment of associated existing dams are involved in the World Bank-funded irrigation and other projects, it is important to assess the safety condition of existing dams in the upstream catchment areas. Detailed procedures of such assessment are provided in the main GPN. Many small but risky dams can exist in the catchment areas whose single or domino failure of cascade dams could cause extensive damage to or failure of the new the World Bank-funded structures. The cumulative impacts and risks from a system perspective may need to be assessed. A risk-informed approach will be critical with priority given to higher-risk dams. It is important to prepare an inventory of those structures and then prioritize those small dams requiring attention.

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Annex A. A List of Case Studies

Burkina Faso: Boura Dam, Dano Dam and Mogtedo Barrage

China: Shengli Dam

Ethiopia: Gum Selassa Dam and Shilanat 4 Dam

Ghana: Baare Dam, Binaba Dam, McLean Dam, Tempane Dam and Winkogo Dam

India: Rajavolu Tank

Nigeria: Akufo Dam, Ilero Dam and Ikose Dam

Sri Lanka: Bandagiriya Reservoir, Basawakkulama Reservoir and Ihala Koone Wewa Tank

United States: CCID Ingomar Reservoir

Vietnam: Bo Lac Dam and Nha Giac Dam

Annex B. Example Checklist for Small Dam Inspection

This checklist is from ICOLD (2016).

DAM NAME:..

TYPE:...

HEIGHT

CREST LENGTH

RESERVOIR CAPACITY

FOUNDATION (Geology):..

LOCATION: ....

DATE: .... Water Level: ....Weather conditions: ....

INSPECTED BY: ....

1. CREST

- Settlements, depressions, sinkholes
- Misalignment
- Longitudinal/transversal cracking
- Animal burrows
- Adverse vegetation
- Erosion

2. UPSTREAM SLOPE

- Loss of rip rap material
- Stone weathering/deterioration
- Inadequate ground cover
- Settlement, depressions, slides, sinkholes
- Longitudinal/transversal cracking
- Animal burrows
- Vegetation (large shrubs, trees)

3. DOWNSTREAM SLOPE

- Erosion
- Inadequate ground cover
- Longitudinal/Transverse cracking
- Settlement, slides, depressions, bulges, sinkholes
- Superficial drainage clogged
- Soft spots or boggy areas
- Movement near the toe
- Animal burrows
- Vegetation (large shrubs, trees)

4. DRAINAGE-SEEPAGE CONTROL

- Internal drains flowing
- Boils near the toe
- Seepage near the toe
- There are sediments at the drainage boxes
- The water is not clear

5. ABUTMENTS AND CONTACTS WITH ABUTMENT

- Erosion
- Differential movement
- Cracks
- Settlement, slides, depressions, bulges, sinkholes
- Leakage water (seepage)
- Animal burrows
- Vegetation at the dam toe (large shrubs, trees)

6. APPROACHING CHANNEL

- Instability of the side channel
- Tilting of sidewalls
- Erosion or back cutting
- Sloughing
- Restriction by vegetation
- Obstruction with debris
- Log boom, condition or need
- Concrete lining deterioration, cracking or settlement

7. OUTLET WORKS - SPILLWAY, SPILLWAY'S CHUTE, STILLING BASING/POOL

- Concrete surfaces show:
    - o Spalling or scaling
    - o Cracking
    - o Erosion
    - o Exposed reinforcement
- Energy dissipators show:
    - o Sign of deterioration
    - o Covered with debris
    - o Sign of inadequacy
    - o Obstruction
- Slab movement, heaving, settlement
- Wall movement, settlement, tilting
- Undermining foundation from plunge poll by erosion

- Poor hydraulic performance, hydraulic jump in bucket
- Excessive vibration

8. OUTLET WORKS - INLET STRUCTURES/CONDUIT

- Seepage into structure
- Debris or obstruction
- Displaced floor slabs
- Poor hydraulic conditions, turbulence or vortices
- Vibrations, interference with flow
- Concrete surfaces show
  - Spalling or scaling
  - Cracking
  - Erosion
  - Exposed reinforcement
- The conduit joints show:
  - Displacement or offset
  - Loss of joint material
  - Leakage
- Are the trash racks:
  - Broken or bent
  - Corroded or rusted
  - Obstructed

Each of these deterioration possibilities need to be addressed in terms of:

(·) Not applicable

(·) No

(·) Yes

(·) Need to be monitored

(·) Need to be investigated

(·) Need to be repaired

(·) Need to be registered

Observation: All important deteriorations need to be registered with one or more photographs taken during the inspection.

