Left: Women and children queuing up at a public water tap stand. (WARM-P)

Right: Construction of a storage tank by capacitated local service providers and community members. (WARM-P)

Gravity Flow Water Supply Systems

Nepal – खानेपानी प्रणाली (ग्रेभिटी फ्लो)

Gravity flow water supply systems with public and private taps in the rural mid-hills of Nepal.

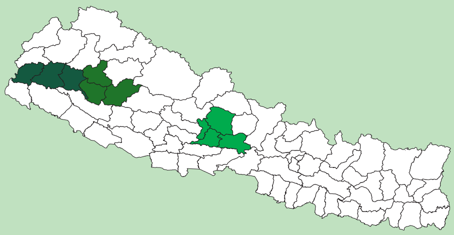
The provision of drinking water to rural communities in Nepal – adequate both in quantity and quality – continues to be a challenge for development; many rural households spend above two hours per day on fetching water from the closest water source. Gravity flow water supply systems are the most popular and widespread water supply technology in the rural mid-hills of Nepal. They form the backbone of water supply measures planned and implemented within the Water Use Master Plan (WUMP) framework for poor communities in these areas (see QA NEP 36 and QA NEP 40). When appropriately designed, constructed, and maintained, gravity schemes represent reliable and robust water supply systems with a low cost of operation. True to their name, gravity flow systems take advantage of gravity to transport water from a source to a service area located at a lower elevation. From the intake, water is transported continuously by a transmission line to one or several storage tanks. Higher capacity distribution pipelines then supply water to public and/or private tap stands.

The assessment of drinking water resources, as well as the design of aligned water supply systems, is governed by five principles:

1. **Quantity:** Systems are designed to provide at least 45 litres per capita (cap) and day (d) for domestic uses at community taps. Private taps are only considered when a safe yield of at least 60 l/cap/d is guaranteed. If the source discharge is higher than the domestic demand (>70 l/cap/d), Multiple Use Systems (MUS) may provide water for both domestic and irrigation purposes (QT NEP 44).
2. **Reliability:** Only perennial sources are tapped which provide at least the minimum safe yield for community connections, i.e., 45 l/cap/d year-round.
3. **Continuity:** Systems are designed to provide water continuously for at least six hours per day.
4. **Accessibility:** Generally, distances from households to taps should not exceed 50 m (uphill) or 150 m (horizontal). Positioning of community taps, each serving on average five households, is discussed with and agreed upon by the community.
5. **Quality:** Intakes at springs providing naturally pure water are favoured over intakes at surface water bodies like streams or ponds, as the scope for water treatment in rural water supply schemes is limited (financial barriers, absence of skilled labour needed for O&M). Source protection and conservation measures are applied while constructing intakes to guard against future pollution (QT NEP 48).

Closed continuous-supply systems are favoured over open or intermittent-supply systems. While open systems (systems with no flow-closing devices) are cheap to build, operate, and maintain, they do not allow for optimization of the available water resources. Closed systems are able to bridge potential gaps between the safe yield of a water source and the peak water demand by introducing storage tanks into the supply system. To control the water flow and minimize wastewater, faucets and valves are installed. Closed continuous systems are less prone to water contamination, as they are under pressure at all times. Accordingly, Break Pressure Chambers (BPC) are introduced at required locations to keep pressure within working limits of pipes, joints, and fittings.

If water sources are located in the vicinity of residential areas, spring protection measures (QT NEP 48) represent a less expensive alternative to a full-fledged distribution system.



Location: 10 districts in the Western, Mid-Western, and Far-Western Development Regions of Nepal

Approach area: per scheme: 1 – 10 km²

Conservation measure(s): Structural

Land use type: Settlements

Climate: Humid subtropical

WOCAT database reference: QT NEP 40

Related approach: QA NEP 40 and QA NEP 36

Related technologies:

Compiled by: Lukas Egloff, Madan Bhatta, Mohan Bhatta, Rubika Shrestha, HELVETAS Swiss Intercooperation

Date: June 2015

Comments: Gravity flow water supply schemes form the backbone of water supply measures planned and implemented within the Water Use Master Plan (WUMP) framework for poor communities in the rural mid-hills of Nepal.

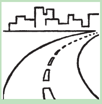
The technology was documented using the WOCAT (www.wocat.org) tool.

Classification

Water use problems

- More than half of the population in Nepal lacks sustainable access to safe drinking water supply.
- Water sources are intermittent and/or far away; households spend upwards of two hours per day on water fetching.
- Growing water demand for both domestic and agricultural use and diminishing or fluctuating water supply due to climate change
- Dubious sustainability of water supply systems: a significant part of existing schemes in Nepal is not fully functional, indicating a lack of proper management and maintenance.

