TECHNICAL NOTE

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Drift Trajectories of a Floating Human Body Simulated in a Hydraulic Model of Puget Sound

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ABSTRACT: After a young man jumped off a 221-foot (67 meters) high bridge, the drift of the body that beached 20 miles (32 km) away at Alki Point in Seattle, Washington was simulated with a hydraulic model. Simulations for the appropriate time period were performed using a small floating bead to represent the body in the hydraulic model at the University of Washington. Bead movements were videotaped and transferred to Computer Aided Drafting (AutoCAD®) charts on a personal computer. Because of strong tidal currents in the narrow passage under the bridge (The Narrows near Tacoma, WA), small changes in the time of the jump (±30 minutes) made large differences in the distance the body traveled (30 miles; 48 km).

Hydraulic and other types of oceanographic models may be located by contacting technical experts known as physical oceanographers at local universities, and can be utilized to demonstrate trajectories of floating objects and the time required to arrive at selected locations. Potential applications for forensic death investigators include: to be able to set geographic and time limits for searches; determine potential origin of remains found floating or beached; and confirm and correlate information regarding entry into the water and sightings of remains.

KEYWORDS: forensic science, human remains, hydraulic models, Puget Sound, aqueous transport

On Friday the 5th, February 1988, a 22-year-old white male leapt from mid-span of the Tacoma Narrows bridge that connects the city of Tacoma and the Olympic Peninsula (Fig. 1). Two friends, who were also at the site of the jump, later told police the time of the jump was 0300 hours (Pacific Standard Time used throughout this note). They then proceeded to a predesignated location on the eastern shore of the Tacoma Narrows (approximately one kilometer away), where they were to meet their friend when he swam to shore. The two friends waited until 0720 hours before reporting to local police. Ac-

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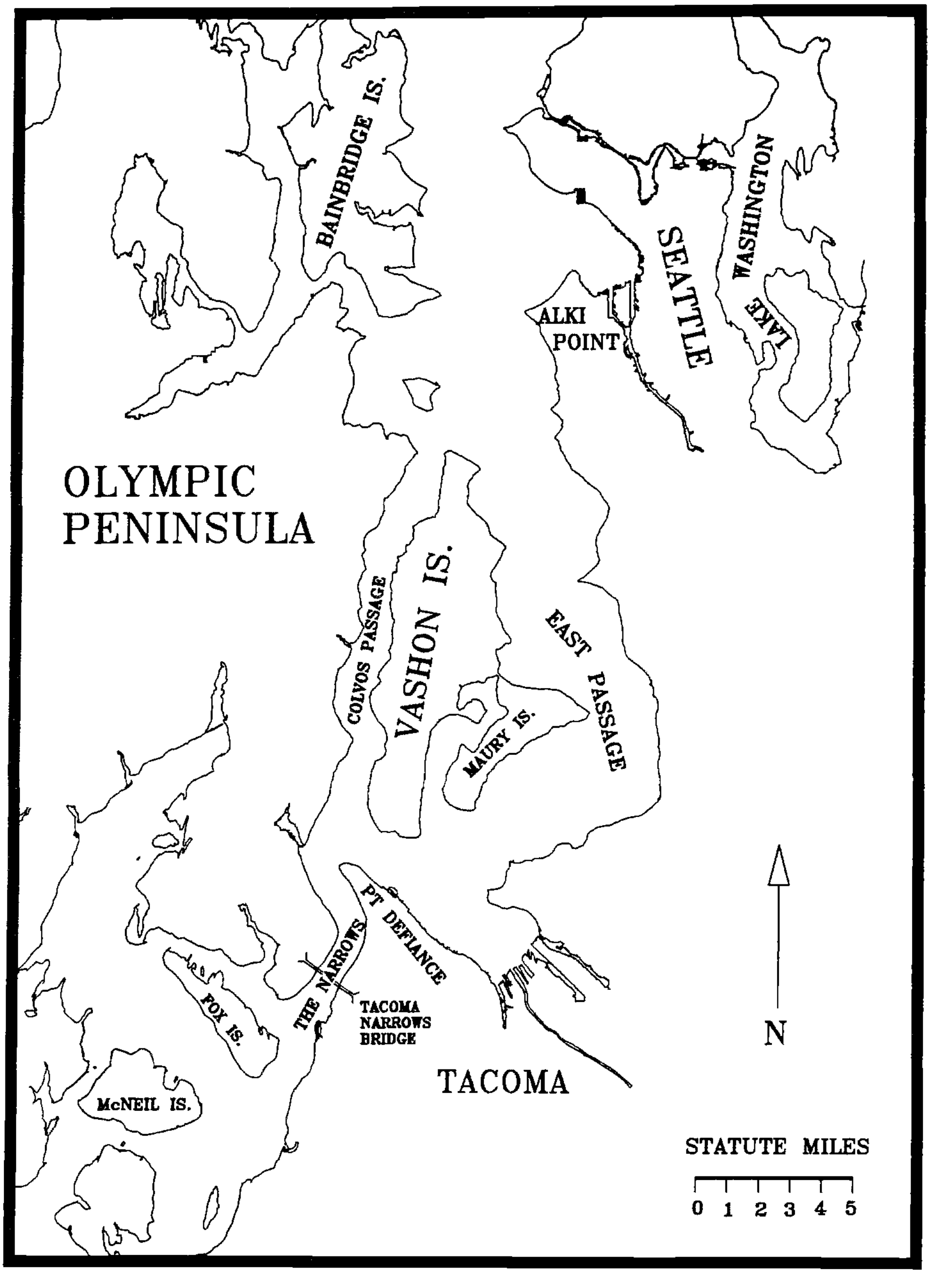

