# Process Selection Report

## Project Name
Phase 2 – Water Treatment
GN Project No.: 04-4417

## Type of Project
Water Systems Improvements

## Project Location
Kugluktuk, NU

## Prepared For
Government of Nunavut
Community and Government Services

## Prepared By
Williams Engineering Canada Inc.

## Date Prepared
September 2011

WE File No. 13655

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Prepared by,

Williams Engineering Canada Inc.

**Kevin Rattray, EIT**
**Civil/Environmental**

Phone: 867.873.2395
Email: krattray@williamsengineering.com

Williams Engineering Canada Inc.

**Justin Hazenberg, P.Eng.**
**Civil/Team Lead Environmental**

Phone: 867.873.2395
Email: jhazenberg@williamsengineering.com

Reviewed by,

Williams Engineering Canada Inc.

**John Clark, P.Eng., FEC**
**Engineering Manager, Civil/Environmental**

Phone: 867.873.2395
Email: jclark@williamsengineering.com


**PERMIT TO PRACTICE**
**WILLIAMS ENGINEERING CANADA INC.**

Signature: ______________________

Date: ______________________

**PERMIT NUMBER: 646**

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# Table of Contents



## Table of Figures



## Appendices

# 1.0 Introduction

Williams Engineering Canada Inc. (WEC) is under contract with the Government of Nunavut (GN) to perform engineering design and construction services for the Water Systems Improvement Project for Kugluktuk, NU (GN Project No: 04-4417). The Project is divided into two phases. Phase 1 is the replacement of the raw water intake and intake pumphouse. Phase 2 is improvements in the water treatment plant (WTP). Phase 1 is currently under construction.

This report is the Process Selection for the Phase 2 – WTP. It is to be read in conjunction with the Preliminary Engineering Report and the Design Development Report Phase 2 where design conditions and assumptions have been established.

## 1.1 Existing Conditions

The current water treatment plant (WTP) situated in Kugluktuk draws raw water from the Coppermine River and is comprised of a cartridge filtration system followed by disinfection. Water storage is comprised of 358,000L of which 90,000L is reserved for fire flow. The Coppermine River experiences high levels of turbidity during the spring and summer. The cartridge filters are unable to maintain an effluent turbidity below the Guidelines for Canadian Drinking Water Quality (GCDWQ).

# 2.0 Water Treatment Design Parameters

## 2.1 Objective

The objective of Phase 2 is to provide the community of Kugluktuk with a safe, stable, reliable, and economical water treatment plant that can meet GCDWQ with local operation. The system is to be able to handle the community's projected water demand until 2037.

## 2.2 WTP Output

Population growth and future demand were discussed in the Preliminary Design Report and the Design Development Report. These figures were updated in 2011 to include the most recent population census data available. Population estimates for Kugluktuk from 1996 to 2010 were obtained from the Nunavut Bureau of Statistics (NBS). These population estimates are based on Statistics Canada census counts. The counts are adjusted based on Statistics Canada's postcensal coverage studies in order to provide a more accurate estimate of the actual population[1]. The 2011 Census results were not yet available at the time of this report; the most recent census results available were from 2006.

**Table 1 – Nunavut Bureau of Statistics Population Estimates**

| Year | Population Estimate (GN) | % Growth | StatsCan Estimate | % Growth |
|---|---|---|---|---|
| 1996 | 1,252 | - | 1,201 | 0.9% (0.18%/yr) – growth from 1991 to 1996 was reported as 13.4% (2.68%/yr) |
| 1997 | 1,240 | -1.0% | | |
| 1998 | 1,239 | -0.1% | | |
| 1999 | 1,255 | 1.3% | | |
| 2000 | 1,271 | 1.3% | | |
| 2001 | 1,273 | 0.2% | 1,212 | 7.4% (1.48%/yr) |
| 2002 | 1,305 | 2.5% | | |
| 2003 | 1,334 | 2.2% | | |
| 2004 | 1,321 | -1.0% | | |
| 2005 | 1,346 | 1.9% | | |
| 2006 | 1,347 | 0.1% | 1,302 | |
| 2007 | 1,374 | 2.0% | | |
| 2008 | 1,375 | 0.1% | | |
| 2009 | 1,405 | 2.2% | | |
| 2010 | 1,458 | 3.8% | | |
| **YEARLY AVERAGE** | | **1.1%** | | |

Even though recent trends show an increasing annual growth rate in 2009 and 2010, WEC believes it to be prudent to look at all the data and not 2 years in isolation. The population estimates were used to calculate an average annual growth rate of 1.1%. In calculating future water demand, we have assumed that construction will be completed in 2012, and that the system will have a 25-year design life. Population growth can be estimated using the following equation:

$$N = N_0 (1 + r)^n \qquad \text{Eq.1}$$

where;

- $N$ = estimated population for final year
- $N_0$ = population for start year (1,458 in 2010)
- $r$ = average annual growth rate (1.1%)
- $n$ = number of years (25)

[1] Statistics Canada. (n.d.). Difference between Statistics Canada's census counts and population estimates. In *CPC Nunavut Bureau of Statistics*. Retrieved July 18, 2011, from http://www.eia.gov.nu.ca/stats/Cenvsest/cenvsest.pdf.

The population for every 5th year was calculated using Eq. 1 and is shown below. The NBS population projections are shown for comparison.

