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Site Selection of Levee-Type Fish Production Ponds

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Assessing the potential of an aquaculture operation is a complex process. It requires the systematic evaluation of marketing potential, capital risk, and personal commitment to the project. Only after this is done should a potential production site be considered (see SRAC Publication 441, "Aquaculture: Realities and Potentials When Getting Started").

This publication can help in assessing a site's potential for the construction of levee ponds, which includes evaluating physical resources and legal and regulatory issues. Unless any potential problems identified in the process can be mitigated or avoided through cost-effective methods, the site should be rejected. (Also see SRAC Publications 101, "Construction of Levee-Type Ponds for Fish Production," and 102, "Watershed Fish Production Ponds: Site Selection and Construction.")

The primary sources of information needed to conduct the site evaluation are various government agencies or private businesses (Table 1). Contact these groups early in the process. A good place to start is with the Extension Aquaculture/Fisheries Specialist at the land grant university in your state. Consulting services for site selection, pond construction, and water drilling are also excellent sources of assistance.

Water sources

One of the first things to do in selecting a site for aquaculture ponds is to make sure that you have an adequate supply of suitable quality water. The amount of water required depends on the species to be cultured, the culture method, the soil type, climatic conditions (particularly precipitation and evaporation), and the size of the operation.

Groundwater is the preferred water source for levee ponds. It provides a dependable supply of water with a stable temperature and is less likely than surface water to

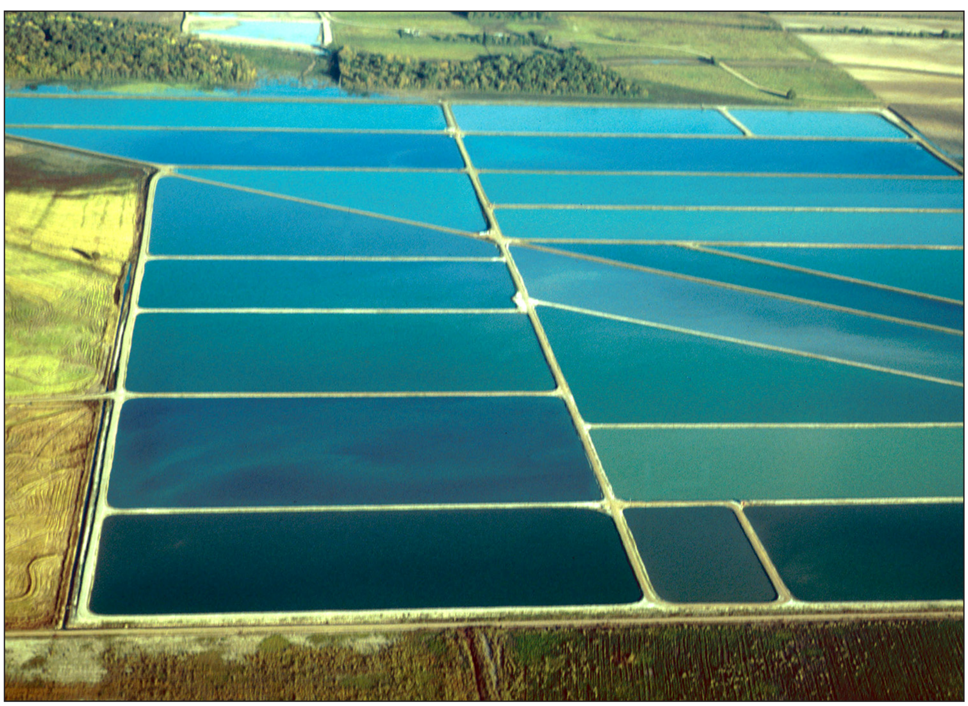

Figure 1. Aerial view of levee ponds.

