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7. Abstract

This safety evaluation examines the potential release of radioisotopes from spent K Basins water treatment systems components. This evaluation examines the potential releases and their resulting dose consequences in relation to both the current and proposed new Safety Analysis Report (SAR). The results of the evaluation show that all the potential releases are bounded by both versions of the SAR.

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SAFETY EVALUATION - SPENT WATER TREATMENT SYSTEM COMPONENTS INVENTORY RELEASE

1.0 INTRODUCTION

Over the past few years various impediments to shipment of generated spent basin water treatment system components have resulted in the accumulation of quantities of these waste items at 100K. Specifically, there are (as of 01/01/95) 13 grout/culvert packaged cartridge filters (CF), four unpackaged cartridge filters, 60 spent ion exchange columns (IXC) and seven ion exchange modules (IXM) at 100K awaiting shipment for final waste disposal. The locations of these various waste items are indicated on Figure 1. As a result of the accumulation of this waste, the question has arisen regarding the consequences of potential releases of the inventory of radionuclides in these waste items relative to the K Area safety envelope. The purpose of this paper is to address this question.

2.0 INVENTORY

The initial step in evaluating the consequences of potential release of material from the spent water treatment system components was to determine the individual and total radionuclide inventories of concern. Generally the radioisotopes of concern to the dose consequences were Sr/Y-90, Cs-137, and the transuranic (TRU) isotopes. The loading of these radioisotopes needed to be determined for each of the components of the total number of accumulated IXCs, IXMs and CFs.

2.1 IXC AND IXM INVENTORY

In the development of the inventory loadings for the IXCs and IXMs, a mass balance technique was used. This method used data from the inlet and outlet to the ion exchange components as the bases for isotopic inventory calculations. Inlet and outlet water sample data were used with the difference being the amount of material loaded in the IXC or IXM. Figure 2 shows the water paths for these systems with sample points identified.

2.2 CF INVENTORY

In the case of the CFs, the water sample data proved not to be useful. Instead, dose rate data and some limited laboratory analysis data were used to determine isotopic loadings.

The mass balance method was not usable for the CF loading determination due to the type of water sampling involved. The water sampling technique consisted of drawing a continuous (composite) sample throughout the time the cartridge filter was in use. However, it was known that during cartridge filter replacement there generally was a release of some of the material from the filter into the CF housing. This would then be disturbed when the filter was replaced and there would be a high initial "pass through" number (e.g. the calculations would indicate that Pu and Cs were being 'created' by the CFs) that make the water sample data invalid. When this data is used, it would indicate that there could be upward of 800 curies of Cs, for example, which

