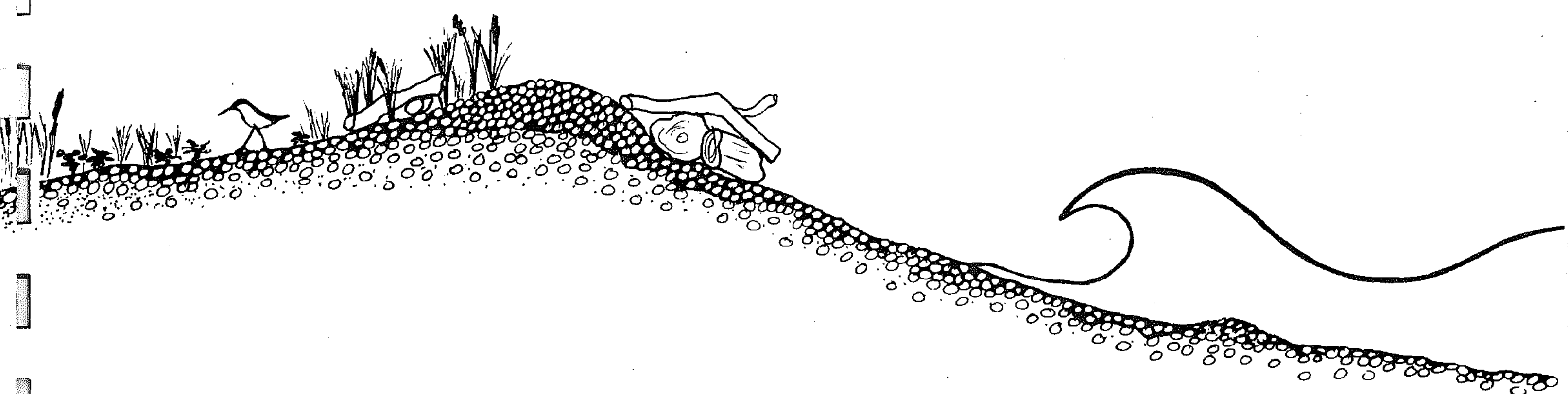
WHATCOM COUNTY BOARD OF EQUALIZATION

DRIFT SECTORS OF WHATCOM COUNTY MARINE SHORES



WOLF BAUER

WHATCOM COUNTY PLANNING COMMISSION

THE DRIFT SECTORS OF WHATCOM COUNTY MARINE SHORES: THEIR SHOREFORMS AND GEO-HYDRAULIC STATUS

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1974

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WHATCOM COUNTY PLANNING COMMISSION

Whatcom County, Washington

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CHAPTER ONE
INTRODUCTION

The marine coastlines of Whatcom County stretches northwesterly along the Strait of Georgia from the Chuckanut and Lummi Island rock belt in the southeast to the outskirts of the Fraser Delta in the northwest at Point Roberts. The total coast and islands encompass approximately 134 shoreline miles representative of three of the four major shore types, i. e. beach, rock, and estaurine. Missing are the non-estuarine marshy shores.

About half of the shores within the county are beach types at the foot of high sea cliffs and low marine terraces. Such recessional bluffs are composed of stratified and unstratified glacial drift and till with various ratios of clay, sand, gravel, and boulder content. Wave action, groundwater and weathering eroding these bluffs account for the material forming the accretion shoreforms, which make up about 17% of the total shoreline. It is noteworthy that this percentage is about four times as high as the average for all shores of Puget Sound. However, the amount of intrusion and alteration of these accretion shores, with their dry, above-tide berm beaches, has already reached 54% in the county, and is considerably higher than what has occurred as an average in the inland sea. Aside from the bluff erosion-accretion shore systems that make up the geo-hydraulic sectors with which this study is concerned, (68.1% of total) there are also estuarine accretion shores in the delta lobes of the Lummi River, as well as the Nooksack, the latter delta being the only major undisturbed estuary in Puget Sound and Georgia Strait. The following table of shore types indicates their extent and relative occurrance within the county, as well as their degree of alteration.

TABLE 1-SHORE TYPES

SHORE TYPES	MILES		PERCENT OF TOTAL		PERCENT OF TYPE
ROCKY SHORES	21.0		15.6%		100
NATURAL BLUFF SHORES	64.3		48.0		94.0
*INTRUDED BLUFF SHORES	4.0		3.0		6.0
TOTAL BLUFF SHORES		68.3		51	
NATURAL POCKET SHORES	1.7		1.2		100
NATURAL ACCRETION SHORES	10.8		8.1		46.0
INTRUDED ACCRETION SHORES.	12.4		9.3		54.0
TOTAL ACCRETION SHORES		23.2		17.4	
NATURAL ESTUARINE SHORES	3.7		2.7		54.0
INTRUDED ESTUARINE SHORES.	3.3		2.4		46.0
TOTAL ESTUARINE SHORES		7.0		5.1	
**INDUSTRIAL SHORES	13.0		9.7		———
	134.		100.0		

* Intruded=riprap, groins, piling, bulkheads, etc., within fore & backshore

** Industrial=docks, bulkhead fills, dikes, RR right-of-way (not roads) (This type is almost entirely located in Bellingham and Blaine.)

The Bauer marine beach classification system distinguishes among erosional, marginal, and accretional beaches in terms of upper foreshore or backshore wetting at mean higher high tide (MHHW) — Class I, II and III respectively.* Most beaches under sea cliffs are marginal Class II type, with only a few Class III wet beaches where the bluff contains little or no gravel to maintain a drift berm above high tide. Most Class I beaches in the County are dry berm beaches that are part of major accretion shoreforms such as points, spits and barrier berms; although a few narrow backshore berm beaches exist in bluff areas along shore offsets or indentations.

Those Drift Sectors of Whatcom County which abut the open waters of the Strait of Georgia are exposed to nearly 100 miles of northwesterly fetch, and thus operate in a high energy zone. Such conditions require adequate structure setbacks from the shore-process corridor, whether that be the top of active feeder bluffs, narrow driftway foreshores, or the bermed backshore of accretional shoreforms. Such setbacks not only preserve the integrity of the drift sector system, but reduce hazards of untenable locations where dwellings are subject to recession slides, storm driftlog battering, or backshore inundation under storm-tide climax conditions of over 8 feet above high-tide line level.

* See classification system in Appendix C, p 62.

TABLE 2

ACCRETION SHORE STATUS OF WHATCOM COUNTY DRIFT SECTORS

	SECTOR NUMBER	SECTOR MILEAGE	ACCRETION MILEAGE	BERM INTRUDED	BERM NATURAL	PERCENT NATURAL CLASS I - BEACH
				(in miles)		
	1	0.3	0.03	0.00	0.03	10%
	2	1.0	0.20	0.00	0.20	10%
	3	0.7	0.05	0.00	0.05	7%
	4	1.7	0.18	0.18	0.00	NONE
	5	2.8	1.40	0.40	1.00	36%
	6	4.5	1.48	0.38	1.10	24%
	7	1.5	0.00	0.00	0.00	NONE
	8	1.2	1.10	1.10	0.00	NONE
	9	2.1	2.10	2.10	0.00	NONE
	10	3.3	2.10	1.30	9.80	24%
	11	2.8	0.00	0.00	0.00	NONE
	12	2.6	0.39	0.08	0.31	12%
	13	0.9	0.02	0.02	0.00	NONE
	14	2.7	1.89	1.62	0.27	10%
	15	2.0	2.00	1.50	0.50	25%
	16	1.1	0.05	0.00	0.05	5%
	17	1.2	0.00	0.00	0.00	NONE
	18	2.5	0.75	0.50	0.25	10%
	19	1.1	0.27	0.18	0.09	8%
	20	2.3	0.60	0.32	0.28	12%
	21	4.0	0.00	0.00	0.00	NONE
	22	3.2	0.64	0.00	0.64	20%
	23	2.8	1.28	0.00	1.28	46%
	24	3.0	1.50	0.00	1.50	50%
	25	1.9	0.28	0.00	0.28	15%
	26	1.7	0.10	0.00	0.10	6%
	27	1.0	0.30	0.20	0.10	10%
	28	1.8	1.17	0.90	0.27	15%
	29	1.8	0.00	0.00	0.00	NONE
	30	0.7	0.38	0.03	0.35	50%
	31	0.5	0.30	0.00	0.30	60%
	32	0.8	0.00	0.00	0.00	NONE
	33	4.6	2.28	1.59	0.69	15%
	34	2.2	0.40	0.03	0.37	17%
TOTALS	34	68.3	23.24	12.43	10.81	15.8%

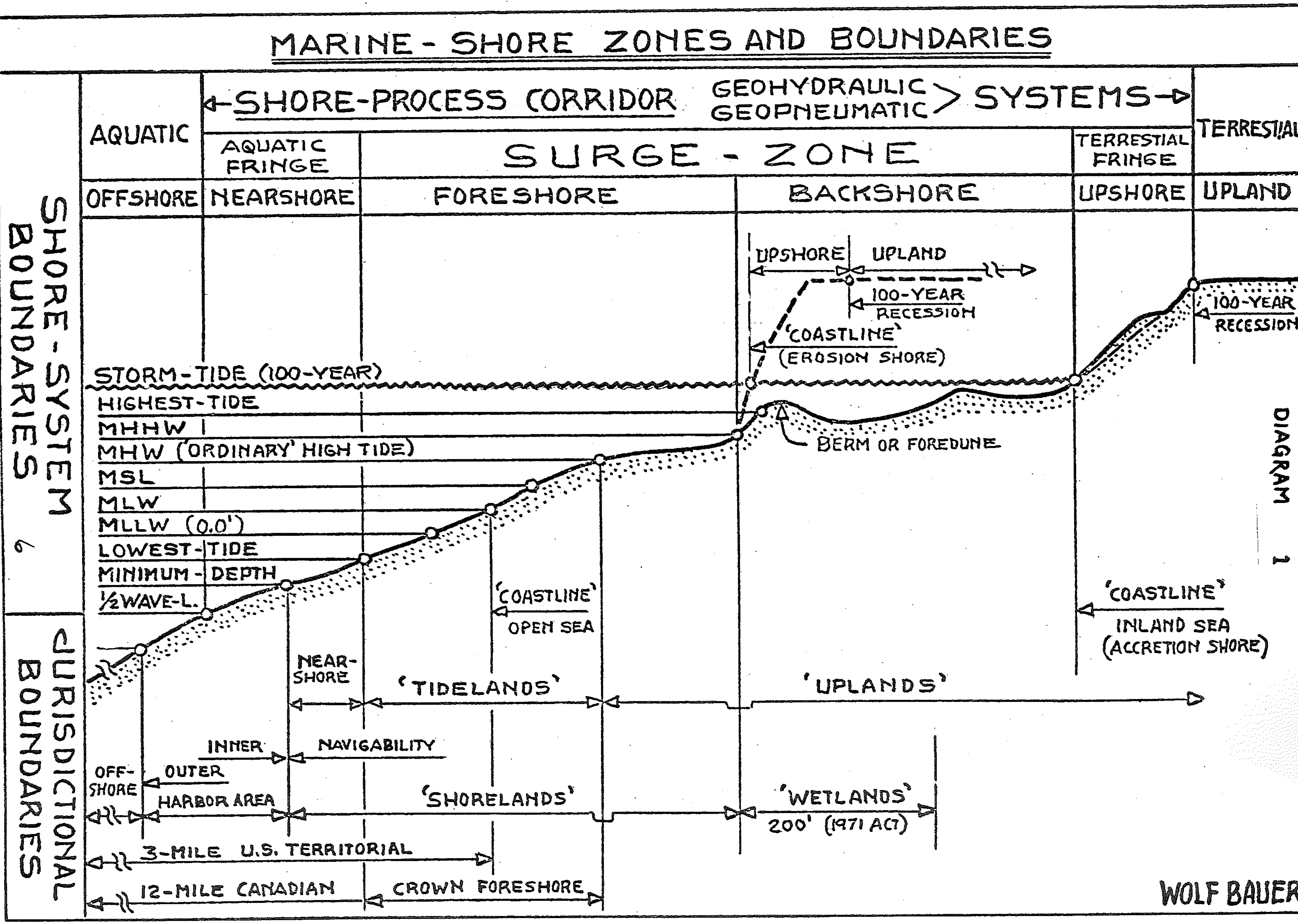
CHAPTER TWO

THE SHORE-PROCESS CORRIDOR

In order to assign proper values, priorities, restrictions and opportunities in shoreline and coastal zone planning and management, it is necessary to identify the genetic relationships that certain shore reaches and shoreforms have with each other, and to establish the limits of their operating shore process systems.

As is the case in all eco-systems, whether biologic or purely physical — the components of that system are interrelated, interdependent, and balance-seeking. It should be noted that, depending on the scale of space and time, such components may also represent systems in themselves.

In coining and using the term "Shore-Process Corridor", it is my purpose to de-emphasize the lineal and geographic connotation popularly associated with such terms as water-line, land-water interface, waterfront, shoreline, etc., and to focus instead on the fact that all shorelines actually represent dynamic zones of variable width — geo-hydraulic and bio-process systems that reflect typical inter-dependent environments. (See Diagram 1, p 6).


MARINE - SHORE ZONES AND BOUNDARIES
SHORE-PROCESS CORRIDOR
GEOHYDRAULIC GEOPNEUMATIC > SYSTEMS
AQUATIC
AQUATIC FRINGE
SURGE - ZONE
TERRESTIAL FRINGE
TERRESTIAL
OFFSHORE
NEARSHORE
FORESHORE
BACKSHORE
UPSHORE
UPLAND
UPSHORE
UPLAND
100-YEAR RECESSION
'COASTLINE' (EROSION SHORE)
100-YEAR RECESSION
STORM-TIDE (100-YEAR)
HIGHEST-TIDE
MHHW
MHW ('ORDINARY' HIGH TIDE)
MSL
MLW
MLLW (0.0')
LOWEST-TIDE
MINIMUM-DEPTH
½ WAVE-L.
BERM OR FOREDUNE
DIAGRAM 1
'COASTLINE' OPEN SEA
'COASTLINE' INLAND SEA (ACCRETION SHORE)
SHORE-SYSTEM BOUNDARIES
JURISDICTIONAL BOUNDARIES
NEAR-SHORE
'TIDELANDS'
'UPLANDS'
INNER
NAVIGABILITY
OFF-SHORE
OUTER
HARBOR AREA
'SHORELANDS'
'WETLANDS'
200' (1971 ACT)
3-MILE U.S. TERRITORIAL
12-MILE CANADIAN
CROWN FORESHORE
WOLF BAUER

The Shore-Process Corridor represents a zone that not only straddles the extreme surge limits of riverine, estuarine, lacustrine, or marine waters, but which includes those aquatic and terrestrial outer fringes on each side that still affect, or are affected by, the prevailing geo-hydraulic system. In terms of a marine shore, for example, the central portion of the corridor forms the extreme intertidal zone. The aquatic fringe is the immediate offshore that receives the geo-hydraulic backlash effects of bottom wave motion and fine sedimentation around sea-grass and kelp bed habitat, while the terrestrial fringe of the corridor may constitute an extensive backshore marsh, or include the top of a receding sea cliff. Thus the shoreline is in reality a zonal belt, or energy diffusion zone, within which the geo-hydraulic mechanisms (erosion, transport or drift, and a accretion) operate along two directions, namely across and along the corridor. Under extreme hydraulic conditions of tidal or flood stage and energy, the central surge zone of the corridor operates like a fully stretched diffusion membrane with maximum energy stages transfers across the corridor, while lesser water and energy stages tend to distribute energy effects more longitudinally along the shore in both riverine and marine systems (see Diagram 2, p8).

The extent to which longitudinal geo-hydraulic effects reach and operate as an integrated system along a marine shore, depends on the location of barriers to wave and current progression within

THE SHORE-PROCESS CORRIDOR

ZONAL HORIZONS

DIAGRAM 2

	VERTICAL ZONES	RIVERINE ENVIRONMENT		ESTUARINE ENVIRONMENT		MARINE ENVIRONMENT
∞ CORRIDOR	TERRESTIAL FRINGE	VALLEY FRINGE		BAY FRINGE		COAST FRINGE
	SURGE ZONE	FLOODPLAIN — BACKSHORE	FLOODWAY FRINGE	FLOODPLAIN — BACKSHORE	SURGEPLAIN UPPER MARSH	STORM-TIDEPLAIN BACKSHORE
		FLOODPLAIN — FORESHORE	FLOODWAY (1% + ½ MPH)	FLOODPLAIN — FORESHORE	LOWER MARSH TIDAL FLAT TIDAL CHANNELS	FORESHORE
	AQUATIC FRINGE	MAIN CHANNEL THALWEG		MAIN DISTRIBUTARIES BAY OFFSHORE		OFFSHORE 3-5 FATHOMS

WOLF BAUER

the corridor. It should be apparent, therefore, that the marine Shore-Process Corridor of Puget Sound, as far as beach shore types are concerned, contains more or less independently operating reaches that are fully or partially separated from adjacent reaches. I have named these independent beach sections "Drift Sectors".*

It is a particular purpose of this shore evaluation report to recognize, define, locate, and analyse these as yet little understood resource entities in Whatcom County, to the end that the preservation of their functions and viability assures the conservation of a county resource heritage in the public and private interest. If the Shore-Process Corridor, as an interdependent geo-hydraulic and bio-process zone, defines the terrestrial (land) boundary between resource and real estate — then the Drift Sector defines those longshore boundaries within which all shore owners must act in literate concert in relation to the integrated natural system.

* See definition, components, and illustration of Drift Sectors in Appendix A, p. 48.

CHAPTER THREE

DRIFT SECTOR INVENTORY AND EVALUATION

The recognition by Whatcom County government that an inventory and analysis of its beach-shore Drift Sectors provides a basic and indispensible shoreline planning and management tool constitutes a significant milestone in modern coastal zone administration.

In a pioneering study of this type, it should be emphasized that the determination of Drift Sector boundaries and their geographic locations represents a preliminary, rather than final or absolute fixation in view of the lack of longshore drift-monitoring data, lack of wave-action observations under various conditions, and the limited time available for a baseline field study for this purpose.

The assumed Sector boundaries are either absolute or overlapping, depending on shore orientation, wave progression or refraction limits, driftway loading, and the effectiveness of natural or artificial drift barriers within the foreshore. Where Sector boundaries are well defined, they are indicated with solid lines on both photo and map and as broken lines representing partial leakage or drift overlap.

Each Drift Sector has been identified with a number beginning with "1" at the U. S.-Canadian border at Blaine, and increasing southward along the coast to Bellingham. Further progression of numerical designation covers Portage, Lummi, and Eliza Islands, and terminates with the two sectors of Point Roberts. There are 34 sectors total.

Rock, including non-drift pocket-beach shores, estuarine and certain industrial shores are not included in this study. These excluded areas are the Nooksack River estuary, south half of Lummi Island, Lummi Aquaculture sea pond, Chuckanut, and Bellingham and Blaine harbor areas. An earlier field study of the marine shores of Whatcom County by Stephen Phillabaum, graduate geology student at Western Washington State College, included shoreline maps on a scale of 1" = 630'.* These maps indicate general type of material making up the foreshore, backshore, and bluffs, as well as the sampling stations where material was collected, to determine composition as shown in accompanying tables. That study divided the shoreline into short reaches bounded by either north-south or east-west Section Survey lines intersecting the shore. Each such reach was printed as

* Phillabaum, Stephen D., A Geomorphic Inventory of Whatcom County Marine Shores, 1973, (Masters Degree Thesis-Geology), Western Washington State College, Bellingham, Washington.

a separate map on a single page of the report. In view of the fact that this information already exists in the County Planning Office, the geographic Drift Sector identification of the Bauer report has been cross-referenced to the Phillabaum report by coding the Sectional reaches of the latter in terms of their page numbers, and entering them in the geographic description of the Drift Sector boundaries.

