INNOVATION AS A MEASURE OF APPROPRIATE TECHNOLOGY

by

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ABSTRACT

The study is an analysis of the relationship between technological choice and innovative activity in Third World development projects. It is based on the author's experience as a manager of a spring protection and shallow wells development project in Kenya.

This thesis is based on the premise that the purpose of technology transfer in Third World development projects is to foster the indigenous capacity to make process-type innovations. It hypothesizes the existence of three main approaches to technology transfer practiced by development organizations(both private and public). One approach assumes the universality of technology in that what "works" for the developed world will also "work" in the developing countries. The second approach directly opposes this and recognizes the need to make "appropriate" changes to technology before it is shipped-off to developing countries. The third approach, and the author's own, understands that the purpose of technology transfer is not to serve as a vehicle for adaptation but as a catalyst for indigenous innovative activity.

Thesis Advisor: Professor Donald A. Schon
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CHAPTER 1: INTRODUCTION

In many Third World development projects with a significant technology transfer element, planning revolves largely around the type of hardware that has been selected for use. In practice we find that technology selection and the mode of implementation of development projects are functionally inseparable. The importance of the initial choice of technology lies not so much in itself but rather in how it tends to dictate the general outline of project implementation. However, though the process of technology transfer seems to lie at the core of development work, guidelines for technology selection are scarce and in some cases misleading.

The main problem is that the interpretation of what is "appropriate technology" varies greatly between different development organizations. Even though many years have passed since the term "appropriate technology" has been coined, those who are in the position to make technical decisions have no real way to measure their appropriateness.

Many factors fueled the appropriate technology movement. One of the most important factors was the realization by the development community (both aid-giving and receiving) that Western style industrialization had not been able to solve the problems of underdevelopment. E.F. Schumacher's book, Small is Beautiful[1] describes this problem and was probably the single most influential book in making popular the notion of intermediate or appropriate technology. The reason for disillusionment with the typical western-style foreign aid has less to do with a lack of effort, than with a lack of understanding. Although we may have considerable understanding of why a particular society has developed, we know very little about how to deliberately engineer such a process. This, essentially, is the reason that "appropriateness" is so difficult to measure.

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1. E.F. Schumacher, Small is Beautiful: Economics as if People Mattered, Harper and Row, New York 1973, The author is the founder of the Intermediate Technology Development Group(ITDG).

Another origin of the appropriate technology movement can be found in the industrialized countries themselves. The heightened interest in the environment during the 1970's, the oil shock, and an increased skepticism towards Western society's values and way of life led to new ways of thinking about technology. While it is a popular misconception that appropriate technology is primarily a product of development aid, the movement was in large part a western cultural reappraisal by Westerners themselves.[2]

Today, as compared to the 1970s, we hear much less of the appropriate technology movement. In fact, with the recent geopolitical trend of many East-bloc countries towards more capitalistic economies and democratic governments, and the accompanying pledges from the west to increase aid for the purpose of rebuilding sagging industrial sectors, the emphasis appears to be returning to big industry as the only genuine means of development.

This reaffirmation of the political and economic basis that makes up the democratic capitalistic nation may have shifted interest away from appropriate technology. It may also have changed the notion of what appropriate technology is. This was, of course, always the weakness of the appropriate technology movement. As Jequier put it,

> "assessing the appropriateness of a technology necessarily implies some sort of value judgement both on the part of those who develop it and those who use it, and when ideological considerations come into play, as they often do, appropriateness is at best a fluctuating concept."[3]

It is because of this conceptual weakness of appropriate technology that there developed no tangible rallying point for its proponents. Thus, the newest hope for development technology suffered because of conceptual instability. However, regardless of its present lack of popularity, the appropriate technology movement has provided us with a new perspective on technology, one which might be called the social and cultural dimension

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2. Jequier p. 19

3. Jequier p. 19

of innovation. The main idea is that the viability of a technology lies not only in its economic value and technical sophistication but also in the level of its adaptation to the local social and cultural environment. Thus, the problem lies in how development organizations perceive their role in this process of adapting existing technology to local conditions.

This role, of course, is large and contributes to the misconception that appropriate technology is primarily an aspect of development aid. This is because most of the effort at making technological adaptations appears to be based in aid-giving organizations. Organizations such as Technoserve and the Intermediate Technology Group are Western institutions. While aid organizations do have a role to play in appropriate technology, their role is not always consistent with its underlying philosophy. As Jequier further explains:

> "Appropriate technology should first and foremost be an indigenous creation of the developing countries themselves and the central problem they have to face is that of building up an indigenous innovative capability and not that of importing more foreign technology."[4]

Thus, instead of viewing appropriate technology as something that should originate from the recipient country, the perspective of many development agencies seems to be rooted in the misconception that they themselves are primarily responsible for adapting the technology. This perspective subtracts from what should be the main focus of technology transfer, namely, to foster the type of innovative activity that will result in "appropriate technology", the appropriateness of which can be measured in the terms of the recipient country. When development organizations play the role of primary innovator, they inhibit the opportunity for indigenous innovative activity. However, apart from the relative social-cultural adaptation of innovation, there might exist

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4. Jequier p. 25

altogether different types of innovation, with different economic implications, that aid-givers need to be aware of in order to successfully foster innovative activity.

Literature on Third World technology transfer often disaggregates technological capability into three basic levels: production, the ability to replicate production facilities, and innovation.[5] Innovation is further divided into those innovations that modify existing technology (process innovation) and those that introduce radically new ideas(radical innovation). The tradition of Schumpeter's[6] analysis has only recently allowed us to understand that the simple measure of radical innovation as the single motivating force behind industrial development is incomplete if not deceptive.

> "For innovation to be economically significant...much more is needed than the capacity for originating new concepts and new ways of doing things[radical innovation]. Implementing new concepts through successful commercialization, or through making them operational in the public sector, is as important, or sometimes more important, than originating the concepts....Thus the implications of innovation for competitiveness may depend as much or more upon the capacity to assimilate, adapt, and make operational new ideas and concepts from others as the ability to originate or invent them."[7]

This thesis is based on the premise that the purpose of technology transfer in Third World development projects is to foster the indigenous capacity to make process-type innovations. It hypothesizes the existence of three main approaches to technology transfer practiced by development organizations(both private and public). One approach assumes the universality of technology in that what works for the developed world will also work in the developing countries. The second approach directly opposes this and recognizes the need to make "appropriate" changes to technology before it is shipped-off

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5. It is important to note the Schumperterian distinction between an "invention" and an "innovation" used in this paper. An invention is an idea, an inspiration or a sketch for a new product, or system. However that does not mean that such inventions necessarily lead to technical innovations. An innovation requires the successful commercialization of a new product, process. (from C. Freeman, 1982, p. 7)

6. Schumpeter, Joseph A. 1939 Business Cycles. New York: McGraw-Hill

7. Brooks p. 329

to developing countries. The third approach, and my own, understands that the purpose of technology transfer is not to serve as a vehicle for adaptation but as a catalyst for indigenous innovative activity. The question becomes how do we go about transferring technology in a way that fosters this particular type of innovative capacity? To answer this question we need to know more about innovation itself. As it happens, there is a large and growing body of literature that is concerned primarily with technology innovation at the firm level(Abernathy and Utterback, Sahal, Teece and others). The central question of this thesis draws upon this body of knowledge to assess the appropriateness of technological choice by its ability to foster innovative activity in the developing country.

This Thesis attempts to move beyond the static question of whether technologies are adaptable to, or are maintainable in certain social and cultural settings. Rather, this thesis views the central question to be: How will this technology change and will its change stimulate the type of learning that results in indigenous innovative capacity?

This study is based on the author's own experience as manager of the Catholic Relief Service funded Rapogi Water Project located in South Nyanza Kenya while serving as a Community Development Water Technician for the United States Peace Corps for two years during the period from 1985 to 1987. As such, it is necessarily only an exploratory study of the relationship between technology choice at the practitioner's level and the indigenous capacity to innovate.

This paper is divided into two sections: The first section will describe the author's work and experience as the manager of a water[8] development project in Kenya, concentrating

8. Water has a special status in development because of the direct link between potable water and good health. Diarrhea and dysentery, skin infections, tachoma, cholera, typhoid, malaria, infectious hepatitis, poliomyelitis, and, schistosomiasis are just few of the many diseases linked to water or sanitation. For this reason water development has traditionally been the first-choice amongst infra-structure development projects. However, the fact that clean water saves lives on a daily basis, is explanation for the relative lack of critical analysis that water development projects receive. Those who have worked on water projects in such places as the African continent are rarely questioned as to the value of their work. The

on describing the technology that was used and changed there. The second section will analyze the technical change that occurred during my experience as a water development manager, attempting to establish some of the links between technological choice and innovation.

Innovation is a process of change, a process by which new problems are solved or old problems are solved in a new way superior to the solutions of the past. They are innovations not only because they are new, an invention, but because they can be sold for profit to either the private or the public sector. The importance of the Rapogi Water Project story lies in its description of a process of technical change as a result of using and learning about technology. Appropriate technological choices can not be made without a firm understanding of how technology changes, and what motivates technological change. This can only be understood when we observe this problem at the practitioners level, in the day to day activities of people who use and change technology. The story is more compelling because it not only describes the development of one type of technology but chronicles how two technologies can come together to streamline or simplify an existing problem. More importantly, the story is in essence the story of industrialization(albeit at a very small scale), but this is precisely the scale that needs to be understood, because the beginnings must be small.

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validity of water development projects is taken for granted almost in the same manner as those in developed countries take for granted the water that pours from their household taps.

My purpose is not to contest the notion of water development as a primary objective of Third World development, on the contrary, of all possible development activities water must take precedence simply because without basic health there can be no other activity. What is of concern is the mode of implementation of water development projects and how that mode is tied up in the choice of technology.

CHAPTER 2: THE RAPOGI WATER PROJECT

After ten weeks of training on a hill overlooking lake Naivasha in the Rift valley, and many more months of anticipation I was assigned to work in the South Nyanza province of Kenya as a U.S. Peace Corps Community Development Water Technician. Regardless of the long time spent waiting for this assignment, my previous development experience at the Asian Rural Institute in Japan, and the ten weeks of Swahili language, cross-cultural and technical training in small-scale community water and sanitation projects that the Peace Corps had provided, I was hardly prepared for the many complex issues that I was to confront during my stay in Kenya. On the other hand, as I had hoped, the one thing that proved valuable and enabled me to be somewhat successful was the experience that I had being part of small construction and plumbing business.

Informally I was given the task of continuing the work of two volunteers who had preceded me in Nyanza. One of these volunteers had fairly strong ties with the Catholic Diocesan Development Coordinator Brother Paul Steverink and together they had begun to put together a small team of workers trained in the protection of naturally occurring springs. Steverink and Andrew Smith's plan was to improve water quality at these springs by constructing "springboxes" to protect the source of water from human and animal contamination.

The impetus for spring protection work in the Rapogi area was a deadly cholera outbreak (cholera is a water-born disease) that occurred in 1983 and had taken many lives. The initial work sites were those that were identified as the water sources for those family groups that were worst hit. It is important to note that cholera acted as the catalyst for this effort even though on a quantitative basis the casualties that result from diarrhea are far larger, taking the lives of many small children whose systems are less resistant to it.

My first four months of volunteer activity in South Nyanza was spent working almost entirely with Br. Paul and the 3 fundis (Swahili for skilled laborer) who had previous work experience with ex-PCVs John Sweat and Andrew Smith. Home base for this group was the Rapogi Secondary School where we had at our disposal two 4 wheel drive pickups, both of which had seen better days, and a small amount of storage space for tools and materials.

