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Evaluation of Radiological Releases from the TOMSK-7 Accident

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On April 6, 1993, there was an uncontrolled release of radioactive material from the fuel reprocessing plant at the Siberian Chemical Combine in Tomsk. The release resulted from the rupture of an over-pressurized feed adjustment tank and subsequent explosion that destroyed the walls and roof of the operating gallery. Radioactive material was released through a 150 meter stack, as well as through the destroyed walls and roof. Relatively stable atmospheric conditions prevailed and a light snow was falling. The radiation release was not excessive, but the spread of radioactive material was compounded by the explosion. Radiation was detected about 26 km from the source. This paper summarizes the information available in the US regarding the release and, using reasonable assumptions, compares the calculated ground activity and radiation levels with the reported measured values.

Introduction

Limited information regarding the radiation release from the Tomsk incident has been available in the United States. Available sources include:

1) The IAEA Mission Report[1]
2) Discussions with the USDOE delegation to Tomsk[2]
3) The IBR document[3]
4) Atomnaya Énergiya journal article[4]

These documents are in general agreement. However, of the initial 559 Ci present in the tank, the reported activity of material released to the environment ranges from 4 to 400 Ci. Table 1 summarizes the information obtained from these references as it pertains to the radiological release.

Based on the available information, this paper uses a plume diffusion model to predict radiological releases, and compares the predictions to the measured ground level dose rates. For the Tomsk accident two release paths are proposed. First, from the 150 m stack that normally discharged filtered exhaust air from the building, and second, by direct release through the breached building walls and roof.

These release paths, and the predicted radioactive material transport and deposition patterns are examined. For this evaluation the most valuable data is from the IAEA Mission Report, which provided a rough map (Figure 1) of the local radiation dose rates downwind of the Tomsk Siberian Chemical Combine.

Table 1. Basic Information and Assumptions

Radiation Sources[1,4]		
Beta-gamma activity	Total -	537 Ci
Zr-95 18.7%		
Nb-95 43.2%		
Ru-103 2.7%		
Ru-106 35.3%		
Alpha Activity	Pu-239 and Np-239	22.4 Ci
Meteorological Conditions[4]		
Wind Speed 8-13 m/sec		
Direction: from 190-210^0		
Temperature: -3^{0}C		
Stability: Pasquill Class D		
Dispersion Coefficients[6]		
h=150 m	$\sigma_y=0.2217*X^{0.9048}$ $\sigma_z=0.3980*X^{0.7552}$	
h=30 m	$\sigma_y=0.6248*X^{0.7672}$ $\sigma_z=0.2048*X^{0.9358}$	

Background

Many variables influence the release, transport, and deposition of radioactive materials. Numerous meteorological models are available for describing radiological releases[5]. One of the most commonly used, for studying the distribution of radioactive pollutants released into the atmosphere, is the Gaussian diffusion point source/plume depletion model. If an amount, Q_0, of radioactive material is released into the atmosphere and if its transport downwind can be considered Gaussian, the spatial concentration of radioactive material can be expressed by the Gaussian diffusion plume model given by:

$$\bar{\chi}(x,y,0) = \frac{Q_o}{\pi\sigma_y\sigma_z u} \exp\left[-\left(\frac{y^2}{2\sigma_y^2} + \frac{h^2}{2\sigma_z^2}\right)\right]$$

The standard Gaussian diffusion plume model can be corrected for depletion of the plume by replacing Q_0 with an effective source strength, Q(x), which is a

function of downwind distance. That is,

$$\bar{\chi}(x,y,0) = \frac{Q(x)}{\pi \sigma_y \sigma_z u} \exp\left[-\left(\frac{y^2}{2\sigma_y^2} + \frac{h^2}{2\sigma_z^2}\right)\right]$$

By defining a parameter known as the deposition velocity, V_d, the ground-level concentration of radioactive material due to the depleting plume (i.e., the flux of material to the surface), is given by:

$$\omega(x,y) \equiv V_d \, \bar{\chi}(x,y,0)$$

A mass balance on the amount of material in the plume leads to an equation for Q(x) as:

$$\frac{Q(x)}{Q_o} = \exp\left[-\sqrt{\frac{2}{\pi}} \, \frac{V_d}{u} \int_0^x \frac{dx}{\sigma_z \exp\left[\frac{h^2}{2\sigma_z^2}\right]}\right]$$

These equations can be used to estimate the surface level concentrations of radioactive material if the dispersion coefficients, σ_y and σ_z, and the disposition velocity, V_d, are known. These parameters are highly dependent on local surface topography and meteorological conditions.

