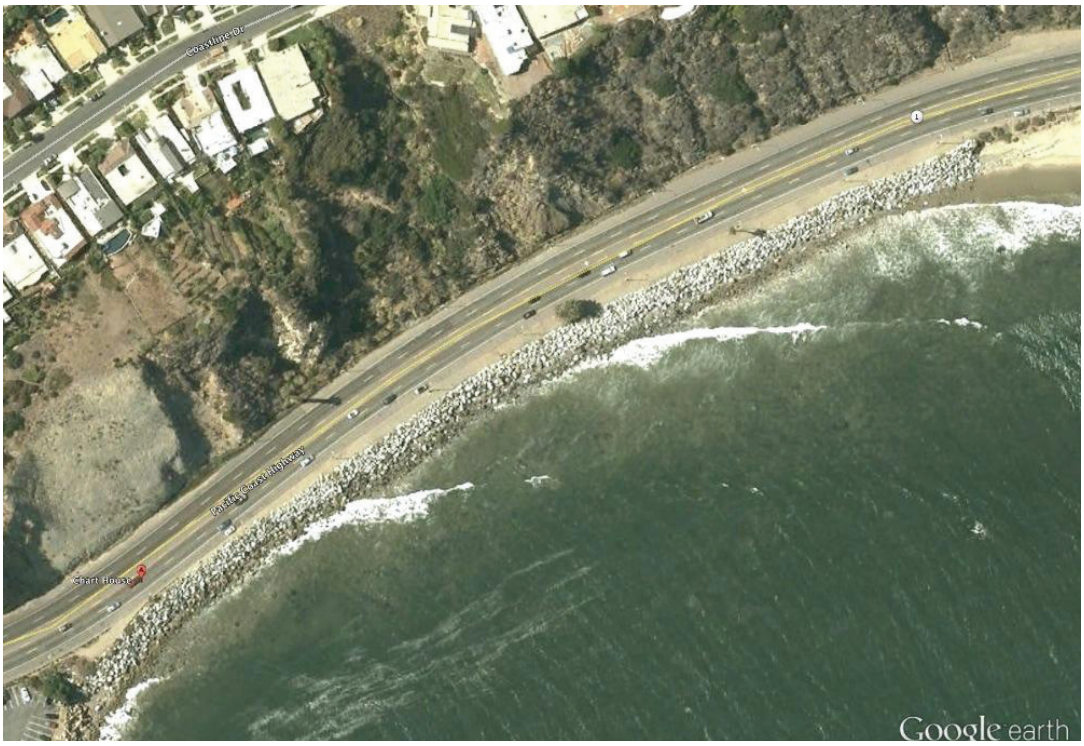
Matrix of Potential Coastal Adaptation Strategies

The matrix provided on pages 60-76, developed by Lesley Ewing (California Coastal Commission) and Dr. Reinhard Flick, outlines some of the most common coastal adaptation techniques available to coastal communities. This matrix is divided into adaptation techniques that help communities:

- Avoid hazards;
- Move development away from hazards;
- Move hazards away from development;
- Provide barriers between hazards and development; and
- Flood-proof.

For each of these sub-categories, information is provided on the details of the technique, the spatial and temporal scales associated with the technique, the ability to adjust the technique depending on changing conditions (referred to in the matrix as "adaptive capacity"), the party or agency that would be responsible for managing the adaptation technique, a relative approximation of costs (e.g. high, medium or low), and general comments.

This matrix is intended to provide insight into the available options for communities and help the community better understand the described technique. In considering any of these options for application in the adaptation planning effort, each should be analyzed for the site-specific conditions, environmental concerns, technical feasibility and compatibility with existing constraints. Clearly, not all techniques are available for all situations; rather, this matrix is meant to provide a range of adaptation response options.



A Google Earth image of heavy rock armoring along PCH in Malibu. Rock armoring is one of the many adaptation strategies described in the matrix on pages 67-83.