It has also been a special objective of this study to produce a visual record of the existing shore environments of the county coastline, and to indicate the Drift Sector locations thereon. To this end, a series of successive, low level oblique, aerial color photos were taken during an approximate mean-higher-high tide water level. These photos were converted to 5" X 7" matt color prints, and hinged together for a more or less complete documentation of the natural and intrusive features of the various Drift Sectors. This series is on file at the County Planning Office and is available for public review.

It has been the writer's experience in the use of this documentary technique that it is important for planners and citizens to visualize shoreforms and shore-process evidence within near-normal eye perspective orientation, rather than through flat photo-map interpretations. (While the writer developed this resource analysis tool originally for streamway management and evaluation purposes, it should be helpful for marine shore processes and shoreline planning as well) It would be my recommendation that a more exact (constant elevation and angle-of-sight, for example) and detailed (lower elevation with greater overlap) sequence series of oblique aerial photos be produced to serve as a base for monitoring natural and man-made processes and activity-effects at future time intervals.

SECTOR: 1 LOCATION: U.S. Canadian Border to Blaine Harbor Causeway Fill CODED SECTION: #147

BOUNDARIES MILES = 0.3	This is the shortest sector in the County since it represents only the southermost segment of a longer sector reaching to the mouth of Campbell River near White Rock B.C. The northern boundary of the U.S. portion of the sector is only political, while the south boundary is absolute — the causeway fill. All this sector is within the City of Blaine.
ACCRETION SHOREFORMS % of sector = 10%	Most of the sector is low bank erosional. The only shoreform is a short, low-berm accretional marsh-barrier beach that is slowly widening into a small crescent-shaped Class I beach at the extreme south-end pocket.
BLUFF FACTORS 13	Bluff is a low, artificial railbed embankment fill over the upper foreshore. Very little gravel is available from natural bank recession. The whole sector lies in a low energy zone in view of the protective headlands and shallowness of Semiahmoo Bay.
DRIFT FACTORS	Upper foreshore drift loading is light, and the material can only move southward in the U.S. reach. Gravel is small, and sand predominates. Only a very narrow upper foreshore drift band is operative above a muddy and broad foreshore.
INTRUSION STATUS	Heavy riprap railway bank revetment extends into the upper foreshore to make this an intruded Class II drift-berm beach.
USE POTENTIAL AND LIMITS	A more natural and useful beach environment could be achieved here by dredge spoil and gravel filling over the upper foreshore. This would create a driftwood beach with backshore, one that should remain stable and permanent at this drift terminal location.
SPECIAL NOTES OR PROBLEMS	If this sector were converted to a beach park, groins or other foreshore intrusions at the International Line would not affect the geo-hydraulics of the Canadian reach of the sector. Such a project would need a bulkheaded beach retainer at the Border if any kind of backshore is to remain in place, and another one normal to the Blaine Harbor Causeway.

SECTOR: 2	LOCATION: Blaine Harbor South Dike to Dakota Creek Mouth — S3/4 of Reach#147; CODED SECTION: N1/2 of #146
BOUNDARIES MILES = 1.0	The boundaries of this sector on Drayton Harbor are well defined and absolute, ending in the south dike pocket of the Blaine Harbor at the north end, and in an unstable accretion spit jutting into Dakota Creek at the south end. All this sector but the spit is in the City of Blaine.
ACCRETION SHOREFORMS % of sector = 10%	Most of this sector is low bank erosional. The sector contains two accretion shoreforms, the northernmost being a small point with narrow back-shore just south of the harbor dike under the railroad embankment. The south accretion terminal is a hooked spit with creek-flooded lagoon and unstable berm to a vegetated broader tip.
BLUFF FACTORS	Most of the natural bluffs along this shore are less than 20 feet high and exceedingly low in gravel. Seaward boulder positions show considerable recession of this flat glacial deposit with only small shoreforms to show for it due to gravel shortage. This is true for most of the southern shores of Drayton Harbor.
DRIFT FACTORS 14	Drayton Harbor lagoon provides a very low energy zone. Drift direction splits near the Blaine Harbor dike because of changes in relative fetch lengths north-south. Most of the shores are erosional Class III except for the shoreforms discussed above. Drift loading is very low in a narrow upper foreshore band.
INTRUSION STATUS	The northern portion is riprapped railroad embankment, while farther south occasional road dumping as well as erosion-control boulders have intruded the upper foreshore. None of these have made serious changes in this low-energy sector.
USE POTENTIAL AND LIMITS	Good opportunities exist in the northern dike corner for creating a Class I crescent pocket beach and park facing a quiet warm-water lagoon and estuary with proper resource management. A groined beach or gravel point with backshore could also be located in front of the park and road north of Dakota Creek.
SPECIAL NOTES OR PROBLEMS	Since nature short-changed this important reach with beach gravel, a multi-purpose shore enhancement program of supplying needed gravel for natural berm building would provide both recreational, esthetic, and erosional-control benefits, and without affecting the bio-process function of the estuary.

SECTOR: 3	LOCATION: Dakota Creek to California Creek — S1/2 of Reach#146; CODED SECTION: NI/5 of #145
BOUNDARIES MILES = 0.7	The boundaries of this sector are absolute and well defined, both being in the form of creek channels across the foreshore of Drayton Harbor.
ACCRETION SHOREFORMS % of sector = 7%	Much of this short sector is low bank erosional Class III beach, with some Class II low-berm near the middle portion where there is some evidence of low-terrace rollback action, especially around the mini-delta of a small creek. The major accretion shoreform is at the southern terminal where a berm and backshore marshy lagoon form a fragile eco-system under estuarine conditions.
BLUFF FACTORS	The low bluff banks are low in gravel content and provide insufficient berm-building material and beach cover. All of the shore is in a low energy hydraulic zone due to limited fetch and shallow, extensive foreshore and offshore. Erosion is steady but slow, and there are no major slide areas.
DRIFT FACTORS	Drift loading is very light but steadily southward due to the north-south shore orientation. No gravel drifting over the lower shore which is soft silt and mud.
INTRUSION STATUS	There is some upper foreshore intrusion in the form of boulder revetments and a concrete bulkhead in the southern reach, neither of which seem to have affected upper shore drift thus far.
USE POTENTIAL AND LIMITS	Two distinct natural shore entities occur in this sector, one being the afore-mentioned marsh and lagoon barrier berm at California Creek mouth, and the other being a small surge-plain grass-marsh and delta over the central foreshore of the sector where a tiny creek enters the bay. Both of these are eco-systems and special mini-features worth preserving as esthetic and wildlife habitat.
SPECIAL NOTES OR PROBLEMS	The barrier beach and marsh-lagoon at California Creek buts against a shell midden at each end, and is thus of some historic interest.

SECTOR: 4 LOCATION: California Creek to Shintaffer Road CODED SECTION: #145, E2/3 of #144

BOUNDARIES MILES = 1.7	The east boundary of this sector on Drayton Harbor is the California Creek channel and is near absolute. The western limit represents an assumed overlap boundary where relative fetch produces increasing wave action in opposite direction.
ACCRETION SHOREFORMS % of sector = 10%	Prior to road construction, this sector contained a low-berm barrier spit extending eastward into the mouth of California Creek. Two-thirds of the sector (eastern) is marshy shore with a very flat fore- and backshore (Class II marshy) beach. Lack of gravel prevented berm formation.
BLUFF FACTORS	Only the shore area near Shintaffer Road junction contains bluff shore in the form of Class III erosion beach. The bluff here too is relatively low in gravel content and evidences variable cohesiveness and some sliding tendencies where groundwater seepage is present. All other bluffs are less that 3 feet high in the marshy reach, rising slowly westward to the west boundary.
DRIFT FACTORS	The only drift action is along the west boundary under the bluff with a very slight net effect westward. The whole sector lies in a low energy zone due to the broad shallow foreshore and small fetch of Drayton Harbor.
INTRUSION STATUS	The Drayton Harbor Road does not yet intrude the foreshore except at the California Creek mouth spit. Some bulkhead foreshore intrusion has occurred at the west boundary bluff area. No consequential drift blockage has taken place — due mostly to the low drift action in this zone.
USE POTENTIAL AND LIMITS	The extremely low elevation of the glacial plain behind the marshy shore provides open seascape vistas, especially due to the harbor road preventing the siting of housing along the shore. This road represents one of the few estuarine shore-bird marsh areas publicly and visually accessible, and as such should be further set back to allow more normal backshore habitat to develop.
SPECIAL NOTES OR PROBLEMS	Shallowness, lack of currents and wave action would make this marshy shore reach particularly exposed to detrimental oil and motor boat pollution, especially as it is a linkage and component of the estuarine lagoon system.

SECTOR: 5 LOCATION: Shintaffer Road to NE Tip of Semiahmoo Spit CODED SECTION:#144,#143 and#142

BOUNDARIES MILES = 2.8	The northern boundary of this sector within Drayton Harbor is absolute due to bulkheading and piling groins at the spit tip. The southern boundary overlaps near Shintaffer Road bluff. (The northern boundary also formerly overlapped into and out of Sector 6 around the spit). Most of this sector was annexed to Blaine in 1974.
ACCRETION SHOREFORMS %of sector = 50%	The predominant shoreform is the Class I berm beach of the spit making up the northern half of the sector, thus the spit is shared by both sectors 5 and 6.
BLUFF FACTORS 17	The bluff on this side of Drayton Harbor is higher and contains more gravel than the east side low bluff. This glacial deposit had a different genetic place and function during the ice-melting stages than the gently-sloping low till that covered the lagoon and left boulders during its rollback erosion. This shore is Class III with various erosional sluffing action along the bluff.
DRIFT FACTORS	This sector is also in a low energy zone with net drift becoming more positive northward along the spit. In view of the limited wave energy, drift gravel along the spit and berm is uniformly small and graded. Since movable gravel of this size is limited in the bluff, only small nourishment is provided to the spit on its east side.
INTRUSION STATUS	There are no major foreshore blockages except at the tip of the spit. Some revetment boulders, cemented sandbag bulkhead and piling project into the upper foreshore near the neck of the spit as toe protection to the road embankment. This revetment has slowed down, somewhat, feeder bluff activity in that reach.
USE POTENTIAL AND LIMITS	The 1.3 miles of small-gravel Class I beach with its stable driftwood berm and meadow backshore represents one of the finest recreational beaches in the county, especially in view of its southern protected exposure, warm water, and unimpaired horizons. Its partial destruction by marina siting at its north end is a short-sighted proposal that has additional detrimental resource impacts on the estuary lagoon itself.
SPECIAL NOTES OR PROBLEMS	The backshore at the neck of the spit in the northernmost portion of Reach #143 represents an outstanding park meadow that owes its environment in part to its former use as an Indian settlement, as witnessed by the substantial shell midden. Poorly managed diggings are already impairimg this historical site and down-grading its esthetic values.

SECTOR: 6	LOCATION: Northwest Tip of Semiahmoo Spit to Birch Point — CODED SECTION: #142, #141, #140 and #139
BOUNDARIES MILES = 4.5	This is one of the two longest drift sectors in Whatcom County. The north-east boundary is absolute at the bulkheads of structures projecting into the foreshore of the tip of the spit, although earlier drift passed around the tip by wave refraction. The south-western boundary overlaps with sector 7 at Birch Point due to the sharp break in shore orientation. The northern half of this sector was annexed by Blaine in 1974.
ACCRETION SHOREFORMS % of sector = 33%	As in the case of sector 5, the spit is the major shoreform with its Class I gravel-berm beach. The spit has a characteristic thickened tip where lower geo-hydraulic energy levels provide a slower drift rate for increased terminal accretion.
BLUFF FACTORS $\overline{8}$	All of the shoreline southwest of the spit represents an actively eroding feeder bluff that created and now maintains the accretion terminal. Height varies from 50 to 100 feet, with considerable variations in clay-sand-gravel composition and adhesiveness; some slide areas are more active in the high clay and water seepage areas. Most of the bluff shore is Class III with short sections of Class II.
DRIFT FACTORS	The north-storm shielding effect of Point Roberts and Boundary Bay produce predominant north-east drift with decreasing energy gradient from medium in the southwest to lesser wave action at the tip of the spit. Drift loading in the upper foreshore is medium with many deeper accumulations where tree and driftwood blockage and shoreline orientation produce temporary accretion zones. Unlike the small and uniform gravel beach of the east side of the spit, the west side berm is robust and built up of all sizes up to cobbles under the greater energy of waves and swash currents.
INTRUSION STATUS	Aside from the structures at the tip of the spit, the access road and its erosion protection by boulder revetment at the spit waist have as yet little beach process effect except for esthetics. The bluff reach has been intruded by some upper foreshore bulkheading just north of Reach #140, but only minor drift impairment has occurred. Some houses have been built too close to the rim of active feeder bluffs.
USE POTENTIAL AND LIMITS	As a whole, this sector represents a natural and active integrated Puget Sound shore system on the grand scale, with much of the original wilderness type environment intact. The narrow lineal scale of the spit limits development because no buffer width is available. The neck of the spit is among the most valuable shore features shared with sector 5. The bluff driftway function must be preserved inviolate.
SPECIAL NOTES OR PROBLEMS	The pressures for future housing locations within the shore process corridor of this sector constitutes its greatest threat at this time, both as to bluff toe or rim siting and subsequent defense works, or structural spit activities. Road protection on the spit should not be done by riprapping but by natural beach-enhancement techniques.

SECTOR: 7	LOCATION: Birch Bay — Birch Point to Village Marina Jetty CODED SECTION: Reach #138
BOUNDARIES MILES = 1.5	While the western Birch Point boundary overlaps into sector 6 with some net loss from each sector at this shoreline orientation break, the eastern boundary is now absolute due to artificial riprap obstruction by jetties across the foreshore.
ACCRETION SHOREFORMS %of sector = 5%	While this drift sector was a completely integrated shore system with its feeder bluff - driftway - accretion spit terminal, the severance of the spit from its supply source by the marina channel and jetties has eliminated the accretion shoreform from this sector.
BLUFF FACTORS	The bluff averages about 50 feet in height with variable and spotty composition. While this bluff is uniformly active in its recession, there are a few major slide areas in the western half where water seepage has weakened its cohesiveness. The beach is predominantly Class II with fairly heavy upper foreshore drift loading. The location is medium high energy.
DRIFT FACTORS	While net drift is eastward, there is considerable west drift as well, hence the heavier driftway loading along this beach. A small amount of drift has begun to accumulate in the groin pocket of the west jetty of the Village boat harbor entrance.
INTRUSION STATUS	Here, as in many other instances, piecemeal attempts are being made to place large beach boulders along the bluff toes to inhibit recession. (A completely futile gesture, one might add). Some riprapping has been placed along the upper foreshore between the end of the bluff and the jetty groin.
USE POTENTIAL AND LIMITS	The arbitrary and uninformed location of the boat harbor entrance and jetties between the barrier spit and its feeder bluff drift-supply source, rather than at the terminal end of the spit, has de-activated the natural system of which this sector-remnant was a necessary component.
SPECIAL NOTES OR PROBLEMS	The bluff recession in this sector is characterized by a sloping ridge-groove type erosion that often produces sudden sluffing and cave-ins. Housing set-back should be in terms of the concave groove or gully intercepts with the top rim, rather than the unstable exposed ridge projections.

SECTOR: 8	LOCATION: Birch Bay — Village Marsh-Barrier Spit (Jetty to east-end fill and marsh preserve.) CODED SECTION: Reach #137
BOUNDARIES MILES = 1.2	The length of this sector has been artifically fixed by the boat harbor jetty to the west, and the terminal fill placed almost to the Birch Bay shore road where the shoreline and drift is oriented at right angles to the sector alignment.
ACCRETION SHOREFORMS % of sector = 80%	The whole sector length makes up a former accretion spit (Class I) that built eastward across a bight of the bay, and enclosed a dependent lagoon and marsh to the north.
BLUFF FACTORS	The spit's feeder bluff, as pointed out previously, has been completely severed from the barrier spit by the wrong location of the boat harbor and its entry channel and jetties.
DRIFT FACTORS	While drift is still eastward as formerly, this littoral drift is now a cannibalizing process in which the east terminus will receive material robbed from the berm and foreshore to the west. There will be a slight reverse-drift collection of sand and gravel in the jetty groin pocket. While there is considerable fetch to the southwest, the shallowness of Birch Bay provides storm energy dissipation, and only the most extreme coincident storm-tide conditions could exact some wave-driftwood battering and inundation damage near the jetty area. The shore seems to be developing into a Class II intruded beach.
INTRUSION STATUS	Aside from the initial amputation of the barrier spit from its feed source to the west, a complete transformation has been allowed to proceed here, and continues to this day. The invasion of the shore process corridor is particularly consequential here because of the involvement of interdependent geo-hydraulic and bio-process eco-systems.
USE POTENTIAL AND LIMITS	The heritage potential of this resource has been lost to irreversible burial, lagoon gouging, berm leveling and occupation, marsh filling, and the destruction of one resource to produce another without heritage compensation to the county shorelands.
SPECIAL NOTES OR PROBLEMS	The degree to which this shore-lagoon-marsh system has been obliterated allows for no last-chance rehabilitation of any original natural systems. Some beach gravel feeding may have to be instigated in the western portion near the jetty, as this area will erode first along the berm. Only the houses built over the beach berm will be subject to much coincident storm-tide damage.

SECTOR: 9 LOCATION: Birch Bay — East End of Birch Bay Village Fill to Mouth of Terrell Creek CODED SECTION: Reach #136, #135

BOUNDARIES MILES = 2.1	Since the artificial closure and plugging of the lagoon by fill for the Village development, the northwest boundary of this sector is not quite as absolute as formerly, and some drifting sand may eventually leak west across to the barrier spit sector. The south boundary of Terrell Creek mouth and channel also allows some lower foreshore drifting northward from sector 10.
ACCRETION SHOREFORMS % of sector = 100%	The original shoreform of this sector comprising the northeast shoreline of Birch Bay seems to have been a rollback berm beach formed from an eroding glacial plain extending partly into the present foreshore, with only minor drift supply from the feeder bluff at Point Whitehorn.
BLUFF FACTORS 21	The beach berm gravel supply has been severely reduced, and the beach is slowly receding and feeding on itself in the southern portion (except what little leaks across Terrell Creek channel.)
DRIFT FACTORS	This shore is in a low energy zone due to the broad foreshore covering the whole bay. There is a shortage of berm-building gravel, and most of the drift is sand. Only very slight reverse-drift takes place. This sector has been groined excessively without producing the desired effects due to lack of material to begin with. Northward drift is so positive, however, that most groins are tilted, drift level differentials up to 30 inches being common.
INTRUSION STATUS	Aside from the afore-mentioned groin intrusion across the foreshore, much of the sector length has been riprapped and bulkheaded for adjacent road defense. Practically all of the backshore is road and housing. Had the road been located landward of the original berm, a fine Class I beach berm would be available without need for road erosion control. Only a few feet of proper alignment could have prevented this loss.
USE POTENTIAL AND LIMITS	While arbitrary shore management and road location have buried a major county and state shore resource, the presence of the road has retained options for beach enhancement and the opportunity to return this sector to a Class I dry beach.
SPECIAL NOTES OR PROBLEMS	Road defense against extreme high storm, tide wave action will continue until the barren upper foreshore is provided with the proper size berm gravel to buffer the eroding toe.