Analysis

Calculations were performed for release heights of 30 m and 150 m which correspond to the heights of the building and the air exhaust stack. The calculations covered the range of reported source terms and a variety of deposition velocities. The maximum distances to the downwind 400 μrem/hr, 100 μrem/hr, 50 μrem/hr, and 10 μrem/hr isopleths are given in Tables 2 and 3. Typical results are illustrated in Figures 2, 3 and 4.

Conclusions

The results of this study indicate that releases of 4 to 400 Ci are consistent with the reported radiological measurements. However, it was found that the higher releases required using very high deposition velocities to match the radiological measurements. This leads one to conclude that the radiological release (i.e., airborne release) was more likely in the 75-150 Ci range. Short range plume depletion may be a significant factor. Based on the dispersion parameters and deposition velocities used, there did not appear to be any difference between a 30 m and 150 m height release at the 20-30 km distance.

Nomenclature

x,y,z	Coordinates in the downwind, crosswind, and vertical directions, m
Q_0	Amount of material released, Ci/sec
Q(x)	Effective source material in the plume at x, Ci/sec
h	height of the release, m
u	wind velocity, m/sec
σ_y, σ_y	Crosswind and vertical dispersion coefficients, m
$\chi(x,y,0)$	Ground level concentration, Ci/m^3
$\omega(x,y)$	Surface contamination, Ci/m^2
V_d	Deposition velocity, m/sec

Table 2. Maximum Downwind Distance for Dose Rates for Releases from 150 m.

				Downwind Distance km			
Case	Height	Ci	V_d	400μr/hr	100μr/hr	50μr/hr	10μr/hr
1	150	4	0.5	6.3	12.6	15.7	29.9
2	150	4	1.0	6.3	9.5	12.6	20.5
3	150	4	1.5	4.7	7.9	9.4	14.2
4	150	40	0.5	17.3	29.9	37.8	66.2
5	150	40	1.0	12.6	20.5	23.6	36.2
6	150	40	1.5	11.0	14.2	17.3	23.6
7	150	400	0.5	41.0	66.2	>75.6	>75.6
8	150	400	1.0	25.2	36.2	42.5	63.0
9	150	400	1.5	17.3	23.6	28.4	37.8
10	150	400	2.0	14.2	17.3	20.5	26.8
11	150	400	2.5	11.0	14.2	15.8	20.5
12	150	40	2.0	7.9	11.0	12.6	17.3

Table 3. Maximum Downwind Distance for Dose Rates for Releases from 30 m.

				Downwind Distance km			
Case	Height	Ci	V_d	400µr/hr	100µr/hr	50µr/hr	10µr/hr
13	30	4	0.5	3.2	7.9	12.6	28.4
14	30	4	1.0	3.1	6.3	9.4	18.9
15	30	4	1.5	3.1	4.7	6.3	12.6
16	30	40	0.5	14.2	28.4	39.4	>75.6
17	30	40	1.0	11.0	18.9	26.8	52.0
18	30	40	1.5	7.9	12.6	17.3	31.5
19	30	40	2.0	6.3	9.4	12.6	20.5
20	30	40	2.5	4.7	6.3	7.9	14.2
21	30	400	1.0	28.4	52.0	69.3	>75.6
22	30	400	1.5	18.9	31.5	41.0	72.5
23	30	400	2.0	12.6	20.5	26.8	44.1
24	30	400	2.5	9.5	14.2	17.3	28.4
25	30	400	3.0	6.3	11.0	12.6	20.5
26	30	400	3.5	4.7	7.9	9.5	14.2

References

1) "Mission Report: Radiological Accident at Tomsk 7, Russian Federation, 6 April 1993", A. J. Gonzalez, B. G. Bennett, G. A. M. Webb, IAEA document, April 1993.

2) "Trip Report Moscow and Tomsk, Russia, June 19-29, 1993, Follow-up to the Tomsk-7 Accident", United States Department of Energy, DOE/DP-0120, 1993.