Avoid Hazards

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Land Acquisition	Fee Simple Acquisition	One or more lots	Short/ Long-term	Yes	Government, Non-Governmental Organization, Homeowner Association, Geologic Hazard Abatement District	High	Provides greatest control over land use and hazard response. Land can be purchased from willing sellers or by governments using eminent domain.
	Conservation Easements	One or more lots	Short/ Long-term – lessen with time	Yes	Government, Non-Governmental Organization, Homeowner Association, Geologic Hazard Abatement District	Low to Moderate	Provides less control than fee simple acquisition. Can be part of a permit action. Land can be purchased from willing sellers.
	Transfer Development Credit	Jurisdiction, Region	Moderate/ Long-term	Yes	Government, Geologic Hazard Abatement District	Low to Moderate	Provides fee simple acquisition of high hazard lots. Takes time to set up TDC Program and develop criteria for hazardous lot acquisitions. Costs to administer are low. Acquisition costs paid by developers. Cost of coastal land may make program infeasible.

Move Development Away from Hazards

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Land Acquisition	(see above)						
Managed Retreat		One or more lots	Moderate/ Long-term – Increase with time	Yes	Government, Homeowner Association, Geologic Hazard Abatement District	Moderate	Best if included in initial design to allow phased removal of development. Costs paid by owners with or without government or non-profit contributions.
Rolling Easements		One or more lots	Moderate/ Long-term – Increase with time	Yes	Government, Non-Governmental Organization, Homeowner Association, Geologic Hazard Abatement District	Moderate to high	Easements acquired by government or NGO. Costs to acquire will be likely to vary indirectly with risk.
Setbacks		One or more lots	Moderate/ Long-term – Lessen with time	Not normally	Government, Homeowner Association, Geologic Hazard Abatement District	Low	Setback provides protection from hazard until setback is gone. Variable cost to developer and/or homeowner - foregoing use of some portions of the property.
Elevation		One or more lots	Moderate/ Long-term – Lessen with time	Not normally	Government, Homeowner Association, Geologic Hazard Abatement District	Low to moderate	Elevation provides protection from ocean hazards. May introduce other risks from slope instability, etc. Need to include access and utilities for long-term effectiveness.

