Indian Point Energy Center

Water Mass Balance and Dose Assessment from Groundwater and Storm Water

An Assessment of 2005 Effluent Impact

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IPEC Water Mass Balance and Dose Assessment from Groundwater and Storm Water

Purpose and Scope:
The purpose of this assessment is to provide a bounding estimate of the amount of radioactivity being transported to the Hudson River via previously undocumented groundwater and storm water pathways. There are other monitored pathways, such as the North Curtain Drain and the Sphere Foundation Drain Sump of Unit 1 that are sampled and directed to the Discharge Canal. These Unit 1 releases have been discharged as described in the Offsite Dose Calculation Manual and they are included in the Regulatory Guide 1.21 Effluents Report. As such, the Unit 1 releases are not included in this IPEC Water Mass Balance Assessment.

The water mass balance methodology is used as a conservative interim measure until sufficient data becomes available from the existing and planned monitoring wells. This current water mass balance methodology is not the complete site conceptual model that describes the groundwater flows. The site conceptual model is under development, and it will be completed after sufficient groundwater elevation and flow data are obtained.

Methodology Description:
The basic methodology for this dose assessment is based on an overall mass balance driven by precipitation. The hydrology portion of this assessment was performed by IPEC's consultant, Matthew Barvenik, of GZA GeoEnvironmental, Inc. IPEC concurs with this methodology. This "watershed analysis" partitions the precipitation falling on the watershed catchment area (i.e., that portion of the Facility area where the surface topography is sloped towards the river) into water that infiltrates the ground to become groundwater (GW), water that flows off the surface as storm water (SW) and that water which directly moves back into the atmosphere via evapotranspiration and other processes. See Figure 1, "IPEC Groundwater and Storm Drain Conceptual Drawing". This method of analysis is based on well established hydrologic principles. Our selection of parameters is heavily biased towards larger flows and higher concentrations of H^3 and Sr^{90}. As such, we believe that this analysis is significantly conservative, resulting in estimates of activity moving to the river (both directly and via the Discharge Canal) that will most likely prove to be substantially higher than the activities we will determine later, as additional data becomes available.

Over the entire watershed catchment area of 3.2 million ft^2, the GW and SW has been segmented relative to the areas of the Facility through which it flows (primarily established based on H^3 concentrations in the various Facility areas). See Figure 2, "Indian Point Site Overview" depicting groundwater areas and storm water zones.

Overall, the partitioning was established as follows for infiltration areas contributing to GW flow (does not include paved or building areas):

GROUNDWATER AREAS:

- **AREA 1.** The northwestern most area where GW appears to move directly to the river, but passes to the north of the Unit 2 Turbine Building Road (area of 0.25 million ft^2). This GW is unlikely to contain appreciable H^3 concentrations based on the data available to date and the lack of likely H^3 sources;
- **AREA 2.** The area where the GW appears to move through Unit 2 facilities (area of 0.57 million ft^2);
- **AREA 3.** The area where the GW appears to move through Unit 1/3 facilities (area of 1.7 million ft^2);
- **AREA 4.** The southwestern most area where GW appears to move directly to the river, but passes to the south of the Unit 3 Turbine Building Road (area of 0.67 million ft^2). This GW is unlikely to contain appreciable H^3 concentrations based on the data available to date and the lack of likely H^3 sources.

SW flow from paved areas and building roof areas has also been partitioned into various zones within the above Facility GW areas as follows:

STORM WATER AREAS:

- **ZONE A.** The eastern most parking lots which likely drain along flow paths where the SW is unlikely to contain H^3, and storm drain exfiltration into the GW flow zone is also unlikely to pick up H^3 (area of 0.35 million ft^2);
- **ZONE B.** Within the Unit 2 Facility, the eastern and western zones where SW appears to discharge to the river, but does not pass through the Unit 2 Transformer Yard (area of 0.21 million ft^2);
- **ZONE C.** Within the Unit 2 Facility, the middle zone where SW flows to the Discharge Canal, and does pass through the Unit 2 Transformer Yard (area of 0.15 million ft^2);
- **ZONE D.** Within the Unit 1 Facility where SW flows to the Discharge Canal (area of 0.13 million ft^2); and
- **ZONE E.** Within the Unit 3 Facility where SW flows to the Discharge Canal (area of 0.75 million ft^2).

