Report for 2002GU6B: Slow Sand Filter Conceptual Design Package forThe Federated States of Micronesia

- Water Resources Research Institute Reports:
  - Khosrowpanah, Shahram, and Leroy Heitz, 2003, Slow Sand Filter Conceptual Design for the Federated States of Micronesia, FSM, Water and Environmental Research Institute (WERI), University of Guam, Report No. 101, 60pp.
- Conference Proceedings:
  - Khosrowpanah, Shahram, 2003, Application of Slow Sand Filtration Technology for Islands in the Federated States of Micronesia, 21st Annual Pacific islands Environment Conference, USEPA, Koror, Republic of Palau.

Report Follows:

PROJECT SYNOPSIS REPORT

Project Title

Slow Sand Filtration Conceptual Design Package for the Federated States of Micronesia, FSM

Problem and Research Objectives

The lack of clean drinking water is a significant problem for residents of the high, volcanic island of the Federated States of Micronesia (FSM) (US EPA, 1986). The island of Pohnpei in the Federated States of Micronesia (FSM) suffered severe outbreaks of cholera in April 2000, which resulted in 20 deaths, and over 3,000 infected people. The epidemic started at Enipein, a remote village of the island where there is no potable water supply and no proper sanitation facilities (PUC, 2001). At the conclusion of a three-day symposium that was held in Pohnpei on the cholera epidemic, lack of proper water and food sanitation were defined as the sources of spread of the disease (Cholera Symposium, Pohnpei 2001). A similar outbreak occurred in Chuuk in 1983. Again, contaminated water supply systems were suspected as a source of spreading the disease. In both states the water systems suspected of spreading the disease are supplying raw untreated surface water to the consumers. Simple filtration and chlorination could do much to improve the sanitation of these systems.

The objective of this project was to put together the findings of earlier Kosrae Slow Sand Filter Pilot studies and to develop detailed conceptual construction drawings, operation recommendations, and construction costs for small slow sand filtration plants. The resulting recommendations and drawings will be planned around and sized appropriately for use by the many small community water supply system throughout the FSM.

The specific objectives were to:

1) Collect information on several potential sites for use of slow sand filtration technology in Kosrae and Pohnpei. This information includes the location, water demand, source of inflow, and the turbidity levels of the source water.
2) Develop detailed conceptual structural drawings of a slow sand filter plant for a typical site in FSM. These drawings include details of structural requirements, and complete descriptions of required inflow and outflow piping systems, filter and underlain systems, and filter controls. The design packages cover (various) potential sites in FSM with construction cost estimates for each site.

3) Develop an operation manual on how to operate the recommended slow sand filter system. This manual will include information on when the filters need to be scraped, how to backfill the filters, and how to control the inflow and out flow from the filter.

Methodology

The project objectives were accomplished by site visitation and development of conceptual construction-drawings for three different sizes of SSF for the FSM.

Phase I. Site Visitation

Pohnpei state has approximately 14 small community water supply systems that deliver untreated water to each community. Kosrae State has three village water supply systems delivering untreated water to village residents. The same situation exists in the other community water supply system in the FSM. Most of these small systems include a pipe that brings water from a small diversion structure at the sources to a large storage tank followed by a gravity feed distribution system to the village houses.

A site visitation was made to all Pohnpei and Kosrae community water supply systems. Two sets of data were collected. The first set of data was the estimation of the needed flow for user consumption. The second set of data deals with the physical characteristics of potential locations for a slow sand filter plant. As mentioned earlier the size of the slow sand filters depends upon the water demands. For example, to provide 1.6 million gallons a day for the Toful municipality in Kosrae requires a filter bed area of approximately one third of an acre. So, it was important to have a site that can physically accommodate the filters. In addition, topographic considerations were evaluated in order to determine the need for excavation that could increase the cost of construction.

Based on the needed flows three flow rates; 150, 60, and 20 gpm were selected for slow sand filter design.

Phase II. Design and construction cost estimates

From the information in phase 1, we developed a conceptual construction-drawing package for a typical slow sand filter that can be applied to water systems in the FSM. This package includes a complete set of structural drawings of the facilities for producing 150, 60, and 20 gpm-filtered water. These drawings as shown in Figures 1 and 2 show inflow and outflow pipes to the plant, the under drain system that lies beneath the filter bed media, and the required flow control systems. Basic structural details are also provided. While these plans will not be final construction drawings, they will useful for those seeking to secure funding to construct an actual facility. These plans will also greatly reduce the workload and thus the expense of producing final construction drawings for each project.

