BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

Integ-Ebasco - Hat Creek Project - Powerplant Revised Worst-case Zero Discharge Water Management Analysis - December 1980

ENVIRONMENTAL IMPACT STATEMENT REFERENCE NUMBER: 56

integ-ebasco

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POWERPLANT REVISED "WORST CASE" ZERO DISCHARGE WATER MANAGEMENT ANALYSIS

Integ-Ebasco
Vancouver, B.C.

December 1980

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Revised April 1981

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HAT CREEK PROJECT POWER PLANT
REVISED POWER PLANT "WORST CASE"
ZERO DISCHARGE WATER MANAGEMENT ANALYSIS

INTRODUCTION

The original Water Management Studies[1/] considered a number of "wet" and "dry" ash disposal systems, while the Alternative "B" Ash Disposal Study[2/] considered the preferred "wet" and "dry" ash disposal systems. The "proposed power plant" included this dry ash disposal system with a zero discharge water balance. This system ensures consistency with the overall Hat Creek Project philosophy of environmental compatibility. For the zero discharge water balance, "normal worst case" analysis was performed to develop power plant water and chemical balances for fly ash/bottom ash ratios of 55/45 and 85/15, and a power plant capacity factor of 100 percent. All current engineering considerations and assumptions were incorporated into this analysis.

CASE DESCRIPTIONS AND ASSUMPTIONS

The cases analyzed consisted of the following power plant operating conditions:

1) Average meteorological conditions for the period corresponding to "normal worst case" reservoir water quality, performance blend coal at a fly ash/bottom ash ratio of 55/45, maximum ash hopper evaporation, a power plant capacity factor of 100 percent, and zero liquid discharge.

2) Average meteorological conditions for the period corresponding to "normal worst case" reservoir water quality with the power plant operating at 100 percent capacity factor, performance blend coal at a fly ash/bottom ash ratio of 85/15, maximum ash hopper evaporation, a power plant capacity factor of 100 percent, and zero liquid discharge.

The period under consideration is 25 March to 5 May, corresponding to the time period during which "normal worst case" reservoir water quality would occur.[2/] The 100 percent capacity factor implies 4 units operating at 560 MW each.[3/] Average meteorological conditions for this period define an average cooling tower evaporation rate of 985 l/s.[2/] Normal worst case reservoir water quality implies the Thompson River supply inoperable for a 40-day period.[2/] This corresponds to the water quality given in Table 1. Theoretically, reservoir water quality can be deteriorated beyond the values presented in Table 1 if a Thompson River pumping system outage occurs immediately following the normal 40 day inoperation period. This is not considered likely, however, as system maintenance and testing functions are assumed to occur during the scheduled outage.

Performance blend coal at a fly ash/bottom ash ratio of 55/45 results in ash generation rates of approximately 64.5 Kg/sec fly ash and 52.7 Kg/sec bottom ash for 4 units at 100 percent capacity factor. For a fly ash/bottom ash ratio of 85/15, the ash generation rates were determined to be 99.6 Kg/sec fly ash and 17.6 Kg/sec bottom ash. The maximum bottom ash hopper evaporation rates were determined to be 25.64 l/s for the 55/45 ash split and 10.17 l/s for the 85/15 ash ratio and correspond to a hopper inflow rate of 42.3 l/s. The trough/surge tank recyle flow to maintain appropriate trough water temperatures was determined to be 65.0 l/s. This flow consists of a continuous recycle of surge tank water through a heat exchange system and the intermittent sluicing of mill rejects.

TABLE 1

"NORMAL WORST CASE" RESERVOIR WATER QUALTIY

Parameter*	Reservoir Concentration
Total Dissolved Solids	91.8
Calcium	17.9
Magnesium	4.9
Potassium	1.0
Sodium	3.4
Chloride	1.2
Sulphate	9.0
Total Silica (SiO_2)	5.5
Alkalinity (as $CaCO_3$)	64.8
Total Organic Carbon	7.3
pH (units)	7.8

* All parameter concentrations in mg/l unless otherwise specified.