Annex C. Summary of Good Practices—Community Participation in Irrigation Management and Small Dam Safety

Institutional and Governance Arrangements

- A legislative and regulatory framework would be instrumental in promoting participatory community management of local-level infrastructure including small dams and irrigation networks.
- Legislation forms can vary but should stipulate the institutional responsibilities for ownership, O&M, and safety regulations of small dams.
- Clear articulation of the role of government is needed, especially with respect to providing technical support to community organizations or high-hazard small dams that pose a significant risk to the public.
- Arrangements and rules need to recognize that multiple users, both formal and informal, may exist around a small dam (for example, livestock, irrigation, fisheries, or household uses).
- An assessment of existing dams in the catchment area is important, including inventorying of small dams to classify small dams and manage risks.

Financial and Economic

- Legislative framework should make clear that community organizations may collect funds to support the O&M of local-level infrastructure.
- Funds may be collected on a seasonal or area basis but should be regular. In more advanced situations, fees would be collected based on use (for example, volumetric irrigation service fees).
- Collecting funds is usually a challenge, so in-kind contributions (for example, labor) is an acceptable alternative.
- It is important to secure O&M funds for small dams in relation to irrigation networks.
- In cases in which government retains ownership of the small dam, local communities may be hired (or provided grain, inputs, and so on) for maintenance work.

Technical Support

- Technical performance of a small dam may be viewed from many different perspectives; it is important that clear benchmarks are established early in the process of monitoring.
- In cases in which community organization exists, collected funds can be used to hire a technical specialist; it need not be on a full-time basis.
- The most practical solution (at least during project implementation) is technical support from existing government departments (for example, irrigation departments or agriculture extension).
- In the absence of (or in addition to) government technical support, specialized technical organizations can be identified during project preparation and be included under the project to provide support to new community organizations.

table continue next page

Community Participation
• "Top-down" formation of new community organizations often faces implementation challenges in practice; it is critical that an assessment of existing institutional arrangements or informal organizations and existing rules and practices for managing small dams be undertaken and well understood during the design and project preparation stages. • Stakeholder consultations and analysis are needed during project preparation to understand the multiple users, multiple objectives, and multi-governance arrangements (if they exist). • Mandatory education, awareness building, and preparedness training are needed for communities so that they understand their future role in small dam management. This should be done as upstream as possible. • It is critical that community organizations receive functioning infrastructure and that the community organization can provide an improved service to its members/farmers. This is essential to establishing legitimacy for any new community organization. • Significant attention and care must be given to define who is included in the "community"; identification of all users (both formal and informal) is critical to managing future conflicts over use. • There is a common misunderstanding that delegating responsibilities to communities means a reduced role for the government; existing government departments are just as important to making community participation work and be sustainable (well beyond the project). The project will need to facilitate the building of relationships between the government field staff and the new community organizations (much like the agriculture extension officer and farmer relationship). • Monitoring and evaluation of community organizations is needed for continual improvement. • Communities are more engaged when wider objectives (beyond the narrow irrigation service) and uses and sustainable operation of small dams are considered (for example, better linkages to agricultural systems and catchment conservation/sediment management).
Design and Construction Quality Management
• It is essential to ensure the quality in small dam design and construction because small dams could cause a significant consequence in case of failure. • This Note provides typical safety issues and recommendations for basic checking and quality control that should be understood by key entities, including project implementation entities, dam owners, and future O&M entities. • The financial and human capacity of project promoters and dam owners may be limited. They may also be keener to save costs rather than assure dam safety. Adequate quality-control mechanisms should be established. • A risk-informed approach is needed for managing small dams or a cascade of small dams including a risk classification system (see more details in the main GPN).

table continue next page

- Though community members may not have the requisite engineering skills, their involvement with local authorities (that is, government field engineers) to support the construction supervision of small dams and their de facto presence helps to build ownership of the infrastructure and longer-term community engagement.
- Users should participate in the design of an infrastructure producing local benefits.

