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Environment Canada
Water Science and Technology Directorate

Direction générale des sciences et de la technologie, eau
Environnement Canada

Waves and Currents off the East Headland, Toronto

By:
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NWRI Contribution # 03-203

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Waves and Currents off the East Headland, Toronto

M G Skafel
NRWI, Environment Canada,
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During the winter, 2000-2001, the National Water Research Institute deployed current meters off the east shore of the East Headland and Endikement, in support of the Toronto Port Authority (TPA) ongoing monitoring of the stability of the headland. Directional wave information derived from the current meter data was determined and compared with two algorithms of wave hindcasting, JONSWAP and Donelan. The two methods bracketed the wave period and height data. The hindcasted direction deviated from the data by an about expected by shoaling and refraction to the meter location in 14 m of water. The mean currents in about 10 m of water were strongly shore parallel usually over 0.1 m/s and up to 0.7 m/s in strength. Under the influence of west winds a large eddy formed in the lee of the southerly tip, extending over 600 m north from the tip.

NWRI RESEARCH SUMMARY

Plain language title
Waves and currents off the east headland, Toronto

What is the problem and what do sicentists already know about it?
The Toronto Port Authority (TPA) undertook a study to examine all coastal aspects of the stability of the shoreline of the East Headland and Endikement (EHE). No measurements of currents and waves had ever been done in this region.

Why did NWRI do this study?
NWRI undertook this study to provide the TPA with data to understand better the physical environment of the shoreline of the site.

What were the results?
The shoreline of the EHE is a region of high energy both due to currents and waves during winter months.

How will these results be used?
The result have been used by the TPA in developing their plans for ensuring the long term staility of the EHE.

Who were our main partners in the study?
Our partner was the TPA.

Vagues et courants au large du promontoire de l'Est, à Toronto

M G Skafel
INRE, Environnement Canada,
Burlington (Ontario)

Au cours de l'hiver 2000-2001, l'Institut national de recherche sur les eaux a installé des courantomètres dans les eaux de la rive orientale de la zone de retenue des eaux et du promontoire de l'Est, pour aider l'Administration portuaire de Toronto (APT) à surveiller en permanence la stabilité du promontoire. Des informations sur la direction des vagues ont été dérivées des données des courantomètres et comparées à deux algorithmes de rétrospection, JONSWAP et Donelan. Les deux méthodes ont permis de faire des rapprochements entre les données sur la période et la hauteur des vagues. L'écart entre la direction établie par rétrospection et les données correspondait à peu près à ce qui avait été prévu en tenant compte de la présence de hauts-fonds et de la réfraction à l'emplacement des courantomètres par 14 m de fond. Les courants moyens dans environ 10 m d'eau étaient très parallèles au rivage, leur puissance variant habituellement de plus de 0,1 m/s à 0,7 m/s. Sous l'influence des vents d'Ouest, un large remous s'est formé du côté sous le vent de la pointe méridionale, s'étendant à plus de 600 m au nord de la pointe.

Sommaire des recherches de l'INRE

Titre en langage clair
Vagues et courants au large du promontoire de l'Est, Toronto

Quel est le problème et que savent les chercheurs à ce sujet?
L'Administration portuaire de Toronto (APT) a entrepris une étude visant à examiner tous les aspects côtiers de la stabilité du rivage de la zone de retenue des eaux et du promontoire de l'Est. Aucune mesure des courants et des vagues n'avait jamais été prise dans cette région.

Pourquoi l'INRE a-t-il effectué cette étude?
L'INRE a entrepris cette étude pour fournir à l'APT des données permettant de mieux comprendre l'environnement physique du rivage de ce site.

Quels sont les résultats?
Le rivage de la zone de retenue des eaux et du promontoire est une région à fort hydrodynamisme à cause des courants et des vagues durant les mois d'hiver.

Comment ces résultats seront-ils utilisés?
L'APT a utilisé le résultat pour développer ses plans de stabilisation à long terme du promontoire.

Quels étaient nos principaux partenaires dans cette étude?
Notre partenaire a été l'APT.