**Table 2 – Population Projections**

| Year | WEC Projected Population | NBS Projected Population |
|---|---|---|
| 2011 | 1,474 | 1,427 |
| 2016 | 1,557 | 1,505 |
| 2021 | 1,645 | 1,572 |
| 2026 | 1,738 | 1,621 |
| 2031 | 1,836 | 1,660 |
| 2036 | 1,939 | 1,694 |
| **2037** | 1,961 | - |

WEC's projected population is higher than the NBS projections. The reason for this difference is that WEC's projections are based on historic population data and observed growth rates for Kugluktuk, while the NBS projections are based on estimated birth, death and migration parameters for Nunavut as a whole and do not consider historic trends for individual communities[2]. WEC's projected population for the design year is 1,961 in the year 2037.

Residential water use and total water use were both calculated in the Preliminary Design report. Residential water use is the average quantity of water consumed by residents in a community, whereas total water use takes into account industrial and commercial water use. The equation for computing the total water use is dependant on the population.

Average total daily water use for the design horizon of 2030 was calculated in the Preliminary Design report to be 235,000L/day, based on a population of 1,835. As the design horizon has been extended due to an estimated plant completion date of 2012.

New population estimates of 1,961 in 2037 yield average total daily water use to be 256,000L/day. Design WTP throughput is dependant on peak demand, the nature of WTP operations (continuous or intermittent), and water storage.

[2] Nunavut Bureau of Statistics (Aug 2010). Nunavut Community Population Projections 2010 to 2036. Retrieved July 18, 2011, from http://www.eia.gov.nu.ca/stats/Popest/Projections/Nunavut%20Population%20Projections%20a%20Brief%20Methodology.pdf

Peak demand is calculated from the average daily water use, peak demand, and truck delivery factor.

$$PDD_{design\ year} = PDF\ x\ TDF\ x\ ADD_{design\ year} \qquad \text{Eq. 1}$$

where;

| | |
|---|---|
| $PDD_{design\ year}$ | = Peak Day Demand in the design year |
| PDF | = Peak Day Factor = 1.5 |
| TDF | = Truck Delivery Factor |
| | = 7/5 based on water delivery 5 days per week |
| $ADD_{design\ year}$ | = Average Daily Demand in the design year (TWU = 131L/person/day) |

Although Kugluktuk has 6 day/week water delivery, a conservative peak factor for a trucked system delivering 5 days a week will be used. This yields a peak day demand of 537,600L/day.

All design options presented in this report utilize slow sand filtration. Slow sand filters require continuous 24hr/day operation while pre-treatment will only operate 8hr/day.

Water storage is required to balance the water demand with the throughput of the WTP and provide water storage for fire flow.

A system running continuously 24hr/day can be sized for the average day demand provided it has adequate water storage to handle multiple peak demand days. Therefore, the system should be designed for a minimum capacity of 256,000 L/day.

### 2.3 Redundancy

A stable reliable water supply for Kugluktuk with 100% runtime is required. It is proposed that three treatment trains be provided, each with 50% of the design capacity, for a total of 150% capacity. This will allow each train to be taken offline for maintenance and filter ripening without affecting the design flow.  Option-specific redundancy is discussed in Section 5.0.

### 2.4 Water Storage

### 2.4.1 Fire Storage

As per the Water and Sewage Facilities, Capital Programs: Standards and Criteria (July 1993) developed by the Government of the Northwest Territories Department (GNWT) of Municipal and Community Affairs (MACA) indicate a minimum of 60,000L of storage should be reserved for fire protection. These GNWT standards are used by the GN as they were published prior to the divide of the NWT and the GN has not published a more recent version. Kugluktuk currently has 90,000L of fire storage. WEC recommends maintaining this quantity of fire storage.

### 2.4.2 Equalization Storage

Equalization storage is used when the treatment capacity is limited and cannot meet the peak demand. MACA recommends that equalization storage be equal to the maximum projected haul day less eight hours of water treatment plant output. A peak day demand of 537,600L/day was calculated previously and the system is able to produce 85,300L in an 8 hour period. Therefore, 452,300L will be required for equalization storage.

### 2.4.3 Dead Storage and In-Plant Use

Dead storage is the amount of storage unavailable for use. Dead storage and in-plant use is assumed to be 5% (27,115L) of the overall storage capacity of the system.

### 2.4.4 Total Storage

The total storage required for fire protection, equalization storage, dead storage, and in-plant use is estimated to be 569,415L. Currently, the total tank storage at the plant is 358,000L and therefore an additional 211,415L is needed.

WEC is proposing the installation of a 500,000L filter feed tank to allow continuous flow through the slow sand filters. WEC is also proposing the installation of a 500,000L treated water storage tank to be placed directly following the slow sand filter. This will yield a total of 500,000L of filter feed water and 858,000L of treated water storage.

## 3.0 Water Treatment Piloting

In the fall of 2010 and spring of 2011 a pilot water treatment plant was operated in Kugluktuk. The pilot plant consisted of three separate treatment trains:

- roughing filter in layers followed by a slow sand filter,

- roughing filter in series followed by a slow sand filter,
- enhanced slow sand system (slow sand filter preceded by coagulation, sedimentation, and clarification),

Additionally, a system consisting of enhanced slow sand with a roughing filter was assembled and evaluated during the final stages of pilot operations. These various arrangements allowed WEC to collect valuable data about the effectiveness of each of these filters.

Roughing filtration proved to be an effective pre-treatment method in reducing turbidity ahead of slow sand filtration. The roughing filter in layers provided the least reduction in turbidity, while the 3rd roughing filter in the series system with the finest media diameter provided the most reduction in turbidity. None of the roughing filters developed significant headloss throughout their operations.

