11. Perform Deep Water Wave Analysis

Obtain information on fetches from all directions for analysis of the waves that influence harbor and entrance channel designs. It is possible to predict the wave climate that may affect the harbor site given wind speed, duration and fetch. Careful consideration of winds from all directions is critical. Shorter fetches, often overlooked, may result in the greatest disturbance in the basin. Wave analysis is necessary for the structural design of protective breakwaters, calculation of wave disturbance in the mooring basin, and longshore transport of sediments.

11.10 Local Design Wave

Analysis of local design waves is necessary to design the breakwater structure and determine inner harbor wave disturbance. Understanding local wind characteristics and the methods for calculating wind/wave forces at the proposed harbor site is critical. Alaska's coastline is complex and a simple numerical analysis may limit our understanding. Numerical models that can evaluate refraction, diffraction, and shoaling may be required if bottom features affect waves at a proposed site.

Complete LOCAL DESIGN FETCH analysis:

1) For design of all protective structures, and to define wave disturbance in the basin
2) If previous analyses were done. Re-check them for accuracy. Evaluate your confidence in the analyses.

Note 1. If present, long-period swell may determine design conditions for the inner basin wave disturbance.

Note 2. The fetch for local design waves is usually less than about 50 miles. Fetch limited analysis is applicable and waves are generated over a direct line of site.

Note 3. If the fetch length is greater than about 50 miles, storm duration may influence the design.

REFERENCES:

1. U.S. Army Corps of Engineers, Dept. of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. Vol. 1. Chapter 3. Pg. 3-39.

11.11 Delineate Fetches (Local Design Fetch)

Local fetches combined with wind speed and duration usually determine the design wave for the protective structures. The relationship between local fetches and the entrance channel configuration is important to maintain inner basin wave disturbance within the acceptable criteria.

Consider in LOCAL FETCH DELINEATION:

1) ALL local fetches that may generate waves of over about 1 foot. This may include fetches as little as 500 feet in directions of high concentrated winds. Always evaluate any fetch greater than 1,000 feet.

2) Steep, short-period waves generated over short fetches. They can be particularly damaging to small skiffs. They may also stress float hinges, encrust floats with ice, or erode unprotected areas of basin perimeter shoreline.

Note 1. Generate a **"Wave Rose"** at the harbor entrance showing relative wave height for directions of roughly 12-degree increments (i.e. W, WNW, NW, etc.) for a full 360° exposure. This is the best visual tool to document and analyze waves generated in all directions.

Note 2. Long narrow fetches require special consideration when calculating the effective fetch and should be used with caution.

REFERENCES:

1. U.S. Army Corps of Engineers, Dept. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. Vol. 1. Chapter 3.

11.12 Estimate Winds (Local Design Fetch)

Wind velocity over local fetches determines the local design wave. Recurrence intervals at 50 and 100 years are common for the structural aspects of design. Shorter intervals of one year or less are considered when evaluating the wave disturbance in the basin. Winds' effects should be considered for vessel navigation and loading on mooring piles as well as for wave growth.

Consider in ESTIMATING WINDS:

1) Obtaining accurate and relevant wind data to estimate wave conditions with a 50-year recurrence interval

2) Long-term wind records may only exist at sites that are miles away from the project. Since winds are site-specific, local data need to be collected.

3) It may be possible to place an anemometer at the site for one or two seasons. These records would then be correlated with longer-term weather station data to estimating recurrence intervals.

Note 1. Hind casting methods assume uniform winds over the entire fetch.

Note 2. Identify the wind that blows across the entire design fetch. The temporal and spatial variation of this wind is seldom known.

Note 3. There are seven steps used to convert measured wind speeds to a wind stress factor used in wave calculation.

REFERENCES:

1. U.S. Army Corps of Engineers, Dept. of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. Vol. 1. Chapter 3.
2. Tobiasson, B.O. & Kollmeyer, R.C. 1991. *Marinas and Small Craft Harbors.* New York: Van Nostrand Reinhold. Pg. 103-134.
3. National Climatic Data Center ("Climatic Atlas"). 1988. Asheville North Carolina.
4. NWS (National Weather Service).