WAVES AND CURRENTS OFF THE EAST HEADLAND, TORONTO

M G Skafel
NWRI, Environment Canada,
Burlington, ON

ABSTRACT

During the winter, 2000-2001, the National Water Research Institute deployed current meters off the east shore of the East Headland and Endikement, in support of the Toronto Port Authority (TPA) ongoing monitoring of the stability of the headland. The mean currents in about 10 m of water were strongly shore parallel usually over 0.1 m/s and up to over 0.7 m/s in strength. Under the influence of west winds a large eddy formed in the lee of the southerly tip, extending over 600 m north from the tip. Directional wave information derived from the current meter data was determined and compared with two algorithms of wave hindcasting, JONSWAP and Donelan. The two methods bracketed the wave period and height data. The hindcasted direction deviated from the data by about the amount expected due to shoaling and refraction to the meter location.

RÉSUMÉ

Au cours de l'hiver 2000-2001, l'Institut national de recherche sur les eaux a installé des courantomètres dans les eaux de la rive orientale de la zone de retenue des eaux et du promontoire de l'Est, pour aider l'Administration portuaire de Toronto (APT) à surveiller en permanence la stabilité du promontoire. Les courants moyens dans environ 10 m d'eau étaient très parallèles au rivage, leur puissance variant habituellement de plus de 0,1 m/s à 0,7 m/s. Sous l'influence des vents d'Ouest, un large remous s'est formé du côté sous le vent de la pointe méridionale, s'étendant à plus de 600 m au nord de la pointe. Des informations sur la direction des vagues ont été dérivées des données des courantomètres et comparées à deux algorithmes de rétrospection, JONSWAP et Donelan. Les deux méthodes ont permis de faire des rapprochements entre les données sur la période et la hauteur des vagues. L'écart entre la direction établie par rétrospection et les données correspondait à peu près ce qui avait été prévu en tenant compte de la présence de haut-fonds et de la réfraction à l'emplacement des courantomètres.

INTRODUCTION

The East Headland and Endikement (EHE), commonly called the Leslie Street Spit, constructed east of Toronto Island by the Toronto Port Authority (TPA), provides protection for the Outer Harbour, the East Gap, and a confined sediment disposal facility within the artificial headland. The latter consists of three cells to hold contaminated sediments dredged from the Keating Channel and elsewhere as specifically permitted. In March 2000, TPA initiated a study to evaluate all coastal aspects of the shoreline of the EHE to determine what solutions to adopt to ensure its long-term stability (See Lundy and Martorana, 2003). During the winter of 2000-2001, the National Water Research Institute monitored currents and waves off the east shore of the headland, in support of the TPA's ongoing monitoring of the stability and integrity of the headland.

Three acoustic Doppler current profilers (RDI ADCP) and one single point Doppler current meter (Sontek Hydra) were deployed from December 2000 to April 2001 off the east shore of the EHE (Figure 1). The instruments were bottom mounted close to shore, but in water deep enough to ensure they would not be damaged by ice throughout the winter, all in about 10 m of water. One ADCP was positioned off each of hardpoints A and D and one ADCP and the Hydra midway between hardpoints A and B. The ADCPs provided the vertical profile of the currents once per hour in one metre sections. The Hydra provided bursts of 2048 scans at 4 Hz every three hours for the three components of velocity and pressure near the bottom.

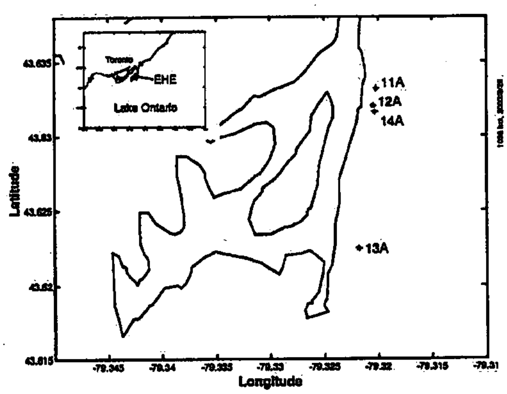

Figure 1. EHE showing locations of ADCPs at Stations 11A, 12A, 13A and the Hydra at 12A

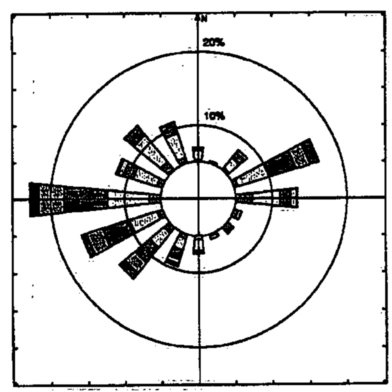

Figure 2. Wind rose from the Toronto Island Airport. The circle is calms (< 5), magenta is 5-10 km/hr, cyan is 10-20, red is 20-30,... Directions are "from".