FIG. 1—*Map showing locations discussed in text. Alki Point is in the city of Seattle.*

cording to these friends, the missing man was an experienced "bridge jumper" and jumped from bridges as a sport.

Police reports indicate that a fisherman sighted a body off Fox Island approximately six kilometers south of The Narrows, late in the afternoon of February 5 (Fig. 1). On February 7th at 1125 hours, after a higher-high tide at 0739 (Table 1), the deceased was

TABLE 1—*High and low tides near Seattle for 4–7 February 1988* [2]. *Also listed are the times of the jump and body recovery.*

February 1988	Pacific Standard Time	Tide height (meters)
4th	2357	0.1
5th (Jump)	0300	
	0657	3.7
	1250	1.6
	1802	2.9
6th	0029	0.4
	0715	3.6
	1325	1.3
	1853	2.8
7th	0103	0.7
	0739	3.6
(Body recovered)	1125	
	1404	1.0
	1947	2.7

recovered on the beach near Alki Point in Seattle approximately 20 miles north of the bridge (statute miles used throughout this note; 32 km). At the time of recovery, the body was clad in a sweatshirt, sweat pants, boxer shorts, shoes and socks. Autopsy revealed that there were bilateral injuries to the lungs, liver, left kidney and spleen, as well as fractures of the right wrist and ribs.

