BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

HAT CREEK PROJECT

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PLUME SIMULATION GAS TRACER STUDIES DURING WINTER, SPRING AND SUMMER, 1976, IN UPPER HAT CREEK VALLEY EXECUTIVE SUMMARY AQ 77-14

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BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

BY

TIMOTHY C. SPANGLER, NICHOLAS E. GRAHAM,
AND EINAR L. HOVIND

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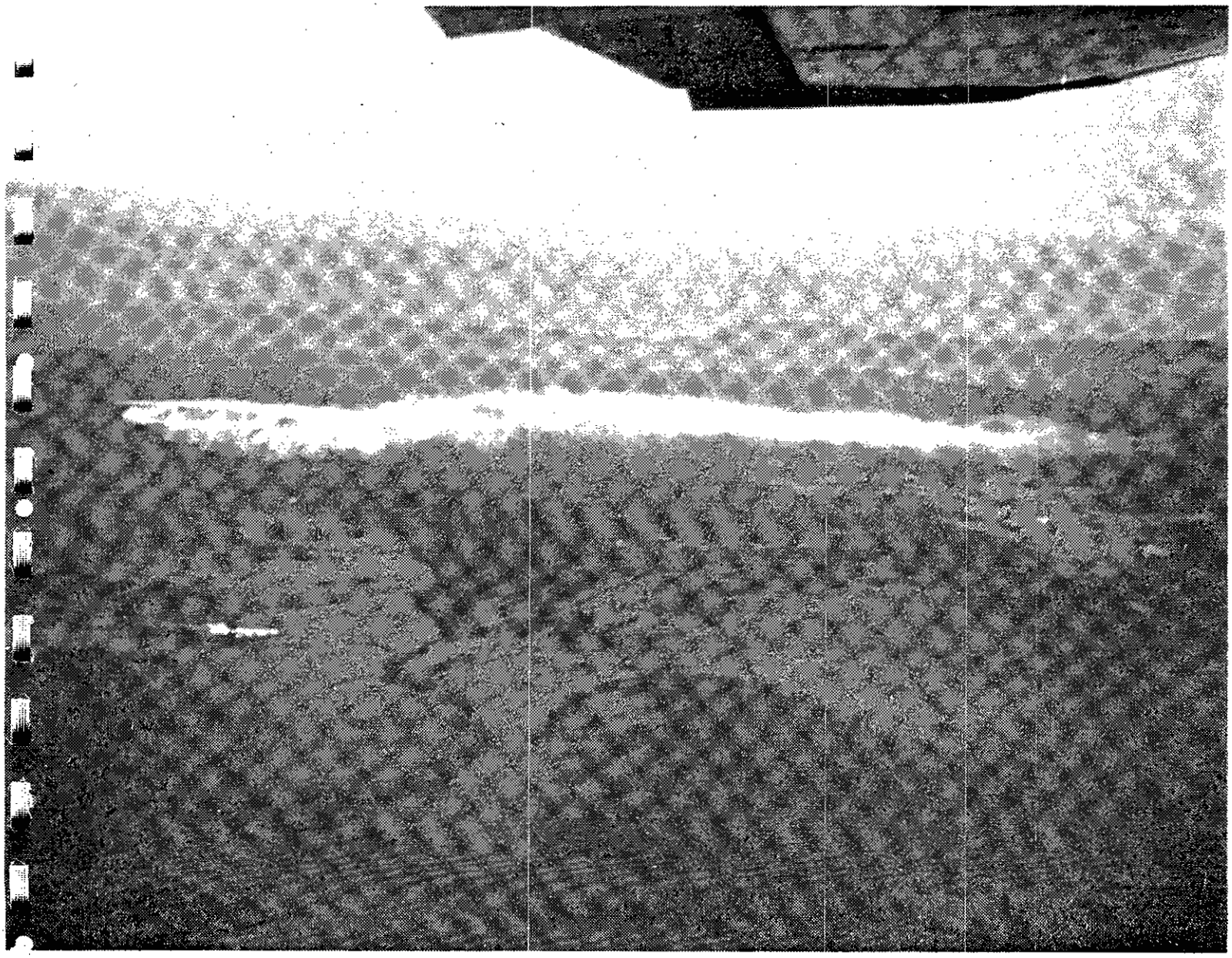