SECTOR: 10	LOCATION: Birch Bay — Terrell Creek Mouth to Point Whitehorn CODED SECTION: Reach #134, #133, #132, #131
BOUNDARIES MILES = 3.3	This sector comprises the south half of the Bay, with upper foreshore gravel drift terminating at the mouth of Terrell Creek. The south boundary is an overlap similar to that at Birch Point, primarily a division line brought about by a sharp change in shoreline orientation. The 110° direction change makes any reverse drift recovery from sector 11 very difficult, thus sector 11 is a drift contributor.
ACCRETION SHOREFORMS % of sector = 64%	While this sector contains a complete erosion-accretion system, the unique lengthy accretion barrier beach spit deflecting Terrell Creek has been partially buried under road and housing structures. Only at, and immediately east of, the State Park is the Class I berm beach still operative and visible, as well as the last 150 yards terminating at the creek mouth.
BLUFF FACTORS	The bluff east of Point Whitehorn is in a moderate energy zone; with the major beach feed material being derived from the higher energy exposure just at, and south of, the Point in sector 11. The bluff shore in sector 10 is Class III with moderate recession by occasional sluffing.
DRIFT FACTORS	No major drift blockages have occurred along the bluff shore, but the north-eastward drift along the berm has been slowed down and partially blocked by bulkheading and foreshore groins in the northern reach of the sector east of the State Park. The drift loading of gravel in the upper foreshore decreases from heavy to meager northward. Little coarse gravel leaks across Terrell Creek's mouth into sector 9.
INTRUSION STATUS	Most of the original backshore of the barrier spit and berm with its creek surge-plain and marshes has been altered and occupied by roads and housing, while most of the upper foreshore north and east of the park is bulkheaded and groined, changing a Class I to a Class II and III beach with erosional problems.
USE POTENTIAL AND LIMITS	A short beach length in Reach #133 is still in a near-natural state just outside (and east) of the park, and should receive preservation or proper development attention for its future. Where the berm beach is still operative, it should not be riprapped to protect roads located too close to the berm, but the latter road should be set back.
SPECIAL NOTES OR PROBLEMS	Location and design of defense works in this sensitive drift sector should be evaluated in terms of the total reach and not at individual property owner discretions. Housing atop the bluff reach is approaching the geo-hydraulic action zone of the feeder bluff that cannot be defended against by bluff-toe bulkheads, especially in view of the critical open driftway needs of this shore.

SECTOR: 11	LOCATION: Point Whitehorn to Arco Pier Ramp — CODED SECTION: #130, #129, #128
BOUNDARIES MILES = 2.8	This sector represents the northern quarter of what was originally the longest drift system in the county, namely 11 miles to the east side of Sandy Point spit. It has more recently been cut off from its southern reach by the upper foreshore bulkhead of the Arco Pier ramp which is, however, not entirely absolute, but allows lower foreshore drifting of sand. The northern sector-limit reaches irreversibly around Point Whitehorn, but the boundary is established at the Point in terms of sector 10.
ACCRETION SHOREFORMS % of sector = 0%	No shoreforms remain in terms of an accretion form fed by this bluff sector, except what drifts around the Point into Birch Bay, and is added to the barrier berm there.
BLUFF FACTORS	Sector 11 is an unbroken erosional bluff shoreline with a narrow Class II marginal berm beach. Bluff recession is on a broad front and fairly uniform, with greatest activity where ridge-gully type erosion patterns have developed, or where water seepages occur. The zone is uniformly high energy not only because of north-south orientation, but close-in deep water allows storm breaker action at the bluff toe.
DRIFT FACTORS	Shore orientation allows for high two-way drift rates. While this sector has now lost its beach feeding function southward, it retains its contribution to sector 10 (Birch Bay). With time, net drift southward will tend to form a crescent pocket beach against the Arco bulkhead, and drift of gravel will leak across into sector 12.
INTRUSION STATUS	In the junction area of Reach #130 and #129, bluff rim housing has led to some boulder placement at the foot of the bluff in the upper foreshore, but without serious drift interruption. The major intrusion is, of course, the Arco Pier bulkhead-ramp, although this one has less impact of the three piers along this coast. It lends itself to low-cost re-design for upper foreshore gravel drift passage.
USE POTENTIAL AND LIMITS	Much of this bluff coast still offers a fine wilderness beach character, especially as it is representative of high energy displays of coastal geo-hydraulics. Facing into the long fetch and distant horizons of Georgia Strait, its exposure to the elements is its prime seascape value.
SPECIAL NOTES OR PROBLEMS	Bluff rim housing will need ample set-back as evidenced by the county road corner exposure to an eroding gully in the middle of Reach #129 , (Aldergrove and Point Whitehorn Roads).

SECTOR: 12 LOCATION: ARCO Pier to INTALCO Pier (Cherry Point on Georgia Strait) CODED SECTION: #128, #127, #126, #125

BOUNDARIES MILES = 2.6	This sector is bracketed between artificial upper foreshore drift barriers in the form of bulkhead pier ramps, the northern ramp at the ARCO installation allowing some lower foreshore sand drift bypass. The southern INTALCO bulkhead is considerably more of an obstacle to gravel movement south, and would need considerable modification to re-establish the original driftway to Sandy Point spit.
ACCRETION SHOREFORMS % of sector =15%	Aside from the accretion berms that are beginning to build in bulkhead pockets of the above-mentioned installations, a low drainage area between bluffs near the Gulf Road provided the conditions for an accretion barrier berm beach to develop, along with its associated backshore marsh and creek outlet. This Class I beach, about 1750 feet long with robust berm, is almost entirely natural (80%).
BLUFF FACTORS	Sector 12 like sector 11 is an active beach material producer, particularly the bluffs at each end of the sector. Being in a high energy zone, and relatively low in clay content, these bluffs can maintain a steady feed rate of gravel to produce a Class II narrow-berm beach.
DRIFT FACTORS	Since this reach is in a general south-east to north-west orientation, considerable drift shuttling and reversing takes place with a slow net effect southward. Drift-loading is fairly thick and heavy, and cobbles as well as gravel are moved actively in this high energy environment. While the marsh and creek channel across the foreshore can be a seasonal drift barrier at times, its overall effect is not critical.
INTRUSION STATUS	No direct top-of-bluff housing intrusion has taken place. Alterations to beach processes are only minor drift hindrances in the barrier beach area by road or abandoned marine structures. The primary intrusion is the riprapped fill ramp of the INTALCO pier.
USE POTENTIAL AND LIMITS	The shore environments within this sector are among the most varied and valuable along this coast. Even though bracketed by the geo-hydraulic and esthetic impacts of industrial piers and activities, the sector is long enough to minimize such intrusion when viewed from the central Class I beach area. The removal of abandoned structures along the marsh and barrier beach would enhance the original resources.
SPECIAL NOTES OR PROBLEMS	The topographic features of a gently sloping meadow bordered by an adjoining idyllic and functional forest-marsh-creek parkland at water's edge was made to order for ancient habitation as evidenced by the Indian shell midden at the north end of the barrier beach. These low elevation park features also represent desirable elements for economical industrial siting and activities. The scale of this accretion shore resource entity does not allow multi-use, and trade-offs invite great pressures here.

SECTOR: 13 LOCATION: INTALCO Pier to MOBIL Pier (on Georgia Strait) CODED SECTION: #125, #124

BOUNDARIES MILES = 0.9	The boundaries of this sector are dictated by the foreshore intruding riprap ramps of the northern INTALCO and the southern MOBIL piers. They are absolute in terms of upper foreshore gravel drift, but allow some lower foreshore and drifting both north and south.
ACCRETION SHOREFORMS %of sector = 2%	This relatively short sector has been arbitrarily created along a bluff-shore reach that does not represent an integrated system. It has no accretion shoreforms except for the first beginnings of pocket accretion against the two terminal bulkheads. The shore is a uniform Class II bluff beach.
BLUFF FACTORS	Although the bluff is heavily timbered, erosional action is mainly of the ridge-gully type where clay pockets or water seepages encourage slides and cave-ins. The zone is high energy. Bluff recession may increase in the northern portion as the drift-berm becomes less of a bluff-toe protection because the lack of gravel drift (blocked by INTALCO ramp) will thin out down-drift loading.
DRIFT FACTORS	Until a drift-passage program past the pier ramps has been made operative, this sector will act as a pocket beach with drift being shuttled back and forth. It would probably take at least a hundred years for the natural accretion buildup around the ramps to re-align a berm line to direct gravel southward and northward past these present sector boundaries now acting as groins.
INTRUSION STATUS	There are no intrusions into the foreshore or bluff zones except the large bulkhead fills at the boundary terminals.
USE POTENTIAL AND LIMITS	In the absence of unique or important shoreforms or resource values, this geo-hydraulicly and visually impacted shore reach is the type that can be further developed for industrial purposes without significant trade-offs or environmental downgrading in terms of the present status.
SPECIAL NOTES OR PROBLEMS	It would be technically possible and economically reasonable to make the necessary alterations in the pier ramp foreshore areas to re-establish longshore drift passage past these drift obstacles, as well as design any new installations with natural beach processes in mind. Thus it would be feasible to return the total coast reach from Point Whitehorn to Sandy Point to its original single-sector status and function supplying and maintaining littoral gravel drift to the spit terminal.

SECTOR: 14 LOCATION: MOBIL Pier to Sandy Point Harbor Jetty (Georgia Strait) CODED SECTION: #124, #123

BOUNDARIES MILES = 2.7	As in the case of the adjacent drift sectors to the north, the boundaries here are also artificially fixed by the groin effect of protruding bulkhead riprap at the MOBIL ramp, and the riprap north jetty and dredged channel at the Sandy Point boat harbor. While the northern boundary prevents berm-building gravel from moving south, the jetty and channel are absolute in terms of both gravel and sand movement.
ACCRETION SHOREFORMS % of sector =70%	Two distinct shoreforms are found in this sector, namely a blocked-marsh barrier beach and a major spit - the former being located in the northern portion of Reach #124 at Neptune Beach, and the latter being the west half of the Sandy Point spit. Only short reaches of unaltered berm beaches remain, the marsh barrier being one. The remaining (over 80%) accretion beaches must now be classified as Class II instead of Class I.
BLUFF FACTORS	Only a half mile of feeder bluff remains within the most imposing drift sector of Whatcom County; the original supply source of six miles of active feeder bluffs having been severed from this integrated system by industrial pier ramps in the foreshore. Thus the bluff shore is beginning to thin out in gravel and is changing from a Class II to a Class III bluff beach.
DRIFT FACTORS	There is a good deal of drift-shuttling along the spit in view of the north-south shore orientation. Not only is this a high energy zone, but the long open water fetch up Georgia Strait to the northwest assures a net longshore-drift southward. Heavy wave action here can move coarse gravel and cobbles, and thus the beach-berm is broad and stable where it has not yet been intruded upon — and thus made inoperative for wave swash percolation.
INTRUSION STATUS	The intrusion pattern indicates a trend toward complete occupancy of the beach berm along the spit by bulkheaded housing — only about 20 percent of Class I beach remains intact. While most houses have been set back from the seaward face of the berm, there has been no coordination, and many bulkhead structures extend into the upper foreshore drift berm, robbing its swash percolation function and severely reducing its protective character.
USE POTENTIAL AND LIMITS	A basic planning and management lesson should emerge from Sandy Point spit development, namely that the natural spit's significant scale provided opportunities for safe, central-core occupancy without the past and continuing losses in Class I beach functions and resource heritage values, and property.
SPECIAL NOTES OR PROBLEMS	Sandy Point spit lies at the exposed terminus of the hundred-mile open wave fetch of Georgia Strait. As such, its west shore housing is subject to inundation and severe wave and driftlog battering within a hundred year extreme and coincident high-tide storms from the north. Increased defense works will compound beach erosion and resource losses, and cannot correct faulty planning.

SECTOR: 15	LOCATION: Sandy Point harbor south jetty to Cove Creek mouth in Sandy Point "cove". (Lummi Bay) CODED SECTION: #122, #121, #120
BOUNDARIES MILES = 2.0	The groin-acting jetty and dredged channel at the marina entrance represents an absolute barrier to long-shore drift, which provides the berm building and maintaining gravel material. The northeast sector boundary at Cove Creek mouth is not leak-proof, but is rather positive in view of the converging shoreline orientation and recessed location of this division between drift sectors 15 and 16.
ACCRETION SHOREFORMS %of sector =100	This sector is the east half of the Sandy Point spit shoreform, plus a marsh-barrier beach at the cove head in the northeast corner of the sector. Within the long Class I intruded berm beach of the Lummi Bay side of the spit, a small accretion point has formed at the northeast end of Reach #122, and which along with the final marsh-barrier beach is as yet undisturbed. Only one quarter of the Class I beach is still natural.
BLUFF FACTORS	Today no bluffs or other feed material source lie within this sector that not too long ago represented the terminus of the long and integrated natural drift sector (11 miles long) beginning at Point Whitehorn. A period of so-called "canibalism" will now begin to unroll the berm gravel northward at the expense of the south tip of the spit.
DRIFT FACTORS	Both south-wind and refracted north-wind waves produce a northward flowing net drift. Since the spit tip and east shore represent the original terminal deposition of the long sector coast, only the smaller gravel sizes and sand are dominant in the drift berm here, especially as the shallowness of Lummi Bay progressively reduces the energy level northward. The marsh barrier beach is made up of only small gravel and much sand, and is heavily vegetated and rooted. Some foreshore groins have been placed near the spit tip to build up gravel in front of a few dwellings.
INTRUSION STATUS	Although some bulldozer-leveling has been done on the berm, about 25% of the shore remains Class I beach, with the remainder occupied by housing and the inevitable beginnings of bulkheading. All lagoons and marsh areas originally part of the spit have been destroyed except for the marsh behind the cove-head barrier berm.
USE POTENTIAL AND LIMITS	The natural marsh and small creek-mouth estaury at the head of the cove at the west end of Reach #120 has, as yet, retained its options in terms of habitat and bio-process preserve.
SPECIAL NOTES OR PROBLEMS	While the west coast housing strip in sector 14 of the spit is exposed to greatest damage under extreme storm-tide conditions, excavation of the spit core for the marina and canals and its tidal water poses an inundation hazard, if not a wave hazard, to the east coast dwellings in terms of tidal surge gradient from wind pressure. The "open" design of the harbor entrance also hints at iminent harbor erosion, along with jetty maintenance and stability problems.

SECTOR: 16 LOCATION: Sandy Point-Cove Creek to mouth of Red River (Lummi Bay) CODED SECTION: #120

BOUNDARIES MILES = 1.1	The extent of this short sector is pretty much defined by the Cove Creek channel and shore orientation change at its west end, and the final east-end barrier of foreshore channel and shallow marsh near the Red River tidal culvert.
ACCRETION SHOREFORMS % of sector = 5%	This sector is characterized by a low energy beach-process system with a central feeder bluff providing material for two small gravel berm beaches at each end, the Cove Creek backshore being narrow and vegetated with sedge and dune grass, while the eastern terminal Class I beach has a more substantial berm and meadow backshore. A small east-end reach of the shore is estuarine marsh. All of the small accretion beach is natural.
BLUFF FACTORS	Most of the sector (80%) is heavily wooded medium height (40 foot) bluff situated in an extremely low energy zone of the shallow, recessed north end of Lummi Bay. Only a few boulders and cobbles remain in the muddy upper foreshore, there being a great shortage of gravel in the bluff, and no chance to produce a drift berm at bluff toe. Thus it is a characteristic low-energy Class III shore, with tree growth outspacing erosion.
DRIFT FACTORS 28	This shore projects a central promontory into the south fetch so that drifting, what little there is, flows both northwestward and northeastward simultaneously from the middle bluff, hence the two small accretion shoreforms at each end. These two Class I beaches make up about 5% of the total shore.
INTRUSION STATUS	No foreshore intrusion has occurred in this sector; however, there now appear the first signs of turning a marshland resource to real estate at the east end of the sector, where filling has occurred over a backshore marsh.
USE POTENTIAL AND LIMITS	This sector might well be divided along environmental and visual-impact (or intrusion) factors, in which the western half, with its deep-forested wilderness bluff shore, forms a compatible and needed buffer for the Cove Creek and marsh nature preserve. The shallowness of the bay and cove tend to discourage motor boat activities, and thus encourage birds and wildlife.
SPECIAL NOTES OR PROBLEMS	Whether a creek-marsh-forest-meadow sanctuary can be sustained here depends to a large degree on the plans and pressures from the adjacent Sandy Point and Sandy Point Heights developments.

SECTOR: 17	LOCATION: (North end Lummi Bay Delta outside of Aquaculture Dike) Red River mouth to Lummi River mouth. CODED SECTION: #119
BOUNDARIES MILES = 1.2	This accretion peninsula between two small rivers is not a true drift sector but a fluvial (stream) deposit in a marine embayment with estaurine marshes and accreting delta lobes. A saltmarsh island between two Lummi River distributaries (branches) is also part of this shore system. It is included as a complex environmental shore resource, bio-process and habitat zone that deserves a separate geo-hydraulic analysis, like the Nooksack Delta.
ACCRETION SHOREFORMS %of sector = 0	
BLUFF FACTORS	
DRIFT FACTORS	
INTRUSION STATUS	A combination of sea-dikes and river-levees have seriously affected the operation and function of the former "surge-plain" operating here. However, a salicorna salt-marsh immediately seaward of the dike is in a natural delta-lobe environment, and the "driftwood-fence" of old pilings along the marsh shore has had little effect on the marsh itself. The marsh island is unfenced.
USE POTENTIAL AND LIMITS	
SPECIAL NOTES OR PROBLEMS	

SECTOR: 18	LOCATION: Lummi Aquaculture Dike South to E-W Line of Smokehouse Road. (South Line of Sec. 27, T38N, R1E.) CODED SECTION: #118, #117
BOUNDARIES MILES = 2.5	This sector makes up the SE portion of Lummi Bay, most of which represents the lower foreshore flats of an earlier Nooksack River Delta. While the north boundary is absolute at the dike, the south boundary is a rather indeterminate overlap zone that could be as wide as a mile. Its location is a function of relative fetch NE to SW, as well as wave refraction angle, fetch trajectories, and foreshore width.
ACCRETION SHOREFORMS % of sector = 30%	The northern half of the sector is low marine terrace upland fronted by narrow Class II and Class I small gravel berm beaches. A small creek estaury near the dike has caused a marshy backshore, the northern portion of which has been buried by the dike road and Aquaculture buildings. A short bay-barrier berm has naturally diked a marsh near Cagey Road, and there is also some primary dune effect along this berm. About one third of accretion beaches are natural.
BLUFF FACTORS	The northern half of the sector is a low marine terrace eroded back over a broad foreshore, with a narrow berm of accreted sand and small gravel forming a Class II beach, and occasionally a narrow back-shore Class I type. The higher cliffs of the southern portion are the feeder bluffs located in a higher energy zone. Covered with trees, they are active nevertheless, with Class III beaches at their toes.
DRIFT FACTORS	The increasing shallowness of Lummi Bay northward along the sector shore decreases wave energy rapidly and drift also becomes more positively northward. There seems to be some dune-effect superimposed, at times, over the narrow gravel and sand berm, the sand derived mostly from Nooksack River silt that has filled the bay.
INTRUSION STATUS	While occasional bulkheading occurs, it is mostly behind the berm along the low-bank terrace middle and north portion. There is evidence that some of the more recent shore houses are being set too close to the high-tide line and low bank edges, requiring foreshore-projecting bulkheads. In view of the narrowness of the drift berm, bulkhead position is very critical in this sector.
USE POTENTIAL AND LIMITS	Housing intrusion is very low key, in terms of visual impact, and the beach is an unusual low-energy and protected warm-water strand, ideally suited for swimming and walking, but not boat accessible at the lower tides. Aside from the natural bluff shore, the short reach of marsh-barrier beach in the central portion is still relatively untouched and an esthetically valuable natural habitat area.
SPECIAL NOTES OR PROBLEMS	Since the southern sector boundary is not sharply defined, only a general statement can be made as to top-of-bluff impacts:namely the farther south the bluff-edge location toward Gooseberry Point, the higher the geo-hydraulic energy level, and greater bluff setbacks for structures should be observed.