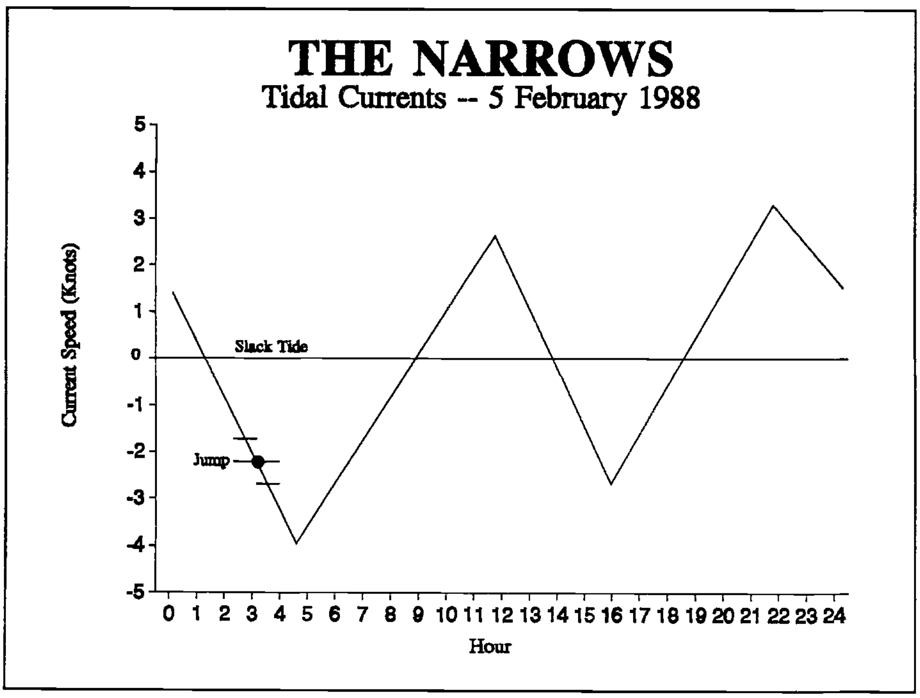

FIG. 2—*Tidal currents predicted by the National Oceanic and Atmospheric Administration* [3] *at midstream in The Narrows during 5 February 1988. Straight line segments connect predictions given for times of slack water and maximum flood (negative) and ebb (positive) tidal currents. Dot indicates approximate time of jump from The Narrows bridge.*

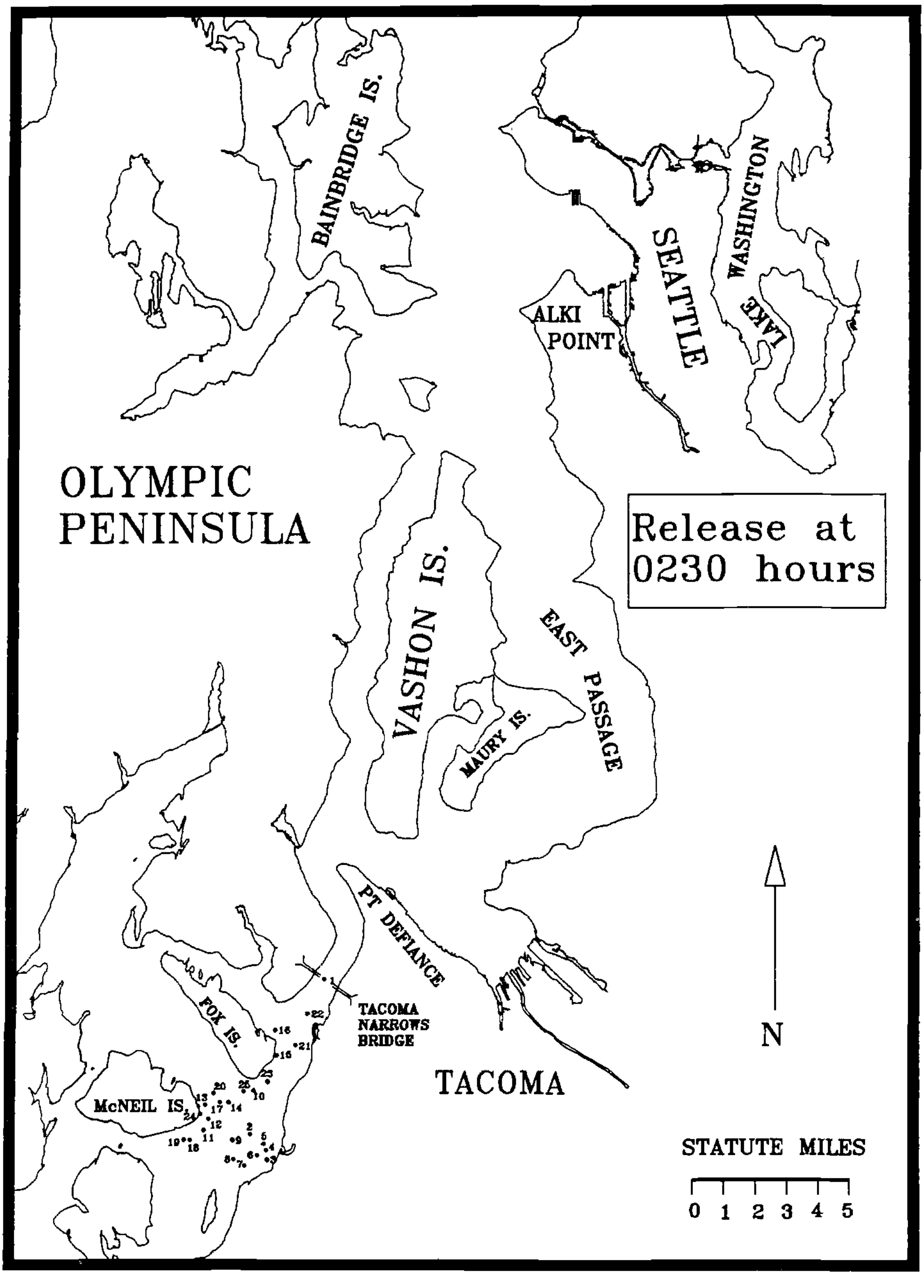

FIG. 3—*Using the Puget Sound hydraulic model, a trajectory of a bead released at approximately 0230 hours on 5 February 1988. Hour 1 corresponds to 0300 and numbers (bead counts) by dots thereafter are spaced at intervals of two hours. Note that after 48 hours (bead count = 25) the bead is still located south of the Tacoma Narrows bridge.*

According to construction drawings the distance from the mid-span of the Narrows Bridge to the water surface is approximately 221 feet (67 meters). Hydrographic charts indicate a water depth of approximately 209 feet (64 meters) at the point of entry [*1*] and mid-channel tidal currents for 5 February 1988, predicted by standard tidal current tables [*3*], are shown in Fig. 2. At the time of the jump (0300 hours), currents in The Narrows were flowing south at approximately 2.3 knots (1.2 meters per second) [*3*]. Winds at Alki Point recorded at three-hour intervals during 5 to 7 October were calm except for a few brief intervals when they were from the north at 3 to 8 knots [*4*]. According to historic records, water temperature at this time of year is near its annual minimum of approximately 8°C (46°F) [*5*]. Fast tidal currents in The Narrows and Colvos Passage cause considerable water turbulence and mix the local waters to near vertical homogeneity such that temperatures and densities near the sea floor are nearly the same as those of the sea surface. If the body was neutrally buoyant, its depth could have varied substantially. That the body was clad and its movement, as shown later, agrees with that of surface currents in the hydraulic model suggests that the body was at the sea surface most of the time between the jump and beaching. Clearly defined flow patterns and several other factors including the known time of entry into the water, the sighting south of the jump, and subsequent recovery of the body north of the bridge, make this case ideal for demonstrating the applicability of hydraulic models for correlation of oceanographic and forensic information.

Methods

Hydraulic models have been used successfully since the 1880s to perform simulations of the tidal currents in estuaries [*6*]. Concrete is often used to simulate the seafloor, where the vertical and horizontal scales are selected based on laws of physics. Water level in the models is made to rise and fall through the use of plungers and water pumps usually placed at the entrance to the estuaries, where the rates of flow are also scaled from physical equations governing tidal currents. They vary in size from areas covering several hundred square feet, to several acres. Experience gained over a century has shown these concrete tidal hydraulic models often to be of considerable accuracy.

The hydraulic model of Puget Sound located at the School of Oceanography, University of Washington was used to simulate the body's drift. The model was constructed in the early 1950s to study currents in Puget Sound [*7,8*]. For more than 40 years it has been in active use as a teaching aid for students, as well as being used in numerous engineering and environmental studies [*9*]. Experience gained by one of us (CCE) from many studies conducted during 25 years has shown that the water currents near the sea surface of the subject area are accurately represented, except close to the shore.

The design of the hydraulic model incorporates a number of physical characteristics, including simulation of tides, that accurately reproduce predictions given in standard tide [*2*] and tidal current [*3*] tables and approximate representation of the outflow of major rivers and the salinity in Puget Sound. For our purpose, simulation was simplified as wind effects could be neglected because local winds were mostly calm during the body's drift.

The model was programmed to simulate tidal currents at the reported time of the jump and was operated for three model-time days (a 24-hour day of model time equals approximately 70 seconds real time; one hour corresponds to approximately 2.9 seconds). To represent the body, a small floating bead with a diameter of approximately 2 mm was used in three experimental runs. As the bead was carried by tidal and mean currents, its location was videotaped and later mapped in a personal computer using Computer Aided Drafting software known as AutoCAD® as shown in Figs. 3 to 5.