-FRONTISPIECE-

The Test 8 oil-fog plume can be seen moving southeastward up Medicine Creek after release from approximately 480 m (stack height assumed to be 183 m) above the proposed upper site at Hat Creek, British Columbia. This test, conducted under near neutral conditions during the early morning hours of August 5, 1976, produced negligible surface concentrations of the tracer material, sulfur hexafluoride.

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ABSTRACT

Three gas tracer studies have been conducted during 1976 in the Upper Hat Creek Valley for British Columbia Hydro and Power Authority. The studies, performed by North American Weather Consultants (NAWC), were designed to evaluate the potential impact of sulfur dioxide emissions from the proposed Hat Creek Power Project.

A total of 14 tracer releases was made during the winter, spring, and summer seasons simulating the SO_2 emission from a 2000 MW fossil fuel power plant located either in the valley (lower site) or at a higher elevation on the eastern ridge (upper site).

The results of the field studies, using stack emission parameters as specified for these tests, show the following:

1. The lower site in Hat Creek Valley has been found to result in ambient air quality levels in excess of the proposed three-hour SO_2 guideline (655 μgm^{-3}).

2. In order to locate the proposed fossil fuel plant in Hat Creek Valley, the site must be at an elevation comparable to that used for the upper site with stack height significantly greater than 183 m.

I. INTRODUCTION

During 1976, North American Weather Consultants (NAWC) received Purchase Orders #643-696 and #648-195 from British Columbia Hydro and Power Authority to perform gas tracer studies in support of plant site evaluation efforts in Upper Hat Creek. The purpose of the studies, as stated in the Original Terms of Reference, dated December 19, 1975, was:

> This field study will investigate the dispersive quality of the lower atmosphere, and plume trajectories during the winter season. The study will also further investigate meteorological phenomena observed during the first two field studies.

The area examined was the Upper Hat Creek Valley, located about 80 km west of Kamloops, British Columbia. The Hat Creek region is located on a plateau characterized by numerous low mountain and valley chains. Within a few kilometers two major rivers, the Thompson and the Fraser, determine the topography which strongly influences the climatology of the region. The Upper Hat Creek Valley itself is 5-10 km wide with sides rising steeply to 1400-1600 m MSL. The ground cover is primarily 5-15 m tall conifers which have been partially logged with extensive clearing for cattle ranching on the valley floor.

Two prospective power plant sites have been examined. The first, referred herein as the lower site, is located near the bottom of the Upper Hat Creek Valley at an elevation of approximately 950 m MSL as shown in Figure 1-1. The second site, referred to as the upper site, is on the east side of the valley at an approximate elevation of 1350 m MSL.

Three gas tracer studies were conducted during 1976. The first was a winter study and carried out during the period February 16-23, 1976. Tracer gas and visible oil-fog were

Figure 1-1 General research area. Diamonds indicate locations of B. C. Hydro weather stations.

released at the two prospective power plant sites in Upper Hat Creek Valley under both stable, low wind speed conditions, and more windy, neutral flows. The study was terminated earlier than planned due to unsuitable meteorological conditions. However, some of the results from the study indicated that a second short study would be advisable to more extensively examine stable up-valley flow at the lower valley site.

The second field program was a spring gas tracer study and was conducted without any oil-fog during the period March 22-26, 1976. The weather was again variable, and the releases were performed under windy, neutral conditions at both the lower and upper sites.

The third field program was a summer study conducted between July 31 and August 10, 1976. A total of eight tracer releases was made from the upper site. Atmospheric conditions included stable air mass with low wind speed, light winds with unstable afternoon lapse rate, and neutral stability with moderate wind speeds. One release was carried out from the lower site under looping plume conditions.