Source: Reference 2.

Flows and water quality concentrations of the primary water use systems (equalization and neutralization pond effluent, sanitary wastewater treatment including HVAC effluent, and oil/water separator effluent) were assumed to remain essentially unchanged from those developed in previous studies.[1,2,3] Water quality parameters of these systems were adjusted slightly to reflect the current makeup water scheme. These data are reproduced in Table 2.

The extractable salts derived from the bottom ash were assumed to be at the rates given in the ash-leaching tests reported in the Water Management Study.[1] These reported rates are 1320 mg/Kg ash for calcium, and 190 mg/Kg ash for magnesium, both as $CaCO_3$.

The recirculating cooling water system chemistry was set at an LSI index of 0.5 (i.e., slightly scale forming) for corrosion protection.

Based on the results of previous studies, the calcium concentration must be maintained at a level of less than 400 mg/l as Ca (1000 mg/l as $CaCO_3$) in the recirculating cooling water system to prevent scaling.[1] This level must also be maintained in all subsequent systems either by setting an appropriate flow/chemical balance between the primary systems' blowdown and secondary systems' makeup or by inserting a wastewater treatment system for calcium removal at an optimal point within the overall water management system.

TABLE 2

WATER QUALITY AND FLOWS OF PRIMARY USE SYSTEMS*

Parameter**	Combined Regenerate Wastes	Treated Sanitary Wastewater	Treated Floor Drainage
Total Dissolved Solids	6119	300	100
Calcium	147	17.9	17.9
Magnesium	26	4.9	4.9
Sodium	1710	3.4	3.4
Chloride	748	56	3
Sulphates	3263	9	9
Silica (SiO_2)	66	5.5	5.5
Potassium	9	1	1
pH (units)	5.0	8.0	8.5
Flow (l/s)	3.4	0.9	6.3

*Inputs to wastewater collection sump.

**All parameter concentrations in mg/l unless otherwise specified.

Source: References 1,2

ANALYSIS AND DISCUSSION

Using the above data and assumptions, several flow-chemical balances were investigated for each operational case in question. For the majority of these analyses, the moisture content of the ash was conservatively fixed at levels previously specified,[2] that is, 20 percent moisture for fly ash and 30 percent moisture for bottom ash, both on a dry weight basis, i.e., weight of water divided by weight of dry ash. Fixing the moisture content of the ash sets the total consumptive use of the system. For Case 1 (fly ash/bottom ash ratio of 55/45) and Case 2 (fly ash/bottom ash ratio of 85/15), this water consumption rate was determined to be 54.4 l/s and 35.5 l/s, respectively. All analyses were predicated on a zero discharge assumption.

Initially, Cases 1 and 2 were evaluated at equilibrium conditions using these water consumption rates together with component design criteria to set system flows. Makeup water quality was then used to determine the resulting water quality concentrations. For Case 1, a cooling tower blowdown flow of 47.1 l/s[a] was required, resulting in 21.9 cycles of concentration, a calcium concentration of 392 mg/l Ca in the blowdown, and a calcium concentration of 1585 mg/l Ca in ash handling system. For Case 2, a blowdown of 28.2 l/s[a] was required, resulting in 35.9 cycles of concentration, and calcium concentrations of 643 mg/l Ca and 1084 mg/l Ca in the blowdown, and in the ash handling system, respectively. In both cases, the maximum recommended literature value to avoid significant scaling, 400 mg/l Ca, was greatly exceeded, implying the need for treatment.

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[a] Includes drift of 3.3 l/s.

As a second step, cooling tower blowdown was set at its maximum chemical limit and the constraints on ash moisture content were removed to determine if excess cooling tower blowdown could be consumed within the system without the addition of a treatment facility. Ash hopper calcium concentrations were set at the maximum of 400 mg/l Ca, and flows were then adjusted to try to satisfy the overall plant water balance while maintaining ash moisture content ranges commonly experienced at other facilities (refer to Table 3). The results of these analyses indicated that reasonable moisture contents could not be achieved. Hence, treatment is required for these two cases under the zero discharge constraint.

