An Analysis of Nitrogen Loads to Hood Canal

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Preliminary results, subject to revision

Revised based on meeting of May 13, 2004

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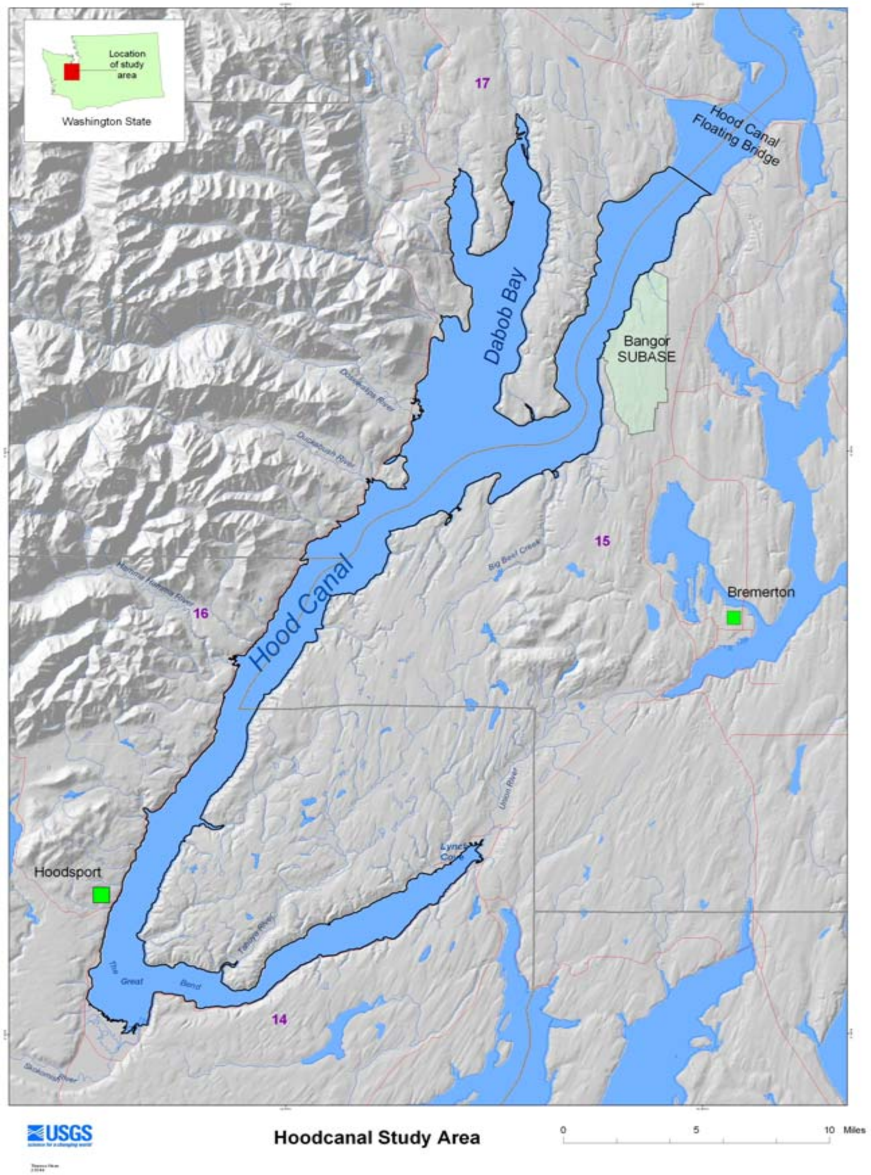
Objective

- **Assess sources and determine loads of nitrogen compounds discharged to Hood Canal**



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General Approach

1. Make initial estimates of nitrogen loading using available data and information
2. Design and conduct focus studies to better quantify loading from major sources and/or to sensitive areas of Hood Canal
3. Improve the initial load estimates using the results of the focus studies

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Nitrogen Loads From River and Stream Basins to Hood Canal

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Objectives

- Estimate annual and monthly inorganic nitrogen load to the Hood Canal from streamflow and regional ground water for each river and stream basin draining to the canal including shoreline catchments with ephemeral streams.
- These loads do not include direct inputs to the canal (e.g., some stormwater runoff, fish carcasses, shoreline septic effluent).

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Approach for Calculating Surface-Water and Regional Ground-Water Loads

LOAD = FLOW x CONCENTRATION x TIME

FLOW

- Streamflow (Qsw) was estimated from streamflow records and regional streamflow-drainage area relations.
- Ground-water flow (Qgw) estimated from mass balance.

CONCENTRATION

- Inorganic nitrogen concentrations [N] were compiled from Department of Ecology, U.S. Environmental Protection Agency, and U.S. Geological Survey data.

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Hood Canal Watershed

Total drainage area of 1,020 sq. miles

Four distinct hydroclimatic regions

1. **Lowland rivers (Tahuya, Union, Dewatto) and streams on the Kitsap peninsula, south shore, and east shore**
2. **North Olympic rivers (Big Quilcene, Little Quilcene) and streams**
3. **South Olympic rivers (Dosewallips, Duckabush, Hamma Hamma)**
4. **Skokomish River**

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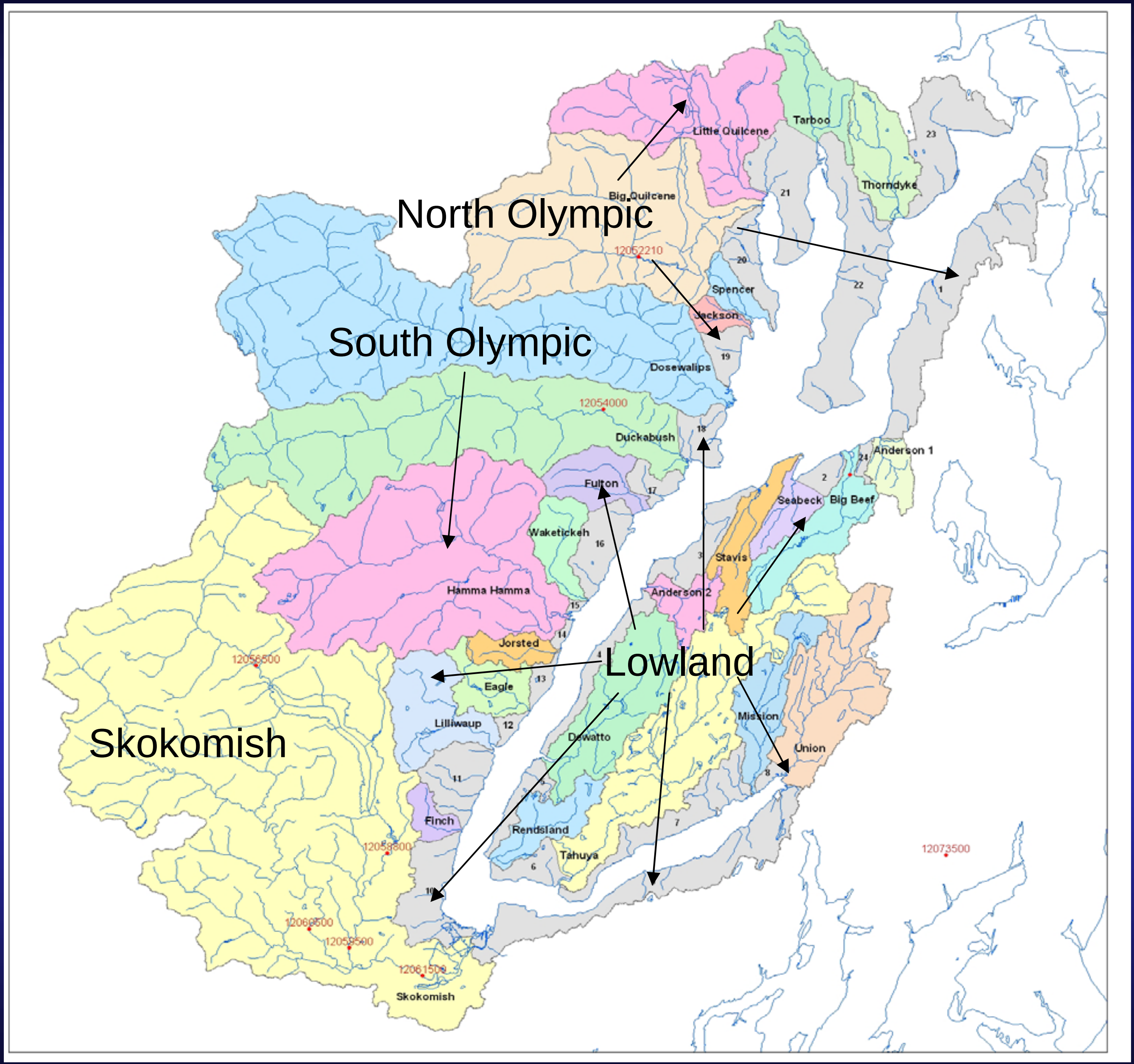
Delineated 26 river and stream basins and 24 shoreline catchments that include small streams



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Streamflow Estimates for 1971-2002

- Streamflow records were used to estimate mean streamflow for the Skokomish River, south Olympic Rivers (Dosewallips, Duckabush, Hamma Hamma), Big Quilcene River, and Big Beef Creek.
- Streamflow records from 23 gages in the Hood Canal watershed were used to develop “area-streamflow” relations for the other rivers and streams in the Lowland and North Olympic regions.
- Streamflow records were used to construct monthly distributions of streamflow for Lowland, Skokomish, and North/South Olympic regions.