Surveillance, Monitoring, and Emergency Preparedness

- Minimum-size and risk criteria will need to be established to determine the frequency and scale of field monitoring and inspection to undertake; this will need to be balanced against the available budget to support such activities.
- The roles of the WUAs and community groups for basic surveillance, monitoring, emergency notification, and so on should be discussed and agreed on by protocols.
- Training and awareness raising of community groups for basic safety management should be provided. This would also reduce the risk of improper use of the dam body and surrounding areas by community members.

Annex D. Approaches to Sediment Management

Siltation is a common problem across the globe in both big and small dams and is initiated by erosion in the catchment area. Several of the case studies highlighted the issues surrounding sedimentation of the small dam (for example, the Nigeria Akufo dam). Silt traps, soil conservation, and catchment protection can be useful measures to reduce the extent of ground erosion. Arumugam, Mohan, and Ramaprasad (1997) estimated that the storage capacity of a reservoir could decrease by 0.5 percent per year from siltation, and Nissen-Petersen (2006) observes that without soil conservation, the useful life of a small dam in Africa could be less than 10 years. The factors influencing the siltation of reservoirs and the approaches to mitigation are well developed in the field literature (IHA 2019; Morgan 2009; Zarfl and Lucia 2018). Soil erosion can be of either natural or anthropogenic origins. Erosion can occur from heavy precipitation, runoff, or wind, particularly when soils are bare and surface cover is low. However, human activities and land use changes are often the major causes of soil erosion. Additionally, Rickson (2014) shows that eroded soils can harm the ecological conditions of reservoirs.

To help control for sedimentation entering small dams, upstream catchment protection and management have been implemented since the early 1950s. This approach involved managing soil erosion at its source or trapping soil upstream of the small dam. It would include either maintaining the existing vegetation or revegetation of upstream lands, depending on the type of lands (for example, forests or rangelands). Common approaches included the planting of trees, grasses (for example, the Baare dam case study), conversion to conservation cropping practices (for example, zero tillage), land contouring (to control and concentrate runoff), gulley rehabilitation, terraces, better management of livestock grazing patterns, silt traps, and so on. Nissen-Petersen (2006) provides some examples of these.

Depending on the size of the catchment serving the small dam, reducing sediment yield by changing land use may require significant and sustained effort with communities as it requires changes in practices from an existing norm. It is also difficult to get governments to apply strong soil conservation measures because these are generally expensive and unpopular. Although it would be ideal if large-scale catchment management policies could serve to limit reservoir sedimentation and to practice soil conservation at the same time, success in this regard has been limited. In fact, some decreases in sediment loads that have been observed in some places are a result of depletion of erodible top soils rather than successes with soil conservation measures. Apart from the problems mentioned earlier, the fine sediment loads transported during regular flooding (typically the 1:10-year flood) in semiarid conditions need long distances to become deposited in slow-flowing conditions. This can only be achieved with extremely large and costly interventions.

In conclusion, although catchment protection measures are often the only possible course of action to reduce soil erosion and sedimentation in small dams, their implementation is often not as straightforward as assumed by many. The following general guidance is offered:

- Catchment management measures need to be “owned” by land users; that is, such measures should not only reduce sedimentation but also improve agricultural practices and, most important, the welfare of local communities. Typical disconnects between those people who benefit from dams—that is, irrigation farmers—and people who need to change practices in catchment management—that is, foresters, herders, and so on—need to be carefully assessed and addressed.

- Removal of coarse sediments (medium sand and above) by means of check weirs, or from the upstream areas of the small dams, should be given priority because coarse sediments are the ultimate "killer" of reservoirs, and such materials have economic value (such as gravel roads, draining backfills, and concrete aggregate).
- Deposits of fine materials on the floor of groundwater recharge ponds can rapidly reduce infiltration capacity of such structures; engaging local communities in periodic removal of such sediments (before they harden too much) is an important sustainability measure. Such labor can be provided in kind or in exchange for grain or other inputs (see the Shilanat 4 dam in the Ethiopia case and the Ihala Koone Wewa tank in Sri Lanka).

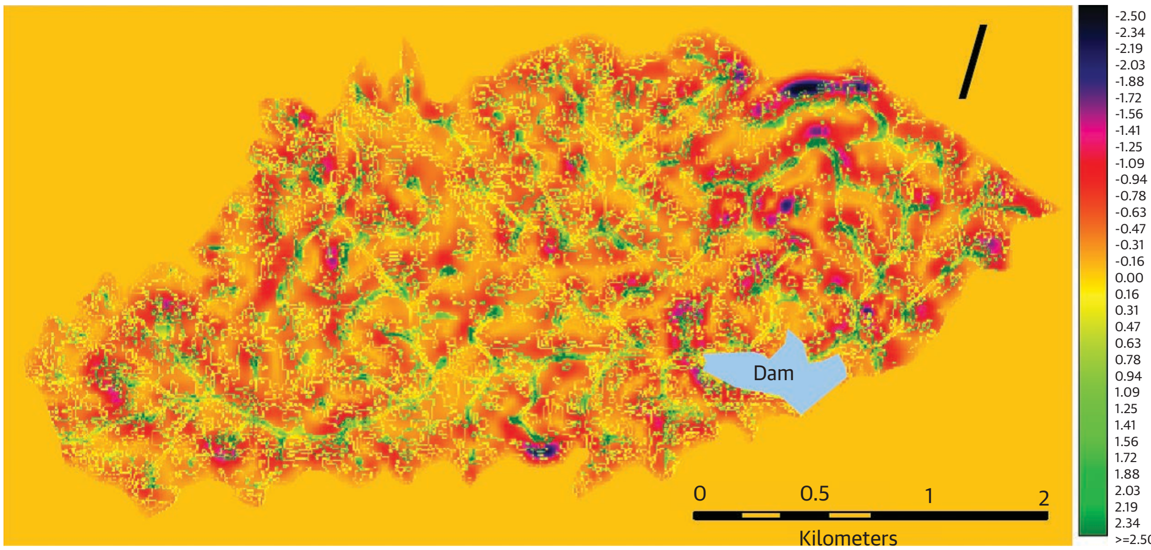
The social and institutional aspects, including proper stakeholders' assessment (including equity in access to benefits of small dams, gender imbalance, and so forth), creation of suitable tools/incentives, preparation of communication strategies, and so forth need to be carefully considered and designed for effective catchment/watershed management seeking from social and institutional specialists.

Modeling tools are also available to better understand the relationship between soil erosion in a catchment and its impacts on siltation rates for small dams (for example, Brunner 2019, figure 4). The reliability of the results that such models provide is sensitive to input data that are rarely available. The RESCON study (Palmieri et al. 2003) concluded the following on the reliability of current predictive tools on sediment yield:

- Catchment soil erosion is less well understood than the process of reservoir sedimentation.
- The Universal Soil Loss equation should not be used in other environments than those in which it was developed and calibrated (that is, western United States).
- The most reliable approaches for quantifying erosion rates are considered to be (in order of increasing complexity): (a) sediment yield maps based on bathymetric surveys of existing reservoirs, (b) sediment load-discharge relationships, and (c) process-based stream power and sediment transport relationships. These methods can be used to identify high sediment yield areas in a catchment where the soil-water program should be focused.

It is important to undertake such sediment assessment and prepare a sediment management plan/strategy in a simple form. Although the assessment should be undertaken by government offices with professional experts, the assessment results as well as good management practice and its impacts should be shared with community groups and other key stakeholders for awareness raising and practices. As an example, photo D.1 shows the spatial distribution of estimated erosion rates in the catchment of a small dam.

PHOTO D.1. Estimated Erosion Rates (Tons per Hectare Using WaTEM/SEDEM for a Small Dam in Burkina Faso)



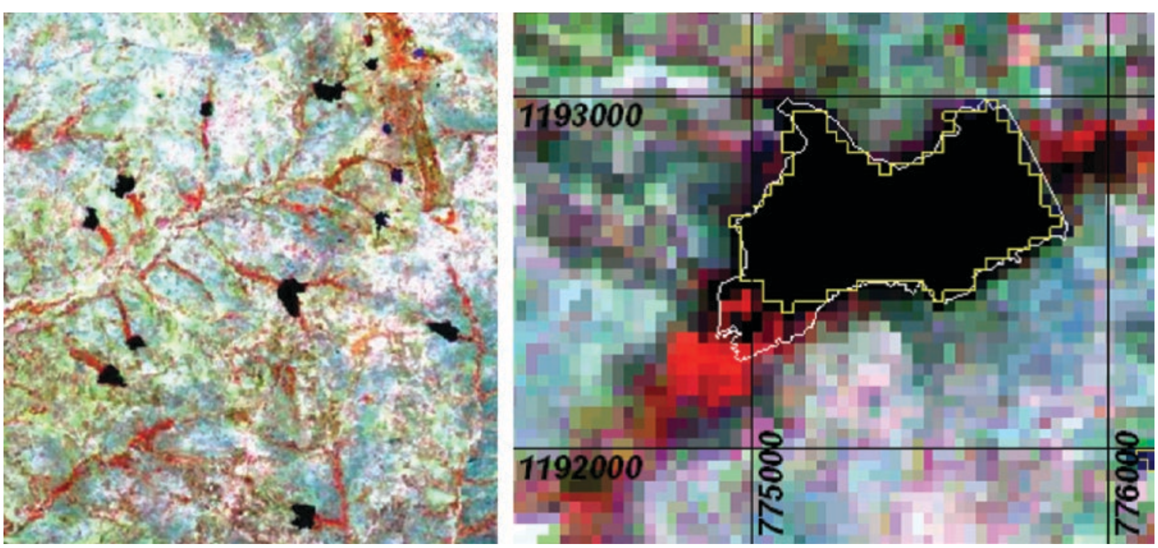
Source: Brunner (2019).

Note: Positive values refer to net sediment deposition; negative values to net erosion.

Annex E. Using Satellite Imagery for Small Dam Inventory Mapping

In many regions of the world, the number, size, and location of small reservoirs is not well known or documented. Developing an inventory would be a prerequisite to being able to classify small dams and to taking a strategic risk-informed approach to managing (from the government perspective) the entire portfolio of small dams. Satellite imagery can be a powerful tool to facilitate the process of collecting this information to establish inventories (Annor et al. 2009; Liebe 2002; Liebe, van de Giesen, and Adreini 2005). High-resolution satellite imagery (at a 30 meter or better resolution—for example, Landsat, ASTER, SPOT, Ikonos, or QuickBird) can be used to identify the surface area of a small dam (photo E.1). This can also be used to estimate the storage volume combined with field-level data (for example, see the Winkogo and Binaba dams in Ghana and the use of satellite imagery and bathymetric surveys to estimate volume-area relationships). Some analysis is needed to avoid false positives (such as cloud shadows) and false negatives (such as water body that is covered with vegetation). Moreover, cloud coverage poses a challenge given that optical satellite imagery depends on clear skies. As such, using this approach is best done after the rainy season when reservoirs are filled to their maximum extent and cloud coverage is at a minimum. Though there are some limitations, the potential to locate many small dams across a landscape outweighs these limitations. This approach can also be used to monitor in almost near-real-time if radar satellite imagery is used (for example, Envisat, Canadian Radarsat, or Japan ALOS) (Liebe et al. 2009). For operational purposes, this would require more-sophisticated algorithms to automate and process imageries. Eilander et al. (2014) presents an approach to automate the dynamic monitoring of small reservoirs (using Ghana as an example) to observe water storage dynamics. Given the relative low cost of imageries (many of which are public and cost-free), incorporating this kind of monitoring into the project design is relatively easy. Drones could be used for more-localized survey.

PHOTO E.1. Use of Landsat to Identify Small Dams (Dark Spots) and Drainage Patterns



Source: Liebe, van de Giesen, and Annor (2019).

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