Three separate treatment schemes were then evaluated for each of the cases under study. In preliminary analyses, a lime soda-ash treatment system following the configuration of withdrawal from the surge tank to treatment, with recycle to the ash hopper was tested (Figure 1). Because of cooling tower blowdown flow constraints and leaching from the ash, this system resulted in scale forming calcium concentrations in the recirculating cooling water system, and therefore this treatment configuration proved to be unsuitable. From an equipment point of view, it was also considered highly desirable to maintain the present design flows to the hopper, and surge tank recycle system.

The next treatment scheme investigated was evaluated for each case under two different concentration constraints: fixing the ash hopper calcium concentration at 400 mg/l Ca (Scenario A) and fixing the surge tank calcium concentration at 400 mg/l Ca (Scenario B). Scenario A is the more restrictive, and does not permit scale to occur within the entire system. Under Scenario B, the surge tank is assumed to be the critical point in the system and potential scaling forming concentrations in the hopper are allowed as long as scale does not occur in the surge tank and associated equipment.

TABLE 3

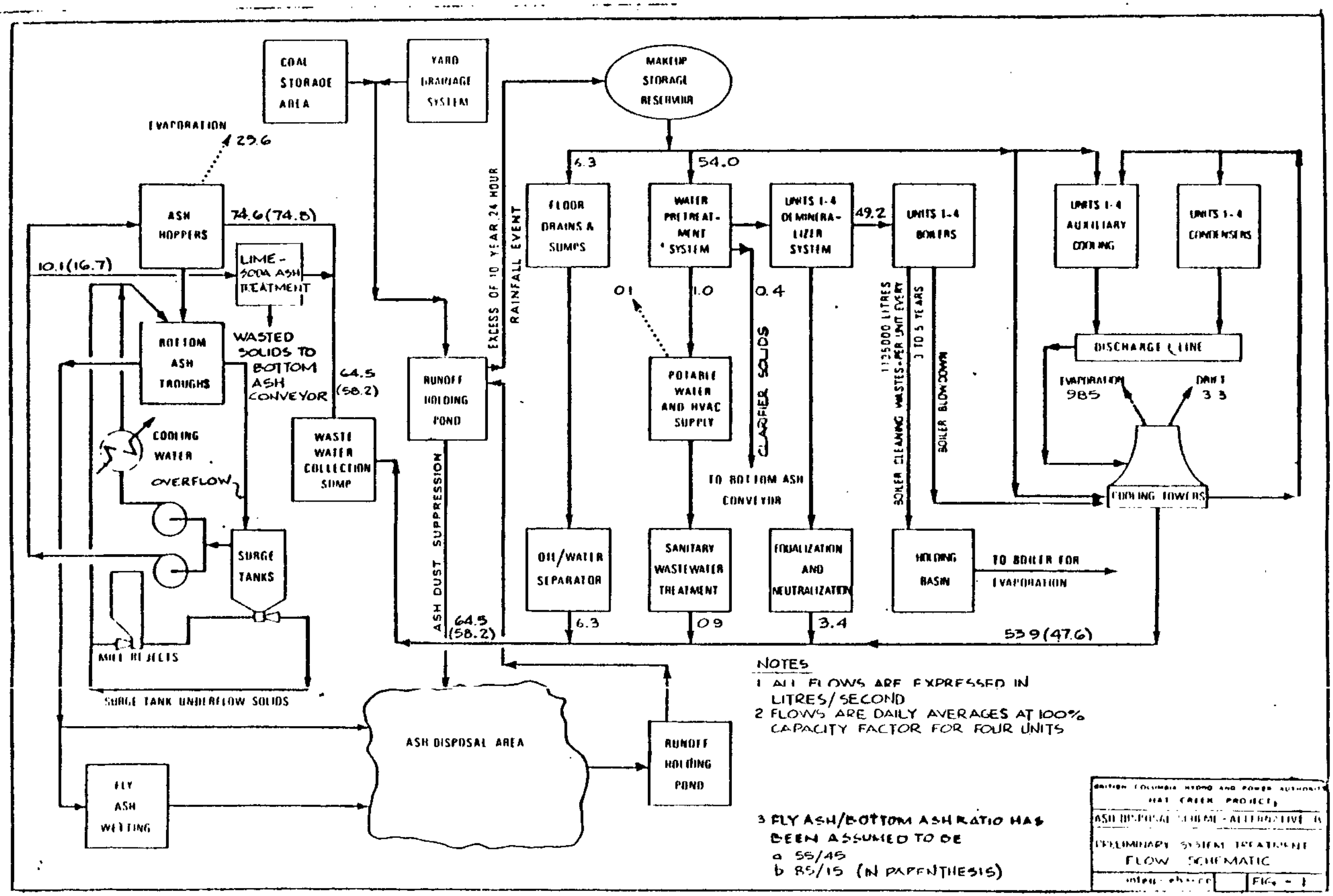
DRY ASH MOISTURE CONTENT FOR OPTIMUM ASH COMPACTION