A completed construction cost estimate has been provided for the conceptual filter design. The construction cost that shows the unit cost of each component of the slow sand filters has also been compiled. A sample of these estimates is shown in Table 1, 2 and 3.

Principal Findings and Significance

The principal investigators of this project have completed two previous studies using a slow sand filter pilot plant that was constructed on the island of Kosrae. The hydraulic loading rate, the bacteria removal rate, and sediment removal was determined during the first study, FY 2000. The results of the second study that was completed in FY 2001 indicated that the local basalt media could perform as well as the imported sand media. This study brings together the results of the two previous pilot studies into a design of an actual full sized filter that includes a detailed conceptual construction-drawing package for three different flow rates 150, 60, and 20 gpm. As mentioned earlier, Figures 1 and 2 show the inflow and outflow to the plant, the under drain system that lies beneath the filter bed media, and the required flow control systems. A typical slow sand filter facility normally consists of two identical filter tanks that supply the community with treated water. During the time when filter scraping is required, one filter will be shut down and scraped while the other remains in service. However, to reduce the operational manpower and project cost we developed a conceptual construction-drawing package with one filter. The extra water from the filter will be stored in a storage tank for the time that filter needs to be scraped. This will avoid a supply discontinuity in providing drinking water for community.

To increase the length of the time between filter scraping the inflow water should be have relatively low in turbidity. This requires having a settling basin before the water inflows to the filters. Flow controls and water distribution to the filter beds has been kept as simple as possible to avoid problems with long-term maintenance of the facility. There are two valves that controls the flow, one located at the inflow, and one located at the outflow of the filters. The function of the inflow valve will be to control inflow and also for shutdown of the filter during scraping times. The outflow valve will be used to control the flow rate through the filter. As shown in Figure 2, the filter has two piezometers. The piezometers will indicate the head loss through the filter's media and thus will serve to warn those operating the filter when scraping will be required. The filter media will be of local crushed basalt or imported sand. The imported sand will be more expensive but it will eliminate the washing requirements. According to the Kosrae pilot study, the performances of local and imported sand are the same; with the exception that local sand requires extensive washing. This washing is for removing small sized particles that will clog the filters.

A completed construction cost estimate has been provided for the conceptual filter design. The construction cost shows the unit cost of each component of the slow sand filters for 150, 60, and 20 gpm. Tables 1, 2, and 3 show the detail costs for three size slow sand filters.