Location of Spent Water Treatment System Components at 100-K Area

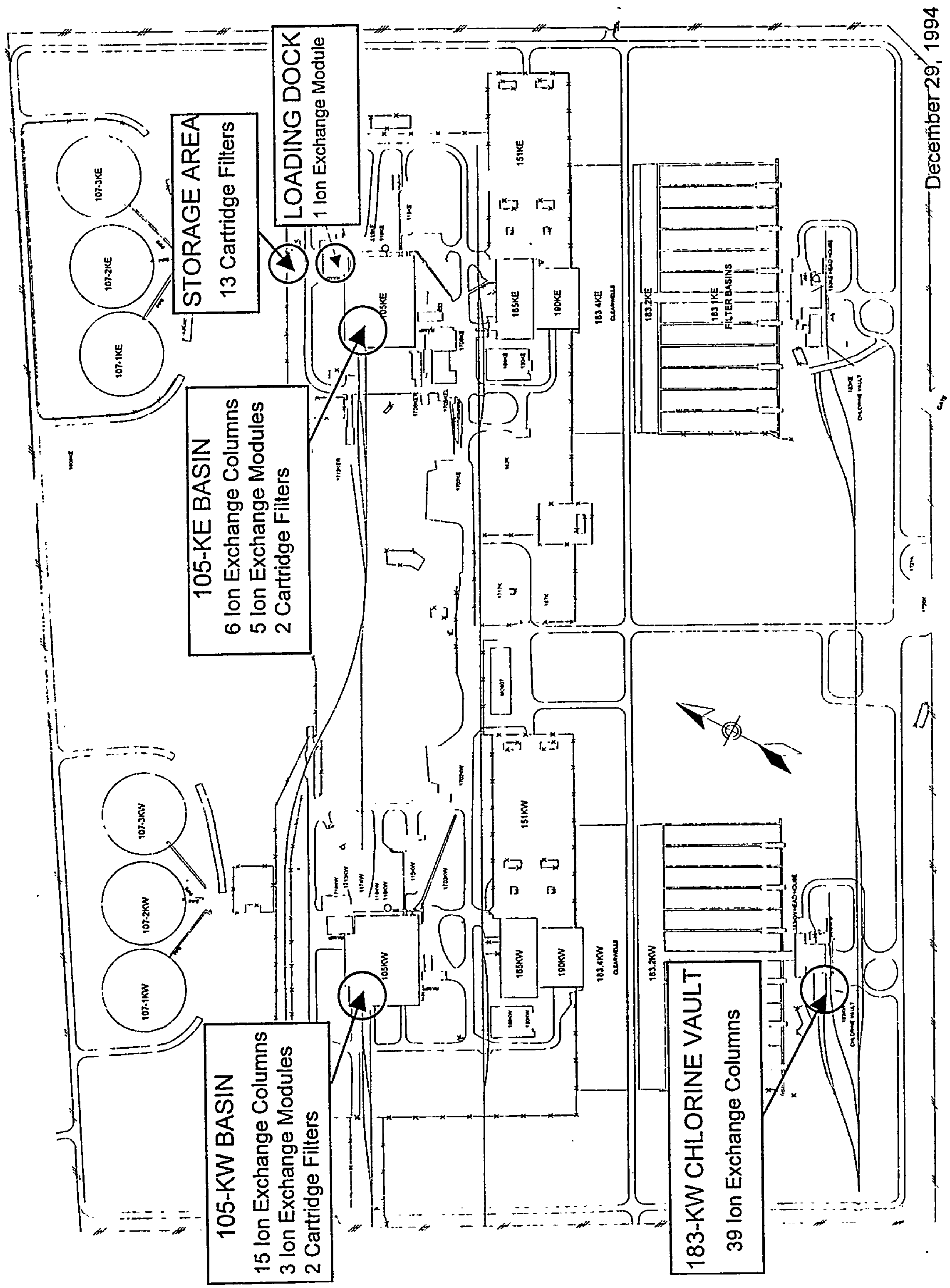

Figure 1

KE Basin Water Treament System

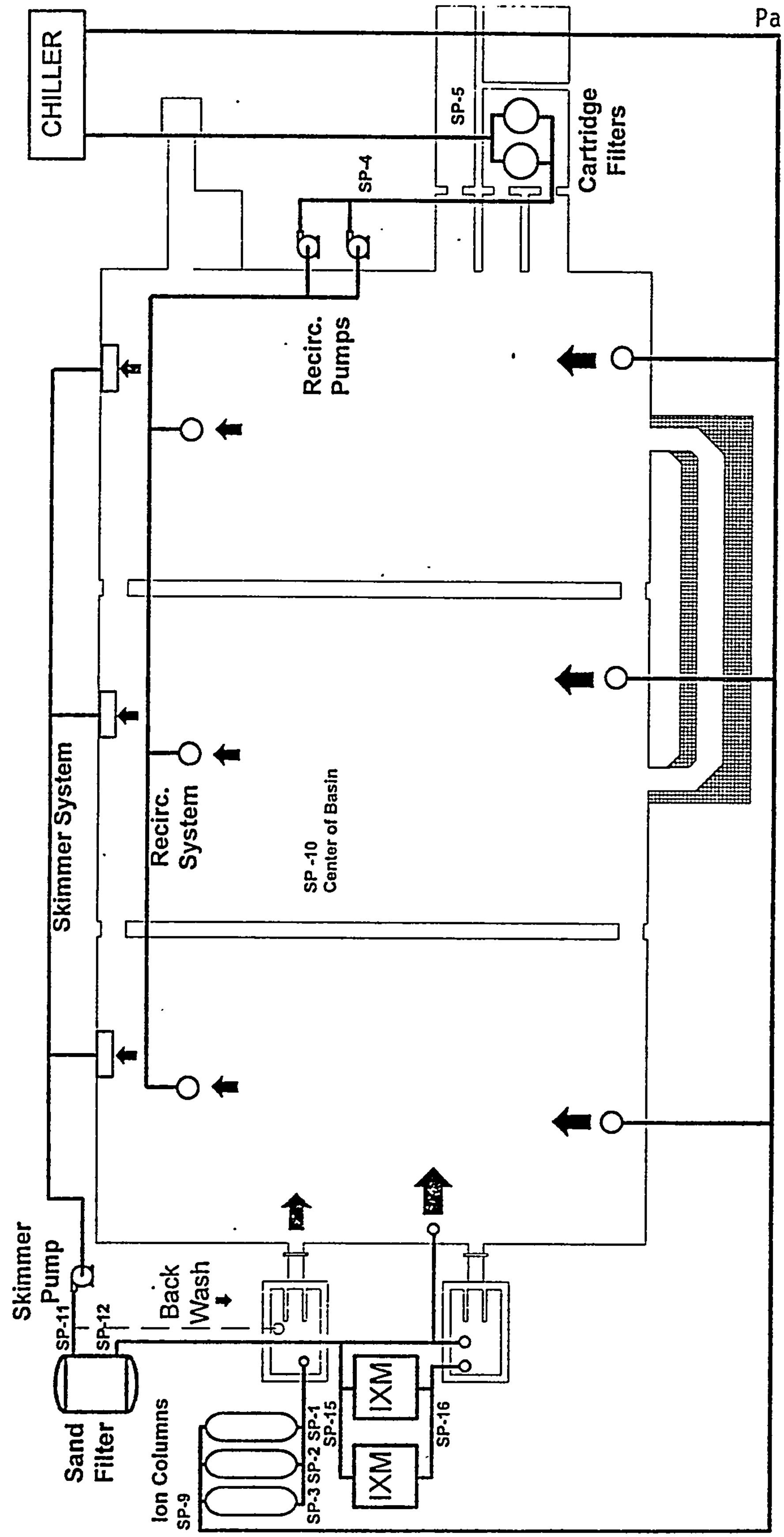

Figure 2

would result in a dose outside the shielding of over 25 R/hr. This level of dose has never been observed and if it were present, the CF could not be stored as they currently are.

Surface dose rates observed on the grouted spent CFs were used to estimate the maximum curie content of gamma emitters (cesium). Two sources were used: recent data from surveys of the grouted CFs behind 105KE and limited data from CFs as they were removed from the basin, prior to shielding. The resulting inventory assigned to the particular CF was the greater of the loadings if both data points were available.

Some limited sample data are also available from both KE and KW CFs. The samples taken were small (0.01-0.03 gms); two samples were an order of magnitude smaller (one from KE and one from KW); these two data points were discounted due to their small size. The remaining 5 data points were used to determine the most likely ratio of TRU to Cs 137 data (see Table 1). The inventory of significant radionuclides represented by the waste described above is as noted in the following table.

Table 1
Cartridge Filter Loading from Sample Analyses

