I. SYNOPSIS

A water circulation study was conducted by DOH staff on October 18, 2005 in order to help determine the source of fecal coliform pollution at its water Station 614. Under the ebb tide conditions observed during this study, it appears that water from the area of the mouth of Cranberry Creek tends to stay longer in the general area of Station 614, and spread out more, than water from the mouth of Deer Creek. These tendencies indicate Cranberry Creek could have a greater impact on water quality at Station 614 than Deer Creek. In contrast, the discharge from Deer Creek could impact water quality at the active northernmost shellfish beds (slightly to the south of Station 614) more than Cranberry Creek. Pollution from the very localized area between the creek mouths may also impact water quality at Station 614.

II. INTRODUCTION

On October 18, 2005 Debby Sargeant and Frank Meriwether of the Shellfish Program in the Washington Department of Health (DOH) conducted a water circulation study in northern Oakland Bay. The purpose of this study was to help determine the influence of Cranberry Creek and Deer Creek on recent elevated fecal coliform results in the very northeastern portion of this bay near Station 614. Results from this study could be useful in helping locate potential sources of pollution and to facilitate remediation efforts.

III. METHODOLOGY

The tide predicted during this study is based on the south portion of Oakland Bay near the City of Shelton. Based on this prediction, high tide (14.3 feet) occurred at 0759 and the subsequent low tide (4.1 feet) occurred at 1408 for the study. This tidal drop of 10.2 feet is similar to the mean tide range of 10.6 feet for Oakland Bay. DOH staff expected that the onset of actual tide
phases in the northern portion of the bay are delayed from the times predicted on the tide chart due to the backup of water in the northern portion of the bay.

Cranberry Creek enters the northeastern portion of the bay on the west, and Deer Creek enters the northeastern portion of the bay on the east. As shown in Figure 1, the USGS map for this specific area indicates that the location of DOH Station 614 is located a couple hundred yards southwest of the northeastern shoreline. However this station, as located by latitude/longitude coordinates, is actually adjacent to the northeastern shoreline. Therefore the USGS map (as displayed in the TOPO mapping system) is inaccurate, as it does not show the true extent of the delta’s land into the bay.

It is also important to note that Station 614 is not located directly over the active shellfish beds in the most northeastern portion of the bay. Two small triangles in each of the attached figures show the approximate location of the northeastern edge and middle of these beds. The width (in a northwest-southeast direction) of these beds is several hundred feet on both sides of the triangles.

Various surface floats and indicators were released in the October study near the mouth of each of the two creeks at two different times in order to observe the path of each discharge in the northern bay. Figure 1 illustrates these two release points (Waypoints 14 and 15), along with DOH Station numbers. The first release of these indicators was at the start of observed ebbing tide, and the second release was about one hour later. Three different types of floats or indicators were used by DOH staff to help identify the pathway of the creeks’ flows, described as follows.

1). A pair of cruciform drogues (surface floats) was released near the mouth of each creek on two occasions (a total of eight drogues was released). Each pair of drogues was released along with a set of oranges (see next paragraph). These drogues consist of cruciform galvanized metal vanes hanging from foam floats. The relative distance between drogues in each pair after release provides an indication of their consistency in following the pathway of the creeks’ flows. The center of the vanes for each drogue was set at approximately one foot below the water surface. Therefore these floats indicate the direction and velocity of water in the bay located slightly beneath its surface. Each drogue was numbered to be able to note its location after its release.

2). Oranges were used to indicate the direction and speed of water in the top two inches or so of the water surface. It was important in this study to assess the pathway of surface water for two reasons. First, freshwater tends to float on top of saline water due to its lighter density. Therefore freshwater from the creeks would tend to stay close to the water surface unless mixing
occurred (from winds for example) with the underlying water. Each orange was labeled in order to note its location after release. Oranges released near the mouth of Cranberry Creek were marked in black, and those released near the mouth of Deer Creek were marked in red. A total of eight oranges was released in a line approximately 100 feet wide at each release. Releasing the oranges in this array helps to demonstrate their relative dispersal pattern as they drifted through the northern portion of the bay. A pair of drogues (see previous paragraph) was released in the middle of each array of oranges.

3). A slug of red tracer dye was released at each release site a little after drogue and orange releases in order to visually observe the dispersal pattern of water in the bay. Approximately three liters of a 50:50 mix of water:Rhodamine WT dye was used in each dye drop. The dye was released in one spot over the side of the boat, rather than in a line release. A sufficient amount of dye was released in order for DOH staff to visually observe the main dye plume as it traveled through the northern portion of the bay. No fluorometer was used in this study to measure concentrations of dye.