Wind conditions were obtained from the Environment Canada meteorological station at Toronto Island Airport and are summarized in Figure 2. The dominant wind direction was from the west, followed by WSW and ESE

RESULTS

Currents

The currents were strongly influenced by the bathymetry because of the close proximity to the shore. The principal axes (Emery and Thomson, 2001) for near surface, mid-depth and near bottom currents are shown in Figure 3 for two of the ADCPs. Most of the variance of each was strongly shore parallel, although there was some vertical shear at the northern station. Current roses for the bottom currents at Stations 12A and 13A are shown in Figure 4. The currents at 12A, the more northerly station show strongly bi-directional flow, with

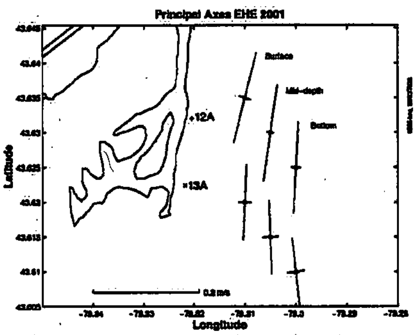

Figure 3. Principal axes analysis of the near surface, mid-depth and near bottom currents at stations 12A and 13A.

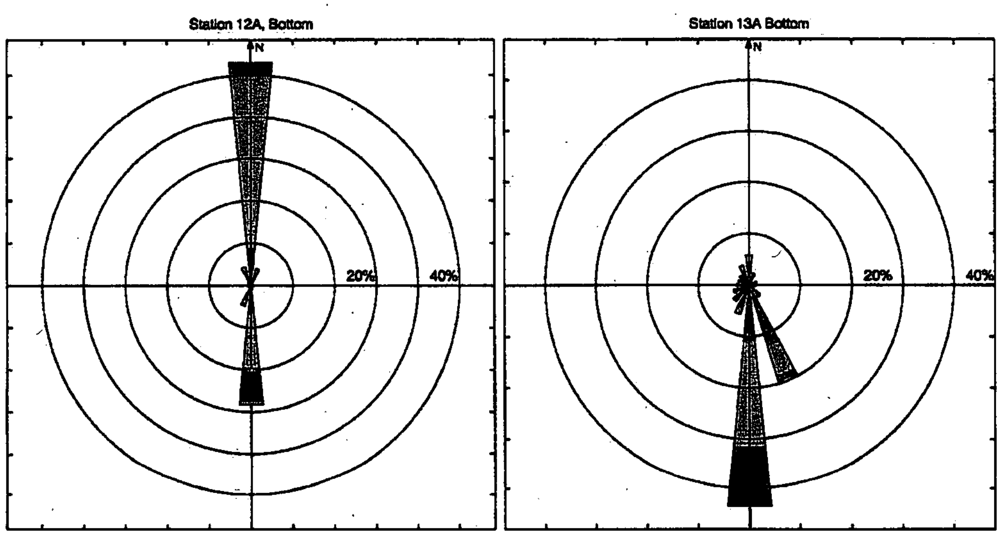

Figure 4. Current roses for the bottom current at Stations 12A (left panel) and 13A (right panel). Magenta is 0.005 to 0.02 m/s; cyan is 0.02 to 0.05; red is 0.05 to 0.1; green is 0.1 to 0.2, blue is 0.2 to 0.5, magenta is 0.5 to 1.0,... Directions are "to".

