Re: D-9, Replace Service Water Piping – Unit 7, Bay D'Espoir, $144,400

Q. Please provide the recommendations resulting from the Service Water System Study undertaken in 2002 for all hydroelectric generating stations.

A. Service water system corrosion/fouling studies were undertaken for Hydro's hydroelectric generating stations and a report produced for each station. Attached are the title page and recommendation sections from each report for generating stations:

- Bay d'Espoir, powerhouse 2 Unit 7 (Attachment A)
- Bay d'Espoir, powerhouse 1 Unit 1 - 6 (Attachment B)
- Cat Arm (Attachment C)
- Hinds Lake (Attachment D)
- Upper Salmon (Attachment E)

Newfoundland & Labrador Hydro

Bay d'Espoir Generating Station

Powerhouse #2 (Unit 7)

SERVICE WATER SYSTEM

CORROSION / FOULING STUDY

Piping

Strainer

Supply Pumps

Control Valves

Heat Exchangers

Prepared for: Newfoundland & Labrador Hydro
Hydro Generation

Submitted to: John Mallam, P.Eng
Mechanical Supervising Engineer

Submitted by: Scott Penney
Mechanical Engineer

Date: April 1, 2002

Recommendations

Coolers
A program is in place for the re-tubing and modification of the surface air coolers. The coolers are being modified to increase the number of passes to increase the tube velocity. A spare surface air cooler has been purchased and each of coolers will be removed and modified on a sequential basis.

The generator bearing coolers have been the cause of downtime during the past year. A failure of these coolers causes forced outages for the unit as this results in water in the bearing oil. From reviewing the past work history it was determined that these coolers have a high frequency of replacement. The coolers were originally installed in 1977, leaked and repaired in 1990, replaced in 1991, leaked and repaired in 2001 and are planned for replacement. Therefore the life of these coolers can be estimated at approximately 10-12 years. The design configuration and materials of these coolers should be reviewed with a view to improving their expected life.

Due to recent failures of the turbine bearing coolers for units 1-6, money was budgeted for replacement of the unit 7 turbine bearing coolers. However, this cooler is stainless steel and has no past history of leaking. It is planned is to purchase a spare cooler to have on hand for replacement and assess the condition of the existing coolers with a hydrostatic test.

Flow meters
The readings from the three flow meters throughout the system are known to be inaccurate. The flow meter design, location and calibration should be reviewed for each of the three meters to verify the accuracy of the measurements.

Supply Source
From the evaluation of the economics for converting the cooling water source from the penstock to the tailrace it is evident that there is a significant potential cost savings. The table below summarizes the net annual cost savings.

Gross Annual Cost Saving	$ 71,529
Annual Pumping Costs	$ 14,302
Annual Maintenance Costs	$ 2,661
Net Annual Cost Savings	$ 54,566

Table 1: Summary of Cooling Water Source Economics

The initial capital cost was estimated at approximately $55,000. The evaluation of the economics is based on the possibility of using an 8” drain line from the pressure relief discharge as the tailrace supply. The feasibility of utilizing this source should be confirmed and a detailed design should be prepared to facilitate the conversion of the cooling water supply to the tailrace.

Pipe Fouling and Corrosion

The following table summarizes the advantages and disadvantages of each of the viable options developed in the study to deal with the pipe fouling and corrosion problem. From this study it is apparent that the option of replacing the piping with corrosion resistant material is the recommended option.

Option	Advantages	Disadvantages
Operate as Current	• Existing design unchanged	• Reduced system reliability • Downtime for maintenance • Future piping replacements
Chemical Treatment	• Reduces corrosion	• Highest cost solution • High chemical costs • Environmental risk
Corrosion Resistant	• Eliminates corrosion • Original pipe was stainless • Lowest cost solution - NPW • Increases system reliability • Existing design unchanged	
Closed Loop System	• High temperature control • Reduces corrosion	• Added equipment mntc. • Loss water to shaft seal of treated water.

Table 2: Option Summary

To implement the “Corrosion resistant” option it is recommended to convert each section of piping to corrosion resistant material as outlined below. This should be performed when the existing system requires replacement due to pipe failures or plugging.