A portion of the SW has been assumed to leak out of storm drains and thus increases the GW flow to the river as follows:

- **ZONE A.** Storm drain exfiltration =0% - set to 0% because exfiltration from pipes in this zone are unlikely to contribute flow to GW which contains H^3 and the SW itself is unlikely to contain H^3;
- **ZONE B.** Storm drain exfiltration =0% - set to 0% because exfiltration from pipes in this zone are unlikely to contribute flow to GW which contains H^3 and the SW itself is unlikely to contain H^3;
- **ZONE C.** Storm drain exfiltration =25% - set to a relatively high value to result in higher than anticipated GW flow through the Unit 2 Transformer Yard which contains the highest H^3 GW values, so as to be conservative;
- **ZONE D.** Storm drain exfiltration =50%; set very high given current knowledge of these drains; and
- **ZONE E.** Storm drain exfiltration =10%; set to a nominal value given current lack of specific data and limited impact on overall H^3 flux due to low H^3 concentrations.

H^3 concentrations have been established for all Areas and Zones using 2005 data. Very conservative Nickel-63 and Strontium-90 have been included for groundwater flow from an early sample result in Area 2.

- **GW flow AREA 1.** $[H^3]$ = 0 pCi/L given lack of likely H^3 source areas and flow path which appears not to flow through areas exhibiting H^3 concentrations in the GW ;
- **GW flow AREA 2.** $[H^3]$ = 200,000 pCi/L which represents an upper bound average of the concentrations found in the Unit 2 Transformer Yard. It is expected that the pending Phase I and II data will prove this assumed value for H^3 in the GW moving to the river through the Unit 2 area to be significantly higher than actual values. Very conservative Ni^{63} and Sr^{90} source terms were added (100 and 50 pCi/L, respectively) from a single early sample from a Monitoring Well in March, 2006.
- **GW flow AREA 3.** $[H^3]$ = 620 pCi/L which represents an upper average of the concentrations found in the Unit 1 and 3 Facility areas;
- **GW flow AREA 4.** $[H^3]$ = 0 pCi/L given lack of likely H^3 source areas and flow path which appears not to flow through areas exhibiting H^3 concentrations in the GW;

- **SW flow ZONE A.** $[H^3]$ = 0 pCi/L given that exfiltration from pipes in this zone are unlikely to contribute flow to GW which contains H^3 and the SW itself is unlikely to contain H^3;
- **SW flow ZONE B.** $[H^3]$ = 651 pCi/L given measured storm drain concentrations;
- **SW flow ZONE C.** $[H^3]$ = 2,900 pCi/L given measured storm drain concentrations;
- **SW flow ZONE D.** $[H^3]$ = 1,560 pCi/L given measured storm drain concentrations; and
- **SW flow ZONE E.** $[H^3]$ = 1,560 pCi/L given measured storm drain concentrations.

The infiltration rate in non-paved/building areas was established at 0.46 feet/year based on the USGS report: Water Use, Groundwater Recharge and Availability, and Quality in the Greenwich Area, Fairfield County, CT and Westchester County, NY, 2000 - 2002. The precipitation rate for the area was set at 3.74 feet/year based on onsite meteorological data.

Based on the above analysis, it is estimated that approximately 1.36 Ci/year of H^3 migrates directly to the river via the GW flow path. It is also estimated that less than 0.02 Ci/year flows directly to the river via SW. It is further estimated that approximately 0.16 Ci/year flows to the river with SW via the Discharge Canal.

It is noted that the H^3 concentrations adopted herein are expected to represent values which are significantly greater than those which actually exist given the conservatism exercised during parameter selection. An example of the conservatism employed in these assessments includes:

- H^3 concentrations selected for the various GW and SW flows are likely to be higher values than actually exist. It is believed that these values will be proven to be significantly too high with the acquisition of additional Phase I and II data. This is particularly true for the 200,000 pCi/L adopted for the Unit 2 Transformer Area;
- The areas contributing GW flow through various IPEC Facilities was biased toward placing more flow through the Unit 2 Transformer Yard where the highest H^3 concentrations were used;
- All GW flow has been assumed to discharge directly to the river. Some of this GW flow must infiltrate the Discharge Canal thus reducing the apportionment to the river;
- All storm drain pipe leakage has been assumed to be exfiltration which will increase GW flow values. However, current data in the Unit 2 Transformer Yard indicates that significant GW infiltrates the storm drain during rainfall events, thus flowing to the Discharge Canal via SW rather than directly to the river as GW. In addition, it is noted that SW H^3 concentrations were typically obtained during non-storm events and thus represent the high end of H^3 values associated with low flow conditions. However, these high H^3 concentrations, were then applied to the much higher storm flows where much lower H^3 values should exist;
- All precipitation falling on paved/building areas was assumed to result in SW flow. Some of this water actually evaporates directly to atmosphere from pavement and buildings; and
- The very large value of GW flow extracted from the GW system via the Unit 1 curtain and footing drains has not been subtracted from the GW flows adopted in the analysis.
- The application of Ni^{63} and Sr^{90} at values determined from one early sample at a Monitoring Well between the Discharge Canal and the Hudson River in early March, 2006.

Results:

The results of the assessment are shown in Table 1. The annual dose from the groundwater and storm water (with the very conservative inclusion of Sr and Ni) remains well below the applicable limits (approximately 0.1%) but are, in fact, significant with respect to our routine levels (due to aggressive waste processing efforts). These results are considered to be quite conservative due to assuming Sr^{90} and Ni^{63} concentrations from a single location as being representative of the bulk fluid in Area 2 for the entire year. These source terms will be re-evaluated after additional Monitoring Well data is assessed.

There are six tables attached, including one summary table, three tables of doses from storm water pathways and two tables of doses from groundwater pathways. The groundwater dose table for the area of Unit 2 transformer yard conservatively includes 100 pCi/L of Ni^{63} and 50 pCi/L of Sr^{90}. For comparison, the summary table shows the tritium dose alone and the total doses (including tritium, nickel, and strontium). In addition, these doses are compared to the annual limit and 2005 routine effluents. Figure 3 shows precipitation data for the site.