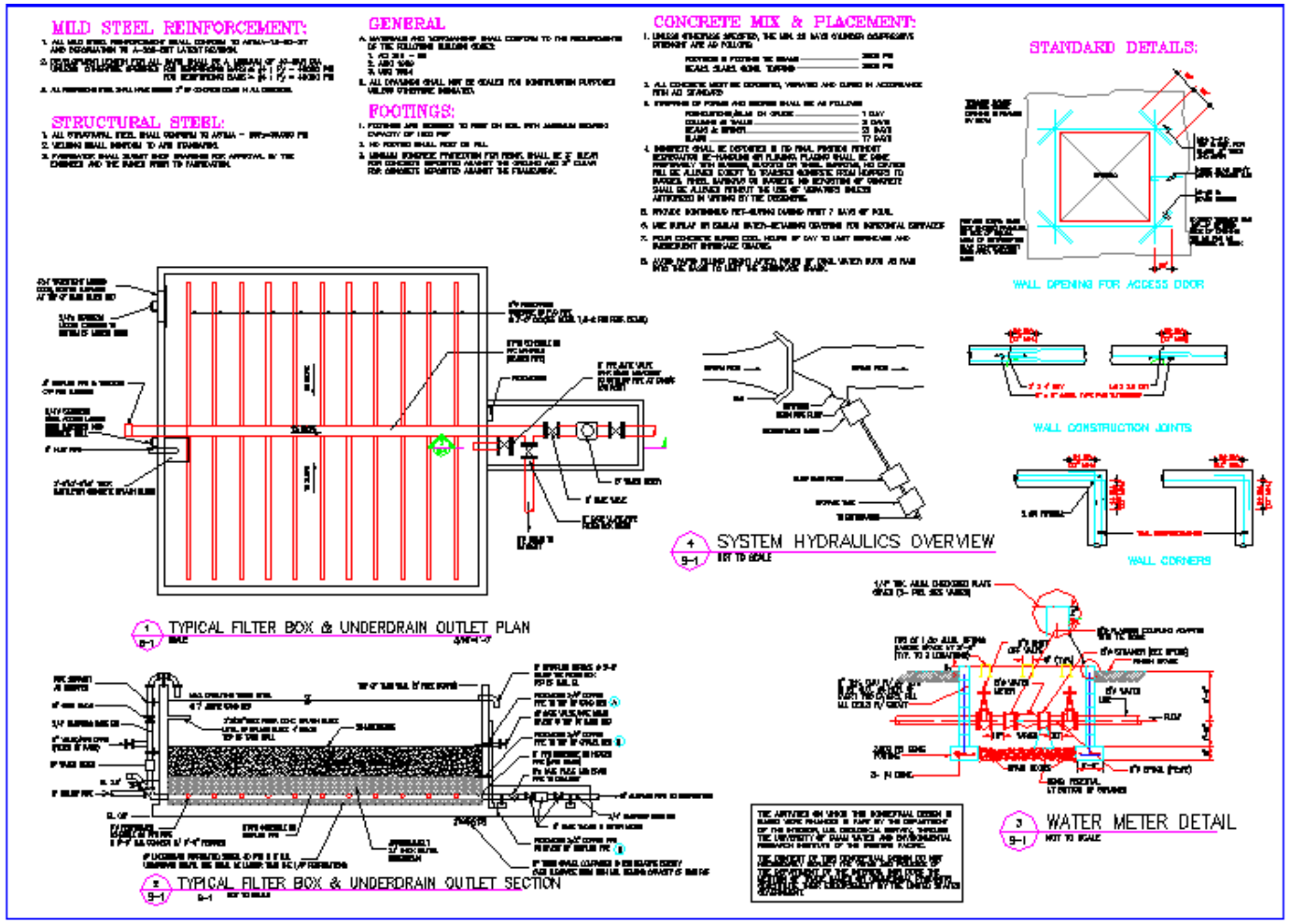

Figure 1. Slow Sand Filter Conceptual Design: Box Filter, under drain outlet, and System Hydraulics

