Navigation Channels Considerations for Marine Terminals: Minimizing Risk

Rice Global E&C Forum
Engineering & Construction

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AECOM

AECOM at a Glance: Integrated Solutions

We provide the entire suite of services for virtually all types of terminals – Petroleum/petrochemical; LNG; liquid/dry bulk; container; break-bulk; military; offshore moorings – around the world

- **Front End/Planning/Environmental/Feasibility/Economics/FEED**
- **Field Investigations**
- **Process engineering, pipeline, infrastructure**
- **Modeling and Simulation**
- **Conceptual, Preliminary, Final Engineering Design**
- **EPC/EPCM/Self Perform Construction Services/Fabrication**

– ***99,000 employees, 500+ offices in 150 countries around the world, $19 Billion revenue 2014***

– ***ENR #1 Ports & Marine, Transportation, Environmental, others***

– ***Global marine design centers; Gulf Coast in Houston, New Orleans***

Topics

- Why you should have some level of knowledge
- Fundamentals of Channel Design
- Environmental & Permit Issues
- Dredging and Dredged Material Placement
- Managing Risk: Operational and Contractual
- Project Example: Port of Columbo, Sri Lanka

This presentation is meant as an introduction to navigation channels; Details are site dependent

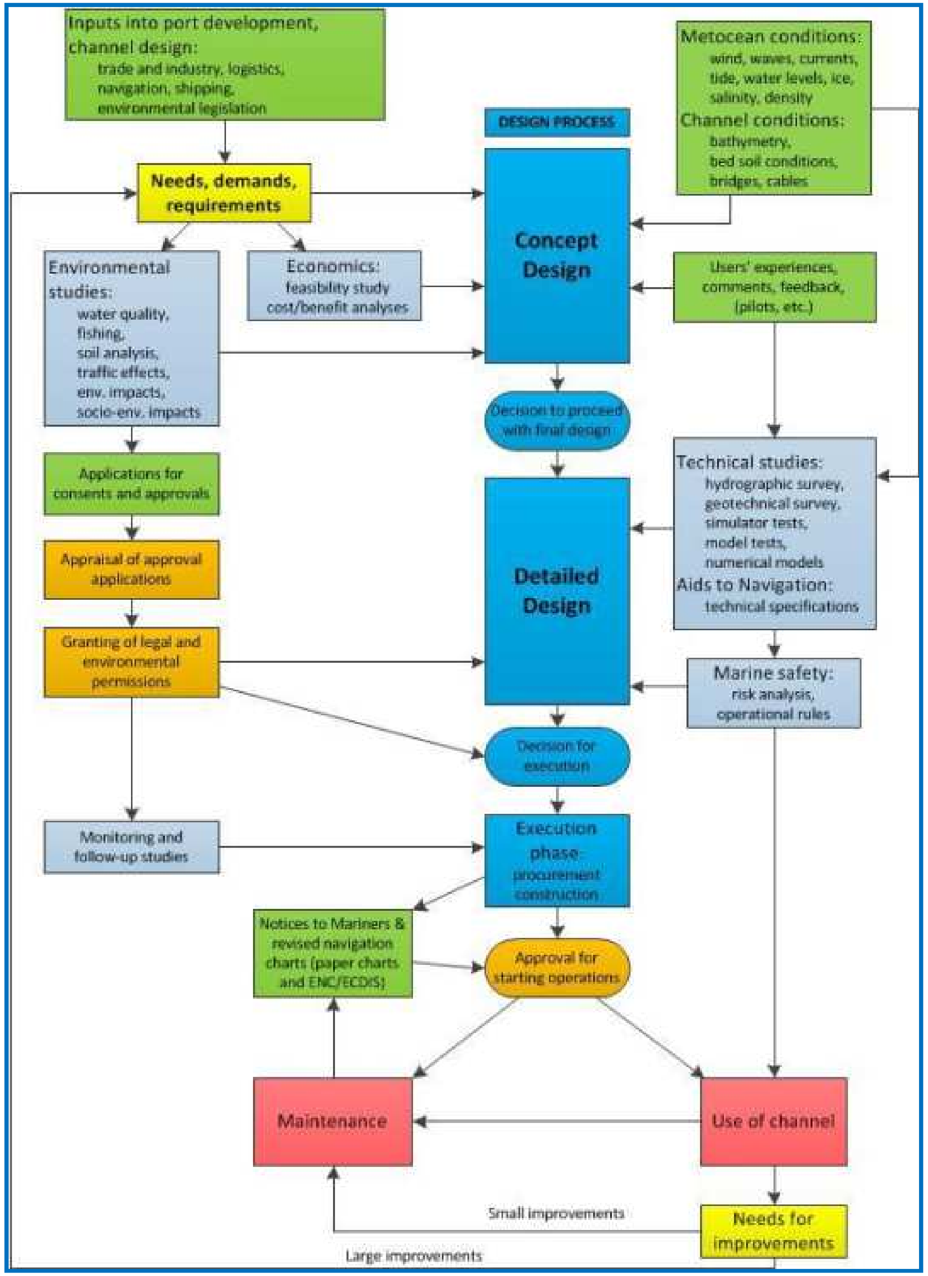
Why should you understand this topic?

- **Gateway to your marine terminal**
- **Navigation Safety, security of terminal**
- **Critical path item in terminal development; long “lead time”**
- **High initial cost and ongoing O&M; specialized market**

<u>Who</u> should know: Anyone involved in the development or operation of a marine terminal

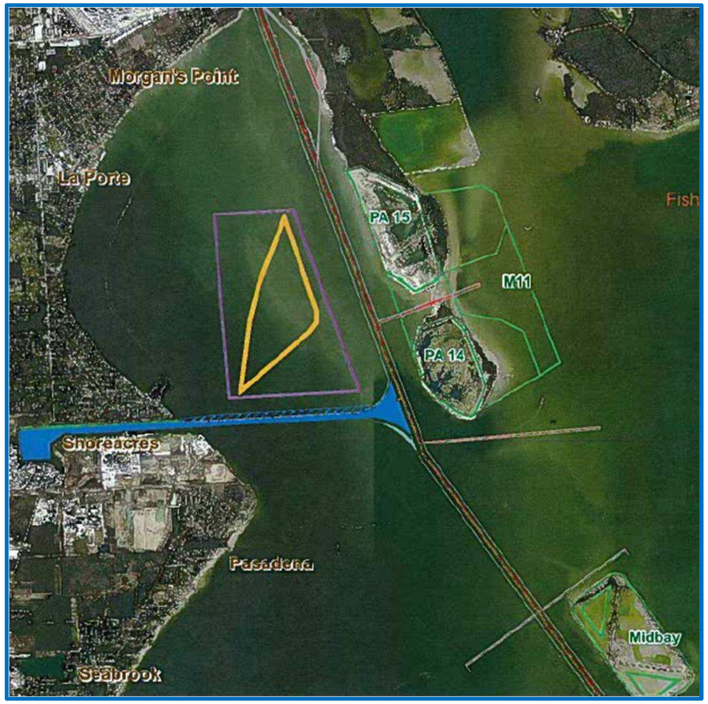
Development Process

- We will touch on these main topics
  - Design guidelines through PIANC and USACE
  - Environmental - site specific
- Concept Design
  - Location & Needs
  - Feasibility & Economics
  - Environmental regs
  - Metocean and channel
  - Go/No-Go
- Detailed Design
  - Environmental permits
  - Technical studies
  - Marine Safety
  - Other site specific
- Approvals and construction



Channel Design: Determining Geometry

- ID System components: Entrance, main channel, turning basins, berths…
- Existing bathymetry
- Obstructions
- Design vessels, other users
- Sub bottom condition – pipelines, etc.
- Calculated design is not absolute; practical/commercial issues considered
- From this you have a pretty good idea of your channel alignment

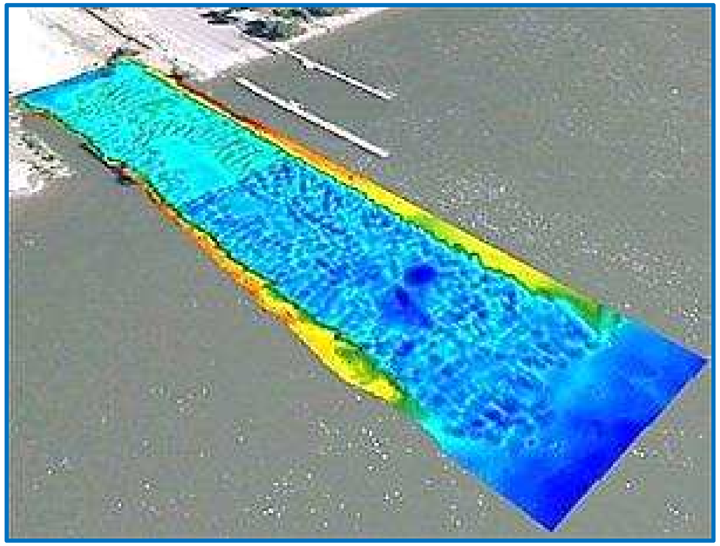


Photos: Bayport (PHA); channel connects to HSC w/wideners for arrival and departure

Field Investigations: These are critical tasks

- **Bathymetry – Accuracy CRITICAL**
  - **Single vs. Multi Beam (preferred)**
  - **Offshore disposal areas**
  - **Areas for mining sand/fill**
- **Side scan, sub-bottom, magnetometer for utilities, pipelines, wrecks**
- **Soil Investigations: CRITICAL**
  - **Sufficient number of borehole sites**
  - **Correct sample # and tests**
  - **Probes useful to find hard material**
  - **Stable platform (jack up for rock or offshore/unprotected)**
- **Met-ocean**
- **Others depending on site (locating pipelines, archaeology, seismic, tsunami, etc.)**

NOT THE PLACE TO CUT COST!