3) "About the Causes and Effects of the Accident in Tomsk-7, Information-Analytical Investigations", IBR, 1993.

4) "Radioecological Aspects of the Accident in Tomsk", Atomnaya Énergiya, V. N. Lystsov, A. B. Ivanov, and A. E. Kolyshkin, Vol. 74, No.4, pp. 364-367, April 1993.

5) "Meterology and Atomic Energy 1968", D. H. Slade, editor, United States Atomic Energy Commission, TID 24190, July, 1968.

6) "Empirical Investigations of the Diffusion of Waste Air Plumes in the Atmosphere", K. J. Vogt, Nuclear Technology, Vol.34, June, 1977.

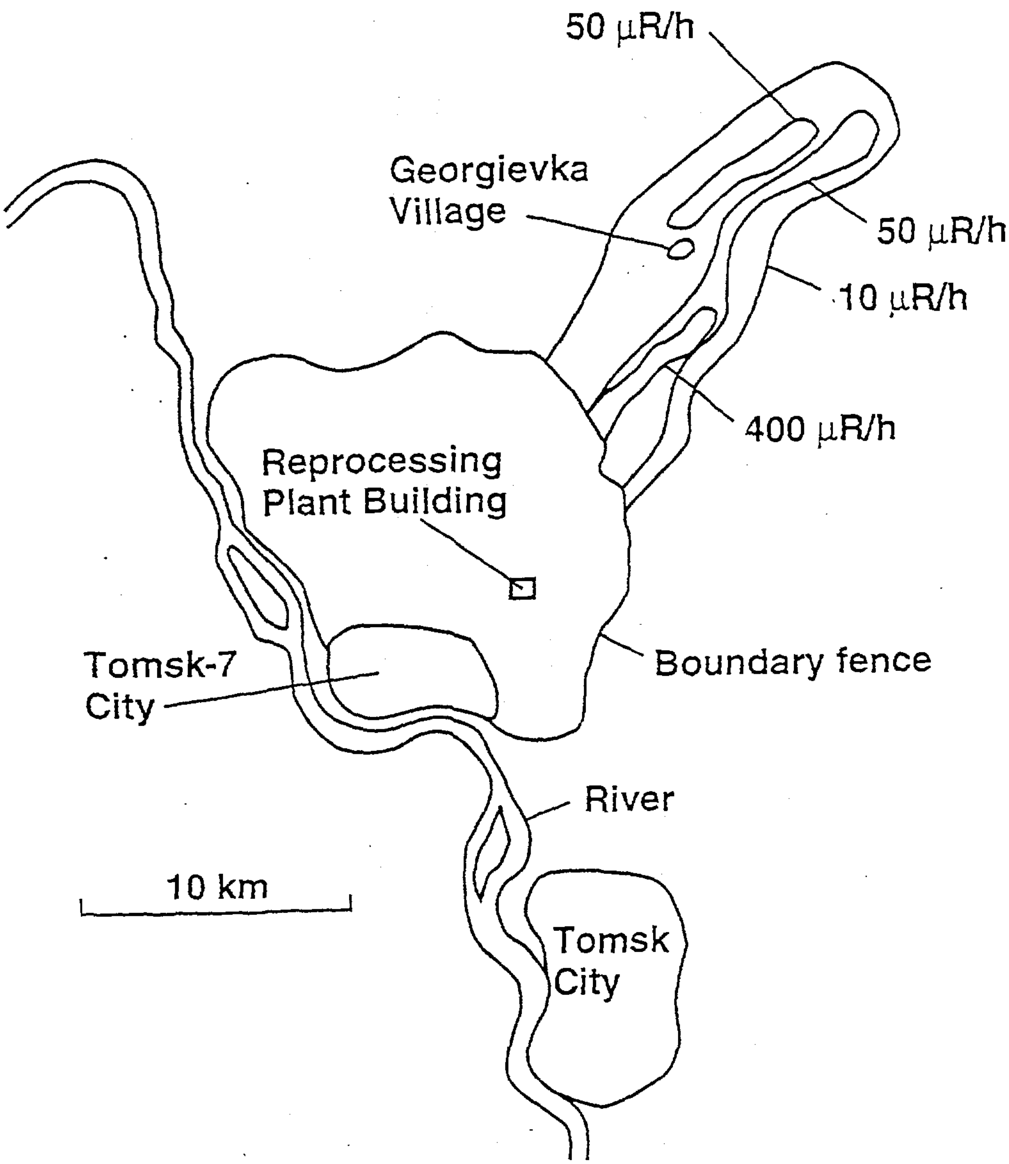

FIGURE 1. IAEA DIAGRAM OF THE TOMSK-7 SITE AND MEASURED DOSE RATE CONTOURS.