- Turbine Bearing Supply and Shaft Seal Piping. This piping should be replaced with stainless steel as it was when originally installed. The material and labor costs were estimated at $1,900. The materials identified for use are stainless steel schedule 10 with victaulic fittings.
- Surface Air Cooler Supply and Discharge Piping. The material and labor costs were estimated at $17,300 for this replacement. The materials identified for use are stainless steel schedule 10 with victaulic fittings.
- Supply and Discharge Header. The material and labor costs were estimated at $16,200 for this replacement. The materials identified for use are PVC schedule 80 pipe and socket fittings, with flanged connections to existing equipment.

Newfoundland & Labrador Hydro

Bay d'Espoir Generating Station

SERVICE WATER SYSTEM
Bay d'Espoir Units 1-6

Prepared for:	Newfoundland & Labrador Hydro Hydro Generation
Submitted to:	John Mallam, P.Eng Mechanical Supervising Engineer
Submitted by:	Scott Penney Mechanical Engineer
Date:	February 11, 2002

Conclusions and Recommendations

Introduction

This section includes the conclusions and recommendations for the study. The process of researching for the study highlighted advantages and disadvantages for each of the options that could not be quantified financially. Therefore, the recommendations made in this section are based on the economics of the options as well as past work history, trending information, and individual considerations for each option.

Root Cause

In order to recommend a solution for the fouling problem in the system it is important to consider the root cause of the problem. The higher equipment temperatures experienced within the system during the summer months are a direct result of fouling in the coolers and piping. The question is what is causing this fouling?

The root cause of the fouling was approached from two possible positions:

1. The fouling could be caused by the presences of organic material that is suspended in the water that precipitates out at higher temperatures and low velocities. This could be causing increased corrosion by producing stagnate pockets of water under the organic material on the internal surfaces of the piping.
2. The fouling could be caused by corrosion due to the high acidic nature of the water within the system. This could lead to iron deposits within the coolers and produce rough surfaces on the piping that the organic material could adhere to.

The root cause of the fouling is probably a combination of both actions. However the results obtained from the analysis of the water sample and the barnacle deposit suggests that the driving force behind the fouling problem is from corrosion. The main result that points to this conclusion is the composition analysis of the barnacle deposit taken from the 10" supply header. The composition of this deposit contains 81% iron; this iron is from the pipe wall and indicates piping corrosion. The sample did contain 13% Loss on Ignition which indicates organic material, however this component is much lower and is considered a result of organics adhering to the pipe wall due to the corrosion process.

The approach for each solution option was to treat the corrosion problem and therefore reduce the fouling within the system. Each of the solutions that were considered viable was developed for further analysis based on this approach.

Conclusions

Of the four options evaluated in this study the option for replacement of the piping with corrosion resistant material has the lowest cost analysis. The table below shows a comparison of the four options discussed in the previous section. The second option has an extremely high cost associated with it; this is due to the large operating cost for the yearly purchasing of chemical.

Option	Cost NPW
1. Operate as Current	$ 336,558
2. Chemical Treatment	$ 1,266,965
3. Corrosion Resistant	$ 313,099
4. Closed System	$ 553,860

Table 1: Comparison of NPW

The figure below shows the net present worth for the top two options. From this figure we can compare the operating costs, capital cost and overall net present worth for the options over the evaluation period. It is apparent from the graph that the "Corrosion Resistant" option has a higher initial capital cost and lower operating costs over the "Operate As Current" option. The final point for the series represents the net present worth of the cost of the option for the evaluation period. As shown by the figure, the cost of the corrosion resistant options is $23,459 lower when compared over the 50-year evaluation period.