EXPERIENCED AT VARIOUS POWER PLANTS

Plant	Fly Ash Percent Moisture[a]	Bottom Ash Percent Moisture[a]
Navajo	17-26	27-38
Sundance	20.7	43
Phillips (Duquesne Light Co.)	<24	--
Marysville (Michigan)	32	--
St. Clair (Michigan)	23	--
Trenton (Michigan)	32	--
Allegheny (New York)	—	13.8-26.2

[a]Moisture content calculated on a dry weight basis; (Water Weight/Dry Ash Weight) x 100.

Source: Personal Communications (Telephone Survey), Aug. 1978.


COAL STORAGE AREA
YARD DRAINAGE SYSTEM
MAKEUP STORAGE RESERVOIR
EVAPORATION 29.6
ASH HOPPERS
74.6 (74.8)
10.1 (16.7)
LIME-SODA ASH TREATMENT
BOTTOM ASH TROUGHS
WASTED SOLIDS TO BOTTOM ASH CONVEYOR
64.5 (58.2)
COOLING WATER
OVERFLOW
SURGE TANKS
MILL REJECTS
SURGE TANK UNDERFLOW SOLIDS
WASTE WATER COLLECTION SUMP
RUNOFF HOLDING POND
EXCESS OF 10 YEAR 24 HOUR RAINFALL EVENT
ASH DUST SUPPRESSION
64.5 (58.2)
6.3
54.0
FLOOR DRAINS & SUMPS
WATER PRETREATMENT SYSTEM
UNITS 1-4 DEMINERALIZER SYSTEM
49.2
UNITS 1-4 BOILERS
UNITS 1-4 AUXILIARY COOLING
UNITS 1-4 CONDENSERS
0.1
1.0
0.4
CLARIFIER SOLIDS
POTABLE WATER AND HVAC SUPPLY
TO BOTTOM ASH CONVEYOR
1135000 LITRES BOILER CLEANING WASTES PER UNIT EVERY 3 TO 5 YEARS
BOILER BLOWDOWN
DISCHARGE LINE
EVAPORATION 985
DRIFT 3.3
COOLING TOWERS
OIL/WATER SEPARATOR
SANITARY WASTEWATER TREATMENT
EQUALIZATION AND NEUTRALIZATION
HOLDING BASIN
TO BOILER FOR EVAPORATION
6.3
0.9
3.4
53.9 (47.6)
ASH DISPOSAL AREA
FLY ASH WETTING
RUNOFF HOLDING POND
NOTES
1 ALL FLOWS ARE EXPRESSED IN LITRES/SECOND
2 FLOWS ARE DAILY AVERAGES AT 100% CAPACITY FACTOR FOR FOUR UNITS
3 FLY ASH/BOTTOM ASH RATIO HAS BEEN ASSUMED TO BE
a 55/45
b 85/15 (IN PARENTHESIS)
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ASH DISPOSAL SCHEME - ALTERNATIVE B
PRELIMINARY SYSTEM TREATMENT FLOW SCHEMATIC
FIG. - 1