11.13 Estimate Wave Height (Local Design Fetch)

Analyzing wave growth over local fetches is essential for proper design of protective structures and estimating wave disturbance in a harbor. This wave field establishes the type of breakwater(s) required and structural requirements.

WAVE HEIGHT considerations using local design fetch should consider:

1) For simple fetches, with relatively constant depth up to the face of the breakwater, using radials and wave growth curves is generally acceptable.

2) If the fetch geometry is complex and/or the bottom is shallow and irregular, a numerical model such as "STWAVE" may be required to determine effects of refraction and shoaling.

Note 1. If the breakwater structure is in shallow water, the wave height may be **"Depth limited,** in which case it will break on or before reaching the structure." See Reference 1, Sect. VI.

Note 2. For structural design, recurrence intervals of 50 to 100 years are recommended. Waves higher than the significant wave ($H_{1/3}$) may also be recommended depending on structure (i.e. H_{10} for rubble breakwaters, H_1 for barriers).

Note 3. For wave distribution in a basin, consider more frequent recurrence intervals such as yearly, monthly, or even weekly. See Inner Harbor Wave Criteria (Chapter 15).

REFERENCES:

1. U.S. Army Corps of Engineers, Dept. of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. Vol. 1. Chapter 3.
2. Tobiasson, B.O. & Kollmeyer, R.C. 1991. *Marinas and Small Craft Harbors.* New York: Van Nostrand Reinhold. Pg. 103-134.
3. Inner Harbor Wave Criteria, Chapter 15.

11.20 Nonlocal Fetches (Swell)

Outlying storms in the open ocean or other large water bodies create waves that travel many miles and decay as they travel inland. Although amplitude decreases with time and distance, the period remains constant. Amplitudes of only a few inches can cause horizontal surge and resonant effects within a basin.

Consider NONLOCAL FETCH wave analysis if:

1) The proposed harbor site is subjected to deep-water swell
2) The site is near a large body of water where wave periods exceeding about 6 seconds may be generated

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Note 1. Effects of swell are most often associated with wave disturbance in the basin rather than structural design of breakwaters.

Note 2. Floating breakwaters and curtain wall wave barriers are generally ineffective against swell.

Note 3. Unit-to-unit connections in a float system must accommodate continuous vertical, lateral, and torsional forces as the system is subjected to the six degrees of freedom (heave, yaw, pitch, sway, roll, and surge).

Note 4. Larger vessels are particularly susceptible to problems associated with swell in the harbor. Vessels moored in a harbor use lines to absorb the forces caused by winds, currents, and waves. Short-period waves affect smaller vessels; long-period waves affect larger vessels. Smaller vessels ride over large waves, whereas larger vessels may resonate with certain frequencies induced by long waves causing excessive loads on the mooring system.

Note 5. Harbors subject to swell should moor the vessels aligned with the wave direction, and avoid steep reflective surfaces. Parallel boundaries may also induce resonance and should be avoided.

Note 6. Wave criteria for swell must consider horizontal wave motions (see Sec. 15.00).

REFERENCES:

1. U.S. Army Corps of Engineers, Dept. of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. Vol. 1, Pg. 1-6,13,15, 2-4, 3-4,24,43,77,106.
2. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg. 94.
3. Tobiasson, B.O. & Kollmeyer, R.C. 1991. *Marinas and Small Craft Harbors.* New York: Van Nostrand Reinhold. Pg. 110, 160.
4. Per Bruun, et al. 1981. *Port Engineering, Third Edition.* Texas: Gulf Publishing Company. pp. 342-348.

11.21 Delineate Fetches (Nonlocal Fetch)

Nonlocal fetches are generally associated with storm systems moving across open water. The fetch is limited by the size of the storm system and distance over water, not by landmasses. These fetches can be estimated from synoptic weather charts, but they are normally determined using computer models. Nonlocal fetches are difficult to predict with complete confidence. The complex Alaskan coastline may limit methods used in wave development. They must consider the basin geometry in determining the radial fetch lengths.