During this time I worked with Brother Paul to acquire a grant from the Catholic Relief Service(CRS) for 30 spring projects, a piped water scheme, and a new 4 wheel drive truck. I became the Project Manager for the Rapogi Water Project, initially funded at US$40,000, and was responsible for all administrative and financial aspects of the project, including project design, organization of work schedules, tools and materials supply and allocation, recruitment, on-site construction supervision, and in-progress reporting to the CRS. Due to the success of our program, by the end of my service in Kenya, CRS had offered to increase this funding to US$225,000.

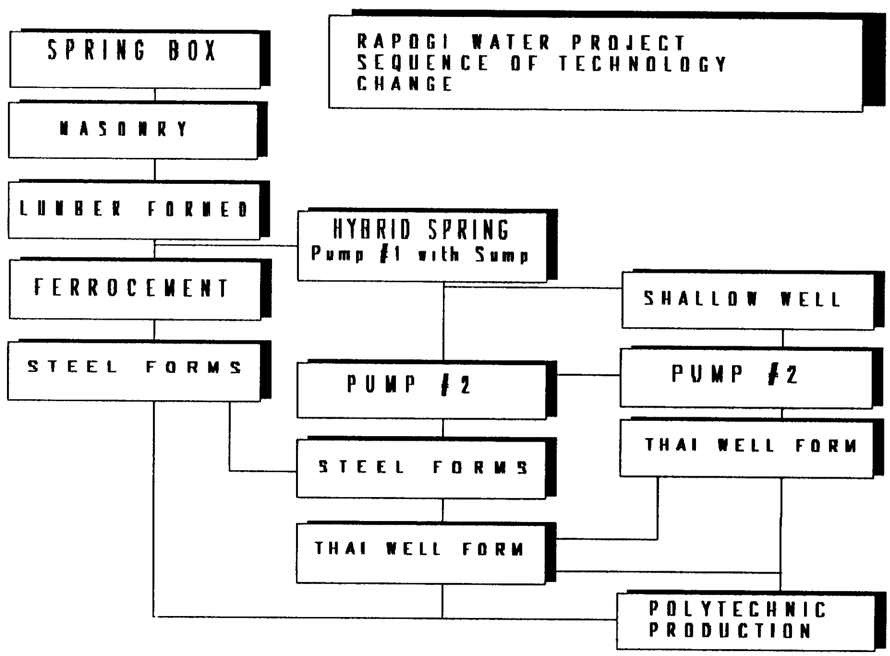
While I helped with the above project proposal and we awaited a response from CRS's Nairobi Office, my emphasis was simply to work alongside the 3 fundis(Wilberforce Matthew, and Joseph) to learn their methods and more importantly to assimilate myself into their group. This was important because I knew that the technical aspects of how they worked were only part of the picture. In order to understand why they did certain things in a certain way, I would have to understand more about their way of life, and they would have to feel comfortable about me, the new foreigner, in order to teach me. The ten weeks of intense Swahili training came to little use at my site simply because those I worked with spoke English more proficiently than Swahili, which to them was just another tribal language. Additionally, Swahili was next to useless in conversations with those in remote rural areas who spoke the vernacular, Luo, because they tended to be less educated and had no other reason to speak the country's national language.

I did not live in the Rapogi area but about 25km north on the road to Kisii in an area called Kamagambo. The ride between my dwelling, a small stone, mortar and corrugated tin roof structure without running water or electricity, and our Rapogi base was usually an easy one as long I wasn't caught in the heavy equatorial showers of the wet season. For a motorcyclist, the downpouring rain would quickly spoil the roads and make every approaching truck a tidal wave of redish-colored water. Motorcycles, standard issue for "Water-Techs", had obvious shortcomings compared to four-wheeled vehicles, but they did have the advantage of increased mobility in what was often extremely difficult terrain. That is, as long as the world stayed dry.

The daily work schedule consisted of meeting at the Rapogi Secondary School compound, loading the vehicle with tools and materials and then driving to the site or sites depending on how many projects were ongoing at the time. In the beginning we usually had two projects, but by 1987 that increased to 4-5 as our skill levels and numbers increased.

The previous work experience of mine that most resembled the Rapogi Project is my work for a plumbing contractor in the Bay Area, California. In Rapogi as in Berkeley, we would pick up the work crew, tools, and materials and then run from one job to the next. There were of course many more differences between the work at Rapogi and that of a contractor in the West. No power-tools, or modern building materials such as plywood were available, and the heat of the East African sun made the already heavy work of manual digging and concrete construction that much more tedious. Also, the western contractor doesn't have to schedule around worker's absenteeism due to regular bouts of malaria or the need to attend another family funeral. In fact, because water contamination is one of the primary causes of death and disease in the tropics, in the evenings we often heard the beat of the funeral drums, constantly signalling the importance of improving the water supply. The prevalence of sickness, the great difficulty of getting anything done with inadequate tools, and materials in short supply were constant incentives to increase the efficiency of spring construction, to find better ways of doing the job.

What follows is a description of the technology that was introduced by and, in the process of implementation, changed by, the Rapogi Water Project. The story will start with the development of the technology for constructing springboxes and then move from there to a description of how the springbox technique was integrated with shallow well technology to provide a solution for what I call "hybrid" springs, and finally to the adaptation of the handpump used for the hybrid spring to shallow wells.



The Springbox

After having worked alongside the work team for a short period of time, it became apparent to me that their construction techniques were less than optimal. Especially lacking was their knowledge of the forming and the properties of concrete. I was already convinced that this was the primary skill required for the job of building springboxes. The spring projects that had been completed before my arrival were built using what were essentially free-form masonry techniques. By free-form, I mean that little attention was paid to the geometric conventions of the West, such as parallel lines, 90 degree angles and vertically and horizontally plumb surfaces.

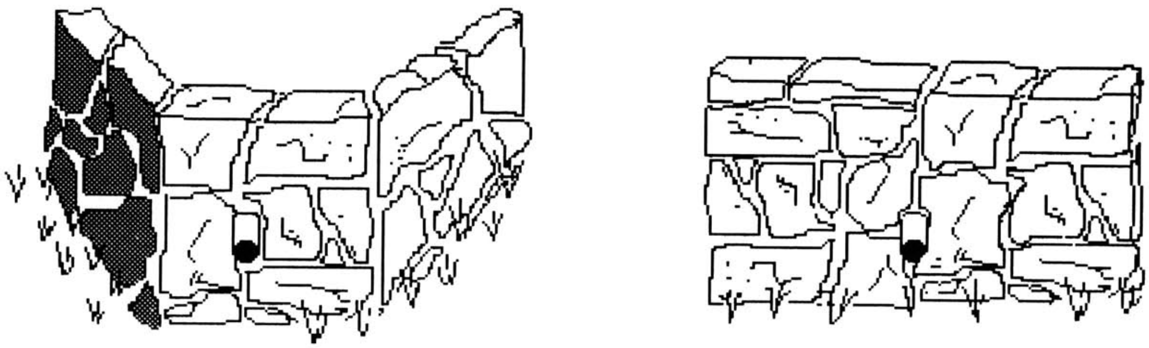


Figure 1. Well-executed Masonry

The biggest problem with this technique was not in its indefinite shapes but in the difficulty of reaching sufficient depth of wall using mortar and stone construction. Water would breach the wall by passing under it and/or around it. Over time, the erosive force of water would cause the spring to find a different path to the surface rendering the springbox useless.

Building a brick or stone wall in wet conditions is extremely difficult if your intention is to create a waterproof barrier. The previous examples of spring protection work(all done with masonry) left by my Water-Tech predecessors made it clear that a better technique of construction was needed. My first step was to improve techniques using materials on hand, which amounted to teaching the work crew basic concrete forming and mixing techniques. It was not long until the team had considerably improved their construction technique which resulted in more permanent structures and less waste of scarce materials.

Within the first four months of my arrival in Nyanza we had completed 2 spring protection projects: Kanyantado and Kanyanbuk. I was responsible for the design and implementation of both of these projects and through them was able to introduce improved form building methods for walls, stairs and platforms, using reinforced concrete. We also improved the quality of sand and gravel that we used. There were no problems with the quality of the cement which was manufactured near the port city of Mombasa.

Both Kanyantado and Kanyanbuk were built using a technique analogous to residential foundation building in the U.S., using mostly 2x6 lumber as the forming material. Since the amount of vertical and horizontal load was small(no houses stood on our springboxes) it was possible to conserve materials by limiting the wall thickness to about 6 inches. Besides this minor difference the design was essentially a keyed footing on which rested a reinforced concrete wall.

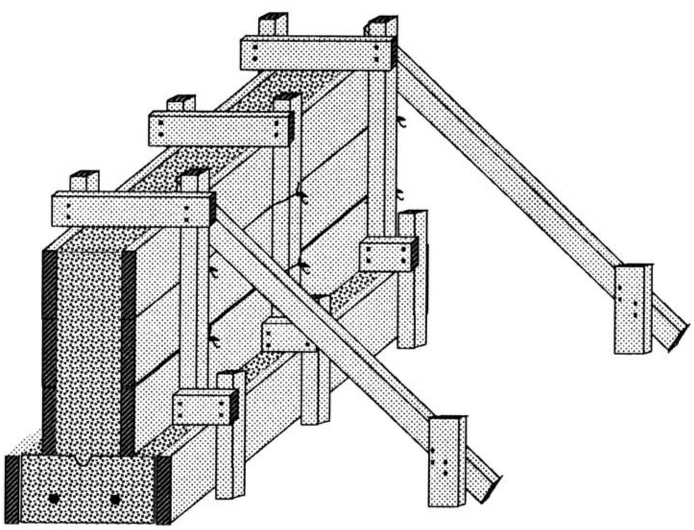


Figure 2. The Lumber Forming Technique

Construction of the springboxes with wood forming techniques borrowed from western house building led logically to using the same techniques to create steps and a splash area under the outlet pipe. This added construction was necessary because the spring outlets were often below ground level, sometimes up to 6 feet, making it difficult for those bearing heavy water containers to climb out of the outlet area. During the rainy season, this situation became worse: it was dangerous for those carrying water in the traditional manner on top of their heads. Also, if the approaches to the spring were not adequately stabilized, then eventually the drainage area would become filled with debris causing the source to back up and finally become contaminated.

Though more effective than doing masonry walls, the lumber-forming technique posed certain problems. First among these was that it was skill and materials intensive. The proper construction of forms for concrete work is difficult largely because of the very high horizontal load induced by the fluid and very heavy concrete that is poured into them. Thus it is necessary to build very plumb, well reinforced forms. This was in practice relieved a little by the fact that hand mixed concrete has significantly less impact on a form then that delivered in cubic yards by a concrete mixing truck(which even if available could never have approached our sites). Nonetheless, significant skill and scarce lumber were necessary in order to implement these projects. Lumber could be reused, but only for a limited number of times before it came to a point where reclamation was not worth the effort.

Another problem with lumber-forming technique was that the art of concrete form building requires a geometric perception of the world. The three fundis lacked the ability to adhere to the regimen of straight, level and perpendicular lines, and for good reason. Having grown up in a world of natural forms, rather than geometric accuracy, it is understandable that they attached less importance to rigid geometry. The Luo people(and for that matter most of the lake region tribes) traditionally live in huts that are a composite of woven sticks and mud. The mud is slapped onto the woven wooden frame. Nowadays these mud walls, in concession to western influences, are roughly rectangular in shape and are shielded from the rain and sun by a corrugated tin roof. Nevertheless, a level floor or straight line remains rare. To the Luo people, the function of a technology, whether it be a house or springbox, did not mean a nagging insistence on the geometric, the institutionalized adherence to the edge of a ruler or a builder's level. For this reason I found that without constant supervision, the work of the three fundis would deviate from what was planned and the quality of the concrete would suffer. The concrete, to be effective, demanded certain standards of construction.