The treatment configuration investigated involves what is termed cooling tower "sidestream treatment", combined with recycle treatment of the bottom ash trough water. The actual water treatment process was again a lime-soda ash water softening system. A flow schematic for this zero discharge system is given in Figure 2. Flow variable values are presented in Table 4 while Table 5 details other important parameters specific to each case. For Case 1, the system is operated at 21.9 cycles of concentration. Under Scenario A, this results in a treatment/recycle flow of 91.5 l/s to the cooling tower and 169.4 l/s to the trough, corresponding to calcium removal rate of 3,242 Kg/day Ca. The recirculating cooling water system is operated at a steady state calcium concentration of 131 mg/l Ca. The treatment flows were minimized by evaluating various trough concentrations. Trough concentrations slightly beyond 250 mg/l will not satisfy all other system constraints. For Case 2, the system is operated at 35.9 cycles of concentration. Under Scenario A, this results in a treatment/recycle flow of 149.1 l/s to the cooling tower and 12.3 l/s to the trough, corresponding to a calcium removal rate of 1642 Kg/day Ca, with a tower basin calcium concentration of 129.2 mg/l Ca. In this case, trough concentrations can attain their maximum acceptable value of 400 mg/l.

For both cases I and II under Scenario B, it was determined that significant scaling would occur in the hopper (theoretical concentrations at 1013.2 and 527.1 mg/l, respectively). In addition, further analysis for Case I indicated that as the sump concentrations approach 400 mg/l, concentration constraints to prevent scaling in the cooling tower, trough, and associated equipment cannot be satisified given the required flow constraints. Therefore, this scenario was eliminated from further consideration.

The final treatment configuration evaluated involves withdrawal from the surge tank, followed by lime-soda ash treatment and recycle to the cooling tower basin. A flow schematic of this system is given in Figure 3. This configuration, based on detailed mathematical analysis for Case 1A, proved to be an incorrect treatment design. Based on the