This report provides a summary of the research methods used in the studies and of the conclusions reached concerning the feasibility of building a fossil-fuel power plant at either location with regards to air quality impact. The evaluation was based upon the B. C. Hydro Gas Tracer Meteorological Study Criteria for the Proposed Hat Creek Thermal Power Plant which are listed in Table 1-1. A comprehensive report in two volumes (Technical Report and Field Data) by Spangler, Graham and Hovind (1977) covers a detailed description of the field work and data analysis.

During the course of the field study, the stack heights were adjusted based upon the preliminary results from the

field measurements. These adjustments applied to both the valley site and the upper site.

Portions of the data gathered during these studies, including airborne plume geometry measurements, turbulence measurements, and aerial and surface SF_6 concentrations, were also processed for another B. C. Hydro consultant. These data were used for calibrating their mathematical diffusion model which was applied to predict contaminant concentration resulting from the proposed operation of Hat Creek Thermal Power Plant.

The results presented in this report concern ambient SO_2 levels only, based upon coal with 0.5% sulfur content. It should be noted that the results are applicable to coal with different sulfur contents as well as to other gaseous (non-reactive) and particulate emissions by scaling the impact levels in this report to the appropriate new source strengths.

Table 1-1 B. C. Hydro gas tracer meteorological study criteria for proposed Hat Creek Thermal Power Plant.

	Valley Site	Upper Site
Stack Height	183 m (adjusted to 305 m based on preliminary field measurements from winter study)	183 m (adjusted from 152 m to 183 m on the basis of field measurements. Experimentally adjusted to 366 m for Test 14).
Stack Gas Temperature	394 K	394 K
Stack Gas Velocity	18.3 m/s	24.4 m/s
*Source Strength SO_2 (2000 MW generating capacity)	4204 g/s	4204 g/s

*SO_2 emission rate is based on a coal sulfur content of 0.5%. The emission rate will vary depending on the sulfur content of the coal as fired.

2. SUMMARY AND CONCLUSIONS

Three gas tracer field programs were conducted during 1976 by North American Weather Consultants for British Columbia Hydro and Power Authority to investigate plume dispersion patterns at two proposed power plant sites in the Hat Creek Valley. The winter program, conducted between February 16 and 23, 1976, consisted of three tracer releases. Two releases were made during the spring project between March 22 and 26, 1976. A total of nine tracer tests was carried out during the summer program between July 31 and August 10. These tracer tests were accompanied by extensive meteorological measurements of winds aloft and at the surface, horizontal (constant volume) flow trajectories, vertical temperature profiles, and aircraft turbulence measurements.

The tracer materials, sulfur hexafluoride (SF_6) and oil-fog, were released by aircraft at the calculated effective stack height. SF_6 was measured both at the surface and aloft. Oil-fog was used for quantitative aerial plume tracking and flow visualization.

The gas tracer programs have provided quantitative plume impact evaluations from both of the proposed sites under various meteorological conditions. The critical dispersion regimes of stable plume entrainment within the valley circulation with subsequent fumigation and low wind speed looping were experienced at both sites. Table 2-1 provides information concerning meteorological conditions, release parameters, and maximum measured impact for each tracer test.

The results of each test are summarized below, with SO_2 concentrations representing equivalent 1 hour and estimated 3 hour impact from 2000 MW generating capabity. These concentration values have been referenced to the "normal temperature and pressure" (NTP) vlaues (i.e., 20°C and 760 mm Hg as

Table 2.1 Hat Creek 1976 tracer studies; test parameters and results.