So I investigated a different solution, one that did not require a builder's level. The idea was simple. With both of the previous building techniques that the project had used, masonry and lumber-formed, we would fill the uphill or spring side of the box with large rocks, after completion of the wall, so that we could pour a concrete cover on the box while maintaining free passage of water from the spring. The rocks acted as a support for the cover but not as a barrier to the flow of the spring.

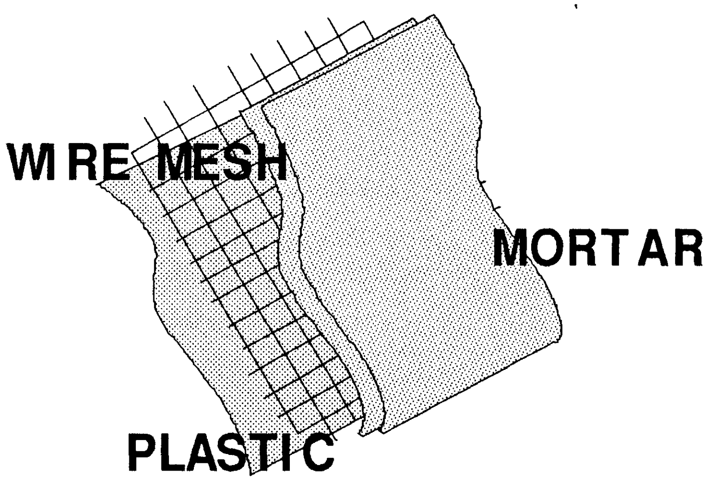


Figure 3. Ferrocement Layers

Why couldn't we just carefully build up the rocks first and then use them as a base and form for a ferrocement wall? Ferrocement is a composite layer of cement mortar and steel mesh and is often used to make rain-water catchment tanks and even boat hulls. It is used in situations where the shape required is curvilinear because it can be conformed to any shape as needed. By using the rocks as the form, we could avoid the necessity of building one.

We tried this technique at a tree nursery close to Awendo, a small road-side town surrounded by fields of sugar-cane. In practice the new wall was made up of three materials: plastic, wire-mesh and a mortar mixture. Our construction technique, after digging the excavation, was first to pour a footing that anchored the wire-mesh backed by plastic, then to fill and form the springbox shape with large stones, and lastly, to mortar the wire-mesh. Apart from certain aesthetic considerations(the end result was rather rough in appearance), the project was a success. The primary benefit of this technique was that it required significantly less material, since the barrier itself was only 2 inches in thickness. We found, however, that this technique suffered a problem also found with the wood forming technique: the difficulty of implementing it under wet conditions. The problem was that it was difficult to maintain the integrity of the polyethylene layer during setup. Once we had punctures we had difficulty in making the wall water-proof.

Beside the basic problem of building the springbox wall, as a barrier to trap water, there was also another problem that we encountered in the protection of springs. Springs are different from one another. This is primarily due to the fact that spring water emerges from the ground at different points depending on the hydrology of the area. The "easier" springs to protect are ones that occur at a location where there is a significant amount of slope.

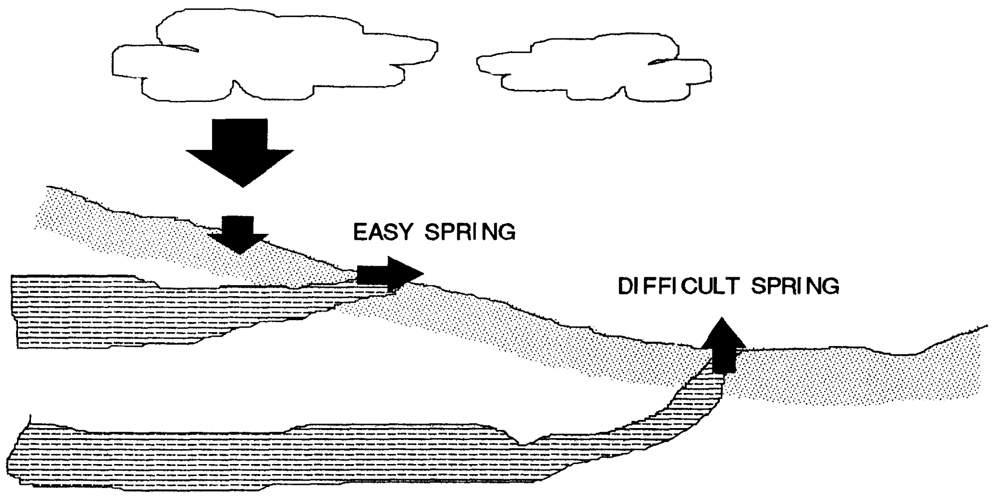


Figure 4. Easy and Difficult Springs

The slope makes entrapment of the spring water easier and provides for clear drainage of the outlet area. But in practice many springs come to the surface in locations where there is little slope, making drainage a very labor-intensive task. In order to make the site safe from contamination by backed-up water, a long channel usually needs to be excavated, with help from the local community. Traditional approaches, such as those we had been using, were very difficult to implement because of the large amount of excavation that needed to be done. Also, though it may be possible to muster the cooperation of the surrounding community to excavate and build a traditional springbox, excavations were problematic due to their tendency to fill with sediment over time. Projects that required extensive excavation also require constant maintenance of the drainage channel. The solution we found to this problem was a "hybrid-type" spring protection scheme that we implemented on the fourth project that I was responsible for in Nyanza.

The Hybrid and Handpump

The hybrid design is a cross between a springbox and a below-grade collection tank or very shallow well depending on your perspective. The distinction at this point between this type of spring protection scheme and a shallow well becomes blurred. Essentially the hybrid is a shallow well that taps a water bearing layer that is very close to the surface. It avoids the necessity of digging a deep and long drainage channel by eliminating the outlet pipe as the source for spring water, leaving only the overflow which is placed at a higher level, enabling a shallower drainage channel.

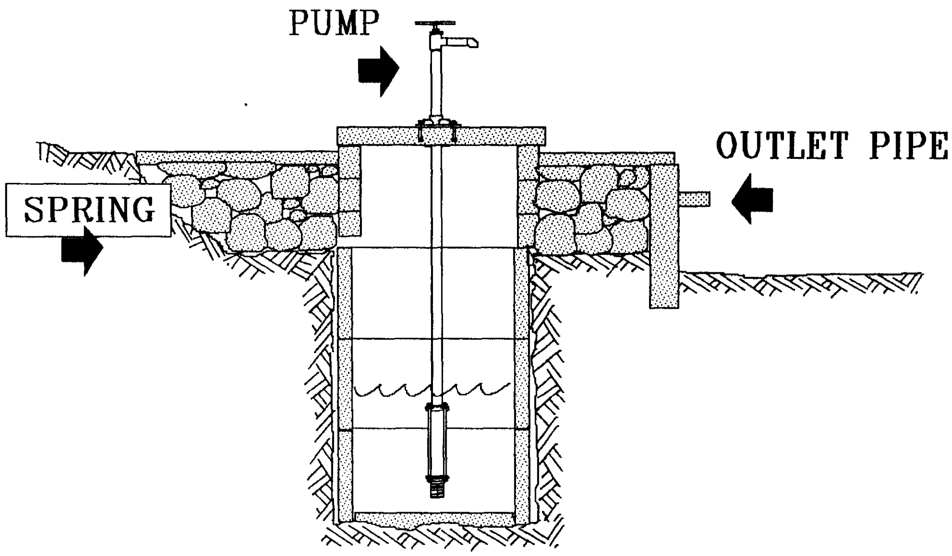


Figure 5. Hybrid Spring Protection Scheme

Though this design relaxes the need for drainage it introduces two new requirements: a pumping device and a way of lining the collection tank. It is the need to lift water from a depth of approximately 3 meters that makes some sort of pumping device necessary

Although the pumping device introduces a new realm of opportunities for mechanical failure, where before there was very little mechanism to fail, it is justified because it reduces the above mentioned drainage problem and improves spring output during the dry season. During off-peak hours the collection tank stores water that would normally flow into the drainage channel and be wasted. Thus, a point source for water that was traditionally unavailable during the dry season maintains its usefulness, if not for the whole year, then for longer than before.

Even in Kenya pumps were available to us from several sources. From previous investigative travels I knew that Kefinco(a joint venture between Kenya and Finland) was producing pumps at a technical school about 3 1/2 hours drive north of us in the town of Kakamega. The Kefinco shop made their own pump superstructure, but their pump cylinder including the piston and valve assembly, was a brass unit imported from Nebraska. The Lake Basin Development Authority(LBDA), a government parastatal involved in a variety of development activities throughout the lake region, was using the SWN(acronym of the engineering firm) series of pumps, which were imported at the time from Europe. Because of the technical sophistication of the pumps, it would have been "overkill" to use them for our purposes. I knew this not only from having seen them and operated them in the field and studied their technical drawings but also from having spoken to one of the engineers responsible for their design. According to him the main pivot for the handle was "1000 times over-engineered." Here, the idea of building "tropical" handpumps had gone to an extreme. "Tropical", in this context, was really taken to mean "community-use." The idea is that traditional handpumps, designed for single family use, need to be improved in order to be used by a larger number of people. According to my informant, however, the main reason for the SWN's over-engineering was the less sophisticated conviction that "Africans have trouble with maintenance."

I had also discovered handpumps being sold at a specialty store selling various types of motorized pumping gear in the town of Kisumu(the main Kenyan town on Lake Victoria) north of us by about 150km. Here, I found, next to the dependable Lister diesels, a pump that had been used in the American Midwest about 50 years ago. It was made of cast iron and cost about sh5000--not such an unreasonable price considering the shipping costs from the U.S., though far out of reach for the majority of South Nyanza's rural inhabitants. Sh15(approximately $1) was a typical day's pay for laborers in the Rapogi area. At this rate, and even at a savings of 50% it would take a laborer two years of constant work to raise sh5000.

Fortunately, there was one more alternative available us. During the spring of 1986 work was ongoing to set up a village polytechnic in Rapogi. This polytechnic was to be managed by a new British volunteer and funded by the Diocese of Kisii Development Office. The purpose of the polytechnic was to instruct local youth in basic metal-working techniques which at the time was right in line with national policy of bolstering informal sector activity in manufacturing.

We knew that we could have acquired pumps from other sources. However, all of the alternatives available to us had at least one major imported component and were excessively "high-tech" in relation to our performance requirements and our level of shop tooling. The fact was that we didn't need anything very sophisticated to raise water to a height of only 3 meters. Also, the lack of an available low-end pumping solution led us to decide that we should use the resources of the polytechnic to fill that product niche by putting such a pump into production. At the time the Lake Basin Development Authority project, using their SWN series of pumps, made well construction contingent upon a community's ability to raise a maintenance deposit of sh2000 for their SWN series of pumps. As a goal we set out to produce a pump that would cost less than LBDA's maintenance deposit, which we felt was still too high for the level of performance required and of the ability of local people to pay. As it turned out, this goal was not such an easy one to reach. The Rapogi pump cost only marginally less than the SWN, proving the SWN, with its real cost of over sh10,000, to be a formidable competitor with its subsidized "price" of sh2000.