Figure 2 Flow Schematic, Side Stream Treatment, Cases I A, II A

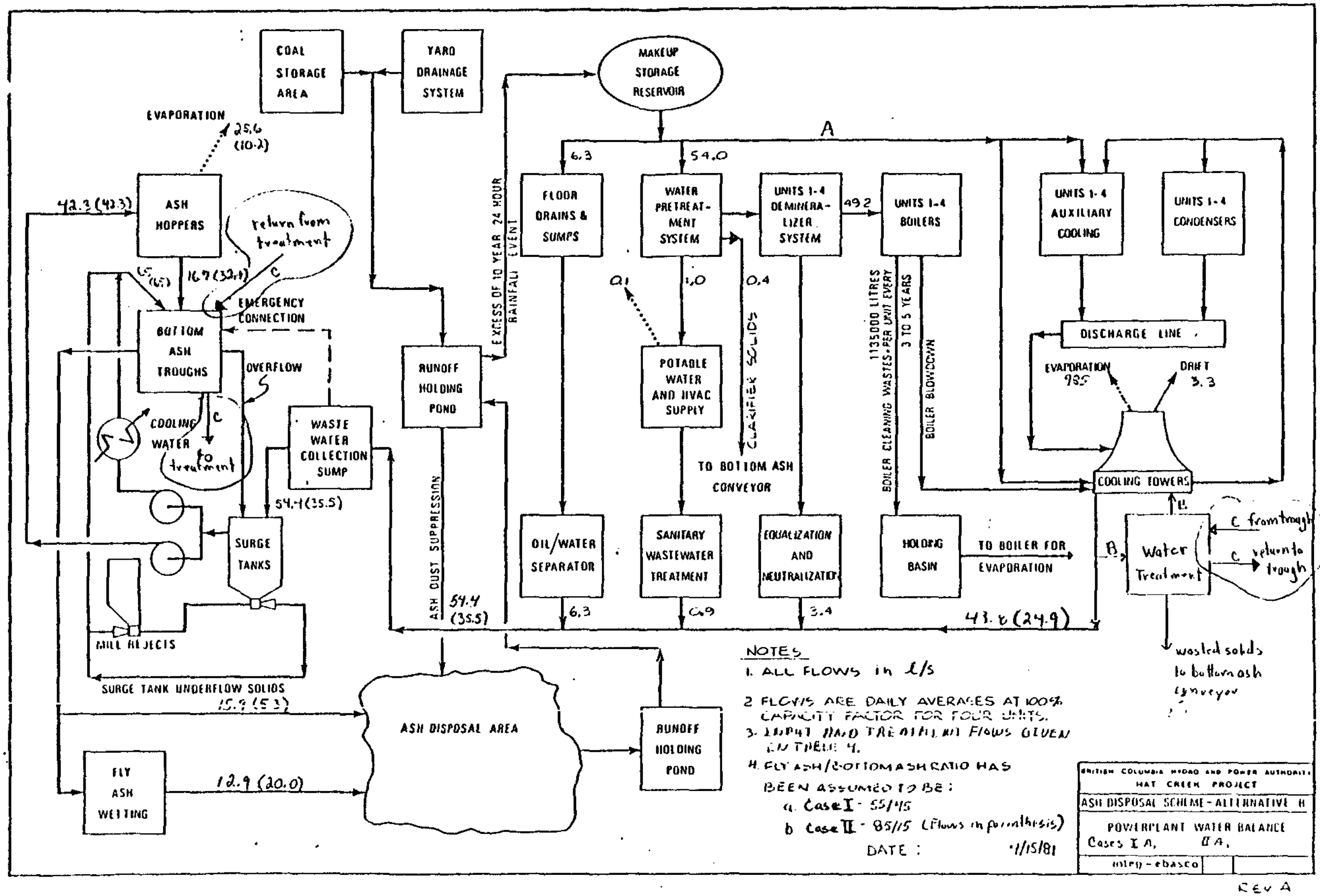


TABLE 4

FLOWS FOR SIDESTREAM TREATMENT CONFIGURATION
GIVEN IN FIGURE 2

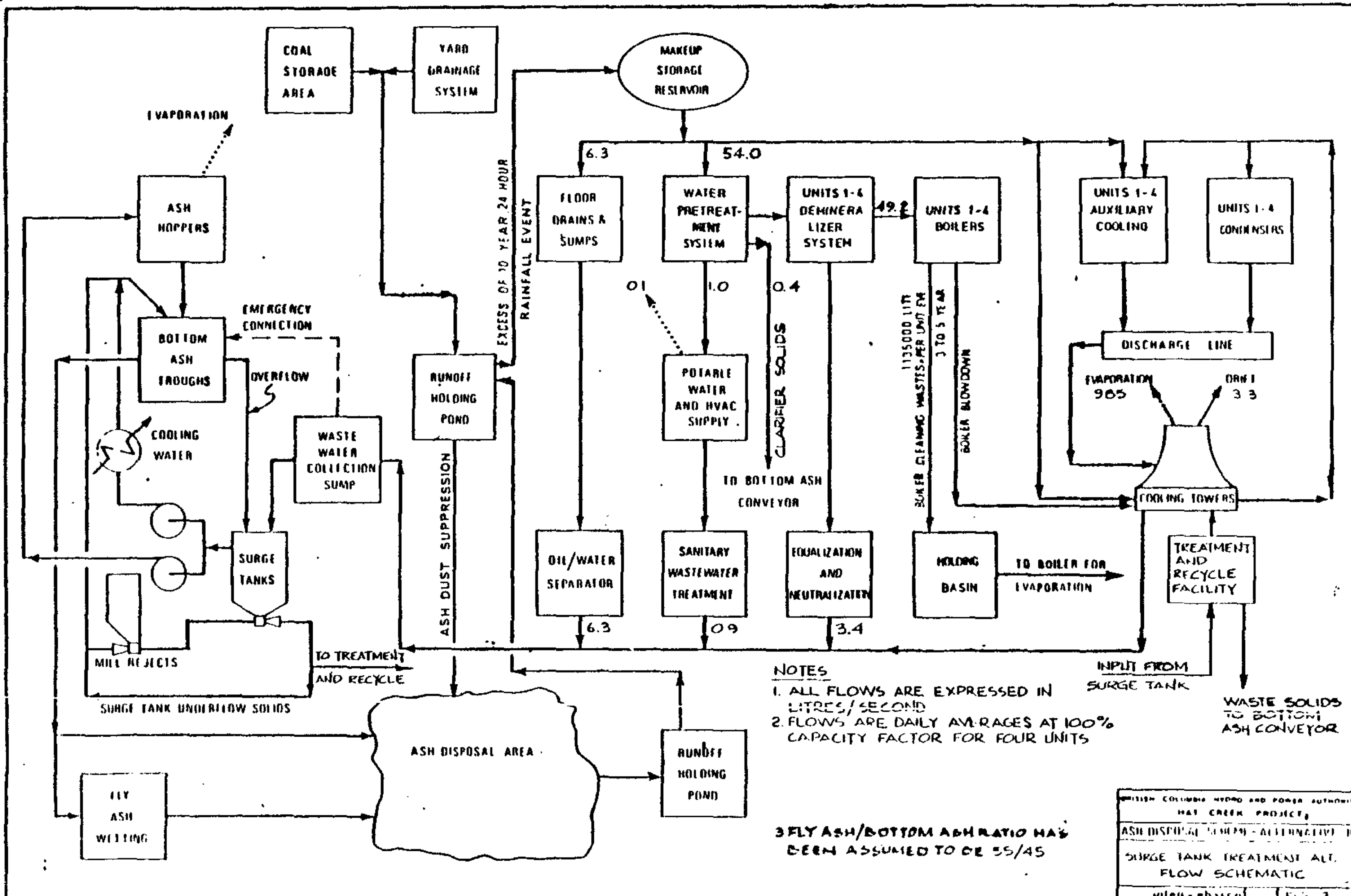
Case	Flow A Input Flow (l/s)	Flow B Treatment Flow (l/s) Cooling Tower	Flow C Treatment Flow (l/s) Trough
1	1032.1	91.5	169.4
2	1013.2	149.1	12.3

TABLE 5

SUMMARY OF RESULTS*

	Case 1	Case 2
Cooling Tower Makeup, l/s	1032	1013
Cooling Tower Cycles of Concentration	21.9	35.9
Cooling Tower Blowdown Calcium Concentration, mg/l Ca	131.0	129.2
Required Treatment Flow, Cooling Tower, l/s	91.5	149.1
Required Treatment Flow, Trough, l/s	169.4	12.3
Calcium Removal Rate, Kg/day	3,242	1,642
Hopper Calcium Concentration, mg/l Ca	<400	<400
Trough Calcium Concentration, mg/l Ca	200	<400
Surge Tank Calcium Concentration, mg/l Ca	157.9	303.5

*Case 1 represents maximum treatment requirements.