Cartridge Filter	Cs 137 (Ci)	Sr 90 (Ci)	TRU (Ci)	TRU/Cs
CF23(KW)	1.37E-01	3.07E-03	2.42E-02	0.18
CF24(KW)	1.16E+00	8.13E-02	5.94E-01	0.51
CF25(KW)	3.96E-01	7.93E-04	2.85E-02	0.07
CF72(KE)	1.12E+00	1.87E-01	3.33E-01	0.30
CF73(KE)	3.27E+00	3.09E-01	1.06E+00	0.32

Though the samples were considered too small to extrapolate up to the total volume, they do show an average TRU/Cs ratio of 0.28. With a 2-sigma uncertainty band, a conservative ratio of 0.6 TRU/Cs137 was used. This is then compared to the estimates of Cs 137 based on surface dose to calculate expected total curie range. With this approach, the expected maximum range of curies from Cs 137 is 1-10 Ci and the resultant TRU range per CF would be 0.3-6 Ci (lowest ratio to highest ratio). It is noted that for the TRU curie loading to be under the 100 nCi/gm TRU waste classification is about 0.02 Ci/CF. Therefore there is a high probability that all the CFs would be TRU and further refinement of the data is not warranted.

There are also two spent CFs in each of the basins, however, their inventory was discounted for this evaluation. The filters are still in their housings in the basins at a depth of about 16 feet. Even if the CFs and the housings were breached, the resulting release would be into the basin water and would not be available for release to the air as would the other portion of the inventory.