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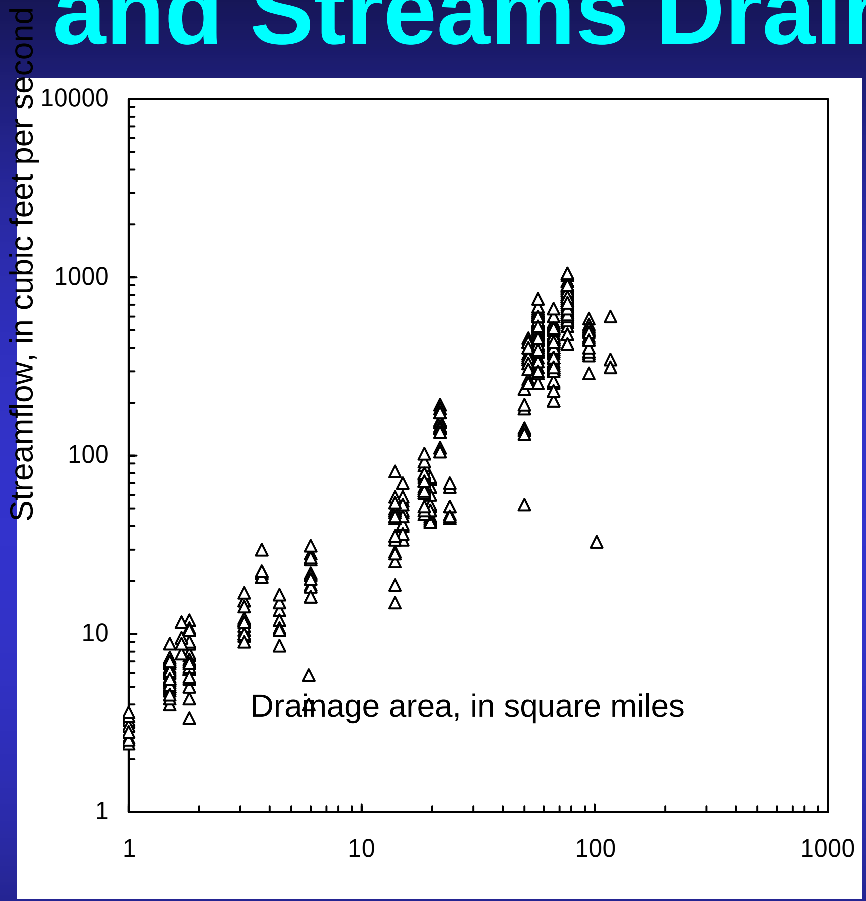
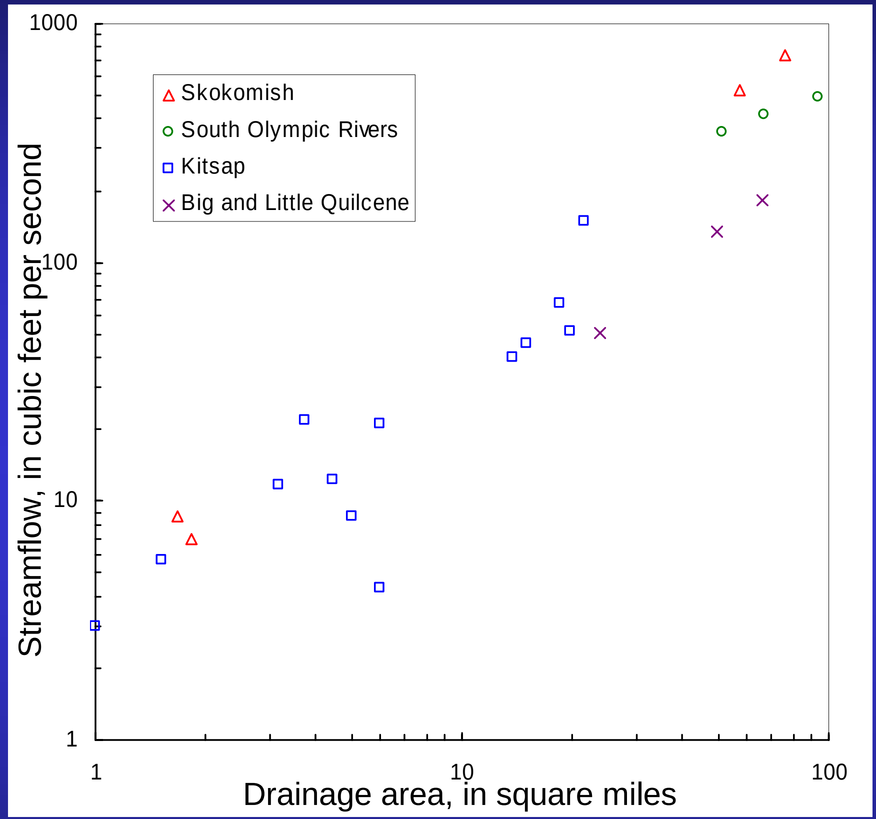
Streamflow and Drainage Area for Rivers and Streams Draining to Hood Canal



Annual mean streamflow, various years of record



Mean streamflow, 1971-2002

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Streamflow Estimates for Ungaged Rivers and Streams

- **Lowland rivers and streams**

$$Qsw = 2.8\ A^{1.04}$$

- **North Olympic rivers and streams**

$$Qsw = 0.9\ A^{1.27}$$

Qsw = Mean streamflow for 1971 – 2002 in cubic feet per second.

A = Drainage area in square miles.

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Mean Streamflow for 1971-2002

River or stream	Mean streamflow (cfs)		Shoreline catchments	Mean streamflow (cfs)
Anderson 1	14			
Anderson 2	19		Shore 1	20
Big Beef	38	USGS gage 12069550	Shore 2	6
Big Quilcene	193	USGS gage 12052500	Shore 3	17
Dewatto	73		Shore 4	13
Dosewallips	618	USGS gage 12053000	Shore 5	9
Duckabush	483	USGS gage 12054000	Shore 6	10
Eagle	24		Shore 7	28
Finch	10		Shore 8	2
Fulton	26		Shore 9	52
Hamma Hamma	578	USGS gage 12054500	Shore 10	956 (includes Lake Cushman)
Jackson	3		Shore 11	22
Jorsted	14		Shore 12	3
Lilliwaup	50		Shore 13	5
Little Quilcene	88		Shore 14	2
Mission	38		Shore 15	1
Rendsland	27		Shore 16	19
Seabeck	17		Shore 17	8
Skokomish	1276	USGS gage 12061500	Shore 18	12
Spencer	5		Shore 19	3
Stavis	30		Shore 20	5
Tahuya	152		Shore 21	10
Tarboo	21		Shore 22	19
Thorndyke	22		Shore 23	11
Union	82		Shore 24	2
Waketickeh	23			