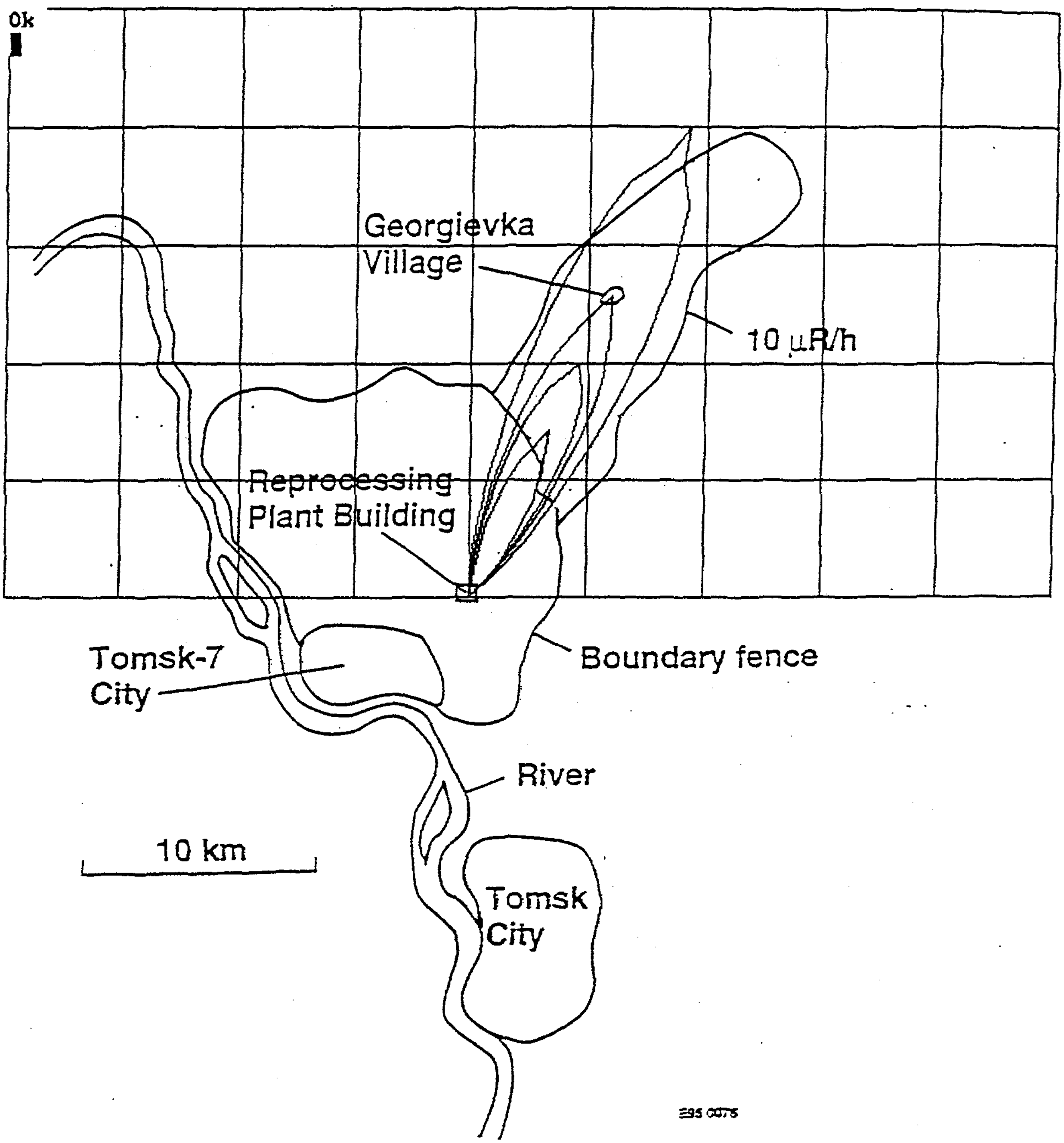

FIGURE 2. CALCULATED DOSE RATE CONTOURS FOR A 4 CURIE RELEASE WITH V_d = 1.0 M/SEC.