During peak turbidity events, although roughing filtration reduced turbidity significantly, effluent water from the slow sand filters frequently exceeded GCDWQ. It is important to note that during these times the systems still dramatically outperformed the existing system.

The enhanced slow sand system was able to meet GCDWQ turbidity targets with periodic coagulation adjustments. Without proper monitoring and adjustments the enhanced slow sand system would fall out of compliance. However, the adjustments required were less frequent and less sensitive than would be required for a traditional rapid sand system.

The enhanced slow sand system with roughing filtration provided to be the most robust system producing the highest quality water with less user intervention than the regular enhanced slow sand system.

## 4.0 Water Treatment Options

Three WTP design options have been developed based on the results of the pilot testing. All three systems utilize slow sand filtration and chlorine disinfection. Slow sand filtration typically requires inlet turbidity less than 10 NTU. The raw water from the Coppermine River frequently exceeds 10 NTU. Therefore, each option presented herein utilizes a different type of pre-treatment ahead of slow sand filtration.

## 4.1 Option 1 - Roughing Filter followed by Slow Sand Filtration

Based on the data collected from the pilot plant, the roughing filter in series followed by a slow sand filter (SSF) was able to maintain an effluent turbidity below 1.0NTU for the majority of the time; however turbidity spikes greater than the Canadian Drinking Water Quality Guidelines (GCDWQ) maximum of 3.0 NTU were noted on numerous occasions.

Operation of this system would require little operator intervention. During pilot testing, feedback provided by the operators indicated that they understood the labour requirements of the system and approved of the limited level of operator intervention.

Maintenance of the roughing filter requires rapidly draining the filter to remove any solids accumulation in the filter. A minimal amount of labour is required each month to do this.

The main maintenance task associated with the SSF is scraping the surface to remove accumulated filtered particles. It is believed that scraping would be required once a month per filter during periods of high turbidity and once every 4 to 6 months during winter months. Each scraping will take a day to complete however ripening of the filter will take up to 10 days. Scraping and ripening will be undertaken on a staggered schedule to ensure that 100% of the plant capacity is maintained.

### 4.1.1 Physical Dimensions

Preliminary design requires a filter tank footprint of 18.3m by 13.2m (241.5$m^2$ or 2599$ft^2$) and a height of 4.7m. In addition to the building, two 500,000L water storage tanks are required. These tanks have a diameter of 8m and a height of 9m. A sketch is provided in appendix A which details a potential layout.

## 4.2 Option 2 - Enhanced Slow Sand

Based on the data collected from the pilot plant, in a full scale operation with proper dosing of the coagulant, the enhanced slow sand system is believed to be able to maintain an effluent turbidity below the GCDWQ.

The coagulation/flocculation/sedimentation (CFS) pre-treatment step within the enhanced slow sand process is only needed during high turbidity months. It is estimated that it would be run from May to November annually. This would provide adequate downtime for maintenance during the offseason and reduced operating costs of the process as the slow sand would operate without pre-treatment from December to April.

A single train providing 100% of the design capacity will be provided for the CFS with no backup stream. The CFS system is sized to run 8 hours per day and redundancy is built into the system with multiple pumps and motors running in parallel. Minor maintenance tasks can be completed without taking the CFS system offline and any major maintenance requiring more than 16hrs of downtime is to be competed during the winter when the CFS is offline.

When in operation, the CFS will require ongoing monitoring and jar testing to ensure proper coagulant dosage. On average, jar testing and monitoring is expected to take 5 hours a week to complete. Sludge disposal from the sedimentation basin is expected to occur once per week and will require a sewage truck to dispose of the accumulated sludge.

Maintenance of the roughing filter requires rapidly draining the filter to remove any solids accumulation in the filter for disposal via sewage truck to the sewage lagoon. A minimal amount of labour is required each month to do this.

The main maintenance task associated with a SSF is scraping the surface to remove accumulated filtered particles. It is believed that scraping would occur once a month per filter during periods of high turbidity and once every 4 to 6 months during winter months. Each scraping will take a day to complete however ripening of the filter will take up to 10 days. Scraping and ripening will be undertaken on a staggered schedule to ensure that 100% of the plant capacity is maintained.

#### 4.2.1 Physical Dimensions

Preliminary design requires a filter tank footprint of 13.6m by 13.2m (179.5m$^2$ or 1932ft$^2$) and a height of 8.0m. This height includes office space and space for the CFS system to be house directly on top of the filter tank. In addition to the building, two 500,000L water storage tanks are required. These tanks have a diameter of 8m and a height of 9m. A sketch is provided in appendix A which details a potential layout.

### 4.3 Option 3 – Enhanced Slow Sand Filtration with Roughing Filter

Based on the data collected from the pilot plant, in a full scale operation and with proper dosing of the coagulant, the enhanced slow sand system preceded by a roughing filter is believed to be able to maintain an effluent turbidity below the GCDWQ.

Operation of this system is similar to Option 2, but with the addition of a roughing filter. The roughing filter reduces the solids loading on the slow sand filter and prolongs the filter runtime between scrapings.

The period during which the CFS is necessary is also reduced by the use of a roughing filter; further reducing O&M costs.

#### 4.3.1 Physical Dimensions

Preliminary design requires a filter tank footprint of 18.3m by 13.2m (241.5$m^2$ or 2599$ft^2$) and a height of 8.0m. This height includes office space and space for the CFS system to be housed directly on top of the filter tank. In addition to the building, two 500,000L water storage tanks are required. These tanks have a diameter of 8m and a height of 9m. A sketch is provided in appendix A which details a potential layout.