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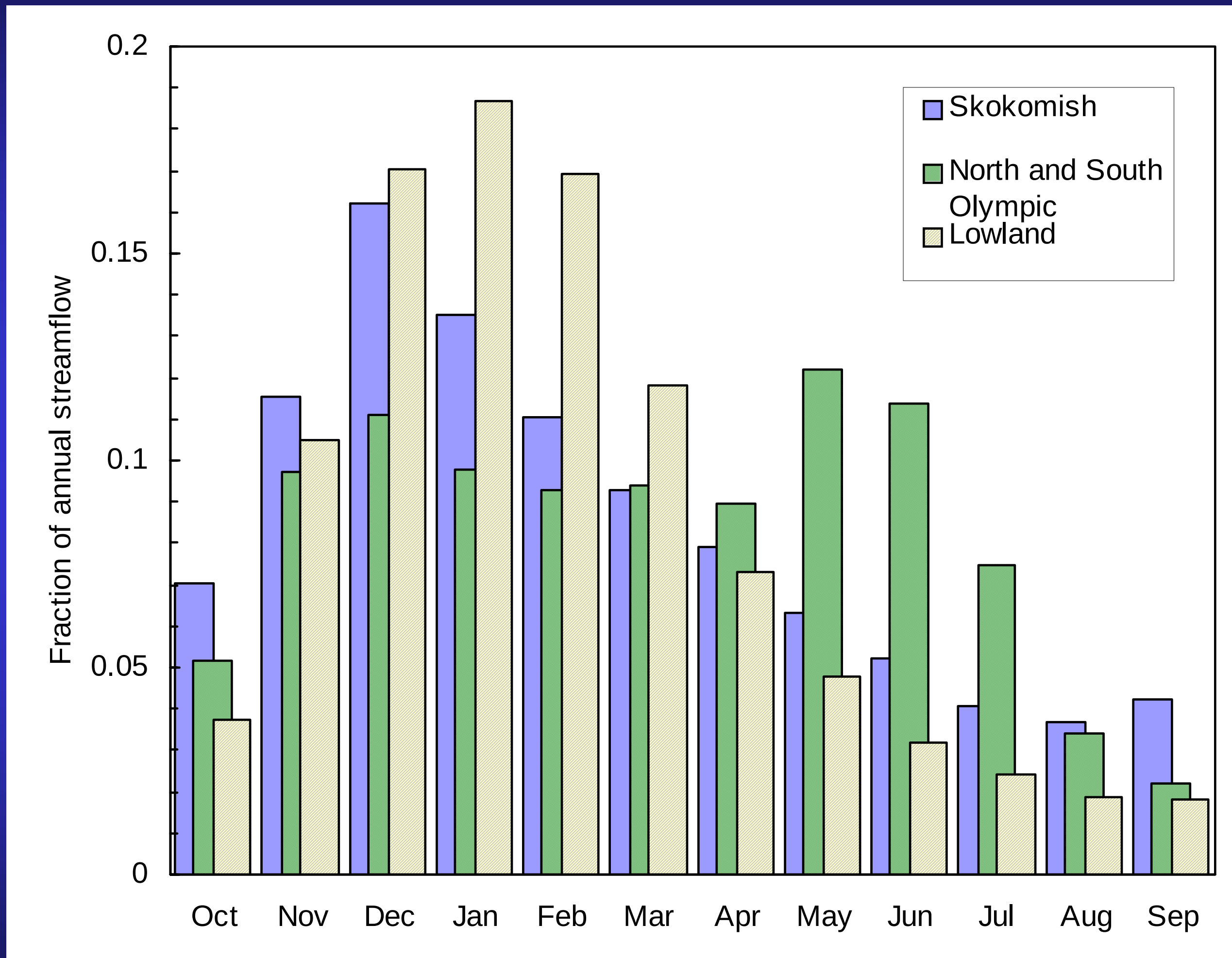
Monthly Distribution of Streamflow



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Nitrogen Concentrations

- Water-quality records were available for 9 rivers and streams.
- Records span from 1959 to 2002.
- Number of samples vary from 12 (Tahuya and Union Rivers) to 311 (Skokomish River).
- Combined NH_3, NO_2, and NO_3, reported as mg N per liter.
- Concentrations of total nitrogen were approximately 23 percent more than the concentrations of inorganic nitrogen.

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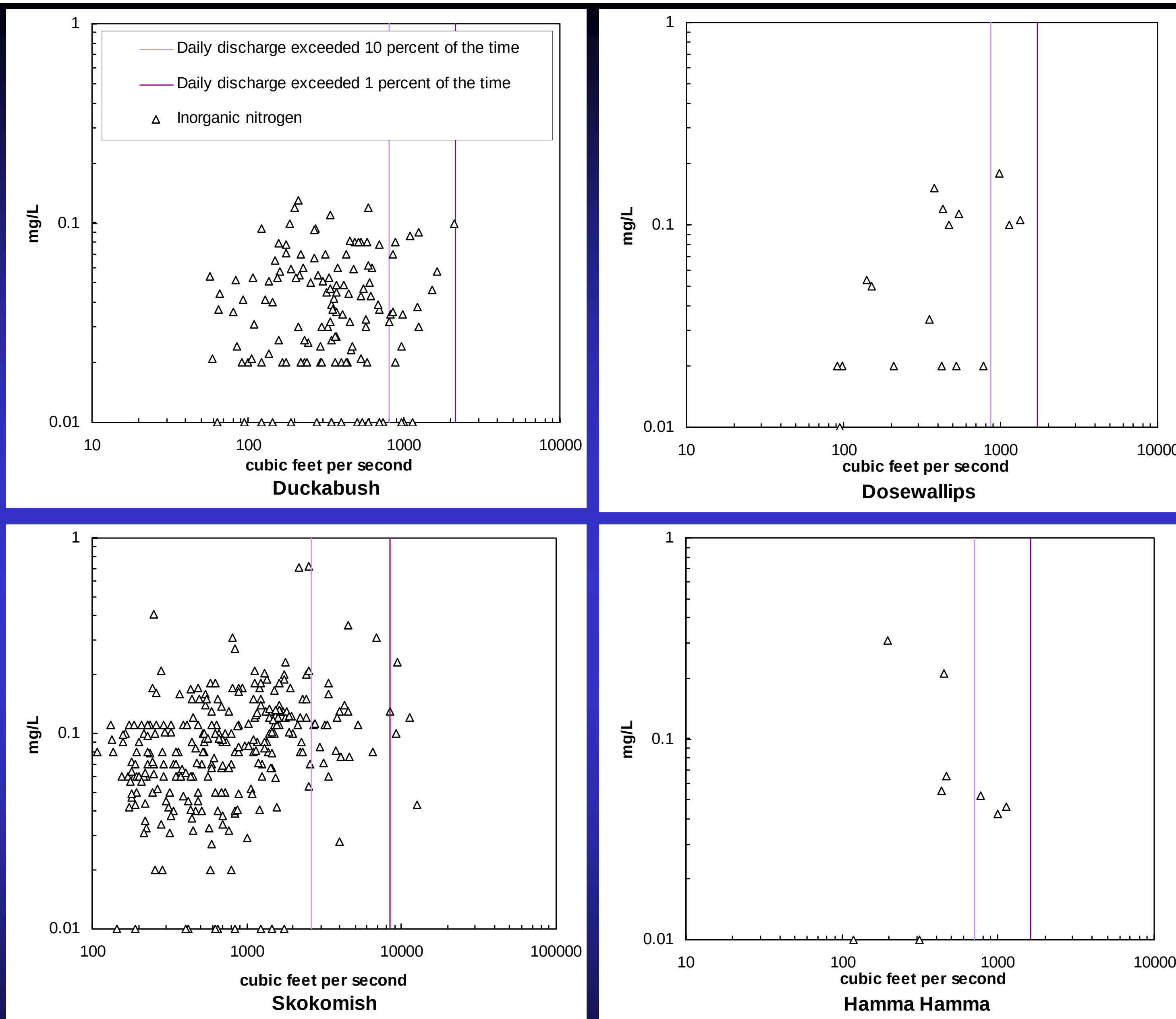
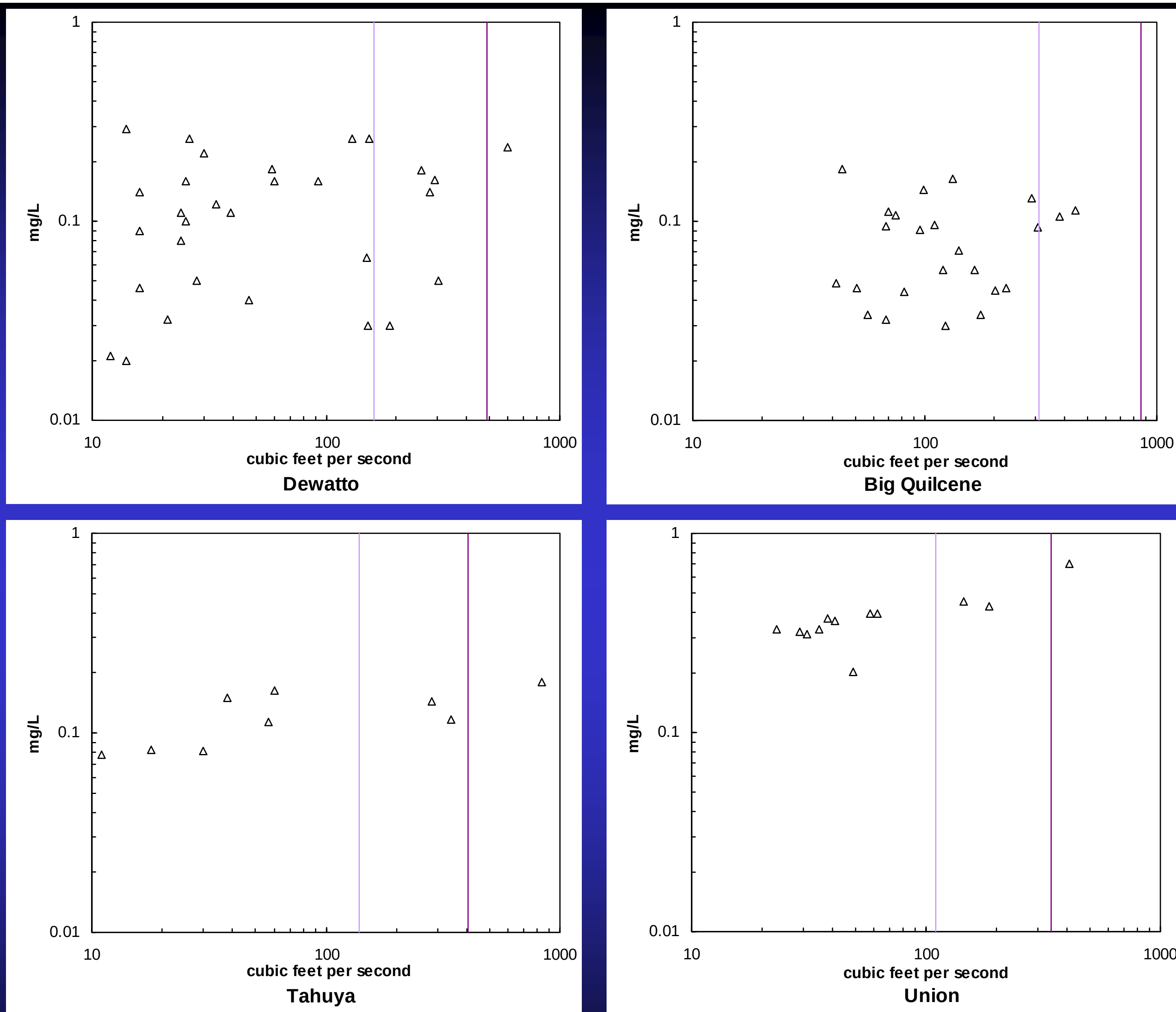