Results

Preliminary model runs (not shown) indicated that the correct jump time within a small tolerance is crucial in determining where the body might have traveled, because

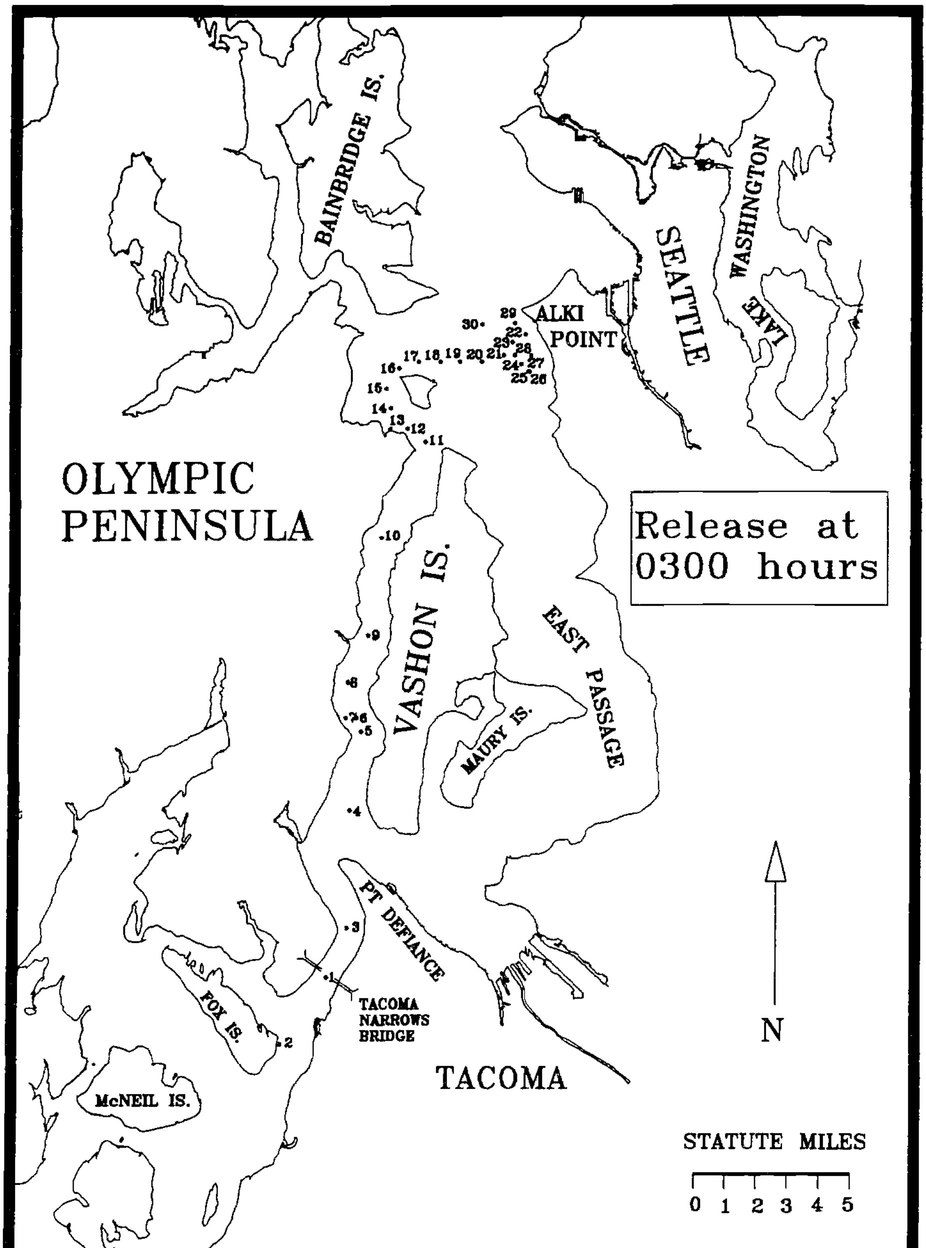

FIG. 4—*A trajectory of a bead released at approximately 0300 hours on 5 February 1988. Hour 1 corresponds to 0300 and numbers (bead counts) by dots thereafter are spaced at intervals of two hours. Note that after two hours (bead count = 2) the bead is located off Fox Island, and that after 56 hours (bead count = 29) the bead is located near Alki Point.*

the tidal currents were changing rapidly at the time of the jump (Fig. 2). Therefore, three simulations, a jump a little earlier than 0300 (approximately 0230), one close to 0300, and another a little later than 0300 (approximately 0330) hours, were investigated (Figs. 3 to 5, respectively). Positions of the bead in the three model runs are shown at two-