Figure 1

IPEC Ground Water and Storm Drain Conceptual Drawing

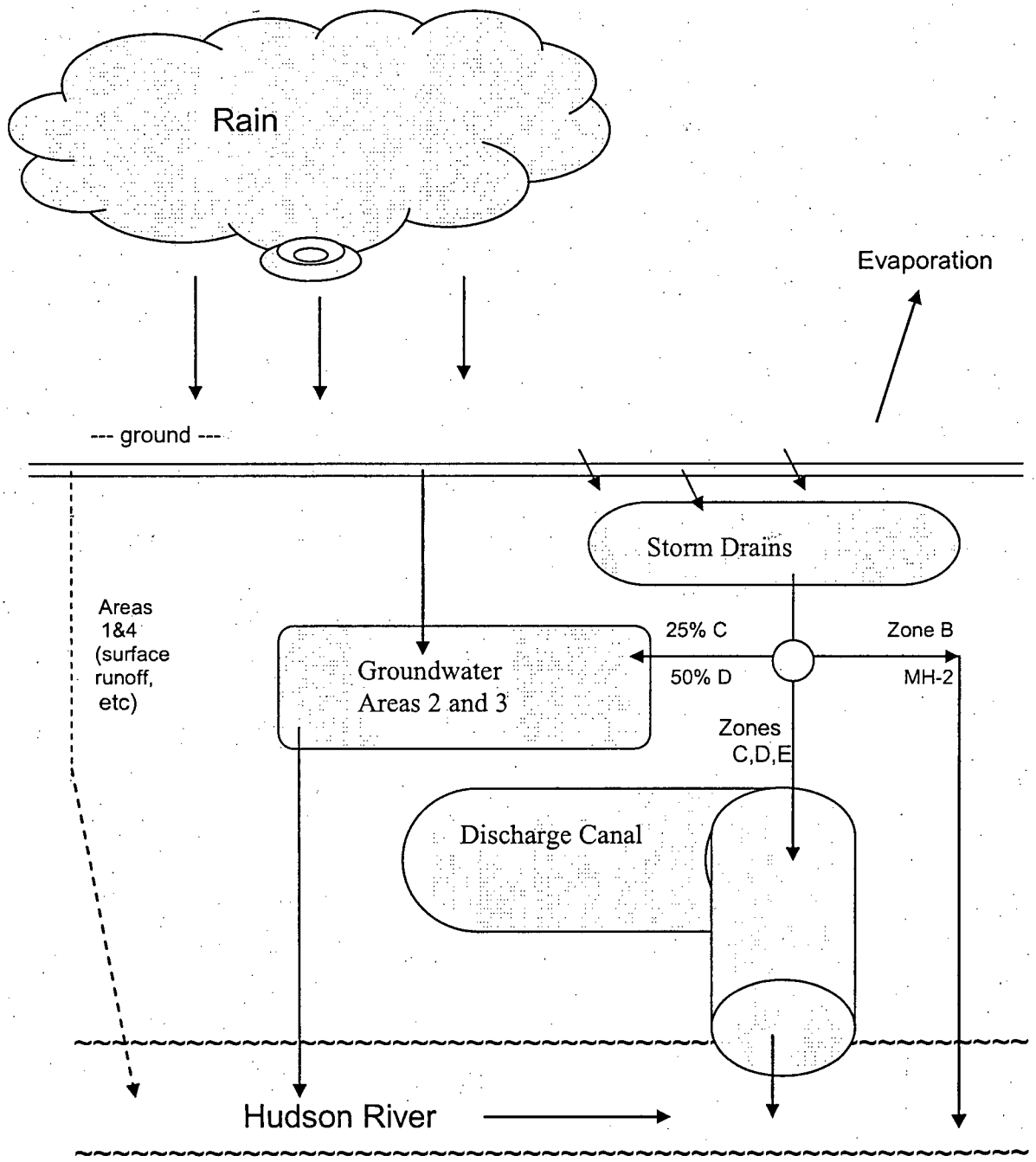


Figure 2.. Indian Point Site Overview

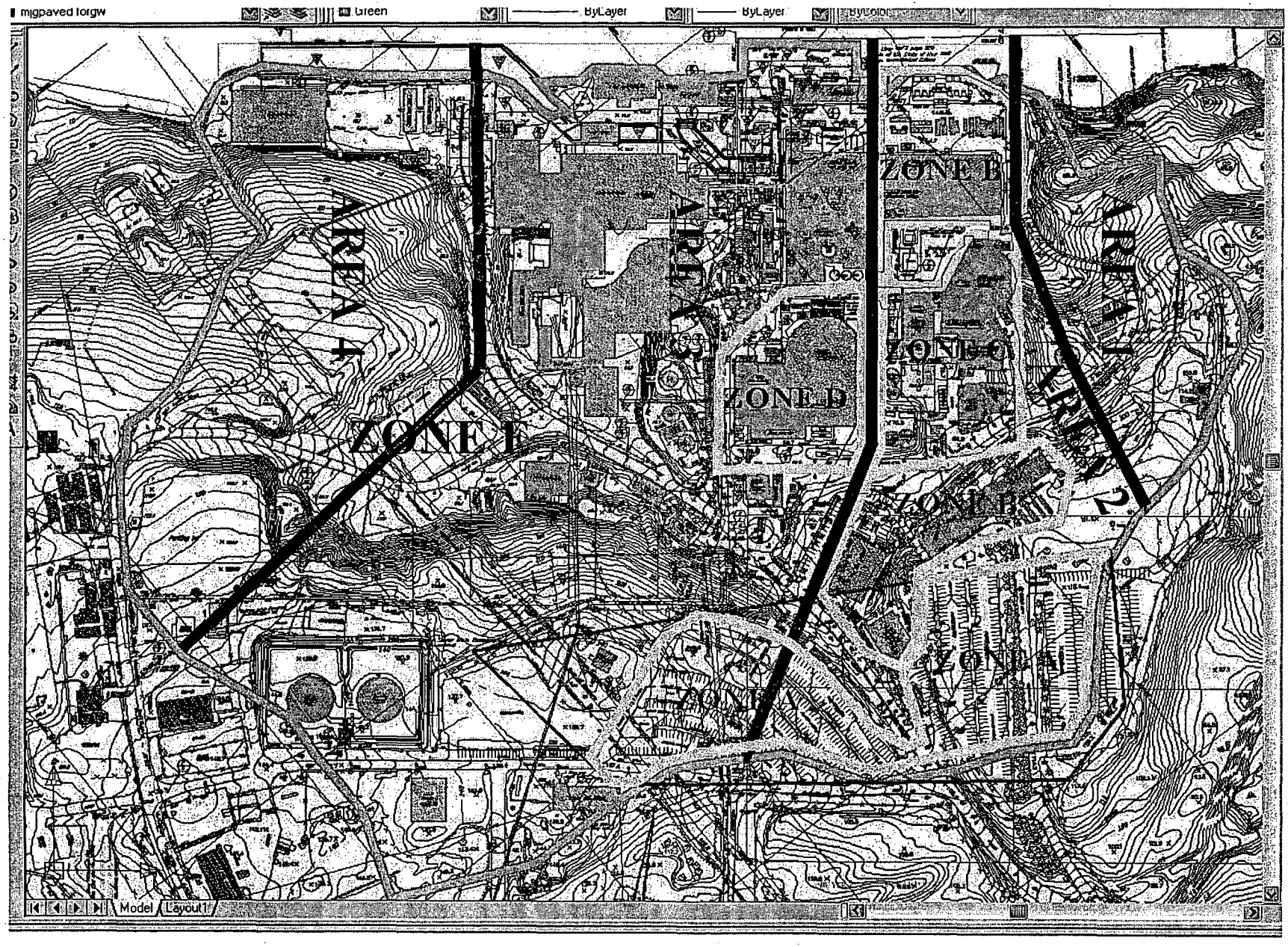


Table 1

Total IPEC Summary for Ground Water releases in 2005 (H-3, Ni-63, Sr-90)

Sum of two monitoring well calculations, IP2 and IP3, Areas 2 and 3

Doses, in mrem

ISOTOPE	BONE	LIVER	TOT BODY	THYROID	KIDNEY	LUNG	GI-LLI	uCi
H-3	0.00E+00	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.52E-05	1.36E+06
Ni-63	1.32E-03	9.17E-05	4.44E-05	0.00E+00	0.00E+00	0.00E+00	1.91E-05	6.70E+02
Sr-90	8.40E-03	0.00E+00	2.06E-03	0.00E+00	0.00E+00	0.00E+00	2.42E-04	3.35E+02
totals	9.72E-03	1.07E-04	2.12E-03	1.50E-05	1.50E-05	1.50E-05	2.76E-04	**1.36E+06**

Storm Drain Water from Zone B, East/West Unit 2, near MH-2, going to river directly

Doses, in mrem

ISOTOPE	BONE	LIVER	TOT BODY	THYROID	KIDNEY	LUNG	GI-LLI	uCi
H-3	0.00E+00	1.63E-07	1.63E-07	1.63E-07	1.63E-07	1.63E-07	1.63E-07	1.46E+04