### 4.4 Disinfection

For each option, disinfection will be provided by chlorine injection ahead of the 500,000L treated water storage tank. The existing chlorine injection system in the truck fill will remain in service and be used to top up the chlorine levels prior to delivery. This is similar to the existing system, with initial chlorination directly after filtration and additional chlorination at the truck fill. Average chlorine contact time is estimated to be 3 days with a minimum contact time of 15.2 hours when 500 000L of treated water is stored. This exceeds the minimum chlorine contact time of 20min. Additional contact time will be provided following the injection of additional chlorine during the filling of each truck and in the end user's water storage tank.

## 5.0 Cost Estimates

### 5.1 General Notes

Pricing for concrete, aggregate, media, and major equipment were obtained from manufacturer quotes. Where shipping dimensions were known, 2011 barge rates from Hay River to Kugluktuk were used. Where insufficient information was available to determine shipping costs, an additional 25-50% was added to the material costs.

The O&M costs listed below do not include the cost of chlorination chemicals, heating of the slow sand facility, or heating of the water storage tanks, as these will be similar for all options. Invoices from the hamlet for labour for the pilot plant were $70/hr. Labour costs were estimated using this rate.

A detailed breakdown of costs can be found in Appendix B.

The net present value (NPV) calculation includes capital cost and 25 years of O&M costs using an 8.5% discount rate. A detailed breakdown of the NPV calculations can be found in Appendix B.

### 5.2 Cost Estimates

The following table summarizes the findings located in Appendix B.

**Table 3 – Cost Estimates**

| Cost Estimates | Capital | O&M | 25-yr NPV |
|---|---|---|---|
| **Option 1** | $3,673,924 | $58,000 | $4,267,507 |
| **Option 2** | $4,597,044 | $109,400 | $5,716,665 |
| **Option 3** | $5,144,342 | $88,000 | $6,044,951 |

## 6.0 Discussion

Although a roughing filter followed by a slow sand filter will likely not meet guidelines, it requires less operator experience and less operator intervention than the other alternatives. The GCDWQ have not yet been adopted in Nunavut, and there is no requirement to meet the guidelines. Therefore, the roughing filter should be considered as a viable option as it would greatly improve the water quality in Kugluktuk in a cost effective manner and with less operator input.

The enhanced slow sand system is more costly than the roughing filter followed by slow sand due to the cost of the CFS equipment, the additional labour required to operate the CFS, and the sludge handling requirements of the CFS process. These increased costs and labour requirements have the benefit of increased performance. It was demonstrated during the 2011 pilot testing season that with chemical coagulation, the enhanced system should be able to meet the turbidity guideline of <1.0 NTU when developed into a full scale plant.

The enhanced slow sand system with roughing filter is the most resilient option, adding an additional level of filtration to the enhanced slow sand system. This has the effect of prolonging the slow sand filter's use and creating a system less sensitive to spikes in raw water turbidity.

| **Process** | **Pros** | **Cons** |
|---|---|---|
| Option 1: Roughing Filter + Slow Sand | • Simple to operate<br>• Minimal staff hours required to operate<br>• Less costly<br>• Does not require use of coagulants | • Not able to adhere to the GCDWQ<br>• Unable to handle large turbidity spikes<br>• Sludge disposal |
| Option 2: Enhanced Slow Sand | • Able to adhere to the GCDWQ<br>• Less sensitive to spikes in turbidity | • Sensitive to errors in coagulant dosage<br>• Significant staff hours required to operate<br>• Coagulant storage<br>• Sludge disposal<br>• More costly then Option 1 |
| Option 3: Enhanced Slow Sand with Roughing Filter | • Able to adhere to the GCDWQ<br>• Less sensitive to spikes in turbidity<br>• Reduces solids loading on slow sand filter and prolongs filter runtime between cleanings<br>• Resilient to errors in coagulant dosage | • More costly then Option 1 & 2<br>• Larger facility to heat<br>• Coagulant storage<br>• Sludge disposal |

## 7.0 Recommendations

WEC recommends that the GN adhere to the GCDWQ wherever possible. Option 2 and 3 both have the ability to adhere to the GCDWQ. Option 3 has the added benefit of increasing the runtime of the slow sand filter while adding a layer of resilience to the entire process, making it less sensitive to both turbidity spikes and coagulant dosage errors. For these reasons WEC recommends Option 3. While Option 3 is the most costly option, WEC believes that this cost difference is offset by the relative performance of the treatment options.

WEC recommends installing the filter components of the pilot plant in the new water treatment plant for training and educational purposes.

## 8.0 Closure

This report has been prepared based upon the information referenced herein. It has been prepared in a manner consistent with good engineering judgement. Should new information come to light, Williams Engineering Canada Inc. requests the opportunity to review this information and our conclusions contained in this report. This report has been prepared for the exclusive use of Government of Nunavut, and there are no representations made by Williams Engineering Canada Inc. to any other party. Any use that a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties.