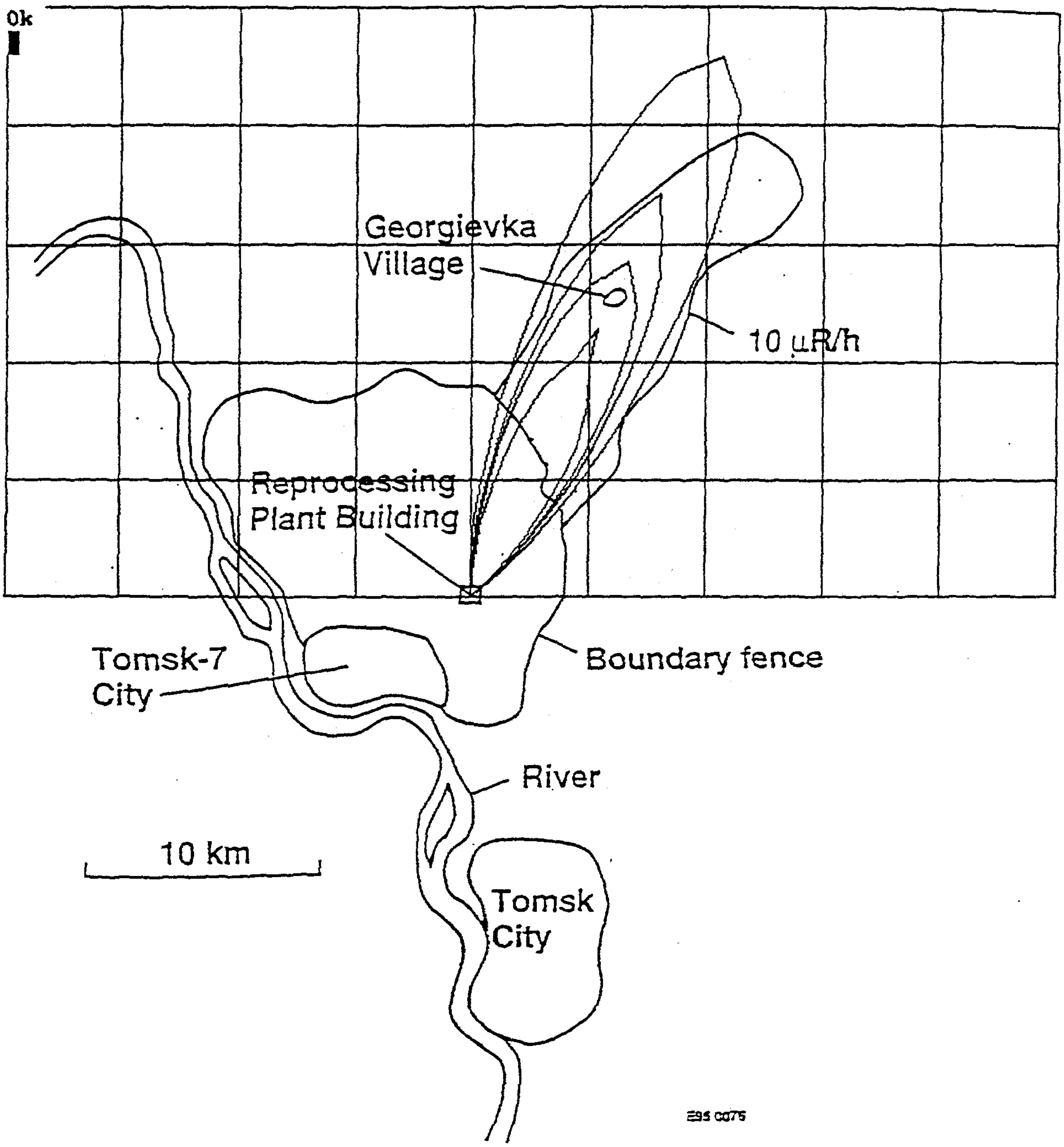

FIGURE 3. CALCULATED DOSE RATE CONTOURS FOR A 40 CURIE RELEASE WITH V_d = 1.5 M/SEC.