Field Investigations, Typical Dredge Project

Bathymetric or topographic survey

- Single beam survey
- Multi beam survey
- Land survey

Detection of seabed obstructions (UXO, wrecks, boulders, ...)

- Side scan sonar
- Multibeam sonar
- Magnetometer survey

Geological and geotechnical investigation

Geophysical seismic
- Reflection seismic
- Refraction seismic
- Geoelectric survey

Sampling methods
- Borehole
- Vibrocore
- (Jet)probe
- Grab sample
- Test pit

Testing
- Laboratory tests
- In-situ tests
- Cone penetration tests

Hydraulic morphological and meteorological data

Hydraulic Data
- Waterlevels
- Tide
- Current

Sediment transport / Turbidity

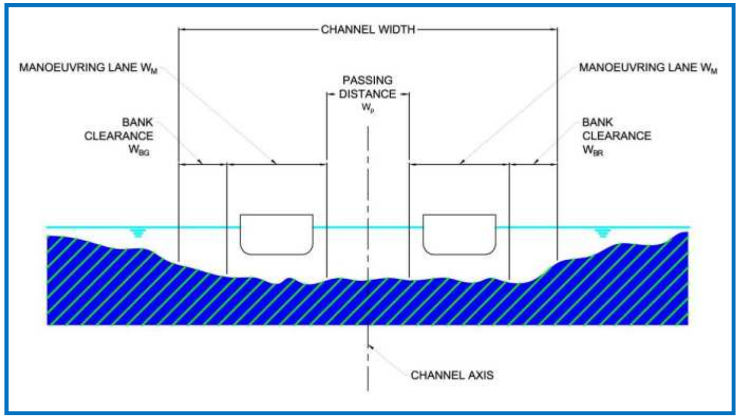
Meteorologic Data
- Waves
- Ice
- Fog

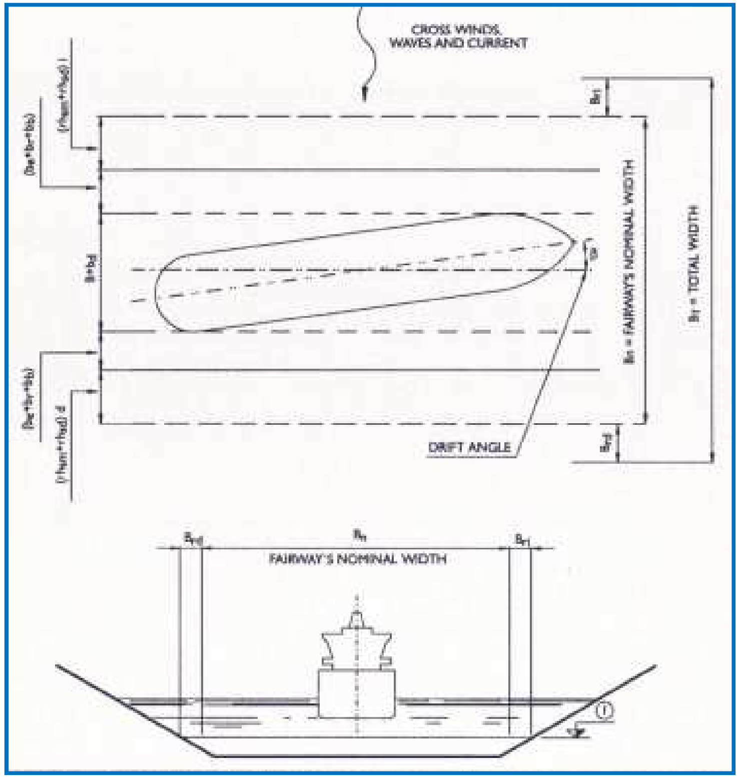
Seismic Data
- Earthquake risk
- Tsunami risk

Schematic chart of data required for a site investigation, adapted from Hydraulic Fill Manual.

Channel Design: Width

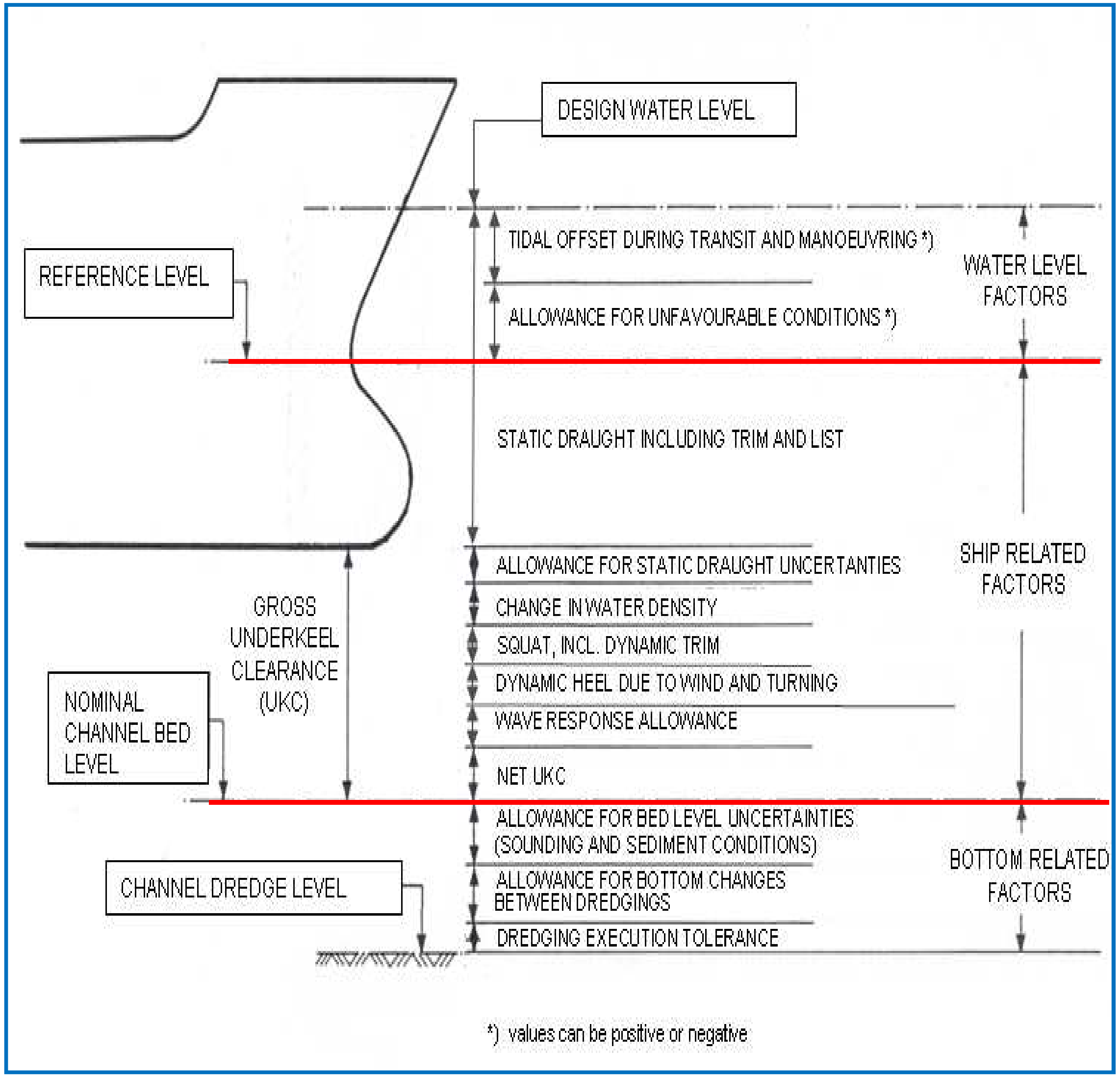
- One way or two way
- Range of vessel characteristics
- Alignment – Straight, bends…
- Vessel "behavior" under design conditions, sailing/maneuvering
- Conceptual Width = Vessel beam + consideration for maneuvering + passing + bank clearance + other (turns, etc.)
- Often expressed as a factor of beam
- Practical/commercial factors considered – HSC Bayou Reach Example





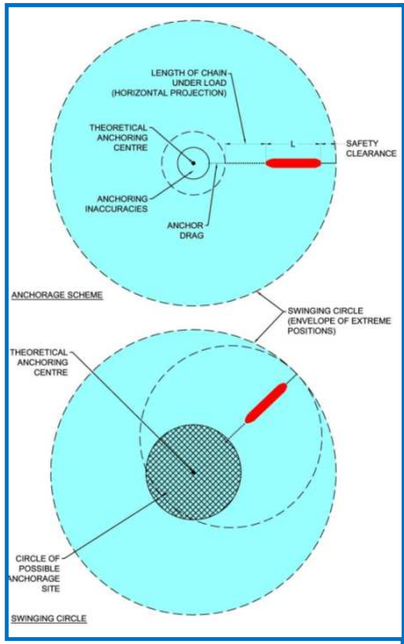
Channel Design: Depth

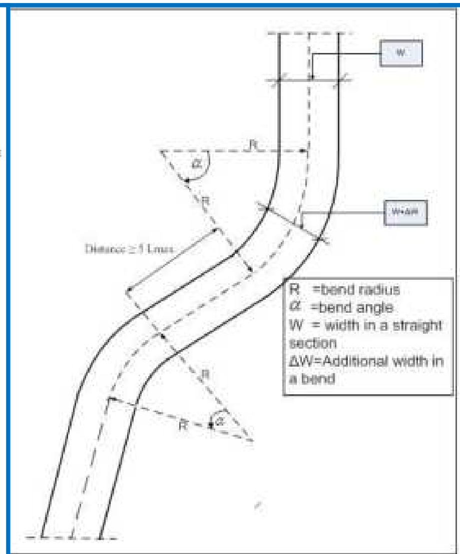
- **Direct calculation**
- **Three "levels" to consider above/below waterline**
- **Sea level factors – waves, tides, etc.**
- **Vessel factors – Draft, trim, list, squat, heel, etc.**
- **Bottom and seabed factors (hardness, uncertainties)**
- **Practical/commercial factors are considered**
- **Often expressed as factor of vessel draft**