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be contaminated with wild fish, waste products, or pesticides. The well depth, potential yield, and the geology of the water-bearing formation determine well construction and pumping costs, so shallow aquifers less than 250 feet (76 m) deep are preferred. Talk with local water-well drilling companies, state water resource agencies, or local fish producers to assess water availability and water quality. If insufficient information is available, it may be necessary to drill a test well. Personnel in the county office of the USDA Natural Resources Conservation Service (NRCS) or water management district office should be able to supply information about permit procedures.

Table 1. Resources for assessing aquaculture development.

Issue	Source
Water sources	USDA Natural Resources Conservation Service U.S. Geological Survey Local water management district Cooperative Extension Service Local well drillers
Soil characteristics	USDA Natural Resources Conservation Service U.S. Geological Survey Cooperative Extension Service
Topography	U.S. Geological Survey Local earth-moving contractors
Wetlands	U.S. Army Corps of Engineers USDA Natural Resources Conservation Service
Climate	U.S. National Weather Service State climatologist
Contaminants	State departments of environmental quality U.S. Environmental Protection Agency Local water management districts
Predators	USDA/APHIS Wildlife Services

The water from free-flowing springs can be a suitable groundwater supply if it can be captured at or very near the source. It is important to determine the spring's flow rate to adequately assess the size of operation it can supply. After the pond is filled, subsequent flow should be diverted so that solar radiation can increase water temperature and so that fertilizers, phytoplankton, or natural food sources will not be diluted. The diversion system (open ditch or pipe) will require an adequate amount of space and should be considered when evaluating the site. Before you decide to use spring waters, assess the potential impact on downstream environments and the legal rights of downstream water users.

Surface water sources include streams, rivers, lakes and reservoirs. Surface waters are less desirable than groundwater because they may not provide a constant supply all year and may contain pollutants. The water quality of surface waters can vary widely, especially during droughts or floods. Wild fish in surface waters can contaminate cultured stocks, compete for food, and serve as vectors for infectious diseases. If surface waters must be used, the water should be filtered or screened, though screens are not practical for debris-laden waters or where large quantities of water must be filtered. Large streams should not be diverted to supply aquaculture ponds because of the problems this could cause downstream. Seek a regulatory opinion concerning the legal implications of diverting surface water sources.

There must be sufficient water volume to fill ponds quickly and to replace losses from evaporation and seepage. Ideally, a producer should be able to fill a pond within 14 days to prevent production delays and weed growth. A standard recommendation is to have a water source capable of delivering about 25 gallons/minute/acre (250 L/minute/hectare). Table

Figure 2. Well water source.

Table 2. Time required to pump different volumes of water (in acre feet) at four different pumping rates.				
	Volume in acre feet[1]			
	1	5	10	502
Pumping rate	Hours			
500 gpm	10.9	54.3	108.6	543 (22 .6)[3]
1,000 gpm	5.4	27.0	54.3	270 (11.3)[3]
2,000 gpm	2.7	13.5	27.2	135 (5.6)[3]
3,000 gpm	1.8	9.0	18.1	90 (3.8)[3]

[1] 1 acre foot (1 surface acre that is 1 foot deep) = 325,850 gallons
[2] The number of acre feet of water in a pond with 10 surface acres and an average depth of 5 feet
[3] Number of days required to pump that volume of water

2 shows the time required to pump different volumes of water at different pumping rates.

The primary factors in assessing water quality will be the requirements of the cultured species. Once the absence of contaminants has been ensured, salinity is probably the most important consideration. Marine species have salinity requirements that may vary with the life stage cultured. Most pond aquaculture of marine species uses brackish water or seawater from surface sources, so all of the mineral requirements are met. Most freshwater fish are raised in water with less than 0.5 ppt salinity, although some freshwater species grow well at salinities up to 7 to 8 ppt.

For groundwater sources, most of the other important characteristics will change after the water is pumped to the surface and impounded. Water temperatures will be influenced by ambient air temperature and solar radiation. When exposed to air, dissolved oxygen and carbon dioxide will approach equilibrium with the partial pressures of these gases in the atmosphere. Dissolved ferrous iron will precipitate as ferric oxides after exposure to rising pH and dissolved oxygen. Hydrogen sulfide will be degassed or oxidized to harmless sulfate after exposure to oxygen. Total alkalinity and total hardness will reach equilibrium after exposure to mineral rich soils. If a soil test reveals low mineral content, agricultural limestone may be added to the pond bottom before filling the pond (see SRAC Publication 4100, "Liming Ponds for Aquaculture").