Inorganic nitrogen concentrations and streamflow

Data sources: WA Department of Ecology, USEPA, and USGS



Inorganic nitrogen concentrations and streamflow

Data sources: WA Dept. of Ecology, USEPA, and USGS

Streamflow - Nitrogen Concentration Relations

Streamflow and total inorganic nitrogen data were log-transformed and linear regressions performed on the data sets to calibrate the general equation $[N] = B\ Qsw^{C}$ for each river where nitrogen data were available.

Olympic rivers	B	C	[N] for mean streamflow
Big Quilcene	0.03	0.16	0.08
Dosewallips	0.001	0.62	0.07
Duckabush	0.01	0.11	0.02
Hamma Hamma	0.01	0.23	0.05
Skokomish	0.03	0.17	0.09
Lowland rivers and streams			
Finch	0.07	0.20	0.12
Dewatto	0.05	0.16	0.10
Tahuya	0.06	0.16	0.13
Union	0.13	0.25	0.40

Used median values to calculate nitrogen concentra- tions for other rivers and streams: $[N] = 0.03\ Q^{0.17}$

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Surface-Water/Nitrogen-Load Calculations

- Used monthly mean discharge and nitrogen-flow relations to calculate monthly loads for each river, stream, and shore catchment.
- Aggregated monthly loads to calculate annual loads.
- Direct discharges to Hood Canal including point sources, stormwater, and septic effluent from shoreline residences were not included.

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Ground-Water-Load Calculations: Flow

Mass balance used to calculate ground-water flow:

Qgw = Precipitation – Qsw –Evapotranspiration

Precipitation for each river and stream basin was estimated from NRCS/NWS map.

Potential (maximum) evapotranspiration was assumed to be 20 inches per year.

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Ground-Water-Load Calculations: Nitrate Concentration

Median concentration of NO_3 for wells in the Washington Department of Health (DOH) data base for WRIAs 14-17 was 0.2 mg/L as N.

For Hood Canal load calculations, the concentration of inorganic nitrogen in ground water was assumed to be 0.3 mg/L to account for a greater proportion of shallow ground water than represented by the DOH data set.

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Annual Inorganic Nitrogen Loads to Hood Canal from Surface and Ground Water

Rivers and streams: 421 ± 162 metric tons per year

Regional Ground Water: 56 ± 30 metric tons per year

Total (not including direct inputs):

477 ± 192 metric tons per year

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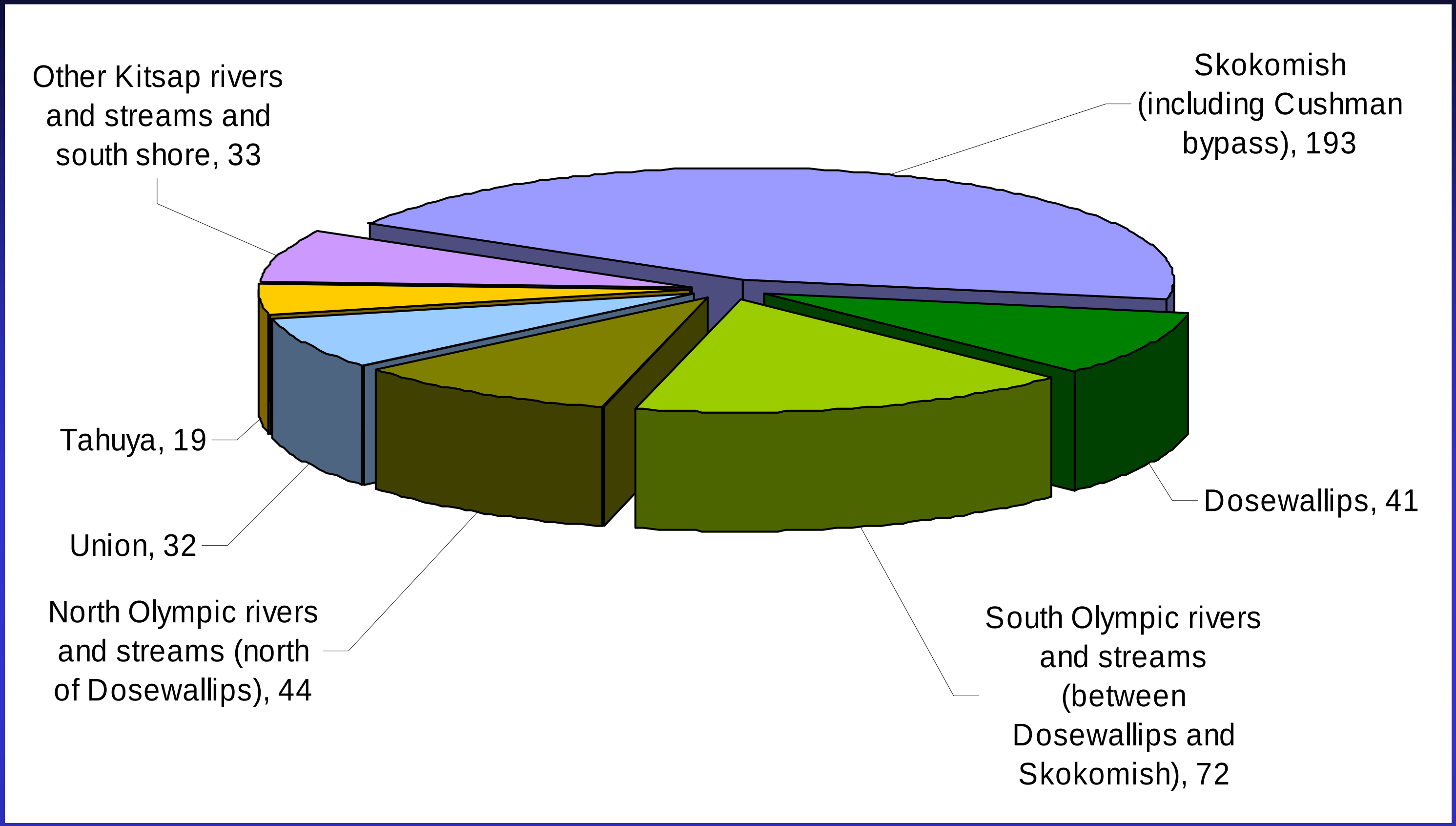

Distribution of Surface- and Ground-Water Load to Rivers and Streams Draining into Hood Canal

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Comparison to Previous USGS Estimates of N Loads

Water-Resources Investigations Report 97-4270 (Embrey and Inkpen (1998) provided estimates of annual inorganic nitrogen loads for five rivers draining to Hood Canal. Two reasons likely account for differences with current estimates: 1) their data set ended with samples collected in 1993 and 2) loads were based on concentrations of individual samples (except for the Skokomish) and were not normalized for a common time period.