Move Hazards Away from Development

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Maintain or Restore Natural Sand Supply	Remove dams	Region/ watershed	Long time/ Long-term	No	Government, Water Board, Non-Governmental Organization	High to Very High	Only effective if stream flows are sufficient to move sediment to the coast. Raises difficult engineering issues if sand must be moved to the coast. Involves multiple jurisdictions. But, dam removal is occurring with as yet unknown benefits.
	By-pass sand around dams	Region/ Littoral cell	Moderate/ As long as continued	Yes	Government, Water Board	High to Very High	Only effective if stream flows are sufficient to move sediment to the coast. Raises difficult engineering issues if sand must be moved to the coast. Feasibility for large volumes is unlikely, since sand transportation cost to the coast is high, and may have unacceptable traffic and air quality impacts as well as barriers to truck access at the beach.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Maintain or Restore Natural Sand Supply	Harbor dredging or By-passing	Region/ Littoral Cell	On-going/ As long as continued	Yes	Government, Harbor district	Moderate to High	Dredging is often necessary for harbor maintenance. Historically, this has been a major source of nourishment sand in certain locations. Testing and placing sand on beaches often adds only a marginal cost.
Improve or Augment Sand Supplies/ Beneficial Reuse of Sand	Interrupt rip currents	Local	Long time/ As long as continued	Yes	Government	High	Complex engineering issue. Unlikely to be feasible even for fixed rip currents located at structures or geomorphic features. This is an unproven idea likely not suitable to high tide-range environments with public opposition to surf-zone structures and likely high cost. Effects would be similar to offshore breakwaters with less guarantee of success.
	Nourish with coarser sand than native	Multiple lot/ Region	Moderate/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowner Association, Geologic Hazard Abatement District	High	This approach is widely used by engineers to increase the lifetime of beach replenishment projects. Feasibility depends on availability of suitable sand sources.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Improve or Augment Sand Supplies/ Beneficial Reuse of Sand	Canyon Interceptors	Region/ Littoral Cell	Long time/ As long as continued	Yes	Government	Very High	Complex and unproven engineering concept that would need detailed studies to determine feasibility. Likelihood of success is not knowable since the amount of offshore sand loss in canyons versus offshore losses along the beach is unknown.
Sources of Beach Material	Offshore Sand	Multiple lot/ Region	Short to moderate/ As long as continued	Yes		Moderate to High	Costs very dependent on scale --- mobilizing the dredge is a fixed cost regardless of volume delivered.
	Reservoir and Debris Basins	A few lots to multiple lots	Moderate/ As long as continued	Yes		High to extreme	Sand testing important. Sorting and handling costs can be large. No unit savings on transport costs with larger volumes moved. Feasibility is unlikely for large volumes, since sand transportation cost to the coast is high, and may have unacceptable traffic and air quality impacts as well as barriers to truck access at the beach. Involves multiple jurisdictions.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Sources of Beach Material	Back-passing	Region/ Littoral Cell	Moderate/ As long as continued	Yes		Moderate to high	Sand quality normally compatible with existing beach material. This method holds promise since fixed plants can be used and engineering basis is relatively simple.
	Cobbles	A few lots to multiple lots	Moderate to long/ As long as continued	Yes		High to Very high	Cobble sources are limited. Poses environmental concerns for beaches without existing cobble.
	Crushed glass	A few lots to multiple lots	Moderate to long/ As long as continued	Yes		Very high	Crushed glass would need to be tumbled to round off sharp edges. Handling costs would be high.
Retention of Sand/Beach Material	Beach Berms	A few lots to multiple lots	Short/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District	Low	May need to be repeated multiple times a season. Source of sand should be identified. State sovereign land issues arise.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Retention of Sand/Beach Material	Groins	Region/ Littoral Cell	Long/ Moderate to long	Yes	Government, Homeowners Association, Geologic Hazard Abatement District	Very high	Engineering issue. Pre-fill likely to be required to minimize downcoast impacts. Sensitive to orientation of waves and sediment supplies and transport direction and magnitude. Public opposition to structures is an issue that needs to be solved.
	Jetties	Region/ Littoral Cell	Long/ Long	No	Government, Harbor District	Very High	Engineering issue. Normally only used at river mouths and harbor entrances. Public opposition to structures is an issue that needs to be solved.
	Dune Nourishment	A few lots to multiple lots	Moderate/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, individual		Limited application in CA, since few beaches depend on dune storage of sand, especially in southern California.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Retention of Sand/Beach Material	Breakwaters	Region/ Littoral Cell	Long/ Long	No	Government, Harbor District	High	Proven effective and feasible. Public opposition to structures, especially ones that directly impact surfing, is an issue that needs to be solved. Presents potential swimming and boating safety hazards. Construction cost is high, but benefits are long-term. Santa Monica Breakwater is about 80 years old and functions well with little maintenance.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Innovative Options for Retention of Sand/Beach Material	Perched beach	A few lots to multiple lots	Long/ Long	No	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, individual		May require frequent re-nourishment. Also can produce negative consequences if large storm waves remove sand shoreward of perching structure that then cannot migrate back upslope onto the beach. Can modify offshore slope and pose a danger to swimmers. Also reduces circulation in the perched beach area, leading to water quality and sand contamination issues.
	Artificial seaweed	Region		Possible	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low to high	Never shown to be effective in field tests, and almost certainly cannot be effective due to low mass in high wave and tide-range environment. Clean up costs can be high.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Innovative Options for Retention of Sand/Beach Material	Artificial headland	Region/ Littoral Cell		No	Government	Very high	Complex engineering; experimental effort. Likely to be effective and feasible if designed to function like a groin or jetty. Public opposition to structures, especially ones that impact beach access or surfing, is an issue that needs to be solved.
	Delta augmentation	Region/ Littoral Cell		Possible	Government	Very high to extreme	Complex engineering; experimental effort unproven in practice. Would require large additions of material spread over large area, and may require multiple additions of material.
	Active Beach dewatering	A few lots to multiple lots	Short to moderate/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Moderate	Principle is sound. Would be a localized effort. Only financially feasible if co-located with other active dewatering, such as desalination plants. May have consequences on other beach communities downcoast. No long-term results known in the reviewed engineering literature.

Move Hazards Away from Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Innovative Options for Retention of Sand/Beach Material	Passive beach dewatering	A few lots to multiple lots	Short/ As long as maintained	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low	Passive beach dewatering has never been successfully demonstrated.
	Floating breakwaters	Region/ Littoral Cell	Short to moderate/ Moderate	Slightly	Government	High	Complex engineering, but proven principle. Most uses have been for temporary protection or ship deployment.
	Multi-purpose reefs	Region/ Littoral Cell	Long/ Moderate to long	No	Government	High to very high	Complex engineering; experimental efforts. Costs to remove have proven to be very high (i.e., Pratte's Reef). Engineering criteria conflict for dual-use surfing-shore protection reefs because of high tide range in CA. Reef must be low to enable surfing at most tide elevations, but high to protect property during high wave and tide events.