Test	Date	Release Time (PST)	Site/ Assumed Stack Height (m)	Release Altitude m(MSL)	Plume Type	Release Altitude Temperature Stability Category	Average Wind Speed (m/s)	Direction of Plume Travel	Maximum Measured 1 hour Surface Concentration (μgm^{-3} SO_2 (NTP) @ 2000 MW)
1	2/19/76	0936-1030	Lower 183	1400	Fanning w/ Fumigation	E	1	SSW	3105
2	2/20/76	0748-0848	Lower 305	1525	Coning	D	6	NE	243
3	2/21/76	0753-0853	Upper 152	1735	Coning	D	7	N	180
4	3/25/76	1105-1149	Lower 183	1500	Coning	D	7	NE	651*
5	3/26/76	TEST RESULTS NOT REPORTED DUE TO SUSPECTED CONTAMINATION							
6	7/31/76	0551-0651	Upper 183	1770	Coning	D	5	NE	<307
7	8/01/76	0531-0631	Upper 183	1770	Lofted	D-E	2.5	NNW	330
8	8/05/76	0528-0628	Upper 183	1830	Coning	D	4	SE	< 26
9	8/06/76	1302-1402	Lower 366	1645	Looping	D	1	SE	1068
10	8/07/76	0539-0618	Upper 183	1890	Coning	D-E	1.5	SSE	< 26
11	8/09/76	0647-0747	Upper 183	1920	Coning	D	7.5	SE	175
12	8/10/76	0532-0632	Upper 183	1890	Fanning w/ Fumigation	D	2	SSE	646
13	8/10/76	1140-1240	Upper 183	1920	Looping	D	1.5	ESE	1216
14	8/11/76	0537-0637	Upper 366	2105	Coning, Fanning	D	3.5	NE	< 28

* Some samples discarded due to suspected contamination

specified by the Province of British Columbia. In this report these values are designated by (NTP) and presented for comparisons with the 3-hour SO_2 Level A ambient air quality guideline of 655 μgm^{-3} (NTP)(0.25 ppm) as proposed by B. C. Hydro.

An analysis of the expected maximum 3-hour SO_2 concentrations has been carried out assuming that each test had been a long-term release. This analysis was designed to delineate those areas where 3-hour concentrations would have exceeded 655 μgm^{-3} (NTP). The results suggest that this level would have been exceeded only during Test 1 which was conducted at the lower site using the initially proposed 183 m stack.

- Test 1, February 19, 1976. The plume release was made over the lower site assuming a stack height of 183 m. The air mass was moderately stable and winds light and variable, a condition characteristic of the transition from down-valley to up-valley flow. The plume, embedded in the valley circulation, gradually sank as it was transported slowly south and westward and eventually fumigated along the western side of Upper Hat Creek Valley. The maximum measured one-hour surface concentration was equivalent to 3105 μgm^{-3} (NTP).

An analysis of the measured results from the one-hour tracer release and the observed flow patterns suggest that an area in the west central portion of Hat Creek Valley probably would have experienced three-hour averages in excess of 655 μgm^{-3} (NTP) with a maximum three hour average of approximately 1800 μgm^{-3} (NTP) had the release been continuous.

- Test 2, February 20, 1976. This tracer release at the lower site was carried out under near neutral conditions at plume altitude with a stable layer below. Winds were