River	Phase I (2004) metric tons per year	Embrey and Inkpen (1998)
Dosewallips	41	43*
Duckabush	10	25*
Hamma Hamma	29	41*
Skokomish	106	155
Dewatto	7	13*

*Potential for large error in load was noted by Embrey and Inkpen for these sites.

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Nitrogen Loads from Near-Shore Septic Systems

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Nitrogen Loads From Near-Shore Septic Systems

Premise: Effluent from near-shore septic systems does not recharge the regional ground-water systems but seeps directly into Hood Canal.

Objective: Estimate the nitrogen load from near-shore septic systems.

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Approach for Estimating Nitrogen Load from Near-Shore Septic Systems

LOAD = PER CAPITA EFFLUENT VOLUME X CONCENTRATION of N X POPULATION

- **PER CAPITA VOLUME: 60 ± 20 gals person^{-1} day^{-1}**
- **CONCENTRATION OF TOTAL N in septic tank effluent: 55 ± 30 mg/L**
- **10 pounds of N person^{-1} year^{-1} is total waste stream delivered to septic system**

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Approach for Estimating Nitrogen Load from Near-Shore Septic Systems (cont.)

- **Ammonia (NH_3) is 75% of total N in septic effluent, 25% is organic N, which is retained in the tank and drain field.**
- **In aerated, sandy soils, there is complete nitrification of NH_3 in effluent to NO_3.**
- **In practice, there is some denitrification and loss of gaseous N_2. 10 percent denitrification of total N is assumed here.**
- **35% ($\pm$ 10%) of total N retained in soil as organic N or volatilized as nitrogen.**

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Approach for Estimating Nitrogen Load from Near-Shore Septic Systems (cont.)

Resulting per capita loading rate:

65% of 10 lbs NO_3 = 6.5 lbs NO_3 as N per person per year

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Approach for Estimating Near-shore Population of Hood Canal

Average water-front lot extends 150 m up from the water.

Estimate population for a 150 m buffer around the shoreline of Hood Canal.

Account for full-time and seasonal residents.

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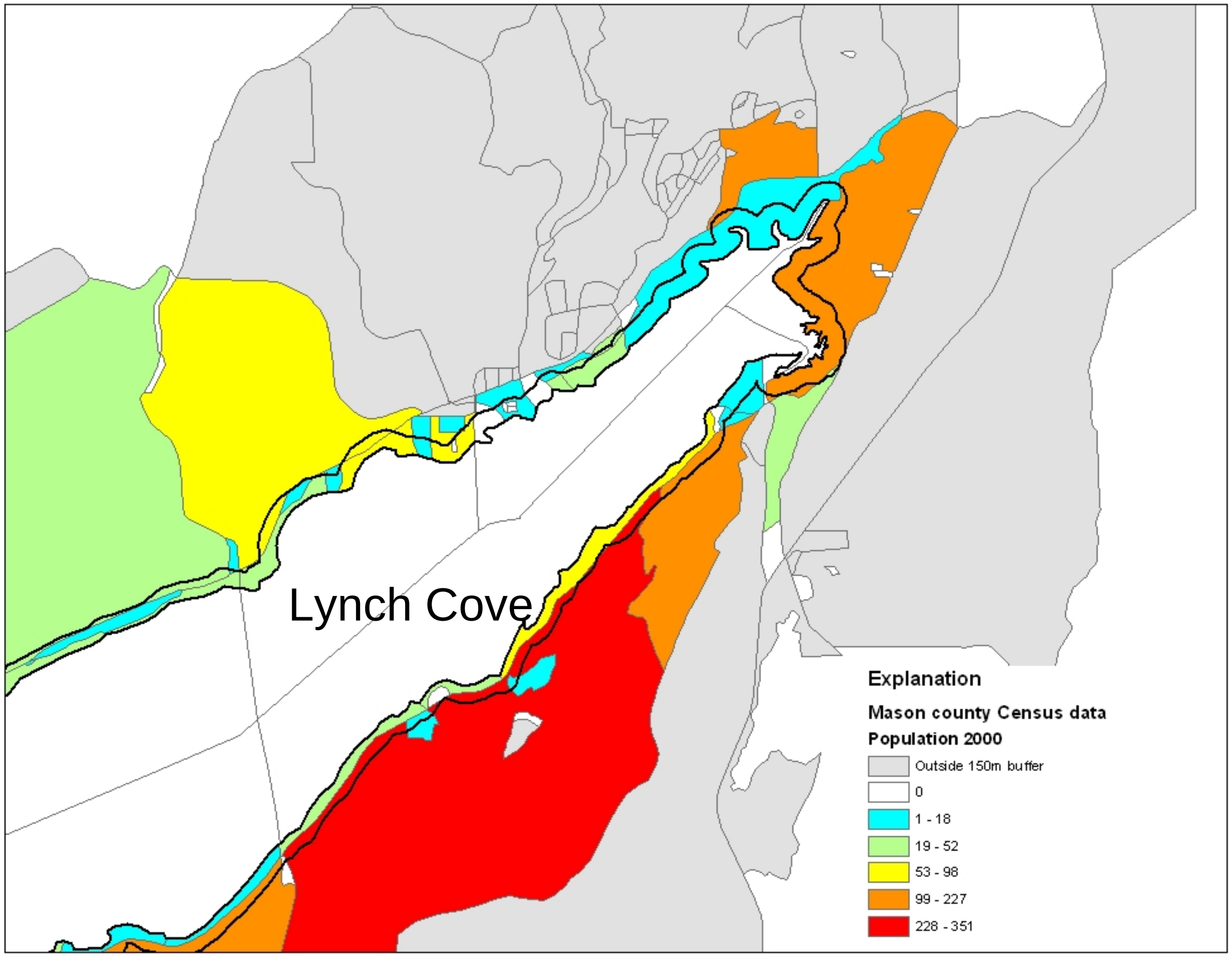
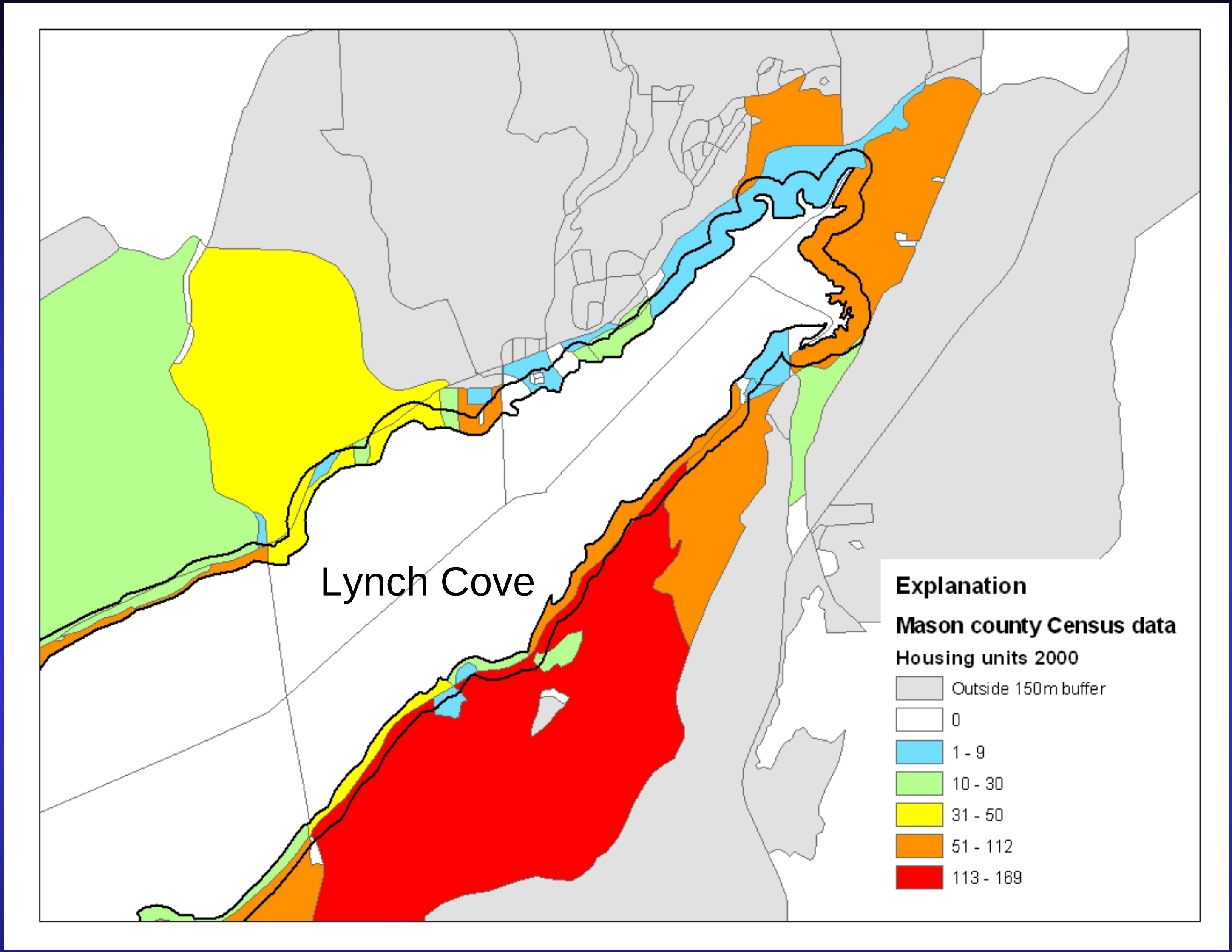


