

APPENDIX II

HISTORICAL BATHYMETRY OF KNIK ARM

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1 INTRODUCTION

This memorandum presents the results of URS' investigation of the long-term stability of the seabed in Knik Arm, as observed in historical surveys from 1941, 1955, 1963, 1974, 1982, 1992 and 2001. The scope of this investigation covered the area near the Cairn Point Depression, a depression of the seabed with a depth of approximately 150 ft. located about one half-mile south of the proposed Knik Arm Bridge at its closest point (Figure 6).

The earliest known survey of Knik Arm performed by the U.S. Coast and Geodetic Survey (USCGS) was that of a 1909 hydrographic survey party lead by H.W. Rhodes (NOAA survey Nos. H03035 to H03044). Tidal current behavior relative to Kodiak was observed and recorded by the party.

This survey was not followed up until a hydrographic survey was requested by Senator Robert Howell, Chair of the Senatorial Committee Investigating the Alaska Railroad. This investigation utilized lead line surveying techniques to identify shoals north of Fire Island and west of Point Woronzof that might be hazardous to shipping approaching the railroad dock at Anchorage. This was completed by a party under F.B.T. Siems in September 1930 (NOAA survey No. H05104).

The first electronic sonar surveys of the upper Cook Inlet took place in the summer of 1941, led by L.C. Wilder using Dorsey No. 3 and 808A Fathometers to hydrographically survey the area of Knik Arm off Anchorage (at the time, pop. 8,000). The surveys, conducted from the U.S. surveying ship Lester Jones and a 30-foot launch named the Black Fox, were completed less than a half year prior to the start of military action in the Pacific theater in World War II (NOAA surveys H06657, H06658, and H06678). A post-war electronic survey by the USCGS, led by L.S. Hubbard, also using the Lester Jones but with an 808J Fathometer, took place in 1947 (off Point Woronzof and Fire Island, NOAA survey No. H07186).

In June 1955, the USCGS completed surveys off Anchorage (by this time a much larger city) from Cairn Point to Fire Island (NOAA survey Nos. H08203 and H08213), under H.C. Applequist from a boat designated Launch 133, using an 808J Fathometer. A further USCGS hydrographic survey ended the decade in June 1959, with a series of echo soundings taking place off Fire Island under Ira Rubottom (NOAA survey No. H08468).

The Port of Anchorage began operation in September 1961 with the start of operations of its first berth. In August 1963, a more extensive U.S. Coast and Geodetic Survey under John O. Boyer took place throughout Knik Arm (NOAA survey Nos. H08727 and H08729), utilizing modernized Raytheon DE723 Fathometers from a 26-foot whaleboat designated Launch 184. A little over a half year later, the Good Friday earthquake hit Southcentral Alaska, devastating Seward, which to that point had been the main port supplying Railbelt Alaska with goods. Following the earthquake, many of the port operations that took place in Seward were moved to Anchorage, changing the character of both harbors. A July 1969 survey under E.A. Taylor completed the decade, with a hydrographic survey for USCGS off Point Woronzof and Fire Island (NOAA survey No. H09076).

In the summer of 1974, an extensive hydrographic survey under K. William Jeffers was conducted from launches attached to the U.S. survey ship Rainier in Knik Arm for the newly formed National Oceanic and Atmospheric Administration (NOAA, Survey Nos. H09438 to

H09445). This survey, using Ross Model 5000 Fathometers, covered as far south as Point Possession on the northern tip of the Kenai Peninsula, and as far north as Birchwood, amid the tidal flats of northern Knik Arm.

Three smaller hydrographic surveys of areas off Fire Island in 1978 (NOAA survey No. H09760), 1980 (NOAA survey No. FE0227), and 1981 (NOAA survey No. H09966) were followed by a larger NOAA hydrographic survey (Nos. H10000, H10012, H10017, and H10018) conducted by Ralph J. Land, again from launches attached to the Rainier but utilizing Ross Finline Fathometers, between Point Possession and Cairn Point. A further NOAA hydrographic survey under John W. Carpenter was conducted in the summer of 1987 near Fire Island (NOAA survey No. H10250).

In the 1990s, studies of Knik Arm were less frequent. A NOAA hydrographic survey took place between Fire Island and Cairn Point in 1992, under Thomas W. Richards from the Rainier, using Raytheon DSF-6000N Echo Sounding Fathometers (NOAA survey Nos. H10430 to H10433). In May 1994, the last single-beam echo sounding survey took place near Point Woronzof and Fire Island under Russell C. Arnold. In 1995, the first multi-beam sonar hydrographic survey in Knik Arm was performed near Fire Island (NOAA survey No. D00124). This was followed by a more extensive hydrographic survey in 2001, by Frederick W. Iversen of Terra Surveys, LLC, under contract to NOAA (surveys No. H11030 and H11031). The survey, carried out from Terra Survey's ships the Sea Ducer and Jolly Pickle using a Reson 8101 Multi-Beam Echo Sounder, ranged from Fire Island to the area of the proposed bridge location.