Land use



Settlements, infrastructure networks

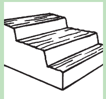
Climate

Humid subtropics

Degradation

Physical degradation: local water scarcity

Conservation measure(s)



Structural: pipeline network with intake, storage tanks, and tap-stands

Stage of intervention

- Prevention
- Mitigation/reduction
- Rehabilitation

Origin

- Land users' initiative:
- Experiments/research
- Externally introduced: 10-50 years ago

Level of technical knowledge

- Field staff
- Land user

Main causes of local water scarcity

- **Natural causes:** temporary water scarcity during dry season; deterioration of water quality during monsoon period; higher fluctuations in supply due to change in seasonal rainfall patterns; diminishing supply and increasing water demand due to temperature increase
- **Human-induced causes:** poor water governance; lack of adequate infrastructure; increasing water demand due to progressively higher living standards and augmented agricultural production

Main technical functions

- improve water service level (accessibility, quantity, quality, reliability, continuity)

Secondary technical functions

- potential to improve sanitation level (given adequate water supply)

Legend

- high
- moderate
- low
- insignificant

Environment

Natural environment

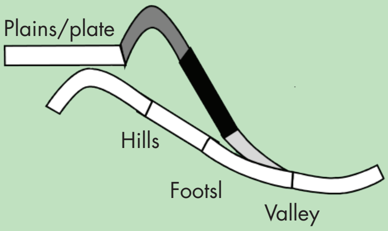
Average annual rainfall (mm)

- >4000
- 3000-4000
- 2000-3000
- 1500-2000
- 1000-1500
- 750-1000
- 500-750
- 250-500
- <250

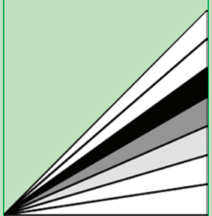
Altitude (masl)

- >4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- <100

Landform

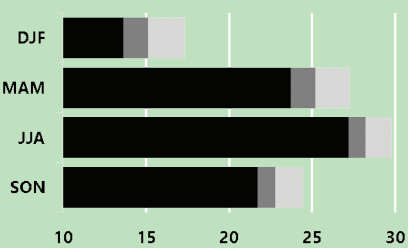


Slope (%)

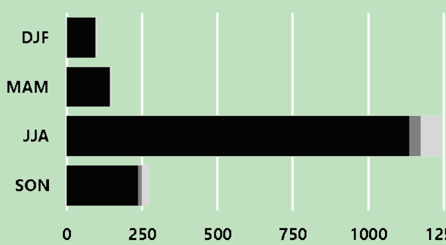


Climate change[1]

Temperature (T) in °C



Precipitation (P) in mm



- – Future **T** increase projected to be most pronounced in dry season
- – **P** projections still with large uncertainty; **P** predicted to stay constant or ly decrease slightly in winter (DJF) and increase during the monsoon period (JJA)
- → Possibility of more frequent winter droughts and summer floods

Historical climate: 1976 - 2005
Future climate: 2020 - 2039
Future climate: 2040 - 2059

Tolerant of climatic extremes: temperature increase; wind storms/dust storms; floods; decreasing length of growing period

Sensitive to climatic extremes: seasonal rainfall increase/decrease; heavy rainfall events (intensities and amount); droughts/dry spells

If sensitive, what modifications were made/are possible: consider rainwater harvesting (e.g., QT NEP 46) or recharge and conservation measures

[1] Historical climate is drawn from local observational records. Future **T** and **P** anomalies are based on the ensemble median of 15 climate models employed in IPCC AR4 representing the SRES B1 emission scenario. Source: World Bank Climate Change Knowledge Portal

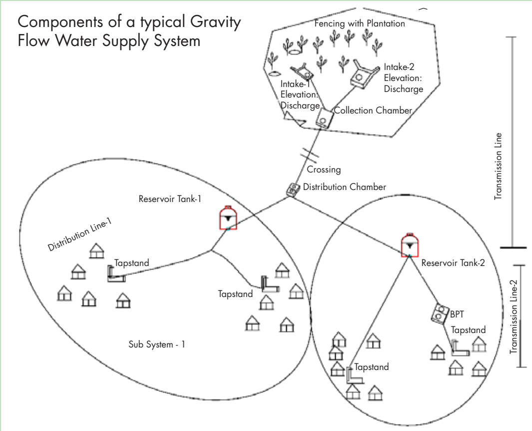
Human environment

Cropland per household (ha)