2000 Census Population Data – used to estimate full-time population



2000 Census Housing Unit Data - used to estimate seasonal population

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Near-Shore Population of Hood Canal

County	Population	Housing Units
Jefferson	1,404	1,221
Kitsap	2,276	968
Mason	2,738	2,678
	~6,400 people	~4,900 units

Population

October to May - 6,400 people.

June to September – 12,000 people (assuming an occupancy of 2.5 people per unit).

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Nitrogen Loads From Near-Shore Septic Systems

Hood Canal

- 28 metric tons ± 15 metric tons including seasonal residents, 20 ± 11 metric tons is from full-time residents

Lynch Cove

- 8 ± 5 metric tons including seasonal residents, 5 ± 3 metric tons from full-time residents

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Nitrogen Loads From Atmospheric Sources

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Direct Atmospheric Deposition

Atmospheric loading is calculated from:

- Marine surface area (111 square miles) and
- Nitrogen Deposition:

a) Hoh Ranger Station =	1.03 kg N per hectare
b) LaGrande =	1.04 kg N per hectare
c) North Cascades=	1.65 kg N per hectare
d) Tahoma Woods=	0.68 kg N per hectare

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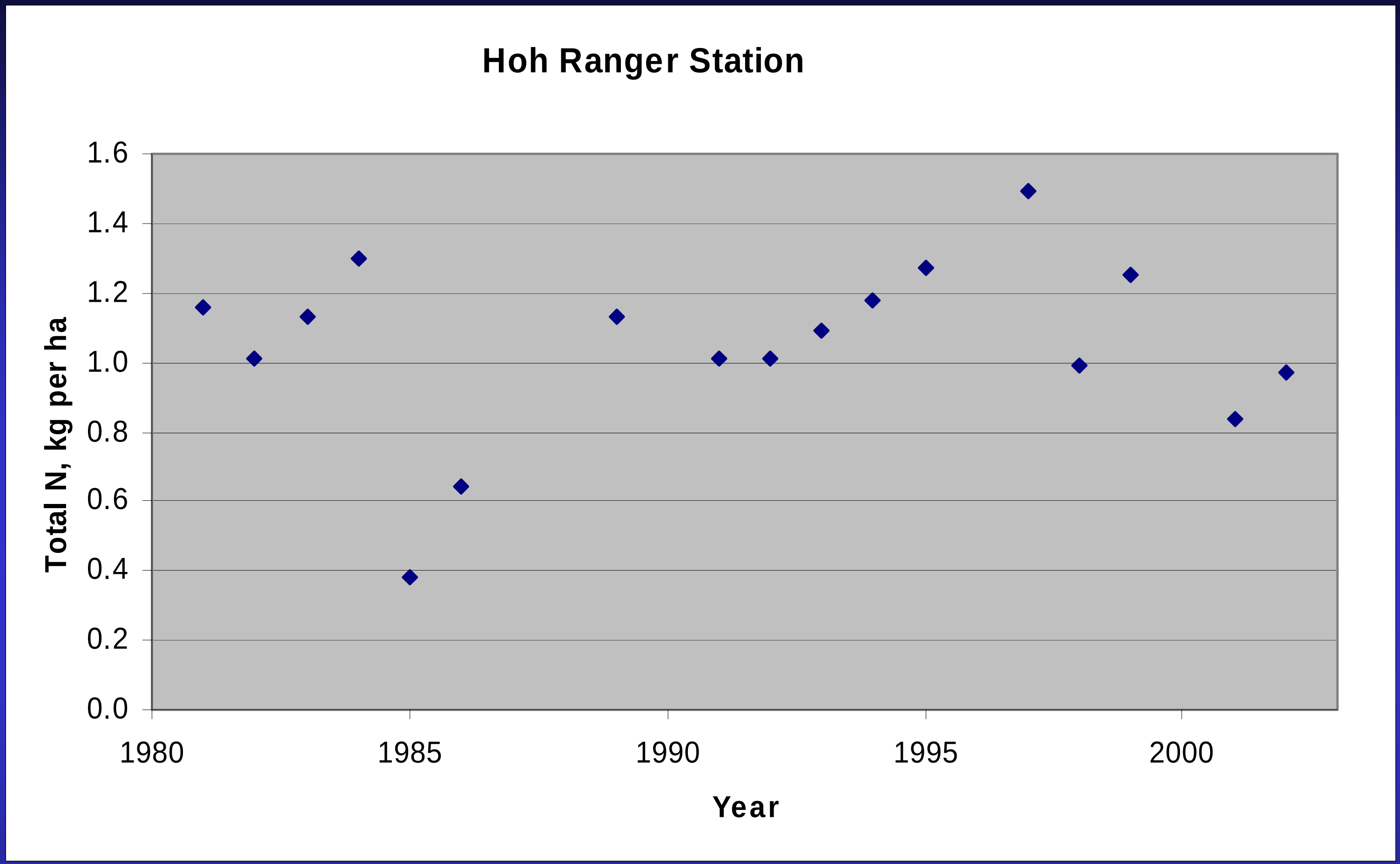

Variability of Nitrate Deposition-Hoh Ranger Station

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Atmospheric Loading

Using Hoh Ranger Station data, total N loading:

To Hood Canal is 30 ± 11 metric tons of N per year

To Lynch Cove is 4.4 ± 1.6 metric tons of N per year

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Comparison of Land Sources

PSAT - Human sewage, agriculture manure, 50% stormwater runoff, and forestry: 64 to 280 metric tons

Atmospheric loading to land (using Hoh Ranger Station data): 192 to 351 metric tons

PSAT plus atmospheric: 256 to 631 metric tons

USGS - Streams, ground water, and near-shore septic- 302 to 716 metric tons

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Nitrogen Loads From Marine Sources