# Appendix A

## Layout Sketches

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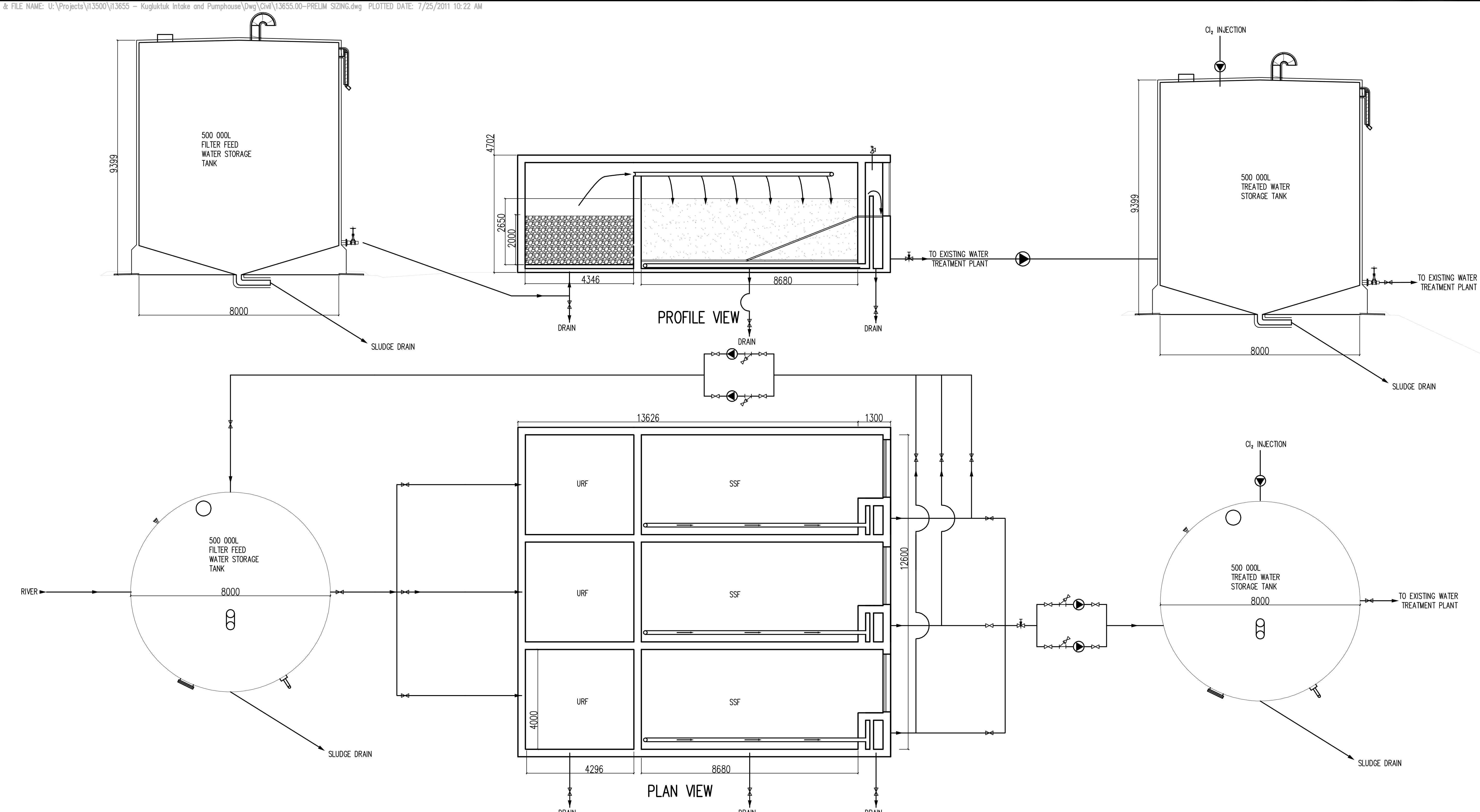


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YELLOWKNIFE OFFICE
P.O. Box 1529
2nd Floor 4902 49 Street
Yellowknife, NT X1A 2P2

Bus: (867) 873-2395
Toll Free: 1-800-263-2393
Fax: (867) 873-2547

info@williamsengineering.com
www.williamsengineering.com

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| JOB. TITLE: | WATER TREATMENT PHASE 2 KUGLUKTUK, NU |
| DWG. TITLE: | OPTION 1 URF/SLOW SAND PRELIMINARY LAYOUT |

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| PEER REVIEW: JH | DATE: (YY-MM-DD) 2011 07 13 | SCALE: NTS |
| CLIENT PROJ. #: 04-4417 | | WE PROJ. #: 13655.00 |
| DWG #: SK-WTP-01 | OF 5 | REV A |

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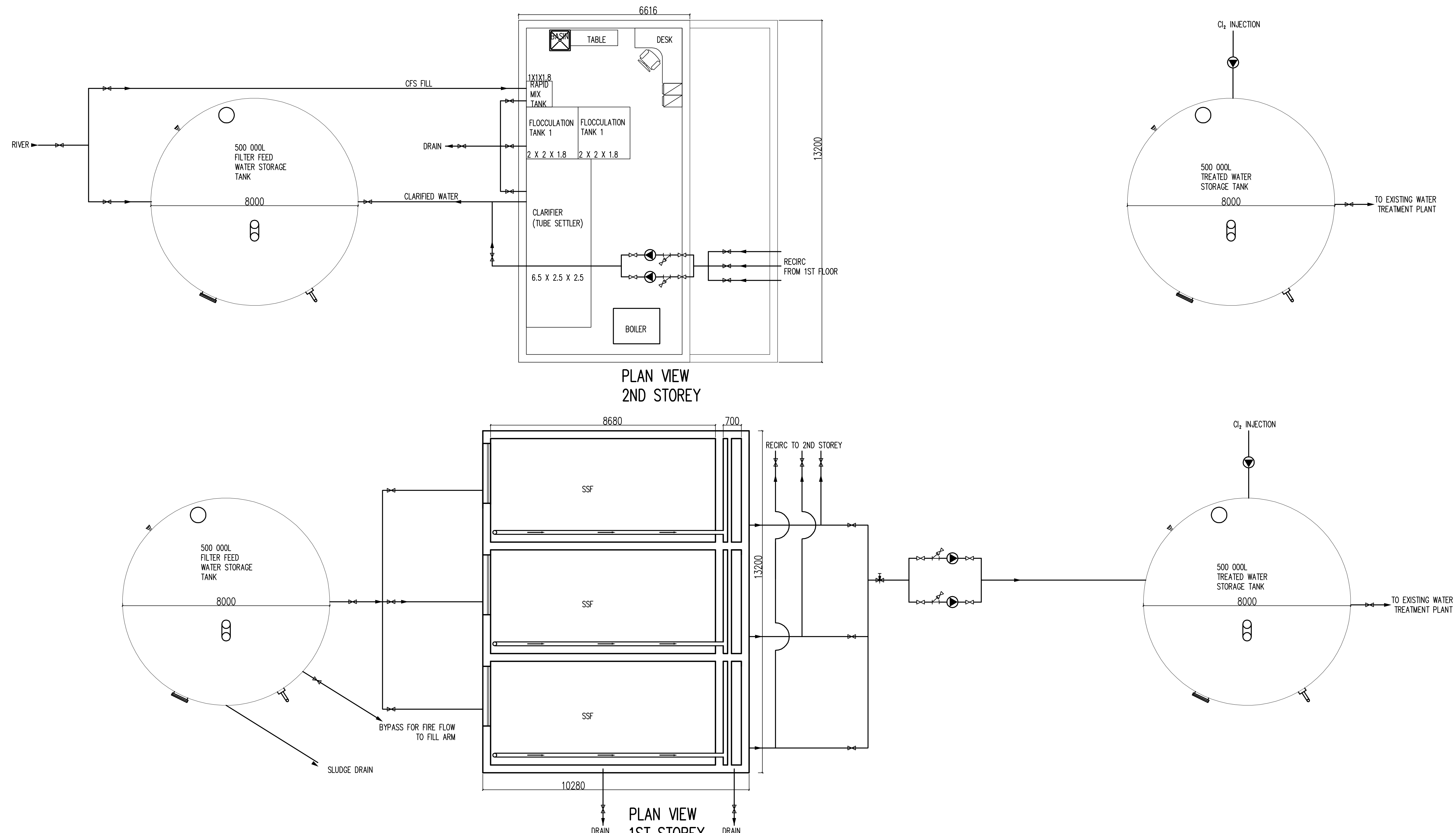


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YELLOWKNIFE OFFICE
P.O. Box 1529
2nd Floor 4902 49 Street
Yellowknife, NT X1A 2P2

Bus: (867) 873-2395
Toll Free: 1-800-263-2393
Fax: (867) 873-2547

info@williamsengineering.com
www.williamsengineering.com

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JOB. TITLE: WATER TREATMENT PHASE 2 KUGLUKTUK, NU

DWG. TITLE: OPTION 2 CFS/SLOW SAND PRELIMINARY LAYOUT

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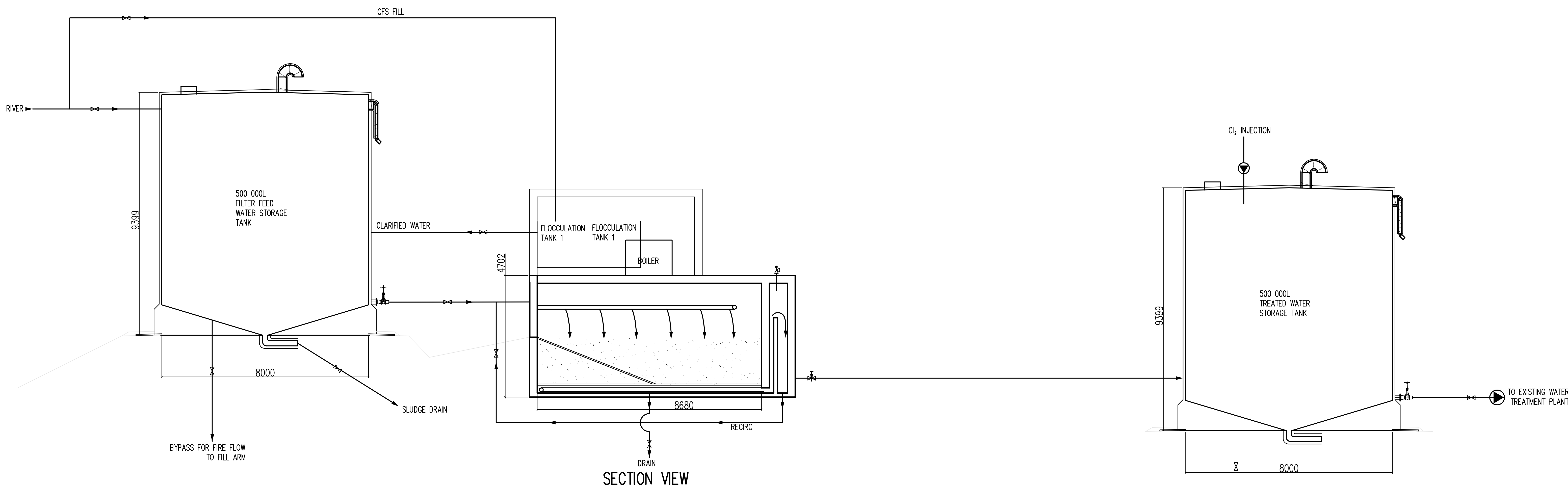


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YELLOWKNIFE OFFICE
P.O. Box 1529
2nd Floor 4902 49 Street
Yellowknife, NT X1A 2P2

Bus: (867) 873-2395
Toll Free: 1-800-263-2393
Fax: (867) 873-2547

info@williamsengineering.com
www.williamsengineering.com

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| DWG. TITLE: | OPTION 2 CFS/SLOW SAND PRELIMINARY LAYOUT |

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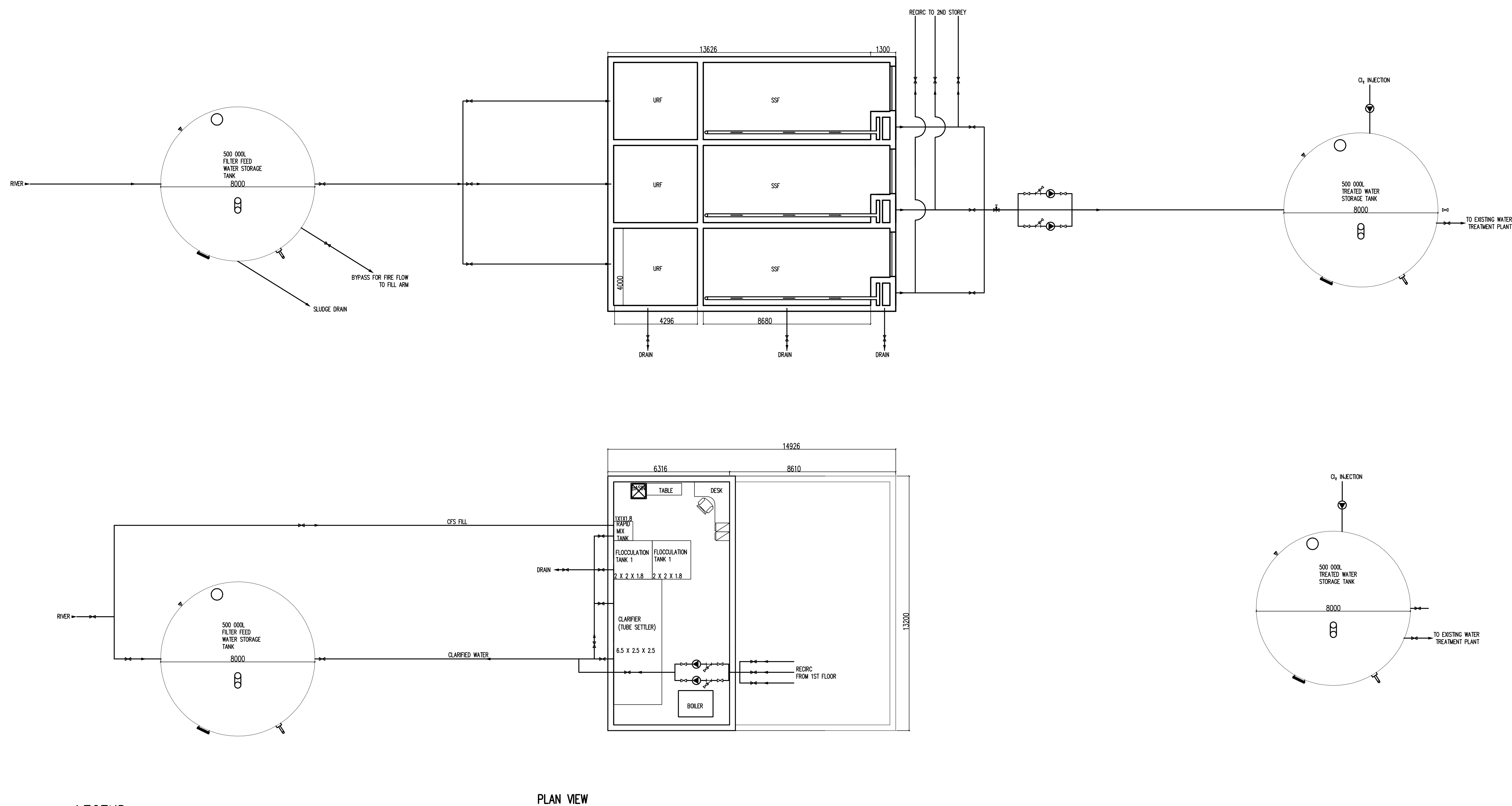


PLAN VIEW

## LEGEND

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YELLOWKNIFE OFFICE
P.O. Box 1529
2nd Floor 4902 49 Street
Yellowknife, NT X1A 2P2