SECTOR: 19	LOCATION: E-W Shore Intersect Line of Smokehouse Road to Gooseberry Point Marina. (South line of Sec. 27, T38N, R1E) CODED SECTION: #116
BOUNDARIES MILES = 1.1	The north boundary of this sector overlaps with sector 18, with sector 19 contributing more drift to sector 18 than can find its way back. The south boundary is absolute in the upper gravel berm foreshore, where drift is prevented from reaching its former extension along the south beach of Gooseberry Point due to the marina bulkhead. There is, however, lower foreshore sand drift around the point.
ACCRETION SHOREFORMS %of sector = 24%	The southernmost tip of the sector west of the Gooseberry Point ferry dock and marina is part of the original point border that forms the shore around a low-elevation peninsula. Thus Gooseberry Point is a combination of glacial marine terrace promontory with an accretion berm fringe forming a Class I beach at the tip. About one third of the accretion beach remains natural.
BLUFF FACTORS	All bluff shores are in the northern portion of the sector, and continue into sector 18. This bluff is in the terminal fetch pocket of north winds down the Strait of Georgia, a fetch of a hundred miles. Bluff recession and geo-hydraulic action is high rate, especially as there are considerable bluff portions with high gravel and low clay content. As bluff height decreases southward, erosion output slows.
DRIFT FACTORS	Because of the open water to the northwest, net drift is south, although some north drift supplies sector 18 in Lummi Bay. Drift loading on the Class II bluff shore section is medium heavy and there is considerable shuttling and reversing. Strong tidal currents near Gooseberry Point, as well as narrow foreshore, have prevented the point from growing out into Hale Pass.
INTRUSION STATUS	Aside from the south boundary bulkhead of the marina acting as an upper foreshore groin, there has been general bulkheading along the low marine-terrace bank between the point and the gradually rising bluff northward. Only one house has recently bulkheaded in the foreshore in a bluff-side area. These would have been unnecessary defense works if proper setback had been observed at the top edge.
USE POTENTIAL AND LIMITS	The Class I berm beach at the point is robust and untouched in front of the present restaurant, which has maintained proper setback for natural beach maintenance and appearance.
SPECIAL NOTES OR PROBLEMS	The recessional bluff in the northern portion of the sector is an important beach maintenance and gravel source, and should be left undisturbed for that function, especially as it also feeds northward into Sector 18.

SECTOR: 20 LOCATION: Gooseberry Point Marina to Hermosa Beach past Portage Point. CODED SECTION: #115, S½ of #114

BOUNDARIES MILES = 2.3	The northwest boundary is the bulkhead off the Gooseberry Point Marina shop which allows some sand drift in the lower foreshore, while the southeast boundary is indeterminate in an overlap zone on Bellingham Bay that obtains its location by virtue of relative fetch ratio and wind-shadow protection around Portage Island.
ACCRETION SHOREFORMS % of sector = 26%	Three distinct accretion shoreforms occur in the sector, two of which are bay-barrier beaches where the berm has accreted across indentations of the shore to create backshore marshes and later meadows. The first of these is the south-facing beach east of the County ferry dock, and the other lies in front of the Lummi Tribal Stommish festival grounds. The third shoreform is the dual-lobed point at the Portage. About one half the total accretion beaches is still natural.
BLUFF FACTORS	All of the intervening shores between the three accretion berm beaches is medium-height (less than 50 feet) bluff shore of Class III classification. Recessional erosion is moderate due to the clay factor in the bluff, as well as shore orientation and storm protection from Lummi Island.
DRIFT FACTORS	The Hale Pass portion of this sector lies in a "wind-slot" orifice that produces fairly strong drift and geo-hydraulic action in both northwesterly and southeasterly directions. The projection of Gooseberry Point Peninsula blunts the otherwise predominant high-energy wave action from Georgia Strait. Drift loading along the bluff shores is light because the clay content of the bluffs inhibits gravel release, and the shore orientation encourages high rate of drift movement toward the accretion terminals.
INTRUSION STATUS	The only intrusion into the upper foreshore and backshore has occured at the Lummi festival center where riprap has been placed over the berm to protect a poorly-located beach road. The present road position at Portage Point is too close to the berm for good beach functioning or people-use needs, and if riprapped for defense may become an erosion area.
USE POTENTIAL AND LIMITS	The south beach at Gooseberry Point is a unique beach area that has been retained essentially in its natural state because of the adjacent road location and preservation as a private community beach. Its robust berm and backshore of high gravel content allows people-use without much damage, and its orientation encourages rollback berm maintenance without great dependency from adjacent feeder-bluffs. Portage Point is a scenic local swimming beach.
SPECIAL NOTES OR PROBLEMS	The location of roads along most of the shores retains much public access, although the road may need to be relocated slightly landward in a few instances of bluff recession. The intertidal and fresh seepage water runoff system of the intruded lagoon and meadow at the Tribal center, while still operative through the berm channel, may be too seasonal to be tolerated in its present space requirement. An early planning assessment of Portage Point backshore needs should be considered.

SECTOR: 21	LOCATION: North end Hermosa Beach to west distributary of Nooksack at Fish Point. CODED SECTION: N¼ of #114, #113, #112, S¼ of #111
BOUNDARIES MILES = 4.0	The northeast boundary of this sector on the shore of Bellingham Bay is fixed by the marine shore termination at the mouth of the western Nooksack River distributary and slough. The southwest boundary overlaps into Sector 20, and reaches into the wave-shadow behind Portage Island off the tip of Brant Point.
ACCRETION SHOREFORMS %of sector = 0%	No distinctive accretion shoreforms are located within this sector, except for some marshy backshore at its northern terminus in the stream channel environment. Due to sporadic concentrations of bluff gravel and cobbles with some boulders, narrow berms and accretion backshore pockets fill occasional shore indentations where insufficient energy prevents further drift passage.
BLUFF FACTORS	The shoreline of this sector is almost wholly made up of one medium-height (40') recessional bluff, which gradually increases in height from sea level to fifty feet northerly. The shallowing of Bellingham Bay by Nooksack River sediments has caused significant reduction in geo-hydraulic activity level northward along this Class III shore. Recession rate is variable in terms of bluff composition and fetch location.
DRIFT FACTORS	Drifting of upper foreshore sand and gravel is initiated primarily by south winds moving material northeasterly toward the river. Occasional east winds reverse this direction, as they also cause drift to Portage Point. At extreme tide with south storms, wave refraction impinges directly on the toe of the bluffs, and erosion is severe. Drift loading is variable from thin to heavy, with geo-hydraulic action decreasing toward the northeastern boundary where the foreshore becomes exceedingly wide.
INTRUSION STATUS	There has been some riprap erosion defense of the county road along the low-bank Hermosa Beach reach at the southwest boundary of the sector. This has not yet had any significant effects on drift passage. Likewise some bluff toe revetment work to protect the road has been done south of Cagey Road intersect in the northern half of Reach #112.
USE POTENTIAL AND LIMITS	Location of the county road along the bluff rim has provided tribal and public access to the beach, although difficult in the higher bluff reaches. An early crucial decision needs to be made for one of the most scenic roads in the county located within the shore-process corridor, one that cannot be defended against by bulkheading. Proper long term re-location will serve scenic overviews and hazard elimination.
SPECIAL NOTES OR PROBLEMS	

SECTOR: 22	LOCATION: East Nooksack River distributary to beach end west of plywood plant in Bellingham. CODED SECTION: E. 1/10 of #111 #110, #108
BOUNDARIES MILES = 3.2	While the west boundary of this sector is a river estuary area overlapping with the marine shore of Bellingham Bay and thus is somewhat indeterminate, the east boundary is fixed and absolute at the foreshore fill projecting into deep water of Bellingham harbor (site of Mount Baker Plywood plant).
ACCRETION SHOREFORMS % of sector = 20%	Three accreted Class I berm beaches may be distinguished, the westernmost being a former spit building westward, and forming a point with considerable backshore (west end of Reach #110) that is naturally diked on the west end by a combination low marine berm and river sand levee. Adjacent on east end of Reach #110 is a narrow sand berm beach with old industrial wastewood accretion. A broader backshore gravel beach is part of a small creek delta in the sector east end at the cement plant called "Little Squalicum"
BLUFF FACTORS	All of the sector is backed by bluffs that gradually rise eastward from 60 to 100 feet. They are low in gravel and high in sand, moderate to highly active in a medium energy zone, with greatest recession rate in the bight area of #109 and near the cement plant. Erosion is frequently of the gully-ridge type. Bluff beaches vary between Class II and III with narrow berm of high sand content.
DRIFT FACTORS	Only south storms produce a predominant westward drift, and while there is considerable fetch for such wave action, both bay refraction and a wide foreshore attenuate bluff undercutting. Wave angle is near perpendicular (normal) to shore direction, thus drift rate is low and drift loading is high. Nooksack River diking with increased bay sedimentation has lowered the shore-process energy level of this sector considerably. Some reverse drift takes place in the extreme east corner of the sector for terminal accretion there.
INTRUSION STATUS	Foreshore intrusion has occurred at the cement works where waste lime and clinker has been dumped with slight upper foreshore drift blockage. Likewise there has been rock dumping over the bluff for stabilization of the Burlington Northern railway embankment, with some minor drift blockage in the foreshore, east of the cement plant. However, all Class I beaches west of plywood plant area are natural.
USE POTENTIAL AND LIMITS	In view of the fact that the Nooksack Delta is the only major unaltered river mouth estuary in Puget Sound, "the western" half of this sector represents a natural, compatible shore environment, and delta approach and viewing corridor. It can serve as a future buffer between the urban and industrial and the estuarine shore habitats. All three accretion beaches can be enhanced for public use.
SPECIAL NOTES OR PROBLEMS	The railroad enters the shore-process corridor in the middle of Reach #109 and follows eastward along the bluff rim with insufficient setback. Defense of this location will require continued foreshore intrusion and bluff alteration over a distance of 1.4 shore miles. (Bluff toe defense will not affect bluff-rim recession rates, and rock revetment dumping will often be at lesser repose angle than the bluff face, thus critical foreshore will be adversely affected.)

SECTOR: 23	LOCATION: Portage Island — Point Frances to and around Portage Spit (Hale Pass shoreline) CODED SECTION: SW 1/3 of Reach #156, #155, NW 5/6 of #154
BOUNDARIES MILES = 2.8	Both boundaries of this complex sector are overlapping in drift passage since they are on a small island where shore orientation relative to wind fetch determines drifting limits if no barriers exist otherwise. The southeast boundary is within the Point Frances feeder bluff shore, while the northwest drift limit is the eastern side beach on Portage Spit neck.
ACCRETION SHOREFORMS %of sector = 46	Two major accretion shoreforms make up almost half of the sector shoreline, the northern one forming a broad-necked spit with adjoining tombolo-bar to Portage Point (4000 feet). South of the spit on Hale Pass past a low-bank marine terrace lies a long barrier beach berm with broad backshore marsh and pond (3000 feet) (N½ of Reach #155). Backshore ponds are only slightly brackish when occasionally invaded by salt water during tide storms. All Class I beaches are natural.
BLUFF FACTORS	The southwestern portion of Point Frances bluff is the major source of sand and gravel making up and maintaining the two shoreforms to the north. This bluff lessens in height northward from 150' to sea level at the barrier beach. A secondary feeder bluff is the low marine terrace bank eroding between the spit and barrier beach. Heavy drift loading makes the bluff beaches Class II.
DRIFT FACTORS	Point Frances bluff splits the southwesterly storm waves in a medium high energy geo-hydraulic zone, there being evidence of significant recession of the bluff face. Gravel production for berm building is particularly prolific in view of the low clay content of the bluff deposit. Wave energy reduces somewhat northerly into Hale Pass. Berms are broad and robust in both barrier beach and spit beach, with only finer size gravel reaching around the spit into its eastern protected shore. The tombolo bar, called the Portage, is still accreting, and will eventually become a tombolo berm beach unless dredged for boat passage.
INTRUSION STATUS	No unnatural intrusion into the shore-process corridor has occurred except for the compaction effect of a primitive dirt road over the berm. A seldom used dwelling is located in the terminal pocket backshore of the eastern neck of Portage Spit, but without physical impacts to the shore.
USE POTENTIAL AND LIMITS	Portage Island with its three drift sectors represents the most varied and concentrated geographic assembly of Puget Sound shoreforms in the natural state, and is of priceless state-wide significance. Each one of its five shoreforms is a classic example of geo-hydraulic processes operating in various energy zones that determine its physical and living environment, a showcase of the Shore-Process Corridor.
SPECIAL NOTES OR PROBLEMS	While scale and often robust shoreland conditions would allow multi-use people-park development in this sector without physical damage, there is nevertheless here presented a unique opportunity for the creation of an island preserve where all primitive eco-systems can be monitored in an open classroom for centuries, and where proper management can provide public heritage experience of a different type than forced upon citizens within the standard marine-park mold of clashing activities.

SECTOR: 24 LOCATION: Portage Island — Point Frances to and around Brant Point spit (Bellingham Bay shoreline) CODED SECTION: N 2/3 of Reach #156, S½ of #157, #158

BOUNDARIES MILES = 3.0	The boundaries of this sector are very similar to those of sector 23 in that they are terminal areas of net drift based on shore orientation and wind direction changes. The Point Frances bluff area is a wide overlap zone where small changes in prevailing southerly winds decide drifting into either sector 23 or 24. The northern boundary is the tip of Brant Point, a hooked spit with back-drifting south on west shore.
ACCRETION SHOREFORMS % of sector = 50%	The entirely natural hooked spit of Brant Point is the one accretion shoreform of this sector. It is somewhat S-shaped with characteristic thickening at the tip where accretion slowdown in a lower energy reach accumulates drift material. The spit (4500 feet long) has evidently undergone considerable westward shifting with time and is in a delicate balance with its supply material maintaining a marginal narrow berm near the neck.
BLUFF FACTORS	While the Point Frances feeder bluff is a very active gully-ridge type quarry with a narrow Class II marginal berm beach, the east-side timbered bluff is in a lower energy zone and operates more as drift way than feeder to the spit. The beach at the toe of the latter bluff is Class III with low drift loading because of the favorable orientation for fast drift transport. The Point Frances feeder bluff is high in gravel.
DRIFT FACTORS	Relative fetch along the north-south shore alignment of this sector creates a positive net drift northward with little reverse movement south. The west shore of the Brant Point spit lies in a low energy zone where drift is generally southward, and gravel size and berm height is less than the east shore.
INTRUSION STATUS	Some timbers rest in the upper foreshore on the east side of the spit past its neck, and these seem to be partly responsible for a thinning and breaching of the berm down-drift (northward). This is a temporary situation that points up the delicate balance of supply and demand of this geo-hydraulic operation. There is log storage in the Portage Bay that may have adverse effect on aquatic bio-processes.
USE POTENTIAL AND LIMITS	All the Class I beaches of the spit represent ideal day-use seascape with meadow backshore room for swimming and picnicking with boat approach, while the spit neck with its meadow and tree fringe would make an idyllic primitive camping area. This meadow represents, however, an impressive Indian midden site, and midden use policies will need to be made in terms of tribal interests and other uniqueness factors.
SPECIAL NOTES OR PROBLEMS	While breaching of the spit berm is a cyclic future problem, it can be inhibited with proper beach housekeeping techniques. An early beach-process and bio-process monitoring system should be for an overall baseline study for best future management approaches. Multi-use, if practiced, needs to be based on eco-system rather than geographic divisions, and thus inter-dependencies need to be early in the planning stage.

SECTOR: 25	LOCATION: Portage Island — Neck of Brant Point spit to neck of Portage spit (Portage Bay shoreline) CODED SECTION: W 1/5 of #157, #158, NE 1/7 of #154
BOUNDARIES MILES = 1.9	The boundaries of this sector are more or less fixed by the bay-embracing spits at each side of the Portage Bay east and west shores, although overlap drifting can occur to a small degree.
ACCRETION SHOREFORMS % of sector = 15%	Two low and narrow berm barriers have accreted across indentations within the bay, and have acted as dikes to ground water and small creek runoffs that still drain through small channels in the berm. The longer eastern berm (600 feet) blocks a brackish marshy lagoon and freshwater marsh-meadow along a flat sloped marine terrace. The western barrier (400 feet) dikes a salt-marsh adjacent to a small creek estuary Both these Class I beaches are natural.
BLUFF FACTORS	All bluffs within the bay along this sector are less than thirty feet high and heavily forested. They are in a very low energy zone and form Class III beach shores with fairly broad foreshores. The main meadow-barrier berm at the head of the bay receives its meager fine gravel material from the low-bank feeder bluff to the east, while the small marsh-barrier is fed from the west. These bluffs are low in gravel.
DRIFT FACTORS	Drift rate, material size, drift loading and berm height are all commensurate with the low energy level in this sheltered bay. Drift direction is generally toward the bay's middle section, thus the eastern portion of the sector operates with net drift westward, and the western sector has east-moving material transport. This opposed action would normally call for splitting such a shore into two sectors, but the small scale and low energy of this bay shore environment is too interrelated to divide, especially as there is lower foreshore continuity and overlap across the channels.
INTRUSION STATUS	Aside from natural barriers to drift, such as fallen tree groins and berm-cutting water channels, no man-made intrusion influences the shore-process corridor.
USE POTENTIAL AND LIMITS	While there remains some commercial impact within the aquatic and terrestial environments of this bay, from log storage and cattle grazing, these activities do not appear to affect the shorelands detrimentally at the present scale and level. Their ready removal would revert the bay and shorelands to a near-pristine environment and nature preserve where game such as deer take over from cattle.
SPECIAL NOTES OR PROBLEMS	In view of the fact that the Nooksack River is a glacial stream that flows steady with heavy sediment load throughout the dry summers, turbidity and fine sediment deposition will continue within and around Portage Bay, as well as growth of the accretion spits. Long-term planning should take into account this geo-hydraulic trend, and whether it should be altered through channel dredging and shore developments, aquaculture, etc. in view of joint public and tribal interests.

SECTOR: 26	LOCATION: Lummi Island–Sunrise Cove to rock spur south of County ferry dock. CODED SECTION: N½ of Reach #161, #160
BOUNDARIES MILES = 1.7	The boundaries of this sector are delineated by foreshore-protruding rock outcrops that make up the base complex of Lummi Island. The southern boundary is the rock headland on the south side of Sunrise Cove, while the northern limits are fixed by a rock spur just south of the ferry landing. This sector fronts on Hale Pass.
ACCRETION SHOREFORMS % of sector = 6	Only one accretion shoreform appears in this sector in the form of a short berm that originally built across a small shore indentation, and which now has a filled-in backshore meadow with super-imposed shell midden. This Class I beach is natural (located in middle of Reach #160 immediately north of the cable crossing from Portage Point).
BLUFF FACTORS	All of the sector except for the short Class I berm beach is low to medium high bluff with the most active beach material source coming from the feeder bluff adjacent to and north of Sunrise Cove. The bluffs are high in coarse material from gravel to boulders in a medium energy zone. Bluff beaches are mostly Class II, with an occasional short Class III reach.
DRIFT FACTORS	Shore orientation parallel to narrow Hale Pass provides rapid drift rates except for the impeding cobbles and boulders cluttering the foreshore. Net drift is northward, but there is also much south movement in an area that has no major terminal drift dumping zone. Drift loading is moderate and confined to the bluff toe.
INTRUSION STATUS	While there has been some bulkheading along the drift berm, no critical blockages of gravel movement are in evidence, although some buildup is noted at the cable crossing.
USE POTENTIAL AND LIMITS	Most of the bluff erosion beaches are natural environments, characterized by cobbles and boulders providing considerable foreshore creature habitat, wilderness-type esthetics, and an especially scenic view eastward to untouched Portage Island—and with Mount Baker as a backdrop.
SPECIAL NOTES OR PROBLEMS	The recessional bluffs will be particularly vulnerable to house siting and thus possible bulkheading. The Indian midden site and Class I beach will be especially under pressure as a building site, unless a case can be made as to its preservation as the only untouched berm beach on the whole east side of Lummi Island.

