



Building confidence in **Billund Aquaculture RAS**

BILLUND AQUACULTURE

Founded in 1986, Billund Aquaculture has more than 35 years of experience in the dimensioning, design, assembly, installation, servicing, and operation of land-based aquaculture systems based on intensive recirculation technology.

With more than 330 employees worldwide and subsidiaries in Australia, Chile, Norway and the USA, Billund Aquaculture with headquarters in Denmark is at the forefront of the world leading Recirculation Aquaculture System (RAS) suppliers.

Totally, the group has designed and implemented more than 150 projects (more than 500 separate RAS modules) in 30 different countries and for more than 30 different freshwater and marine species. With a market share of approx. 22 % of the worldwide Smolt market, 35% of the Post-Smolt market and more than half of all commercial scale Salmon Grow-Out facilities (> 500 tons/ a) worldwide installed, the annual turnover of the group is 90 % related to the salmon industry.

Main principles to secure successful results in planning, construction, and operation.

When Billund Aquaculture design and engineer a RAS facility and associated support functions, the following main considerations are applied:

1. Production Plan/ Dimensioning Criteria

Before entering a contract, it is significant for both parties to agree to a realistic, reliable, and achievable Production Plan. Typically, Billund Aquaculture would suggest choosing conservative and safe figures for e.g., fish densities, growth rates, feed conversion rates as well as mortality rates in line with documented performance data from either e.g., feed or breeding companies or the management's extensive industry experience. It is further important to determine the final size of the product and whether the operation will be staggered or e.g., based upon a batch-in/ batch-out plan.

Once the Production Plan is set out, the development of the Dimension Criteria will allow the preliminary biological engineering of the RAS module(s). The criteria for the biological engineering must be generous enough to allow for deviations in feed load and feed quality and provide a buffer for operational convenience. As such, safety margins in the design of the water treatment system can aid to prevent fish loss in case of unplanned events, or potentially utilize further improvement in feed quality, fish genetics and general performance of the RAS (e.g., quicker production or increased biomass/production volume). Safety margins above the production requirements can be tailored to specific needs and Billund Aquaculture can advise their clients on CAPEX and OPEX requirements.

2. Operation of the facility

Accessing RAS-experienced staff can be challenging in certain areas of the world and generally due to the increasing demand in recent years. It is therefore important to assess the requirements for the mode of operation of a project, before designing it. Automation and Digitalisation are vital elements to reduce staff and can aid avoiding the risk of operational bottlenecks caused by staff-shortage. Generally, RAS need to be easy to operate and maintenance of the equipment must be minimized, but the balance between CAPEX and OPEX can and must be customized for each project and client. In any case, automation does not replace the need for skilled management and staff with the ability to plan and control both an optimal production, and an efficient and safe operation.

3. Biosecurity

Avoiding disease outbreak is mostly about controlling the level of pathogens. A successful bio secure design will depend on four main factors:

1. Sanitary status of eggs to be used as primary biological source.

2. Water sources and water treatment system design.
3. Architectural design of the facility, considering the different processes taking place in the daily operation.
4. Water Quality Management.

4. Water Quality

Billund Aquaculture RAS are well-known for the best water quality in the industry. After almost a decade of experience with Salmon Grow-Out system, the need for outstanding water quality especially in respect to the levels of Carbon Dioxide (CO₂) and suspended solids (SS) is identified as crucial parameter for adult salmon. Therefore, all Billund Aquaculture Grow-Out RAS are designed to achieve the best water quality parameters. These parameters are crucial part of the dimensioning criteria agreement and guaranteed through the “Biological Performance Warranty”.

5. Biological Filtration:

Billund Aquaculture’s biological filtration technology masters both FBBR and MBBR, though the design for Grow-Out is mainly based on FBBR technology, which has been successfully utilized in large-scale commercial marine and freshwater applications. This technology has been under constant development for more than three decades, focussing on improved biofiltration efficiency and hydraulics (laminar flow), removal of very fine suspended solids and sedimentation prevention within the filter through engineering solutions. Over the most recent five to ten years, the land-based fish farming industry has generally shifted from medium size facilities (< 1000 tons production) to large scale projects (several thousand tons production per year). Simultaneously, the share of marine systems compared to freshwater based RAS has significantly increased, due to the Atlantic Salmon Post-Smolt and Grow-Out sector.