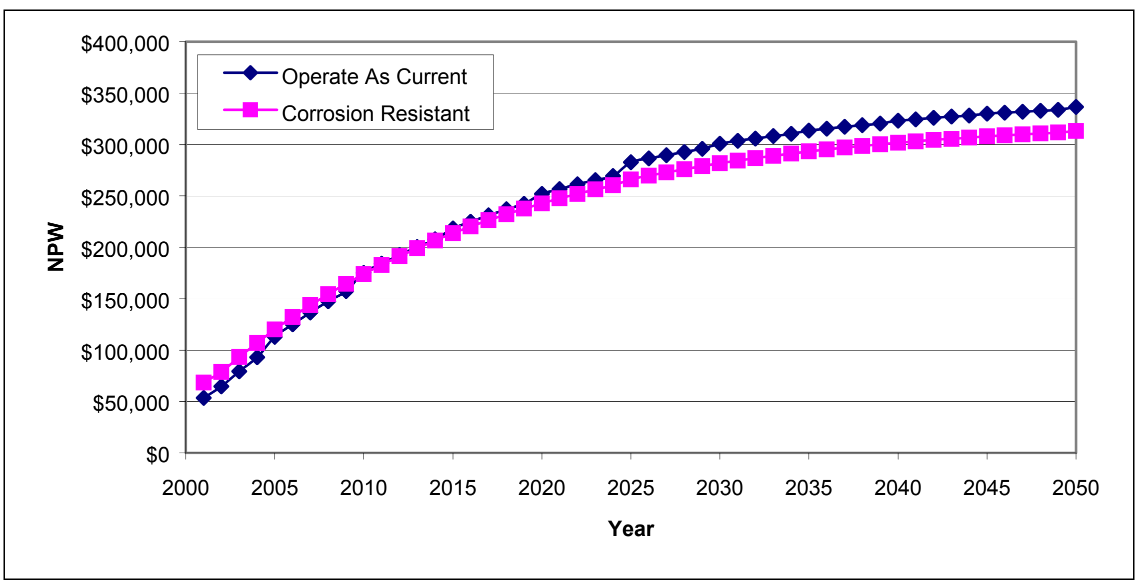

Figure 1: NPW Comparison of Options

Recommendations

The following table summarizes the advantages and disadvantages of each of the viable options developed in the study.

Option	Advantages	Disadvantages
Operate as Current	• Existing design unchanged • No effect on other supplies (Firewater, Machine Shop)	• Reduced system reliability • Future piping replacements • Downtime for mntc.
Chemical Treatment	• Reduce corrosion	• Highest cost solution • High chemical costs • Environmental risk • Lose supply to other areas
Non-Corrosive Piping	• Eliminate corrosion • Some piping converted • Lowest cost solution - NPW • Increases system reliability • Existing design unchanged • No effect on other supplies (Firewater, Machine Shop)	• High initial cost
Closed Loop System	• Temperature control • Reduce corrosion	• Added equipment mntc. • Reduced system flexibility • Don't address turbine brg. • Lose supply to other areas

Table 2: Option Summary

It is recommended to continue with the conversion of the remaining piping to corrosion resistant piping. This will not effect the current operation of the system. All existing branches and additional connections will be maintained. This option is the lowest cost option as shown by the NPW analysis. The high initial cost, which was estimated at $50,577 per unit, will be offset by the long term saving due to the reduced maintenance and piping replacement. An added benefit of converting to corrosion resistant piping is the increase in the overall system reliability. That is, the system will have fewer unscheduled outages due to piping failures, less scheduled downtime for cleaning and no major outages for piping replacement.

This solution can be implemented along with the existing program of piping replacement that is currently underway. The materials identified for use are stainless steel schedule 10 with victaulic fittings inside the generator housing for the SAC supply and PVC schedule 80 pipe and fittings outside the generator housing, for the emergency supply and all drains.

Newfoundland & Labrador Hydro

Cat Arm Generating Station

SERVICE WATER SYSTEM

Piping
Strainer
Supply Pumps
Control Valves
Heat Exchangers

Prepared for: Newfoundland & Labrador Hydro
Hydro Generation

Submitted to: John Mallam, P.Eng.
Mechanical Supervising Engineer

Submitted by: Shane White, B.Eng.
Mechanical Engineer

Date: November 23, 2001

CONCLUSIONS AND RECOMMENDATIONS

From the material presented there were four different solutions that could be taken to resolve the problem. To recap the four alternative solutions were to continue to operate as we have "do nothing approach", replace the piping with corrosion resistant material, inject chemical into the service water for treatment, or install a closed loop system with treated water to cool the units. Each solution has it's benefits and draw backs.

The NPW analysis calculated the following dollar figures for each solution;

Do Nothing	$217,320 x 2 units = $434,640
Replace the Piping with s.s & PVC	$210,126 x 2 units = $420,252
Closed Loop System	$293,131
Chemical Injection	$679,865

Table 1

The "continue to operate as we have" will mean scheduled outages for cooler and pipe cleaning. There is an uncertainty with this solution when it comes to forced outages due to cooling problems during the summer months. If a maintenance program for cleaning and maintaining the cooling water system is not implemented forced outages due to cooling problems during the summer months in the height of the maintenance season will occur. In order to prevent this a fouling monitoring program for the cooling water system has to be put in place.

In addition the cooling water system that is currently in place in Cat Arm has a redundant control valve. There is a pressure-reducing valve located in the inlet header and there are temperature control valves located in the discharge header. The service water pumps maximum pressure is still to low to damage any of the components in the service water system. It seems that the pressure control valve in the inlet header is back up pressure-reducing valve for the secondary water supply that comes off the penstock, yet the penstock lines have there own pressure-reducing valves. This warrants further investigation.

Also the temperature control valves located in the discharge lines regulate flow through the coolers based on the temperature of the water exiting the coolers and not on the temperature of the bearing oil, which they are cooling. This also warrants further investigation.

The other alternative of replacing the piping with corrosion resistant pipe solution has an initial capital investment with a low operating cost associated with it. The Cat Arm plant has been in operation since 1985 and most of the cooling water pipe's expected life is coming to an end. The labour cost of replacing this pipe is going to be the same regardless of what type of pipe you use to replace it. Already the SAC piping inside of the generator housing has been replaced with stainless steel sch 10 pipe.

One of the benefits of having the corrosion resistant pipe like stainless steel and PVC is lower maintenance. Unit outages for cleaning service water piping will be less frequent, hence will free up more manpower for other tasks during the maintenance season.

Another benefit to corrosion resistant piping is the reduced likely hood of the pipe becoming clogged with debris. Since the pipe is resistant to corrosion from the service water it is not likely that enough organic material will be able to adhere to the pipe wall to impend flow to the point of stagnation. It is believed that only a small layer of organics will adhere to the inner pipe wall and once that layer is in place the rest of the organics will be washed through the system. Cleaning of the coolers and piping will still have to be done to optimize the efficiency of the system but the frequency of cleanings will be drastically reduced from the current operation.

Another benefit to the replace piping with corrosion resistant pipe solution is that no new equipment or design changes have to be made to the existing system, just replace the existing pipe.

As can be seen from the NPW analysis replacing the piping with corrosion resistant pipe has a NPW of $420,252 and the other solution of continuing to operate like we have in the past has a NPW of $434,640. In order to continue to operate as we have the existing piping has to be replaced and the labour alone is $42,000. This labour figure does not include the SAC piping that was replaced in the Fall 2001 outage.

The closed loop system has a NPW of $293,131which makes this solution better than the other solution presented from a financial point of view. The problem with this solution is that it is add on to the existing cooling water system. Seeing that the service water piping is almost at its life expectancy the cost of replacing that piping has to also be considered.

With the closed loop solution the piping inside of the generator housing can be mild steel sch 40 pipe and the piping outside of the generator housing can be PVC to help reduce costs. This solution will use treated water for recirculating through the unit and use the existing service water to cool the heat exchangers.

The closed loop solution will have more components with the extra two recirculating pumps and heat exchangers. This increases the chances of more problems within the system.

The maintenance of the unit's coolers and piping will be non-existent but the outside heat exchanger will have to be cleaned. The frequency of this clean will have to be determined from operating the system. These outside heat exchangers should be positioned for easy cleaning.

The chemical injection solution has a NPW of $679,865, which makes this solution not feasible compared to the other alternative solutions. Also any solution that doesn't impact the environment is always a better alternative.

It is recommended that we go with the solution of "replacing the piping with corrosion resistant pipe" for Cat Arm. The pipe's life expectancy within the service water system is coming to an end and will need to be replaced in the near future. With this alternative we still have the ability of replacing sections of the existing system year by year until it is all changed over, reducing the over all capital expenditure for that year. Also this solution will result in lower maintenance costs for the system. Another benefit is that no new design work has to be done in order for this solution to be implemented.

It is also recommended that the current design of the cooling water system be re-evaluated to determine if it is indeed operating in the most efficient way. It seems that there is a complexity build into the design that doesn't need to be there, i.e. too many control valves.

Newfoundland & Labrador Hydro

Hinds Lake Generating Station

SERVICE WATER SYSTEM

Piping

Strainer

Supply Pump

Control Valves

Heat Exchangers

Prepared for: Newfoundland & Labrador Hydro
Hydro Generation

Submitted to: John Mallam, P.Eng.
Mechanical Supervising Engineer

Submitted by: Shane White, B.Eng.
Mechanical Engineer

Date: November 25, 2001

CONCLUSIONS AND RECOMMENDATIONS

From the material presented there were four different solutions that could be taken to resolve the problem. To recap the four alternative solutions were to continue to operate as we have "do nothing approach", replace the piping with corrosion resistant material, inject chemical into the service water for treatment, or install a closed loop system with treated water to cool the units. Each solution has it's benefits and draw backs.

The NPW analysis calculated the following dollar figures for each solution;

Do Nothing	$152,494
Replace the Piping with s.s & PVC	$218,064
Closed Loop System	$213,427
Chemical Injection	$473,956

Table 1

The "continue to operate as we have" will mean scheduled outages for cooler and pipe cleaning. There is an uncertainty with this solution when it comes to forced outages due to cooling problems during the summer months. If a maintenance program for cleaning and maintaining the cooling water system is not implemented forced outages due to cooling problems during the summer months, in the height of the maintenance season, will occur. In order to prevent this a fouling monitoring program for the cooling water system has to be put in place.

The service water system currently has all of its original piping that was installed when the plant was first came on-line in 1980. This life expectancy of this pipe is near its end. The cooling water pipe will have to be replaced in the near future. A quick calculation of the labour cost associated with replacing that piping is $52,000 this figure does not include the pipe.

The other alternative of replacing the piping with corrosion resistant pipe has an initial capital investment with a low operating cost associated with it. The labour cost of replacing the pipe in the cooling water system is going to be the same regardless of what type of pipe you use to replace it.

One of the benefits of having the corrosion resistant pipe like stainless steel and PVC is lower maintenance. Unit outages for cleaning service water piping will be less frequent, hence will free up more manpower for other tasks during the maintenance season.

Another benefit to corrosion resistant piping is the reduced likely hood of the pipe becoming clogged with debris. Since the pipe is resistant to corrosion from the service water it is not likely that enough organic material will be able to adhere to the pipe wall to impend flow to the point of stagnation. It is believed that only a small layer of organics will adhere to the inner pipe wall and once that layer is in place the rest of the organics will be washed through the system. Cleaning of the coolers and piping will still have to be done to optimize the efficiency of the system but the frequency of cleanings will be drastically reduced from the current operation.

Another benefit to the replace piping with corrosion resistant pipe solution is that no new equipment or design changes have to be made to the existing system, just replace the existing pipe.

As can be seen from the NPW analysis replacing the piping with corrosion resistant pipe has a NPW of $218,064 and the other solution of continuing to operate like we have in the past has a NPW of $152,494. The NPW of the solution to continue to operate as we have has a lower NPW. This NPW figure doesn’t include replacing the existing piping with the same mild steel sch 40 pipe. The cost of labour to replace this pipe not including the pipe is $52,000. If this figure was included into the NPW analysis these two solution would be very close.

The closed loop system has a NPW of $213,427 making this solution on par with the other alternative solution of replacing the piping with corrosion resistant pipe. The problem with this solution is that it is add on to the existing cooling water system. Seeing that the service water piping is almost at its life expectancy the cost of replacing that piping has to also be considered. A quick calculation of labour costs just to replace the piping not including the pipe is around $52,000.

With the closed loop solution the piping inside of the generator housing can be mild steel sch 40 pipe and the piping outside of the generator housing can be PVC to help reduce costs. This solution will use treated water for recirculating through the unit and use the existing service water to cool the heat exchangers.

The closed loop solution will have more components with the extra two recirculating pumps and heat exchangers. This increases the chances of more problems within the system. Also Hinds lake power house does not have much room to accommodate such a system.

The maintenance of the unit’s coolers and piping will be non-existent but the outside heat exchanger will have to be cleaned. The frequency of this clean will have to be determined from operating the system. These outside heat exchangers should be positioned for easy cleaning.

The chemical injection solution has a NPW of $473,956 which makes this solution not feasible compared to the other alternative solutions. Also any solution that doesn’t impact the environment is always a better alternative.

It is recommended that we go with the solution of “replacing the piping with corrosion resistant pipe” for Hinds Lake. The pipe’s life expectancy within the service water system is coming to an end and will need to be replaced in the near future. With this alternative we still have the ability of replacing sections of the existing system year by year until it is all changed over, reducing the over all capital expenditure for that year. Also this solution will result in lower maintenance costs for the system. Another benefit is that no new design work has to be done in order for this solution to be implemented.