Storm Drain Water from Zones C and D/E (Central U2 & U1/U3) to Discharge Canal

Doses, in mrem

ISOTOPE	BONE	LIVER	TOT BODY	THYROID	KIDNEY	LUNG	GI-LLI	uCi
H-3	0.00E+00	2.82E-08	2.82E-08	2.82E-08	2.82E-08	2.82E-08	2.82E-08	1.58E+05

Totals:

Doses, in mrem

H-3 only	0.00E+00	1.54E-05	1.54E-05	1.54E-05	1.54E-05	1.54E-05	1.54E-05	1.53E+06
	BONE	LIVER	TOT BODY	THYROID	KIDNEY	LUNG	GI-LLI	uCi H-3
H-3, Ni-63, Sr-90	9.72E-03	1.07E-04	2.12E-03	1.54E-05	1.54E-05	1.54E-05	2.76E-04	
% Annual Limit	0.097	0.001	0.071	0.000	0.000	0.000	0.003	

	BONE	dose	TOT BODY
IPEC Routine Effluents	1.70E-03	mrem	1.26E-03
GW/Storm Drains	9.72E-03	mrem	2.12E-03
Total Site Liq Dose	1.14E-02	mrem	3.38E-03
Percent Limit	0.11%		0.11%
GW/SD % of total	85%		63%

Comparing the assessed groundwater and storm water pathways (with **very conservative source terms**), versus the total routine liquid effluent for the site in 2005. While still well below the limit, these GW/SD pathways indicate they can be as much as 5 times more significant than the routine effluent.