6. Sedimentation/ Dead-Spot Prevention

Billund Aquaculture are aware of the risk of development of Hydrogen Sulphide (H_2S) in marine RAS. H_2S is a naturally occurring component in marine eco systems and can prevail in RAS only in poorly circulated or unaerated part of the system. To avoid these, all Billund Aquaculture RAS are designed to reduce risk of sedimentation or “dead spots” through the following engineering solutions:

- Calculated velocity for each single pipe in the RAS: Designed with a minimum speed of 0,8 m/s to avoid settling of solids.
- Calculated velocity for the bottom of each reservoir: Designed with a set of vertical plates to keep a minimum speed of 0,8 m/s to avoid settling of solids.
- Slopes in concrete chambers: All horizontal concrete surfaces designed with slopes directed towards flushing points.
- Video camera inspection access points in all critical areas of the RAS.
- Automatic flushing system: All pipes and sumps are equipped with an automatic flushing system to avoid build-up of potentially anaerobe sludge.
- Automated backwashing of biofilters: The correct biofilter backwashing routine is crucial for the systems performance and to avoid the development of oxygen-deprived areas. Therefore, large-scale facilities with multiple FBBR can be optionally equipped and programmed with a fully automated cleaning routine for the biological filter.

7. Fish logistic (transfer, handling, grading)

The considerations for fish logistic within a facility, are focused on high capacity and maximum fish welfare with a minimum of required manpower. These considerations impact directly on the dimensions of corresponding equipment like water and fish pumps, and transfer pipes for fish movements. etc., which determine how quickly a fish tank can be emptied and re-filled.

8. Redundancy

A further safeguard for the protection of the livestock is in the redundancy of all equipment. Billund Aquaculture can offer their clients an overall “risk assessment process” of each facility, where the degree of redundancy for each equipment and support function can be evaluated. Generally, each facility is designed for full functionality during service and maintenance operations and even in the unlikely events of major malfunctions or power outages.

9. Service and Maintenance

Billund Aquaculture provides their clients with customized operational manuals as well as service and maintenance manuals for all essential equipment. The design of each facility further includes considerations for access to service and maintenance operations without impacting on the ongoing operation/ production of the facility.

As a further service to their clients, Billund Aquaculture is further able to offer production-matching service plans and conduct planned maintenance for all aspects of the facility.

10. Mass Mortality

Mass Mortality events in RAS are tragic and certainly not normal. When correctly designed and operated, such events are extremely rare in Billund Aquaculture RAS. Within in the last 35 years and after building more than 500 RAS Billund Aquaculture has only experienced six mass mortalities globally in our RAS facilities. With the assistance of Billund Aquaculture’s Bio-Team and the client’s commitment to follow operating procedure manuals (re. water levels, cleaning procedures for mechanical filter, biofilters) and agreed feeding and biomass

limits for the facility according to provided guarantees while observing/reacting to variations from the norm such events are kept to an absolute minimum.

However, due to recent focus on mass mortality events in one or more tanks, Billund Aquaculture continues to focus on reducing chances of mass mortality events occurring and further on the fish tank design to prevent clogging of the centre-outlet and thereby secure proper water circulation inside the fish tank during an event. This way the event may be contained to the impacted tank(s) rather than affecting the whole RAS.

11. Biological support from day one

Land-based fish farming requires highly skilled operators. As a crucial component to any successful RAS project, Billund Aquaculture provides a Training & Education Package that involves not only an overall education in RAS (this can be conducted during the construction of the RAS in our “Billund Aquaculture Academy”) but also includes the physical presence of Billund Aquaculture’s Bio-Team personnel on-site from day one, to enable a safe and efficient start-up of the systems and a “production from day one”. Billund Aquaculture further offers ongoing on-site support through the Bio-Team on a regular basis to support the local operational staff, as well as a 24-hours hotline and remote assessment of water quality parameters and biological data on a continuous basis. Additionally, Billund aquaculture can perform audits on a regular basis, providing comfort and trust to the client and to the associated insurance companies.