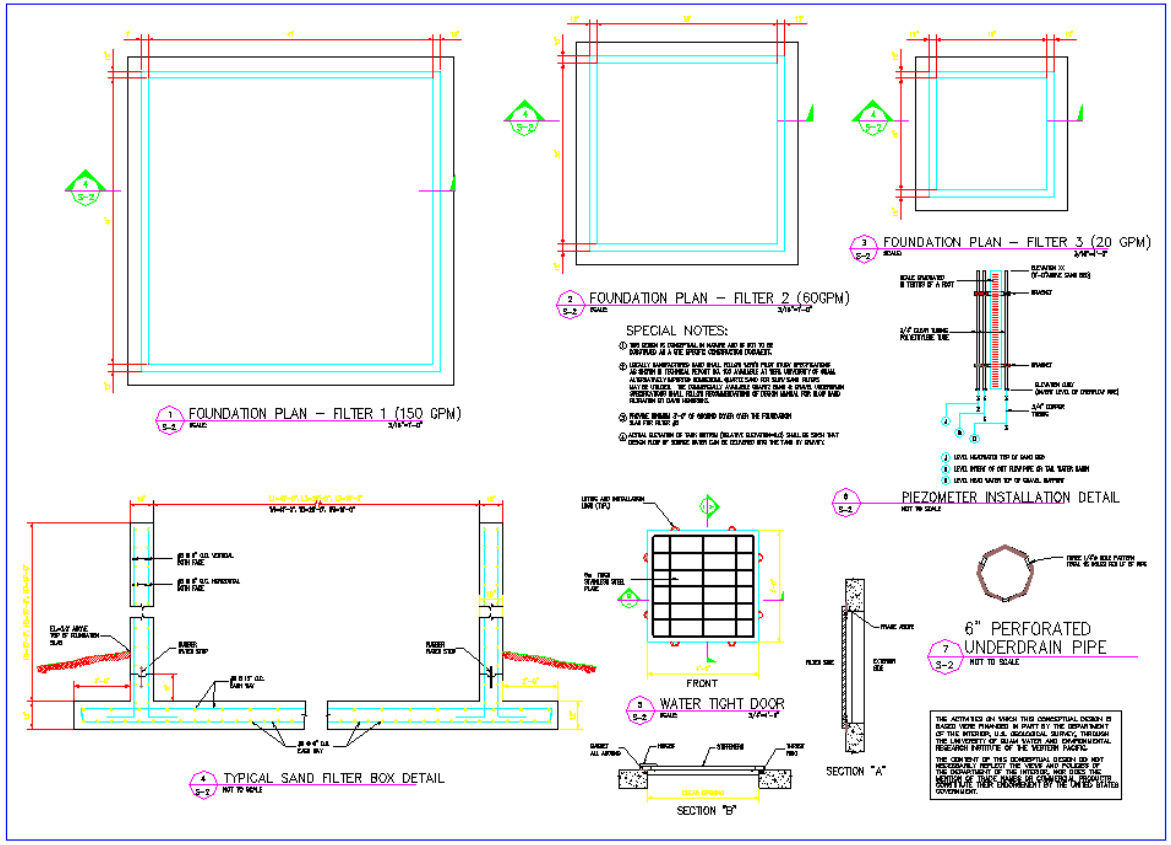

Figure 2. Slow Sand Filter Conceptual Design: Foundation Plan, Filter Box Detail, and Piezometer Installation detail for 150, 60, and 20 gpm filter capacity

Table 1. Cost Estimate for Slow Sand Filter with 150 gpm Capacity

SLOW SAND FILTER BUDGETARY CONSTRUCTION COST ESTIMATE (150 GPM CAPACITY)					
COST ESTIMATE PROVIDED BY MASOUD & COMPANY (JANUARY 2003)					
NO.	ITEM	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	8" SCHEDULE 80 PVC PIPE	80	FT	$19.94	$1,595.00
2	8" PVC SCHED. 80 COUPLING	8	EA	$56.25	$450.00
3	8" PVC SCHED. 80 ELBOW 90 DEGREE	3	EA	$65.00	$195.00
4	6" SCHEDULE 80 PVC PIPE PERFORATED	600	LF	$25.00	$15,000.00
5	6" PVC SCHED. 80 COUPLING	20	EA	$31.25	$625.00
6	6" PVC SCHED. 80 ELBOW 90 DEGREE	5	EA	$40.00	$200.00
7	6" TO 8" PVC SCHED 80 REDUCER	15	EA	$62.50	$937.50
8	8" GATE VALVE BRASS	6	EA	$687.50	$4,125.00
9	8" SCHEDULE 40 GALVANIZED PIPE	80	LF	$29.11	$2,328.57
10	8" MJ 90 DEGREE ELBOW	4	EA	$225.00	$900.00
11	8" SOLID SLEEVE JOINT	8	EA	$225.00	$1,800.00
12	4'X4' SS WATER-TIGHT DOOR & FRAME	1	EA	$3,562.50	$3,562.50
13	MAGNETIC TAPE	1	LS	$250.00	$250.00
14	STRUCT. STEEL REINFORCED CONC. (3000 PSI, GRADE 40 STEEL)	174	CY	$312.50	$54,386.57
15	TRENCH BEDDING SAND	1	LS	$1,500.00	$1,500.00
16	GRAVEL BASE COURSE	46	CY	$45.00	$2,083.33
17	COMPACTION	1	LS	$1,250.00	$1,250.00
18	TRENCHING/BACKHOE/EXCAVATOR	1	LS	$22,400.00	$22,400.00
19	3/4" HOSE BIB	2	EA	$6.25	$12.50
20	LOCALLY MANUFACTURED SAND FILTER (commercial sand quartz @ $462/cy	249	CY	$150.00	$37,355.56
21	LOCALLY MANUFACTURED GRAVEL FOR UNDERDRAIN	125	CY	$120.00	$14,942.22
22	PIZOMETERS	3	EA	$435.00	$1,305.00
23	WATER METERS 8"	2	EA	$1,250.00	$2,500.00
24	PIPE ADHESIVE, PLUGS, MISC. FITTINGS	1	LS	$500.00	$500.00
25	FENCE & GATE	400	LF	$56.25	$22,500.00
26	STAINLESS STEEL LADDER	2	EA	$1,800.00	$3,600.00
27	MISC. CONCRETE STRUCTURES, OPEN CHANNEL, WIER, ETC.	1	LS	$4,500.00	$4,500.00
28	SMALL TOOLS & MISC. EQUIPMENT	1	HR	$1,400.00	$1,400.00
29	LABOR	1920	HR	$15.00	$28,800.00
30	SUPERVISION	240	HR	$30.00	$7,200.00
31	LAND SURVEYING DURING DESIGN AND CONSTRUCTION PHASES	1	LS	$2,500.00	$2,500.00
32	SITE SPECIFIC DESIGN AND CERTIFICATION	1	LS	$4,500.00	$4,500.00
33	CONSTRUCTION PERMITTING, FEES	1	LS	$900.00	$900.00
	SUBTOTAL				$246,103.76
	OVERHEAD, TAX, & CONTINGENCIES @ 25%				$61,525.94
	GRAND TOTAL				$307,630

Table 2. Cost Estimate for Slow Sand Filter with 60 gpm Capacity

SLOW SAND FILTER BUDGETARY CONSTRUCTION COST ESTIMATE (60 GPM CAPACITY)					
COST ESTIMATE PROVIDED BY MASOUD & COMPANY (JANUARY 2003)					
NO.	ITEM	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	8" SCHEDULE 80 PVC PIPE	80	FT	$19.94	$1,595.00
2	8" PVC SCHED. 80 COUPLING	8	EA	$56.25	$450.00
3	8" PVC SCHED. 80 ELBOW 90 DEGREE	3	EA	$65.00	$195.00
4	6" SCHEDULE 80 PVC PIPE PERFORATED	380	LF	$25.00	$9,500.00
5	6" PVC SCHED. 80 COUPLING	14	EA	$31.25	$437.50
6	6" PVC SCHED. 80 ELBOW 90 DEGREE	5	EA	$40.00	$200.00
7	6" TO 8" PVC SCHED 80 REDUCER	10	EA	$62.50	$625.00
8	8" GATE VALVE BRASS	6	EA	$687.50	$4,125.00
9	8" SCHEDULE 40 GALVANIZED PIPE	80	LF	$29.11	$2,328.57
10	8" MJ 90 DEGREE ELBOW	4	EA	$225.00	$900.00
11	8" SOLID SLEEVE JOINT	8	EA	$225.00	$1,800.00
12	4'X4' SS WATER-TIGHT DOOR & FRAME	1	EA	$3,562.50	$3,562.50
13	MAGNETIC TAPE	1	LS	$250.00	$250.00
14	STRUCT. STEEL REINFORCED CONC. (3000 PSI, GRADE 40 STEEL)	110	CY	$312.50	$34,259.26
15	TRENCH BEDDING SAND	1	LS	$1,500.00	$1,500.00
16	GRAVEL BASE COURSE	29	CY	$45.00	$1,316.67
17	COMPACTION	1	LS	$1,050.00	$1,050.00
18	TRENCHING/BACKHOE/EXCAVATOR	1	LS	$14,140.00	$14,140.00
19	3/4" HOSE BIB	2	EA	$6.25	$12.50
20	LOCALLY MANUFACTURED SAND FILTER (commercial sand quartz @ $462/cy	100	CY	$150.00	$15,022.22
21	LOCALLY MANUFACTURED GRAVEL FOR UNDERDRAIN	50	CY	$120.00	$6,008.89
22	PIZOMETERS	3	EA	$435.00	$1,305.00
23	WATER METERS 8"	2	EA	$1,250.00	$2,500.00
24	PIPE ADHESIVE, PLUGS, MISC. FITTINGS	1	LS	$500.00	$500.00
25	FENCE & GATE	400	LF	$56.25	$22,500.00
26	STAINLESS STEEL LADDER	2	EA	$1,800.00	$3,600.00
27	MISC. CONCRETE STRUCTURES, OPEN CHANNEL, WIER, ETC.	1	LS	$4,500.00	$4,500.00
28	SMALL TOOLS & MISC. EQUIPMENT	1	HR	$1,400.00	$1,400.00
29	LABOR	1210	HR	$15.00	$18,150.00
30	SUPERVISION	150	HR	$30.00	$4,500.00
31	LAND SURVEYING DURING DESIGN AND CONSTRUCTION PHASES	1	LS	$2,500.00	$2,500.00
32	SITE SPECIFIC DESIGN AND CERTIFICATION	1	LS	$4,500.00	$4,500.00
33	CONSTRUCTION PERMITTING, FEES	1	LS	$600.00	$600.00
	SUBTOTAL				$165,833.11
	OVERHEAD, TAX, & CONTINGENCIES @ 25%				$41,458.28
	GRAND TOTAL				$207,291