Barriers between Hazards and Development

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Revetments	Rock	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	High impact on beach areas short and long-term, including passive erosion. Changes habitat along a sandy shoreline. Public opposition to structures, especially ones that impact beach access is an issue that needs to be solved.
	Concrete units	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	High impact on beach areas short and long-term, including passive erosion. Changes habitat along a sandy shoreline. Also, public opposition (see above).
	Gabions	One or more lots	Moderate/ Short	Possible, but not likely	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Moderate to high	High impact on beach areas short and long-term, including passive erosion. Changes habitat along a sandy shoreline. Poor long-term performance due to weaknesses in netting. Also, public opposition (see above).

Barriers between Hazards and Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Seawalls	Vertical tie-back walls	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	Low initial impact on beach, high long-term passive-erosion impact. Also, public opposition (see above).
	Gravity walls	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	High impact on beach areas short and long-term, including passive erosion. Also, public opposition (see above).
	Cantilever walls	One or more lots	Moderate/ Moderate	Possible if part of initial design	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	High	Low initial impact on beach, high long-term passive-erosion impact. Also, public opposition (see above).

Barriers between Hazards and Development (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Miscellaneous	Native vegetation	One or more lots	Short/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low	Not useful by itself on the CA moderate-wave energy and high tide-range coast. Normally used as part of a larger sand nourishment project to stabilize back shore.
	Sea cave fills	One or more lots	Moderate/ Moderate	No	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low to moderate	Can slow erosion in areas with bluff undercutting or cave formation. Proven feasible and cost effective. Low initial impact on beach, high long-term passive-erosion impact. Also, public opposition (see above).
	Surface & ground water controls	One or more lots	Short/ As long as continued	Yes	Government, Non-Governmental Organization, Homeowners Association, Geologic Hazard Abatement District, Individual	Low	Normally used as part of a larger project. Proven feasible and effective (even necessary) to reduce or prevent sudden cliff collapse. Not usually considered a form of beach sand erosion control.

Flood Protection

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Building Protection	Elevate structure	Individual structures	Moderate/ Long-term – Lessen with rising sea level	Not unless part of initial design	Building Owner	Low to Moderate	Elevation can provide protection from flood water if building is high enough. Often includes lower stories with break-away walls that can become floating debris.
	Sand Bags	Individual structures	Short term/ Long-term – lessen with rising sea level	Height will depend on bag stability	Building Owner	Low	Sand bagging can provide short-term protection. Requires warning of impending flood and ability for rapid response prior to the flood event. Interrupts building access while in use.
	Storm shutters	Individual structures	Moderate/ Long-term	Moderate	Building Owner	Low	Storm shutters can be available to cover all openings (normally doors and windows). Requires warning of impending flood to secure all entrances. Interrupts building access while in use.

Flood Protection (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Electrical Equipment	Elevation	Individual structures	Short term/ Long-term	Depends on building height	Building Owner Building Code	Low	Elevation of electrical equipment can insure continuity of power during and after a flood provided equipment can be located higher than flood levels
	Vaults	Individual structures	Short-term/ Long-term	None	Building Owner	Low to Moderate	Vaults would protect electrical equipment from flooding; would need routine maintenance to insure effectiveness when needed.
	Pumps	Individual structures	Short-term/ Moderate	None	Building Owner	Moderate	Useful to remove flood waters from sensitive areas. Require a reliable power source and location to which water can be pumped.

Flood Protection (continued)

General Techniques	Technique Details	Spatial Scale	Temporal Scale (Implement/ Effective)	Adaptive Capacity	Responsible Party	Costs	Comments
Tunnels	Permanent Storm Barriers	Individual systems	Moderate/ Long-term – Lessen with rising sea level	Low	Community/ Project Manager	Moderate	Storm barriers would need to cover all openings – tunnel openings, ventilation, etc. Requires warning of impending flood to secure all entrances. Interrupts access and tunnel use while barriers are in place. Depending upon storage method, they can be an annoyance to travelers when not in use.
	Temporary Entrance covers	Individual structures	Short term/ Long-term – lessen with rising sea level	Low	Building Owner	Low	Entrance covers (sand bags, inflatable plugs, etc,) can provide short-term protection. Requires warning of impending flood and ability for rapid response prior to the flood event. Interrupts tunnel access while in use.