■	<0.5
■	0.5-1
□	1-2
□	2-5
□	5-15
□	15-50
□	50-100

Land user: individual/household, small-scale land users, disadvantaged land users, men and women
Population density: 120 persons/km²
Annual population growth: 1-2%
Land ownership: individually owned/titled
Land use rights: individual
Water use rights: communal (organised)

Relative level of wealth: very poor and poor, which represent 39% and 27% of population in the area, respectively.
Importance of off-farm income: less than 10% of all income
Access to service and infrastructure: low: health, technical assistance, employment, market, energy, financial services; moderate: education, roads & transport, drinking water supply and sanitation
Market orientation: mainly subsistence (self-supply)



Technical drawing
Components of a typical gravity flow water supply system with public tap stands

BPT = Break Pressure Tank

Implementation Activities, Inputs, and Costs

Establishment activities
The establishment of the whole system could be completed within three months. However, the construction phase is generally spread out over a period of about six to eight months, which allows for several social mobilization and awareness raising orientations, as well as hands-on training workshops. Main establishment activities include:

1. Detailed survey (Preparation phase)
2. Discharge and demand supply assessment (Preparation phase)
3. Collection and transportation of local and external materials
4. Excavation of main pipe lines and development of structures on main lines
5. Construction of water storage and regulating chambers
6. Construction of distribution system and tapping structures
7. Final commissioning

Establishment costs and inputs for a typical GWS system catering to a community of 50 households with two intakes, one distribution chamber, two reservoir tanks (5 m³) and 10 public tap stands.

Inputs	Costs (US$)[1]	% met by users
Skilled Labour (140 person days)	700	0%
Unskilled Labour (1,500 person days)	5,250	43%
Construction Materials		
HDPE and GI pipes	1,450	0%
Fittings and valves	540	0%
Cement (5,600 kg)	880	0%
Other construction materials	1,310	0%
Tools	**180**	**0%**
Local Materials (costs reflect unskilled labour effort for collection and portering)		
Stone (43 m³)	300	100%
Sand (21 m³)	1,160	37%
Aggregate 5-40 mm (8.5 m³)	730	100%
Wood (1.6 m³)	25	100%
Bamboo (10 pieces)	10	100%
Total	**12,550**	**29%**

[1] Exchange rate as per June 2015 US$ 1 = NRs 100

Maintenance/recurrent activities
Monitoring of structures by walking along the pipeline network

Minor repair and maintenance works

Maintenance/recurrent inputs and costs for the above-mentioned typical GWS system per household and year

Inputs	Costs (US$)	% met by users
Labour and equipment	240	100%
Total	**240**	**100%**

Remarks: The above cost breakdown is based on the analysis of 66 schemes implemented in the period from 2010 to 2014. Costs for portering and road transportation of non-local materials – very much subject to the remoteness of the project site – were omitted. In the mid-hills of Nepal, the average transportation costs amount to about 10% of the total construction cost. Village Development Committees (VDC) contribute on average about 5% to the overall costs (2.5% is the minimum contribution). Community contribution to the overall costs (including all transportation costs for non-local materials) typically ranges between 20 and 25%, which includes collection and portering of local materials, as well as unskilled labour work for the distribution line network and all tapstands. The programme reimburses the unskilled labour required for the construction of the intake structure, storage tanks, and the transmission line.

Establishment costs and O&M fees also depend on whether the schemes include public or private connections: average cost for schemes with public taps amount to USD 40–45 per capita compared to USD 55–65 per household in schemes with only private tap stands. Operation and maintenance activities are carried out by Village Maintenance Workers and are financed out of the scheme's O&M fund. The latter is managed by the scheme's Users Committee

Connection charges, which also serve as initial contributions to the O&M fund during the construction phase, amount to USD 10 per public tap stand (catering on average to five households) and USD 10 per private connection. Users with private connections also pay a higher regular water tariff: public tap stands users pay a monthly fee of USD 0.2 into the O&M fund; in contrast, monthly user fees for private connections range from USD 0.6 to 0.8.

Note that, while the collected user fees suffice to pay the wages of the local maintenance worker and finance minor repair works (replacement of small fittings and parts, e.g., taps, valves, washers, etc.), they are not adequate to deal with major system failures such as the reconstruction or replacement of larger structures, e.g., the reservoir tank, intake, or the main pipeline.