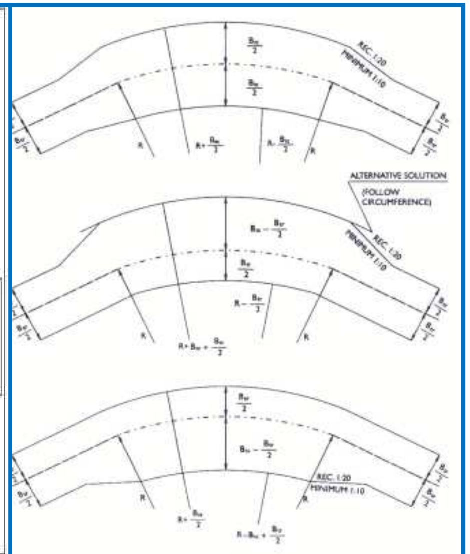


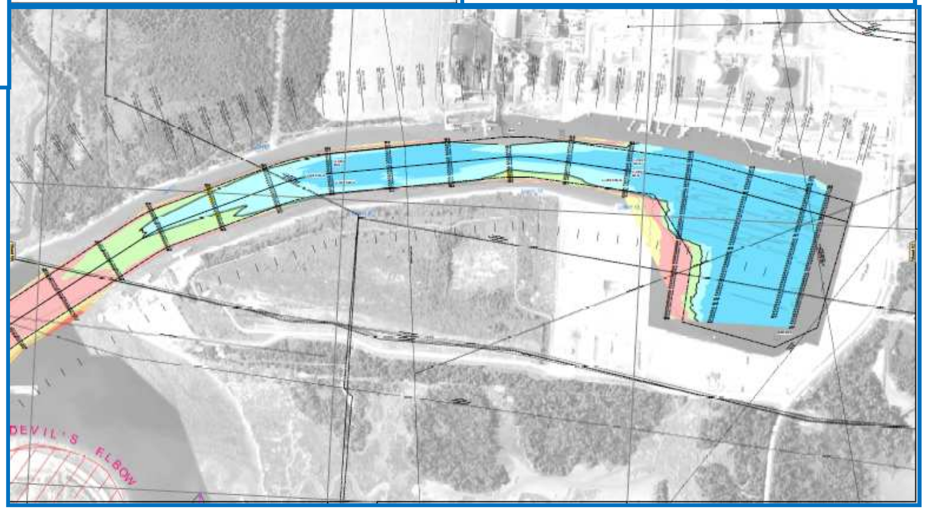
Channel Design: Other Aspects

- **Turning radius**
- **Passing lanes**
- **Wideners**
- **Turning basins**
  - **Length X Factor**
- **Anchorage**
  - **Length X Factor**
- **Air draft: Can limit vessel size, alter channel design**





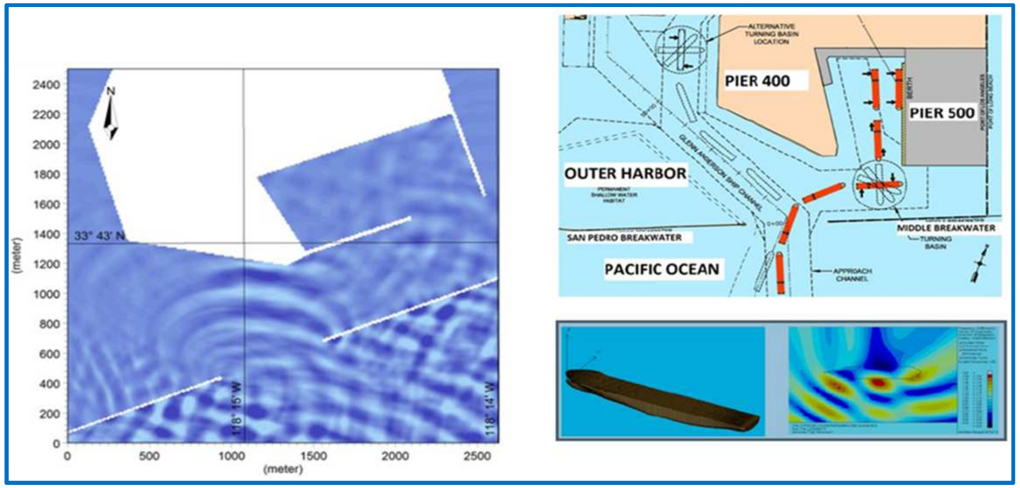


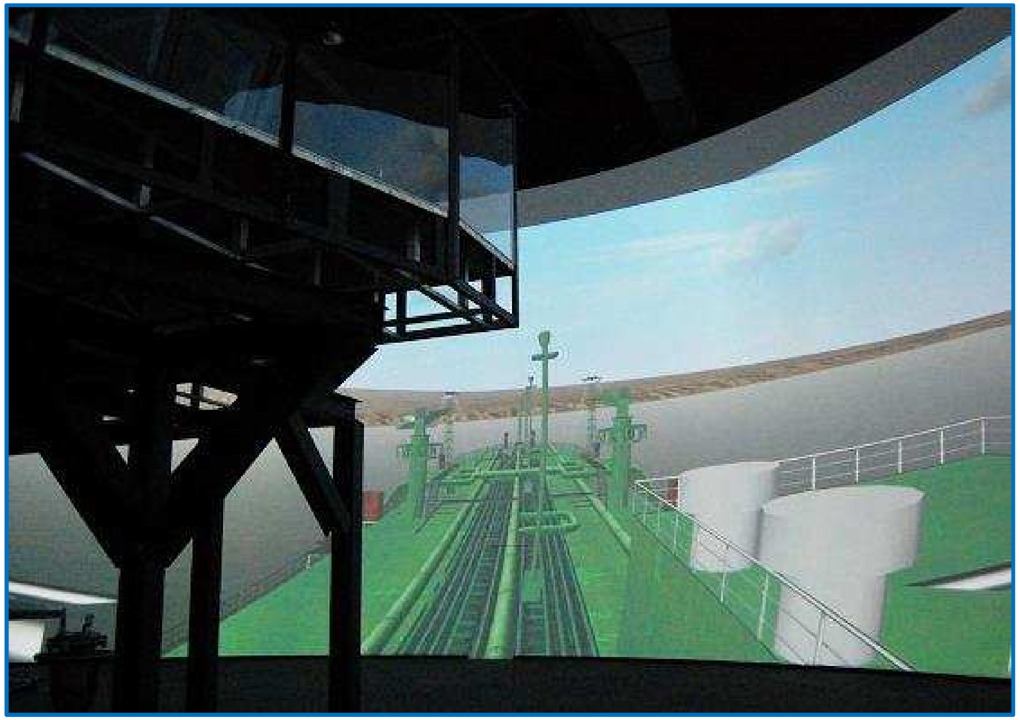


Channel Design: Numerical Modeling

- Coastal engineering: Waves, currents, sedimentation, etc.
- Navigation models:
  - Fast time: SHIPMA, DynaSim
  - Real time simulators: PMI, MITAGS, Star Center, etc.
- Pilots, operators, other users involved
- Berthing and Mooring analysis, effect of passing vessels
  - OPTIMOOR, others
- Verify channel design, safety

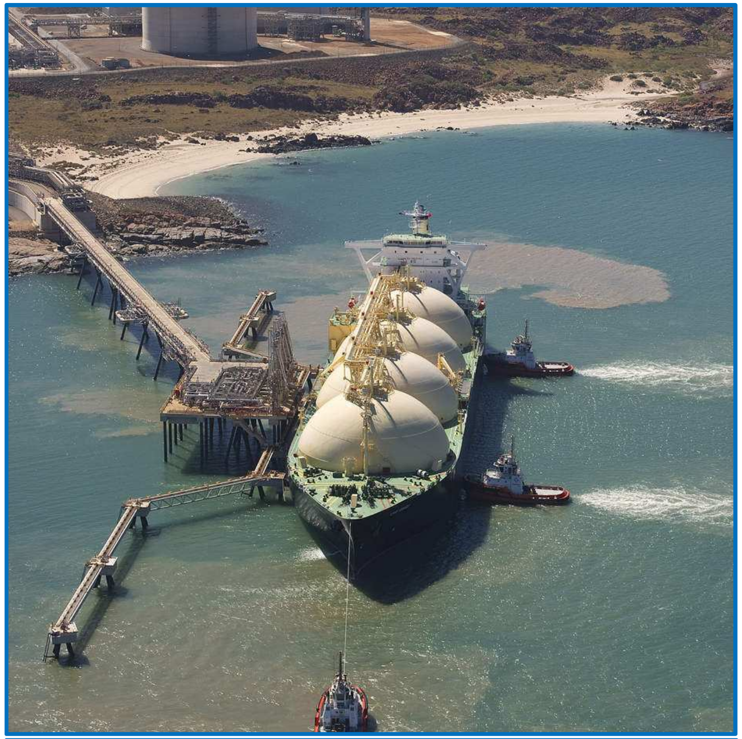
Use results to ID areas of concern, modify design; an iterative process