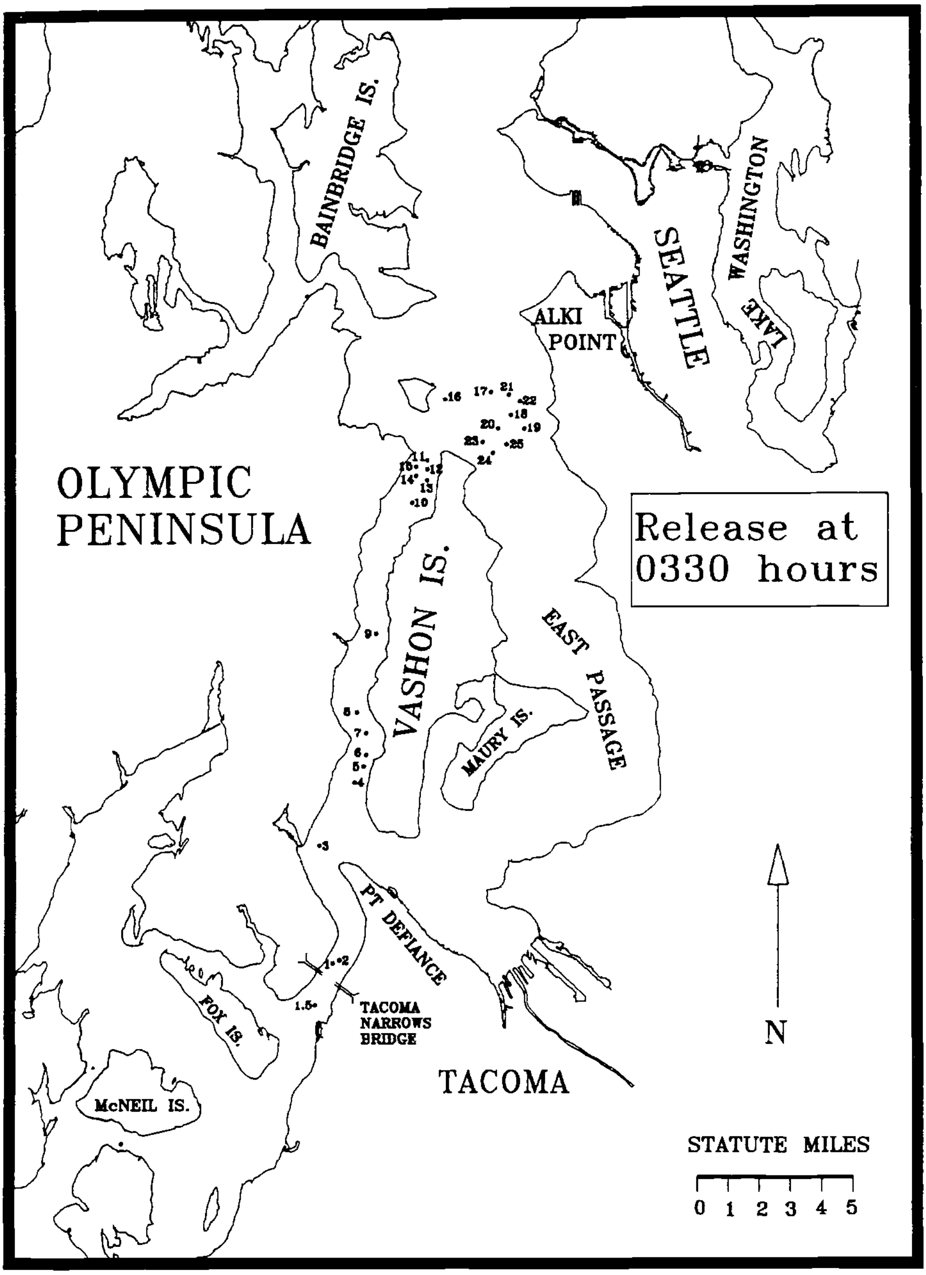

FIG. 5—*A trajectory of a bead released at approximately 0330 hours on 5 February 1988. Hour 1 corresponds to 0300 and numbers (bead counts) by dots thereafter are spaced at intervals of two hours. Note that after a half hour (bead count = 1.5) the bead is located about a mile south of the Tacoma Narrows bridge, and that after 48 hours (bead count = 25), the bead is located off the northern end of Vashon Island.*

hour intervals, with positions numbered consecutively, beginning with "1" at the time of jump (Figs. 3 to 5).