SECTOR: 27	LOCATION: Lummi Island — Lummi Point CODED SECTION: N½ of Reach #176 and S½ of #175
BOUNDARIES MILES = 1.0	The boundaries of this sector have been arbitrarily placed at about one mile apart, as this is one of the few shore entities in Puget Sound that is beginning to cease its operation as a self-maintaining geo-hydraulic sector. The boundaries are rocky outcrops into the foreshore shelf that allow only minimal sand drift along the lower foreshore, but no berm-building gravel drift for maintenance.
ACCRETION SHOREFORMS % of sector = 30	Most of the sector is an accretion point that is no longer accreting because of the natural depletion of former marine terraces, the erosion of which provided the original berm material. The uniqueness of this situation is primarily due to the fact that glacial deposits forming feeder bluffs both north and south of the point rested on rock shelves, and little of this material now remains exposed at tide level for further recession. About one third of the Class I beach remains natural.
BLUFF FACTORS	Only short remnants of glacial till make up erosional bluffs immediately south and north of the Point's berm beach, and rocky wave-cut foreshore terraces have slowed down recession of these bluffs and banks. North and south beaches adjacent to the point berm are Class III types with little drift loading or movement.
DRIFT FACTORS 39	Net drift is northward as much of the Georgia Strait fetch and wave-energy from the north is blunted by refraction around the north head of Lummi Island at Migley Point, as well as by the comparative shallow offshore immediately to the north of Lummi Point. However, this northward drift is illusionary in terms of accretion, as lack of maintenance gravel from outside the point is cannibilizing the south beach to feed the north beach.
INTRUSION STATUS	The major intrusion on the point is in the form of erosion defense bulkheads along the south beach, where houses are losing their original setback distance and berm buffer, and are coming within reach of south-storm driftwood battering. The tip of the point has not been altered, and much of the north beach berm is broad and stable with natural dunegrass cover at the northern reach.
USE POTENTIAL AND LIMITS	Most of the potential resource values of this shoreform has been lost by house siting over the berm, which now requires defense works. The point tip and north-reach berm are still viable as a heritage beach and esthetic resource. There is also historic value in the extensive shell midden evidence throughout the point backshore and marsh-tree environment, site of a former Indian potlatch activity center.
SPECIAL NOTES OR PROBLEMS	In view of the unique supply and demand situation of this geo-hydraulic system of Lummi Point, a slow shifting northward of the shoreform seems already in progress. While normal pressure for maintaining existing house locations through massive defense works will further degrade this shoreform, options otherwise call for retracting houses landward, and/or beach feeding with groin retention on the south beach.

SECTOR: 28 | LOCATION: Lummi Island-Fern Point to East-end Legoe Bay | CODED SECTION: S 2/3 of Reach #173, #172, NW ¼ #171

BOUNDARIES MILES = 1.8	The boundaries of this sector are fixed by rock outcrops at both ends, both acting as groin barriers to longshore drift. The northwestern shore reach of Lummi Island is a mix of rock outcrops and interspaced sandy pocket beaches locked between them. Only minor lower foreshore drift takes place past such rock promontories, one of which is the north boundary for sector 28 at Fern Point.
ACCRETION SHOREFORMS % of sector = 65	This sector contains the longest reaches of accretion shoreforms on the island. The northermost is a narrow but thick berm deposit of coarse gravel and cobbles in the middle of Reach #173. Village Point is a projecting marine terrace with a fringe accretion beach around it, the berm continuing eastward as a barrier beach blocking a former lagoon and present freshwater pond and marsh. About one fourth of these Class I shores are natural: Village Point (500 feet long) and the northern berm.
BLUFF FACTORS	All of the present feeder bluff for this section lies in the reach north of Village Point in a high energy zone with open fetch into Georgia Strait. Although the bluff is not over fifty feet high, its recession is relatively slow, the foreshore beaches being narrow Class II types, except for the massive but short cobble berm at a flat accretion point between Fern and Village Points.
DRIFT FACTORS	Net drift is southward to Village Point and then east into Legoe Bay. Drift loading is generally high along the bluff shores, and the Village Point berm is broad and stable, as is the barrier berm in Legoe Bay. The northwest island coast north of Village Point is high energy, while the eastern reach of the sector in Legoe Bay is medium high, both from north and south storms. There is considerable drift direction reversal and accretion balance along the north-south oriented coast.
INTRUSION STATUS	A number of intrusions have occurred, the major foreshore structure being the Legoe Bay marina acting as drift groin to the eastern section of the barrier berm beach. Houses have been sited over the end of this barrier berm beach into the backshore and upper foreshore. The berm has been extended to the east headland with fill blocking the now culverted marsh-connecting channel. The county road at Village Point intrudes the berm.
USE POTENTIAL AND LIMITS	Because of the shore-skirting county road along this sector, there has been preserved both access to bluff and berm beaches, as well as scenic vistas. The fore and backshore of the Legoe Bay beach is heavily used for commercial reef-net fishing activities, but is generally also accessible as a multi-use resource. Village Point is the only major natural accretion beach on the island, and could be further enhanced.
SPECIAL NOTES OR PROBLEMS	The ponds and marshes in the Legoe Bay backshore should be re-established for self-recharging and water movement either by providing it with original channel or use of a proper tidal gate culvert. This marsh is in a eutrophication stage with little or no movement as a lagoon or pond system. The county road along the bluffs may need some set-back at certain recession areas, as well as where it now cuts into and interferes with the berm on the east side of Village Point, where it is riprapped.

SECTOR: 29	LOCATION: Lummi Island — Legoe Bay East-end rock point to rock shore near road end (cable area) — CODED SECTION: S 2/3 of Reach #171, #170
BOUNDARIES MILES = 1.8	The sector boundaries are well defined by rock outcrops or promontories extending across the foreshore. In earlier geologic times before the bluff receded to its present position, this sector was part of sector 28 when gravel could still drift around the rocky point at the east end of Legoe Bay.
ACCRETION SHOREFORMS % of sector = 0	There are no accretion shoreforms except the shuttling drift berm at the foot of the bluffs.
BLUFF FACTORS	The total length of this sector is made up of recessional bluffs between 30 to 50 feet in height. Erosion is a modified gully-ridge type with considerable vegetation and trees. Exposure is in a medium-high energy zone, and there is enough gravel in the bluff to form a narrow berm Class II beach. The convex bulge in the shore has faster drift and becomes a Class III shore.
DRIFT FACTORS	Drift direction seems to be fairly - well balanced northward and southward with evidence of a slight net drift north.
INTRUSION STATUS	Intrusion into the shore process corridor is, as yet, slight, and takes the place of bluff-rim housing, some bulldozed roads diagonally down the bluff to the beach, and some boulders placed against the bluff toe in the upper foreshore for erosion defense.
USE POTENTIAL AND LIMITS	Even though these bluff shores are in a fairly exposed wave-action zone, only isolated bluff sections operate as steady beach feeders, and since no terminal accretion shoreform removes berm gravel from the beach, the shuttling gravel acts as a flexible natural bulkhead to slow down bluff toe erosion. If structures are to be built over the foreshore, it should be done at each end, not the sector middle.
SPECIAL NOTES OR PROBLEMS	These are some unstable clay-pocket and water-seepage areas, as in the extreme south end of the sector where bank sluffing into the foreshore has occurred, and sliding can take place all along this shore when these factors are present.

SECTOR: 30 LOCATION: Eliza Island — northwest shore CODED SECTION: #159

BOUNDARIES MILES = 0.7	Eliza Island geology is similar to much of northern Lummi Island in that glacial till remnants are lodged between and over rock outcrops forming its base. The northern tip of till lies over a rock base at tide line forming an overlap boundary for sector 30 and 32 in the lower foreshore, while the southwest boundary is absolute against the rocky west point of the island.
ACCRETION SHOREFORMS % of sector = 55	About half of the shore, the western portion, is an accretion berm beach terminating at the rocky west promontory. This berm is higher and broader than the island's south barrier berm in sector 31, and seems to be the older and probably the true original tombolo shoreform that annexed a rock island which is now the west point. About 90% of this Class I beach is natural.
BLUFF FACTORS	The feeder bluff for the tombolo berm is a steep and active 40-foot cliff resting on a rock base, at the island's northern tip, just accessible to wave action, with the remainder forming a Class III narrow beach. Between this bluff and the accretion berm shore is a gently-sloping low marine terrace forming a low erosion bank that also contributes material to the berm beach. This northwestern exposure is in a medium-low energy zone.
DRIFT FACTORS	While material was able to drift around the north tip of the island from the east to the west shore before the glacial bluff had worn back to the rock base, all drift is now within the sector from north to southwest, and there is a considerable terminal deposit in front of the west rock point now. The berm is stable with a good Class I beach.
INTRUSION STATUS	Some houses have been located on the berm back of the high tide line, and a dock has been extended on pilings over the foreshore where the marine terrace and berm meet. A landing strip has been bulldozed over the lowest, west portion of the sloping terrace. None of these have had a detrimental effect on the shore processes, nor have houses near the recession bank of the terrace.
USE POTENTIAL AND LIMITS	
SPECIAL NOTES OR PROBLEMS	

SECTOR: 31	LOCATION: Eliza Island — south shore embayment — CODED SECTION: Reach # 159
BOUNDARIES MILES = 0.5	Both the west and southeast boundaries of this short sector are absolute, the shore system being locked between two rock promontories acting as groins over the foreshore.
ACCRETION SHOREFORMS % of sector = 60	The sector represents a complete system of feeder bluff, driftway, and wholely natural accretion berm beach on an abbreviated scale, especially as the source bluff is no longer than the berm beach. This shoreform probably came into being after the north beach berm connected up with the west rock point to form a tombolo, after which time the south beach berm was protected as it formed a barrier to a former lagoon, now turned into a marshy pond and meadow backshore.
BLUFF FACTORS	While the west point of Eliza is a former island now annexed, the south point is a peninsula eroding into a future island, the narrow neck of which forms the berm feeder in the south bay. This bluff is relatively low (less than 30 feet) and grades into the gently sloping terrace and low bank as it passes the runway. The bluff beach is Class II in the north portion and Class III in the south corner.
DRIFT FACTORS	Both the west and south point promontories refract the south-fetch waves to form a crescent-curved berm beach which has rolled back as the southern bluff eroded back to its present location. Net drift is slowly northwesterly from the south bluff with some reversal due to wave refraction. The berm is well developed in a medium-high energy zone.
INTRUSION STATUS	No intrusion of the 1000 foot long Class I beach has occurred as yet, although houses are being located at the rim of the low bluff and terrace south of the runway. There are no obstacles to drift or foreshore and bluff operation.
USE POTENTIAL AND LIMITS	This esthetically magnificent crescent berm beach and backshore marsh-meadow still retains its essential natural qualities, and represents a priority resource intact for all island dwellers and the county heritage. Because of the higher energy zone and lower and narrower berm of the south beach versus the north beach, housing over the berm of the former is unwise and an unwise resource trade-off.
SPECIAL NOTES OR PROBLEMS	In view of the fact that a safe and well-drained terrace slopes westward from the island east ridge, housing can be economically and esthetically located on these uplands rather than on the more exposed and esthetically valuable beach sites, including further north beach occupancy on the berm.

SECTOR: 32 LOCATION: Eliza Island — east shore CODED SECTION: Reach #159

BOUNDARIES MILES = 0.8	The boundaries here are well defined in the form of a deep-water rock groin making up the southern tip of the island, and a sharp rock-base point on the north tip that allows only marginal drift to pass around the lower foreshore by wave refraction during southerly storms.
ACCRETION SHOREFORMS % of sector = 0	No accretion shoreforms are located in this sector, although it would be possible to create an accretion point within such a north-south oriented active bluff shore by groining.
BLUFF FACTORS	Most bluffs along this east-coast are below 50 feet in height and back up both Class II and III beaches depending on the location with respect to the slight meander curves of the shore. Bluffs are generally wooded with variable recession activity due to varying composition.
DRIFT FACTORS	While the north - south orientation of the shore makes for frequent drift reversals and fairly high rates of movement, predominant direction is probably northward because of fetch, and lack of accretion evidence in the south pocket. The shore exposure is medium-energy with fairly high erosion rate due to the orientation to angled waves.
INTRUSION STATUS	Intrusion is minimal now, but with bluff-toe bulkheading becoming a possibility as more houses are being located on the bluff rim.
USE POTENTIAL AND LIMITS	
SPECIAL NOTES OR PROBLEMS	

SECTOR: 33 LOCATION: Point Roberts - west and south shores. CODED SECTION #153, #152, #151, #150

BOUNDARIES MILES = 4.6	The northwest boundary of the sector is the Tsawassen Ferry jetty in Canada while the southwest end is an overlap zone due to shore orientation changes and fetch ratios, identified as the west end of the major bluff slide area just west of Lily Point.
ACCRETION SHOREFORMS % of sector = 49%	Almost half of the total sector length is Class I berm beach forming the accretion point around Lighthouse Point. Both the west and south beach berm is robust and broad, with coarse gravel and cobble due to the high energy shore conditions. The south beach was originally a barrier berm that finally closed its lagoon which since changed to a marsh.
BLUFF FACTORS	Boundary Bluff on the west coast was the major feed-source accreting Lighthouse Point in front of the sloping marine terrace, but the feeder bluff has been successively deactivated, first by Fraser River shoaling, and recently by jetties to the north. The east half of the south shore is still a very active feeder bluff that feeds the south beach berm. Bluff beaches are mostly Class III; bluffs are unstable west of Lily Point.
DRIFT FACTORS	While the west shore was a separately operating drift sector while Boundary Bluff was still active, net drift is now north to the bluff instead of from the bluff southward, and at the expense of the berm at the lighthouse. North and east winds reverse drift on the south beach, while south winds tend to pile up the berm with little drifting. Drift loading is heavy all along the berm beaches, but marginal on the bluff shores, especially as there is much clay and sand in the bluffs that cause sluffing and foreshore burial. The energy gradient is downward from high to low on the west coast from south to north.
INTRUSION STATUS	There has been some bulkhead intrusion on the Canadian side of Boundary Bluff which does not affect the US side due to north drift. There is some questionable bluff-slope housing at the south end of this bluff. Berm beaches both west and south are variously intruded over the berm, with a few groins on the west side slowing drift northward. Foreshore bulkheading on south beach berm has minor effects.
USE POTENTIAL AND LIMITS	This is a large sector composed of contrasting environments and energy zones, thus limiting various development and structure siting such as housing, boat ramps, boat harbors, etc. In view of the drift situation described, backshore marinas should be sited on the west coast as far north as possible for the least channel jetty impacts on the shore process. Bluff housing setback is a function of bluff make-up.
SPECIAL NOTES OR PROBLEMS	The high energy zone of the south beach and west shores provide ocean-type atmosphere in both visual and structural impacts. Lighthouse Point is trending toward an erosional cycle, thus groining along the west shore could be beneficial, especially when combined with boat herbor jetty, if one is to be sited. A short original berm and backshore is still untouched just west of South Beach community, and its preservation should be a priority consideration. Housing under the east-bluff is in a hazardous site.

SECTOR: 34 LOCATION: Point Roberts - Headland west of Lily Point to Maple Beach at U. S. - Canada boundary. CODED SECTION: NE 4/5 of Reach #149, #148.

BOUNDARIES MILES = 2.2	The south boundary is an overlap zone under northwind conditions, and where prevailing south winds cause drift splitting at the projecting headland bluff. The north boundary is the drift terminal of a long sand spit in the northwest portion of Boundary Bay in Canada. The Maple Beach boundary is political only since bulkheading there is only in the upper foreshore.
ACCRETION SHOREFORMS % of sector = 18%	Two major accretion shoreforms occur in this sector, the larger being Lily Point near the southern boundary, and a bluff-berm or flat-point just north of Lily. The latter has been partially covered by a slide on the west side, its berm being low and wide with backshore meadow on midden soil. A freshwater marsh and runoff seeps through the berm from the center backshore. The northern flat point seems to have started through a former slide into the foreshore. It has a high gravel berm and narrow backshore.
BLUFF FACTORS	The southwestern bluff is feeder to Lily Point, and to sector 33 with east winds. It is highly active and a sluffing zone, and a foreshore-offshore wavecut terrace indicates rapid recession. The bluff between the two accretion points is mostly sand with clay interbedded and does not contribute to the Class I beaches of either, but it and remaining northern bluffs provide sand berms to Boundary Bay.
DRIFT FACTORS 46	Net drift is northward with a decreasing energy gradient northward into the shallower Boundary Bay waters. Thus this east shore of Point Roberts is a mirror image and action of the west shore, except that there is less gravel available and sand forms the heavy drift loading in the upper foreshore. The shores under the bluff are Class III, while the former Class I sand berms at Mable Beach have been changed to intruded Class III shores by bulkheading. There seems to be active drift reversal and overlap all along the headland bluffs west of Lily Point to affect both sector 33 and 34.
INTRUSION STATUS	Outside of the afore-mentioned Maple Beach road bulkheads placed into the upper foreshore there has, as yet, been no critical intrusion. The former cannery operation at Lily Point was on pilings over the foreshore, and only a few remnants of these remain, as well as an iron slag pile from waste cans. There are a few concrete foundations in the backshore meadow, as well as pits. Bluffs are not yet developed.
USE POTENTIAL AND LIMITS	The Lile Point shroeform is one of the finest remaining natural accretion points in this region, especially as it is buffered by wilderness bluff beaches on each side, and no negative seaward or landward vistas affect a natural esthetic experience. Its greatest value lies in its clean-up and preservation as a historic site and beach-process component.
SPECIAL NOTES OR PROBLEMS	Lily Point and adjacent flat point and sand beaches are located not only in one of the few remaining natural, secluded areas, but the wind-protected and shallow foreshore with warm water Boundary Bay makes this a choice recreational shore system that can attract high real estate values and tax base to the plateau hinterland and the whole peninsula if left undisturbed as a pulling magnet. There will be some set-back buffer requirements on several bluffs. No groins should be placed into the foreshore to protect the points.

The Drift Sectors of Whatcom County Marine Shores

Their Shoreforms and Geo-Hydraulic Status

APPENDICES

A. THE PHYSICAL SHORE SYSTEM

Beach Elements
Drift Sectors

B. THE DYNAMIC SHORE SYSTEM

Hydraulic Elements
Transport Elements
Geo-Hydraulic Energy

C. BEACH SHORE CLASSIFICATION SYSTEM

Classes III, II, I
Shoreforms

D. THE ACCRETION SHORE RESOURCE

Recreational Factors
Bio-Process & Habitat

Note: This text, representing excerpts from the author's "Shore-Resource Manual" is released to Whatcom County Planning Commission as a pre-publication courtesy, and may be used for county shore-resource management purposes. It should not be reproduced for other uses elsewhere without the author's knowledge.