Consider including DELINEATING FETCH for nonlocal wave analysis:

1) When long period swell is diffracted or refracted into a selected site and it could be a determining factor for structural design and wave disturbance in the basin.

Note 1. Design the basin to eliminate swell.

Note 2. If swell enters the basin, design the float system to withstand the motions and forces associated with surge. Of particular interest are connections and wear surfaces that may fail from cyclic loading.

Note 3. Vessels should be oriented into the wave to minimize the mooring loads.

REFERENCES:

1. U.S. Army Corps of Engineers, Dept. of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. Vol. 1. Chapter 3.
2. ASCE Manual No.50. Task Committee on Marinas 2000. 1982. *Planning and Design Guidelines for Small Craft Harbors.* New York. Pg. 87-98.
3. Tobiasson, B.O. & Kollmeyer, R.C. 1991. *Marinas and Small Craft Harbors.* New York: Van Nostrand Reinhold. Pg. 108-110, 124-131.
4. Per Bruun, et al. 1981. *Port Engineering, Third Edition.* Texas: Gulf Publishing Company. pp. 342-348.

11.22 Estimate Winds (Nonlocal Fetch)

Synoptic weather charts are derived from barometric pressure gradients. These geostrophic winds are the best simple estimates of true winds in the free atmosphere. Geostrophic winds are converted to velocities measured at a height of 10 meters. Finally, the velocities are adjusted to get the wind stress factor used in design.

Make ESTIMATES OF WIND for nonlocal fetches:

1) When nonlocal waves generate a surge in a basin that must be factored into the design
2) When a site is near or adjacent to a large water body

Note 1. Shifting winds at a site may produce a cross-sea condition. Adding wave trains together will result in a higher wave. This condition occurs in relatively open areas, such as in the Bering Sea.

Note 2. Geostrophic winds must be adjusted similarly to local winds. There are eight steps in this procedure.

REFERENCES:

1. U.S. Army Corps of Engineers, Dept. of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. Vol. 1. Chapter 3.

11.23 Estimate Wave Height (Nonlocal Fetch)

Combine fetch and winds. Duration is significant in estimating these long period waves.

Consider WAVE HEIGHT for nonlocal fetches when:

1) A nonlocal fetch is a design factor

2) Normally determined with an appropriate computer model

Note 1. Check offshore NOAA buoys for historical wave statistics. You can often adjust this data for the project site using the proper wave model.

Note 2. The wave period is equally important to height when evaluating the effects of long period waves.

REFERENCES:

1. U.S. Army Corps of Engineers, Dept. of the Army. 1984. *Shore Protection Manual.* CERC. Vicksburg, Mississippi. Vol. 1. Chapter 3.

11.30 Secondary Fetches

Breakwater stability and performance is generally based on the fetch generating the largest wave at the harbor site. Shorter length, secondary fetches can also generate waves that may exceed inner harbor wave disturbance criteria. Secondary fetches are often overlooked because the distance over which they occur is not considered critical for the breakwater design.

Consider SECONDARY FETCHES when:

1) They may generate waves in the mooring area that exceed the criteria in Sect. 15 (Inner Harbor Wave Criteria)

Note 1. These secondary fetches will generally be identified by a "Wave Rose" that evaluates the full 360 degrees of exposure created in 11.11.

Note 2. Any fetch over 1,000 feet is normally sufficient to generate waves exceeding design criteria. Fetches on the order of 500 feet aligned with high winds will exceed criteria for small vessels tied abeam to the wave direction.

Note 3. When evaluating the wave disturbance in the basin , check for secondary fetches. These fetches are often overlooked. If only one wave is used in design, it is probable that secondary fetches haven't been properly identified.

REFERENCES:

1. Smith, Harvey N., Department of Transportation and Public Facilities, (Department observations of Port Lions, Cordova, Sitka, and other harbors.)