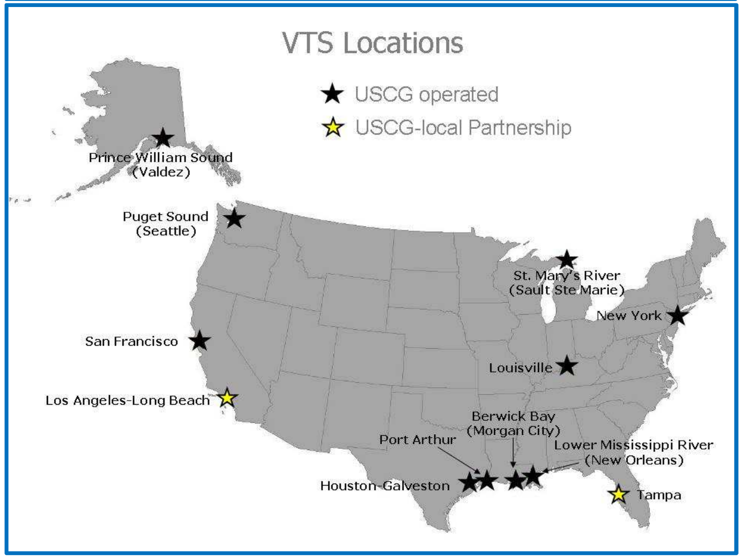




Channel Design: Safety

- Channel suitability studies (as with LNG Waterway Suitability Assessment)
- Navigational risk analysis
  - Sea conditions
  - Channel arrangement
  - Traffic analysis, vessel encounters
  - Proximity to SPM, dangerous cargo
  - Risk of accident
- Modeling – Vessel traffic simulations
- Tug assists, #tugs and specifications
- Vessel Traffic Systems - USCG
- ATON
- Other site-specific items





Environmental & Permitting

- **Typically Issued through Federal, State, Local authorities**
- **Conditions <u>highly</u> dependent on locality, resources, regulators**
- **Some typical resources/issues:**
  - **Coral, “hard bottom”**
  - **Sea grass, wetlands**
  - **Endangered species**
  - **Marine mammals**
  - **Fish and wildlife**
  - **Turbidity/water quality**
  - **Contaminated sediment**
- **Mitigation or improvements may be needed**

Top: Bolivar Marsh, HGNC

Bottom: Sonoma Wetlands, CA

Environmental & Permitting: HGNC

Example: HGNC Deepening and Widening (~$700MM) – Creation of habitat/confined disposal of dredge material

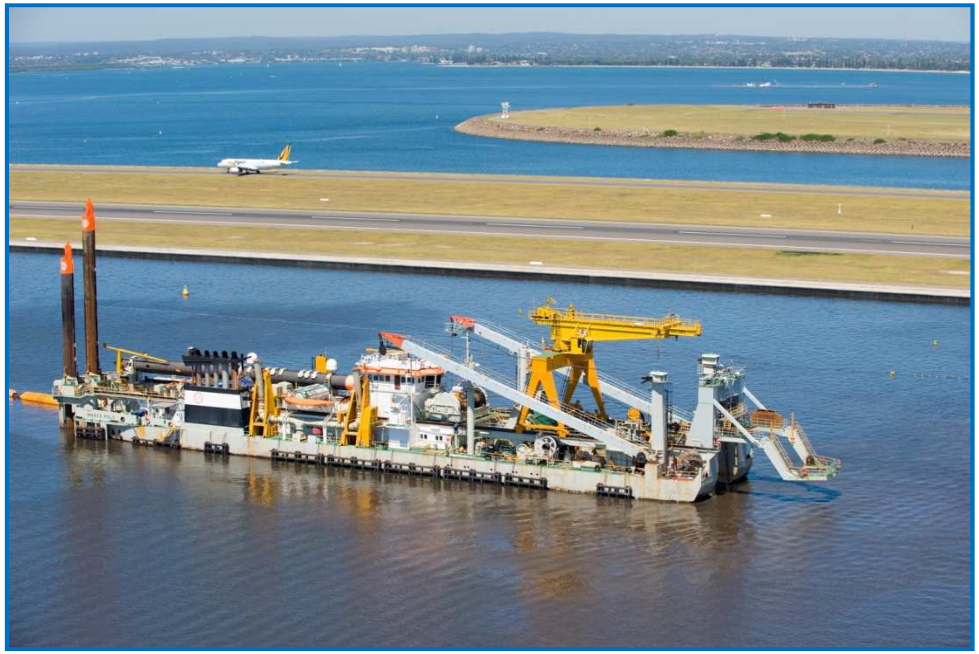
- **Dredge material was once pumped overboard into Galveston Bay; habitat loss, WQ degradation**
- **Mandate beneficial use of dredge material, contain all dredge matl**
- **Inter-tidal marsh; habitat islands; reefs; DMPA improvements**
- **Agencies involved: USACE; PHA; EPA; NMFS; USFWS; TXPWD; GLO; NOAA, TCEQ**
- **How? Multi-year effort between PHA and consultants (AECOM-GBA JV); USACE, agencies (Beneficial Use Group)**

Environmental & Permitting: HGNC

- **New Work w/USACE cost share; follow USACE guidelines**
- **Reconnaissance (in National Interest); Feasibility (cost/ben); Congressional Authorization & Funding; LRR/EIS, Sect. 404 & Sect. 10 of CWA, Sect. 408/Title 33 of US Code, 203/204 assumption of maintenance under WRDA….strong local sponsor in PHA**
- **Broken up into multiple projects; marshes, islands, offshore reefs, habitats, monitoring, etc. – Model project**

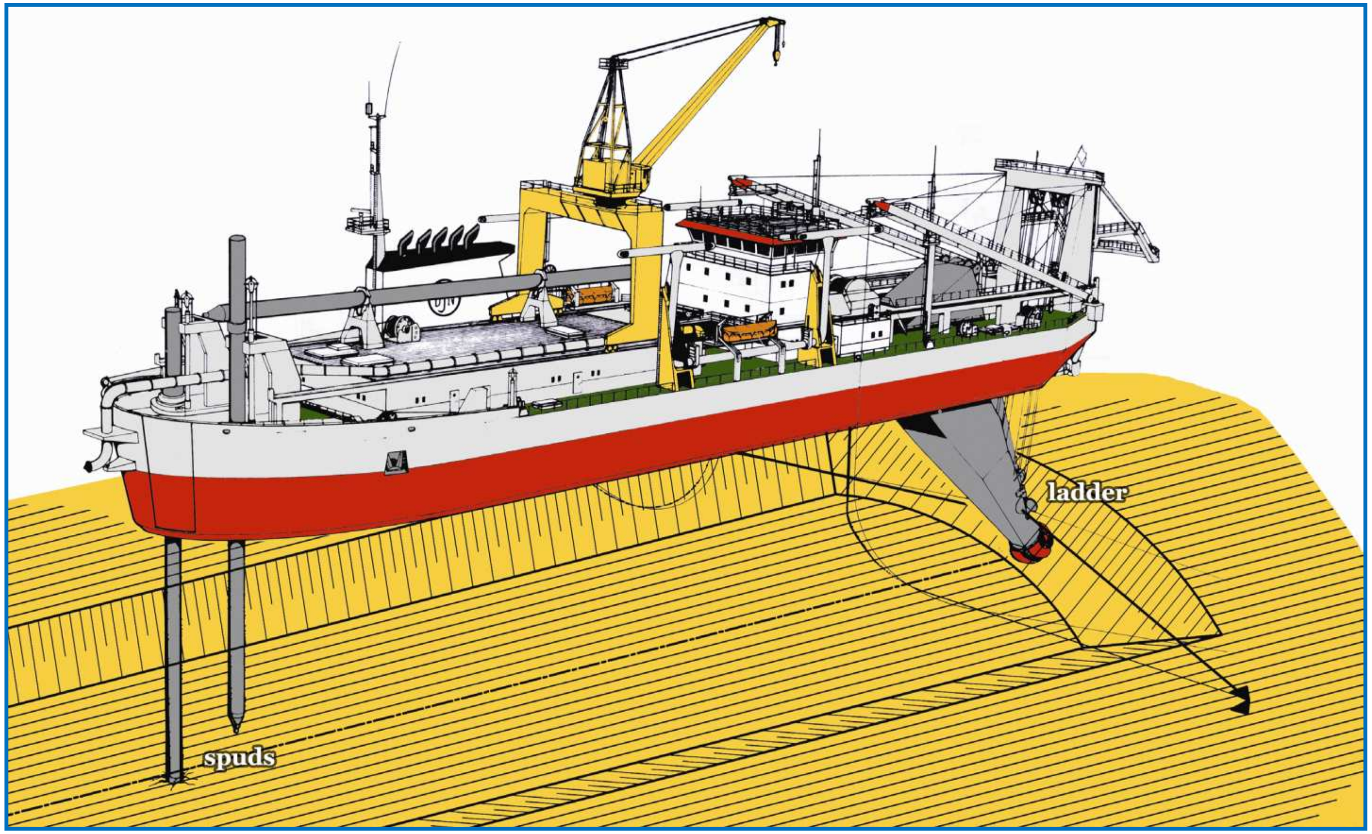
Dredging and Dredged Material Disposal

- *Avoid it if you can! If not, minimize it to extent possible*
- **Three primary equipment types, used individually or in combination**
  - **Cutter Suction Dredger (CSD)**
  - **Trailing Suction Hopper Dredger (TSHD)**
  - **Mechanical Dredge (Bucket or Backhoe)**



Cutter Suction Dredger

- Many different configurations: kW, pumps, discharge, pontoon…
- Can be designed to cut most material, incl. soft rock (~50 MPa)
- Rotating "cutterhead" agitates material; dredge swings across channel, pump slurry material via pipeline to final disposal (~70% H_2O or more)
- High production rates, limitations include sea state, pump distance