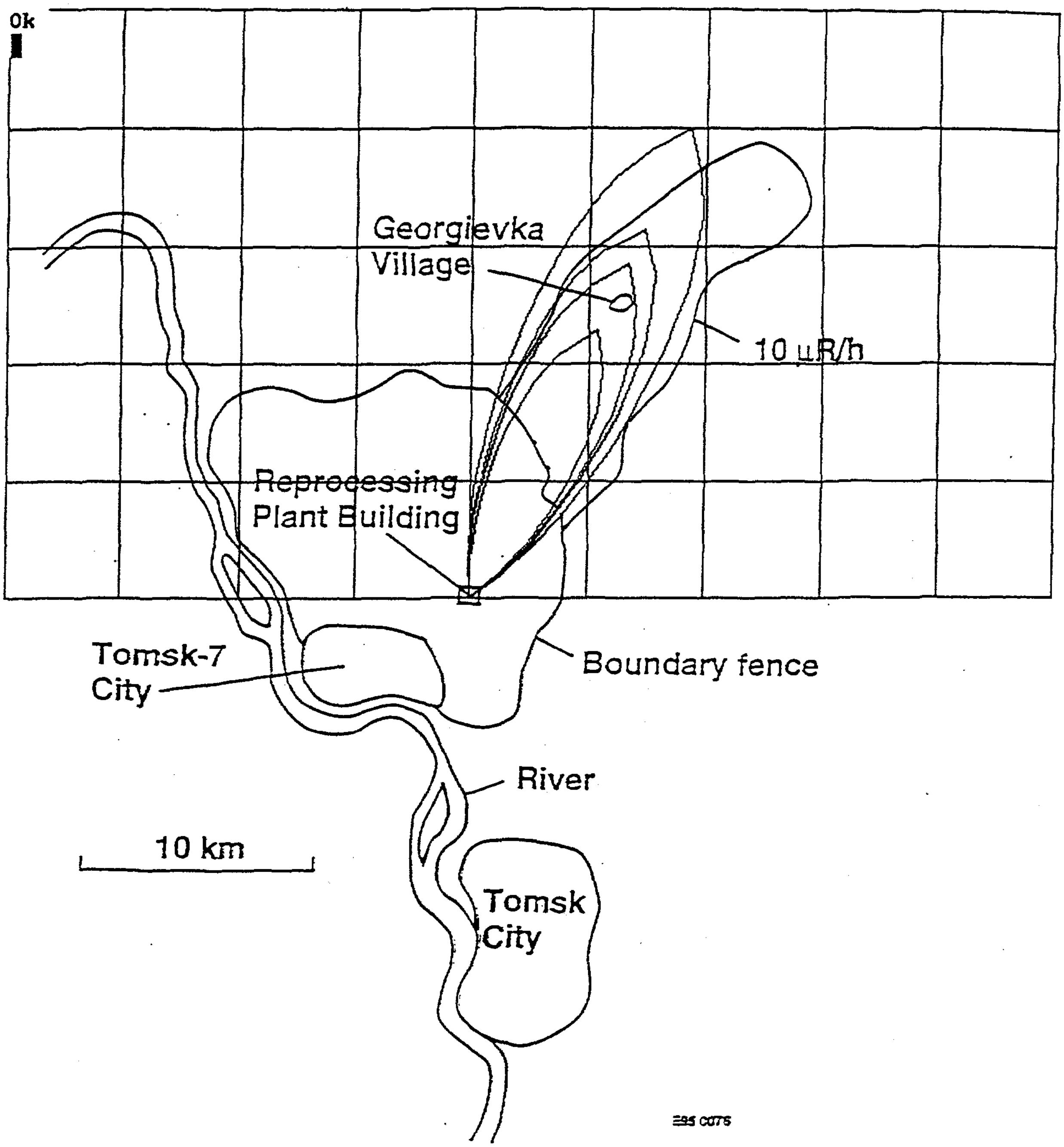

FIGURE 4. CALCULATED DOSE RATE CONTOURS FOR A 400 CURIE RELEASE WITH V_d = 2.5 M/SEC.