2 INVESTIGATION METHOD

Historical bathymetry data of Knik Arm were collected from NOAA via its website (<http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html>). The data were then used to generate point locations at each surveyed location, which was then developed into Triangulated Irregular Network (TIN) surfaces in AutoCAD. Contour lines were added to these surfaces, which were all superimposed one on another to create comparative cross sections. These cross sections were then analyzed to identify the long-term stability of surface features on the sea floor of Knik Arm over time.

3 RESULTS

Of the six bathymetric surveys of the area of Knik Arm containing both Cairn Point and the proposed bridge location, three were made before the Good Friday Earthquake of 1964.

Of particular interest to the determination of the stability of the Cairn Point Depression within Knik Arm is **Transect A-A**, which is the transect set at an azimuth of 036° along the longitudinal axis of the Arm (Figure 1). The 1941 survey indicated the existence of a significant shoal at where the deepest portion of the hole is located today, with the bottom of the depression being farther away from the bridge location than it is today. The 1955 survey did not cover the same area as extensively, but the seabed seemed to follow closely to that found by the 1963 survey, performed just before the Good Friday Earthquake. By the later survey, the seabed depression had taken on a configuration more closely associated with today's seabed.

The difference between the 1963 and 1974 surfaces indicated a shift of the bottom of the depression toward the bridge location, but the lip of the depression had not shifted at all from its pre-earthquake location. By 1982 and 1992, the bottom of the hole seemed to shift back away from the bridge location, and observations seemed to indicate that the hole was becoming shallower.

Transects B-B, C-C, D-D, and E-E show the cross depths of the Arm at different points across the Cairn Point Depression.

Transect B-B (Figure 2) covers the area of the hole with the most thorough survey coverage. Again, the 1941 survey showed a much deeper hole in this area than more recent surveys, in some areas by as much as 50 ft. deeper. By 1955, the surface approximated more closely the current surface of the seabed in this section of the Arm; indeed, a shoal had risen approximately 60 ft. over the same period in the center of the channel. There were no major changes between the 1963 pre-earthquake and 1974 surveys. However, in 1982, the center shoal had eroded away as the seabed became closer to uniform in elevation during its periodic rise. By 1992, the side of the Arm furthest away from Anchorage had dropped in elevation by 20 ft. in some places.

Transect C-C (Figure 3), located closest to the narrowest point of the seabed depression, shows again the greatest change between surveys as those between 1941 and later surveys. The 1955 survey was incomplete here, and seemed to indicate possibly a shallower seabed in this area. The balance of the remaining surveys show an unchanging surface in this area, with a general trend toward a more uniform cross channel depth between 1982 and 1992.

Transect D-D (Figure 4), located a little over a half-mile closer to the bridge than C-C, was absent of significant data from 1941 and 1955. What was available from the 1941 survey indicated again a different seabed surface from what was observed in later surveys. The greatest change in surfaces occurred between the 1963 and 1974 surfaces, with a 20 ft. drop occurring in this location, but with a general rise of the seabed since then.

Transect E-E (Figure 5), the closest cross study area of the depression to the bridge location, contained only data from 1963 onward. The seabed elevation dropped greatest, again, between 1963 and 1974 surveys, by as much as 20 ft. However, the surfaces had not undergone greater changes than that during the survey period.

One last cross section of the arm was studied, that of the proposed bridge location at **Transect F-F** (Figure 6). This area was covered in the 1963, 1974, 1992, and 2001 surveys. The differences between the 1963 pre-earthquake and 1974 surveys seemed to indicate a drop in the channel depth of 18 ft at the below the shelf on the Point Mackenzie side, along with up to a 10 ft drop in the shoals occupying portions of the center of the channel. The Anchorage side witnessed an increase of the slope at the edge of the center trench due to erosional shifting of the side trench by 500 feet to the east. In the 1980s, the area appeared to have undergone significant deposition of sedimentation as upward to 15 feet of material settled out in the middle of the channel by 1992. In the 1990s, this deposition reversed slightly, but remained relatively close to the same contours in the 2001 survey.