By comparing the bead counts with times when the body was observed, the approximate time of the jump was inferred to be a fraction of an hour earlier than given in the police reports. The first sighting of the body off Fox Island at approximately 1600 hours on 5 February (about 13 hours after the jump) corresponds to a bead count of 7–8. The second sighting (that is, recovery) at 1125 hours on 7 February on Alki Point (about 56 hours after the jump) corresponds to a bead count of 29. However, as the winds were calm, it is likely that the body actually beached at a high water prior to being discovered. For example, the body could have beached at approximately 1853 hours during darkness on 6 February, or at 0739 hours on 7 February. These times correspond to approximately 40 and 53 hours after the jump, or bead counts of 21 and 27–28, respectively. Therefore, the body could have beached at any time between bead counts 21 and 29.

That the jump occurred earlier than (0300 hours) was determined as follows. In the model simulation, the body was off Fox Island at the reported location at bead counts of 15 and 2, corresponding to jump times of 0230 and 0300 hours (Figs. 3 and 4, respectively). For a jump at 0330 the body did not reach Fox Island (Fig. 5). A bead count of 8 for the sighting off Fox Island corresponds to a model time approximately mid-way between counts of 2 and 15 in Figs. 3 and 4, or approximately 15 minutes before 0300 hours.

The effect of a jump a little earlier than 0300, as shown in Figure 4, is to increase the bead count off Fox Island by 6 and to decrease it by 6 to 23 off Alki Point. The count of 23 nearly corresponds with the high water of 6 February mentioned earlier (count = 21). This correlation suggests that the body was in the vicinity of Alki Point shortly after darkness on 6 February. Given the uncertainties with the model, it is possible that the body actually beached at Alki Point during the evening of 6 February, but was not discovered until the morning of 7 February. Also it is possible that the body beached during the night then floated away for a time before being washed ashore.

In the three simulations (Figs. 3 to 5), within two days after the jump, the beads were found as far south as 6 miles from The Narrows Bridge and as far north as 20 miles from The Narrows bridge, off Alki Point. This wide dispersion occurred for jump times spanning one hour (0230–0330), thereby illustrating the sensitivity of the sightings to small changes in the jump time.

Discussion

The hydraulic model does not show with complete reliability where a floating object will travel under all environmental conditions for a number of reasons. Winds are not represented, and within a distance of approximately a quarter inch in the model (equivalent to approximately 0.16 miles of the shore), beads released in the model are repulsed or attracted by the shore because of water surface tension. Despite shortcomings, the model does predict probable trajectories the body could travel and indicates areas that the body is not likely to travel.

Oceanographic models have been constructed for many estuaries and coastal areas of the United States. Some are physical, being constructed mostly of concrete covering substantial areas, and some are numerical, being run on electronic computers. Examples of physical or hydraulic models include the one described in this note for Puget Sound and models on display at the U.S. Army Corps of Engineers Waterways Experiment Station at Vicksburg, Mississippi. Unfortunately, a complete list is not available in a single citation; however, information about models accessible for a given case may be obtained from appropriate oceanographic institutions. Oceanographic institutions are located at intervals along U.S. coasts: for example, West Coast, University of Washington, Oregon State University, and Scripps Institution of Oceanography; East Coast, Woods Hole Oceanographic Institution, Rutgers University, Old Dominion University, and the University of Miami; and Gulf of Mexico, Louisiana State University and Texas A & M University. When contacting universities, technical experts known as "physical oceanographers" should be sought.

Conclusions

Hydraulic models may be used to demonstrate trajectories of floating human remains and to obtain the time required to arrive at certain locations. Applications for forensic death investigators include: sets limits for searches, determines potential origin of floating or beached remains, and correlates information regarding points of water entry and sightings of remains. Using AutoCAD®, the trajectories in the hydraulic model may be superposed with up-to-date field data from other drifting objects, e.g., the ADDAM buoy (Air Deployable Datum Marker) available from Seimac Ltd., Dartmouth, Nova Scotia. This buoy can be configured either as a dominantly current-driven object, similar to a drifting body, or dominantly wind-driven, similar to a liferaft. The buoy may be launched from a plane or boat at the site of an accident, then tracked, using the Global Positioning System (GPS). As the buoy transmits its position hourly to Coast Guard rescue centers via satellite, the results may be updated on AutoCAD® to modify forecasts made with hydraulic models. Since the GPS signal is not dependent on weather, sea state, or daylight, model and real-time data may be combined in ways useful to forensic investigators.

Acknowledgments

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