When British volunteer Stephen Payne arrived to manage the Rapogi Polytechnic, he made available to us not only his fabrication expertise but the use of a few vital pieces of equipment that totally changed the chemistry of the pump design problem. The main piece of equipment was, of course, the arc-welder. The welder made it possible for us to go beyond the simplest and always hygienically problematic techniques of lifting water from a shallow well. For example, the traditional rope and bucket solution. This is not to say that it was impossible to construct a simple handpump using only hand-assembled plumbing parts with no welding. But the arc-welder made assembly easier and less expensive. The use of the arc-welder reduced the need to manually thread large diameter pipe(a strenuous and failure prone task), reduced the number of high cost prefabricated joints and also solved a design problem related to attaching the pump to the well top using only standard parts. Another benefit was that the production of any pump we designed could become part of the curriculum for the more advanced students at the polytechnic. The problem then was to find an appropriate design.

In considering the pump design, we realized that the pumping solution for the hybrid could logically extend to a pump that would also work for shallow wells or wells deeper than the 3m depth of our initial spring application. Thus, from the beginning, one of the parameters for the hybrid pump was that it be upgradable or adaptable to shallow wells, which meant in practice that it had to be operable at depths of approximately 10 meters.

The first Rapogi pump was inspired by a picture in the book "Shallow Wells",[9] published by the DHV Consulting Engineers of the Netherlands, a beautifully illustrated manual of the activities of the Shinhanga Shallow Wells Project located near Rapogi on the Tanzania side of Lake Victoria.

The picture was one of a pump used for executing yield tests of potential well sites. This pump had not been installed as a permanent piece of equipment; it was made almost entirely out of commonly available galvanized steel plumbing components. From this and numerous other sources of pump design information came the design for the first Rapogi pump. The "Shallow Wells" picture gave us the confidence that pumps could be made out of simple and commonly available materials.

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9. DHV Consulting Engineers, 1979, "Shallow Wells", Amersfoort, The Netherlands. The Shinyaga Shallow Well Project was bilateral technical aid project of the Governments of the United Republic of Tanzania and the Kingdom of the Netherlands and was executed by DHV Consulting Engineers, in cooperation with ILACO International Land Development Consultants and ONV Organization of Netherlands Volunteers.

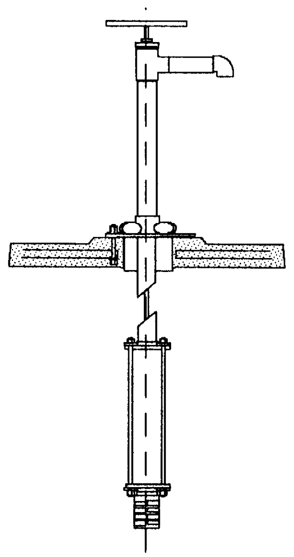

Figure 6. The Rapogi #1 Handpump

The Rapogi pump went through at least two major design changes. In the first stage, its design consisted almost entirely of off-the-shelf components; only its base was fabricated, using sheet steel. Its piston was made from a combination of heat-flattened PVC, industrial belt, and inner-tube rubber. All commonly available in Kisii.

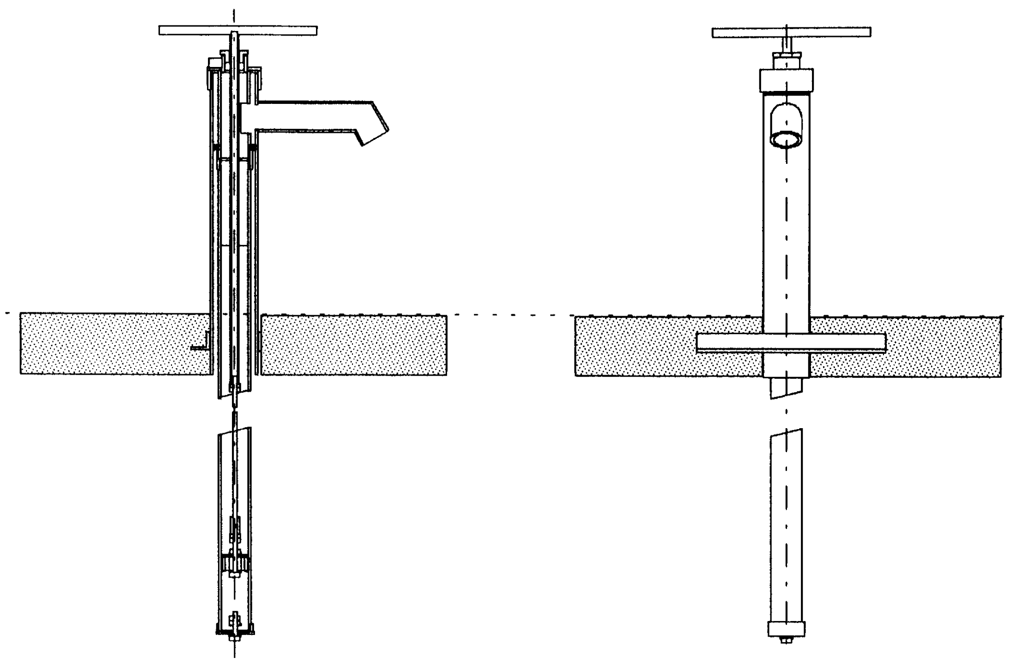

Figure 7. The Rapogi #2 Handpump

In the second stage, the design deviated from the DHV inspiration though was still based on galvanized pipe and joinery. Rapogi #2 used fewer connectors, and these were bisected and welded to the permanent side of their connection, making it possible, in effect, to double the use from each piece.

Our second design was also influenced by a desire to make the pump both more secure and easier to service. These might seem contradictory requirements, but we met them by making it possible to disassemble the pump with just one custom-made tool fitted to the dimensions of the headpiece, which would be provided to the designated care-taker of the pump. The pump would be secure because this tool or a sufficiently large pipe wrench would be very difficult and/or costly to acquire in the Rapogi area, where even a basic crescent wrench is a rarity. Serviceability was enhanced by increasing the diameter of the pump superstructure to 3" so that with removal of the headset all down-well components could be extracted in one piece.

The first hybrid scheme was set up using conventional well-rings for the collection tank. These were made on site using steel shuttering and were then moved(with considerable difficulty) to the excavation prepared for them. The well-rings were a problem because it was both difficult and dangerous to move them. It was also difficult to make a good seal between the rings so as to avoid surface water infiltration of the collection tank.

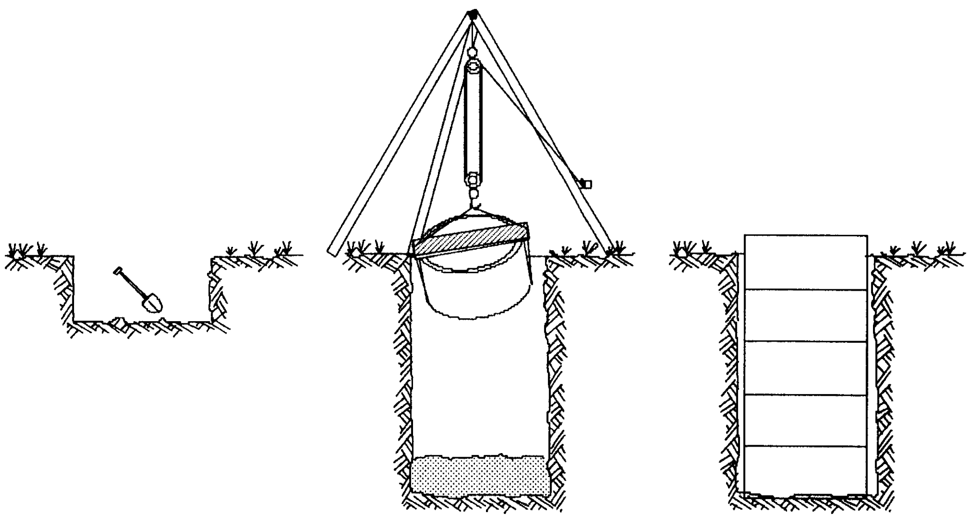

Figure 8. Conventional Well-lining

At time of our development of Rapogi #2, I made trips to nearby organizations involved in similar projects to see what techniques they employed. Most of the larger organizations, such as the Lake Basin Development Authority(LBDA) and Kefinco(Kenya-Finland cooperative venture), were involved in large-scale well construction. Though their methods gave me an insight into the current state-of-the-art of well and handpump construction, the information they gave me was not of much use for spring protection. In the spring of 1986, I was informed by Brother Paul that a peer of his, the manager of the Rural Water Development Project at Sikri, had just received a sizable project grant from a West German organization and was using steel shuttering for spring projects and well lining. Not only was this individual using steel forms(of which I will speak later); he was also using a well-digging and lining technique that we had not seen before.

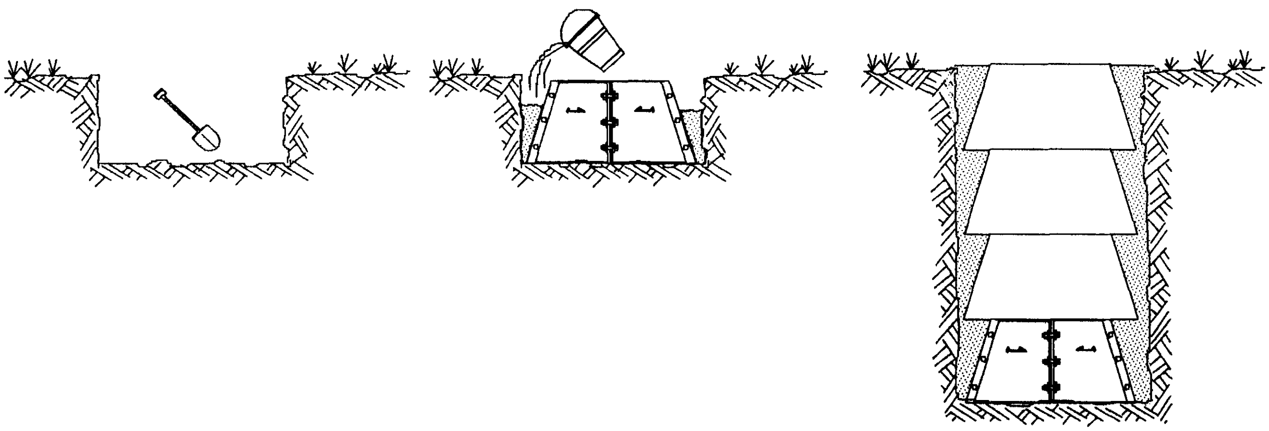

Figure 9. Thai Well-lining Method

According to the Sikri project's manager, this well construction system originated in Thailand. It is unique in that the digging and lining of the well are done together. In most cases, lining of the well is done after the well has been dug, but with the Thai technique, lining is done as you dig. With this technique, concrete is lowered a bucket at a time and poured into the conical-shaped shuttering to form well-rings. The primary benefit of the system is that it is extremely well suited to small well-digging teams, with no requirement for heavy lifting equipment. It is also inherently very safe due to the concentric shape of the form which results in "steps" to the bottom of the well. With this system, there is no need for a ladder.

Steel Springbox Forms

As I mentioned earlier, the Sikri outfit was also using a steel form for their spring projects. Their form was made out of sheet steel and angle iron and bolted together from 4 separate pieces. Each piece was approximately 2m long and required two people to lift it.