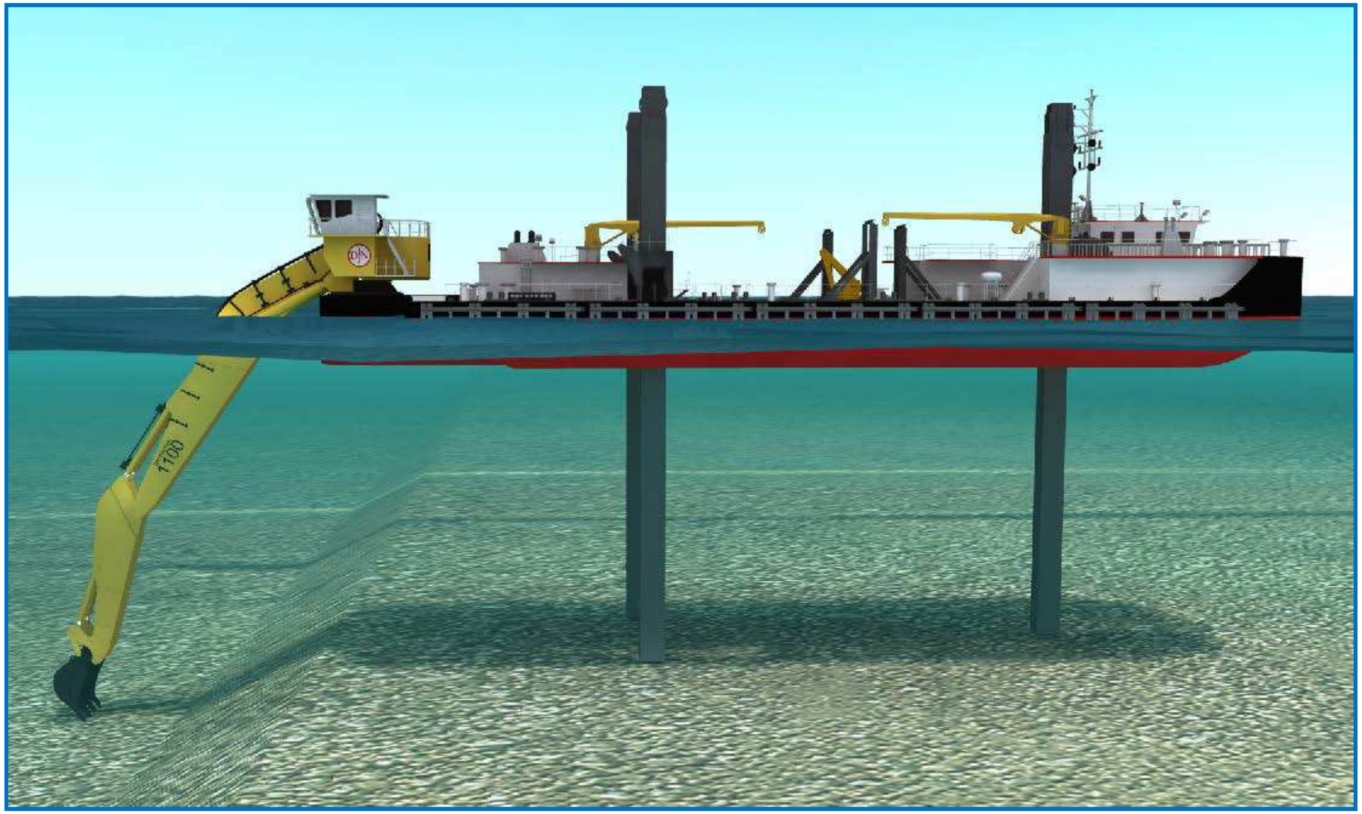


Trailing Suction Hopper Dredger

- Cuts softer/looser mud and sand; water jets/teeth for firm matl.
- Self propelled vessel; suction pipe with “draghead” lowered to seabed, material sucked from bottom and deposited in hopper
- Sizes vary <5k to 40k M^3, can work offshore, sail in “S” pattern
- High production rates, needs wide open areas and sufficient depth; production limited by transit distance to disposal site, material type

Mechanical Dredge

- Cuts many different types of materials, incl. soft/shot rock
- Fixed barge on spuds/anchors – mechanically dig material from bottom, load into barges, tow to offshore disposal
- Sizes range by crane type: Up to 50 CM bucket
- Relatively low production rates, can dredge in restricted areas



Placement/Disposal of Dredged Material

- Offshore; upland (CDF); reclamation; beneficial use (marsh, beach restoration)
- CDF is a contained area nearby channel to contain material; weirs to control water and drain facility
- Offshore & CDF most common, also reclamation
- Mechanical dredge nearly always offshore disposal; TSHD primarily offshore but many have pump-off capability; CSD nearly always upland, reclamation, beach, marsh

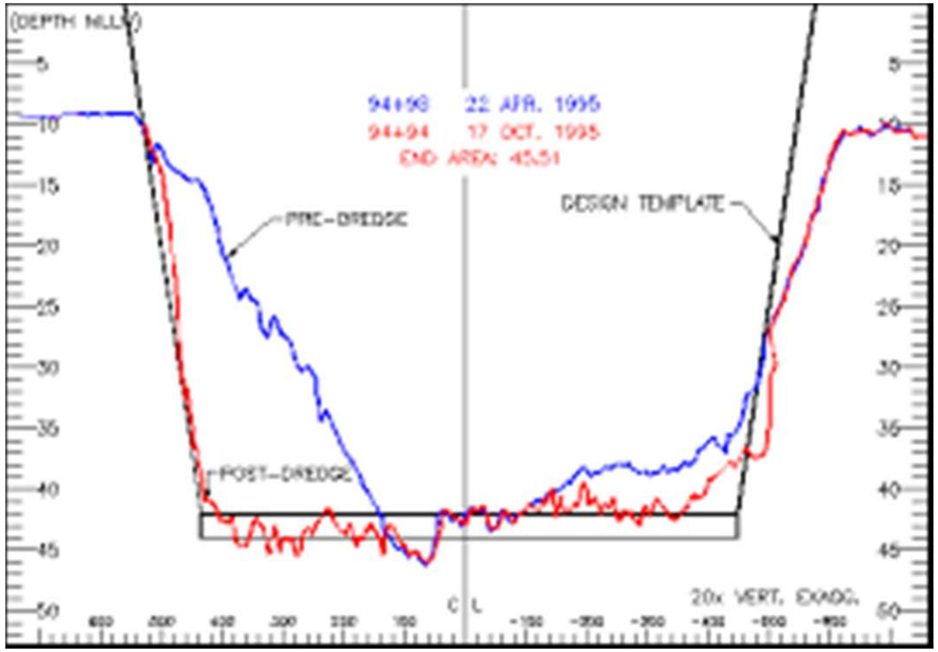
Placement/Disposal of Dredged Material

Production and Cost

- Most dredges are unique/custom designed and built
- Costs are *relatively* stable: Relatively few variable costs
- The variable is <u>production</u> - M^3/Net Operating Hour
- Efficiency is constant focus: Small increase in production = large cost and schedule savings
- Production limited by: Cutting (strength of material), area coverage, or transporting/pumping material
- Production calculated with:
  - Volume of material, size of area, average depth
  - Type and consistency of material
  - Workability (the % time dredging)
  - Other project specific factors, environmental, etc.
  - And of course the dredge's capabilities

Basic Estimating Considerations – Production

- Production: Sometimes difficult due to "custom" nature of equipment
  - Dredges of similar dimensions will not have same productions; Software available
  - Look at similar projects, historical averages, input from contractors
  - Do a "sensitivity" analysis
  - Can develop an algorithm
- Volume calculated by subtracting survey surface from template
- Calculated as M3 per net operating hour; deduct down time
  - CSD workability ~60% - 75%; TSHD workability ~75% - 90%



Basic Estimating Considerations - Cost

- Assume details of project are known and bid items determined
- Determine dredge volumes: Survey surface vs. channel template
- Determine the equipment spread required
  - Suitable dredge + attendant plant – tugs, anchor barges, etc.
  - Pipeline, valves, joints, anchors, pontoons, moorings, and so on
  - Land/Dry plant required for fill – loaders, excavators, dozers, crew, other
- Equipment costs consist of:
  - Ownership costs: Value, depreciation, interest, repair, insurance
  - Operating costs: Consumables, repair, wear parts, labor
  - Allowance for ownership, operating, factors, and utilization
  - Utilization = working months per year to recover cost (9 to 10 months)
- Other ancillary costs

CIRIA Guide to Cost Standards for Dredging is a great resource

Cost Estimate Example

- TSHD 7,600 CY capacity
- Pump 4,200 CY/NOH
- Offshore disposal 8 NM
- Material is soft clay/mud
- Load factor 30%
- Production cycle includes loading, turning, sailing, discharge
- Volume removed includes pay + unpaid
- Volume/Production = Time
- Time X Unit Cost = Total
- Add Mobilization costs (get to/from site)

EXAMPLE PROJECT SUMMARY SHEET						
HOPPER DREDGE CONCEPTUAL ESTIMATE						
MULTIPLE DREDGE AREAS						
Volumes	Grade	OD	Total			
13-OR	-	629,041	629,041			
12. 11. 9	796,605	602,918	1,399,523			
Total	796,605	1,231,959	2,028,564			
Removed	796,605	1,231,959	2,028,564	(Assume pay plus unpaid = total available)		
Assumptions:	Generic Hopper Dredge		7,600	CY Hopper Capacity (Water)		
Load Ratio (hopper to soft clay):			30%			
Mud Capacity/Hopper			2,280	CY		
Mud Production Rate			4,200	CY/NOH	(33" suction diameter)	
Production Details:						
Loading			33	Minutes		
Turning	2 each	5 min	10	Minutes		
Sail Loaded	8 mi	10 mph	48	Minutes		
Sail Light	8 mi	12 mph	40	Minutes		
Discharge/Washout			10	Minutes		
Total Cycle			141	Minutes		
			2.3	Hours		
Production (Net)			973	CY/NOH		
Efficiency (NOH)		90%	22	Hours/Day	Net Operating Hours	
Total Production/Day (Net)			21,020	CY/Day		
Cost Details:						
Daily Cost (Dredge)			$ 78,000	Per Day	All in	
Supervision/Field OH			$ 8,000	Per Day	From Dredge Estimate	
Survey Vessel			$ 1,200	Per Day	From Dredge Estimate	
Subtotal			$ 87,200	Per Day		
Markup		24.4%	$ 21,277	Per Day	(16.0% OH and 8.4% PFT)	
Total Cost/Day			$ 108,477	Per Day		
Total Cost/CY			$ 5.16			
Mob/Demob	4	Days	$ 108,477	$ 433,907		
Dredge Cost	2,028,564	CY	$ 5.16	$ 10,468,460		
TOTAL COST, HOPPER DREDGE:				**$ 10,902,367**		