Table 3. Cost Estimate for Slow Sand Filter with 20 gpm Capacity

SLOW SAND FILTER BUDGETARY CONSTRUCTION COST ESTIMATE (20 GPM CAPACITY)					
COST ESTIMATE PROVIDED BY MASOUD & COMPANY (JANUARY 2003)					
NO.	ITEM	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	8" SCHEDULE 80 PVC PIPE	80	FT	$19.94	$1,595.00
2	8" PVC SCHED. 80 COUPLING	10	EA	$56.25	$562.50
3	8" PVC SCHED. 80 ELBOW 90 DEGREE	5	EA	$65.00	$325.00
4	6" SCHEDULE 80 PVC PIPE PERFORATED	240	LF	$25.00	$6,000.00
5	6" PVC SCHED. 80 COUPLING	8	EA	$31.25	$250.00
6	6" PVC SCHED. 80 ELBOW 90 DEGREE	5	EA	$40.00	$200.00
7	6" TO 8" PVC SCHED 80 REDUCER	8	EA	$62.50	$500.00
8	8" GATE VALVE BRASS	6	EA	$687.50	$4,125.00
9	8" SCHEDULE 40 GALVANIZED PIPE	80	LF	$29.11	$2,328.57
10	8" MJ 90 DEGREE ELBOW	4	EA	$225.00	$900.00
11	8" SOLID SLEEVE JOINT	8	EA	$225.00	$1,800.00
12	4'X4' SS WATER-TIGHT DOOR & FRAME	1	EA	$3,562.50	$3,562.50
13	MAGNETIC TAPE	1	LS	$250.00	$250.00
14	STRUCT. STEEL REINFORCED CONC. (3000 PSI, GRADE 40 STEEL)	70	CY	$312.50	$21,759.26
15	TRENCH BEDDING SAND	1	LS	$1,500.00	$1,500.00
16	GRAVEL BASE COURSE	18	CY	$45.00	$830.00
17	COMPACTION	1	LS	$1,050.00	$1,050.00
18	TRENCHING/BACKHOE/EXCAVATOR	1	LS	$6,300.00	$6,300.00
19	3/4" HOSE BIB	2	EA	$6.25	$12.50
20	LOCALLY MANUFACTURED SAND FILTER (commercial sand quartz @ $462/cy	38	CY	$150.00	$5,688.89
21	LOCALLY MANUFACTURED GRAVEL FOR UNDERDRAIN	19	CY	$120.00	$2,275.56
22	PIZOMETERS	3	EA	$435.00	$1,305.00
23	WATER METERS 8"	2	EA	$1,250.00	$2,500.00
24	PIPE ADHESIVE, PLUGS, MISC. FITTINGS	1	LS	$500.00	$500.00
25	FENCE & GATE	400	LF	$56.25	$22,500.00
26	STAINLESS STEEL LADDER	2	EA	$1,800.00	$3,600.00
27	MISC. CONCRETE STRUCTURES, OPEN CHANNEL, WIER, ETC.	1	LS	$4,500.00	$4,500.00
28	SMALL TOOLS & MISC. EQUIPMENT	1	HR	$1,400.00	$1,400.00
29	LABOR	760	HR	$15.00	$11,400.00
30	SUPERVISION	95	HR	$30.00	$2,850.00
31	LAND SURVEYING DURING DESIGN AND CONSTRUCTION PHASES	1	LS	$2,500.00	$2,500.00
32	SITE SPECIFIC DESIGN AND CERTIFICATION	1	LS	$3,500.00	$3,500.00
33	CONSTRUCTION PERMITTING, FEES	1	LS	$450.00	$450.00
	SUBTOTAL				$118,819.78
	OVERHEAD, TAX, & CONTINGENCIES @ 25%				$29,704.94
	GRAND TOTAL				$148,525