COAL STORAGE AREA
YARD DRAINAGE SYSTEM
MAKEUP STORAGE RESERVOIR
EVAPORATION
ASH HOPPERS
BOTTOM ASH TROUGHS
EMERGENCY CONNECTION
OVERFLOW
COOLING WATER
WASTE WATER COLLECTION SUMP
SURGE TANKS
MILL REJECTS
TO TREATMENT AND RECYCLE
SURGE TANK UNDERFLOW SOLIDS
RUNOFF HOLDING POND
EXCESS OF 10 YEAR 24 HOUR RAINFALL EVENT
ASH DUST SUPPRESSION
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FLOOR DRAINS & SUMPS
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COOLING TOWERS
OIL/WATER SEPARATOR
SANITARY WASTEWATER TREATMENT
EQUALIZATION AND NEUTRALIZATION
HOLDING BASIN
TO BOILER FOR EVAPORATION
TREATMENT AND RECYCLE FACILITY
6.3
0.9
3.4
INPUT FROM SURGE TANK
WASTE SOLIDS TO BOTTOM ASH CONVEYOR
ASH DISPOSAL AREA
RUNOFF HOLDING POND
FLY ASH WETTING
NOTES
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ASH DISPOSAL SCHEME - ALTERNATIVE 1C
SURGE TANK TREATMENT ALT. FLOW SCHEMATIC
FIG. 3