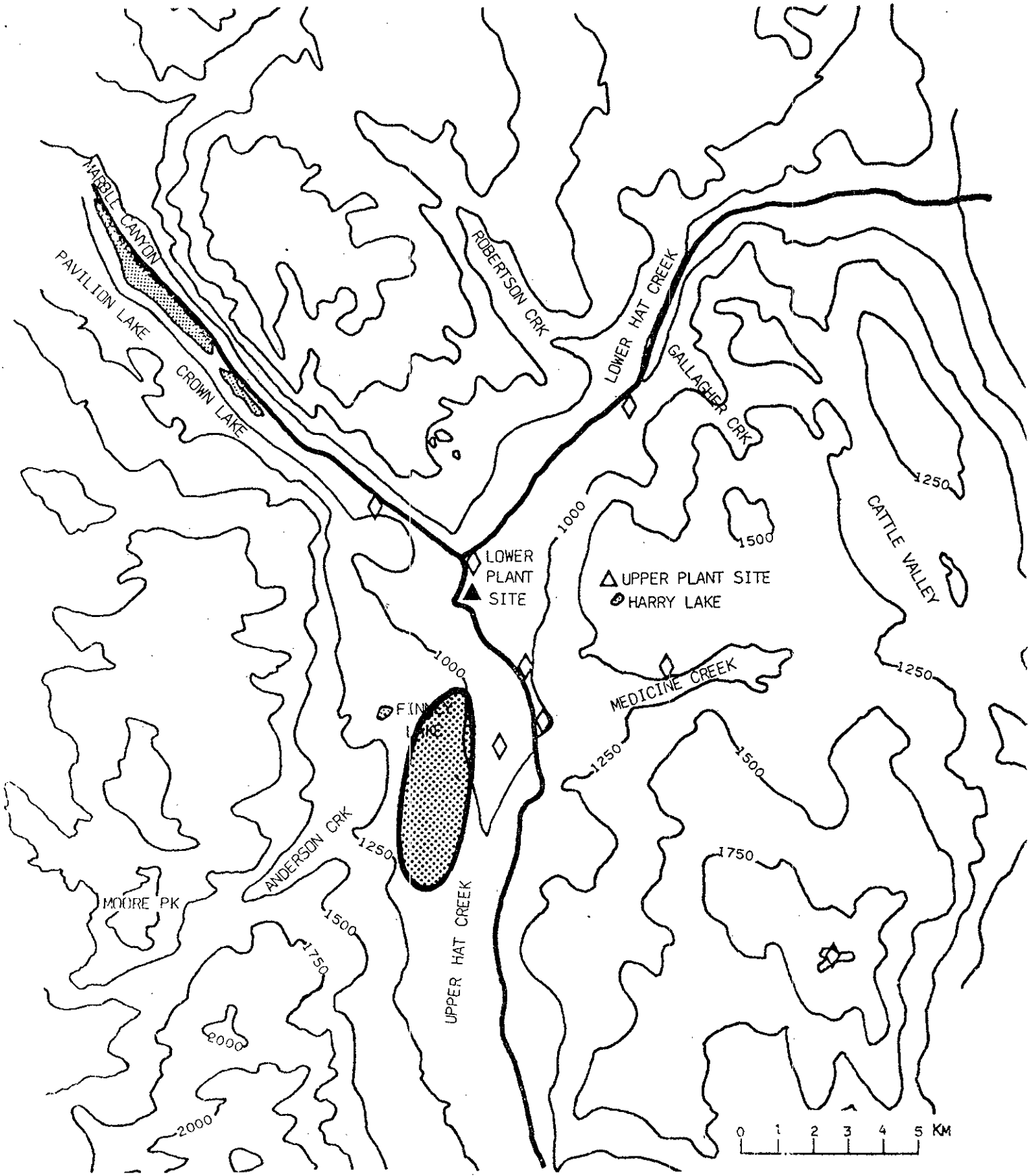

Figure 2-1 Area expected to have experienced 3-hour average concentrations in excess of 655 μgm^{-3} (NTP) had a 2000 MW thermal plant been operating continuously during the morning of February 19, 1976 (Tracer Test 1) with a 183 m stack at an Upper Hat Creek Valley location.

moderately strong from the south-southwest. A stack height of 305 m was assumed in an attempt to place the plume above the valley circulation. The plume moved down the Lower Hat Creek Valley with the gradient flow, and exhibited terrain channeling. Ground level impact was light with a maximum equivalent one-hour concentration of 243 μgm^{-3} (NTP). Maximum three-hour concentrations are estimated to have been 200 μgm^{-3} (NTP). The low concentrations found during this test are attributed mainly to favorable dispersion conditions rather than the increased stack height.

- Test 3, February 21, 1976. This test was conducted at the upper plant site with an assumed stack height of 152 m. Dispersion conditions were very good with fresh southerly winds and slightly stable lapse rates.

This plume dispersed rapidly and showed little indication of terrain channeling. As a result, the maximum measured one-hour surface concentration was limited to 108 μgm^{-3} (NTP). The maximum three-hour average concentration is estimated to have been about 100 μgm^{-3} (NTP).

- Test 4, March 25, 1976. The plume release was made over the lower plant site, assuming a 305 m stack, in a well-mixed atmosphere with neutral stability and moderate westerly winds.

The plume was transported towards the ground sampling network on the elevated terrain to the east of the site. The constant volume balloon data revealed localized circulation patterns with downdrafts which brought some of the balloons to the ground within 4-10 km of the site.

High ground concentration values were found over the sampling network, as would be expected with the observed downdrafts. However, the maximum concentration values were one to two orders of magnitude higher than observed during previous tests and were therefore suspect of contamination. After discarding these extreme values, the maximum equivalent one-hour concentration appears to be 651 μgm^{-3} (NTP). It is estimated that the maximum three-hour concentration for a continuous release may have been about 465 μgm^{-3} (NTP).

- Test 5, March 26, 1976. The plume release simulated the upper plant site with a 152 m stack. However, in view of the peculiar circulation patterns observed during Test 4, the actual release site was moved 8 km south in order to repeat plume impact on the Trachyte Hills from a higher release point. The atmosphere was again well mixed with neutral stability but the wind increased to strong south-southwesterly flow by the time of the release. No useful quantitative tracer data were obtained from this flight because of suspected contamination of the sampling bags.

- Test 6, July 31, 1976. This early morning test was conducted at the upper plant site assuming a stack height of 183 m. Meteorological conditions were characterized by light to moderate southerly winds and slightly stable lapse rates. A malfunction resulted in a 90% reduction in the source strength of SF_6 during the release, raising the detectable limit for this particular test to 307 μgm^{-3} (NTP).

The plume moved northward and showed little indication of interaction with the terrain and no indication of surface impact within 35 km of the plant site. It is concluded that the lack of downward transport resulted in one-hour surface concentrations of less than the detectable limit and estimated three-hour concentrations of about 75 μgm^{-3} (NTP).

• Test 7, August 1, 1976. This early morning tracer release was made over the upper plant site, assuming a stack height of 183 m. The plume was released near the top of a weak surface-based inversion, and was transported initially towards the northwest. The stable-appearing plume approached the elevated terrain to the northeast of Marble Canyon, causing moderate surface impact. The plume then drifted slowly to the west and southwest, passing over Marble Canyon and was last visible over the hills west of Crown Lake. Measurable surface impact was experienced only on a small area of the plateau northeast of Marble Canyon, where a maximum one-hour concentration of 330 μgm^{-3} (NTP) was recorded. The distribution of surface concentrations suggests that this test represents a case of a lofted plume impact on elevated terrain. Surface concentrations might have been higher had stronger insolation (and therefore greater vertical mixing) been present. In view of the observed shifting plume trajectory maximum three-hour concentrations are estimated to have been 140 μgm^{-3} (NTP).

• Test 8, August 5, 1976. This early morning test simulated emissions from a 183 m stack at the upper plant site. The atmosphere was neutral at plume height, with a shallow surface-based inversion below. Winds were from the northwest at moderate speeds. The plume was transported to the southeast and split into two sections over Medicine Creek. One branch continued over upper Medicine Creek, while the other branch moved to the east and then southeast as it followed Cornwall Creek. No surface impact was detected at any of the sampler sites, probably due to a combination of favorable dispersion conditions. The maximum three-hour concentration from a continuous source is estimated to have been less than 50 μgm^{-3} (NTP).

- Test 9, August 6, 1976. This early afternoon test was conducted at the lower plant site assuming a stack height raised to 366 m. The atmosphere was neutral at plume height with a shallow superadiabatic layer at the surface. The wind was very light. The plume behavior was marked by extensive vertical transport in the well-organized convection cells. As a result, surface impact was varied and widespread across the upper valley. The maximum one-hour equivalent SO_2 concentration was 1068 μgm^{-3} (NTP) 2.4 km southwest of the lower plant site. The estimated maximum three-hour concentration, based on a continuous source, was 525 μgm^{-3} (NTP).

- Test 10, August 7, 1976. Test 10 was an early morning test carried out at the upper plant site assuming a stack height of 183 m. Except for a shallow surface inversion, the air mass was near neutral with light northerly winds. Weather conditions deteriorated during the test and the tracer release was cancelled after 40 minutes, when the lowering visibility made successful low altitude flying unlikely. The abbreviated plume was visually noted to pass over one sampler, but no measurable impact was recorded over the sampling network. It is presumed that the combination of low wind speeds, surface stability, and cloudiness suppressed vertical mixing, resulting in observed one-hour and estimated maximum three-hour concentrations of less than the detectable limit of about 30 μgm^{-3} (NTP).

- Test 11, August 9, 1976. This early morning test was conducted at the upper plant site assuming a stack height of 183 m. Winds were strong (7-8 m/s) and the air mass, neutral. The plume was transported toward the southeast and was tracked down Cornwall Creek to near the Ashcroft airstrip. The data indicate that the strong winds and neutral atmosphere caused very rapid dispersion near the surface, resulting in maximum one-hour surface concentrations of 175 μgm^{-3} (NTP). It is estimated that the maximum three-hour concentration did not exceed 50 μgm^{-3} (NTP).

• Test 12, August 10, 1976. Test 12 was an early morning test using a simulated 183 m stack at the upper plant site. The plume height stability was neutral, but surface inversions were observed at both valley and hillside locations. Initially, the plume drifted slowly to the south (up-valley) for about 90 minutes, extending as far as Oregon Jack Creek. After that, the plume began to move westward as it was entrained in a cross-valley circulation caused by solar heating of the east-facing slopes. Through the test the plume layer was observed to sink in response to the effect of the differential heating in the valley. The plume fumigated on the western slopes of the valley, dispersing up the slopes. The maximum one-hour equivalent SO_2 concentration was recorded during the fumigation period and had a value of 646 μgm^{-3} (NTP). A one-minute grab sample at that sampler site had a concentration of more than 8400 μgm^{-3} (NTP). The great range in one-minute to one-hour average concentrations is typical of the short-lived fumigation process. This test demonstrated the depth and transport capacity of the valley circulation. The maximum estimated three-hour concentration was about 527 μgm^{-3} (NTP) for a continuously operating source.

• Test 13, August 10, 1976. This test was conducted at the upper plant site near noon. The tracer release simulated emissions from a 183 m stack. The atmosphere was neutral and winds were very light. As in Test 9, plume transport was greatly influenced by well-organized convection. During the early phase of the test, the tracer release aircraft encountered extreme down-drafts and held altitude only by the use of full power. Organized, but less severe, up- and down-drafts were encountered throughout the remainder of the test. Although surface impact was widespread, the maximum value was found within 1 km of the upper plant site and had a one-hour average

equivalent SO_2 concentration of 1216 μgm^{-3} (NTP). Concentrations in the central Hat Creek Valley were lower, averaging at most 215 μgm^{-3} (NTP) for a one-hour period. The maximum three-hour concentration is estimated to have been about 450 μgm^{-3} (NTP).

- Test 14, August 11, 1976. This early morning test simulated emission from a 366 m stack at the upper plant site. The raised stack height was used to investigate possible entrainment in the valley circulation at this higher level. The air mass was neutral with shallow morning surface inversions and winds were from the southwest at speeds of 3 to 4 m/s. Plume transport was similar to that of Test 6 except that this plume remained at greater heights above the terrain. The plume was tracked for over three hours, during which time it passed over more than 80 km of moderately rough terrain, showing no signs of significant interaction with local circulations. Surface impact was negligible and the maximum three-hour concentration is estimated to have been less than 30 μgm^{-3} (NTP).

- Conclusions. The gas tracer studies at the proposed Hat Creek generating station sites have provided quantitative information of plume dispersion behavior under variety of meteorological regimes.

The lower site has been found to result in ambient air quality levels in excess of the proposed three-hour SO_2 guideline (655 μgm^{-3}) with stack heights high at 366 m, due to the depth of the valley circulation. One-hour concentrations up to 3105 μgm^{-3} (NTP) were found during a winter fumigation episode with a 183 m stack. During summer, assuming a 366 m stack, one-hour concentrations reached 1068 μgm^{-3} (NTP) during a test conducted under typical convective afternoon conditions.

The upper site, with a stack height of 183 m, has also been found to be unsuitable, although dispersion appears to be excellent during periods of moderate winds and neutral stability. In the 183 m configuration, one-hour surface concentrations reached 1216 μgm^{-3} (NTP) during a test conducted under light wind, looping plume conditions. An early morning release, carried out during a period typified by light winds and near neutral lapse rates, resulted in one-hour concentrations of up to 646 μgm^{-3} (NTP) after a long period of complex transport.

One test was conducted from the upper site, assuming a stack height of 366 m. Conditions were relatively favorable for entrainment in the valley circulation, yet the plume traveled more than 80 km across moderately rugged ground with no indication of significant interaction with the terrain or surface impact.

In summary, the results of the tracer study show that in order to locate a 2000 MW fossil fuel power plant in the Hat Creek Valley with stack emission parameters as specified by B. C. Hydro (Table 1-1), the site must be at an elevation comparable to that used for the upper site with stack height significantly greater than 183 m.

3. RESEARCH METHODS

The plume simulation studies in Upper Hat Creek Valley have used oil-fog and sulfur hexafluoride (SF_6) as tracer materials. The tracer releases were made at the calculated effective stack height by a specially modified Stearman biplane. Both tracer materials were released simultaneously from the Stearman while it was flown in circles of approximately 130 m radius around a ground reference point at the plant site. Releases were typically one hour in duration. A photo of a typical release is shown in Figure 3-1.

Tracer materials were sampled both aloft and at the surface. Aerial oil-fog measurements were made with an integrating nephelometer on the NAWC tracer aircraft to determine spatial and temporal oil-fog concentrations. Aerial sampling of SF_6 was done by helicopter at discrete locations in the plume. In addition, the oil-fog plume was extensively photographed from the air.

Ground level samples of SF_6 were taken with sequential and singular bag samplers deployed under the plume by helicopter or truck. Sequential samples were taken at a rate of one each half-hour, while the singular samples were generally made over one hour.

SF_6 concentrations in each sample bag were determined with a gas chromatograph. The resulting concentration was scaled to equivalent concentration of sulfur dioxide emitted from the projected plant operating at an output of 2000 MW.

Supporting meteorological measurements made during each test included winds at the surface and aloft over the proposed plant site and atmospheric stability over the plant site and other areas of interest. Winds aloft measurements were made

by tracking pilot balloons with two theodolites. A Contel Corporation minisonde system, supplied by B. C. Hydro and operated by B. C. Hydro personnel, as well as a Contel "Metrosonde" tethered balloon system, were used to obtain temperature soundings at the plant site. The NAWC tracer aircraft also made temperature sounding measurements at selected locations. A more detailed discussion of the research methods is given by Spangler, Graham, and Hovind (op. cit.).

Figure 3-1 An aerial oil-fog-SF_6 tracer release over the Hat Creek Upper Site is shown. This photo is of Test 14; the view is towards the northeast.

REFERENCES

Spangler, T. C., N. E. Graham, and E. L. Hovind, 1977: Plume Simulation Gas Tracer Studies During Winter, Spring, and Summer, 1976, in Upper Hat Creek Valley. NAWC Report AQ-77-13, Vol. I - Technical Report and Vol. II - Field Data. Prepared for B. C. Hydro and Power Authority, Nov. 1977.