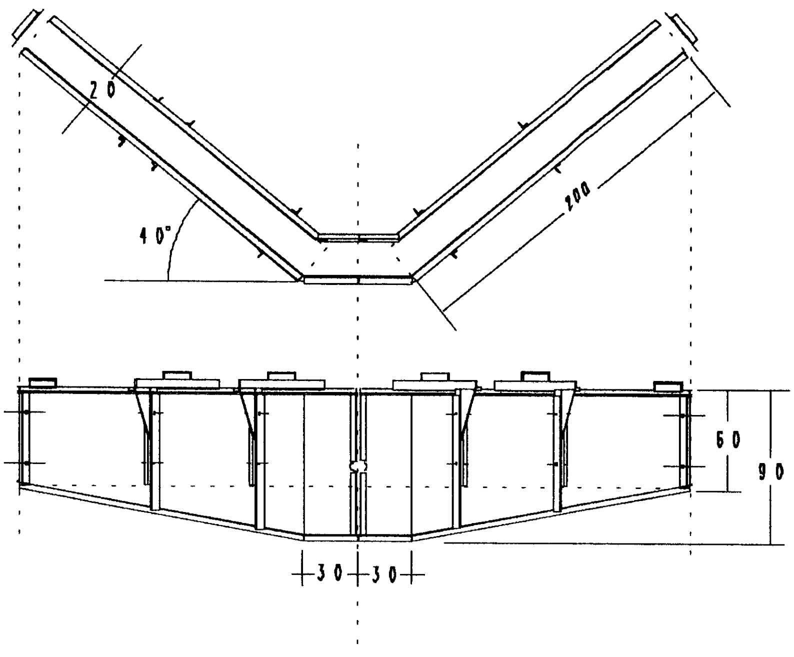

Figure 10. The Sikri Springbox Form

When I visited the Sikri operation along with the manager of the Rapogi Polytechnic, Stephen Payne, we took quick measurements of the form. After a few alterations we came up with the following design for the Rapogi Team.

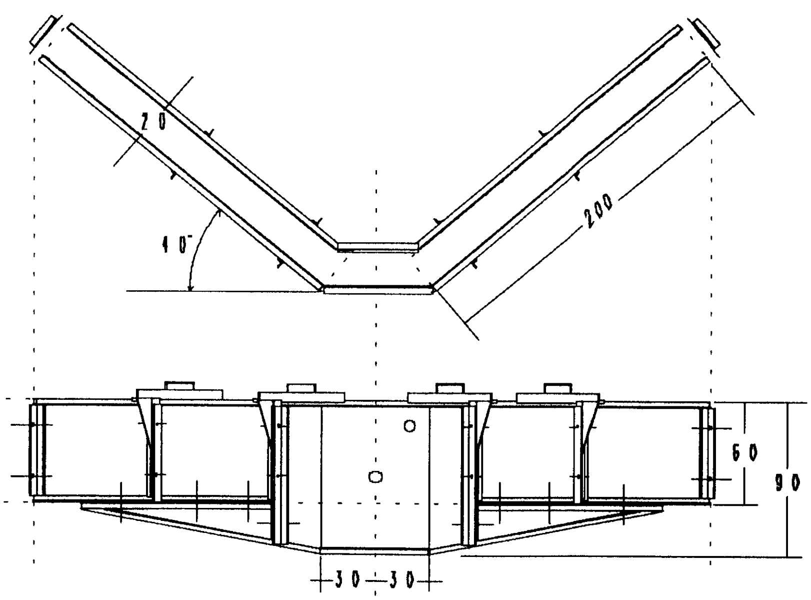

Figure 11. The Rapogi Springbox Form

Though the final Rapogi form was essentially identical to the Sikri form, two changes were made in order to increase its usefulness to the Rapogi Team. These changes were made to increase transportability and modularity. The Rapogi form breaks down into 6(rather than 4) pieces, which makes it possible for one person to handle and load the parts into a pickup truck(the Sikri team had a larger double axle truck for carrying heavy materials which made large size less of an issue). Also the "wings" of the Rapogi form could be extended by adding additional "straight-type" form pieces, essentially the same idea used in building residential foundations in the U.S., which made it possible to build wider springboxes.

The following are diagrams of the final designs we used for the construction of hybrid spring protection schemes and shallow wells using the Rapogi #2 pump.

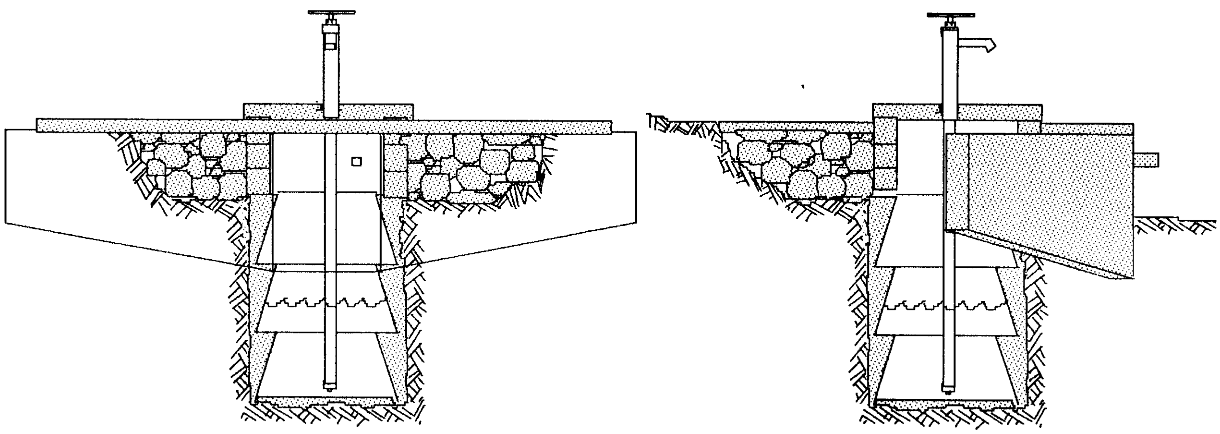

Figure 12. The Final "Hybrid-style" Spring Scheme

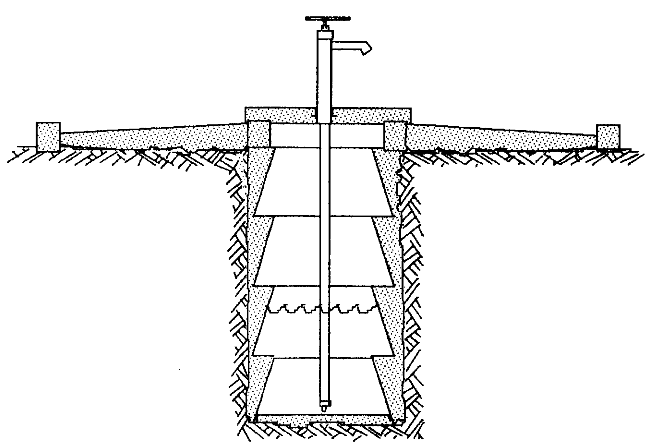

Figure 13. The Final Well Scheme With Rapogi #2

In the final design the spring and shallow well construction designs form highly modular systems. Components in one system are interchangeable with the other, and more importantly, workers trained in the construction of one system are easily trained in the other because building techniques are almost identical in the two cases.

The following are excerpts from a report made to my Regional Director for the period of Sept. - Nov. 1986. This report provides a fairly accurate description of the types of problems we dealt with on a daily basis and captures the general trend of the project towards setting up relatively independent work groups linked by their shared task of developing water supply.

> "During September I was chiefly occupied with getting the 1st steel shuttering for springbox construction together and in use and also with the acquisition of the 4 wheel drive p/up from CRS. The shuttering was completed by mid-month. I picked up the new 4 wheel drive on the 26th from CRS in Nairobi. The next week we transported the shuttering to Kobonyo spring from the Rapogi Polytechnic where it was made. The steel form works well and we have funds to construct 3 more. 1 from CRS(for a total of 2) and 2 from the British Counsel(Stephen Payne VSO, manager of the above mentioned polytechnic is responsible for the British grant)...
>
> ...Started a "rock breaking group" to provide the project with kokoto which we currently buy from A.J. Shamji in Kisii. This will considerably reduce our cost as we are currently being charged sh800(at about 16 shillings to the U.S. dollar) per lorry for transport alone. This will also keep project money in this area where it is more needed. We are budgeted at over 70,000/= for sand and kokoto. Sand we already buy locally...

...The project team is beginning to expand into shallow wells. I am now overseeing 2 new projects both of which have hit water. One well which is at the Piny Owacho Primary School close to Rapogi is now being lined using the "Thai" technique(cone shaped steel shuttering) by two well-diggers that we have contracted and trained for the job. The British Counsel grant includes 2 more of these as they are proving to be safe and cost-effective. After these are made we hope to contract with other well-diggers for the use of the system. Rental schemes are being considered. We also have been getting many inquiries about the well liner and pump. 10 pumps are on order now from the Polytechnic...

...Which brings us to the new 2" pump(Rapogi #2) which is finally off the paper but only partially in material form as we have been waiting for a drill-press machine from Nairobi[needed to make holes in the base]. The drill press arrived just recently...

...Hired a grade-2 mason mid November so that we can expand into 2 work teams the beginning of next year(1987). Presently we have 4 full-time fundis and 2 well-diggers who work on a contract basis.."

As can be seen from this report, the basic technical problems associated with spring and shallow-well construction had been largely solved. The emphasis of my work has shifted to organizational issues.

Organizing a group to break rock by hand for the concrete mixture sounds a bit like a hard-labor in a prison camp; nonetheless, it was a job where none had existed before and it would help to keep grant money in the rural area where we worked. The request for such work actually came from the local community. My response was simply to provide a few tools and agree to purchase the gravel as long as quality was consistent and price competitive with other sources.

At the time the above report was written, we intended to organize the spring project team in two work groups, one headed by Wilberforce, and the other team, Samwell, the new grade 2 mason. This would leave Joseph to deal with the home office. The two work groups would specialize in the more technical aspects of spring and well making, such as the installation and maintenance of the pumps, Tasks such as the digging of the wells would be contracted out to independent well-diggers after they had been trained in the Thai well-lining method.

However one aim of our project was to influence private well-digging projects by providing access to improved well-lining methods. For these well-diggers, the Rapogi Project would supply technical support and access to well-lining equipment. The idea was to get local farmers to buy into the new pump/well lining system developed by the Rapogi Project. This was a form of subsidization for the purpose of increasing demand for the new pump. Finally, the Rapogi Polytechnic would train a production team, which would eventually become independent, to manufacture the direct-action pump which would be sold to either the Rapogi Water Project for community projects or to private buyers for their own use.

CHAPTER 3: TECHNOLOGICAL CHANGE AT RAPOGI

The Range of Choice

Technology transfer is a shortcut to the acquisition of new ideas and new tools in the developed world just as much as it is in less developed countries. In this way technology transfer is as equally important to the developed world as it is to a developing area such as Rapogi. If anything, the ability to take advantage of external sources of progress in science and technology and to apply this knowledge to economic activity grows ever more critical to economic competitiveness for all countries. This means that time is of the essence, and the rapidity of technology transfer spells the difference between those countries that develop and those that don't.

The passage of time coupled with the greater pace of progress in the industrialized countries, however, has given rise to the main difference between the conditions of technology transfer encountered in a less developed area such as Rapogi versus those in DCs. For the DC, choice of technology is a question of which new technology to pursue, or which as yet untested technology holds the most promise for a firm's future competitiveness. This is a choice that occurs at the frontiers of technical and scientific knowledge. In contrast, choice of technology in Rapogi is better described as a choice of the level of technology to buy into, a choice bounded on the one side by Rapogi's present circumstance and, on the other, by the latest range of technologies available in developed countries. As long as developed countries continue to develop faster than Rapogi and Kenya, the gap between technologies will become greater. In turn, as the gap becomes greater, so does the range of possible choices of technology.