given flow constraints and system concentration constraints, system mass and flow equations could not be satisfied simultaneously, indicating that the configuration is not feasible. Therefore, this configuration was eliminated from further consideration.

Additional analyses were conducted on the Scenario A treatment scheme for other critical parameters. It was determined that in order to destroy makeup alkalinity, sulphuric acid (H_2SO_4) must be added to the circulating cooling water system at a rate of approximately 60-65 mg/l (100 percent H_2SO_4) in all cases. Also, acid addition will likely be required in the surge tank/trough recycle loop to maintain pH and avoid excessive carbonate scale formation. Silica concentrations approach borderline scale formation, and may require periodic cleaning of the bottom ash trough recycle heat exchange system.

Finally, the water quality data for Medicine Creek which are used to derive reservoir water quality were investigated, using regression analyses and least-squares techniques. It was found that slightly higher ionic concentrations could be predicted, but that unavoidable discrepancies exist in both sets of predicted values. Therefore, since this method could not provide more reliable results and to preserve consistency, the present reservoir water quality concentrations were maintained.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the analyses, it appears that the power plant under present design concepts and assumptions cannot be operated using the proposed Medicine Creek Reservoir makeup water supply system without the addition of a wastewater treatment/recycle system to control calcium sulphate scaling under zero discharge constraints. A satisfactory treatment configuration was developed, using lime-soda ash addition for calcium removal and analyzed for two different concentration limitations. This treatment configuration involves sidestream treatment around the cooling tower basin and bottom ash trough. Alternate lime/soda ash treatment configurations investigated did not prove to be feasible. Therefore, based on present engineering and water quality data, it is recommended that this configuratior be adopted for incorporation into the power plant design. It is also recommended that the Scenario A scheme, with ash hopper calcium concentrations set at <400 mg/l Ca be followed to prevent scale formation in the surge tank and to protect critical secondary system components, e.g., the heat exchangers and high pressure pumps.

Also, a "backup" heat exchanger should be incorporated into the bottom ash trough recycle system design as this component is probably the most sensitive to scaling problems. If scaling occurs, the heat exchanger can be taken off-line and mechanically cleaned without altering power plant operation.

In addition, the chemical analyses performed indicate a potential for carbonate scale formation in the hoppers, troughs, and other associated equipment if pH is not controlled. Therefore, it is recommended that provision be made for pH control via acid addition in the trough recycle system.

It should be noted that this analysis is based on projected "normal worst case" water quality data, which does not differ greatly in terms of scaling potential from average projected water quality. It should also be realized that all reservoir water quality projections are based on an extremely limited number of data points. Therefore, to assure the integrity of the design, we recommend that a monitoring program be instituted to collect water quality data to verify the synthetically generated reservoir concentration levels and, if necessary, adjust the above analysis.

REFERENCES

1) British Columbia Hydro and Power Authority. Water Management Study for Hat Creek Power Plant, Integ-Ebasco, Vancouver, B.C. Feb. 1978.

2) British Columbia Hydro and Power Authority. Hat Creek Project, Alternative 8 Ash Disposal Study. Integ-Ebasco, Vancouver, B.C. Nov. 1978, with Rev. Dec. 1980.

3) British Columbia Hydro and Power Authority. Hat Creek Project. Section 3, Power Plant Description, Revision F. Integ-Ebasco, Vancouver, B.C. Oct. 1977.