Table 2

Storm Drain Zone B (MH-2 East & West Unit 2) to the Hudson River directly, 2005

Release Rate: 6.15E+07 ml/day or 1.62E+04 gpd or 11.28 gpm

Duration of Release, in days: 365 Waste vol released = 5.93E+06 gal

Dilution flow: 1.11E+05 gpm Dilution vol released = 5.83E+10 gal

Dil Factor 1.02E-04 *(dilution data per **IP-CHM-05-042** from Dr. John Hamawi)*

ISOTOPE	Activity Released uCi/ml	10CFR20 EC*10 conc limit	PRE-DILUTION CONC/MPC	POST-DILUTION uCi/ml	POST-DILUTION CONC/MPC	MICRO-CURIES RELEASED
H-3	6.51E-07	1.00E-02	6.51E-05	6.62E-11	6.62E-09	1.46E+04
MN-54		3.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FE-55		1.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-58		2.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-60		3.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NI-63		1.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SR-90		5.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SB-125		3.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-134		9.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-137		1.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-57		6.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTAL	**6.51E-07**	**n/a**	**6.51E-05**	**6.62E-11**	**6.62E-09**	**1.46E+04**

NUREG 0133 "Applicable Factor" for Near Field Dilution = **1.00E+00**

Adult Total Body mrem

ISOTOPE	BONE	LIVER	TOT BODY	THYROID	KIDNEY	LUNG	GI-LLI
H-3	0.00E+00	1.63E-07	1.63E-07	1.63E-07	1.63E-07	1.63E-07	1.63E-07
MN-54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FE-55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NI-63	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SR-90	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
SB-125	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-57	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTAL	0.00E+00	1.63E-07	1.63E-07	1.63E-07	1.63E-07	1.63E-07	1.63E-07

Table 6

IP2 Activity Released to Hudson River via Bedrock Pathway, 2005

(from the area near IP2 transformer yard, as determined by samples from Monitoring Wells - Area 2)

Release Rate 1.84E+07 ml/day or 4.85E+03 gpd or 3.37 gpm

Duration of Release, in days 365 Waste vol released = 1.77E+06 gal

Dilution flow 1.11E+05 gpm Dilution vol released = 5.83E+10 gal

Dil Factor 3.03E-05 *(dilution data per **IP-CHM-05-042** from Dr. John Hamawi.)*