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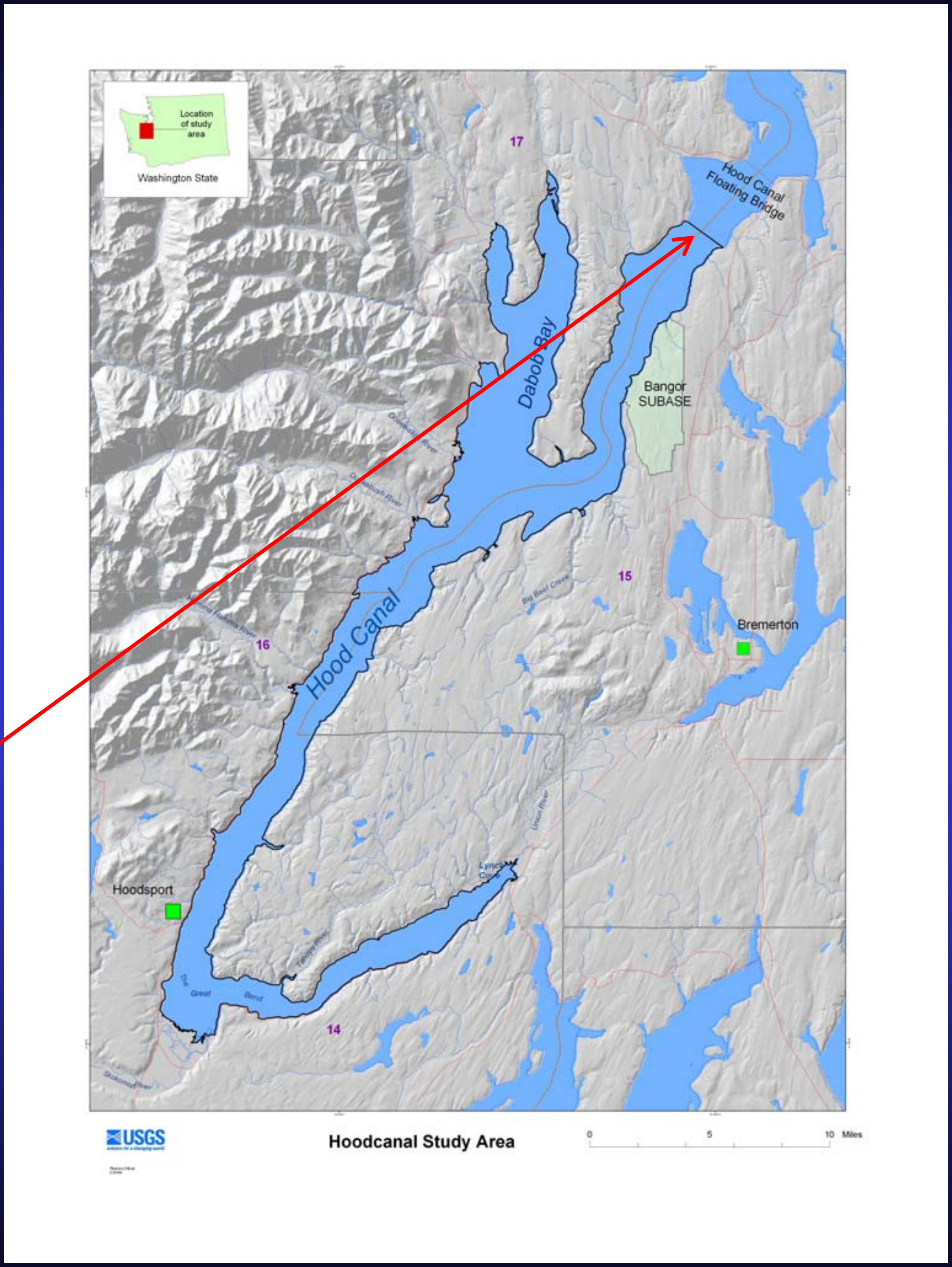
The boundary for the calculation of marine inputs of nitrogen is near the South Point-Lofall sill.



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Marine Inputs of Nitrogen to Hood Canal

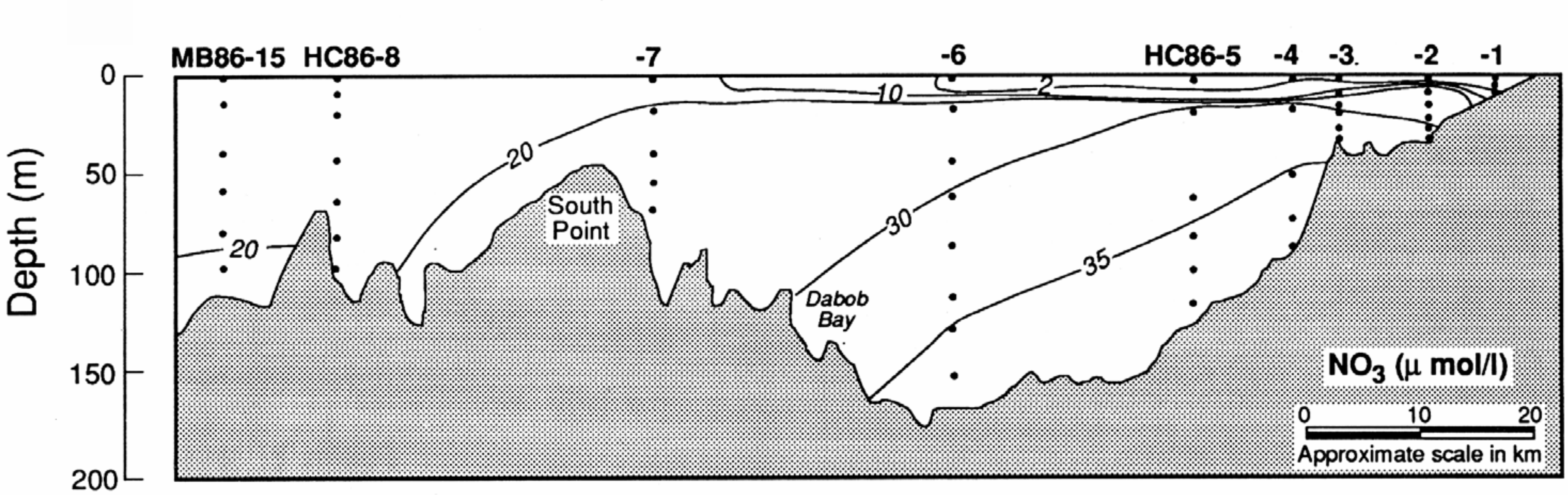
Marine inputs were calculated using:

1) NO_3 concentrations seaward of the South Point-Lofall sill and;

2) Net landward transport of water in the lower layer over the sill.

Nitrogen Concentrations in Hood Canal, August 1986

(Paulson and others, 1993)



Nitrate concentrations seaward of the sill (station 8) were 0.28 ± 0.01 mg/L as N (19.7 ± 0.6 µM/L)

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Estimates of Net Landward Transport of Water in the Lower Layer over the Sill

Cokelet and others, 1990 – using calculations from the mass balance of water and salt: 1,500 - 3,600 m^3/s.

Warner and others, 2002 – using calculations from changes in chlorofluorocarbons:

890 - 3,280 m^3/s.

Ebbesmeyer and others, 1984 - showed that net transport of water decreased to 1000 m^3/s near Eldon.

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Marine Inputs of Nitrogen to Hood Canal

Estimates of the flux of marine nitrate over the South Point-Lofall sill range between 8,700 and 31,200 metric tons per year.

Caution: The marine flux is highly dependent on the placement (seaward extent) of the boundary of the study area.

Estimates of Other Sources of Nitrogen to Hood Canal (from PSAT)

Direct Point Discharges:
.3 – 2.7 metric tons of N/yr

Chum Salmon Carcass Disposal:
15 – 22 metric tons of N/ year

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Summary of Nitrogen Loads into Hood Canal

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Inputs of Nitrogen into Hood Canal and Lynch Cove, in Metric tons N per Year

	Hood Canal	Lynch Cove
Rivers and Streams	421±162	64±25
Regional Ground Water	56±30	7±4
Near-Shore Septic Systems	28±15	8±5
Atmospheric	30±11	4.4±1.6
Other Sources	20±5	1.5±1.2
Marine	8,700-31,200	???

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Inputs Of Nitrogen into Hood Canal

- The large input of nutrients is a result of the large input of seawater (i.e. flushing) in the northern part of Hood Canal.
- The more extensive flushing in Northern Hood Canal is not inconsistent with the lack of a dissolved oxygen problem there.
- The input of marine nutrients at other landward points along in Hood Canal (such as into Lynch Cove), is unknown at this time.