Utilizing all of the above mentioned data for the CFs, estimated loadings for each of the filters was developed. Based on the review of the dose rate calculation and the sample analyses data, a table of resulting radioisotopic inventory for all the CFs stored behind 105KE (Table 2) was developed. The loadings for Sr 90 were assumed to equal the loadings for Cs 137 as a worst case.

Table 2
Cartridge Filter Isotopic Loading

Cartridge Filter	Cs 137 (Ci)	Sr 90 (Ci)	TRU (Ci)	Method Used
CF69(KE)	0.75	0.75	0.45	Dose Rate Calc.
CF70(KE)	2.05	2.05	1.23	Dose Rate Calc.
CF71(KE)	4.25	4.25	2.55	Dose Rate Calc.
CF72(KE)	1.75	1.75	1.05	Dose Rate Calc.
CF73(KE)	3.27	3.27	1.96	Lab Analysis
CF74(KE)	1.75	1.75	1.05	Dose Rate Calc.
CF75(KE)	1.30	1.30	0.78	Dose Rate Calc.
CF76(KE)	4.00	4.00	2.40	Dose Rate Calc.
CF21(KW)	0.08	0.08	0.05	Dose Rate Calc.
CF22(KW)	0.10	0.10	0.06	Dose Rate Calc.
CF23(KW)	0.14	0.14	0.08	Lab Analysis
CF24(KW)	1.16	1.16	0.70	Lab Analysis
CF25(KW)	0.40	0.40	0.24	Lab Analysis
TOTALS	21.00	21.00	12.60	

2.3 TOTAL INVENTORY

Using the above data, the total K Area inventory was developed. The following table presents the summary results for each location.

Table 3

Items/Locations	Cs 137 (Ci)	Sr 90 (Ci)	TRU (Ci)
IXCs/183 KW	1324.5	968.9	5.77
IXCs/105 KE	143.3	45.1	4.00
IXCs/105 KW	78.3	3.4	0.01
IXMs/105 KE	630.0	290.0	4.47
IXMs/105 KW	12.9	0.8	0.01
CFs/KE Storage	21.0	21.0	12.60
TOTALS	2210.0	1329.2	26.86

The data in this table was generated from the best available information or the best estimates of radionuclide inventory.

3.0 POTENTIAL RELEASES

This evaluation examines four potential releases of material from the spent water treatment system components. These releases are:

The release of material from all 39 IXCs stored in 183-KW.

The release of material from the IXCs, IXMs and CFs at 105-KE and 105-KW.

The release of material from the 13 CFs stored behind 105-KE.

The non-mechanistic release of the total stored waste inventory.

3.1 183-KW INVENTORY

The inventory of spent water treatment system components in the 183-KW chlorine vault consists of 39 spent IXCs. The mechanism of release assumed for this evaluation was a collapse of the building from a seismic event. In this case it was further assumed that the concrete burial boxes were also breached and the total inventory of spent IXCs split open. Review of Mishima (1993) resulted in determination of a release fraction of 4.0E-05 for aerodynamic entrainment (resuspension) of material.

3.2 105-KE AND 105-KW INVENTORIES

At 105-KE, there are a total of six IXCs and a total of five IXMs (four in 105-KE and one outside the facility). No mechanism for release of the material inside the facility could be determined except for an IXC or IXM drop. The 105-KE facility has been evaluated as a 3 over 1 structure and will withstand a Design Basis Earthquake (DBE) seismic events without collapse. In the case of the IXM stored on the pad behind the 105-KE building, the mechanism of release assumed was a drop. Again, review of Mishima (1993) resulted in determination of a release fraction of 4.0E-05 as appropriate for depressuration of free volumes above liquid surfaces.

At 105-KW, there are a total of 15 IXCs and two spent IXMs. As in the case of 105-KE, this facility has been evaluated as a 3 over 1 structure and results showed that it will withstand seismic events without collapse or significant structural damage. No specific mechanism of release could be determined except for drop of the IXCs or IXMs during handling. Although this event would occur within the facility, for conservatism the assumed release fraction is again 4.0E-05.

In both 105-KE and 105-KW there are two CFs that are stored under water in their filter housings. In their stored configuration, no release to the air is possible since any release would be into the water of the basins. However, when these CFs are removed from their housings in preparation for waste disposal, drop of a filter is a potential mechanism for release of material. Review of Mishima (1993) again results in determination of a release fraction of 4.0E-05 for free-fall spills of slurries with a fall distance of 3 meters or less.