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Appendix A

THE PHYSICAL SHORE SYSTEM

A. BEACH PROFILE ELEMENTS (See Figure 1)

1. BEACH SHELF: This is the fixed-profile bench or shelf cut into the sea bluffs by more than ten thousand years of wave action. It forms the gently sloping platform on which sand and gravel is being wave-shuttled vertically and laterally to produce the changing beach profiles and shoreforms characteristic of Puget Sound.

2. COASTLINE: This is the highest landward line of long-term erosional attack of marine waters upon the land. It may be active as such only once in fifty years or more often under extreme coincident storm and tide surge conditions, or it may be under daily wave erosion.

3. HIGH TIDELINE: This is the intersection of the mean-higher-high tide level (unruffled) with the shore. As such it is a purely artificial and arbitrary demarcation used as a legal property line for want of a more realistic shore-process boundary. Since most beach profiles (height and slope) change with every passing storm, so will also the exact location of the high tideline. In the context of vertical beach horizons, it is used here as a demarcation reference between the backshore and foreshore.

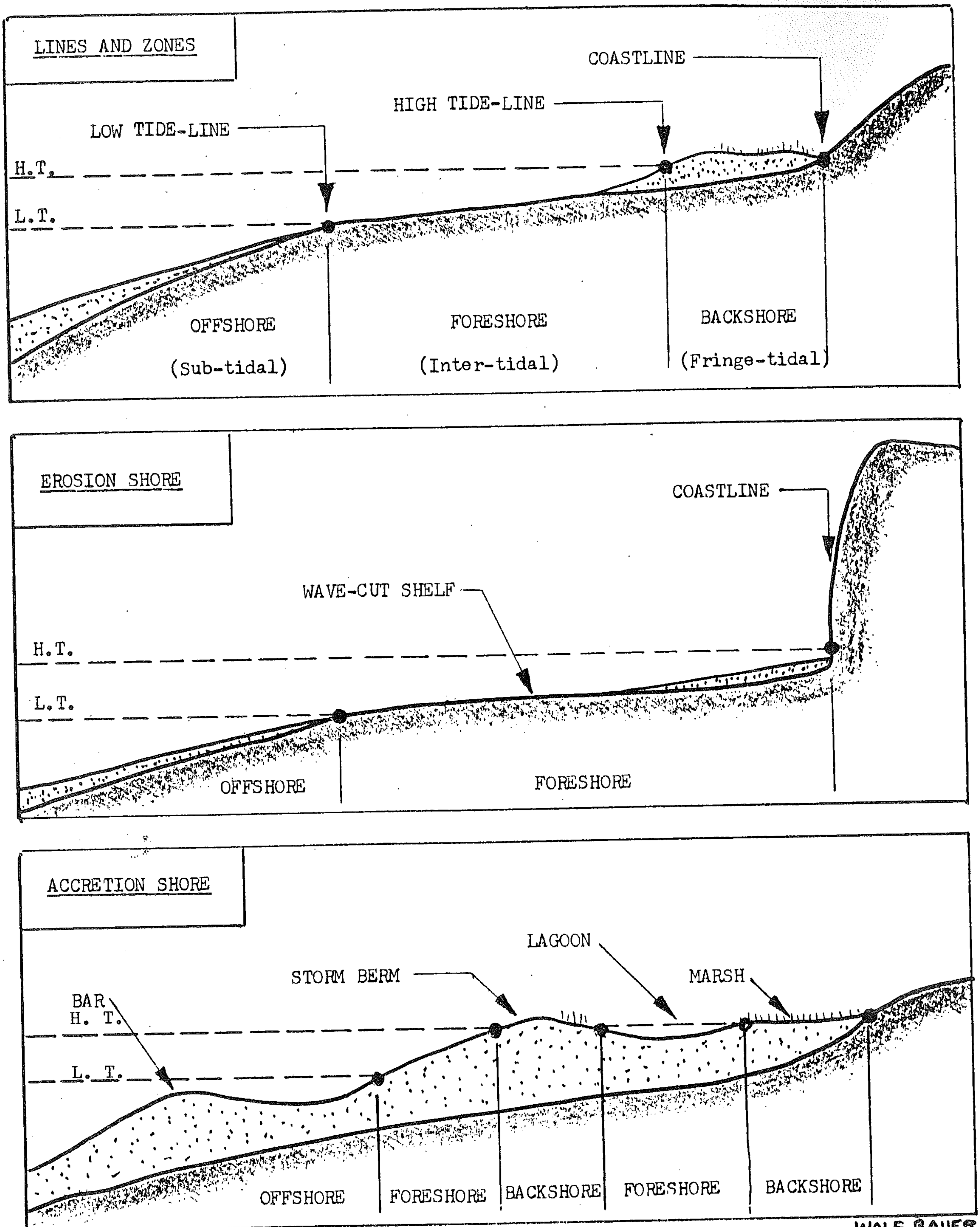
4. LOW TIDELINE: This is the intersection of the unruffled mean-lower-low tide level with the foreshore slope. It demarcates between the foreshore and offshore.

5. BACKSHORE: This is the storm-tide wetted, but normally dry, erosion or accretion zone located between the coastline and the high tideline. The backshore may be a more or less narrow storm berm (ridge of wave-heaped gravel) under a seabluff, or it may constitute a broader complex of berms, marshes, meadows, or dunes landward of the high tideline. It is part of the littoral drift process along its seaward boundary.

6. FORESHORE: This is the intertidal zone between the high and low tidelines, and in its upper section represents the active sediment transport zone in vertical shuttling and lateral longshore drift.

7. OFFSHORE: This is the sloping sub-tidal zone seaward from the low tideline. In terms of immediate fringe element of the shore system, it is part of the original wave-cut shelf that receives some of the fine drift particles, and often anchors extensive eel-grass and kelpbeds. Its geo-hydraulic (earth-water) dynamics is tied to both wave action and tidal currents.

FIGURE 1. - Beach Profile Elements



B. THE DRIFT-SECTOR SYSTEM (See Figure 2)

The longshore-operation or Drift Sector is that length or reach of shoreline which allows uninterrupted foreshore and backshore sediment drift or transport, and which contains any and all sources of such sediment both erosional and accretional. Under such shoreline sectoring, all beaches are either fully self-contained sectors (pocket beaches), or are link-components of longer multi-operations sectors. Each Drift Sector contains the following beach process elements:

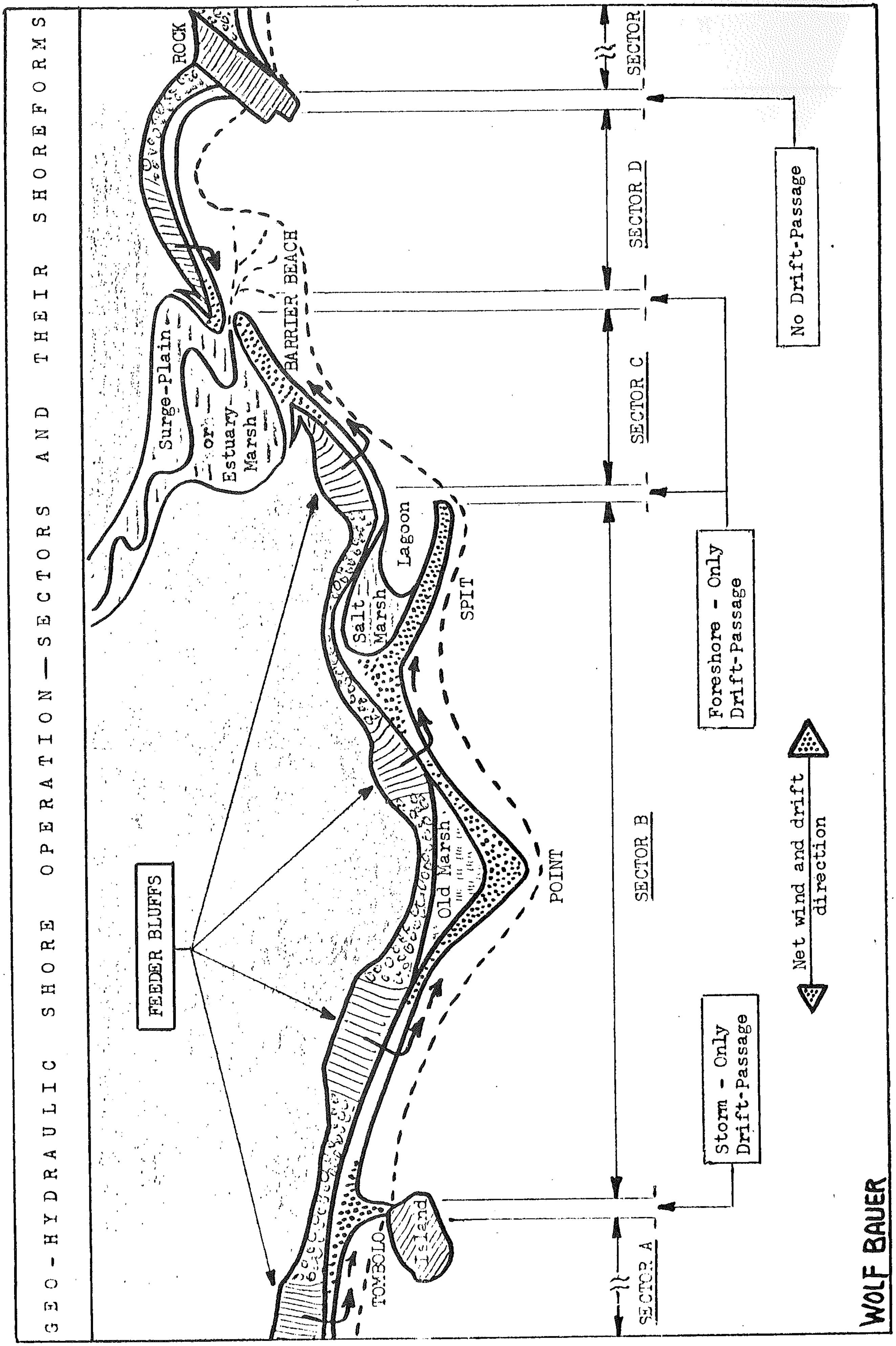
1. FEED SOURCE: The most prevalent beach-paving and beach-building material sources on Puget Sound are the high sea bluffs. Wherever they are in an active operating state, they are hereafter referred to as "Feeder Bluffs".

   The rate of nourishment from the feeder bluff depends on its geo-hydraulic energy system. Orientation to a long wave fetch coupled with a low clay-content bluff composition contributes toward a high and uniform rate of natural excavation. When the bluff is composed of a non-uniform or layered composition of clay-sand-gravel, beach feeding or maintenance action may be in the form of sporadic cave-ins and slides onto the foreshore. When the feeder bluff has a uniformly distributed clay content, its quarry face is near-vertical, and its operating rate is slow but steady. As a general statement, it may be said that the higher the gravel content of the feeder bluff, the more likely will its drift sector contain a dry point, spit, or barrier beach.

   Stream deltas sometimes provide an additional source of beach material on Puget Sound. Where the stream maintains floodway-zone gradient to its mouth, some gravel may be supplied to fringe beaches. However, fine sand is the usual material supplied from the extreme side-lobes of the fluvial (stream) cones where no further stream branches can interrupt lateral drifting to the adjacent shore sector.

2. DRIFTWAY: This is the longshore passage or corridor (primarily lower backshore and upper foreshore) along which sand and gravel is transported in either direction by wave breaker action. The driftway may also be defined as the beach corridor which connects the feeder bluff with its accretion shoreform, i. e. the transport-way between the "excavation quarry" and the dumping or fill "terminal".

FIGURE 2 - The Drift Sector System



3. ACCRETION TERMINAL: Longshore or littoral drift movement is in the direction of prevailing wind, and may thus take place in reversing cycles with changes in wind direction. However, in terms of net effect, sand and gravel finally accumulate at the down-wind or down-drift end of the drift sector as spit, point, barrier or other type of dry-beach shoreforms.

4. SECTOR BOUNDARIES: It can be seen from Figure 2 that each independent drift sector is separated from the adjacent sector by a drift gap or drift barrier. Such sector boundaries may be quite absolute, as in the case of a natural rock spur or deep water promontory, or an artificial deep-water bulkhead, jetty, or groin. Drift sectors may also be separated from each other less positively by "leak-barriers" which may be storm-breached. These may be young tombolo bars or wave-shadow zones, small tidal or fluvial stream channels, low-profile groins, or low-intrusion bulkheads. Such barriers allow limited drift to take place along the lower foreshore and upper offshore.

Appendix B

THE DYNAMIC SHORE SYSTEM

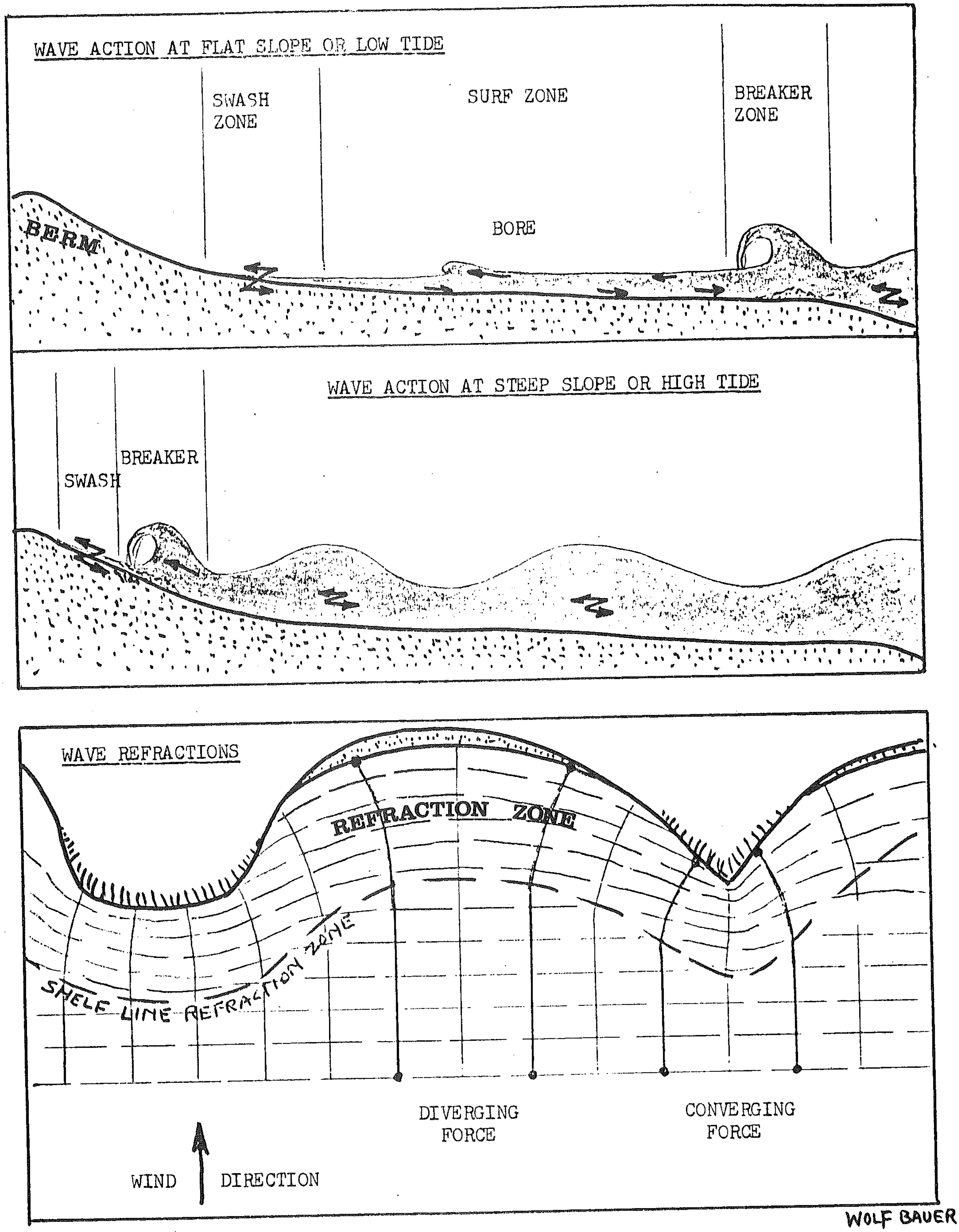
A. HYDRAULIC ELEMENTS (See Figure 3)

1. REFRACTION ZONE: This is the offshore area where incoming wave fronts are first caused to bend toward the shallower regions of the beach shelf by bottom friction, thus causing their divergence upon entering bays, and their convergence around headlands. The location of this zone is a function of wave size and tide level at any one time. A pronounced refraction effect will increase wave power at promontories, and lower it in bays. It is this refraction phenomenon that has created and maintains our crescent-shaped beaches.

2. BREAKER ZONE: This is the constantly shifting, variable-action zone in which waves and swells steepen and overturn upon approaching shallow offshore or foreshore bottoms at a depth of less than 1.5 times wave height.

D Y N A M I C   S H O R E   S Y S T E M

FIGURE 3 - Hydraulic Components



3. SURF ZONE: This is an opposed-current action zone landward of the breaker zone wherein the water from the collapsed breaker surges forward over the receding current of the previous wave — often in bore-like surges. Its location, extent, and even existence is determined by wave and tide conditions, as well as foreshore slope. It is a normally occuring zone on ocean sand-beaches, or wherever the foreshore profile has a relatively flat slope. Surf conditions on Puget Sound shores generally occur at low tide.

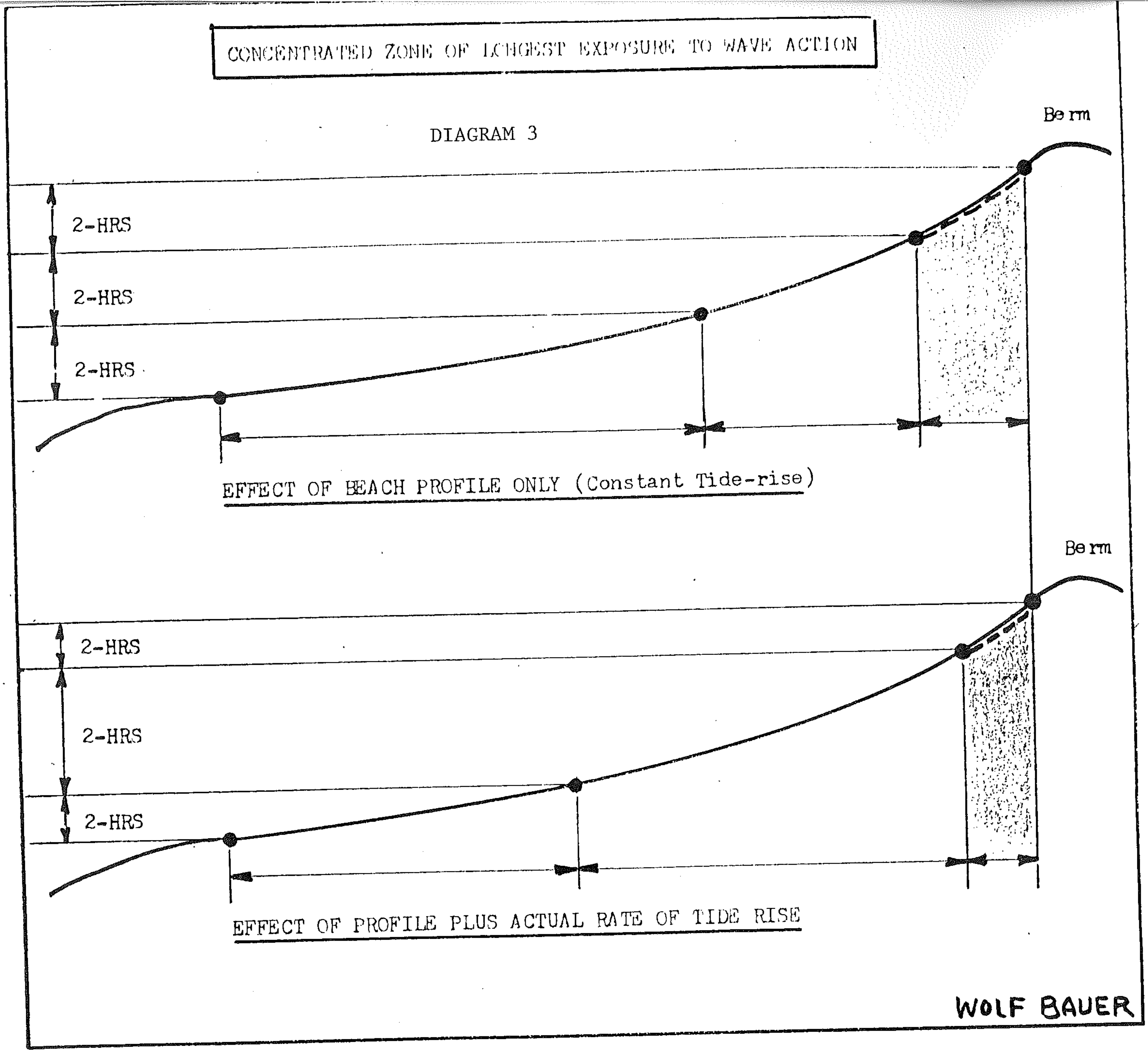
4. SWASH ZONE: This is the terminal action zone in which the wave outwash alternately surges up and down the exposed foreshore and backshore surface in a single current layer above the still-water tide level. The strength and volume of the return swash current, and therefore its erosive power, depends on the amount of water that is subtracted by percolation through the beach material, and is thus a function of foreshore and backshore berm porosity.