The existence of a range of alternative technologies is the premise upon which the issue of technological choice in developing countries rests. Obviously it would be impossible to address the question of the usefulness of current firm-level innovation theory to technological choice if no choice existed at all. On one side of the theoretical debate, neoclassical economic theory assumes the existence of an infinite number of alternative technologies for the production of any good at any scale. It also assumes that these technologies lie on a continuum along which it is possible to substitute one factor of production for another. Others theorists argue that there is no choice, and that one technology, the latest, uses the least of both capital and labor and thus, because it is the most efficient, will always be chosen.[10]

These contradictory positions coexist mainly because very little information has been collected about the practical availability of alternative technologies for the production of a given good in LDCs.[11] Yet, another position questions the basic mechanism that neoclassical theory assumes as the source of technology choice. These countertheorists argue that factor cost minimization is not the main objective of the decision maker in choosing a technology. Rather they stress other more important factors such as the minimization of risk associated with new technologies, and the protection of an oligopolistic market situation.

For the purpose of this thesis we will assume that there does exist a choice of alternative technologies though it need not be a choice as extensive as assumed by neoclassical theory. In fact, my own experience in Rapogi suggests that although choice does exist, it is composed of discrete technologies that vary widely in their technical sophistication. Aside from my own observations, however, we have the luxury of assuming choice for the following reason. Third World development projects managed and funded by non-profit organizations, such as the U.S. Peace Corps and the Catholic Relief Service, are by definition not driven entirely by cost considerations, and thus fall within the countertheorist's argument that considerations other than price can drive choice. Thus, on the premise that choice exists, especially for development projects, the question is

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10. Amsalem 1983 PP 2-3

11. Amsalem 1983 pp 4-5

what kind of choice or mode of implementation increases the likelihood of fostering indigenous innovative capacity.

Before specifically examining the RWP from the perspective of this question, there is another point to consider, one which is at the core of the technology choice problem. The question of choice necessarily leads to the question of "leap-frogging"; is it possible to "leapfrog" and thereby avoid taking all of the incremental steps from one level of technological sophistication to another?[12] In fact, assuming that "choice exists" is tantamount to assuming the ability to jump ahead, if we consider those available choices to be composed of increasingly sophisticated technologies.

One could say that this is both a basic feature and complication introduced by development agencies. We can expect that profit oriented institutions provide a certain type of technological choice to developing countries, rigidly constrained by cost considerations and the private interest of the company. Similarly, large government-based aid organizations would provide another level of choice, less constrained by cost and concerned with the longer-term social benefit of the receiving country. While smaller, church or secular organizations would provide yet another set of technological choices. Development agencies, because of their nature as aid-giving institutions, bring a larger spectrum of technology choice to LDCs, making leapfrogging from one level of technology to another level that much more possible. The appropriate technology movement is the prime example of the expansion of technological choice available to LDCs. The idea behind the appropriate technology movement is that the simple transfer

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12. Soete argues that, "..the opportunities offered by the international diffusion of technology to jump particular technological paradigms and import the more, if not the most, sophisticated technologies that will neither displace the capital invested nor the skilled labor of the previous technological paradigm, constitute one of the most crucial advantages of newly industrializing countries in their bid for rapid industrialization." Also.. the international diffusion of technology fits historically within the overall process of "spurts" of industrialization and that due to the overall conditions of the microelectronics revolution the potential for developing countries to leapfrog have never been better. [in the context of NIC, Soete p416]

of technology as it exists in the developed world is inappropriate to the "vastly different needs" of less developed countries. As would be expected from charitable institutions technology is viewed as an aggressor towards culture and needs to be modified in such a fashion that it be more palatable for the receiving country. This modification of existing technology leads to increased choice.

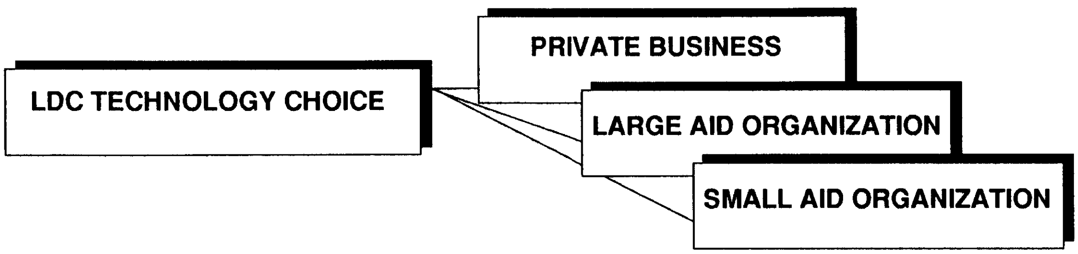

Figure 14. The Choice of Technology

It is also the case that in the rural areas of many developing countries, such as Rapogi, voluntary organizations are the only or primary link to external sources of technology. Without development organizations the choice would be simpler and more extreme: the low-tech of indigenous resources or the high-tech of multinational corporations.

Technological Change in Rapogi

Technology development at the Rapogi Water Project can be divided into three basic streams of activity: the development of new springbox construction methods, the development of a new way to protect "problem" springs, and the spin-off to shallow wells of the pump technology originally developed for the hybrid spring.

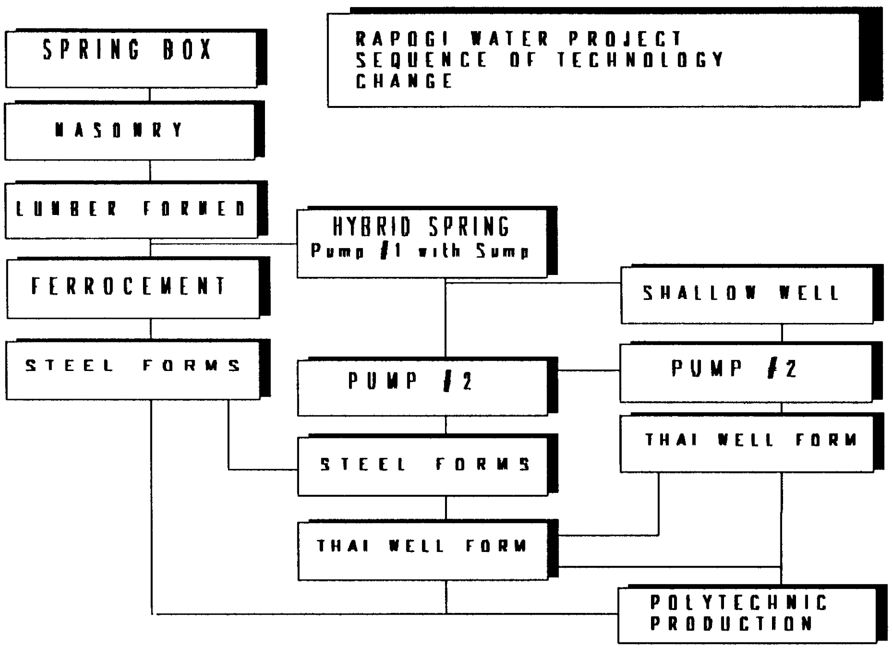

Figure 15. The Technology Change Flow chart

All of these activities involved the introduction of new problem-solving techniques from abroad, i.e., the act of technology transfer. However, analysis of how each technology changed after introduction, whether it be the concrete forming method or the handpump, reveals the impact that the initial choice of technology has on its own subsequent path of change and how that path of change affects indigenous learning and thus innovative capacity.

Constraint Induced Change

Upon my arrival in Rapogi there already existed a technique of protecting springs that had been in use for two to three years and had previously undergone some minor changes. A masonry catchment was used to channel the natural flow of a spring through a pipe, thus protecting it from contamination. By the time of my departure this spring protection technique had undergone at least four major changes. From masonry to concrete, from concrete to ferrocement, from ferrocement to steel-formed, and finally from steel-formed to hybrid. However, it is important to note that, though changes did occur, and as a result the quality and output of springs were greatly enhanced, they were all limited to process changes in construction and materials and did not affect the overall concept of a gravity-flow spring water collection method, the springbox. In this sense our model of how to collect water, or in a more general sense how to provide clean drinking water by improving traditional sources, was not altered by the succession of innovations that we made to building springboxes. In fact, the springboxes that were built in Rapogi, and those used elsewhere in the world, today and yesterday, look and act much the same even though the methods used to build them or the materials of construction might be very different. However, in the case of Rapogi, the process of implementing springboxes had changed drastically as a consequence of the change in the level of technology used to build them.

The past investment and commitment to the idea of springboxes provided a rigid framework within which we made only small incremental changes to the springbox building process, such as a change in materials in one project, or a change in the shape of the springbox in another. The idea of a springbox acted as the technological frame within which changes were made. In fact, the changes were induced by what our work team perceived as the most restrictive constraints of the technology, such as the difficulty of making waterproof barriers with masonry or the problem of springs with little drainage.

Once a change was made, however, there was a tendency for that change to beget further changes. The change from simple masonry to using concrete formed with steel shuttering led to our awareness of the weakness of continuing to build the steps using the old technique of stone and mortar. Though not initially viewed as part of the problem, the performance of the steps(in this case measured in longevity) decreased relative to that of the springbox. Thus, our attention then shifted to improving the steps. The most efficient solution was derived from the previous learning about the new box building process(steel shuttered concrete). The final result was that all components of the project(springbox, steps, splash area) were made using the new forming technique. This shift from the pursuit of one constraint to another suggests, as Rosenberg put it, the possibility of formulating an "...approach to technical change in terms of a bottleneck analysis."[13]

Another example of a constraint-induced innovation can be seen in the development of the Rapogi pump. After the prototype was constructed and successfully implemented in our first hybrid spring, the next step was to reduce the difficulty of producing the pump itself. The result was a pump that required fewer threaded components, thereby reducing the time needed to carefully make threads in large diameter pipe. Of course the innovation of making hybrid type springboxes was itself a constraint-induced innovation; the constraint was the difficulty of using traditional methods at spring sites without adequate drainage. In this case two different types of technology were integrated, traditional springbox and shallow well, to produce what Sahal calls a "systems innovation."[14] Systems innovations, by bringing together two symbiotic technologies, have the property of simplifying the overall outline of the previous design problem. In our case, this meant reducing the need for an extensive drainage channel.

This constraint-induced innovation is a self-perpetuating process. For example, a spring protection project consists of different components: the spring wall, the steps, and the splash area. When one of these components develops faster than the other components as

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13. Rosenberg p.24

14. Sahal p. 70

a result of it being viewed as the primary constraint on the operation of the system, it leaves the other components behind. This has the affect of causing a technical imbalance of interdependent processes to occur. As a result, one of the other components becomes viewed as the next primary constraint on the system. This causes the cycle of change to repeat itself. In this sense there is a tendency towards constant improvement of the technological system through a process of correction of the weakest component. As Rosenberg states in his discussion of the development of medieval siege machinery:

> "Part of the reason for the effectiveness of technological disequilibria in inducing innovations is that they involved compulsive sequences. The relationship among components was such that some imbalance *had* to be corrected before an initial innovation could be fully exploited."[15]

The idea of the introduction of technology leading to a progression of technical improvements, however, depends on one critical aspect of the technology. That is, the technology must possess technical space for improvement. If the technology that is introduced is already perfectly suited to the task, then there would be no need nor room for technical improvement. However, it is apparent that, the process of reaching a stage where technology is optimally suited to its task is, as Rosenberg put it, a "cumulative and self-generating one."[16]

Different Types of Constraints

Returning to the original springbox, the questions are: What exactly were the constraints that drove the change from masonry to steel-forms, and are there different types of constraints that result in different types of change? The initial change from masonry to lumber-formed concrete was motivated by what were primarily performance issues. The concrete was a better barrier and lasted longer. However the attempt to use ferrocement

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15. Rosenberg p. 66

16. Rosenberg P. 62

was motivated by issues other than the performance of the finished product. The constraint in this case was the available human resources.