3.3 CF INVENTORY

In the area behind the 105-KE building, 13 spent CFs are stored that have been grouted and are contained in culverts. Eight of these filters came from KE basin and the other five were used in KW. Although no specific mechanism of release could be determined other than possibly drop of a CF during handling, a non-mechanistic release of the total CF inventory was assumed. As was the case of the release of the total K Area inventory, a release fraction of 4.0E-05 was selected as appropriate.

3.4 TOTAL INVENTORY

For the purposes of this evaluation, it was assumed that the entire inventory within the K Area is available for release. The mechanism of release is not defined. With the nature of the material and the various components in which it is contained, Mishsima (1993) was reviewed to determine an appropriate release fraction. The review resulted in the determination that 4.0E-05 is appropriate for use in calculating the actual inventory released and available for respiration by the target recipient.

4.0 DOSE CALCULATIONS

For the calculation of dose to the maximum onsite and off-site individual the following relations were used:

$$\text{Dose} = \text{RF} * \text{Inventory} * \chi/Q * \text{BR} * \text{DCF}$$

where: RF = release fraction
χ/Q = atmospheric dispersion (sec/m^3)
BR = breathing rate = 3.33E-04 m^3/sec
DCF = Dose conversion factor (rem/Ci)

This equation must be solved for each of the significant isotopes of concern and then the total dose calculated by summing all of the isotopic doses.

The values for χ/Q used were obtained from Marusich (1994), and are:

Onsite - Fire Station (4000 m) - 1.47E-04 sec/m^3
Offsite- Site Boundary (12040 m)- 3.60E-05 sec/m^3

The Dose Conversion Factors used were based on those from Marusich 1994 in Sv/Bq. Using them and the conversion of Sv/Bq (3.7E+12) = rem/Ci, the rem/Ci Dose Conversion Factors are:

	Dose Conversion Factors (rem/Ci Inhaled)		
Isotope	EDE	Organ	
Sr 90	2.41E05 rem/Ci	2.70E06 rem/Ci	bone surface
Y 90	7.77E03 rem/Ci	3.29E04 rem/Ci	lung
Cs 137	3.18E04 rem/Ci	3.33E04 rem/Ci	"other"
TRU	4.44E08 rem/Ci	7.77E09 rem/Ci	bone surface

Using the χ/Q values for both onsite and offsite, a unit doses at these locations can be determined by the relation:

$$\text{Unit Dose} = \chi/Q * \text{BR} * \text{DCF}$$

This Unit dose represents the dose to an individual at the respective locations per Ci released . Performing this calculation results in the following:

Unit Doses
(rem/Ci Released)

Isotope	Onsite (rem/Ci) EDE	Onsite (rem/Ci) Organ	Offsite (rem/Ci) EDE	Offsite (rem/Ci) Organ
Sr 90	1.18E-02	1.32E-01	2.89E-03	3.24E-02
Y 90	3.80E-04	1.61E-03	9.31E-05	3.94E-04
Cs 137	1.56E-03	1.63E-03	3.81E-04	3.99E-04
TRU	2.17E01	3.80E02	5.32E00	9.31E01

Using the values from this Unit Dose table and the previously described Release Fractions, the doses at the onsite and offsite receptor location can be determined.

$$Dose_i = Unit\ Dose_i * RF * Inventory_i$$

where the subscript "i" refers to each significant isotope in the cartridge filter loading.

The total dose is then the sum of the individual isotopic doses. Applying this to the above determined values results in the following.

4.1 183-KW INVENTORY RELEASE DOSE

The dose calculation for the release of material from the 183-KW stored inventory is as follows.

EDE - Onsite (4000 m)

Sr 90 - 1.18E-02 rem/Ci (4.0E-05) 969 Ci = 4.58E-04 rem

Y 90 - 3.80E-04 rem/Ci (4.0E-05) 969 Ci = 1.47E-05 rem

Cs 137- 1.56E-03 rem/Ci (4.0E-05) 1325 Ci = 8.27E-05 rem

TRU - 2.17E01 rem/Ci (4.0E-05) 5.8 Ci = 5.02E-03 rem

TOTAL DOSE = 5.58E-03 rem

Similar calculations for the onsite organ dose and the Offsite EDE and organ doses provide the following results for dose consequences.