Table 1. Relative accuracy of data sets, per method

Year	Method	Approx. Area Surveyed	Approx. No. Soundings	Minimum Error
1941	Dorsey No. 3 and 808A Fathometers	8.08 sq. miles	5,203 (644/sq. mile)	± 8 percent [†]
1955	808J Fathometers	3.66 sq. miles	2,897 (791/sq. mile)	± 8 percent [†]
1963	Raytheon DE723 Fathometers	8.29 sq. miles	4,053 (489/sq. mile)	± 0.25 percent [†]
1974	Ross Model 5000 Fathometers	13.80 sq. miles	10,666 (773/sq. mile)	± 0.25 percent [†]
1982	Ross Fineline Fathometers	7.77 sq. miles	5,984 (770/sq. mile)	± 0.01 percent [†]
1992	Raytheon DSF 6000N Fathometers	16.34 sq. miles	22,110 (1,353/sq. mile)	± 0.25 percent [†]
2001	Reson Seabat Multibeam Echo Sounder	9.87 sq. miles	113,140 (11,466/sq. mile)	± 0.5 percent [‡]

[†]Published manufacturer's claims, [‡]IHO Special Order standards

Source: Adams (1942), Umbach (1976), IHO (1998)

4 DISCUSSION

The trend that retained the highest interest for this study of Knik Arm hydrology was the stability of the northern lip of the Cairn Point Depression. Results from the analysis of Transects A-A and E-E indicated that the greatest local change in depth coincided with the Good Friday earthquake of 1964, involving at least a 20-foot drop in elevation below the lip within the depression between 1963 and 1974 surveys. However, by 1992, depositional/erosional equilibrium was again achieved at its pre-earthquake floor depth near the northern lip. No lateral movement meanwhile was noted in any of the surveys for this lip of the Cairn Point Depression (neither closer to nor away from the proposed bridge site) since 1963.

The apparent permanence of the northern lip of the Cairn Point Depression would seem to indicate that the sea floor depression is more likely a feature whose presence is measured in geologic time, rather than one in which modern marine processes play a major role. As such, changes in the sea floor resulting from constriction of a bridge north of Cairn Point should be minor or unnoticeable.

Of worthy notice would be the relative accuracy of measuring instrumentation (Table 1). The 1941 survey was one of the first to use echo sounding, and had employed both the Dorsey No. 3 echo sounder and 808A Fathometer, both pioneers in sonar hydrographic surveying equipment. The Dorsey was the first echo sounder designed for measurements ranging from a few feet to several thousand fathoms. The 808 Fathometers, manufactured by the Submarine Signal Company of Boston, MA, were operational to 160 fathoms. By contrast, the depths experienced in Knik Arm hardly ever extended deeper than 30 fathoms (180 feet).

Between the 1959 survey off Fire Island and the 1963 survey of Knik Arm below Eagle Bay, the 808 Fathometer was replaced by the Raytheon DE723 for USCGS surveys. This equipment remained in use in Knik Arm surveys through the 1974 survey between Point Possession and Birchwood, when

the new Ross Model 5000 Fathometer was introduced to service in Southcentral Alaska. This was replaced in 1978 with the Ross Fineline Fathometer, which was used in upper Cook Inlet bathymetric surveys through 1987, when the Raytheon DSF-6000N Echo Sounder Fathometer was placed into service.

In 1995, NOAA made use of its first multi-beam echo sounding survey equipment in the area of Knik Arm with a survey off Fire Island. After this, NOAA began to subcontract surveying tasks to outside contractors. However, at least for the upper Cook Inlet, the outside contractor, Terra Surveys, LLC, was managed by veterans of NOAA hydrographic survey efforts of years past. As such, no appreciable level of quality was anticipated to have changed between the survey quality of prior NOAA efforts and recent subcontracted products.

The accuracy of early surveying equipment (used in the 1941 and 1955 hydrographic surveys) was figured to be around 8 percent minimum error (Table 1). The accuracy of surveying equipment was similar in the 1960s and 1970s, which manufacturer's claiming their product's minimum error of 0.25 percent. The 1982 survey used Ross Fineline Fathometers, which the manufacturer claimed could achieve an accuracy of 0.1 percent minimum error. After this apex, manufacturer claims seemed to reflect a greater amount of potential error due to instrumentation (perhaps more closely reflecting reality). The multi-beam Reson Seabat, current state-of-the-art sounding equipment, retains a claim of 0.5 percent minimum error on their instrumentation (IHO 1998).

In general, based on these estimates of equipment accuracy, there is a greater chance of error in the 1941 and 1955 surveys. Accuracy, presuming correct usage of equipment by hydrographic survey teams, should have remained consistent from 1963 onward.

5 CONCLUSIONS

Based on historical trends, rates of deposition and erosion in the subsurface of the channel within the area of the bridge is not expected to vary more than 20 feet due to local shifting of shoals across the bridge alignment location. The Cairn Point Depression, also based on historical trends, is expected to remain a stable feature in either of the build options, or the no-build option.

6 REFERENCES

Adams, K.T. 1942. *Hydrographic Manual*. U.S. Coast and Geodetic Survey, Special Publication No. 143.

International Hydrographic Organization. 1998. *IHO Standards for Hydrographic Surveys*. 4th Ed. Special Publication No. 44. April.

Umbach, M. J. 1976. *Hydrographic Manual*. National Oceanic and Atmospheric Administration. July 4.