Bus: (867) 873-2395
Toll Free: 1-800-263-2393
Fax: (867) 873-2547

info@williamsengineering.com
www.williamsengineering.com

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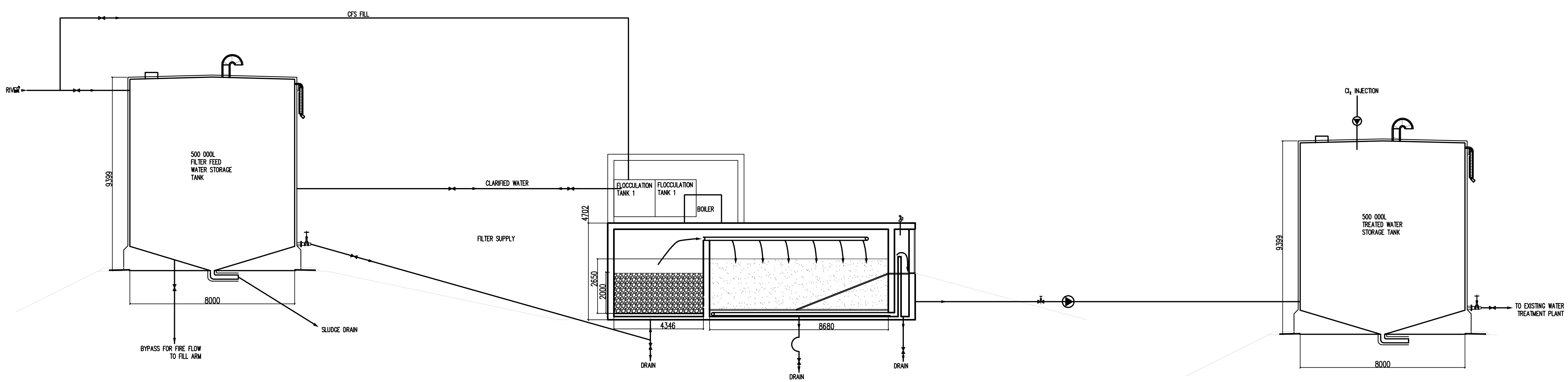


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P.O. Box 1529
2nd Floor 4902 49 Street
Yellowknife, NT X1A 2P2

Bus: (867) 873-2395
Toll Free: 1-800-263-2393
Fax: (867) 873-2547

info@williamsengineering.com
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| JOB. TITLE: WATER TREATMENT PHASE 2 KUGLUKTUK, NU | DWN. BY: KR | DES. BY: KR | PROJ. MGR.: JH |
| | PEER REVIEW: JH | DATE: (YY-MM-DD) 2011 07 13 | SCALE: NTS |
| DWG. TITLE: OPTION 3 CFS/URF/SLOW SAND PRELIMINARY LAYOUT | CLIENT PROJ. # 04-4417 | | WE PROJ. # 13655.00 |
| | DWG. SK-WTP-05 | OF 5 | REV A |

# Appendix B

## Cost Estimate Tables

Option 1: Cost Details

| Item | Unit | Quantity | Price | Shipping | Price | +15% |
|---|---|---|---|---|---|---|
| SS Container | m3 | 275 | $1,900 | | $653,125 | $751,094 |
| SS Media | m3 | 276 | $541 | $264,724 | $451,455 | $519,173 |
| RF Container | m3 | 125 | $1,900 | | $296,875 | $341,406 |
| RF Media | m3 | 103 | $622 | $98,883 | $179,036 | $205,892 |
| Filter Feed Tank | each | 2 | $633,200 | | $1,266,400 | $1,456,360 |
| Construction | | | | | | $400,000 |
| | | | | | Capital | **$3,673,924** |
| Operator Hours | Hours | 260 | $60 | | | $40,000 |
| SSF Cleaning | Hours | 300 | $60 | | | $18,000 |
| | | | | | OM | **$58,000** |

Option 2: Cost Details

| Item | Unit | Quantity Ex | Price | Shipping | Price | +15% |
|---|---|---|---|---|---|---|
| SS Container | m3 | 275 | $1,900 | | $653,125 | $751,094 |
| SS Media | m3 | 276 | $541 | $264,724 | $451,455 | $519,173 |
| CFS | each | 1 | $656,885 | $100,000 | $756,885 | $870,418 |
| Filter Feed Tank | each | 2 | $633,200 | | $1,266,400 | $1,456,360 |
| Construction | | | | | | $1,000,000 |
| | | | | | Capital | **$4,597,044** |
| Operator Hours | | | | | | $88,400 |
| SSF Cleaning | Hours | 200 | $60 | | | $12,000 |
| Building Heat | | | | | | $9,000 |
| | | | | | OM | **$109,400** |

Option 3: Cost Details

| Item | Unit | Quantity Ex | Price | Shipping | Price | +15% |
|---|---|---|---|---|---|---|
| SS Container | m3 | 275 | $1,900 | | $653,125 | $751,094 |
| SS Media | m3 | 276 | $541 | $264,724 | $451,455 | $519,173 |
| CFS | each | 1 | $656,885 | $100,000 | $756,885 | $870,418 |
| RF Container | m3 | 125 | $1,900 | | $296,875 | $341,406 |
| RF Media | m3 | 103 | $622 | $98,883 | $179,036 | $205,892 |
| Filter Feed Tank | each | 2 | $633,200 | | $1,266,400 | $1,456,360 |
| Construction | | | | | | $1,000,000 |
| | | | | | Capital | **$5,144,342** |
| Operator Hours | Hours | | | | | $70,000 |
| SSF Cleaning | Hours | 150 | $60 | | | $9,000 |
| Building Heat | | | | | | $9,000 |
| | | | | | OM | **$88,000** |

$NPV = \Sigma (R_t)/(1+i)^t$

Where:

$t$ = the time of the cash flow

$i$ = the discount rate

$R_t$ = the net cash flow at time t

Net Present Value:

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| **Yearly O&M** | $58,000 | $109,400 | $88,000 |
| **Number of Yea** | 25 | 25 | 25 |
| **Discount Rate** | 8.50% | 8.50% | 8.50% |
| **NPV of O&M** | $593,583 | $1,119,620 | $900,609 |
| **Capital** | $3,673,924 | $4,597,044 | $5,144,342 |
| **NPV** | **$4,267,507** | **$5,716,665** | **$6,044,951** |