Newfoundland & Labrador Hydro

Upper Salmon Generating Station

SERVICE WATER SYSTEM

Piping

Strainer

Supply Pump

Control Valves

Heat Exchangers

Prepared for: Newfoundland & Labrador Hydro
Hydro Generation

Submitted to: John Mallam, P.Eng.
Mechanical Supervising Engineer

Submitted by: Shane White, B.Eng.
Mechanical Engineer

Date: November 23, 2001

CONCLUSIONS AND RECOMMENDATIONS

From the material presented there were four different solutions that could be taken to resolve the problem. To recap the four alternative solutions were to continue to operate as we have "do nothing approach", replace the piping with corrosion resistant material, inject chemical into the service water for treatment, or install a closed loop system with treated water to cool the units. Each solution has it's benefits and draw backs.

The NPW analysis calculated the following dollar figures for each solution;

Do Nothing	$86,210
Replace the Piping with s.s & PVC	$73,806
Closed Loop System	$98,075
Chemical Injection	$340,501

Table 1

The "continue to operate as we have" will mean scheduled outages for cooler and pipe cleaning. There is an uncertainty with this solution when it comes to forced outages due to cooling problems during the summer months. If a maintenance program for cleaning and maintaining the cooling water system is not implemented forced outages due to cooling problems during the summer months, in the height of the maintenance season, will occur. In order to prevent this a fouling monitoring program for the cooling water system has to be put in place.

The service water system currently has all of its original piping that was installed when the plant was first came on-line in 1983. This life expectancy of this pipe is near its end. The cooling water pipe will have to be replaced in the near future. Already the SAC piping inside the generator housing has been replaced with stainless steel sch 10 pipe. Also the shaft seal piping inside the turbine pit has been replaced with copper pipe. The SAC discharge six-inch line outside the generator housing is scheduled for replacement with PVC pipe before the end of 2001.

The other alternative of replacing the piping with corrosion resistant pipe has an initial capital investment with a low operating cost associated with it. The labour cost of replacing the pipe in the cooling water system is going to be the same regardless of what type of pipe you use to replace it.

One of the benefits of having the corrosion resistant pipe like stainless steel and PVC is lower maintenance. Unit outages for cleaning service water piping will be less frequent, hence will free up more manpower for other tasks during the maintenance season.

Another benefit to corrosion resistant piping is the reduced likely hood of the pipe becoming clogged with debris. Since the pipe is resistant to corrosion from the service water it is not likely that enough organic material will be able to adhere to the pipe wall to impend flow to the point of stagnation. It is believed that only a small layer of organics will adhere to the inner pipe wall and once that layer is in place the rest of the organics will be washed through the system. Cleaning of the coolers and piping will still have to be done to optimize the efficiency of the system but the frequency of cleanings will be drastically reduced from the current operation.

Another benefit to the replace piping with corrosion resistant pipe solution is that no new equipment or design changes have to be made to the existing system, just replace the existing pipe.

As can be seen from the NPW analysis replacing the piping with corrosion resistant pipe has a NPW of $73,806 and the other solution of continuing to operate like we have in the past has a NPW of $86,210. The NPW of the solution to replace the piping with corrosion resistant pipe has a lower NPW.

The closed loop system has a NPW of $98,075. The problem with this solution is that it is add on to the existing cooling water system. Seeing that the service water piping is almost at its life expectancy the cost of replacing that piping has to also be considered. A quick calculation of labour costs just to replace the piping not including the pipe is around $26,000.

With the closed loop solution the piping inside of the generator housing can be mild steel sch 40 pipe and the piping outside of the generator housing can be PVC to help reduce costs. The SAC piping inside of the generator housing has already been replaced with stainless steel. This solution will use treated water for recirculating through the unit and use the existing service water to cool the heat exchangers.

The closed loop solution will have more components with the extra two recirculating pumps and heat exchangers. This increases the chances of more problems within the system.

The maintenance of the unit's coolers and piping will be non-existent but the outside heat exchanger will have to be cleaned. The frequency of this clean will have to be determined from operating the system. These outside heat exchangers should be positioned for easy cleaning.

The chemical injection solution has a NPW of $340,501 which makes this solution not feasible compared to the other alternative solutions. Also any solution that doesn't impact the environment is always a better alternative.

It is recommended that we go with the solution of "replacing the piping with corrosion resistant pipe" for Upper Salmon. The pipe's life expectancy within the service water system is coming to an end and will need to be replaced in the near future. Also the SAC piping inside of the generator housing has already been replaced and this section of piping is the most costly. With this alternative we still have the ability of replacing sections of the existing system year by year until it is all changed over, reducing the over all capital expenditure for that year. Also this solution will result in lower maintenance costs for the system. Another benefit is that no new design work has to be done in order for this solution to be implemented.