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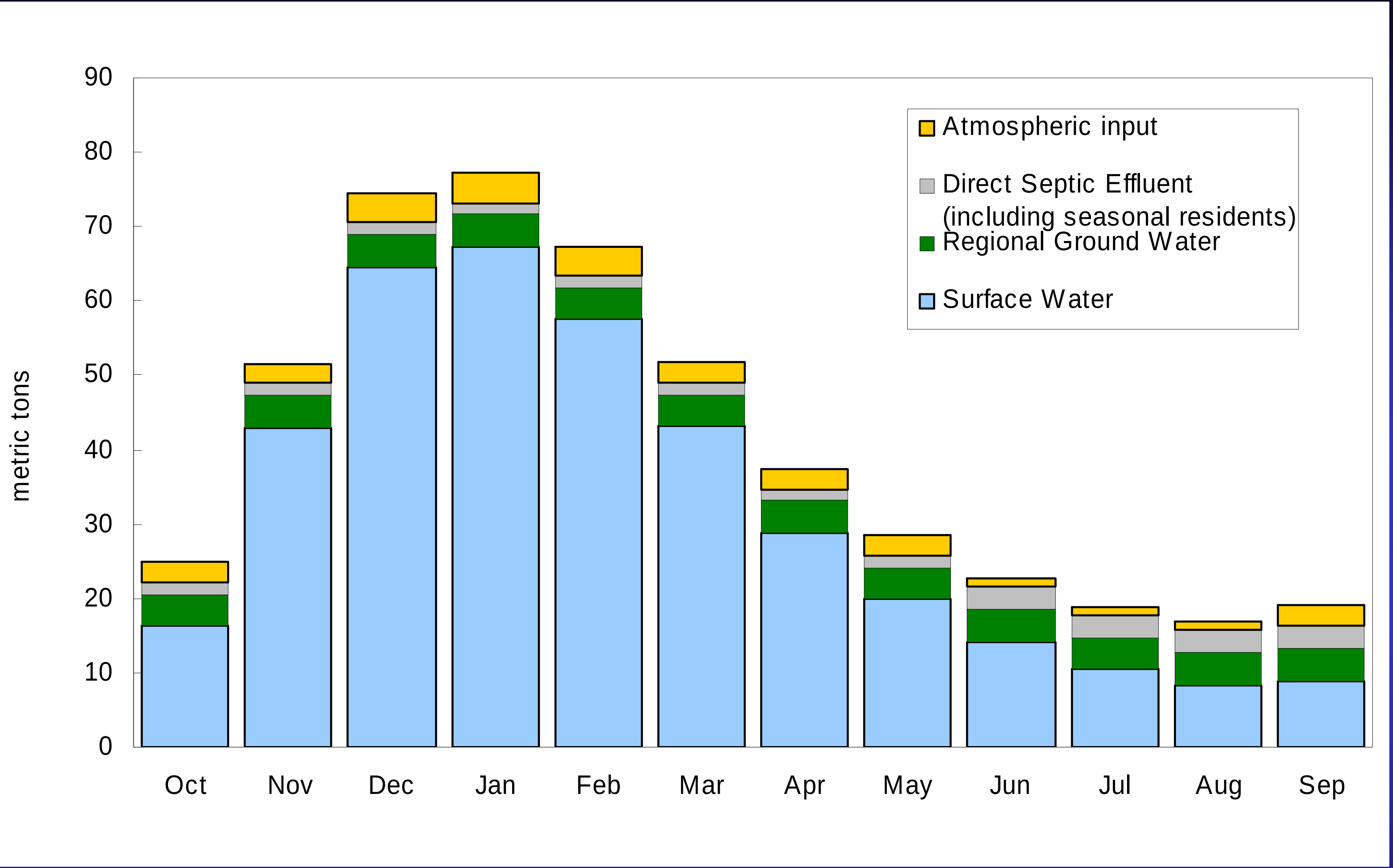

Estimated monthly inorganic nitrogen load to all of Hood Canal, excluding marine inputs.

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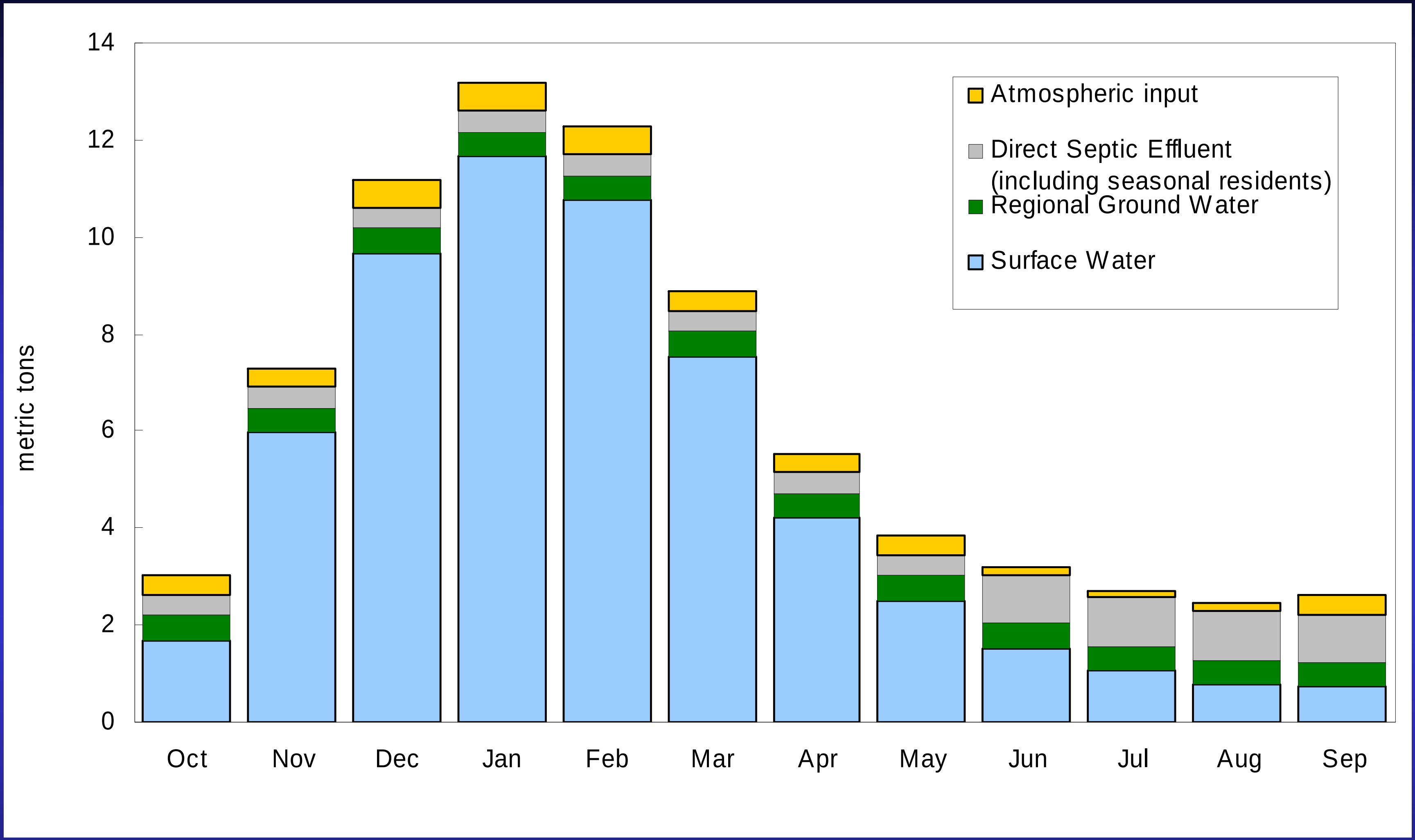

Estimated monthly inorganic nitrogen loads to Lynch Cove, excluding marine inputs.

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Proposed Focus Studies

1) Relate nitrogen concentrations to land use

Will help to better understand how land use affects nitrogen inputs from rivers to Hood Canal

- Conduct studies in three basins – Skokomish, Union, and other basin(s) discharging into Lynch Cove.
- Collect samples along the length of the rivers at 8-10 points where land use changes.
- Look at nutrient concentrations, nitrogen isotopes
- One sampling effort, in the summer during low flow.

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Proposed Focus Studies (cont.)

2) **Measure current velocities in Hood Canal at the Great Bend**

   Critical to developing a summer time loading for Lynch Cove. Also, needed for calibration of any current models

   - Deploy two acoustic Doppler current profiler in about 50 meters of water in the vicinity of Great Bend. Measure current velocities at 1-5 meter intervals, continuously for a period of at least one month.
   - Collect nutrient samples at 1-5 meter intervals biweekly, to coincide with velocity measurements.

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Proposed Focus Studies (cont.)

3) Refine input estimates from septic systems

- Use same methods as for initial estimates, only with plat data for Mason County.
- Not proposing any additional septic tank work, specifically seepage to shore or the canal from individual septic systems, due to potential problems with representativeness and up-scaling.

http://wa.water.usgs.gov/

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