If surface waters are used, there will be little change in water quality after impoundment. Surface waters that are consistently turbid will introduce suspended soil particles or other solids that, if not settled, could interfere with biological processes in the pond. Low pH water coming from acid-sulfate soils or active mining sites should not be used.

Soil characteristics

Soil is used to construct levees and keep water in the pond. Ponds built with unsuitable soils will have levee erosion and excessive seepage, requiring more water to compensate for losses.

Soil texture is the most important physical characteristic related to pond construction. Texture depends on the sizes and shapes of soil particles and the distribution of those particles. Soils contain coarse-grained particles (gravel and sand), fine-grained particles (silts and clays), organic matter, and water. A good soil for compaction has a wide range of particle sizes. A clay content of 15 to 20 percent is preferred, although soils with 5 to 10 percent clay can be used if well graded. Coarse-textured sands and sand-gravel mixtures are unsuitable. The amount of water in fine-grained soils determines how workable these soils are. Soils with too much water should be allowed to dry before levee construction. Conversely, soils that are too dry may need water added to aid compaction.

Seepage is the amount of water that exits the pond through the soil either at the bottom of the pond or through the levees. To prevent seepage, the pond must contain an impervious base layer that is 12 to 18 inches (30 to 45 cm) thick across the pond area. Other soil characteristics that influence seepage include the amount of organic matter in the soil and the depth to the hardpan. The amount of water needed to maintain water levels in ponds with different seepage rates is illustrated in Table 3. These water requirements are based on evaporation

Table 3. Water required (inches/year) to maintain levels in ponds with different seepage rates at various locations in the United States.				
	Seepage rates (inches/day)			
Location	0.05	0.1	0.3	0.5
Tallhasse, Fla.	1	19	92	165
Augusta, Ga.	20	38	111	184
Raleigh, N.C.	20	38	111	184
Columbia, S.C.	17	35	108	181
Knoxville, Tenn.	12	30	103	176
Auburn, Ala.	7	25	98	171
Stoneville, Miss.	15	33	106	179
Little Rock, Ark.	17	35	108	181
Baton Rouge, La.	13	31	104	177
Houston, Tex.	25	43	116	189
Wichita Falls, Tex.	55	73	146	219
Bakersfield, Calif.	81	99	172	245
Sacramento, Calif.	58	76	149	222

Source: Adapted from Boyd (1986).

and rainfall for the various locations and assume that all rainfall is captured and no overflow occurs.

Soil texture, water content, and other soil properties should be evaluated to the maximum depth of excavation. Knowing soil characteristics over the entire site can be useful in determining whether particular areas need special attention or should be excluded. If soil conditions vary across the site, delineate the construction area and take core samples to the necessary depths along a 55-yard (50-m) grid. Three or four borings per acre may be sufficient if the soils are uniform. Composite samples for analysis should be taken from the surface, mid-depth, and bottom of the cores. Ponds with sandy areas can be sealed with clay or with pond liners, although such measures can be expensive (see SRAC Publication 105, "Renovating Leaky Ponds").

Figure 3. Bulldozer constructing levees.

Topography

One goal in selecting a site is to impound the largest amount of water with the least amount of earth moved. Levee ponds are most efficiently built by using soil from the pond bottom to simultaneously build levees. In areas that are extremely flat (less that 1 percent slope), the pond bottom will be below the original ground surface, which may not allow the pond to drain entirely. On sites with average slopes of 2 to 5 percent, earth-moving cost can be minimized and ponds can be drained by gravity flow. Levee ponds built on low-gradient slope sites usually require about 1,100 to 1,200 cubic yards of dirt to be moved per acre (2,078 to 2,266 m^3/ha), although the actual amount of dirt that must be moved can vary greatly.

Wetlands

Wetlands are areas that are normally inundated or saturated by surface or ground water and that usually support vegetation adapted for saturated soil conditions. Examples of wetlands are swamps, marshes, bogs and similar areas. Although the availability of water and the relatively flat topography of wetlands make them attractive sites for ponds, wetland soils often have a high organic matter content (more than 10 percent). Organic soils begin to decompose when exposed to air, making them unsuitable for constructing stable levees. Wetland soils are difficult to work with machinery, difficult to compact, difficult to drain and dry, and have a low load-bearing capacity. Wetlands are, by nature, susceptible to seasonal flooding from heavy rainfall or severe storms.

Some wetlands have acid-sulfate soils, which may be highly acidic when dry. Acid-sulfate soils can be used in aquaculture, but will need large amounts of lime to control low pH, which will be a continuing and expensive effort. Soils with more than 0.75 percent sulfur should be avoided.

Any clearing of vegetation or movement of soil in a wetland requires a permit from the United States Army Corps of Engineers. In some states, additional permits may be needed from one or more state agencies. Even if approval is granted, the process can be costly and time consuming.

Climate

Climatological records for the proposed site should be evaluated to determine average precipitation and the likelihood of floods, droughts, and severe storms—all of which can cause problems.

Sites for fish ponds should make good use of available rainfall whether groundwater or surface water is used. Monthly and annual rainfall averages, minimum and maximum precipitation, and evaporation rates should be determined for each site to estimate water losses and gains.

Absolute values as well as year-to-year variations should be assessed. When rainfall storage capacity is maximized, the costs associated with pumping replacement water can be minimized. Evaporation rates, rainfall amounts, and seepage losses (Table 3) determine the amount of supplemental water needed to maintain pond levels.

Unfortunately, sites with ideal slopes for aquaculture ponds (2 to 5 percent slope) are often located in floodplains or valley floors that are subject to periodic flooding. Flooding of ponds can result in loss of cultured animals, contamination with wild aquatic animals, mixing of poor quality flood water with pond water, and damage to levees. The NRCS can provide information on historic flood levels and how often they occur, how to avoid sites in flood-prone areas, and how to minimize the flooding of adjacent lands when ponds are constructed. Look for sites that flood no more than five times in 100 years. Exterior (or perimeter) pond levees and drain pipes should be 20 inches (50 cm) above the historic high flood level when compared to interior levees. This allows the facility to be isolated from rising floodwaters.

Droughts can have a significant effect on production, especially where surface waters are used. Sites where losses from evaporation and seepage cannot be replaced by available water resources should be avoided. If pond water volumes cannot be replenished, water quality can deteriorate. This may cause cultured animals to feed less, which can delay harvest and increase mortality. Increasing a pond's storage capacity may help prevent drought problems, but may be cost prohibitive and cause production problems associated with excessive water depth in non-drought years.

Severe storms can create prolonged power outages, limit access to facilities, and cause production problems. Severe storms and hurricanes can be commonplace along the Gulf of Mexico and Atlantic coasts. The Texas coastline is struck by more than one hurricane every 2 years. Rainfall records can be used to estimate the maximum amounts of rainfall such events may bring (see U.S. Weather Bureau Technical Paper 40). Ponds located in these areas should be designed and constructed with levees high enough to avoid overtopping by unusually high tides, storm surges, and floods. Higher levees mean that surface water will have to be lifted several feet for transfer to canals and ponds, which increases energy use and pumping costs. Thus, the best coastal sites for ponds are flat areas that are above the highest tide level.

Figure 4. Dirt pan equipment.

Contaminated soils or water sources

Most agricultural lands have been treated with pesticides. However, most of these lands and water sources are not considered contaminated. Today's pesticides have a much shorter half-life in the environment and are considered safer than earlier pesticides.

Chlorinated hydrocarbon insecticides such as toxaphene, dieldrin and endrin were widely used in agricultural production before 1975. The recommended maximum concentration of toxaphene in soils to be used in aquaculture is 0.5 ppm. The combined concentrations of dieldrin and endrin should not exceed 0.1 ppm. These are general guidelines and have no regulatory status.

When selecting a site for aquaculture, the main concern is soils in low areas where runoff collects, sites previously used for pesticide storage or disposal, and areas where aerial or ground application equipment was loaded or washed. These areas should be tested for residual pesticides because contaminants in the soil could affect biological processes within the pond or be discharged with effluents. Typically, contaminants accumulate in the top 6 inches (15 cm) of topsoil, so samples should be confined to this depth. Pesticide analysis can be conducted by private or state chemical laboratories. If contaminants are found, the affected soil layer should be removed from the site or used in areas that will not come in contact with pond water (e.g., levee cores, building pads, or access ramps).

Sites in rural areas have a lower risk of contamination than those in urban areas. Effluents from urban wastewater treatment plants and industrial facilities can contaminate surface waters, and seepage from hazardous waste holding ponds at industrial facilities can contaminate groundwater sources.

Access

Ponds must be accessed year-round. Roads and ramps to levee tops must allow vehicular traffic for equipment maintenance, water quality monitoring, feeding, and harvesting. Large-volume facilities must be accessible with multi-axle vehicles, so roadways and levee tops must be wide enough to accommodate these loads.

Access to electrical service must also be considered. Most electric companies will provide only a limited number of poles and a limited amount of power line from existing infrastructure before additional charges begin. The farther the site is from existing power lines, the more expensive the project will be. If wells will be powered by electric motors, or if aerators larger than 1 horsepower will be used, three-phase electricity may be required. This may eliminate some potential sites because single-phase is the predominant electric source in rural settings.

Consider the potential effects of any rights-of-way for power lines, gas pipelines, or railroads that cross the property. Utility rights-of-way are usually sprayed routinely with herbicides to control vegetation. Maintenance for gas pipelines could require the draining of ponds. Power lines should be high enough that they are not hazardous for loading equipment or feed truck deliveries. Railroad crossings could lead to equipment/train collisions or limit access to ponds during long train passages.

In the site selection process, it is important to allocate land and resources for ancillary facilities such as hatcheries, headquarters, shop, storage, and housing for employees. If the production system is successful, the owner may seek to expand the operation. Will there be access to adjoining or nearby sites for this expansion? Expansion of a facility across sites distantly removed from a centralized location can lead to management concerns and additional transportation costs.

Environmental concerns

Several state or federal agencies may have jurisdiction over land use and pond construction. Contact the local NRCS office for guidance. Additional site review may be required by the U.S. Army Corps of Engineers, which administers and enforces provisions of Section 404 of the Clean Water Act. Section 404 regulates, among other things, the conversion of wetlands to farming, including aquaculture ponds. In some areas, land-use zoning may preclude agriculture in general or aquaculture in particular.

Consider how pond construction and operation may disrupt activities and resources downstream. Construction of facilities and access roads could alter the natural water flows needed to maintain surrounding habitats and downstream environments such as wetlands and groundwater aquifers. Construction of ponds can lessen or increase the potential for flooding by altering the natural hydrology of the watershed, depending on the size (i.e., storage volume) and position of the ponds and drainage patterns.

Also consider how aquacultural effluents might affect receiving waters, and whether you will need to retain these effluents in constructed drainage systems before discharge. Discuss the frequency of discharge and allowable discharge limits with environmental resource agency personnel.

Avian predators can cause significant losses and spread diseases. Contact your USDA/APHIS Wildlife Services office for information on known rookeries or feeding areas of predatory birds near the potential site. Avian predation may be mitigated to some extent by grouping ponds with vulnerable life stages near areas with lots of human activity. For more information on avian predators, see SRAC Publication 400, "Avian Predators at Aquaculture Facilities in the Southern United States."

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USDA United States Department of Agriculture | National Institute of Food and Agriculture

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