Managing Risk: Contractual and Operational

- **Many projects are part of EPC; dredger is a subcontractor**
- **Contract form: FIDIC or equal, T&Cs generally understood; modifications for specific items**
- **Simple projects - IFB (lowest price, responsive contractor)**
- **Contractual Risk Items – Technical Specifications:**
  - **Scope of work not clearly defined/customized to project**
  - **Bid items and/or schedule of prices**
  - **Insufficient/inadequate field investigations (i.e. rock)**
  - **Contractor lacks proper experience, equipment, staff**
  - **Pricing – LS vs. Unit Price (prefer UP for complex projects)**
  - **Environmental risks not adequately accounted for**
  - **Others depending on project**

Consulting engineer must be experienced with all aspects of work

Managing Risk: Contractual and Operational

- Complex projects should be RFP (best value)
  - Prequalification: Contractors with proven equipment, experience, staff, resources, financial, etc.
  - Detailed scope of work – Take a bit of risk to reduce costs
- Key items in the RFP:
  - Equipment spread and specifications
  - Dedicated PM and key staff qualifications
  - Detailed project experience, references, safety record, etc.
  - Detailed Project approach
  - Detailed work plan, environmental protection, contingency
  - Logistics plan (if applicable)
  - Detailed bid tab, delineated by risk items, break in work

Significant thought, preparation, and attention to detail pays off – only as good as the Specifications

Managing Risk: Contractual and Operational

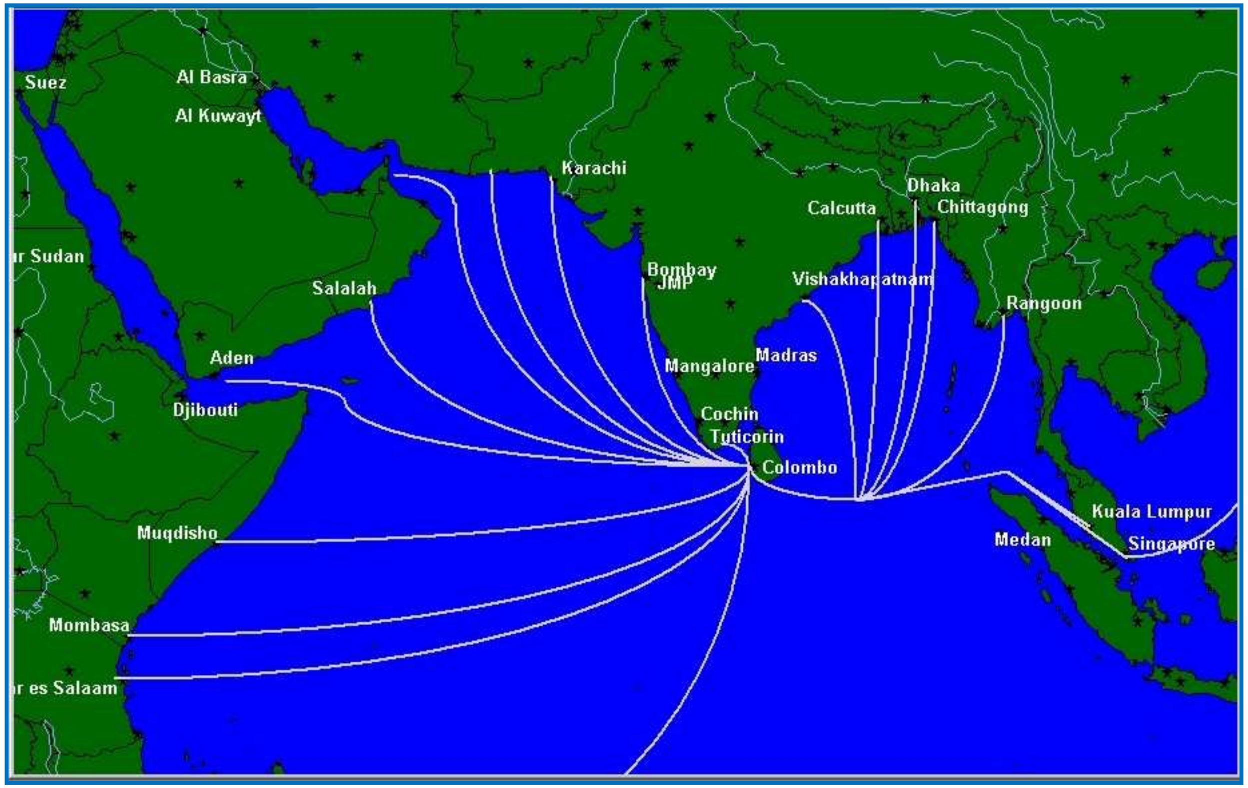
- Operational risks often due to environmental restrictions
  - Contaminated sediment
  - Turbidity – Miami River example
  - Stress/destroy coral reefs, vegetation
  - Nesting seasons
  - Injure/kill protected species
  - Work “windows” that drastically reduce schedule (Pacific NW)
  - Public perception/opposition
  - Government/political issues
- Substantial production issues/differing site conditions (i.e. rock)
- Persistent equipment problems/inadequate equipment, under-qualified management and/or staff
- Safety issues/injury/fatality
- Delays starting/mobilizing
- Schedule risk (weather, accidents/repairs to equipment)

Managing Risk

- Exhaustive, detailed up-front work/Pre-FEED/FEED
- Detailed, well thought out scope of work, best-value RFP for complex projects
- Vet/prequalify contractors thoroughly
  - Many are clearly qualified – GLDD, Jan de Nul, Boskalis, etc.
  - Is proper team in place? Experience working with contractor?
  - Early Contractor Involvement is often a great idea
- Early Contractor Involvement: Part of planning and design
  - Can offer ideas that fast-track project and reduce risk
  - Can verify design and construction means
  - Become stakeholder, responsible; develop risk analysis at all stages
  - Can be a competition through conceptual/early design, budgetary cost

Relevant Project Examples

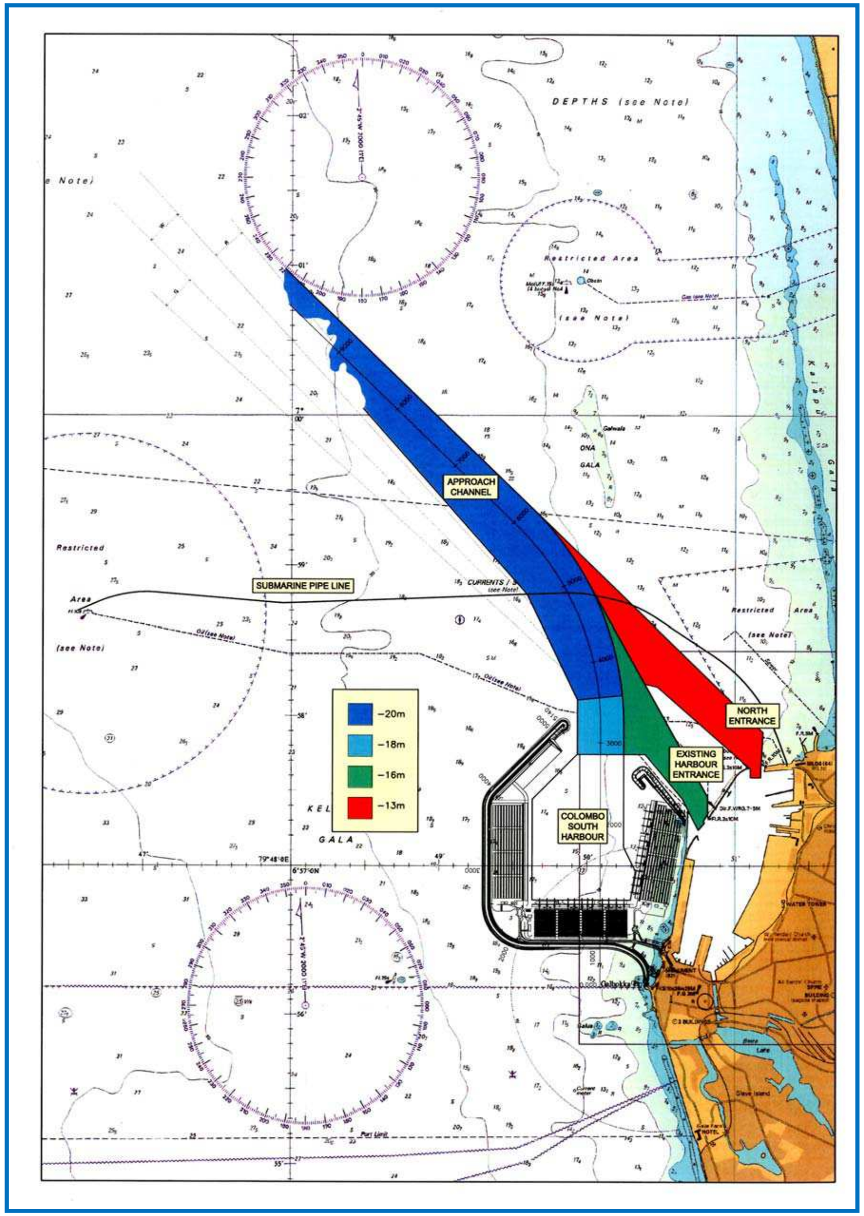
Example: Port of Columbo, Sri Lanka



- AECOM developed design for expansion of this major transshipment port
- Included 6 km of breakwater and a new two-way approach channel
- Design to accommodate deep draft (16m) container vessels + future demand

Example: Port of Columbo, Sri Lanka

- **New Approach Channel (blue); North Entrance (red); Existing Harbor Entrance (green)**
- **Existing entrance relatively narrow, sharp turn**
- **Poorly sheltered during SW monsoon**
- **Increasing ship traffic in existing port**
- **Design Vessel: 400 m length; 55 m beam; 16 m draft**
- **Petroleum pipeline crosses channel limit**
- **Dredge material needed for reclamation**
- **New ATON**

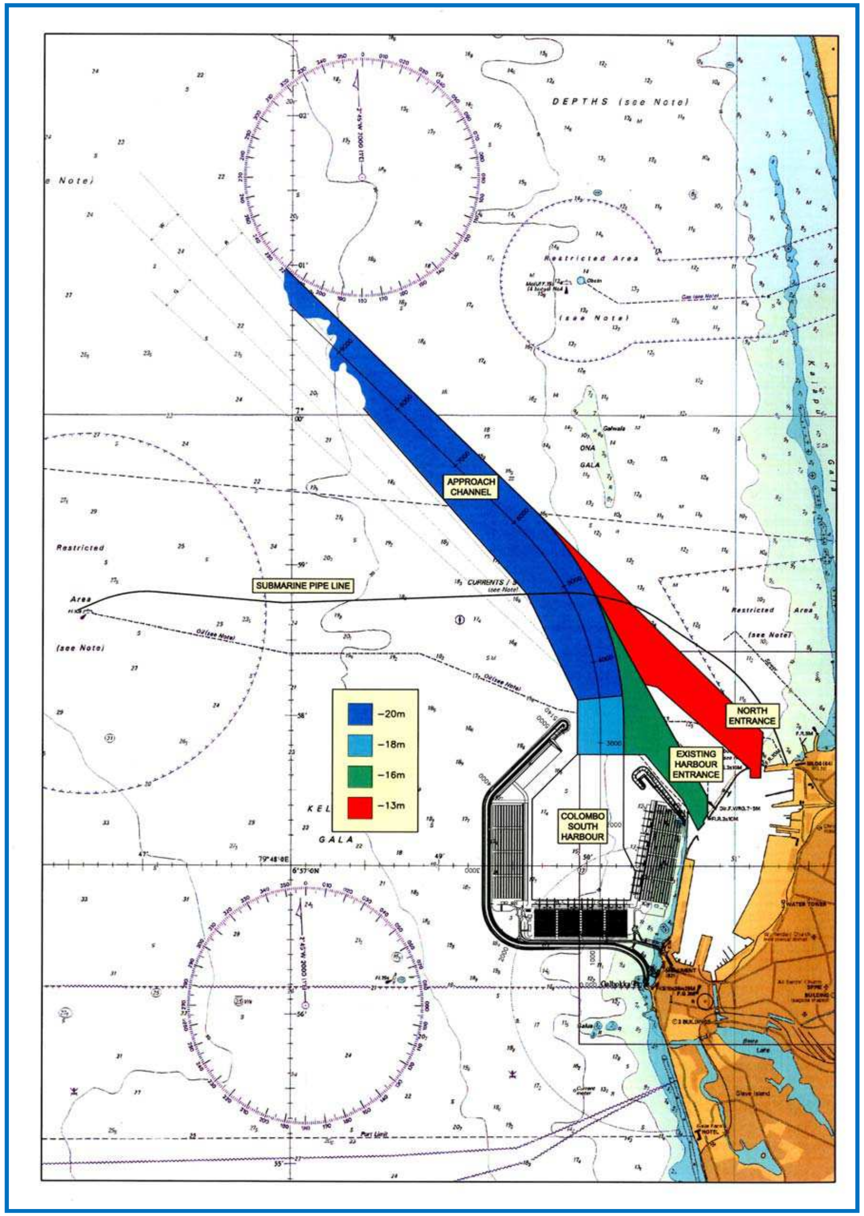


Example: Port of Columbo, Sri Lanka

- **SE approach chosen to avoid sharp bend and clearance to petrol SPM**
- **Dredge material suitable for reclamation**
- **Offshore wave environment = 1.25 factor for depth: 1.25 X 16m = 20m**
- **Breakwater required due to seas; seasonal wave climate developed**

Table 1: Seasonal Wave Climate near Breakwater

Hs (Swell) (m)	% of Period (Swell/Sea)			
	Oct-Nov	Dec-Feb	Mar-April	May-Sept
Up to 0.6	46/ 38	83/ 69	82/ 63	8/ 3
0.6 - 1.0	52/ 30	14/ 23	18/ 19	39/ 32
1.0-1.2	2/ 26	2/ 7	-/ 9	19/ 31
1.2-1.4	-/ 7	1/ 2	-/ 4	14/ 18
1.4-1.6	-/ -	-/ -	-/ 4	17/ 10
1.6-1.8	-/ -	-/ -	-/ 2	2/ 3
1.8-2.0	-/ -	-/ -	-/ -	2/ 2
Over 2.0	-/ -	-/ -	-/ -	1/ 1