more occurrences to the north, in keeping with the prevailing westerly winds. The strongest flows were to the south under strong easterly winds, reaching speeds over 0.7 m/s. The currents at the other northerly stations showed similar characteristics (Data from all instruments are available in Skafel, 2001). In contrast, the currents at 13A were mostly to the south, but reaching similar high values. In order to explore more fully the differences in flow between the northern stations and the southern station, the shore parallel bottom flow at stations 12A and 13A are shown in Figure 5 along with the shore parallel winds from the Toronto Island Airport. The shore parallel direction for the winds is taken to be 80°T, the regional shoreline trend, and for the currents to be 10°T, the local shoreline trend. It is clear that, during the winter when there is no significant thermal structure in the lake, the currents are driven directly by wind events. Winds from the east produce westerly currents and winds from the west produce easterly currents. It is evident that the westerly winds do not produce persistent easterly currents at Station 13A as the same winds do at Station 12A. After a strong westerly wind event the current at 13A was eastward for a short period, then it reversed (Julian Days 32 to 40; 57 to 61 – red in Figure 5). Some smaller westerly wind events did not cause any easterly flow (Julian Days 21-30 – green in Figure 5). These flow events opposite the west wind suggest the formation of a separation eddy off the end of the headland. Station 13A was about 600 m from the end of the headland, so the scale of the eddy was at least that great.

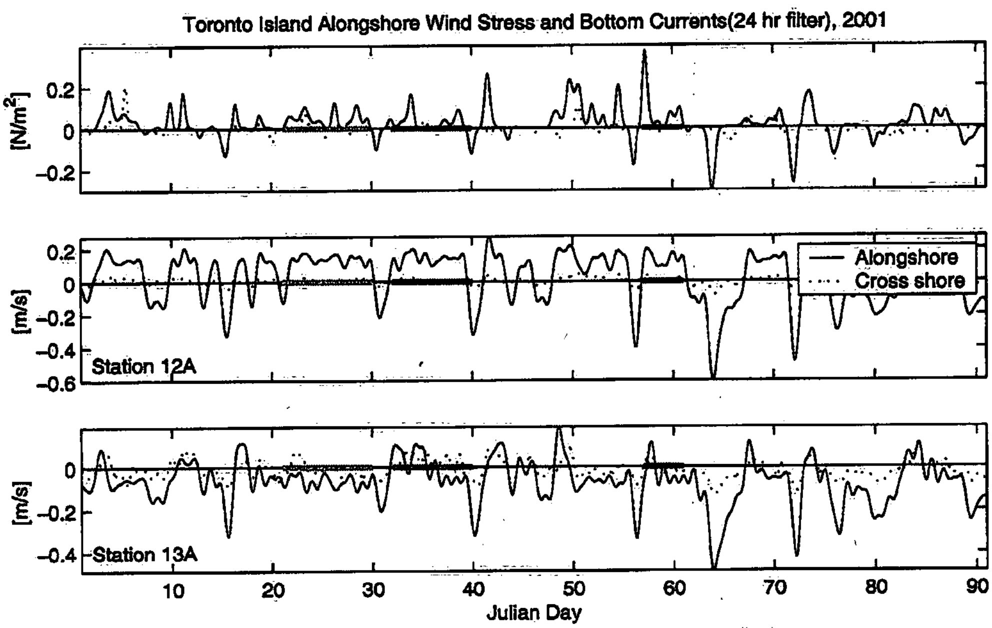

Figure 5. Shore-parallel wind and bottom currents. Positive shore-parallel is to the east and positive cross-shore is onshore.

Waves

The horizontal components of velocity and the pressure near the bottom measured by the single point Hydra meter were used to estimate the wave conditions off the Headland. The method used was a nonlinear one, the iterative maximum likelihood method (IMLM), Pawka (1983), as implemented in the DIrectional WAve SPectra Toolbox (DIWASP) for Matlab (Johnson, 2001). In selecting the wave bursts to be analyzed, the velocity spectra of all bursts were examined, and only those bursts with peak periods greater than about 3 seconds and velocity spectral shapes that were typical of wave induced flow were processed further.

The wave period and height roses for waves greater than 0.3 m are shown in Figure 6. Virtually all of the waves are within the west and WNW bins. All of the waves exhibited relatively narrow single-peaked directional characteristics as shown in the example, Figure 7. The storm wave directions are plotted as a function of wave period in Figure 8.

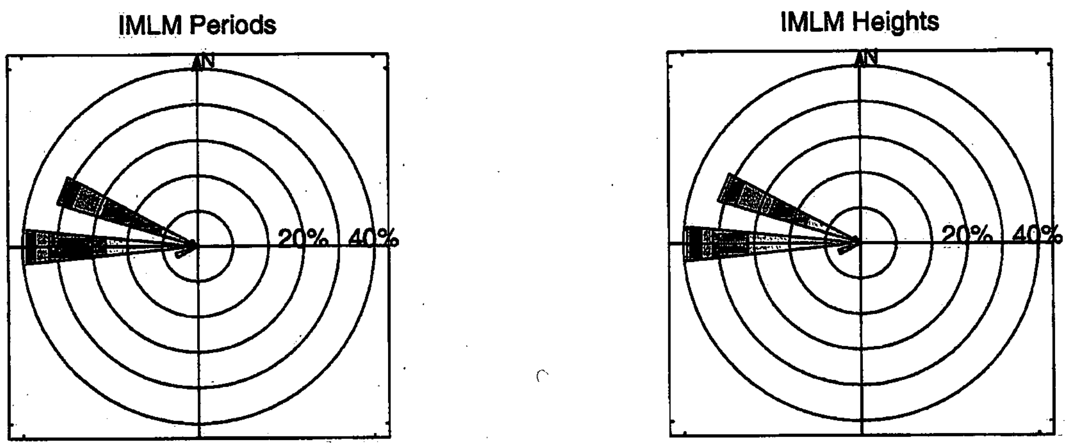

Figure 6 Storm wave roses from current data at station 12A using the IMLM method. For periods the circle is <3 s, magenta is 3-4, cyan 4-5, red 5-6,... , and for heights the circle is <0.3 m, magenta is 0.30-0.5, cyan 0.5-1.0, red 1.0-1.5, green 1.5-2.0,...

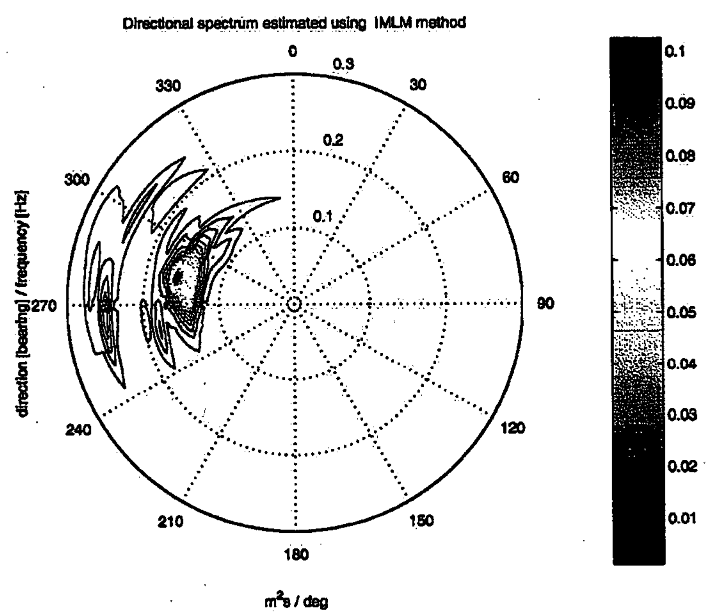

Figure 7. Sample of the directional spectra produced by the DIWASP program.

The shore-normal is 280°T. The mean storm wave direction was 279°T with considerable scatter in the measured results. A clear trend exists with the shorter wave periods directed more to the south and the longer period waves directed more to the north. This result is consistent with increased refraction at the larger wave heights.

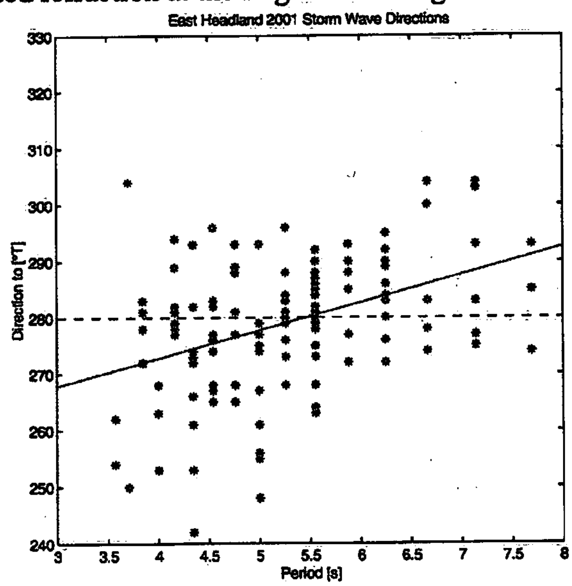

Figure 8. Storm wave directions plotted against wave periods.