	EDE	Organ
Onsite	5.58E-03 rem	9.34E-02 rem
Offsite	1.37E-03 rem	2.29E-02 rem

4.2 105-KE AND 105-KW INVENTORY RELEASE DOSES

In the cases of release of the inventories from 105-KE and 105-KW, three separate calculations of dose consequences were performed. They were as follows:

105-KE Release Dose

For the release of material from 105-KE, the event examined was the drop of the IXM located on the pad behind the facility. It was assumed that the drop resulted in cracking of the concrete block and breaching of the internal columns. As a worst case, the entire inventory of the IXM was assumed to be available for release. In this case, the inventory of isotopes used in the calculation of dose consisted of:

Sr/Y 90 - 73.3 Ci

Cs 137 - 137.0 Ci

TRU - 1.28 Ci

This inventory is that determined by mass balance calculation for the IXM stored on the pad outside 105-KE.

The calculations for dose consequences for release of this inventory were the same as that for the total inventory release in Section 4.1 above. These calculations resulted in the following:

	EDE	Organ
Onsite	1.15E-03 rem	1.99E-02 rem
Offsite	2.84E-04 rem	4.86E-03 rem

105-KW Release Dose

The event examined for release of material from 105-KW was the drop of the IXC shipping cask, loss of the lid and breaching of the six IXCs in the cask. The examination assumed the entire inventory of the six IXCs was available for release. In this case, the inventory of concern was:

Sr/Y 90 - 2.0 Ci

Cs 137 - 35.0 Ci

TRU - 7.3E-03 Ci

Calculation of the dose consequences from release of this material was performed in the same manner as the calculations in Section 4.1 above. Results of these calculations were:

	EDE	Organ
Onsite	9.23E-06 rem	1.20E-04 rem
Offsite	2.26E-06 rem	2.92E-05 rem

Unshielded CF Release Dose

In the case of release of material from the CFs located in the basins, the event examined was the drop of one of the KE filters with no containment. Also, no credit was taken for the event occurring within the facility. All of the CF inventory was assumed to be available for release to both on and off site receptor locations. The inventory used for this examination was based on the loadings of the eight grouted CFs stored behind 105-KE that were used in the KE Basin. The loading used was the average loading of the CFs plus a two sigma error band. The resulting inventory assumed to be on the dropped CF was:

Sr/Y 90 - 5.0 Ci

Cs 137 - 5.0 Ci

TRU - 3.0 Ci

The dose consequences for this event were calculated in the same manner as those above. Results of these calculations were:

	EDE	Organ
Onsite	2.60E-03 rem	4.56E-02 rem
Offsite	6.41E-04 rem	1.12E-02 rem

4.3 GROUTED CF INVENTORY RELEASE DOSE

As noted in Section 3.4, the event examined for this release was the non-mechanistic release of the entire inventory of the 13 stored grouted CFs. In this case, the inventory available for release was:

Sr/Y 90 - 21.0 Ci

Cs 137 - 21.0 Ci

TRU - 12.6 Ci

Calculations for the dose consequences were performed in the same manner as for the previous releases. The results of the dose consequence calculations were:

	EDE	Organ
Onsite	1.09E-02 rem	1.92E-01 rem
Offsite	2.69E-03 rem	4.69E-02 rem

4.4 NON-MECHANISTIC TOTAL INVENTORY RELEASE DOSE

The dose calculation for the non-mechanistic release of the total inventory of radionuclides in the spent water treatment system components were performed in the same manner as those above. The inventory of concern was:

Sr/Y 90 - 1330 Ci

Cs 137 - 2210 Ci

TRU - 26.9 Ci

Results of the calculations provided the following dose consequences:

	EDE	Organ
Onsite	2.41E-02 rem	4.16E-01 rem
Offsite	5.93E-03 rem	1.02E-02 rem

5.0 COMPARISONS WITH SAFETY ENVELOPE

The current approved safety analyses for K Basins (WHC 1994a) have the dose consequences for the maximum credible accident as:

Onsite - EDE - 2.5E-01 rem
Organ - 4.7E+00 rem

Offsite - EDE - 2.9E-01 rem
Organ - 5.4E+00 rem

Similarly the new SAR recently submitted to DOE-RL (WHC 1994b) shows the following dose consequences for the maximum credible accident:

Onsite - EDE - 4.3E-02 rem

Offsite- EDE - 1.5E-02 rem

An overall comparison of the calculated doses from the various events examined and these SAR dose consequences is shown in Table 4.