DOH staff followed the course of the drogues, oranges and dye through the very northernmost portion of the bay during most of the ebb tide cycle. The study focused on the area northeast of DOH Station 129. Due to the shallowness of the tidal flats in this area, this study had to be conducted at the higher tidal levels. This portion of the ebb tide is appropriate for this study, since marine water samples for stations in the northern bay are also collected by DOH staff on higher tide levels.

Winds can affect on the drift of surface waters and surface floats during circulation studies. DOH staff estimated and noted the apparent wind speed and direction on various occasions during the study.

Rainfall information for Oakland Bay is collected daily at 0800 at the Taylor Shellfish FLUPSY dock. Rainfall in the week prior to the study is as follows:

10/11/05: 0.08 inch
10/12/05: 0.01 inch
10/13/05: 0.22 inch
10/14/05: 0.01 inch
10/15/05: 0.30 inch
10/16/05: 0.04 inch
10/17/05: 0.32 inch
10/18/05: 0.01 inch
IV. RESULTS

The first set of oranges and drogues was released from Waypoint 14 near the mouth of Cranberry Creek at 0840, when the start of ebbing tide was evident. Weather conditions were ideal for a circulation study at this time, with 90% cloud cover, no precipitation or wind. The water surface was also glassy in this portion of northern Oakland Bay at this time.

Wind speeds and directions noted during the study are as follows:

<table>
<thead>
<tr>
<th>TIME</th>
<th>ESTIMATED SPEED (knots)</th>
<th>DIRECTION (from the …)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0850</td>
<td>calm</td>
<td>-</td>
</tr>
<tr>
<td>0908</td>
<td>calm</td>
<td>-</td>
</tr>
<tr>
<td>0924</td>
<td>less than 5 knots (first breeze)</td>
<td>north</td>
</tr>
<tr>
<td>1020</td>
<td>less than 5 knots</td>
<td>north</td>
</tr>
<tr>
<td>1026</td>
<td>less than 5 knots</td>
<td>north</td>
</tr>
<tr>
<td>1058</td>
<td>~ 5 knots</td>
<td>north</td>
</tr>
</tbody>
</table>

The results of the first sets of orange releases are shown in Figure 2 (attached). Two “diamonds” showing the locations of DOH sampling stations 614 and 129 are in the figure, along with triangle markings for the active shellfish beds. The dark dashes in the figure show the general location and spread of the released oranges at particular times. The average speed of the oranges released from near the mouth of Cranberry Creek (from Waypoint 14) was 36 feet per minute (fpm) as of 0859, and 38 fpm at 0930. In contrast, oranges released from near the mouth of Deer Creek (Waypoint 15) traveled at an average speed of 48 fpm as of 0924. Oranges released from Waypoint 14 also tended to spread out in a more east-west pattern than those released from Waypoint 15. Both sets of oranges in the first release appeared to converge near the area of DOH Station 129. No oranges got hung up or attached to any shoreline.

The second sets of oranges were released from Waypoints 14 and 15 at 0948 and 0952, respectively. The directions of their paths and spread are shown in Figure 3. Oranges released from Waypoint 14 averaged 42 fpm as of 1023, and 44 fpm as of 1055. Oranges released from Waypoint 15 averaged 62 fpm as of 1042 and 63 fpm as of 1113. In contrast to the first releases, the orientation of the oranges in both releases was generally parallel to the shoreline of the bay. No oranges got hung up or attached to a shoreline.
Several slugs of dye were released from the same release points as (but slightly later than) the oranges and drogues. Only one slug release of dye occurred at Waypoint 14 because the northern end of the dye plume remained at the release point an hour after the first dye release there. In contrast, dye released from Waypoint 15 left the release area, as indicated in Figure 4. A second slug release of dye occurred at Waypoint 15 about 70 minutes after the first dye release there. The visible dye plumes for all three releases were relatively narrow, usually ten yards wide or less. The greatest width of any portion of dye plume observed in the study was about 80 feet. The leading portion of the dye plume tended to travel at the same speed and direction as the oranges. Many of the oranges were located in or near the leading edge of the visible dye plume that originated from their same release site.

Two pairs of drogues were released at each of the two waypoints during this study. Each pair of drogues stayed close together throughout the study, except for one drogue that got hung up on an attached piece of floating wood. With this exception, none of the drogues in this study were hung up or attached to any shoreline. All drogues traveled at a slower speed, but in the same relative alignment as oranges and the leading edges of the dye plumes. Ripples were evident around the floats of drogues for the first half hour or more after their release, due to faster surface water that flowed past the drogues’ foam floats.