B. TRANSPORT ELEMENTS (See Figures 3 & 4)

1. VERTICAL MOVEMENT

a) Surf Zone: By referring to the current flow in an approaching wave system as the illustrations show, it can be seen that there are two centers of action. Maximum energy is developed at the excavation and entrainment point or line of wave collapse (breaker), where the falling water curtain penetrates through the returning current of the previous wave to reach the foreshore sediments. Here the major portion of material is excavated and suspended, and subsequently exposed to the double layer opposed-current system of the surf zone. If the foreshore has a flat slope and therefore a long and deep return current, the larger particles tend to sink into the return current before the swash zone is reached. Under these conditions, landward transport of material is a rather inefficient operation.

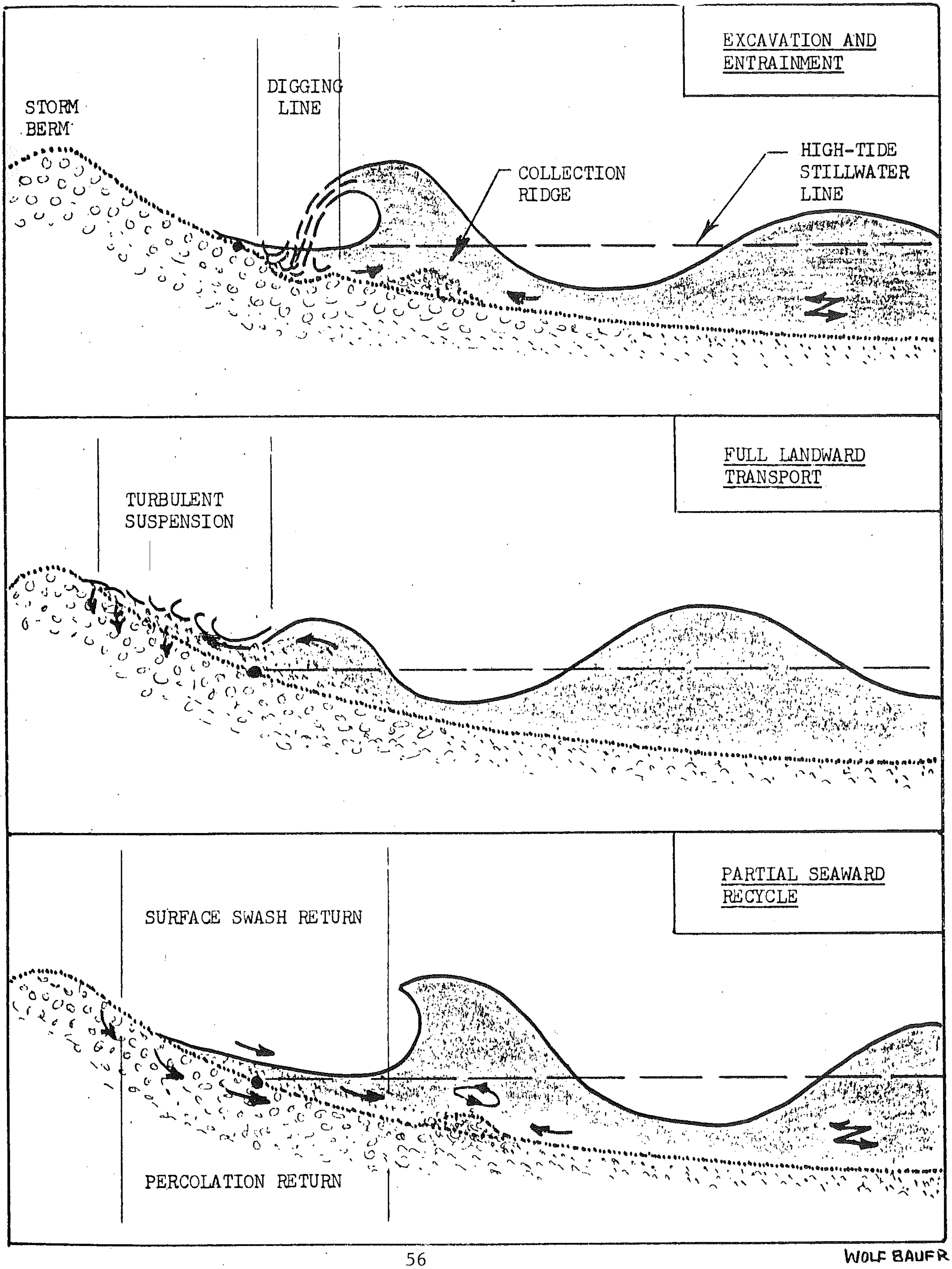
b) Swash Zone: When the swash current is an outrider of the surf zone, it is likewise ineffective as a vertical transport medium. It is not until the rising tide brings the breakers onto the steeper slope of the upper foreshore that the surf zone tends to shrink and disappear, and the swash current operates close to the breaker. Now the collapse of the breaker proceeds without the cushioning and blunting effect of a deep surf water layer. The digging and entraining action becomes effective, and the swash can carry the emulsified sand and gravel up the beach slope. (See Diagram 3)



SPECIFIC TO PUGET SOUND

Berm - building is a vital process for the creation and maintenance of Class I beaches and accretion shoreforms. In studying the effects of decreasing water - rise rates during each final flooding cycle, when superimposed on increasing beach profile slopes as shown in the above diagram, it becomes apparent that most of the geo-hydraulic action takes place in the upper foreshore and lower backshore. Thus in terms of shoreline management in general, and of bulkheading in particular, it is important to realize that even a slight intrusion into the upper foreshore is of major beach-process significance, It should also become obvious that the mean-higher-high tideline as an arbitrary property line finds itself positioned in the middle of major geo-hydraulic action, and represents an unrealistic and improper boundary in terms of shore-resource management.

FIGURE 4 - Vertical Transport Elements



It is under these high-tide conditions that a distinct accretion ridge or storm berm is piled up along the high tideline between upper foreshore and lower backshore. If this berm is predominantly coarse sand and gravel, then the return swash looses much of its volume and carrying capacity as part of the water returns through the porous gravel and sand voids, allowing only the finer sediments to return seaward. Material transport is thus predominantly landward as the backshore berm is being built up under high energy conditions. Conversely, when the backshore is more or less impervious, storm breakers produce a more powerful return swash, and the upper shore is eroded and transported into the foreshore. Subsequent reduced wave action may then again transport this material up the slope over longer periods of time.

2. LATERAL MOVEMENT: Waves seldom break exactly parallel to a shoreline, but generally impinge at varying angles. While this does not change the action, zoning, or vertical material transport action previously discussed, it does add a lateral or longshore drift component. It is therefore, obvious that shoreline orientation with respect to prevailing wind direction is a critical factor in its erosion or accretion rate, as well as its profile variability or stability.

   Seasonal longshore (littoral) drift may extend for miles, or it may be confined to very short distances due to natural or artificial barriers. Drifting distances are also a function of particle size. Thus boulders and large cobblestones tend to remain in the vicinity of their bluff of origin, (although driftwood impact under storm conditions can shift their position) while slow-moving gravel and faster moving sand will travel accordingly. Thus a beach is simultaneously being cut and eroded by high velocity swash currents running parallel to its backshore. (A parallel swash current may exceed five miles per hour in only mild storm wave action on Puget Sound.)

C. GEO-HYDRAULIC ENERGY LEVEL

Beaches and shoreforms on Puget Sound may be in either high or low energy levels and zones. These energy environments are a result of both beach location and orientation, as well as beach bluff height and composition. The energies have their origin in the kinetic energy of tide and waves, as well as the releasable static or gravity energy residing in every particle of sand and gravel poised above the shoreline. There are many regional and also local conditions that contribute to the tapping of this energy reservoir, and these will trigger shore-process operations on a broad front. They include:

1. Significant rainfall for eroding and saturating seabluffs to promote sluffing and caving action for beach material production.

2. Relatively steady coastal winds parallel to the major shoreline north-south orientation, and thus blowing over ample fetch to produce breaker swash currents that result in vigorous shore-process operations, as also wind-blown sand from fore- to backshore.

3. Substantial tide peaks which, when coincident with prevailing wave action, result in simultaneous feeder-bluff "quarrying", high rates of drift transport, and substantial gravel-berm building.

4. Widespread distribution of intermediate-size gravel in both high and low clay-content seabluffs furnishing ideal porous berm-building material for accretion shores and shoreforms.

5. Abundant accumulation of driftwood which, during high wind conditions, performs as an impact tool for more effective high-clay feeder bluff operation, while at the same time helping to trap and accumulate wind-blown sand in the backshore.

6. Strong tidal currents which by scouring and eddy-deposition control may offshore profiles, and which in turn can encourage or limit beach process operations.

Inventories of drift sectors and shoreforms must relate these local energy levels to the relative opportunities and restrictions they present in terms of planning and management. Thus, for example, the placement of a bulkhead into the backshore or foreshore of a low-energy driftway may result in very minor beach changes over a fifty-year period, while a bulkhead of the same size and position within a high energy drift sector can result in drastic beach-process disturbances in a matter of ten years or less. The geo-hydraulic energy level is therefore as valid a consideration as the inter-relationship of the drift-sector components, and should be part of any shoreform inventory and evaluation. Puget Sound shore-process environments dramatically reflect the geo-hydraulic energy gradient from a high level in the more open northern sectors to a reduced activity level in the more confined channels of the southern reaches. However, irrespective of geographic location, the beach-process energy level is low in any wave-sheltered bay, cove, or shallow inlet, while it is high along deeper, wave-exposed open water shorelines.

While hydraulic energy plays a predominant role in beach process operation and the resulting environment, the "geo-static" component often controls its total effectiveness. As pointed out, this releasable gravity (geo-static) energy is a function of colloidal clay-holding power as well as material height above water level.

TABLE 3

DRIFT - SECTOR LOGISTICS

Wolf Bauer

GENERAL RELATIONSHIPS OF
FEEDER BLUFF OPERATION

QUANTITATIVE
FACTORS: H = Height

W = Active Width

G = Percent Gravel

C = Percent Clay

RELATIVE
FACTORS: E = HYDRAULIC ENERGY (Average wave height x length, fetch in miles, shore orientation, offshore depth, foreshore width, refraction, supplemental storm swells, boat wakes)

D = DURABILITY 1 = free-sliding repose slope .... 5 = compact vertical
1 = fractured, weak ...... 5 = homogenous cohesive

(Degree of compaction, clay-coating, drift depth, seepage planes, particle size distribution, bedding, clay seams, high-tide level composition versus upper bluff composition)

S = DRIFTWAY STATUS (percent foreshore blockage, absolute 1 to 100)

DRIFT-SECTOR OPERATIONS LEVEL

RELATIVE BLUFF RECESSION RATE .... $\frac{E}{H \times D}$

RELATIVE TOTAL FEED RATE TO BEACH .... $\frac{E \times H \times W}{D}$

RELATIVE BERM BEACH MAINTENANCE POTENTIAL .. $\frac{E \times H \times W \times G}{D \times C \times S}$

Thus for the same hydraulic wave energy expended against the same length of feeder bluff, the higher bluff produces the greater quantity of beach material and size of downdrift shoreform. On the other hand, equal-height feeder bluffs will produce unequal amounts of material with the same available wave energy if only the clay content varies slightly (colloidal-bond energy).

Aside from the total level of geo-hydraulic energy available to any one drift sector, it should be obvious that feeder bluff composition in terms of sand-to-gravel ratios is a modifying factor influencing beach and shoreform type, size, stability, and environment. There are many other minor contributing factors influencing the environmental status of Puget Sound accretion beaches, but for the purpose of this inventory evaluation, the aforementioned elements and conditions are pertinent.

D. BIO-ENERGY ZONES

While high geo-hydraulic energy conditions create major accretion shoreforms, their wind and wave-baffling effect in turn produces low energy pockets that encourage marine-dependent flora and fauna in biotic communities to establish themselves in the shoreform's protected lee. To those original low-energy shallow bays and inlets of Puget Sound that are located some distance from vigorous tidal mixing currents and open waters, there have been added many smaller low-energy lagoons and salt marshes which, by virtue of their parent accretion shoreforms, are located next to nourishing high-energy waters. Thus high geo-hydraulic energy zones have created low hydraulic energy zones which, in turn, shelter high biologic energy environments.

APPENDIX C

BEACH SHORE CLASSIFICATION SYSTEM

It can be seen from the baseline geo-hydraulic system of shore classification diagrammed in Figure 5, that marine shores can be divided into four categories: Estuarine, Marshy, Beach, and Rocky; and furthermore, that beach shores can be subdivided into erosional Class III, marginal Class II, and accretional Class I types. Such a sub-classification represents not only a genetic differentiation, but as we shall see later, it grades Puget Sound beaches as to "wet", "marginal", or "dry" in terms of relative recreational use potential.

The beach classification system to be described herein was developed for easy public recognition and use — one that would not require scientific knowledge or determination of beach geo-morphology. It is simply based on the presence, absence, or marginal extent of a walkable dry backshore at high tide water level — an observed or inferred condition determining whether it is a dry Class I or a wet Class III beach. In this context, it is coincidental that most Class III and Class II beaches are, in fact, erosional; and that Class I beaches are the accretion type. Thus all beaches have foreshores (intertidal zones) but only accretion Class I beaches additionally encompass stable, infrequently-wetted backshore berms, dunes, or marshes. (See Figure 6)

FIGURE 5

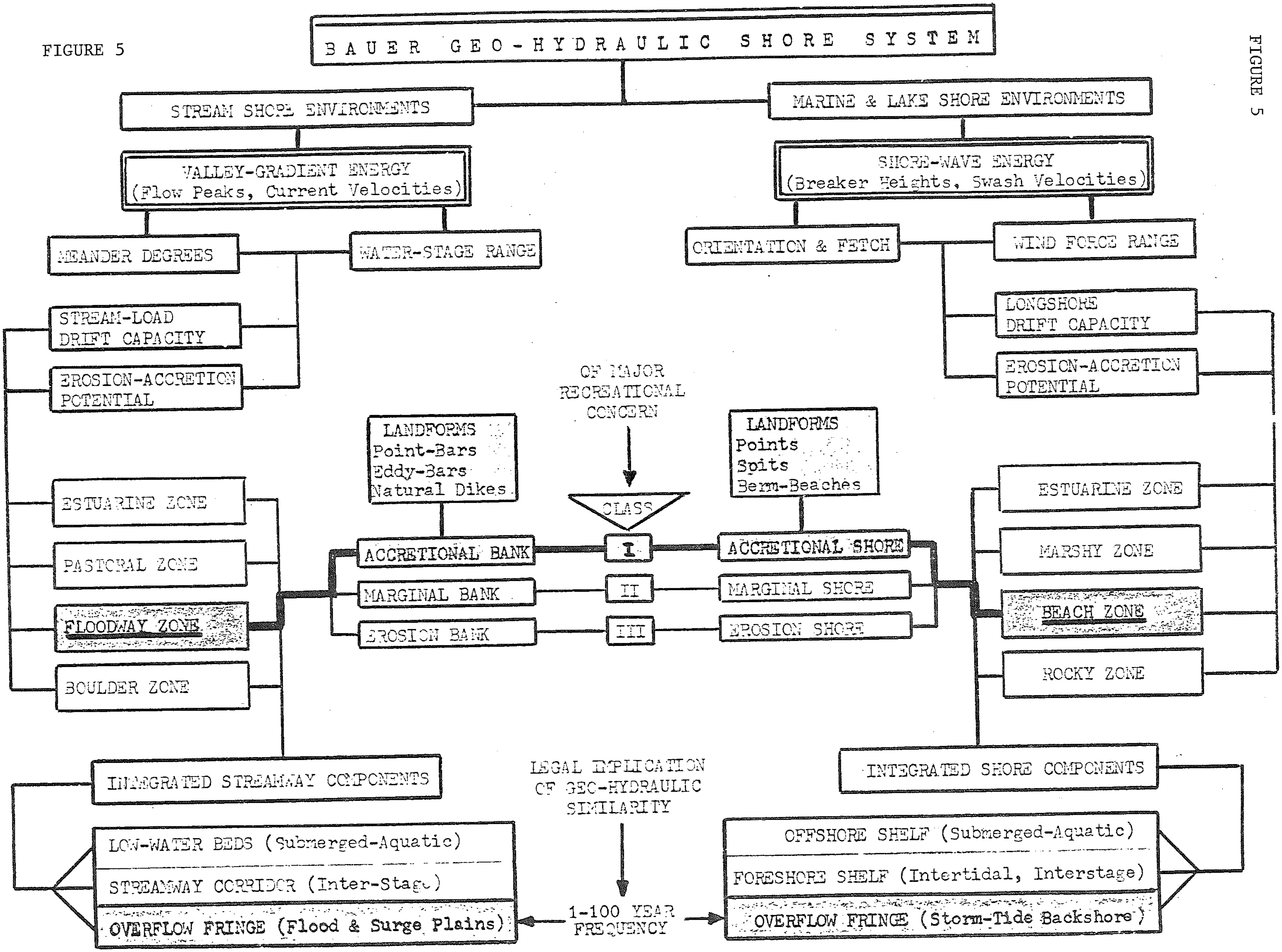


FIGURE 5

CLASS III EROSIONAL WET BEACHES

PHYSIOGRAPHIC DEFINITION

Class III beaches are characterized by the fact that the Coastline coincides with the High Tideline, and that the Backshore is missing. Thus the Foreshore, or wet intertidal zone, constitutes the beach, one which is always under water during high tide, but which may also be covered by water during tides of lower than mean-higher-high tide level.

Class III beaches may account for a small or major portion of their drift sector, or they may constitute all of a "pocket beach". (A pocket beach is here defined as a short drift sector beach that is usually crescent-shaped and confined between two rock spurs; and where all of the bank or bluff acts as beach material source. Depending on the amount of gravel making up the bank, the pocket beach may be either Class III or Class II type, rarely Class I.)