The wave data are compared in Figure 9 with two algorithms of wave hindcasting, JONSWAP and Donelan, incorporated in the PHEW model (Fleming et al. 1984). The

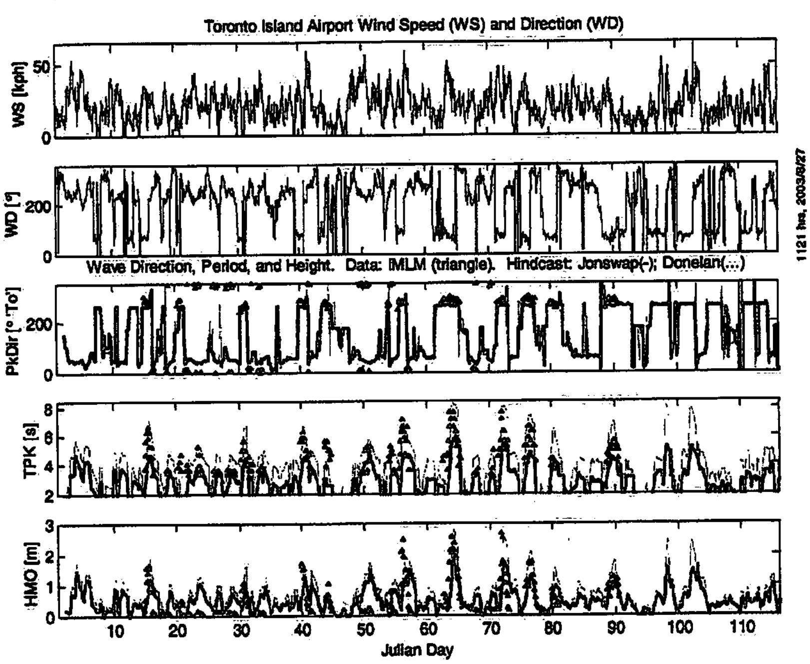

Figure 9. Wind, hindcasted and measured wave data.

major wave events from the east were all tracked by the hindcasting model. Generally speaking the JONSWAP estimated wave heights and periods near the peaks of the storms were slightly larger than the measured waves and the Donelan heights were slightly smaller. The directions of storms from the east were tightly grouped around 267°T for both models, compared to the mean for the measured data some 12° to the north.

DISCUSSION

The East Headland and Endikement is located in a region of high energy, both in terms of currents and waves. Current data from the winter of 2001 off the East Headland, in about 10 m of water, revealed strong shore parallel flow, closely coupled to the wind. Currents were up to about 0.8 m/s and seldom were less than 0.1 m/s. Flows were more common to the north (during west or southwest winds), but the largest currents were typically to the south (easterly winds). These strong southerly flows were accompanied by high waves, so that any sediment suspended by the waves would be quickly transported off into deepwater to the south of the headland. There appeared to be an eddy along the southern end of the headland when the wind was from the west or southwest. During those events the flow was weakly to the south at the southern most current meter, but strongly to the north at the current meters situated farther north.

Estimates of the wave conditions were made from current meter data in 10 m of water. Eight storms out of the east with waves greater than one metre height and five second peak period were observed. Wave direction was such that the waves approach the headland shore nearly normally, with some variation to the south for shorter periods and to the north for longer periods, consistent with increased refraction at longer periods. One of the original design conditions for the headland was that it be oriented such that the waves approach normally to minimize alongshore transport. These measurements indicate that that condition was successfully accomplished. Waves were also hindcasted with two techniques and compared to those from the measured data. The hindcasted heights and periods bracketed the field data, but the direction of travel was about 10°T south of the measured directions, because the hindcast model assumed deep water and hence refraction was not included.

ACKNOWLEDGEMENTS

Toronto Port Authority provided logistical support, Steve Smith of Technical Operations, NWRI deployed the instruments, Bob Rowsell and Doug Doede, NWRI provided technical and data analysis support.

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