The paths of the first sets of released drogues are shown in Figure 5. The average speeds of the first drogues (#11 and #13) released at Waypoint 14 were 15 fpm and 17 fpm at 0939 and 1018, respectively. These speeds are less than half the average speeds of the oranges released with these drogues. The average speeds of the first drogues (#14 and #16) released at Waypoint 15 were 22 fpm and 21 fpm at 0909 and 0959, respectively. These speeds are about one-half the average speed of the oranges released with these drogues.

The paths of the second pairs of drogues released at the two waypoints are shown in Figure 6. The drogues (#17 and #18) released from Waypoint 14 traveled at average speeds of 13 fpm and 15 fpm as of 1028 and 1101, respectively. The drogues (#19 and #20) released from Waypoint 15 traveled at average speeds of 21 fpm and 20 fpm as of 1031 and 1107, respectively. These average speeds are similar to the average speeds of the first sets of drogues released from these waypoints.

Another observation was made during this study. An apple was dropped at 0852 next to the white PVC pole at the grass island close to DOH Station 614 (as shown on Figure 1) in order to observe the direction of water flow at this specific location. Over the next 15 minutes this apple drifted about 30 yards to the southwest. After that time the apple was not observed.
V. CONCLUSIONS

The circulation study was conducted during a tidal range – the height between high tide and subsequent low tide - that is typical in Oakland Bay. Little or no wind occurred during the study, so that the results are indicative of a water circulation pattern that is relatively unaffected by winds. The results obtained during this study reflect these hydrographic and meteorological conditions. Other tidal and wind conditions could yield results different from those observed in this study.

The flow from Deer Creek appeared to more closely approach the two floats marking the active, northeastern-most shellfish beds than that of Cranberry Creek. However there was no indication in this study that the main discharge from Deer Creek approached the immediate area of Station 614. The near-surface (top two inches or so) of water ebbing south from the mouth of Deer Creek flowed quickly through the area of this study, averaging 48-63 fpm. Water at a one-foot depth discharged from the mouth of this creek appeared to take this same pathway, but at slower speeds (averaging 21-22 fpm). There did not appear to be a rapid lateral dispersion of this creek water in the bay. There was no indication of substantial changes in observed circulation patterns (average speeds, direction, or dispersion) between the first and second releases of surface floats from the mouth of Deer Creek.

The near-surface discharge of water from the mouth of Cranberry Creek did not travel as fast as similar water from Deer Creek, averaging 36-44 fpm. Water at a one-foot depth traveled slower (15-17 fpm) but in the same general pathway as the near surface water. These trends were very similar to those observed for the Deer Creek discharges.

The main difference observed in circulation patterns between the mouth of the creeks was that the water from Cranberry Creek appeared to remain longer in the area of its mouth. This tendency was indicated by a portion of dye remaining at Waypoint 14 (its release point) an hour after its release. In addition, a fairly consistent spreading (in an east-west orientation) of oranges was also observed in this area during the first set of releases. Finally, there was a slight indication (using an apple as a surface water float) that water from the immediate area of Station 614 may join the ebbing water from the mouth of Cranberry Creek. Therefore it appears that, if one creek or the other has a direct influence on water quality at Station 614, Cranberry Creek could more likely affect water quality at this station. There may also be a very localized source of pollution between the mouths of the two creeks that impacts water quality at Station 614. In contrast, water quality over the active shellfish beds immediately south of Station 614 could be
more directly affected by Deer Creek than Cranberry Creek, since the discharge from the mouth of Deer Creek appeared to more closely approach the floats at these beds.

**FIGURE 1. LOCATIONS IN THE CIRCULATION STUDY**
FIGURE 2. FIRST SET OF ORANGE RELEASES
FIGURE 3. SECOND SET OF ORANGE RELEASES
FIGURE 4. TRACER DYE RELEASES

- ORANGES: WP 14 released at 0948
- WP 14 oranges
- 1023
- 1051-1059
- WP 14 oranges
- 1113-1114
- WP 15 oranges
- 1039-1043
- WP 15 oranges
- ORANGES: WP 15 released at 0952

Map created with TOPO® © 2002 National Geographic (www.nationalgeographic.com/topo)
FIGURE 5. THE FIRST SET OF DROGUE RELEASES
FIGURE 6. THE SECOND SET OF DROGUE RELEASES