The ferrocement type spring was attempted primarily because it did not require the skills necessary for the lumber-framed method of building. That is, it didn't require what I referred to earlier as a "geometric perception of the world." No float levels or accurate measurement were necessary for construction. The ferrocement technique failed, however, primarily because it could not compete with the durability of concrete(a performance aspect), even though it definitely solved the problem of geometric awareness(a human resource aspect).

While the ferrocement technique failed, another innovation induced by a human resource constraint proved to be a success. The steel form method was developed as an attempt to circumvent the inability of the fundis to build vertically and horizontally plumb surfaces. Of course, the fundis were perfectly able to learn how to be master carpenters. However, introducing the steel form eliminated any need to teach them master carpentry skills. Thus, developing and adopting the steel form method proved much less difficult from a managerial point of view, than spending the time necessary to train the fundis.

From the above discussion, it is possible to posit the existence of two types of constraints that induce different types of innovation in development projects. The first can be generalized as a hardware based "performance constraint", that induces the type of change characterized by the change from masonry to lumber formed concrete. This was a essentially a materials innovation that addressed the problem of leakage. The second is the "human resource constraint", or "lack-of-available-skills-constraint" that drives the type of change that occurred between the lumber-formed technique and the steel-formed technique. This change did have a performance element but was primarily driven by the need to de-skill the process. Use of the steel forms resulted in better springboxes, but a well-executed lumber-formed box would have been more than adequate.

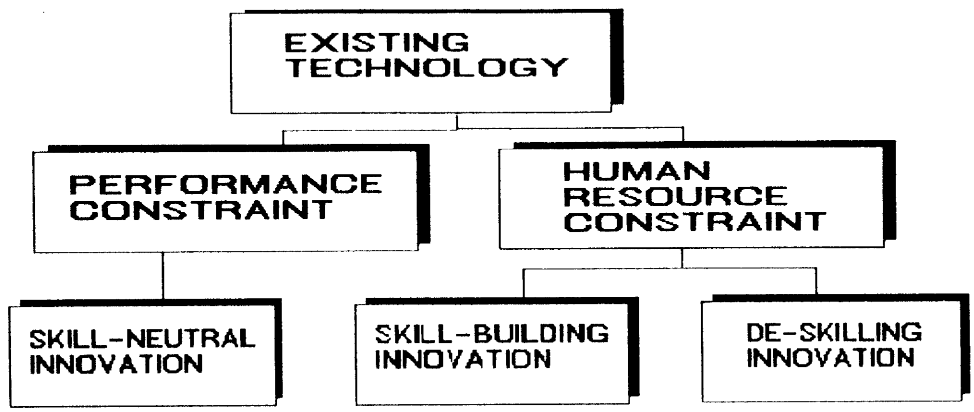

Figure 16. Constraint Based Innovation Flowchart

While addressing human resource constraints often leads to de-skilling, a skill enhancing affect can also occur. A prime example is the Thai well-lining technique. The introduction of this technique enhanced the capability of the well-diggers who up to then had no method to safely line wells. The introduction of the Thai technique also required that the well-diggers learn how to use it. Thus, in this case a main characteristic of a skill-building innovative response to the human resource constraint was that it required an element of learning. In contrast, the de-skilling response attempts to circumvent the need for learning. While, the purely performance based constraint can induce skill neutral innovation, such as the redesigning the steel-forms to break down into six pieces rather than four, simply so that they would be easier to carry, the response to the human resource constraint is never skill neutral. Thus, different types of constraints appear to exist that result in different types of innovation, or the "bottleneck" takes on different forms requiring different responses. The question then becomes, does any one type of constraint have a tendency to dominate innovative activity in development projects?

Reaction to Constraints

One of the overriding characteristics of the Rapogi Project was the rapid spread of the steel-shuttered concrete building technology through all aspects of the work. Initially only the springbox was constructed in this manner but in the end not only the springbox but also the spring's steps, the hybrid spring's sump-lining, the shallow well-lining, and well-cap were all accomplished using the same technique, though of course the shape of the forms were different. The transfer of previous learning, in this case from springbox to all of the components, led to the standardization of building technology throughout the project.

However, by labelling this process "standardization", one needs to exercise some caution. "Standardization" can mean different things depending on the context of the technology in question. Within the framework of the Rapogi Project, standardization meant for the most part the use of one particular building technique for all the different types of components we built. One construction technique was used for all aspects of the job, making skills acquired in order to implement one part of the building process readily transferable to other parts of the project. Thus, this was a standardization of the building process and not the product.

On the other hand the normal use of the word "standardization" in the industrialized countries is one that refers to market forces, standardizing across industry. This allows competing production units to build interchangeable components with the intention that total market demand for some new technology will grow. Examples such as the Compact Disc(CD) and VHS video tapes come to mind. Standardization, and thus the loss of monopoly profits in modern industry, is tolerated only because all parties gain. Thus, this is the standardization of the product and not the process.

Of course, in Rapogi there was little need for standardization in the above sense even though the issue of standardization is an important one for the maintenance of equipment.

in developing countries. A frequent problem with the maintenance of handpumps and other hardware in developing countries is the lack of spare parts. One reason for this difficultly is the large number of organizations involved in the installation of equipment who are all served by different suppliers. The different hardware also means that operation and maintenance requirements are also dissimilar.[17] However, for the Rapogi project, there were other reasons to standardize.

From the perspective of the project manager, deviation from planned construction design is most likely the main problem of daily activity. In developed countries extremely detailed construction drawings outlining every aspect of the job from structural to electrical are distributed to contractors who are responsible for their own portion of the job. On the other hand, in the field of development work, it is more often the case that workers are not trained to read blue-prints. This provides the manager with a very strong incentive to incorporate into the project building techniques that have less skill requirement. To serve this purpose the steel form not only defined the shape of the springbox but it also defined how the job was to be done. The location, shape and depth of the excavation, and the type of concrete mixture, including the specific amounts of materials needed per project, were largely defined by the dimensions and function of the steel form. This greatly reduced the amount of decision making that needed to be made at the spring site.

Standardization in this sense is more closely related to what is usually referred to as "automation" in developed countries. The main goal is less worker contact, primarily because worker contact decreases the quality of production. With the steel form, the shape and size of springbox are predetermined and are thus taken out of the hands of the

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17. NCIH 1983

worker. The manager no longer has to be concerned with how the project is done, but only that it gets done.

This tendency to de-skill at such an early stage of development or at such low levels of technological sophistication is important because it has little to do with the usual explanation for substituting capital for labor. Factor costs are not the issue in this case; control of quality is. In the developed countries, it is expected that automation plays a dominant role in competitiveness when we speak of mass production, flexible specialization or any industry that requires a high level of output of more sophisticated products. But automation is not only robotics and sophisticated computer technology; it comes into play very early in any kind of production setting. There is a strong tendency to innovate with the express purpose of increasing managerial control at the expense of worker control over production. We can expect that in development projects where the skill level of workers relative to managers is low, this tendency would be that much stronger. Further, when skill levels are low to start with, because no prior investment in skills have been made, the tendency to introduce sophisticated technologies that require lower levels of understanding is that much greater.

In the project setting, it is not always clear to the manager that the real reason for a change in hardware is to make the job less skill dependent. In practice, steel forms are just a "better" way of doing the job than lumber-formed concrete or ferrocement. The change to steel appears as an obvious step to take, especially when one considers that it more closely resembles "how it would be done back home." Since the steel forms embody a more sophisticated technology they are justified as just that much more technology transfer. However, by doing so, technology transfer becomes merely the act of hardware transfer and not the development of local resources.

In this type of situation, innovation is driven by the need to de-skill the job. The impetus behind the act of innovation becomes the struggle to make the system work without depending on human resources. De-skilling is necessary is because it is easier to implement than any innovation which would require teaching. Thus, instead of spending the necessary time to instruct workers in the carpentry skills necessary for building high quality lumber-based forms it was easier to upgrade to a level of technology where those skills were altogether unnecessary. The fundis are now able to use the steel-formed technology but are doing so without really having the skill to build "geometrically correct" objects. Thus, though they are able to build springs using the form, they would be incapable of building without it. Also, if faced with the need to build a project of non-standard dimensions, they would be unable to make this adjustment because they lack the fundamental construction skills to do so.

Another problem with de-skilling innovation is that there is a built in mechanism for "leapfrogging" that is managerially driven. Essentially, leapfrogging occurs when the move from lower forms of technology to higher is not the product of any learning-induced succession. Leapfrogging is preferred not because it benefits the workers or the job at hand(which is not only building water supply, but also fostering innovative capacity) but rather because it benefits management.

Luckily not all of the Rapogi Project was a process of de-skilling workers by the gradual introduction of less skill dependent systems. The introduction of the handpump required the fundis to learn how to install and maintain the pumps. As mentioned above, the handpump was used to teach aspects of metal working and arc-welding to those students at the polytechnic. Another example of skill-building change was the development of the hybrid spring system that made it possible to develop springs sites with inadequate drainage. In this case, the introduction of a new technology required that the Rapogi work group learn the new process in order for the system to be built.

To reiterate a previous example, the local well-diggers we contracted were trained in the use of the Thai well lining system, which made it possible for them to build complete concrete lined wells, something they had no way of doing before. Thus, compared to the steel springbox form, the pump, hybrid, and well-lining methods all had skill-building effects. On the whole, it could even be argued that the change to concrete-based construction using the steel shuttering technique actually increased the total repertoire of the Rapogi work team.

The tendency for the "standardization" across all components of a project can in large part be driven by the managerial need to increase control over construction quality. This increase in control is made by decreasing the need for the worker to make decisions, resulting in de-skilling the job. In this situation, innovation can occur in order to circumvent the learning required to master the "craft" of a lower, and possibly more appropriate technology. This type of "standardization" can lead to technological leapfrogging.

Maintenance

The issue of hardware maintenance provides further examples of innovative activity that is de-skilling. At minimum, a successful water development project requires equipment, the funds to pay for it, and the capacity to install, operate and maintain it. Given the availability of the hardware and the capability to operate it, the success of a water project hinges on maintenance. According to USAID statistics, the developing world is full of broken handpumps, with two-thirds of an estimated 150 million pumps inoperable at any given time. The World Health Organization reports that 40 to 80 percent of all handpump installations in developing countries fail within a time period of only three years.[18] These statistics point out the importance of developing well designed

18. National Council for International Health(NCIH), *U.S. Based Agencies with Water Supply and Sanitation Activities in Developing Countries* , July 1983.

maintenance systems for water projects, the primary ingredient of which is skilled technicians. In light of the previous analysis, however, the skill-building necessary to train those technicians is not often accomplished. Furthermore, skill-building appears to occur only with the introduction of technology that enhances already existing capabilities, rather than technology that circumvents the need for skill.

One can hypothesize two general trends that occur when technology undergoes change in Third World development projects. One is the trend to decrease the necessary human input into the technology system by de-skilling. This is evidenced by the development of the spring-building process. Second is the trend to innovate for the purpose of empowering the users of existing systems. This is the type of innovation that occurred when the second version of the handpump was changed to increase the ease of field maintenance. Prior to Pump #2, any repairs required the complete removal and transport of the pump back to the polytechnic where those who originally manufactured the pump could make repairs. Innovation to the pump in this case meant increasing access by users to its component parts. In the long run, this modification made it possible to train an individual, who was either responsible for the pump as a representative of the community or as a private owner, to be able to self-maintain the pump. This type of pump is called a Village Level Operation and Maintenance(VLOM) pump, and differs from other types of pumps introduced in the area.

Our main competitor in the handpump business was the Lake Basin Development Authority who implemented shallow well systems using the SWN series of pumps imported from Denmark. This pump typifies the opposite of VLOM handpump design.

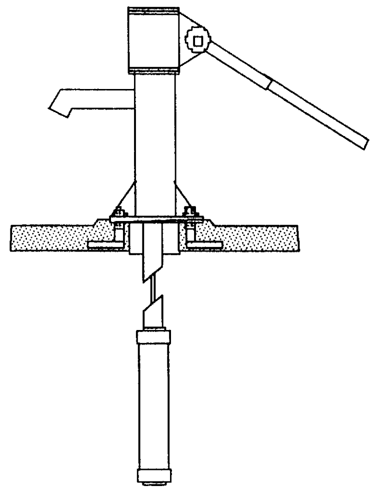

Figure 17. The SWN 40 Handpump

Though it may not be readily apparent, the SWN series of pumps are extremely heavy duty. As noted earlier, critical components have been over-designed by more than a factor of 100, according to one of the engineers responsible for its design. The Lake Basin Development Authority installs hundreds of these pumps annually and is very successful at building shallow wells.

Though the design of the SWN is very sophisticated, and the Rapogi pump itself owes a good deal of its heritage to ideas borrowed from it, it is a sophistication that is aimed primarily at de-skilling the technology. The incentive is to decrease the need for pump maintenance. During my conversation with the engineer mentioned above, I was told that the pump was designed to last 10 years without any need for care. The design objective was essentially to create a pump that did not require any maintenance at all, which would make it possible to circumvent the whole issue of a field maintenance system. It is for this reason that the SWN pump is not only heavy duty, but is designed to be inaccessible.

It is ironic, considering the emphasis placed on "appropriate technology" in development work, that development agencies such as LBDA insist on the use of "state of the art" equipment for even such simple and established technologies as the handpump. It is important to remember that handpumps are a low technology option. However, the "state of the art" in the SWN pump is purely the result of efforts to make it maintenance free. In contrast, the Rapogi pump operates under the assumption that it will break down, but since production is localized this is less of a problem. Localizing the production of the system provides a built-in training system for future maintenance of the system. The SWN pump, on the other hand, is designed on the assumption that local maintenance is either not possible or more of a problem than designing a maintenance-free pump. It is true that the hardware solution is easier, just as it was easier to switch to steel-formed concrete construction rather than teach carpentry skills. This is not to say, however, that the hardware solution is trivial. According to Jequier;

> "..the design of an intermediate or appropriate technology, contrary to what is generally believed, is often very complex from an engineering point of view. In fact, the weaker the innovation system and its components(e.g. repair services, educational level of the users, credit facilities, transportation network, etc.), the more important the reliability and economic attractiveness of the hardware."[19]

However, the complexity of this type of "appropriate technology" poses a contradiction. If the "innovation system" is less developed we would normally expect that a technology that would "fit" would also be somewhat less developed, instead of being "complex" from an engineering perspective. Apart from the level of technological sophistication, the main difference between a Rapogi and a SWN type pump has to do with their links or "fit" with the surrounding community. The Rapogi pump depends heavily on the existence of what Teece calls "complementary assets",[20] such as the Rapogi Polytechnic, the well-diggers, and of course the fundis of the water project itself for production and maintenance, while the SWN approach attempts to reduce this dependency. If a pump

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19. Jequier p. 50

20. Teece, p. 285. Innovating firms often fail to obtain significant returns from an innovation especially when two conditions prevail: One is when the innovation is easy to imitate and two, when the firm does not have a prior position in the certain parts of the market necessary for overall production and marketing of the innovation. The later are what Teece calls complementary assets. To be competitive, firms require not only the ability to come up with new and saleable ideas, but must also have the requisite manufacturing and related capacities so that imitators do not reap the economic the benefits instead.

maintenance, while the SWN approach attempts to reduce this dependency. If a pump needs to depend on its complementary assets for production and maintenance we would expect it to be at the same level of technical sophistication as its surroundings, otherwise how could it be locally supported, let alone be a product of local innovative activity?

In its general function, the SWN pump was essentially the same technology as the Rapogi pump. It is a low technology way of lifting water from a well. The main components are the same, including the pump cylinder, down pipe, superstructure, and the pump-rod connected to a handle.

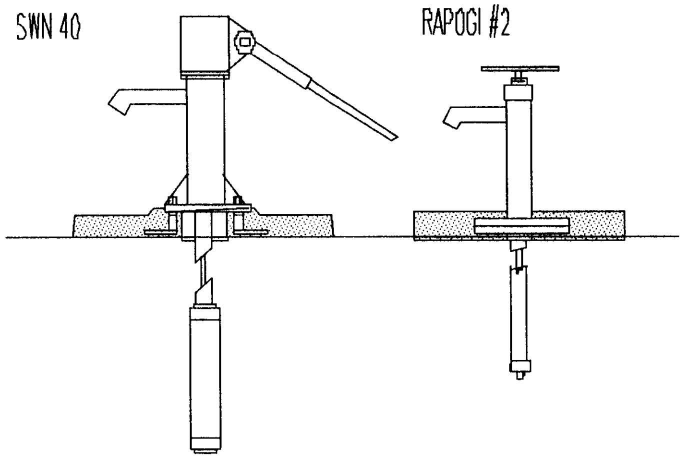

Figure 18. The SWN and Rapogi Pump

What differentiates the SWN from the Rapogi pump is that it is designed and made out of sophisticated imported materials that are heavily geared towards reducing the possibility of failure.

However, the most interesting aspect of this type of pump is the fact that though it in an overall sense embodies an old technology, there has never actually been a pump quite like it in the history of handpump technology. In fact if we use an S-curve to map the development of the water pump over time(the handpumps technological trajectory) the SWN type of pump would be off the S-curve altogether.

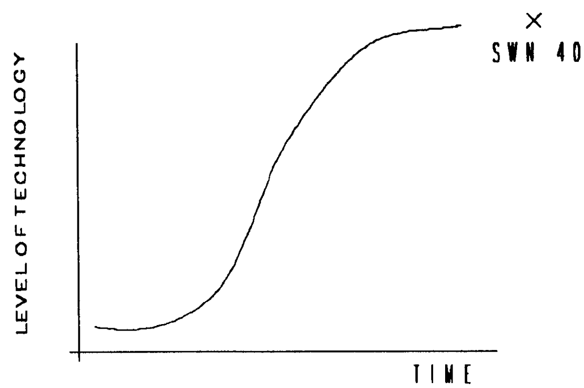

Figure 19. The Technological Trajectory of the Handpump and the SWN

The SWN pump would have undoubtedly been happily used if it existed 100 years ago on a rural farm in Nebraska. However the development of handpump technology in the U.S. stopped short of reaching the sophistication of the SWN. This was either because new and more sophisticated technologies took its place or else the need for such extremely low maintenance pumps never existed. In this sense the SWN pump is a technological anomaly specially designed for operation in less-developed countries.

The basic problem with systems that are designed with a large emphasis on low maintenance, besides the fact that this often requires expensive imported components, is that they tend to be "black boxes" to the local community. They are not designed with access in mind. In fact, much of the design effort goes into constructing pumps that are difficult to access primarily for security reasons. However, systems that are not amenable to change or adaptation pose a problem if the change and adaptation of technology is considered the main mechanism of technological learning or skill-building in society.

According to Sahal the origin of innovation lies in the process of adapting the size or structure of technologies to meet different needs.[21] Since the act of adapting is constrained by the inherent nature of the technology's structure and materials, learning occurs. Sahal calls this "learning by scaling." In the context of the Rapogi project

21. Sahal p. 63

examples of this kind of scaling would be: adapting the Sikri springbox form to Rapogi conditions, or adapting pump #1 to work in shallow wells. It could also involve the adaptation of western technology to local culture. Sahal's point is that the origin of innovation lies in learning to overcome the constraints that arise from the process of changing the technology. Thus, without technological change, there is no possibility of learning. If learning can only occur if scaling is possible this would mean that technology transfer can only occur with those technologies that are amenable to adaptation locally.

CHAPTER 4: CONCLUSION

From the practitioner's perspective technological decisions are in one sense easy to make. This is because the day to day necessities of the job at hand do not leave much latitude for choice. Yesterday's planning is usually left in the wake of today's problem and once today's problem is solved there is always another problem requiring immediate attention.

However, before the start of a new development project, the project planner needs to make an initial judgement on what technology to use. This initial choice is important, because it determines what form the implementation of the project will take, and the character of implementation will determine whether the capacity to innovate will be fostered. The initial choice is also important, because once chosen, rarely is there deviation from its overall framework.

The difficulty of choice is partly embedded in the nature of the development organization. Unlike the private firm with its rigid cost constraints and need to satisfy the demands of a market, the development organization is by its nature less controlled by these demands and is able to dictate the "needs" of its market. This flexibility, however, contributes to the development organization's confusion over its role in technology transfer. The analysis of the technical change that occurred in the Rapogi Project, however, helps us to understand some of this confusion.

Innovation, in the setting of the development project, has dominant characteristics that help us determine whether certain types of technology will act as a catalyst to indigenous innovative activity. The two main characteristics are; one, that innovation occurs as a response to technical imperfection and second, innovation is means by which to circumvent human resource constraints. Technological learning is a product of this process of responding to perceived problems. Whose learning that becomes, however, depends largely on the response to the perceived human resource constraint. If the response is to find a way to avoid any dependence on local resources, whether human or material, then the learning is invariably that of the aid-giver, and usually comes in the form of an exercise in hardware innovation. On the other hand, if the response is to make links with available resources and to build on existing capability, both aid-giver and receiver can benefit from this learning experience.

It is apparent that for learning to occur, change is the key. In fact, change needs to be a constant and desired feature of the technology. A technology choice, if based only on the static performance of the technology in question(whether or not it will "work"), is bound to be problematic. What is far more important is how the technology will change. This is where the idea of project "maintenance" is conceptually misleading. If, through technology transfer, our intention is to foster innovative capacity, designing systems that stay the same should not be the focus of effort. This is also an argument for the introduction of technologies that have technical space for improvement. Without space for improvement, there is no possibility of learning. Thus, if learning can only occur if change is possible, this would mean that successful technology transfer can only occur with those technologies that are amenable to adaptation locally. If this is the case, technological "leapfrogging" is not desirable because the higher the technology, the less amenable it would be to local adaptation. Thus, hardware designs that have a heavy emphasis on low-maintenance should be a warning signal to the planner, especially designs that have been given labels such as "Tropical" or "African."

Of course, low-maintenance technology is also the imported solution. If new products (i.e. handpumps, agricultural machines, consumer goods, etc.) are all imported from abroad to meet the needs of successful farmers or community groups, local innovators and entrepreneurs will, as a result, find themselves cut off from any access to this initial market represented by the people who have the ability to pay for a new technology. These imports in effect preempt the market which is so vitally important to the initial success of any new indigenously-designed technology and innovators and entrepreneurs have to turn to customers who have less money and who are less able to take risks. This argument is even more critical for imports of technologies that are essentially low-tech, like handpumps, which compared to tractors, or electronic goods, are within the reach of existing technical capacity.

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