BEACH VARIATIONS

Class III beaches may show considerable differences in their shore environments within this classification — primarily as a result of the geo-hydraulic energy level associated with their location.

1) Low-Energy Zone: In the low energy level environment of a shallow inlet or cove, for example, the foreshore often ends at the tree-line because bank or bluff erosion is slow enough to allow trees and vegetation to take root between slides and cave-ins, and thus further inhibit steady surface erosion. Such low-energy Class III beaches may have extensive foreshores that are a result of glacial physiography and topography rather than post-glacial beach-shelf cutting. In more recent times, however, shore breaker action from boat traffic wakes is beginning cycles of increased beach-process operations in what were historically low-energy shores.

2) High-Energy Zone: The Class III beach environment in this zone is greatly influenced by both bluff composition and incident wave orientation. A no-berm beach will result when:

   a. The clay content of the bluff is either high or very uniformly distributed so that a stable vertical cliff results which contributes beach gravel at a lower rate than the transport capacity of longshore drift. This

GEO-HYDRAULIC BEACH SHORE CLASSIFICATION

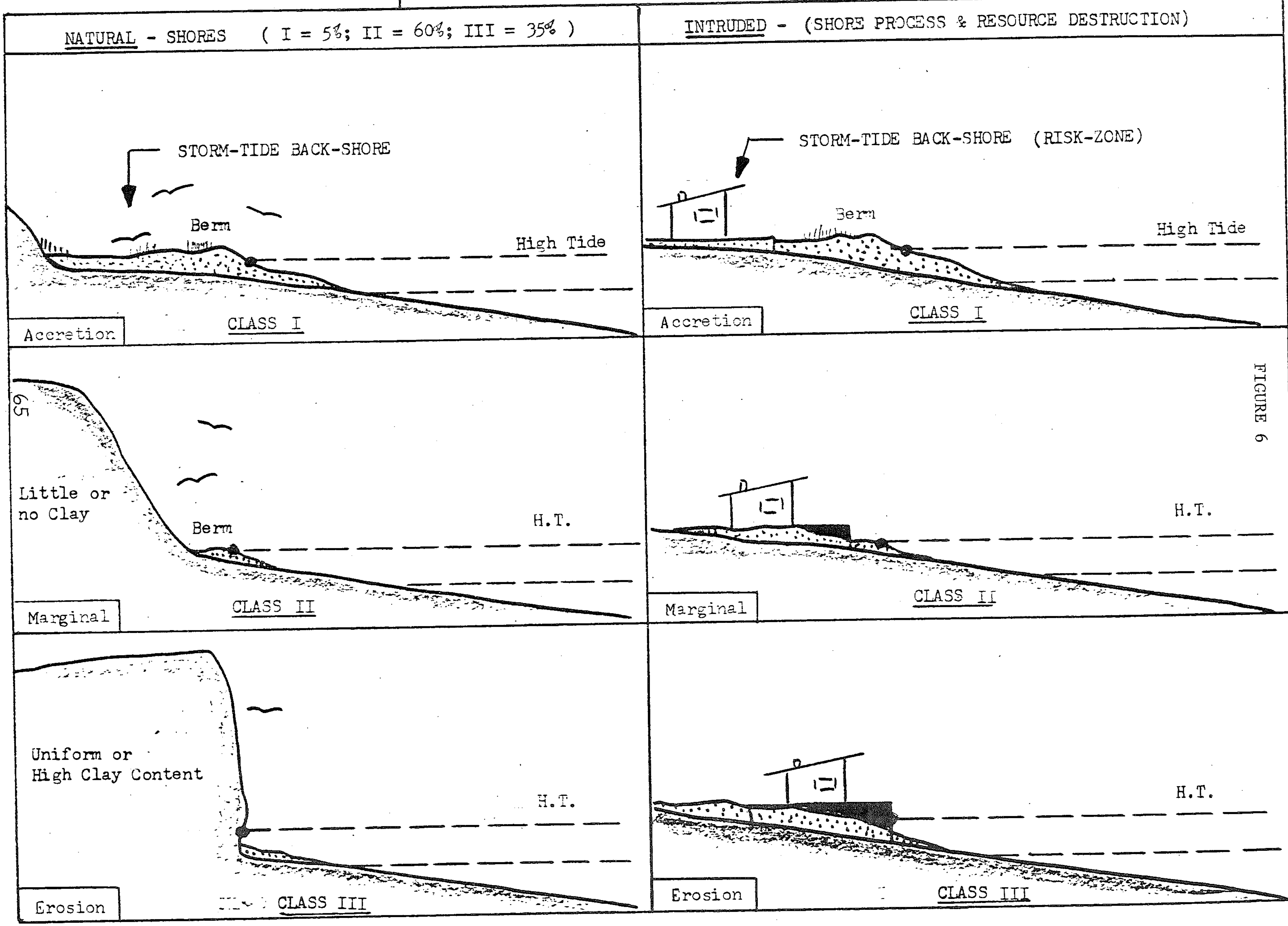


FIGURE 6

condition produces a natural bulkhead with the toe of the bluff situated below the high tideline so that the near-vertical swash plus echo-waves tend to keep the toe clean of sediment, and sometimes of driftwood as well.

b. There is no berm-building gravel in the bluff composition, and the foreshore does not act as a driftway for gravel from another feeder bluff. This may be the case with pure clay or clay-pocket bluffs that slide sporadically, and which may therefore be of uneven profile and tree-covered. If the bluff is pure sand there will be a steady feed to the foreshore, and the profile is more uniform and less steep. Waves frequently impinge on the bluff toe, and eroded material is quickly carried away.

CLASS II. MARGINAL DRY BEACHES

PHYSIOGRAPHIC DEFINITION

Class II beaches are here defined as those in which the beach shelf along the high tideline carries a layer or shallow berm of sand and gravel, as well as driftwood, and which remains dry at mean-higher-high tide level but is wetted by breaker action and all higher tides. Thus the Class II beach has a narrow, unstable backshore, the material of which is constantly involved in beach-feeding and longshore drift operations.

What has been described for Class III beaches generally also applies to Class II types. Both are erosional. In view of the widespread occurrance of gravel in most of the glacial drift deposits making up the Puget Sound sea bluffs, Class II beaches are by far the most prevalent. They usually represent active driftways in the high geo-hydraulic energy zones. In low energy shoreline areas, however, conditions for narrow backshore formation must be extremely favorable, such as proximity to active loose gravel feeder bluffs, or being part of the feed area.

CLASS I. ACCRETIONAL DRY BEACHES

PHYSIOGRAPHIC DEFINITION

Class I beaches are defined here as those having a relatively permanent backshore composed of a storm-tide berm of sand, gravel, and driftwood that is wetted only under extreme tide and wave conditions. Class I "dry" beaches are, with only few exceptions, accretional shore deposits that represent both driftway and net accretion terminal within their drift sector. While stable, storm-tide backshore berms may occur at the base of favorably oriented loose-gravel bluffs, Class I beaches are more characteristically associated with shoreforms such as spits and points, and barrier berms accreted across marshy or estuarine embayments.

ASSOCIATED SHOREFORMS (See Figure 2)

Class I accretion beaches might be called "derived" beaches, since their origin and present maintenance actually depends on the Class II and III erosional beach systems. Just as the latter are associated and integrated with the various types of seabluffs described earlier, so are the Class I beaches a windward component of accretion shoreforms. The major accretion shoreforms operating on Puget Sound as geo-hydraulic as well as distinct land and marine biologic entities are points, spits, tombolos, and barrier beaches, along with their associated and interdependent lagoons, salt marshes, and older marsh meadows.

<u>SPITS</u> (and HOOKS) are current and wave-built narrow sand and gravel deposits extending parallel to, or curving out from shore, and are characterized by a wave-built beach berm on the wind or seaward side (Class I beach), and a more gently-sloping muddy or marshy shore on the lagooned or leeward side. (Curved spit = hook)

<u>POINTS</u> are low-profile shoreline promontories of more or less triangular shape, with one side forming the backshore coastline as a baseline, and the apex extending seaward. Points may be the wave cut shelf remnant of a headland bluff, or they may be a last-phase purely accretional deposit that had its beginning in a hooked spit, and which subsequently closed its lagoon gap and re-connected to the mainland. Points are therefore in several stages of development, each with a characteristic environment reflecting its particular geomorphology. Points are characterized by the dike-like berm that storm tides have heaped along the high tideline of the two converging beaches, and a central inter-tidal lagoon, brackish pond or marsh, or an older salt or dune-grass meadow enclosed by such berms.

<u>BARRIER BEACHES</u> are accretional shoreforms of sand and gravel that have been deposited, like storm barriers, in front of bluffs, bays, marshes, and estuaries by longshore drift-growth from either or both headlands. They are characterized by a storm-tide berm above high tide which acts as both dike and seawall to the backshore, bluff-shelf, meadow marsh, lagoon, or estuary.

TOMBOLOS are causeway-like accretion spits connecting an offshore rock or island with the main shore. Tombolos usually develop from bars (submarine berms) that build up by sedimentation in the low-energy "wave shadow" zone between the wave barrier (the island) and an active driftway.

When tombolos reach maturity they constitute an accretion terminal for each part of the drift sector they have divided. Depending on its orientation to prevailing winds, as well as the fetch exposure of each side, a tombolo may have two Class I berm beaches, or one side may be more sheltered to produce a marshy shore and lagoon.

POCKET BEACHES are "residual" or "in-situ" shore deposits, rather than longshore-drifted accretion forms. As indicated previously, they may form any of the three classes of beaches depending on the degree of backshore berm-building permitted by local shore composition and energy level. It feeds on itself, so to speak.

The pocket beach may be at the foot of a high bluff or low bank, under which conditions it generally forms either a Class III or Class II erosional beach. When the pocket beach is located between headlands, or is part of a low isthmus (similar in appearance to a wide tombolo), then the prevailing windward side often creates a major Class I dry berm beach.

APPENDIX D

THE ACCRETION-BEACH AS A RECREATIONAL RESOURCE

Recreational shoreline experience on Puget Sound has many facets, some of which are basic to all waterfront activities, while others are peculiar to certain shoreforms and local conditions. Recreational shore use and activities also change with weather, tide level, and season. Shore appreciation is further tied to individual tastes, interests, and sense of values. Thus erosional beaches with their high cliff buffer zones, especially the most common Class II type, possess cherished scenic and recreational values for an increasing number of people. They are often the most inaccessible wilderness-type shore environments in our midst, and the seabluffs themselves present a dramatic showcase of glacial geology as well as biologic habitat. It is nevertheless possible to assign overall recreational priorities to certain beaches and shoreforms in terms of quantitative considerations that lend themselves to rating and comparisons with a minimum of bias.

The first quantitative priority factor to be associated with Class I beaches is that of relative uniqueness. Thus in terms of their occurence on Puget Sound, accretion beaches and shoreforms represent only a very small fraction of total shoreline-less than five percent-and a major portion of these has been and is being converted to erosion-type shores by improper bulkheading, developments and other shore disturbances.

A second priority factor is that of overall accessibility. Class I accretion beaches are the only ones with dependable dry, above-tide berms and walkable backshores, even under high wave action conditions. Where they are components of spits, tombolos, and points, they also offer protected leeward access from the water by virtue of a dual shore system.

A third factor focusing priority attention onto such beaches and their associated shoreforms is the time element in terms of their preservation as a heritage resource. In view of their general accessibility and flat topography, they have become a prime target for real estate development. The few remaining undeveloped examples of this heritage have now become a truly endangered shore species.

A major recreational plus-factor of Class I beaches, as compared to the more common erosional seabluff shores, is that of backshore use-potential. All three types of beaches have intertidal wet foreshores with tide-regulated walkability, clamming opportunities, and other shared water-involvement uses. However, the accretion beach has in addition to this foreshore commonality a dry sand and gravel driftwood berm with dune grasses and flowering vegetation, a beach environment that is available on a 24-hour basis without tidal interruption.

While swimming or clam-digging may be an avowed reason for visiting Puget Sound beaches, relatively few people actually swim in the short summer season and cold waters (as opposed to wading) and clamming is confined to certain infrequent minus-tides in limited favorable locations. Shore activities, as far as year-round or daily people-hours are concerned, will involve boat-landing, skin-diving in the offshore, walking and browsing, hunting for and gathering of driftwood, flotsam and pebbles, as well as bird and nature study. As the high tides or wind waves take possession of the wet and narrow erosion shores, such activities as camping, fire-building for cooking and socializing, and especially dry sand and gravel picnicking and sun-bathing become increasingly marginal. Especially in areas of high frequency beach visitation, the importance of remaining Class I dry beaches and associated environment will be more and more sought-after and valued.

THE ACCRETION SHOREFORM AS A BIOLOGICAL RESOURCE

As in so many instances of man's invasion of natural environments, recreational shore use is not always in the best interest of the resource, or of man himself. Some open space entities such as estuaries, for example, are invaluable bio-process environments at the food chain baseline, and intensive co-recreational use can bring about serious reductions in natural process operation. Man can affect such biologic systems in two ways- either directly in terms of comsumptive or pollutive activities, or indirectly in terms of affecting the <u>less flexible geo-sphere to which the more flexible bio-sphere is trying to adapt</u>.

In the Puget Sound shore process scheme-of-things, the basic and constantly recurring geo-hydraulic process sequence is the Feeder Bluff-Driftway-Accretion Terminal system. Not only has this resulted in accretion shoreforms composed of high priority recreational Class I berm beaches, but a direct consequence of this process has also been the creation of biotic environments in the form of shallow lagoons and protected salt marshes leeward of these shoreforms. Here the phyto-plankton, algae, and related baseline habitat, even though usually modest in size and activity, is nevertheless performing a valuable cumulative function within the total biosphere of the inland sea. Thus it is this dual recreational-biological resource potential that establishes the high priority resource position of accretional shoreforms at this time. It remains to be determined whether this is a dilemma or an asset. It is an unusual juxtaposition of dry recreational and wet biological environments — both esthetically and functionally valuable in their own right. (See Figure 7).

From the standpoint of recreation, this dual resource has fared without major problems thus far. The windward beach system has readily absorbed boat landing and beach traffic because of its rugged gravel and driftwood composition, while the leeward marshy shores and shallow lagoons have tended to discourage polluting motor boats, or consumptive marine activities aside from seasonal bird hunting. However, it has been in its use as a real estate development commodity that the effects have been devastating. Attesting to this are the bulkhead blocking of feeder bluffs and driftways, obliteration of storm-tide Class I berms, and the conversion of marshy lagoons into sterile boat basins and fills, all challenging system integrity.

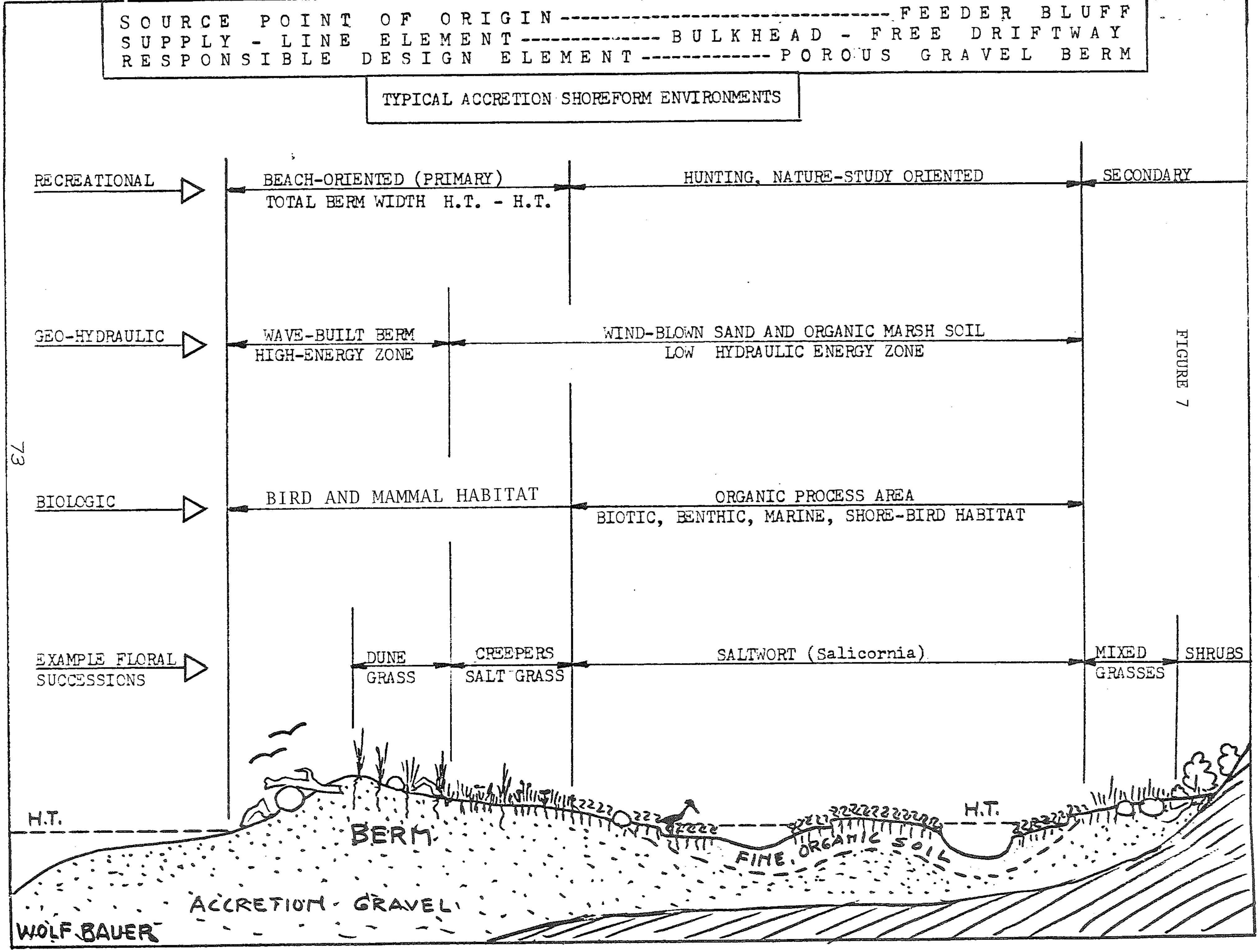

SOURCE POINT OF ORIGIN — FEEDER BLUFF
SUPPLY - LINE ELEMENT — BULKHEAD - FREE DRIFTWAY
RESPONSIBLE DESIGN ELEMENT — POROUS GRAVEL BERM
TYPICAL ACCRETION SHOREFORM ENVIRONMENTS
RECREATIONAL
BEACH-ORIENTED (PRIMARY)
TOTAL BERM WIDTH H.T. - H.T.
HUNTING, NATURE-STUDY ORIENTED
SECONDARY
GEO-HYDRAULIC
WAVE-BUILT BERM
HIGH-ENERGY ZONE
WIND-BLOWN SAND AND ORGANIC MARSH SOIL
LOW HYDRAULIC ENERGY ZONE
BIOLOGIC
BIRD AND MAMMAL HABITAT
ORGANIC PROCESS AREA
BIOTIC, BENTHIC, MARINE, SHORE-BIRD HABITAT
EXAMPLE FLORAL SUCCESSIONS
DUNE GRASS
CREEPERS
SALT GRASS
SALTWORT (Salicornia)
MIXED GRASSES
SHRUBS
H.T.
BERM
H.T.
FINE ORGANIC SOIL
ACCRETION GRAVEL
WOLF BAUER

FIGURE 7

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