Table 4

DOSE CONSEQUENCES				
Event	On-Site Doses (REM)		Off-Site Doses (REM)	
	EDE	Organ	EDE	Organ
SAR Maximum Credible Accident	**2.5E - 01**	**4.7E - 01**	**2.9E - 01**	**5.4E + 00**
New SAR Maximum Credible Accident	**4.3E - 02**	----	**1.5E - 02**	----
Non-Mechanistic Total Inventory Release	2.4E - 02	4.2E - 01	5.9E - 03	1.0E - 01
183 KW Inventory Release	5.6E - 03	9.3E - 02	1.4E - 03	2.3E - 02
105 KE Release	1.2E - 03	2.0E - 02	2.8E - 04	4.9E - 03
105 KW Release	9.2E - 06	1.2E - 04	2.3E - 06	2.9E - 05
Unshielded CF Release	2.6E - 03	4.6E - 02	6.4E - 04	1.1E - 02
Grouted CF Inventory Release	1.1E - 02	1.9E - 01	2.7E - 03	4.7E - 02

As can be seen by review of Table 4, the dose consequences of all of the examined releases from the spent water treatment system components do not result in consequences as great as those of the maximum credible accident in either the current SAR or the new SAR.

Specifically, the Onsite EDE dose for the non-mechanistic release of 2.41E-02 rem is 2.26E-01 rem less than the current SAR maximum credible accident dose. The comparison of the non-mechanistic release dose consequences to the new SAR maximum credible accident consequences shows the new SAR doses still exceed those of the non-mechanistic release. In the case of the Onsite EDE dose, which is the governing dose, the difference is 1.9E-02 rem.

The examined release dose consequences are all bounded by both the current safety envelope and the new SAR maximum credible accident consequences. As a result, the storage of the spent water treatment system components in the K Area does not constitute an USQ. In fact, if we assume (based on review of available IXM loading data) an expected worst case IXM loading of:

Cs 137 - 250 Ci
Sr 90 - 105 Ci
TRU - 1 Ci

calculation of the dose consequences of release of these quantities of material results in an Onsite EDE dose of 9.35E-04 rem for the IXM release. Comparison of this dose with the margins between the non-mechanistic release and the safety envelope dose consequences shows that

$$\frac{2.3E-01}{9.35E-04} = 245.9 \quad \text{and} \quad \frac{1.9E-02}{9.35E-04} = 20.3$$

or, that 245 more IXMs can be accumulated at K Area before the current safety envelope is reached and similarly, 20 additional IXMs can be accumulated before the new SAR maximum credible accident dose consequences are reached.

As was noted earlier, the release of the total K Area inventory cannot be envisioned as the result of a single event. A more realistic evaluation results in the conclusion that a single event will more likely result in the release of material from a single location within the K Area. Table 4 shows that the event that is second in dose consequences to the non-mechanistic total inventory release is the release of the 183-KW inventory. This event, as hypothesized, results from a seismic event and collapse of the 183-KW vault. Assuming such an event occurs, the resulting Onsite EDE dose consequences are 2.44E-01 rem less than the current SAR and 3.74E-02 rem less than the new SAR maximum credible accident consequences. Comparison of these dose consequences to the hypothetical IXM release consequences results in

$$\frac{2.44E-01}{9.35E-04} = 261.0 \quad \text{and} \quad \frac{3.74E-02}{9.35E-04} = 40.0$$

or a maximum of 40 more IXMs can be accumulated at the worst case IXM inventory location before the new SAR maximum credible accident consequences are reached.

Therefore, based on the worst case IXM inventory, a maximum of 261 (40 for the new SAR) additional spent components (IXC, IXM, CF) may be stored at any identified storage site and still be within the authorized safety envelope. This assumes that the current inventory remains constant. Any changes in the current inventory will change the margin to the authorized safety envelope.

The allowable number of additional spent components is fixed at the above numbers even when components currently in storage are removed since the current inventory does not assume worst case IXM loading. Storage of new spent components beyond the calculated additional 261 (40 for the new SAR) components will require a new baseline calculation based on actual storage inventory at that time.

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