Assessment

Impacts of the Technology			
Production and socioeconomic benefits		**Production and socioeconomic disadvantages**	
+ + +	Improved drinking/household water availability and quality	-	Regular payments to O&M fund
+ +	Increased irrigation water availability if source discharge is higher than domestic water demand. Given established market access, surplus supply can be used for irrigating vegetables and cash crops to raise household income		
+ +	Income opportunities for village maintenance workers		
Sociocultural benefits		**Sociocultural disadvantages**	
+ +	Significant reduction of reported incidents of water-borne diseases due to improved water access		
Off-site benefits		**Off-site disadvantages**	
+	Reduced risk of downstream flooding	-	Reduced water availability further downstream
Contribution to human well-being/livelihoods			
+ + +	Decreased workload due to reduced time for water fetching: on average two hours per day per household. The saved time is reported to be spent on livestock raising, vegetable cultivation, and household chores.		
+++: high / ++: medium / +: low			

Acceptance/adoption
The implemented water schemes are identified and prioritized based on inclusively planned WUMPs (QA NEP 36). Moreover, representatives of the community take a lead role in the detailed planning and implementation process, resulting in a high acceptance rate of the technology; virtually all households are making use of their public/private tap stands. On the other hand, gravity water flow schemes are often too costly for communities to adopt without substantial external material support, provided by either the government (VDC/DDC) or other donors.

Concluding Statements

Economic costs and benefits per household (USD) for a typical GWS (50 households; 10 public tap stands)	Assumptions
	▪ **Saved time:** two hours per day per household, assume that half of the saved time is spent on productive activities ▪ **Local rate for one person day (eight hours) of unskilled labour:** USD 3.5 ▪ **O&M fees/costs:** USD 0.6 per HH and month (~3% of total construction costs per year) ▪ **Discount rate:** 10%
Under the above assumptions, break-even point is reached after about two years. The net present value of the whole GWS system (with an assumed lifetime of 20 years) is around USD 50,000. The scheme has a Benefit/Cost Ratio of 4:1 and an Economic Internal Rate of Return (EIRR) of about 56%. While establishment costs are too high for most poor communities to bear by themselves, O&M expenses for minor repair works are generally paid by the users. Economic benefits can increase substantially if surplus water and waste water is used for irrigation of vegetables/cash crops.	

Strengths and ➔ how to sustain/improve	Weaknesses and ➔ how to overcome
Strong physical foundation of schemes: 98% of the schemes are functional five to ten years after construction, with the potential to function up to a designated lifespan of 20 years ➔ strengthen institutional mechanisms related to O&M and ensure that they remain active throughout the projected lifetime of each scheme	Management, operation and maintenance of gravity flow schemes is non-trivial and requires appropriate knowledge and skills of the managing user community and the responsible maintenance workers➔ include capacity-building activities as an integral part of the technology implementation process
Schemes lead to a marked improvement of domestic water supply in the dimensions of quantity, quality, access, and reliability ➔ ensure that improved household water supply leads to improved health outcomes by raising HWTS and hygiene awareness and conducting behaviour change campaigns).	Spring water quality may not meet drinking water standards at all times and can be particularly impaired after heavy rainfall events; water quality may also deteriorate during transportation and storage ➔ raise HWTS awareness and promote treatment methods such as SODIS, filtering, or boiling of water.
Pilot schemes with private connections show very promising results in terms of increased ownership, better maintenance of the system, less conflict, more productive water use, and a higher willingness to pay for connection charges and fees for O&M fund ➔ support private taps on a case-by-case basis (subject to technical feasibility and willingness to pay). Make sure that services still serve lower income households adequately.	Gravity systems are on the upper end of the price scale of low-cost technologies, making them too expensive for poor communities to adopt or to finance major repairs without substantial external material support ➔ (i) WUMP serve as an instrument for dissemination and marketing with potential resource organizations to secure additional funding; (ii) source protection represents a low-cost alternative if the source is in the vicinity of the community; (iii) microfinance or governmental subsidy schemes may represent an additional funding source.
As women are predominantly responsible for water fetching, improved water access reduces their workload and frees up time for other activities ➔ consider how additional (income) opportunities could be seized (e.g., cultivation of vegetables in kitchen garden).	If gravity schemes are designed with only domestic water demands in mind, opportunities for income generation via irrigation may be missed ➔ given sufficient supply, consider development of Multiple Use Systems by adding additional storage facilities, e.g., irrigation ponds ( ) to capture surplus supply and domestic wastewater.

Key references: SWISS Water & Sanitation NGO Consortium (2013) Beneficiary Assessment of WARM-P, Nepal. Lalitpur, Nepal: WARM-P/HELVETAS;
HELVETAS (2013) The Effectiveness and Outcomes of Approaches to Functionality of Drinking Water and Sanitation Schemes. Lalitpur, Nepal: WARM-P/HELVETAS

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