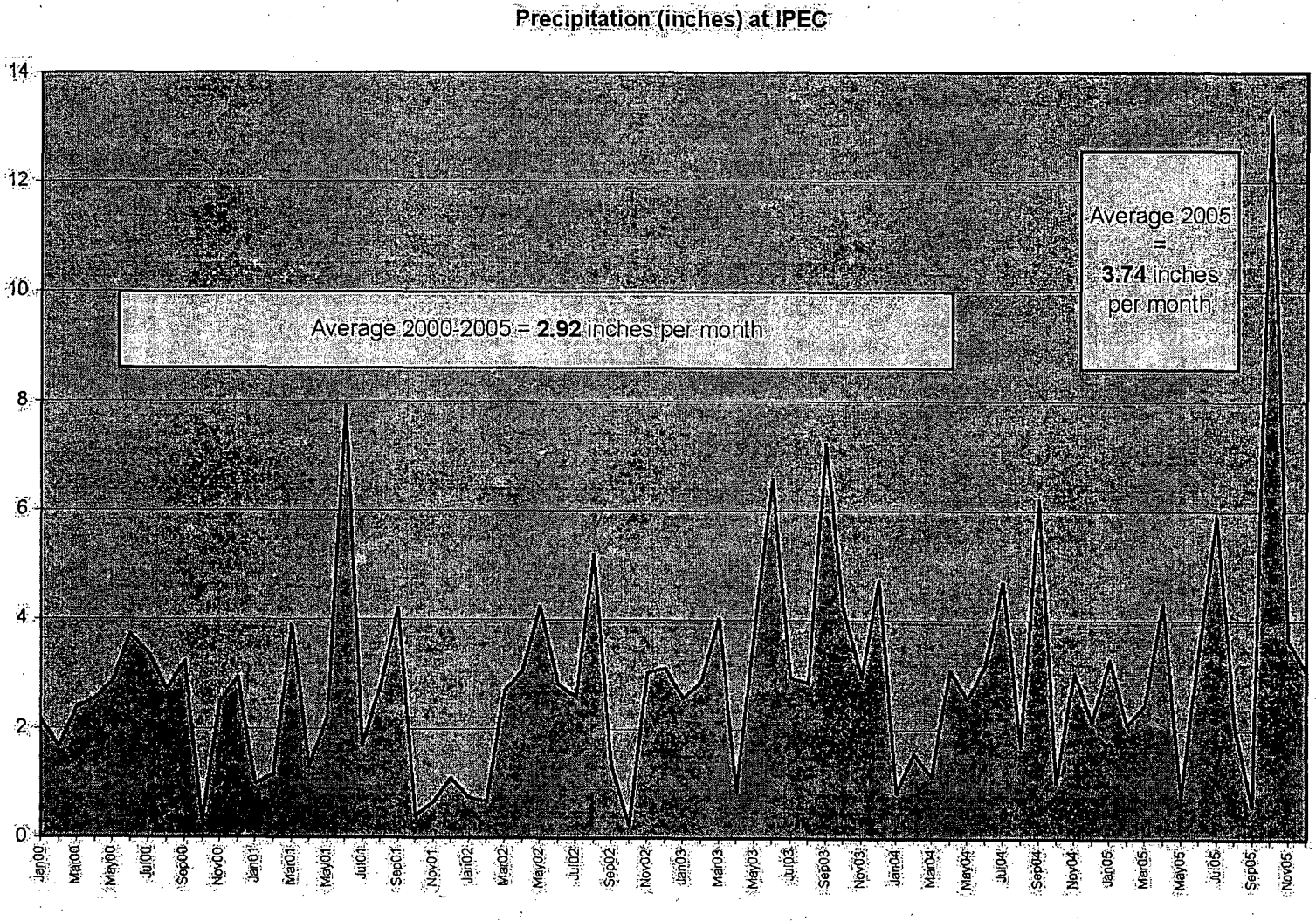
ISOTOPE	Activity Released uCi/ml	10CFR20 EC*10 conc limit	PRE DILUTION CONC/MPC	POST DILUTION uCi/ml	POST DILUTION CONC/MPC	MICRO-CURIES RELEASED
H-3	2.00E-04	1.00E-02	2.00E-02	6.07E-09	6.07E-07	1.34E+06
MN-54		3.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FE-55		1.00E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-58		2.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-60		3.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NI-63	1.00E-07	1.00E-03	1.00E-04	3.03E-12	3.03E-09	6.70E+02
SR-90	5.00E-08	5.00E-06	1.00E-02	1.52E-12	3.03E-07	3.35E+02
SB-125		3.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-134		9.00E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-137		1.00E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-57		6.00E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTAL	**2.00E-04**	n/a	**3.01E-02**	**6.07E-09**	**9.13E-07**	**1.34E+06**

NUREG 0133 "Applicable Factor" for Near Field Dilution = 1.00E+00

Adult Total Body mrem

ISOTOPE	BONE	LIVER	TOT BODY	THYROID	KIDNEY	LUNG	GI-LLI
H-3	0.00E+00	1.50E-05	**1.50E-05**	1.50E-05	1.50E-05	1.50E-05	1.50E-05
MN-54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FE-55	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NI-63	**1.32E-03**	9.17E-05	**4.44E-05**	0.00E+00	0.00E+00	0.00E+00	1.91E-05
SR-90	**8.40E-03**	0.00E+00	**2.06E-03**	0.00E+00	0.00E+00	0.00E+00	2.42E-04
SB-125	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-134	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CS-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO-57	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTAL	**9.72E-03**	1.07E-04	**2.12E-03**	1.50E-05	1.50E-05	1.50E-05	2.76E-04

Figure 3


Precipitation (inches) at IPEC
Average 2000-2005 = 2.92 inches per month
Average 2005 = 3.74 inches per month
0
2
4
6
8
10
12
14
Jan00
Mar00
May00
Jul00
Sep00
Nov00
Jan01
Mar01
May01
Jul01
Sep01
Nov01
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