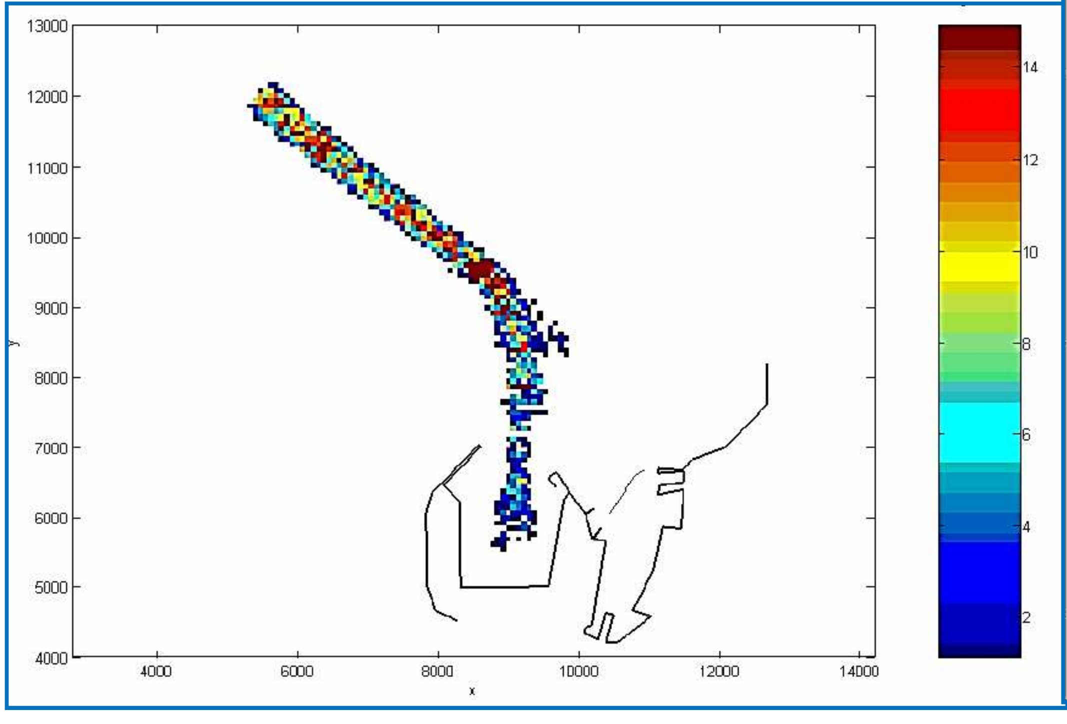


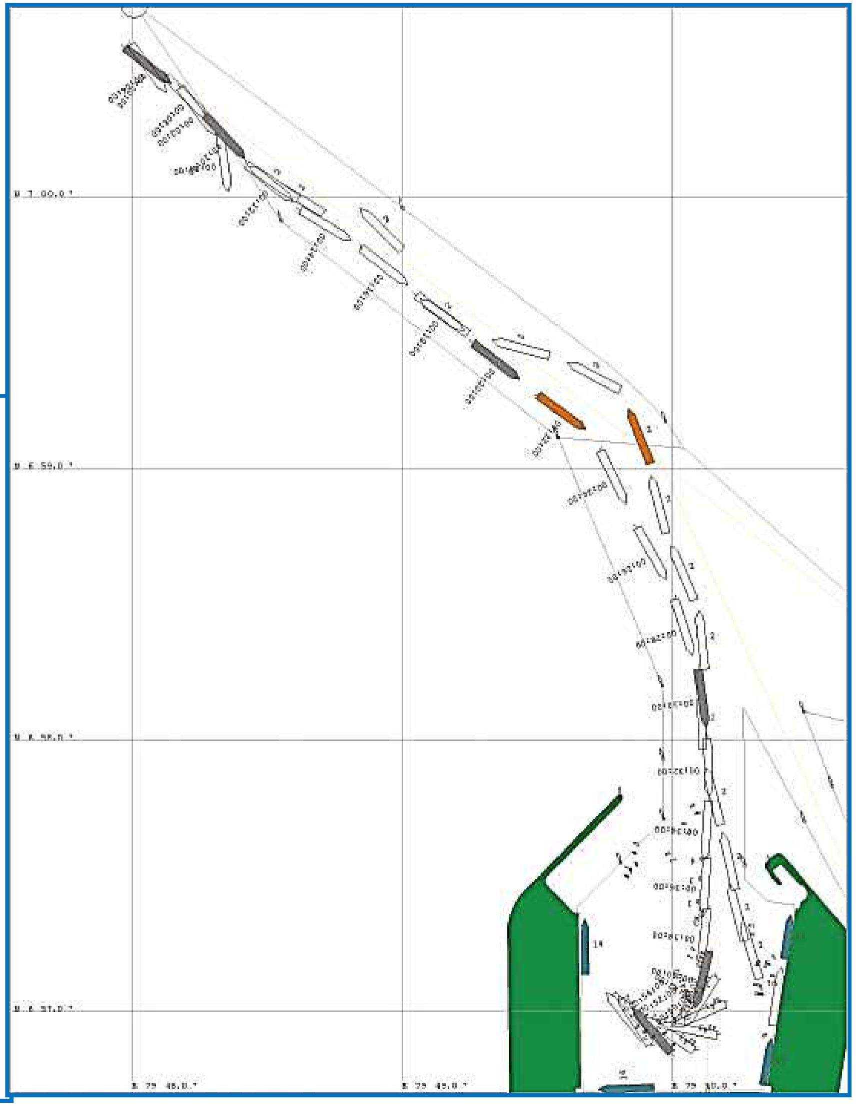
Example: Port of Columbo, Sri Lanka

- PIANC Guidelines used for channel design
- Vessel speed of 10 knots = squat between 0.5 to 0.8m; wave induced motion ~1m; heave, pitch/roll, tide range, bottom type, maintenance dredging, water density considered.
- Final calculation resulted in -19.2 m channel offshore, rounded to -20m; reduced to -18m inside
- Two way channel; width calculated at 10.4 X vessel beam = 570 m width
- Bend radius calculated at 3,400m; increased channel width to 790m at bend
- Turning circle 1.5 times vessel length + clearances = 820m minimum; actual basin 1,300m X 1,500m for safety factor
- Channel modeled for navigation safety and marine traffic

Example: Port of Columbo, Sri Lanka

- **Model results – Encounter densities (below) and plot of arriving/departing vessels (right)**





Example: Port of Columbo, Sri Lanka

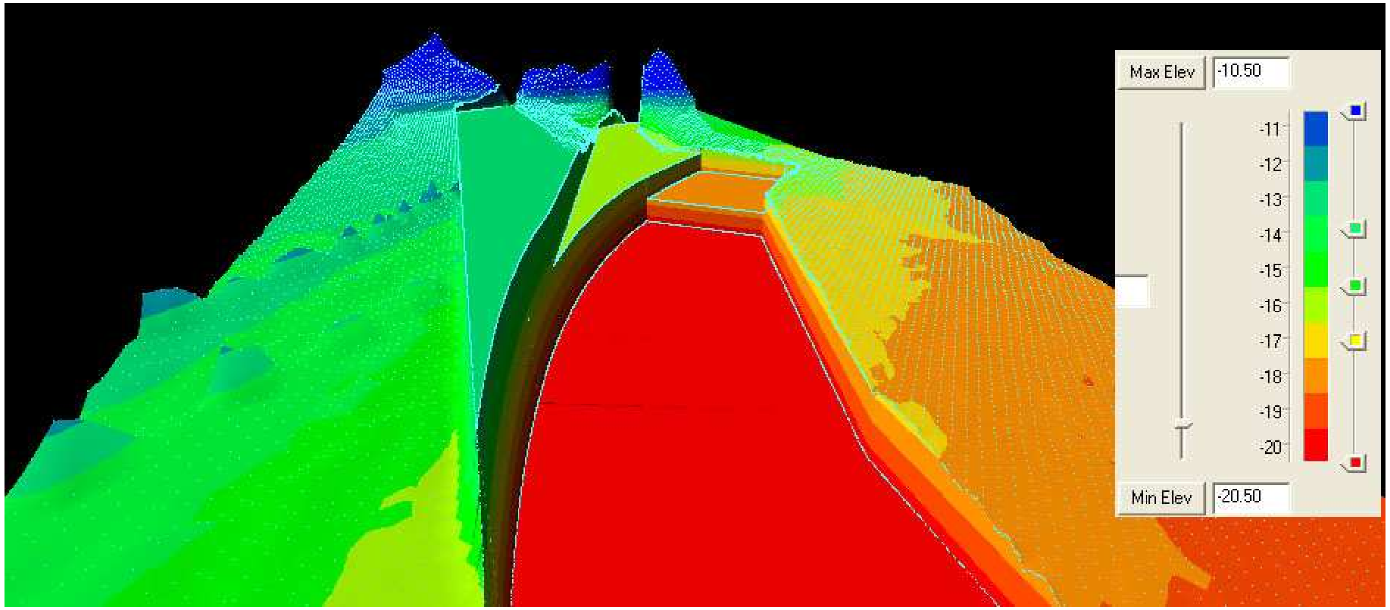
- **Dredging volume 15m M3 initially, small infill of 100,000 M3 per year**
- **CSD and TSHD evaluated, TSHD used for dredging and reclamation because of high workability**

Table 3: Dredger Workability as a % of Period

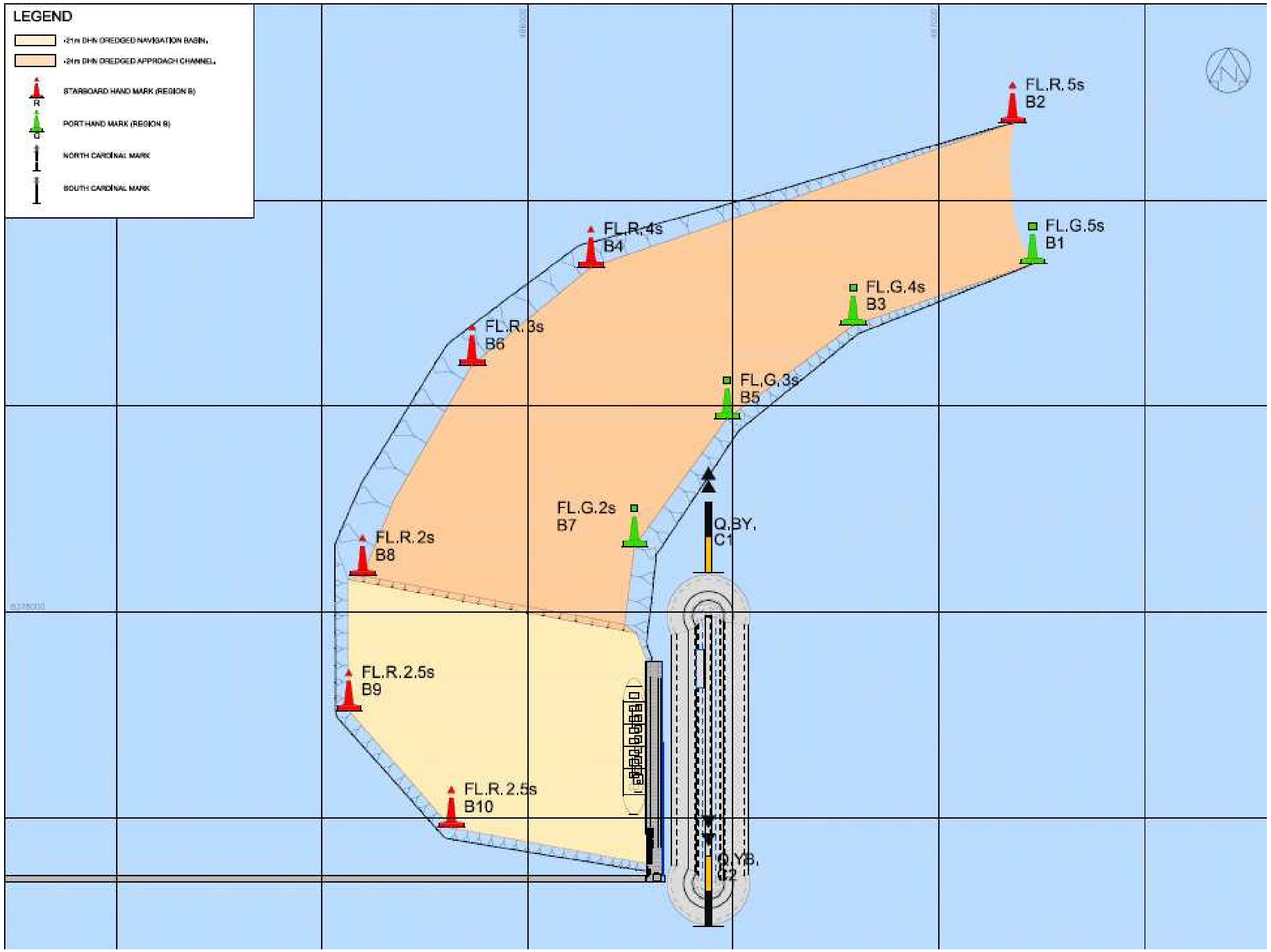
Dredger	Workability % of Period			
	Oct-Nov	Dec-Feb	Mar-April	May-Sept
Large CSD	66	88	63	11
8,000 m3 TSHD	100	100	100	86.5
5,000 m3 TSHD	96	98	90	48

Table 4: Estimated Weekly Production Rates

Dredger Size (m3)	Bottom Discharge (m3/wk)		Pump or Rainbow Ashore (m3/wk)	
	In situ	In Reclamation	In situ	In Reclamation
6,500	340,000	290,000	228,000	195,000
8,000	494,000	411,000	320,000	267,000



Example: Pedra de Ferro Terminal, Brazil



Final Layout

Thank You

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