12. Organizational support

A strong organization of both management and operational personnel is essential for success, quick decisions in critical situations and the ability to identify problems in time to implement corrective measures and avoid major issues. Billund Aquaculture has an

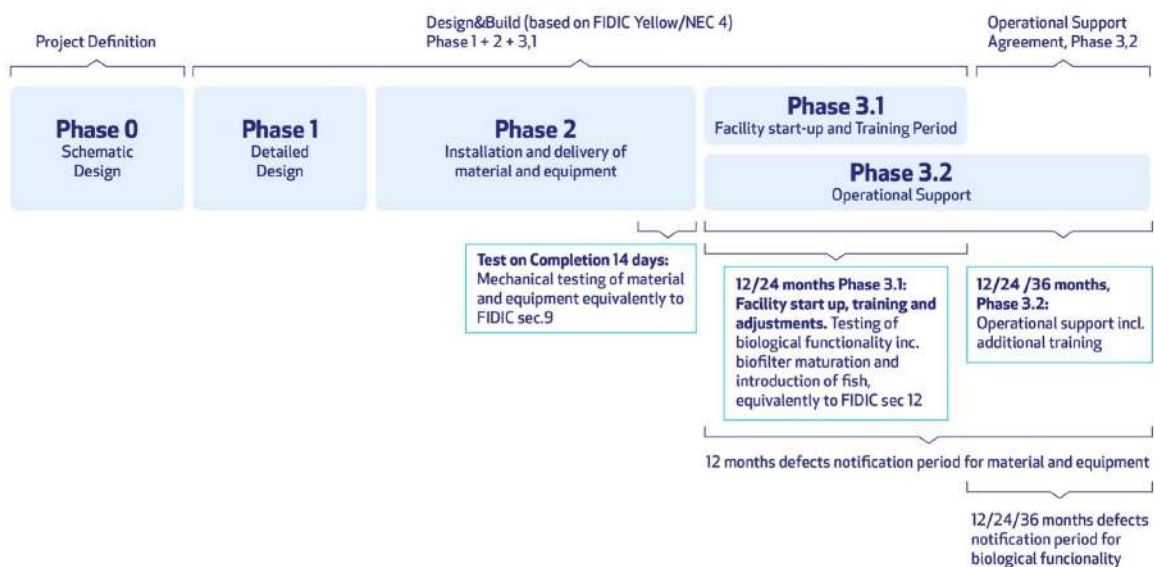
extensive network of specialist of all disciplines and substantial experience in working with staff members of all skill levels and in most regions of the world. The group can therefore assist in advising on required staff members, evaluating candidates for all levels of employment and advise on forming suitable teams for the operation of the client’s RAS projects.

13. Contractual Phases

To ensure successful completion and follow up of the solution and execution, the contractual process from the first discussions and until and including operation support comes in various phases with varying contractual setup.

Depending on the phase in the project the contractual setup is accommodated to local requirements and balancing risk and responsibilities.

Description of phases



14. Turn-Key solution

To ensure that the client receive a project which between the RAS and the civil works is a “fully functional whole”, Billund Aquaculture is committed to establishing strong relationships with parallel contractors engaged for the civil works part of the Project.

By benefitting from the various experience and expertise’s from Billund Aquaculture as the RAS supplier and a parallel civil works contractor, with local expertise, the parties are jointly able to minimize the risks of project execution and any potential scope of work gaps.

15. Project execution

Billund Aquaculture has a strong and well proven project execution model developed over 35 years and has been further developed and finetuned during the last 4 year to grow-out and other large-scale RAS projects. Building on a strong contractual base our model involves all stakeholders in a large-scale project. The different phases in a project can be seen on below illustration.

How do we work together? - STEPS



To secure strong anchoring in Billund’s organization, project management always report directly to group executive management. Design teams and Site management and supervision resources are always Billund employees. Installation activities can be organized according to our clients’ preferences, and local opportunities. Either direct Billund employees, subcontracted or clients’ own resources. Below an illustration of the organization of resources.

Project organization Billund Aquaculture

In Billund Aquaculture, we organize ourselves into permanent Teams aimed at Key Customers, so there a permanent staff of people who lead and are associated with the projects, see illustration below:

